JAMHUURIYADDA DIMOQRAADIGA SOMAALIYA
WASAARADDA BEERAHA
SOMALI DEMOCRATIC REPUBLIC
MINISTRY OF AGRICULTURE

GENALE-BULO MARERTA PROJECT

ANNEX I

Soils

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

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SUMMARY OF REPORT TITLES

Master Plan Report		
Feasibility Study Report		
Annex	I	Soils
Annex	II	Water Resources
Annex	III	Human Resources and Institutions
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PROJECT AREA AND STUDY AREA

This study contained two elements, a Master Plan covering 67 400 hectares and a feasibility study of 5 000 hectares.

Throughout the reports the term Study Area refers to the area covered by the Master Plan studies and the term Project Area is used for the feasibility study area.

ABBREVIATIONS USED IN THE REPORTS

ADB	African Development Bank
ADC	Agricultural Development Corporation
CARS	Central Agricultural Research Station - Afgooye
DAP	Diammonium phosphate
EDF	European Development Fund
ENB	National Banana Board
FAO	Food and Agriculture Organisation
FAO/PP	FAO Pilot Project (Afgooye - Mordiile Project)
HASA	Hides and Skins Agency
HTS	Hunting Technical Services Limited
HV	High volume (crop sprayer)
IBRD	International Bank for Reconstruction and Development (the World Bank)
ITCZ	Inter-tropical convergence zone
ITDG	Intermediate Technology Development Group (London)
JOSR	Jowhar Offstream Storage Reservoir
LDA	Livestock Development Agency
Libsoma	Libya-Somalia Agricultural Development Company
LSU	Livestock unit
LV	Low volume (crop sprayer)
MLFR	Ministry of Livestock, Forestry and Range
MMP	Sir M. MacDonald & Partners
NCA	Net cultivable area
NCB	National Commercial and Savings Bank (formerly National Commercial Bank)
ONAT	National Farm Machinery and Agricultural Supply Service
PLO	Palestine Liberation Organisation
SDB	Somali Development Bank
SNAI	Jowhar Sugar Estate
TDN	Total digestible nutrients
TDP	Total digestible protein
ULV	Ultra-low volume (crop sprayer)
UNDP	United Nations Development Programme
USBR	United States Bureau of Reclamation
USDA SCS	United States Department of Agriculture, Soil Conservation Service
WHO	World Health Organisation

SPELLINGS OF PLACE NAMES

Throughout the report Somali spellings have been used for place names with the exception of Mogadishu 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
Awdheegle	-	Audegle
Balcad	Balad	Balad
Baraawe	Brava	Brava
Buulo Mareerta	Bulo Marerta	Bulo Mererta
Falkeerow	-	Falcheiro
Gayweerow	-	Gaivero
Golweyn	-	Goluen
Hawaay	Avai	Avai
Hargeysa	Hargeisa	-
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
Hagai	-	Climatic season June to September characterised by light scattered showers
Jibal	-	Area of land approximately 25 m by 25 m or 0.0625 ha
Jilal	-	Dry season from January to April
Kawawa	-	Two man implement for forming irrigation ditches
Moos	-	Measurement of land area equal to a quarter of a jibal
Quintal	-	Unit of weight measurement equivalent to 100 kg
Uar	-	See hafir
Yambo	-	Small short-handled hoe
Zareebas	-	Thorn cattle pen

CHAPTER 1

INTRODUCTION

1.1 Location and Purpose of Study

Soils and land classification studies were carried out in the Janaale - Buulo Mareerta area, which comprises some 70 000 ha of the lower flood plain of the Shabeelle river. This area is located between latitudes 1°30' to 2°00' N, and longitudes 44°25' to 44°50' E, 100 km south-west of Mogadishu (Figure 1.1).

The principal objective of the soil and land classification studies was to evaluate the potential of the land for irrigated agriculture. This essential information was required for the associated master planning and feasibility studies of the Janaale - Buulo Mareerta study.

1.2 Methods of Study

Field surveys were carried out over the period May 1977 to February 1978, followed by a six week report writing phase in the United Kingdom.

1.2.1 Field Studies

Field studies were conducted in four stages.

(a) Reconnaissance Survey

This survey, carried out during Phase I of the overall study, involved a general assessment of the soil and land capability characteristics of the area, based upon brief field reconnaissances, an examination of aerial photographs and a review of published literature. The reconnaissance stage was primarily a desk study, involving no formal field survey or mapping. The Terms of Reference required that a 5 000 ha area for subsequent feasibility study be identified during this phase. Three areas were identified of which the Qoryooley area was subsequently selected by the Client for feasibility studies for irrigation development.

(b) Semi-detailed Survey

The entire 70 000 ha Study Area was subjected to semi-detailed survey as part of the Phase III master planning exercise.

An initial stereoscopic examination was made of the 1 : 30 000 scale aerial photographs, followed by routine field study of the soils at an overall density of one investigation site per 100 ha (Table 1.1) including three sample areas which were studied at a density of some 30 sites per hectare. Soils were examined and described to depths of 1.0 to 1.5 m using profile pits and auger holes. At 48 sites, located along traverses across the area, profiles were investigated to depths of 3.5 to 4.5 m. Soil samples were collected from fixed depth horizons in the upper metre at each site for salinity and exchangeable sodium determination. Soil series were defined on the basis of profile and parent material features and samples were collected from major horizons of profile pits representative of each series and subjected to detailed chemical and physical analyses.

The results of the semi-detailed field surveys were compiled as a series of three maps at 1 : 50 000 scale, which accompany this annex. The distribution of soil series is shown in the Soils Map (Map 1A). In Map 1B the soil series mapping was re-interpreted to show land suitability for irrigation. Map 1C shows the locations of survey sites.

TABLE 1.1

Soil Survey Investigation Sites

Investigation site	Numbers	
	Semi-detailed (Study Area)	Detailed[1] (Project Area)
Routine augers (1.0 - 1.5 m)	584	284
Profile pits (1.5 - 2.0 m)	72	14
Sample area augers (1.0 - 1.5 m)	46	15
Total sites	702	313
Total area (ha)	67 410	5 769
Sites per 100 ha	1.04	5.43

Note: (1) Includes some sites described in the semi-detailed survey.

(c) Detailed Survey

As part of the Phase II feasibility studies, the soils of the Qoryooley Project Area were surveyed at a detailed level. Soils were examined along parallel traverses across the area to provide an overall density of almost 5.5 sites per 100 ha (Table 1.1). Maps were produced at a scale of 1 : 25 000 to show soils (Map 2A), land suitability for irrigation (Map 2B) and survey sites (Map 2C); these maps accompany this annex.

(d) Soil Physical Tests

A series of soil physical tests were performed concurrently with the routine surveys. These tests were designed to evaluate the behaviour of the soils under irrigation, specifically in terms of soil-water relations. They included measurements of hydraulic conductivity, surface and sub-surface infiltration, moisture contents and distribution in the profile under different forms of irrigation and available water capacities of the principal soil series.

LOCATION OF STUDY AREA

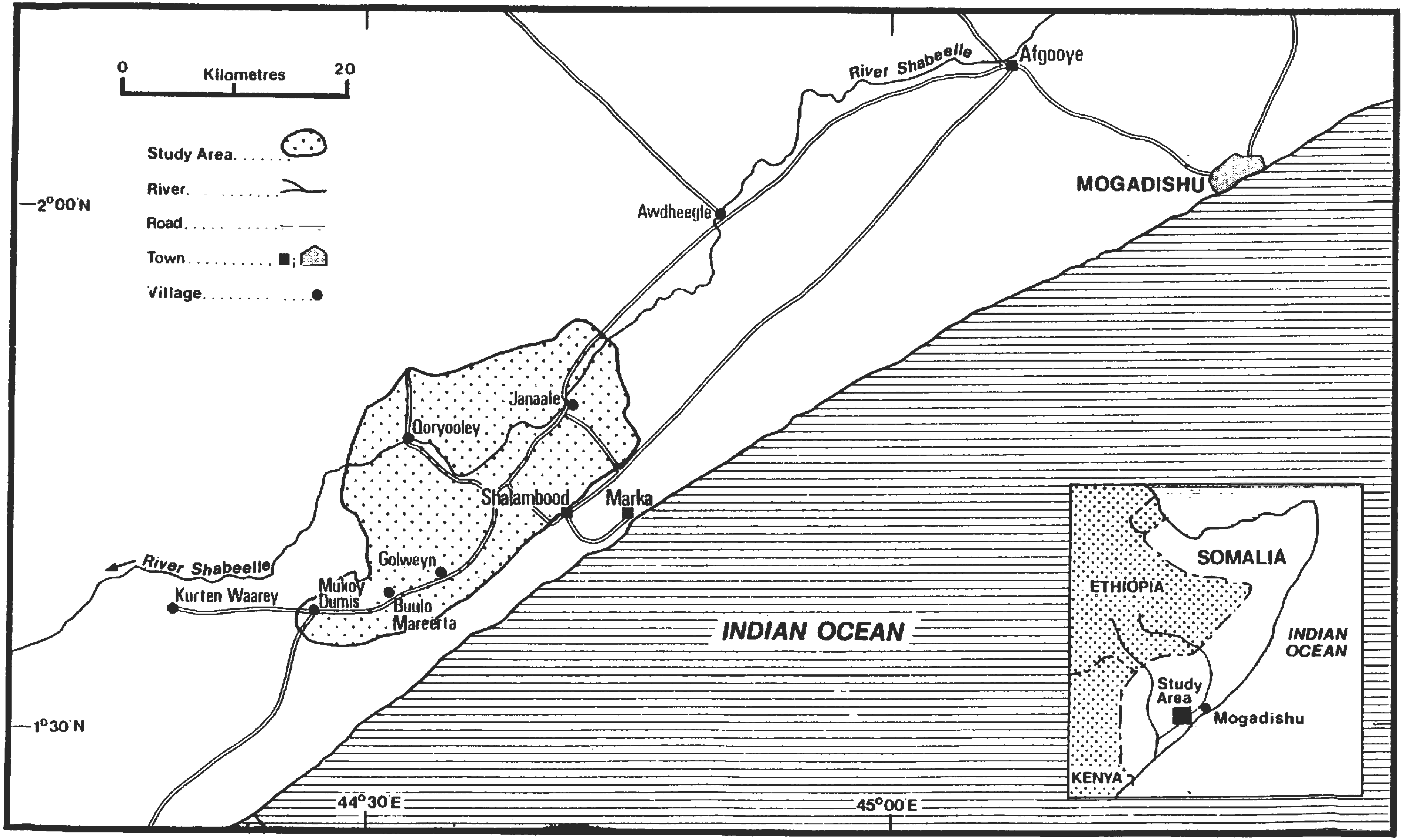


FIGURE 1.1

1.2.2 Report Production

The report writing stage commenced on completion of the field studies and is presented here as Annex I. This annex comprises a description of the environment, including a review of earlier soil studies in the area (Chapter 2), followed by a detailed presentation of the soils information gained during the present study. In Chapter 3, the characteristics of the soil mapping units are summarised, supported by detailed descriptions in Appendix A. The results of the field surveys, soil physical tests and laboratory analyses are evaluated in relation to irrigated land use in Chapter 4, drawing on the specialised data on soil chemistry and soil physics contained in Appendices C and D.

The information contained in Chapters 3 and 4 was then used to classify the land according to its suitability for irrigation of annual crops, as described in Chapter 5. Finally, in Chapter 6 the methods of soil and land classification used in this study are compared with those used in previous studies in the region.

1.3 Summary of Results

Results are presented for the semi-detailed soil survey of the Study Area (67 410 ha), the detailed survey of the Qoryooley Project Area (5 769 ha) and for specialised soil tests and analyses.

The parent materials for the soils of the entire Study Area comprise predominantly fine textured meander flood plain deposits of the Shabeelle river, divisible into old, semi-recent and recent alluvium. This division was used in the separation of the eleven soil series, which formed the basis of the soil mapping units.

The soils are classified as Vertisols, or their intergrades, being developed on expanding - lattice clays and exhibiting the Vertisol properties of deep cracking and self-mulching. Thses properties are less well expressed in some of the soils of the recent and semi-recent alluvium, which contain significant layers of silty medium textures. Profiles are deep and moderately well drained.

The terrain is level. Areas of gilgai micro-relief occur locally and uneven topography is associated with channel remnants which traverse the area.

Soil physical properties are strongly influenced by moisture content; in the dry state the clays contract to form deep cracks, a friable surface mulch and discrete structural aggregates in the lower horizons, whereas aggregates disintegrate and the cracks close when the soil is saturated. This is seen to reduce flexibility of tillage operations under irrigation and to retard moisture movement in saturated soils. Initial infiltration rates into dry, cracked soils are rapid but rates are slow in moist soils (80 mm in eight hours) and moisture penetration is generally limited to the upper 0.5 m except where perennial irrigation is practised. Total available water capacities are high, at some 200 mm/m, but, due to negligible stable porosity, much of this is held outside the easily available range. The drainability of the soils is seen to be limited by the slow hydraulic conductivities (mean 0.23 m/d) recorded in the underlying clays of the old alluvium.

The soils are calcareous and base-saturated with very low proportions of sodium on the cation exchange complex, indicating negligible alkalinisation hazard. Salinities are generally low, although some increase occurs with depth; mean values for electrical conductivity of the saturation extract (ECe) are 2.0 and 2.9 mmho/cm for the 0 to 0.5 m and 0.5 to 1.0 m depths, respectively. Due to the high reserves of soil calcium, leaching of salts should not cause deterioration of soil permeability.

Moderate to low fertility levels are recorded, nitrogen and phosphorus being deficient. The combination of moderately high pH values and an imbalance in calcium and magnesium ions, may reduce the availability of some nutrients.

The land is ranked according to its suitability for irrigation of annual crops on the basis of permanent (soil profile and drainability) and rectifiable (topography, salinity and flooding) deficiencies. Approximately 90% of the Study Area and 93% of Qoryooley Project Area are either rated suitable or moderately suitable for irrigation. Soils of the recent and semi-recent alluvium are classed as being generally more suitable than those of the old alluvium, due to more favourable profile and drainability characteristics.

A close similarity is shown between the results of soil and land classification in the present study and those of previous studies in the region.

CHAPTER 2

ENVIRONMENT

2.1 Geology and Geomorphology

The area forms part of the meander flood plain of the lower reaches of the Shabeelle river. The flood plain is uniformly flat except for local areas of uneven relief along old river courses and channel remnants. The land slopes away from the river towards the south-west, where the area borders the Shabeelle Swamps; elevations range from 70 m to 62 m above sea level.

Alluvial deposits cover the entire area to a depth of some 250 m; no rock outcrops occur. These deposits can be divided into Fluvio-marine and Meander Flood Plain alluvia.

2.1.1 Fluvio-marine Alluvium

This alluvium comprises mixed sediments of gravels, silts and clays laid down in the early Quaternary era, when flows in the Shabeelle river were greater than at present. This alluvium also contains marine sediments originating from periodic incursions by the sea. Within the upper 4.5 m strata examined (Figures 2.1 and 2.2) the Fluvio-marine alluvium was recorded in the central and northern areas as a fine sand sediment. Particle size analysis of this material shows the texture to be almost identical to that of a sample from the present coastal dunes (Table 2.1 and Appendix F), suggesting the alluvium underlying the Study Area also includes aeolian deposits.

TABLE 2.1

Particle Size Analysis

Particle sizes	Site R35 subsoil (4.0 - 4.5 m)	Coastal dune (0.75 - 1.0 m)
Fine gravel (2.0 - 1.0 mm)	1.2	0
Coarse sand (1.0 - 0.5 mm)	2.2	1.0
Medium sand (0.5 - 0.25 mm)	29.7	22.3
Fine and very fine sand (0.25 - 0.05 mm)	50.9	62.7
Silt (0.05 - 0.002 mm)	9.0	6.0
Clay (less than 0.002 mm)	7.0	8.0

2.1.2 Meander Flood Plain Alluvium

This alluvium everywhere overlies the Fluvio-marine alluvium and forms the parent material for the soils of the area. Details of the depositional sequence and textural characteristics of this alluvium, derived from an examination of a series of deep auger holes, are shown in Figures 2.1 and 2.2. The sediments are differentiated into old, semi-recent and recent facies on the basis of position in the depositional sequence. These facies formed the fundamental bases for subsequent soil and land suitability mapping in the area.

(a) Old Alluvium

This comprises extensive deposits of dark greyish brown to brown clays with minor lenses of silts. This alluvium was probably deposited under active meander flood plain conditions from the river courses which now form only channel remnants. The old alluvium includes a layer of very dark grey clay containing many shells. A similar layer observed in the Afgooye area was considered to represent former swampy conditions (Hunting Technical Services Ltd., 1969).

The old alluvium forms the parent material for some 50% of the soils of the area and forms the subsoil for the remainder.

(b) Semi-recent Alluvium

This alluvium comprises reddish brown clays which have been deposited from the Shabeelle river while flowing in or near its present course. The deposits occur along each side of the present river channel and broaden to cover an extensive area in the south-west, bordering the Shabeelle Swamps. In the south-west the sediments are intercalated with silt loams and silty clay loams, especially along minor channel remnants. The sediments are rarely thicker than 3.5 m and are directly underlain by old alluvium.

(c) Recent Alluvium

This consists of reddish brown sediments of stratified silts, clays and fine sands, deposited from the Shabeelle river adjacent to its present course and along overflow channels which extend laterally into the main flood plain. The sediments are seldom thicker than 1 m and directly overlie semi-recent alluvium. The river is now confined within its course so that contemporary deposition of recent alluvium in the Study Area is spread throughout the irrigated fields, where it forms superficial accretions of fine material derived from sediment carried in the irrigation water.

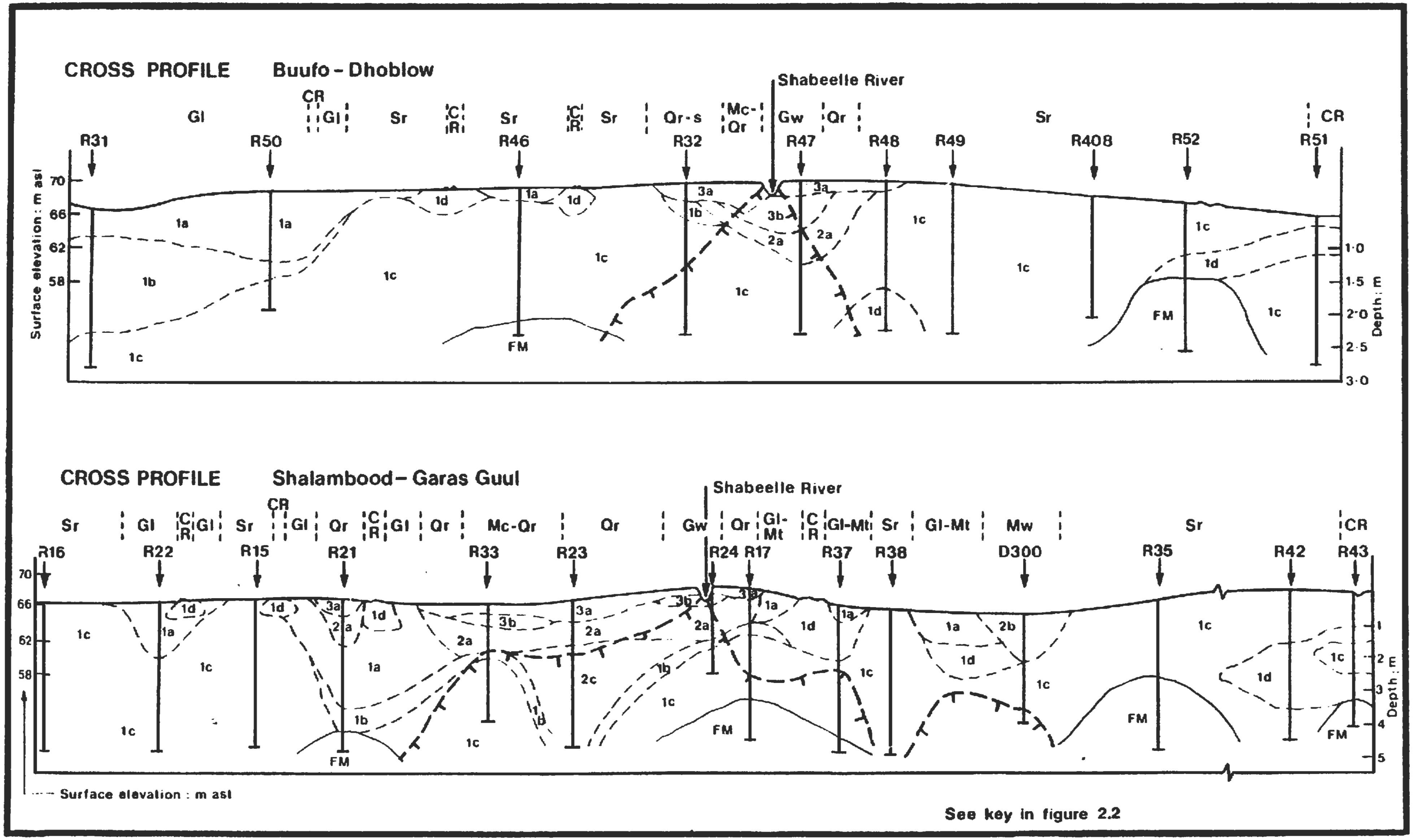
2.2 Climate

The present climate is tropical semi-arid, with a mean annual precipitation of 475 mm. This precipitation falls mainly during the gu season (April to July) and the der season (October and November). Temperatures are uniform throughout the year, mean monthly maxima ranging from 29 to 34°C and minima from 21 to 24°C. Open water evaporation is estimated to be about 5 mm/d, with the highest values occurring during the hot, dry season from January to April.

Detailed descriptions of the climate are presented in Annex II.

FIGURE 2.1

CROSS PROFILES : BUUFO - DHOBLOW AND SHALAMBOOD - GARAS GUUL



See key in figure 2.2

CROSS PROFILE : BUULO MAREERTA - QORYOOLEY

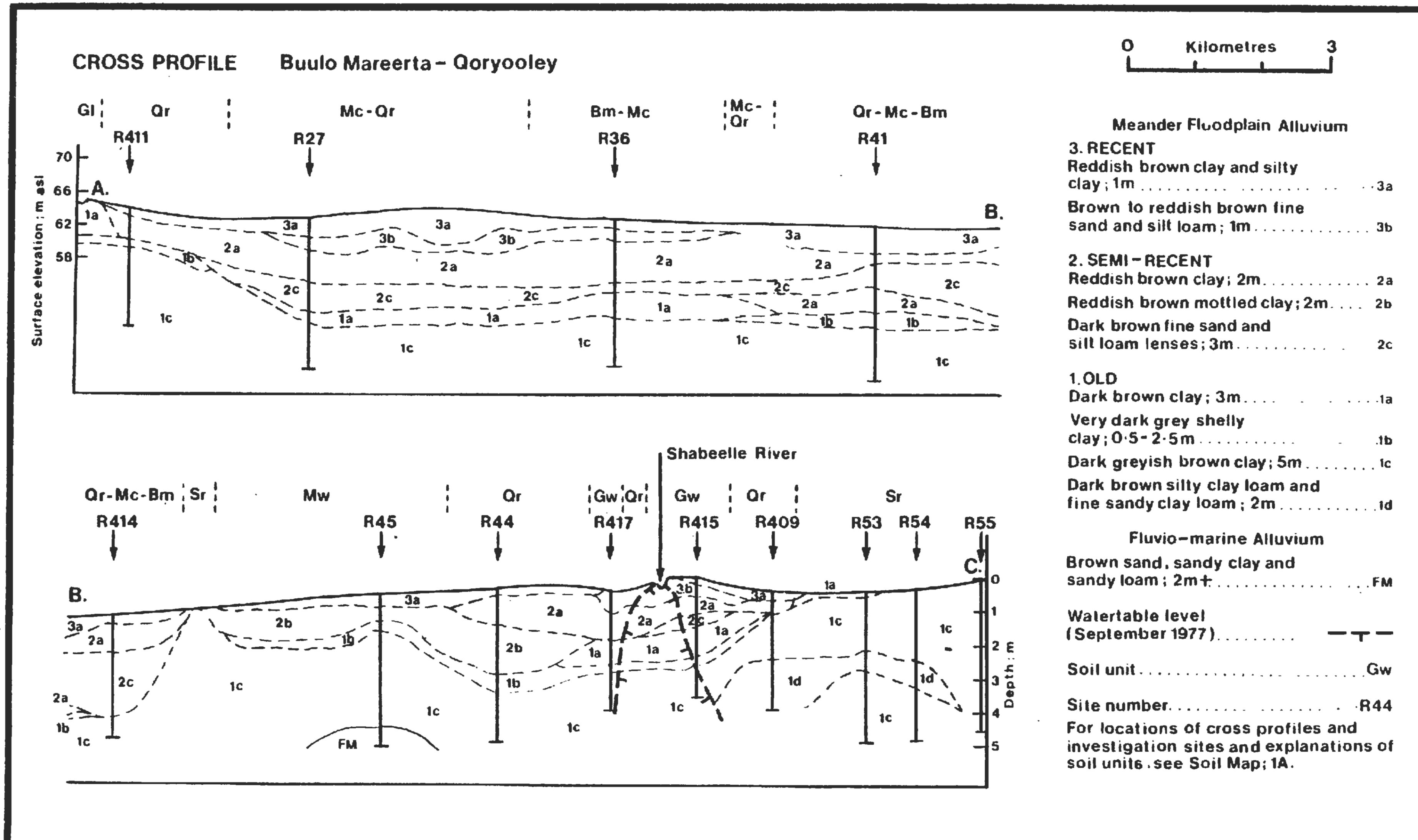


FIGURE 2.2

2.3 Vegetation and Present Land Use

2.3.1 General Features

The area lies within a natural vegetation zone of semi-arid open tree-shrub woodland and grassland steppe. This original natural vegetation has either been cleared for cultivation or severely modified by intense browsing and felling for fuelwood, persisting as shrub thickets only in areas remote from settlement. The agriculture which has replaced the natural vegetation comprises small-scale subsistence farming and commercial banana production, all based on irrigation from the Shabeelle river. Large areas of former farm land are abandoned.

2.3.2 Vegetation

The ensuing descriptions of the vegetation features of the area are based on field observations and subsequent identification of plant specimens collected during the course of the soil survey (Appendix G).

Remnant thickets of natural vegetation persist only in areas remote from the irrigation schemes, mainly along the northern and south-western borders of the area. They are characterised by a low density of tree species, including Acacia bussei, A. ehrenbergiana, Salvadora persica and Grewia villosa interspersed between a low bush undergrowth (Thespesia danis, Indigofera schimperi, Acacia nubica and Grewia tenax) and herbs, which include species of Barleria, Serra, Coleus, Lippia and Aloe.

Most perennial grass species have been grazed-out leaving only unpalatable annual grasses such as Dactyloctenium scindicum. Remnant natural vegetation persists locally as thickets of Acacia nilotica, Thespesia danis and Solanum sp. along channel remnants.

Development of the land for irrigation results in the removal of all natural vegetation, except in marginal areas where the trees of Grewia and Boscia species are left standing within fields. Regeneration of indigenous species occurs along roadsides and canals, especially A. nilotica and Thespesia danis, and introduced exotic tree species are well established including species of Eucalyptus, Cassurina, Conocarpus, Tamarix, Cassia, Bombax, Delonix and some herb species including Psoralea corylifolia, Abutilon pannosum and Lippia danensis.

The most important weed species identified are listed in Appendix G and are discussed in detail in Annex IV. The weeds Heliotropium cinerascens, Flaveria trinervia and Psoralea corylifolia are especially quick to become established and rapidly form a dense cover in fields between irrigation seasons. Cyperus sp. forms an important weed in wetter areas and the grass Cynodon dactylon is a persistent weed under cultivation and also forms a dense sward on canal banks. Ricinus communis similarly colonises canal and river banks locally. Aquatic species are common in storage basins and in swampy areas near canals and the river; on the main river levees Ficus and Kigelia spp. occur as large trees.

Eucalyptus, Cassurina and Conocarpus spp. have been planted locally as windbreaks and attain heights of 50 to 60 m. The spiny bush Parkinsonia aculeata is frequently planted along field boundaries to exclude cattle.

2.3.3 Present Land Use

The four main categories of land use which have been recognised in the area are listed in Table 2.2 and are briefly reviewed in this section. Detailed descriptions are to be found in Annex IV.

TABLE 2.2

Present Land Use

Land use category	Area ha	%
1. Uncultivated	17 450	25.8
2. Marginal production of annual crops	15 565	23.1
3. Irrigation of annual crops	27 010	40.1
4. Irrigation of perennial crops (bananas etc.)	7 385	11.0
TOTAL	67 410	100.0

Source: Annex IV

Present land use is based on irrigation agriculture, which commenced in the 1930s with the development of commercial banana plantations. The area now under irrigation covers over 50% of the area (Table 2.2) and is dominated by the production of annual crops by subsistence farmers; the principal crops are maize and sesame, which are grown in the der and gu seasons. In marginal areas, remote from the irrigation canals, subsistence farming of maize and sesame is partly rainfed and partly irrigated. The remaining areas (uncultivated) consist of remnant natural vegetation, which is used for livestock browse and fuelwood, and areas of farm land which have been abandoned due to deficient irrigation water supplies.

2.4 Erosion

Erosion by water and by wind has been identified in the area, although neither constitutes a serious hazard to agriculture.

2.4.1 Erosion by Water

In an area of clay soils and level terrain, the risks of erosion by water are low; the clay soils are cohesive and so detachment of soil particles by either rainfall impact or flowing water are minimised. Under conditions of level terrain, flow velocities of surface run-off are very low and thus relatively non-erosive.

Once any soil particles are detached and transported by water, however, the settling velocity of these fine particles is very low and consequently eroded materials can be transported long distances in river or canal waters. Incoming river waters carry heavy loads of suspended sediment, much of which is finally deposited only at the actual fields which are being irrigated. The area is therefore a net receiver of erosion products derived from the upstream parts of the catchment. Accretion of fine clay material occurs throughout the areas under irrigation.

2.4.2 Erosion by Wind

Sand dunes form the south-eastern boundary of the Study Area. For most of their length these coastal dunes are stable and carry a moderately dense woodland vegetation but at two points (to the north-east and to the south-west of Shalambood) the vegetation has been destroyed and subsequent wind erosion has resulted in the dunes encroaching on the clay plains. Around the village of Buufo, north-east of Shalambood, the dunes have been stabilised by an extensive conservation programme.

To the south-west of Shalambood no conservation measures have been applied and thus the dunes continue to encroach on the clay plains. The rate of advance of these dunes is calculated to be some 10 to 15 m per year. Aspects of wind erosion and dune stabilisation are described in Appendix F.

2.5 Soils

2.5.1 Review of Previous Studies

Soil and land suitability maps at a scale of 1 : 500 000, produced by FAO/Lockwood (1968), have provided the basis for most subsequent surveys in the Shabeelle - Juba area. However, these maps were prepared from exploratory reconnaissance surveys with only minimal detailed pedological information and can be used to provide only general indications of land suitability. The results of this original survey have recently been reviewed in the light of more recent data (Hunting Technical Services Ltd., 1977) and the land suitability classification slightly modified.

According to the FAO/Lockwood (1968) mapping, the Janaale - Buulo Mareerta area lies within the soil units Saruda, Goluen (revised Somali spelling as used in this text is Golweyn) and Gofca of the Shabeelle Meander Flood Plain (FPm). These soils, which were described as Grumsols (Vertisols) with low salinity and alkali hazard, were classed as suitable to marginally suitable for irrigation.

Detailed studies of the Saruda and Goluen soil units have subsequently been carried out by Hunting Technical Services Ltd. (HTS, 1969) at Afgooye and Balcad, confirming the overall suitability of these soils for irrigation. More recently, semi-detailed and detailed land classification mapping was conducted by Citaco (1974) in an area of 7 500 ha near Buulo Mareerta as part of the European Development Fund grapefruit project. These surveys included no new soil mapping but the area lies within the Goluen unit as originally mapped by FAO/Lockwood (1968). Citaco (1974) concluded that all but 1% of the area was suited to irrigation.

2.5.2 Soil Classification

Previous studies (FAO/Lockwood, 1968, Hunting Technical Services Ltd., 1969) have shown that the soils of the Lower Shabeelle Flood Plain, in which the present area is located, are dominated by Vertisols developed in the fine clay textured flood plain alluvium. These soils are characterised by deep clay profiles and the formation of vertical cracks in the dry state, due to shrinkage of the expanding lattice montmorillonitic clays in which they are formed.

Hunting Technical Services Ltd. (1969) classified the flood plain soils of the Afgooye area, which resemble those of the present Study Area, as principally Udic Chromusterts and Udorthentic Chromusterts with Typic Ustorthents on the channel remnants (classification according to USDA, 1967). In the present study the soils are classified according to the FAO/UNESCO legend (1974) as Chromic Vertisols and Vertic Cambisols. These units correspond approximately with Paleustollic Chromusterts and Vertic Ustifluvents of the revised USDA nomenclature (USDA Soil Taxonomy, 1975).

CHAPTER 3

SOIL MAPPING UNITS

3.1 Introduction

The soil survey was based on the identification and mapping of soil series. Each series represents a grouping of taxonomically similar soils which have the same parent material and a range of profile characteristics which may vary within certain defined limits. This mapping formed the essential basis for the subsequent evaluation of the suitability of the land for irrigation agriculture.

Eleven soil series were identified during the course of the study and were mapped either singly or as complexes of two or more series. The results of the soil mapping are shown at 1 : 50 000 scale for the Study Area (Map 1A) and at 1 : 25 000 for the Project Area (Map 2A).

The Saruda and Golweyn soil units of the FAO/Lockwood (1968) reconnaissance survey formed the initial basis of series identification. These two soil units were defined as individual series for use in the present survey and an additional nine new soil series were defined. Complete definitions of each series and detailed descriptions of representative profiles are to be found in Appendix A. In this chapter the principal features of each mapping unit are described, including their distribution, physiography and profile morphology. The features are summarised in Table 3.1 and the range of profile characteristics is illustrated in Figures 3.1 and 3.2. These descriptions apply to the soils of the Study Area as a whole: the soils of the Qoryooley Project Area are discussed in the concluding section of this chapter.

The area lies in the lower reaches of the meander flood plain of the Shabeelle river in which the alluvium is predominantly fine textured. The soils are mainly clay textured, calcareous and classed as Vertisols (Chapter 2.1, 2.5). Soil parent materials are divisible into those of the old, semi-recent and recent flood plain alluvium; this division formed an important basis for series definition and the ensuing descriptions follow the same sequence. Approximate areas of each group of soils are shown in Table 3.2.

3.2 Soils of the Old Flood Plain Alluvium

These soils occur extensively in the northern and south-eastern sectors of the Study Area. The terrain on the main flood plain is level and the parent materials comprise deep layers of brown to greyish brown, calcareous clay. Within the flood plain alluvium there occur remnants of former river channels which have more uneven relief and more silty-textured soils.

3.2.1 Saruda Series (Sr)

These soils are deep, clay textured and dark greyish brown in colour. Profiles are very uniform, with little horizon differentiation. The Saruda soils are classed as Chromic Vertisols; in the dry state they possess a shallow surface mulch and deep cracks with blocky wedge and prismatic structure in the lower horizons. The series covers nearly 25% of the Study Area and just over half the Qoryooley Project Area (Table 3.1).

TABLE 3.1

Soil Series: Summary of Characteristics

Soil series	Physiography	Soil class	Drainage	Profile characteristics	Study Area ha	Study Area %	Project Area ha	Project Area %
Soils derived from Old Flood Plain Alluvium								
Saruda (Sr)	Main flood plain; gilgai	Chromic Vertisols	Moderate	Dark greyish brown clay; strongly calcareous	15 976	23.7	2 925	50.7
Dhoblow (Db)	Meander scars on flood plain; level, gilgai	Vertic Cambisols	Moderate	Dark greyish brown to brown silty clay over clay and clay loam horizons; calcareous	674	1.0	-	-
Golweyn (Gl)	Main flood plain; level	Chromic Vertisols	Moderate	Brown clay; strongly calcareous	11 729	17.4	808	14.0
Majabto (Mt)	Flood plain near channel remnant, depressions; level	Vertic Cambisols	Moderate to imperfect	Brown clay overlying dark brown silt loam and silty clay subsoil; strongly calcareous	1 011	1.5	156	2.7
Shalambood (Sh)	Channel remnant levees; uneven	Vertic Cambisols	Good to moderate	Dark yellowish brown to brown, alternate silt loam, clay and silty clay horizons; strongly calcareous	3 303	4.9	98	1.7
Soils derived from Semi-recent Flood Plain Alluvium								
Madhuulow (Mw)	Main flood plain; level	Chromic Vertisols	Moderate	Reddish brown clay, grey mottles in subsoil; strongly calcareous	2 629	3.9	594	10.3
Qoryooley (Qr)	Main flood plain; level	Chromic Vertisols	Moderate	Reddish brown clay over dark grey shelly clay subsoil; strongly calcareous	18 875	28.0	692	12.0
Mukoy Dumis (Mc)	Main flood plain; level	Chromic Vertisols	Good to moderate	Reddish brown clay over brown silt loam, subsoil reddish brown clay; strongly calcareous	6 404	9.5	115	2.0
Buulo Mareerta (Bm)	Minor channel remnants and low ridges; weakly undulating	Eutric Cambisols	Good	Stratified; alternate reddish brown clay to silty clay and yellowish brown silt loam horizons; strongly calcareous	2 225	3.3	-	-
Soils derived from Recent Flood Plain Alluvium								
Faraxaane (Fx)	Minor overflow channel remnants; level	Eutric Cambisols	Good	Brown loam and silt loam abruptly overlying reddish brown clay subsoil; strongly calcareous	809	1.2	-	-
Gayweerow (Gw)	Overflow channels and levees of Shabeelle river	Vertic Cambisols	Moderate to imperfect	Brown and reddish brown fine sandy loam, silt loam and silty clay horizons; strongly calcareous	3 775	5.6	381	6.6
TOTAL					67 410	100.0	5 769	100.0

Notes: 1. Area measurements based on frequency of occurrence of each series.
2. Profile description terminology according to FAO (1968).

DIAGRAMMATIC PROFILES OF SOIL SERIES

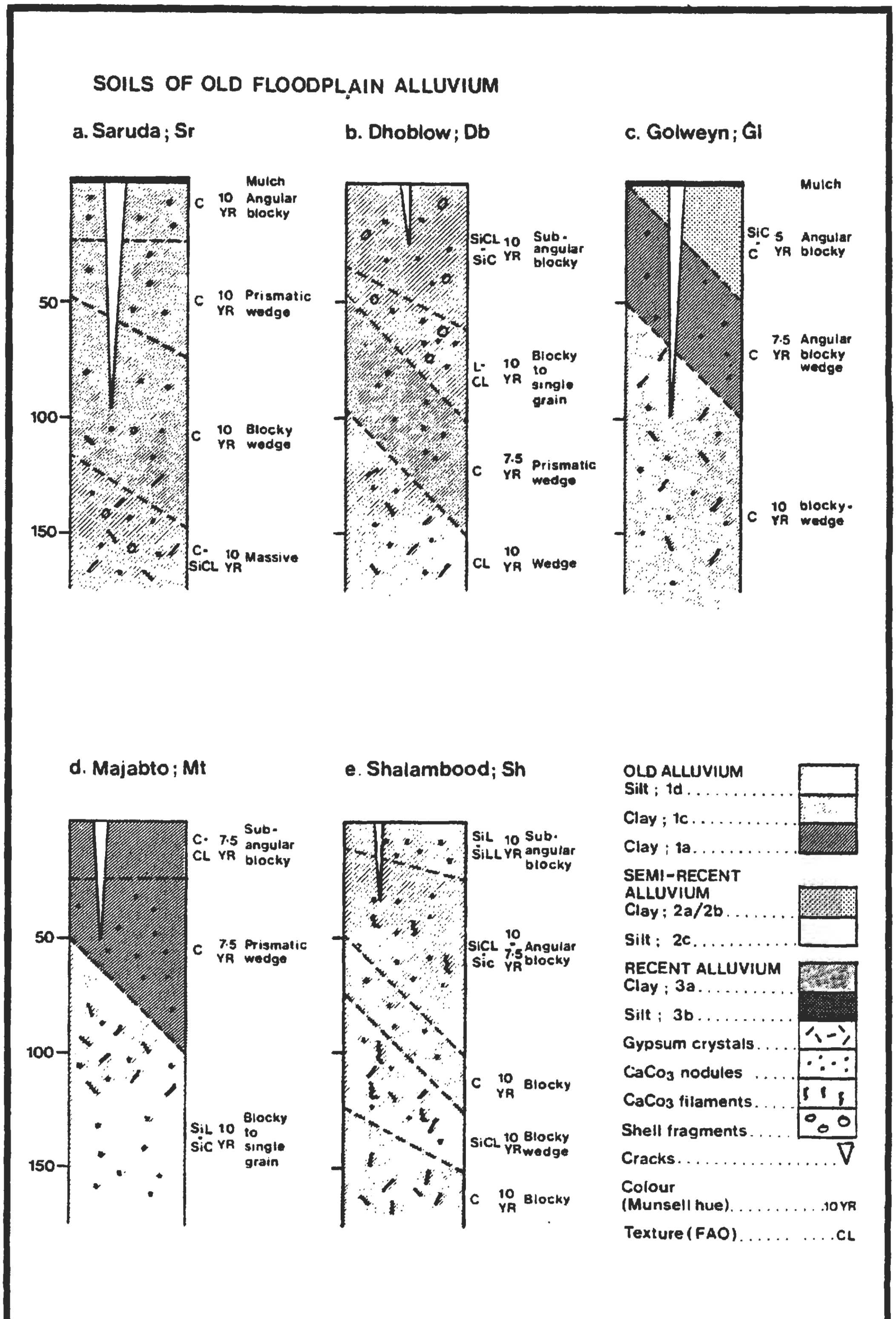
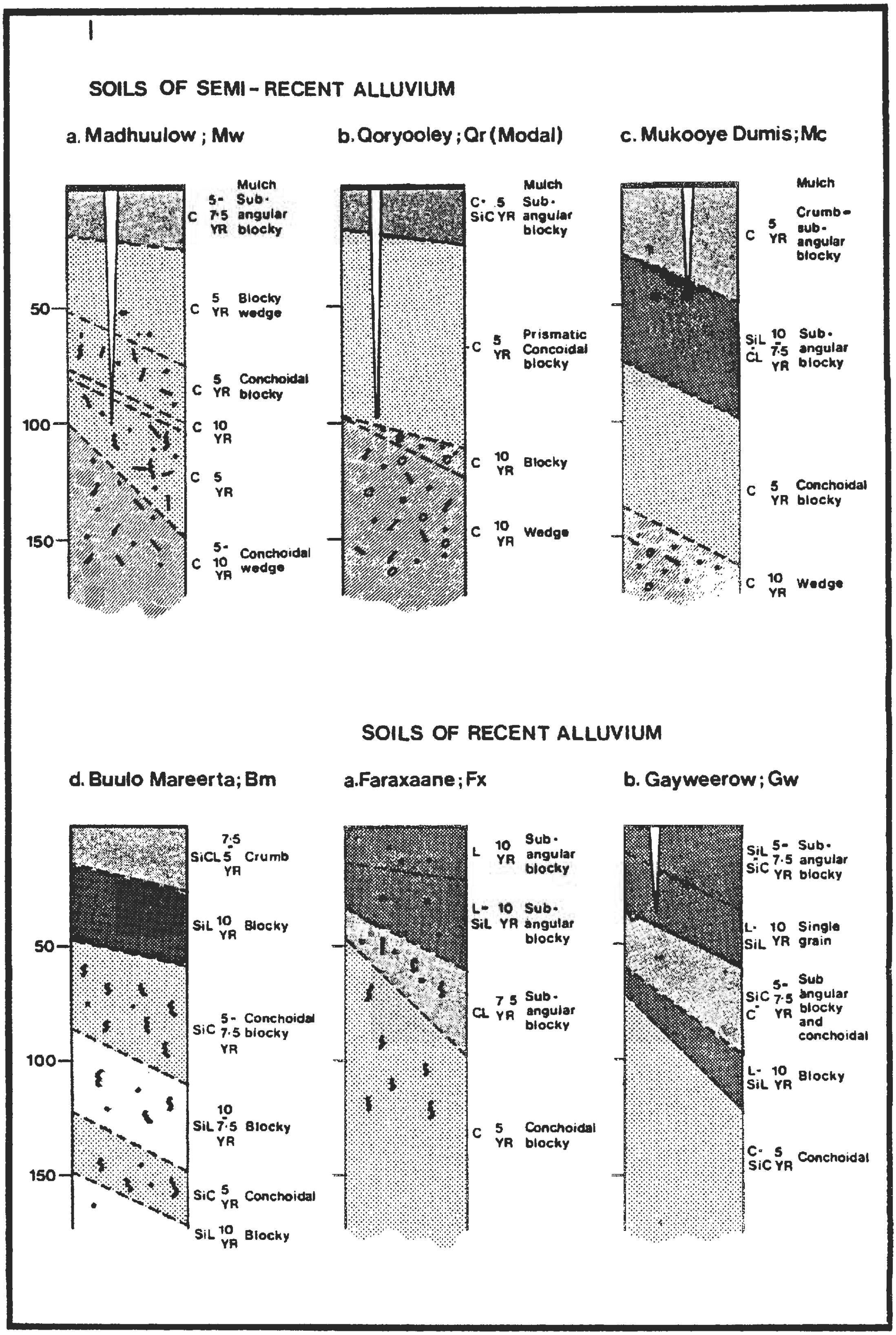


FIGURE 3.2

DIAGRAMMATIC PROFILES OF SOIL SERIES



3.2.2 Dhoblow Series (Db)

Dhoblow soils are deep, brown to dark greyish brown coloured and have predominantly silty textures but are interstratified with clay, loam and clay loam. Profiles are very varied, reflecting differences in textural horizons. The soils are classed as Vertic Cambisols; cracking is only weakly developed although gilgai micro-relief is often present at the surface and wedge structures occur in the deeper horizons. The series comprises a very minor unit (1.0% of the Study Area) and is mapped as a complex with Saruda series.

TABLE 3.2

Areas of Principal Soil Units (Study Area)

Soil parent material	Principal series	Area ha	Area %
Old Flood Plain Alluvium:			
Flood plain soils	Saruda, Golweyn, Majabto	28 986	43.0
Channel remnant soils	Shalambood	4 247	6.3
Semi-recent Flood Plain Alluvium:			
Flood plain soils	Qoryooley, Madhuulow, Mukoy Dumis	27 369	40.6
Channel remnant soils	Buulo Mareerta	3 370	5.0
Recent Alluvium:			
Levee and overflow channel remnant soils	Faraxaane Gayweerow	3 438	5.1
TOTAL		67 410	100.0

Note: Areas measured planimetrically

3.2.3 Golweyn (Gl)

This series includes deep, brown soils with clay textures which are classed as Chromic Vertisols. The soils crack deeply in the dry state and form a shallow mulch at the surface. Golweyn soils overlie the greyish brown clays of Saruda series, which occurs at a depth of between 50 and 100 cm. Some profiles include a shallow surface horizon of reddish brown clay of semi-recent alluvium. The series is moderately extensive, covering 17.4 and 14.0% of the Study Area and Qoryooley Project Area, respectively.

3.2.4 Majabto Series (Mt)

These soils are two layered, comprising an upper layer (50 to 100 cm) of clay or clay loam with brown colours and Vertisol characteristics, overlying silt loam and silty clay loam horizons with friable single grained structure. The Majabto soils are classed as Vertic Cambisols but include Chromic Vertisols similar to Golweyn series where the upper horizons are clay textured and deeper than 50 cm. This series is a very minor unit and is always mapped as a complex with Golweyn series. Majabto soils are often associated with a high water table.

3.2.5 Shalambood Series (Sh)

Shalambood soils are typically formed in stratified clay, silt loam and silty clay loam alluvium associated with channel remnants. Individual profiles range from those in which textures are predominantly silt loam to those which are wholly clay textured. Vertisol characteristics are usually only weakly expressed and the series is classed as a complex of Vertic Cambisols and Eutric Cambisols. The relief is often undulating and uneven along the main channel remnants and profiles are well to moderately well drained. Shalambood series is mapped within the Channel Remnant (CR) miscellaneous land type, in which it forms the dominant soil, associated with poorly drained soils of the old channel beds. The Channel Remnant unit comprises narrow, sinuous units of land covering some 5.0% of the Study Area.

3.2.6 Complexes

Two soil complexes are mapped within the soils derived from old flood plain alluvium:-

(a) Golweyn - Majabto Complex (Gl - Mt)

This soil unit occurs in the vicinity of the major channel remnant which lies to the south-east of the Qoryooley Project Area. Golweyn soils predominate, interspersed with Majabto soils, where medium textured material lies within 100 cm of the surface. The complex occupies 7.4% of the Project Area.

(b) Saruda - Dhoblow (Sr - Db)

This complex occurs locally within the areas mapped as Saruda series, often associated with weakly undulating meso-relief of minor channel remnants and meander scars. The Dhoblow soils occur on the more elevated sites with Saruda series in the intervening level terrain.

3.3 Soils of the Semi-recent Flood Plain Alluvium

These soils form a broad tract of land extending from the vicinity of the Shabeelle river in the north-east to the Shabeelle Swamps in the south-west. Most of these soils are mapped on the left bank of the river and in the south-west of the Study Area. The main flood plain has level relief but is interspersed in the south-west by minor channel remnants which have weakly undulating terrain locally. Soil parent materials comprise reddish brown clays within which thin strata of silty loam and silty clay loam textures are widespread in many areas. These semi-recent alluvial materials overlie clays of the old flood plain, often within 100 cm of the surface. The parent materials of the channel remnants include more frequent layers of silty medium textured alluvium.

3.3.1 Madhuulow Series (Mw)

These soils are clay textured, moderately well drained and have predominantly reddish brown colours. The lower horizons are characterised by compact conchoidal blocky structure (see Chapter 4.3.3 for definition of this structure type), with greyish brown coatings to individual peds. Madhuulow soils have uniform profiles and are classed as Chromic Vertisols. In the dry state they form a surface mulch and deep vertical cracks. Profiles are at least 100 cm deep over the older greyish brown clays. The series occurs south of the river in the west of the Study Area and locally on the right bank, where it covers about 10% of the Qoryooley Project Area.

3.3.2 Qoryooley Series (Qr)

Qoryooley profiles are characterised by an upper profile of reddish brown clay overlying a subsoil of greyish brown clay derived from the old alluvium. The reddish brown clay layer, which ranges in depth from 50 to 100 cm, has a compact conchoidal structure. The soils are classed as Chromic Vertisols and show the typical Vertisol features of surface mulching, vertical cracking and blocky wedge structures and slickensides in the subsoil. Qoryooley series covers 28% of the total area studied and comprised 12% of the profiles examined in the Qoryooley Project Area. In the latter area, a shallow phase (Qr-s) was mapped where the reddish brown clays were less than 100 cm deep.

3.3.3 Mukoy Dumis Series (Mc)

These soils are predominantly reddish brown in colour and are characterised by distinct textural stratifications in which clay or clay loam surface horizons overlie a silty, medium textured horizon which in turn overlies clays of semi-recent alluvium. The medium textured horizon ranges in thickness from 25 to 50 cm. The upper horizons are moderately friable with subangular blocky structure compared with the compact conchoidal blocky structure of the lower clay horizon. The Vertisol features of mulching, cracking and subsoil slickensides and wedge structures are usually well developed, and the soils are classed as Chromic Vertisols. Prominent sink holes occur locally in uncultivated areas. Mukoy Dumis profiles account for nearly 10% of the sites examined in the Study Area but, in all cases, they were mapped as complexes with other soils, particularly Qoryooley series.

3.3.4 Buulo Mareerta Series (Bm)

Profiles of the series are characterised by alternating layers of silty clay loam, silt loam and silty clay. They are well drained and range in colour from dark yellowish brown to reddish brown. The depth of each textural horizon is very varied, depending on the original sequence of the alluvium. The clay horizons have conchoidal blocky structure and slickensides, but cracking rarely occurs; the soils are classed as Eutric Cambisols. Buulo Mareerta soils occupy the minor channel remnants of semi-recent alluvium which occur in the south-west of the area, terrain is locally weakly undulating with slight slopes along minor ridges. About 3% of profiles examined in the Study Area were classed as Buulo Mareerta series; these were mostly mapped as complexes with other series.

3.3.5 Complexes

Three complexes were mapped in which soils of the semi-recent alluvium predominate:-

(a) Qoryooley - Mukoy Dumis - Buulo Mareerta Complex (Qr-Mc-Bm)

This complex was mapped moderately extensively in the west of the area. The unit comprises level terrain with soils in which the incidence and thickness of a medium textured sub-surface horizon is too varied to map separately as Qoryooley or Mukoy Dumis series. In addition, Buulo Mareerta soils occur locally throughout the complex, associated with discontinuous, minor channel remnants and meander scars.

(b) Mukoy Dumis - Qoryooley Complex (Mc-Qr)

Where Buulo Mareerta soils can be mapped separately the intervening lands are mapped as the Mukoy Dumis - Qoryooley complex. The relief is generally level but local minor undulations were recorded in the extreme south-west. In the vicinity of the Shabeelle river, where irrigated bananas are cultivated, a high water table was frequently encountered.

(c) Buulo Mareerta - Mukoy Dumis Complex (Bm-Mc)

This complex is mapped in the south-west where minor channel remnants are associated with Mukoy Dumis soils. Buulo Mareerta soils occur on the broad, low convex ridges whereas Mukoy Dumis soils occupy the more level intervening areas.

3.4 Soils derived from Recent Alluvium

These soils are confined to the levee and overflow channels in the immediate vicinity of the Shabeelle river. The parent materials are varied, comprising loams, silt loams, silty clay loams and clays, often stratified within the soil profile. Similarly, relief ranges from level to undulating or irregular terrain along the river, many of the soils are affected by temporary high water tables and surface flooding.

3.4.1 Faraxaane Series (Fx)

Faraxaane (pronounced as Faraharni) soils have a distinct two layered profile in which at least 50 cm of loam and silt loam material overlie a compact dark reddish brown clay horizon of semi-recent alluvium. The upper medium textured horizons are brown, friable and well drained, contrasting with the conchoidal blocky structures of the clay subsoil. The soils are classed as Eutric Cambisols although remnant Vertisol features are present in the clay subsoil. The series occurs locally in the central parts of the area, complexed with Mukoy Dumis series. The series constitutes 1.2% of profiles examined during the semi-detailed survey, whereas only two sites were recorded in the Project Area.

3.4.2 Gayweerow Series (Gw)

Most Gayweerow profiles have a well defined stratified sequence of horizons ranging from loamy very fine sand, silt loam to clay. In some cases the clay predominates with only minor lenses of medium textures. The soils occur in association with the levee and backslopes of the Shabeelle river as well as along the main overflow channels extending from the river. The relief is normally level to weakly undulating, but broken relief occurs close to the river. The soils range from well drained along ridges to imperfectly drained behind the main levees, where high water tables and flooding frequently occur. About 6.0% of the profiles examined were classed as Gayweerow series, although the soils also occur widely in complexes with other series.

3.4.3 Complexes

Three complexes were mapped in which the dominant soils are derived from recent alluvium:-

(a) Gayweerow - Mukoy Dumis Complex (Gw-Mc)

This complex is locally mapped along the main overflow channels of the Shabeelle river, especially in the Qoryooley Project Area. The Gayweerow soils lie mainly along the crest of the low ridges which these channels form, whereas the Mukoy Dumis soils occupy the lateral parts of the ridges, transitional to Qoryooley or Madhuulow series.

(b) Gayweerow - Qoryooley Complex (Gw-Qr)

A very small area of this complex is mapped on the former island within the Shabeelle river, south-west of Janaale. The relief is generally level but locally minor undulations occur. The Gayweerow soils tend to be located near to the river channels with Qoryooley series in the level central area.

(c) Faraxaane - Mukoy Dumis Complex (Fx-Mc)

This mapping unit occurs locally in association with the minor overflow channel alluvium in which Faraxaane soils are formed. The former soil predominates along the minor ridges where the medium textured recent alluvial deposits are deeper, with Mukoy Dumis soils being located on the level intervening areas, forming a transition to the surrounding clay soils of Qoryooley and Madhuulow series.

3.5 Soils of the Qoryooley Project Area

The soil mapping units in this area are essentially similar to those described for the whole region; their distribution is shown at a scale of 1 : 25 000 on Map 2A. Table 3.3 indicates the proportions of each soil series and complex as mapped.

TABLE 3.3

Soil Mapping Units (Project Area)

Mapping unit	Area ha	Area %
Old Flood Plain Alluvium		
Saruda (Sr)	3 052	52.9
Golweyn (Gl)	540	9.4
Golweyn - Majabto (Gl-Mt)	427	7.4
Shalambood (Sh)	141	2.4
Channel Remnants (CR)	57	1.0
Semi-recent Flood Plain Alluvium		
Madhuulow (Mw)	523	9.1
Qoryooley (Qr)	734	12.7
Recent Alluvium		
Gayweerow (Gw)	170	2.9
Gayweerow - Mukoy Dumis (Gw-Mc)	126	2.2
TOTAL	5 770	100.0

Note: Total area excludes about 160 ha occupied by villages

3.5.1 Soils of Old Flood Plain Alluvium

These soils account for nearly 75% of the area, principally occurring as Saruda series (53%). The terrain is flat but slopes very slightly to the south, forming a series of shallow depressions along the boundary between old and semi-recent alluvium. Less even relief occurs in the south-east, associated with major channel remnants.

The Saruda soils have very uniform profiles, as described in the previous section. This was confirmed by the sample area No. 3, which was located in the Project Area and showed Saruda profiles to be morphologically similar within a detailed mapping area. Locally the soils are underlain at depth by silty or sandy textured older alluvium.

Golweyn series is mapped in minor areas between Saruda and the soils of semi-recent alluvium and more extensively in the south-east, where it is frequently complexed with Majabto soils. In the latter area, high water tables are encountered adjacent to the Channel Remnant and Asayle canal. Shalambood series was mapped along the weakly undulating former levee of the Channel Remnant.

3.5.2 Soils of Semi-recent Alluvium

Qoryooley and Madhuulow soils occupy the level areas of the semi-recent flood plain alluvium, forming a belt between the Saruda series and the soils associated with the levee of the Shabeelle river. The greater density of observations during the survey of the Project Area enabled the shallow phase of Qoryooley series to be mapped separately. This soil has 50 to 100 cm of reddish brown clay overlying the greyish brown clay subsoil and was mapped between the deep Qoryooley soils and Saruda series.

3.5.3 Soils of Recent Alluvium

Gayweerow constitutes the principal series along the levee of the Shabeelle and the three principal overflow channels which protrude into the Project Area. These soils tend to have a higher clay content than the main area of Gayweerow soils mapped to the north-east of Janaale. Along the overflow channel ridges the series is complexed with Mukoy Dumis soils which occur mainly along the transitional areas between recent and semi-recent alluvium. These overflow channels are characterised by weakly convex ridges which rise some one to two metres above the main flood plain. The relief of the Shabeelle levee is more broken due to considerable artificial bunding and earthworks to prevent flooding.

CHAPTER 4

INTERPRETATION OF SURVEY DATA

4.1 Introduction

In the previous chapter the soil mapping units were described in terms of physiography and morphology, emphasising features relating to classification and mapping. The soils are now examined specifically in relation to irrigated agricultural land use in order to assess the effects of soil characteristics on land productivity and management requirements. Aspects of topography, morphology, soil physical properties and soil chemistry are reviewed individually, drawing on data provided in Appendices C and D. This interpretation of the survey data provides the essential information for the classification of the land according to its suitability for irrigated agriculture, which is described in Chapter 5.

4.2 Topography

The overall landform of the Study Area is flat with slopes generally less than 0.1%, presenting few major constraints to irrigation development. However, local topographic irregularities were observed which could either render surface irrigation impractical or complicate its installation. Instances of such irregularities occur along the major channel remnants, the present course of the Shabeelle river and locally within the main flood plain, especially in the south-west.

The Channel Remnant mapping unit (CR) includes convex natural levee ridges and former stream channels with varied degrees of dissection, forming prominent topographic features. In other cases the unit comprises gentle slopes down to shallow depressions which represent former stream channels. Similarly, the levee and overflow channel features of the present course of the Shabeelle river are varied in their topographic characteristics. In general these features have subdued relief with slopes of less than 1% and seldom rise more than 1 m above the level of the main flood plain. However, within 20 to 50 m of the river, the relief is often very irregular due to construction of bunds and artificial levees against flooding.

In the south-west of the Study Area, especially where the Buulo Mareerta soil is mapped, the channel remnants of the semi-recent flood plain alluvium cause local irregularities in the relief which could be anticipated to interfere with irrigation layouts. These irregularities usually comprise low convex ridges dispersed amongst the Qoryooley and Mukoy Dumis soils of the main flood plain.

Apart from the relatively pronounced topographic constraints associated with channel remnants, the micro-relief phenomena typical of Vertisols, namely gilgai and sink holes, are a widespread feature of the soils of the main flood plain. Gilgai consist of a complex pattern of convex ridges and intervening depressions orientated in a polygonal pattern, resulting from the alternate swelling and shrinking of the clays. The ridges are usually some 50 to 150 mm high with an amplitude of 2 to 5 m. Sink holes often form at the centres of the depressions, producing cavities of 200 to 300 mm diameter. This micro-relief occurs most frequently in the soils of the semi-recent flood plain, although examples were recorded throughout the region. In areas where this feature occurs, additional initial land levelling will be required but provided the land is subsequently well maintained under regular irrigation the gilgai relief should not re-develop.

4.3 Soil Morphology

4.3.1 Taxonomic Aspects

The majority of soils with potential for agriculture are either Vertisols or have significant Vertisolic characteristics and are considered to have relatively uniform morphology in terms of agricultural use. Even the Faraxaane and Buulo Mareerta series, which are classified as Eutric Cambisols, are usually mapped as complexes with Chromic Vertisols of Mukoy Dumis series.

Vertisols have a distinctive morphology which has significant influence on their tillage characteristics and soil-water relations as well as their chemical and fertility attributes. A brief description of their morphology is therefore relevant. Vertisols typically have fine textures dominated by expanding lattice (montmorillonitic) clay minerals, which have the capacity to expand and contract on wetting and drying, respectively. In the dry state the soils develop a shallow friable surface mulch and vertical cracks to a depth of at least 50 cm, separating prismatic structure units. Some of the mulch falls or is washed into the cracks so that, when the soil is re-wetted and expands, pressure develops in the lower horizons, giving rise to a churning effect in the whole profile, the development of slip-faces (slickensides) and wedge structures in the lower horizons and often to gilgai micro-relief at the surface (Dudal, 1965; De Vos and Virgo, 1969).

4.3.2 Soil Texture

The soils of the Study Area have moderate to high clay contents (Table 4.1). The flood plain Vertisols of the old and semi-recent alluvium, which account for some 84% of the total area, have textures almost exclusively in the clay classes. Clay contents are lower and more varied in the horizons of Vertic Cambisols and Eutric Cambisols of the channel remnant alluvium, such as Mukoy Dumis, Gayweerow and Shalambood series, but the balance of the mineral particles comprises mainly silt, resulting in silt loam, silty clay loam and silty clay textures. The derived cation exchange capacities (CEC) of the clay fraction are well in excess of 25 meq/100 g (mean 64.5), indicating a predominance of illitic and montmorillonitic clay minerals, confirmed by the X-ray diffraction analyses reported in Appendix C, Section C.5.

TABLE 4.1

Soil Clay Contents

Series	Classification	Texture range	n	Clay % Mean	SE
Saruda Golweyn	Chromic Vertisols	C	21	51.1	2.0
Dhoblow Majabto Shalambood	Vertic Cambisols	L-C	13	31.6	3.1
Madhuulow Qoryooley	Chromic Vertisols	SiC-C	22	55.8	2.1
Mukoy Dumis	Chromic Vertisols	L-C	7	34.0	4.7
Buulo Mareerta Faraxaane Gayweerow	Vertic Cambisols Eutric Cambisols	L-SiL-C	15	33.6	4.5

Notes: Data for clay % in upper 100 cm (Appendix C.1);
n = number of horizons for which clay % available;
SE = standard error of mean.

4.3.3 Soil Structure and Consistency

Due to the combination of expanding lattice clays and high clay contents, structure in the Vertisols is largely dependent upon the prevailing soil moisture content. Structural development is best expressed in the dry state (as in the representative profile descriptions, Appendix A, Section A.2) but in this condition the soils are very hard. When wet the clays slake, causing the disintegration of structural aggregates (Appendix D, Section D.2), producing a soil which is sticky and plastic.

This variation in structure with moisture content has important implications for tillage practices. The range of moisture content within which tillage is feasible is limited - in the dry state cultivation is difficult due to the hardness, producing a cloddy surface and, if mechanical cultivation is used, a high demand for power. Tillage under wet conditions results in a puddled and massive soil with the risks of clogging wheeled equipment.

However, due to the natural self-mulching process, these soils have the capacity to form a friable surface layer some 20 to 30 cm thick. Under small scale subsistence irrigation cropping, farmers usually skim off this friable layer to form field bunds, exposing the hard prismatic, blocky sub-surface horizon. After the first irrigation water application and subsequent drying, this former sub-surface horizon rapidly breaks down to form a new friable surface layer. In addition, provided the soils are permitted to dry sufficiently to form deep cracks, into which this surface material can fall, the resulting self-churning effect produces much the same results as deep tillage.

Consequently, although the Vertisols impose severe limitations on the flexibility of tillage operations due to either hardness or intractability, their natural self-mulching character, under the effects of alternate wetting and drying, can reduce the need for tillage other than for weed control purposes.

A less critical tillage-soil moisture relationship exists in the soils which have significant medium textured surface horizons, such as Faraxaane, Gayweerow and Buulo Mareerta series. However, these soils mostly occur in close association with Vertisol series and therefore, although the medium textures probably improve overall tillage characteristics, it is only at the individual field level that they are likely to permit more flexible cultivation practices.

Field observations and limited tests on disturbed samples (Appendix D, Section D.2) indicated that the aggregate stability of Vertisols derived from the recent and semi-recent alluvium is somewhat greater than for soils of the old greyish brown alluvium, possibly related to differences in clay mineralogy (Appendix C, Section C.5). In the former, the sub-surface horizons possess a compact conchoidal blocky structure comprising cubo-spherical aggregates with a pronounced conchoidal fracture, as compared with the wedge-shaped blocky aggregates normally associated with Vertisols and typical of the soils of the old flood plain alluvium. It appears that this conchoidal blocky structure aids profile drainage, enabling soils with this feature to be cultivated sooner after wetting than the greyish brown old flood plain soils. This is broadly confirmed by the experience of local farmers.

The expansion and contraction of the clay aggregates in the lower horizons of Vertisols can have an adverse effect on root growth, causing compression and splitting of individual roots. However, under perennial crop irrigation or well scheduled irrigation of annual crops, soil moisture contents should not decline to the point at which severe contraction of the aggregates occurs, thus minimising adverse effects. In general crop roots were observed to penetrate to depths of only 50 to 60 cm, probably limited more by the higher bulk densities of the lower horizons than by the expansion/contraction phenomenon.

4.4 Soil-water Relations

The predominance of the Vertisol characteristics of very fine textures and expanding lattice clays have a profound influence on soil-water relations, which is particularly significant for irrigation agriculture. Due to the observed tendency for soil aggregates to slake on wetting, little stable macro-porosity exists in the saturated soil and transmission of water is confined almost entirely to the very fine pores between the clay particles. The principal problems associated with irrigated land use on Vertisols therefore involve water movement, specifically the efficiency of:-

(a) Entry of sufficient water to meet gross water requirements.

(b) Removal of sufficient water to meet drainage requirements.

Several soil physical tests were conducted to assess the soil-water relations of the soils of the Study Area; these are described in detail in Appendix D and the results are summarised in this chapter.

4.4.1 Infiltration

Infiltration tests were conducted to evaluate the cumulative intake rate of water into the soils. This is defined as the total volume of water which infiltrates through a unit of horizontal area of soil surface over a given period, measured from the beginning of infiltration. Measurements of this parameter are essential for the design of surface irrigation systems. In the current test cumulative infiltration rates were measured over an 8 hour period, to simulate the period of normal field irrigation operations.

Reliable estimates of infiltration characteristics can be difficult to achieve in Vertisols, as rates of water entry can be largely influenced by the volume of cracks and, consequently, the moisture content of the soil at the commencement of the test. Nevertheless, cracks do form an important access route for deep penetration of water during the initial irrigation, and allow water to enter the profile under gravity. Once the cracks become filled either with water or soil flushed down from the surface, water entry is dependent upon hydraulic gradients within the soil mass. In previously moist irrigated soils it is movement in response to hydraulic gradients which principally controls the rate of intake.

Three methods of measuring infiltration were utilised, namely the conventional double-ring infiltrometers, basin tests and 100 mm diameter single ring 'Hill' infiltrometers (Hill, 1970). Cumulative intake rates into an initially cracked soil (Saruda series) were estimated to be some 300 mm over a 5 hour period. Under a normal irrigation regime, in which soil cracking does not significantly affect water entry, the 8 hour cumulative intake capacity of the soils is in the range 75 to 85 mm. The patterns of infiltration for 50 tests are illustrated in Figures D.5 to D.7 (Section D.3).

In the Vertisols the cumulative intake of 75 to 85 mm is usually achieved within 7 hours but although water continues to enter in the soils of the semi-recent alluvium, the rate of entry falls to nearly zero in the case of Saruda and Golweyn series. In soils which have significant medium textured horizons, such as Gayweerow and Mukoy Dumis series, cumulative intake is greater and the rate of entry continues to be 5 to 10 mm/h after a lapsed time of 7 hours. The varied textural horizons in Gayweerow series are reflected in the wider range of recorded infiltration values.

4.4.2 Moisture Retention and Available Water

The available water capacity (AWC) of a soil is defined as that portion of the total water holding capacity which is available to roots to sustain plant life. To absorb water from the soil, the plant root has to overcome the matric suction forces which hold the water in the soil. These forces are greatest in soils with very fine pore spaces, such as Vertisols, and increase with decreasing moisture content. In addition, the presence of salts in the soil solution can reduce water availability by raising the osmotic suction of the water against which the roots have to compete.

For the reasons discussed in Appendix D, Section D.1, available water parameters are difficult to establish for Vertisols. The upper limit of water availability or permanent wilting point is accepted as being represented by a soil matric suction of 15 bar; the lower limit is taken as 0.0 bar (saturation), there being no field capacity in the normally accepted sense. For soils other than

Vertisols, such as Gayweerow series, the lower limit is taken as the 0.1 bar retention. However, soil moisture is not equally available over the range from 0.0 to 15 bar: at higher suctions extraction of water causes increasing stress on the plant whereas at very low suctions anaerobic conditions can develop which retard root growth and their ability to absorb water (Crawford, 1977). A second parameter has therefore been calculated, the easily available water capacity (EAWC), which indicates the volume of water held in the soil between 0.1 and 1.0 bar suctions.

Complete data on the moisture retention characteristics of the 12 profiles tested are given in Appendix D, Section D.1. AWC and EAWC values for these profiles are summarised in Table 4.2 and soil moisture characteristic curves for selected profiles, representative of the principal soil series, are illustrated in Figure 4.1.

TABLE 4.2

Soil Available Water Capacity

Soil series and profile no.		AWC (mm)	EAWC (mm)	EAWC as % of AWC
Old Flood Plain Alluvium				
Saruda	R38	226	44	19.5
	R62	197	65	33.0
Golweyn	R50	202	59	29.2
	R39	204	46	22.5
Majabto	R37	163	58	35.6
Semi-recent Flood Plain Alluvium				
Madhuulow	R63	237	60	25.3
Qoryooley	R56	194	52	26.8
	R13	182	39	21.4
	R17	189	38	20.1
	R21	229	39	17.0
Mukoy Dumis	R33	197	68	34.5
Recent Alluvium				
Gayweerow	R47	237	119	50.2
Mean		205	57	

Note: AWC and EAWC values refer to mm of moisture in the upper 1.0 m profile.

FIGURE 4.1

SOIL MOISTURE CHARACTERISTIC CURVES (DESORBTION)

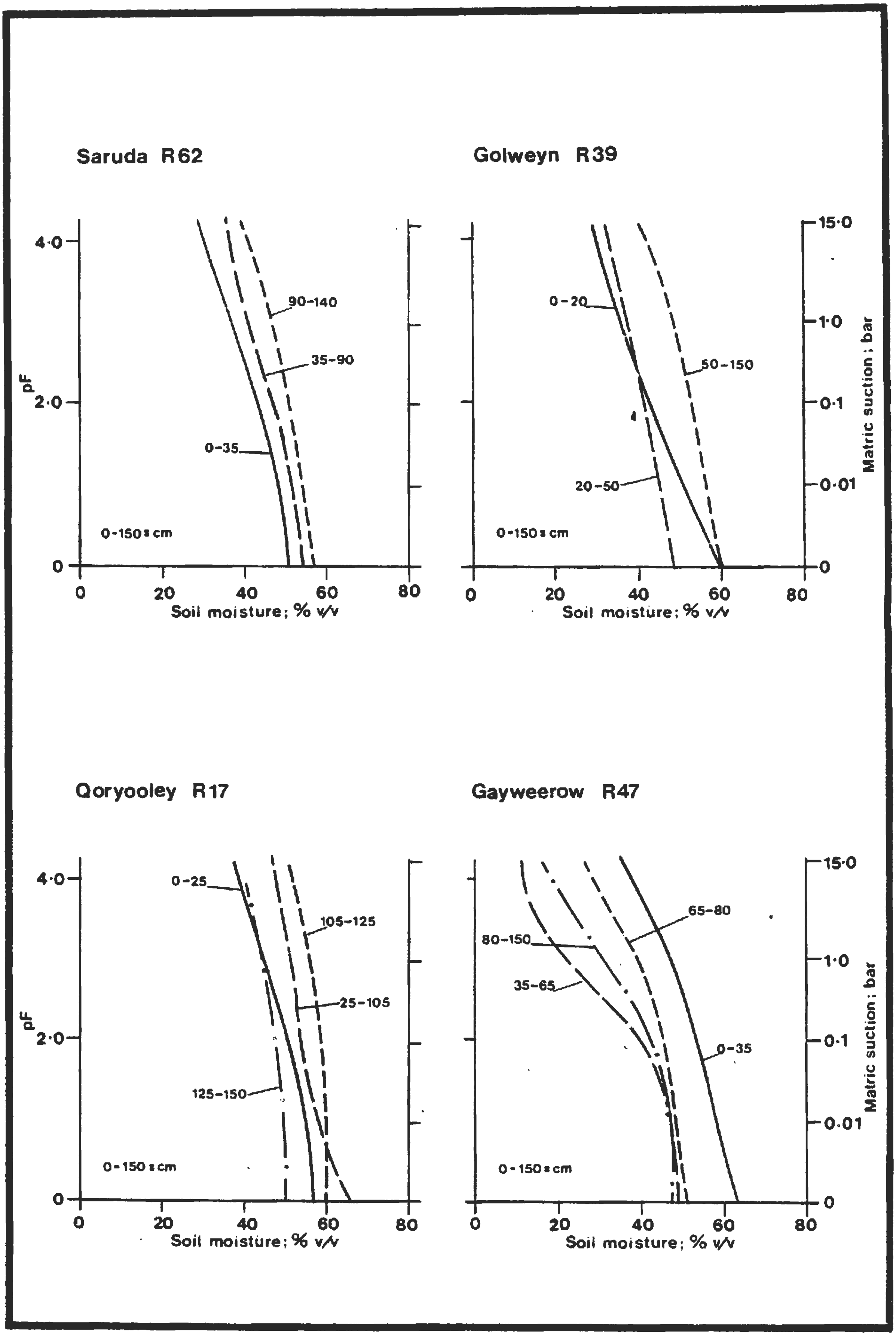


Table 4.2 indicates that all the soils examined have relatively high available water capacities, each being in excess of 150 mm. In addition, there is little apparent difference between series or parent material groups. However, the moisture characteristic curves (Figure 4.1) clearly demonstrate the difference between Vertisols and the medium textured Gayweerow series. In Vertisols, in which the horizons are uniformly clay textured, the moisture released against increasing suction is fairly even over the range from saturation (0.0 bar) to permanent wilting point (15 bar): moisture released over the easily available range (0.1 to 1.0 bar) accounts for an average of only 24% of the AWC, the remainder being released at lower and higher suctions. Even at 15 bar suction the Vertisols retain 25 to 30% (v/v) of moisture. By contrast, the loam and silt loam horizons of Gayweerow series release 50% of their AWC within the easily available range, most of the remainder being lost at higher suctions between 1.0 and 15 bar. Mukoy Dumis and Majabto series, which have medium textured horizons in their profiles, have EAWC values which lie midway between the Vertisols and Gayweerow series.

These results indicate that the existence of medium textured horizons in the soils increases the degree of availability of soil moisture, probably through increasing the proportion of pores of a size which release moisture in the 0.1 to 1.0 bar range. In terms of EAWC values, the Gayweerow, Mukoy Dumis and Majabto soils, and by inference Buulo Mareerta and Faraxaane, have more favourable characteristics than the exclusively clay textured Vertisols.

In calculations to determine the permissible length of irrigation interval it is recommended that the mean value of 205 mm for available water capacity is used. However, this value represents all water held between saturation and 15 bar. In the absence of a field capacity value in Vertisols, no allowance can be made for the reduced availability of moisture held in the 0.0 to 0.1 bar range but as availability declines above a suction of 1.0 bar it can be replenished by irrigation. It is thus more reasonable to calculate irrigation intervals on the basis of the 0.1 to 1.0 bar retentions. This would involve reducing the total AWC value by some 25% to 150 mm. Similar allowances should be made for root distribution within the 1.0 m profile to which the AWC data refer. As the majority of plant roots are normally concentrated in the upper parts of the profile, it is conventional to accept 50% of the AWC (75 mm) as being easily exploited by the plant roots. However, in the profiles examined (Table D.3, Section D.1) a relatively high proportion of the total available water occurs in the upper 20 to 30 cm, suggesting that it would be more reasonable to adopt a figure of 60 to 65% of the AWC (i.e. approximately 100 mm) in the irrigation interval calculations.

4.4.3 Drainage Characteristics

In any study of soils for irrigation it is essential also to examine the ease with which water can be removed from the soil as drainage. As most of the soils in the Study Area are fine textured, with low stable porosity and a predominance of fine pores, they could be expected to be difficult to drain artificially. So far, drainage does not present a serious problem, except locally where high water tables are associated with seepage from canals or the river. However, water tables have been rising steadily (Annex II) and extensive artificial drainage could be required in the future. Soil drainage therefore deserves attention in this study.

(a) Horizontal Hydraulic Conductivity Measurement

Measurements of the rate of water movement through a saturated soil, the hydraulic conductivity, provide an indication of the drainability of the soil and are used in the calculation of drainage requirements. In the present study, hydraulic conductivity was measured in the field at 22 sites (Appendix D, Section D.6). For the reasons discussed in Section D.6, the single auger hole pump-out method was relied upon to provide data on horizontal hydraulic conductivity whereas the limited data available from deep infiltration tests were adopted as indicative of vertical hydraulic conductivity.

The pump-out auger hole test offers the simplest method of measuring hydraulic conductivity (k) in the field and the test conditions closely resemble those which are likely to occur when a drain is installed. The principal limitation of this test is that it requires the presence of a water table within the soil layer to be tested. Within the Study Area, high water tables were recorded at only some 45 sites; these were mostly located near to the Shabeelle river (see Map 1B) and many were underlain by silt loam or loamy lenses which, due to their higher permeability, facilitate the lateral transmission of water and enable the formation of locally high water tables. Consequently, selection of test sites according to the presence of a water table resulted in the choice of a non-representative sample of soils.

(b) Subsoil Drainability Characteristics

As all the sites in the area are either formed directly in, or are underlain at relatively shallow depth by, the dark greyish brown clays of the old flood plain alluvium (Figures 2.1 and 2.2) it is reasonable to suppose that it is the hydraulic conductivity of these clays which will most significantly affect the drainage characteristics and drainability of the area. The results of the hydraulic conductivity tests (Table 4.3) are therefore separated into those for the clay soils and those for soils with significant medium textured lenses within or close to the test depth. Moderate rates were recorded in the latter soils whereas low k-values were measured in the clay soils.

TABLE 4.3

Hydraulic Conductivity

Soil texture	No. of tests	Hydraulic conductivity (m/d)	
		Mean	SE
Clays	12	0.23	0.03
Clays with silt loam lenses	5	0.76	0.14

The greater k-values recorded in soils with lenses of medium texture result from the higher proportion of larger, and therefore more easily drainable, pores in these lenses. An examination of the bulk density and moisture retention results (Appendix D, Section D.1) shows that within the 11 clay profiles tested, bulk densities tend to increase with depth. More significantly from a drainage point of view, the drainable porosity, indicated by the volume of water held between 0.0 and 0.1 bar suctions, averages 13.4% (SE = 1.73) in the surface horizons but is significantly ($p = 0.001$) less at the 100 to 150 cm depth, where the mean value is 5.8% (SE = 0.81).

An examination of the results of all hydraulic conductivity tests conducted on the dark greyish brown clays indicates that k-values similarly decrease with increasing depth, presumably reflecting the decline in drainable porosity. Plotting the values (Appendix D, Section D.6) gives a negative linear correlation between k-value (x) and depth (y), in the form $x = 0.11\ y + 0.52$ ($r = 0.68$; d.f. = 6). If, as seems reasonable, the dark greyish brown clays of the old flood plain alluvium form the main restriction to future drainage efficiencies, it is recommended that the above relationship between depth and hydraulic conductivity in these soils be used to estimate drainability. In this way the hydraulic conductivities in the Study Area are estimated to be 0.32, 0.17 and 0.08 m/d for the 2.0, 3.0 and 4.0 m depths, respectively.

These results closely correspond with k-values reported for soils elsewhere in the Lower Shabeelle Flood Plain. Comparable values have been recorded at Jowhar, using the same method of measurement (MMP, 1976). During the earlier reconnaissance study of the Buulo Mareerta - Qoryooley area (USAID, 1964) hydraulic conductivity values were determined in the laboratory for a range of soil profiles and depths, giving a mean value of 0.31 m/d for 29 tests (SE = 0.04). The values reported for soils of the Afgooye and Balcad areas (HTS, 1969) also generally conform with the results of the present study, although the results of laboratory tests are not always directly comparable with field measurements.

(c) Soil Profile Drainability Characteristics

During the present study a series of infiltration tests was conducted at depths of 50 and 150 cm (Appendix D, Section D.6) in order to assess the vertical hydraulic conductivity of the soils. The results (Section D.6) indicate that vertical hydraulic conductivities may be lower than horizontal values, as measured in the pump-out tests, indicating anisotropic conditions, especially in the greyish brown clays.

Such anisotropic conditions are to be expected in the lower horizon of soils derived from stratified alluvial clays but in the 50 cm horizon it would have been anticipated that the cracking phenomenon would have increased vertical movement of water. Indeed, it has been suggested elsewhere in Somalia (Booker McConnell, 1976) that the cracks persist as minor fissures even after saturation of the soil and consequently aid drainage.

In the present study an examination of cracking patterns in Saruda series showed that although water can be transmitted several metres laterally through the cracks of an initially dry soil, the cracking pattern which re-forms after complete saturation of the soil is different from the original pattern (Appendix D, Section D.4). This tends to indicate that fissures and planes of weakness, along which cracks could develop, do not persist in the saturated state and that cracking cannot be depended upon to aid drainage significantly in these soils. On the other hand, the conchoidal blocky structure associated with soils of the semi-recent flood plain alluvium appears to be more permanent. Deep infiltration tests indicate that vertical hydraulic conductivity in the upper horizons of these soils (Qoryooley, Madhuulow, Mukoy Dumis series etc.) is greater than in the Saruda and Golweyn soils of the old alluvium (Appendix D, Section D.6). Consequently, cracking in the soils with conchoidal blocky structure may indeed assist drainage in the upper horizons, even in the saturated state. It is important to note that the profile drainage nomenclature used in the detailed profile descriptions and map legends refers to the natural state of the soils, as indicated by pedological features such as colour and the presence of mottles or concretions. Under extended periods of intensive irrigation many of the soils assume the characteristics of imperfectly or poorly drained profiles.

4.4.4 Soil Moisture Distribution and Availability

In the preceding sections the infiltration, moisture retention and water conductivity properties of the soils have been reviewed in general terms with reference to the whole Study Area. In the present section the distribution and availability of soil moisture is discussed in relation to each of the three principal methods of irrigation currently practised in the area, drawing on the results of soil moisture monitoring tests described in Appendix D, Section D.5. The monitoring tests were performed at three sites, each on Qoryooley soils, representative of the principal irrigation practices.

Site 1 Perennial crop irrigation - banana plantation

Site 2 Annual crop irrigation - traditional small-scale subsistence farming

Site 3 Controlled flood 'waska' irrigation - maize

The tests involved recording of soil moisture contents at fixed depths at regular intervals of time between September 1977 and February 1978. Moisture contents and the available moisture ranges were plotted (Figure 4.2) for the period of study.

The results of the moisture monitoring provided a useful comparison of depths of moisture penetration and availability under each of the three forms of irrigation. No measurements were available for actual quantities of water applied during irrigations. Furthermore, above average rainfall occurred during the period of study and some variation in soil moisture conditions can be expected from year to year. It should also be stressed that moisture availability is expressed only in terms of matric suction: a minor reduction in availability can be anticipated due to osmotic suction arising from dissolved salts in the soil solution. With these qualifications in mind, several conclusions may be drawn:-

(a) Availability of Soil Moisture under Irrigation

Under perennial crop irrigation (Site 1) the soil moisture is consistently within the available range throughout the upper 1.5 m of the profile. In most cases the soil suctions are at or below 0.1 bar, indicating moderately waterlogged conditions. Indeed, at the monitored site, the water table varied from 1.65 m immediately after irrigation to 2.80 m later in the cycle and for much of this time moisture contents in the 1.5 m zone could have been affected by capillary rise of moisture from the water table. The effect of a single flood of some 200 mm under controlled flood irrigation (Site 3), is sufficient to maintain soil moisture in the entire profile within the available range for nearly 110 days, which is adequate for the cultivation of maize. Under the traditional system of irrigation (Site 2) the initial water application can be insufficient fully to wet the whole profile and a second application of water is

SOIL MOISTURE PROFILES

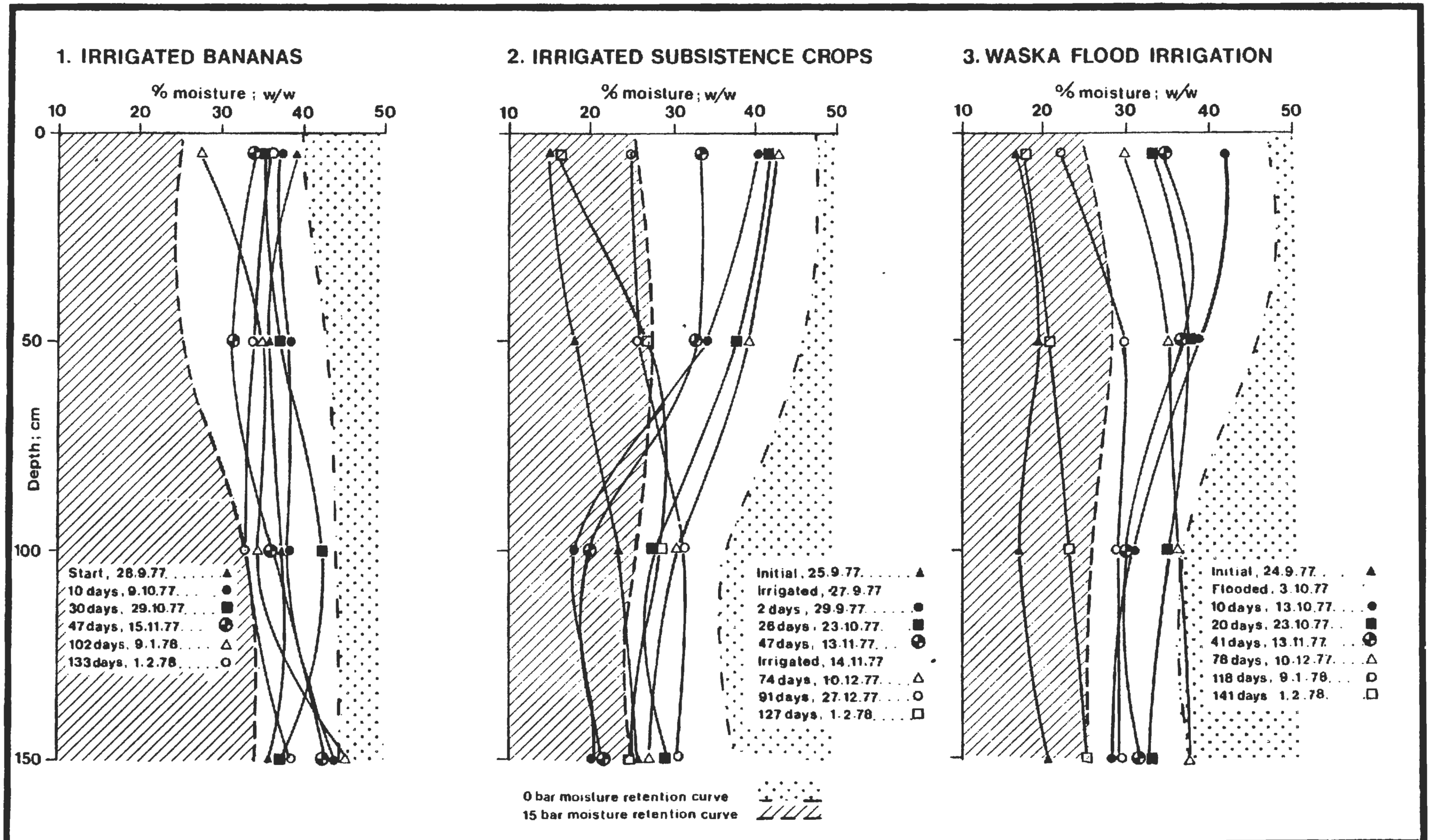


FIGURE 4.2

required to affect subsoil moisture levels significantly. A second irrigation after six weeks enables moisture levels, at least in the upper 0.5 m, to be maintained within the available range for nearly 90 days. This length of time is only barely adequate for the maize varieties currently cultivated in the area and indicates a need for more frequent water application under this form of cropping. No measurements were available for actual quantities of water applied during irrigations. Furthermore, above average rainfall occurred during the period of study and some variation in soil moisture conditions can be expected from year to year.

(b) Moisture Penetration

Following application of irrigation water to an initially dry profile (Site 2) there is a rapid response in the upper horizons as moisture suctions enter the available range, consistent with rapid initial entry of water via cracks. Changes in moisture content in the lower horizons, dependent upon moisture moving under the influence of hydraulic gradients, are much slower and may be insignificant unless large quantities of water are added, as under controlled flood irrigation. A similar response was also recorded on a Saruda soil during basin infiltration tests (Section D.3, Figure D.4).

Significant soil cracking develops only when soil moisture contents fall to 25 to 30% (w/w), which correspond to soil moisture suctions in the extreme upper range of availability. Consequently, allowing soils to dry sufficiently to form cracks and thus aid infiltration is unlikely to be a practical proposition.

(c) Groundwater Recharge

For much of the period, moisture contents in the soils under perennial cropping (bananas) lie within the range at which downward movement of water under gravity could be expected to occur, that is, at suctions of less than 0.1 bar. Under such conditions a hydraulic connection could be established between the soil profile and the water table, permitting direct recharge of water to the aquifer following each application of irrigation water. This is confirmed by the hydrogeological studies (Annex II), which indicate that most recharge occurs in the area currently under perennial crop irrigation. Under controlled flood irrigation ('waska') a hydraulic connection can occur for a short period, allowing some recharge, but soil moisture contents under traditional subsistence agriculture rarely approach the level at which downward movement under gravity could be expected. Consequently, groundwater recharge can be expected to occur principally under banana plantations but also to some extent under controlled flood basins. However, if improved annual crop irrigation practices are implemented, as recommended by the Consultants, it is probable that soil moisture contents, under this form of agriculture would also be sufficiently high to enable recharge.

4.5 Soil Chemical Properties

The results of chemical analyses (Appendix C) show the soils to be rich in clay content, moderately alkaline in reaction and highly base saturated. Salinity values of surface soils are generally low to negligible whereas levels of exchangeable sodium are universally very low. Such features are favourable for crop production but it should be emphasised that these analyses refer to present soil conditions and could be altered by changes in land use practices, a fact which must be considered in their interpretation. In particular, the currently low salinity values could be increased if excessive quantities of saline irrigation water were to be applied without provision of adequate drainage. Similarly, soil chemical characteristics can, within the limitations of prevailing economic conditions, be improved.

4.5.1 Soil Salinity

Salinity is caused by the presence of soluble salts in the soil solution and is most conveniently determined as the electrical conductivity (EC) of a soil water extract, expressed in mmho/cm. High salinity values have an adverse effect on plant growth due to the raising of the osmotic suction of the soil solution, which interferes with uptake of water by roots, and due to the toxicity of specific ions in the solution.

(a) Electrical Conductivity

Electrical conductivity was determined on the saturation extract (ECe) of samples from the two upper fixed depth horizons (0 to 50 and 50 to 100 cm) of all survey sites as well as on samples from deeper horizons from selected profiles. Complete results are presented in Appendix C, Section C.3 and are summarised in Figures 4.3 and 4.4 as probability curves for each fixed-depth horizon in the Study Area and Qoryooley Project Area, respectively. These figures indicate that overall salinity values in the region are low in the upper horizon but increase down the profile. In each of the four upper horizons (0 to 50, 50 to 100, 100 to 150, 150 to 250 cm) of the soils of the Study Area the approximate ECe values for cumulative probabilities of 80% are 2.0, 3.1, 4.8 and 5.2, respectively. Figure 4.4 demonstrates that similar values apply in the Project Area.

This trend for salinities to increase with depth, presumably the consequence of leaching of soluble salts, is reflected in the mean values for all sites (Table 4.4) and for the principal series (Table 4.5). However, the variations in ECe values at depth are greater than near the surface, as shown by the standard errors of the mean figures (Table 4.4).

TABLE 4.4

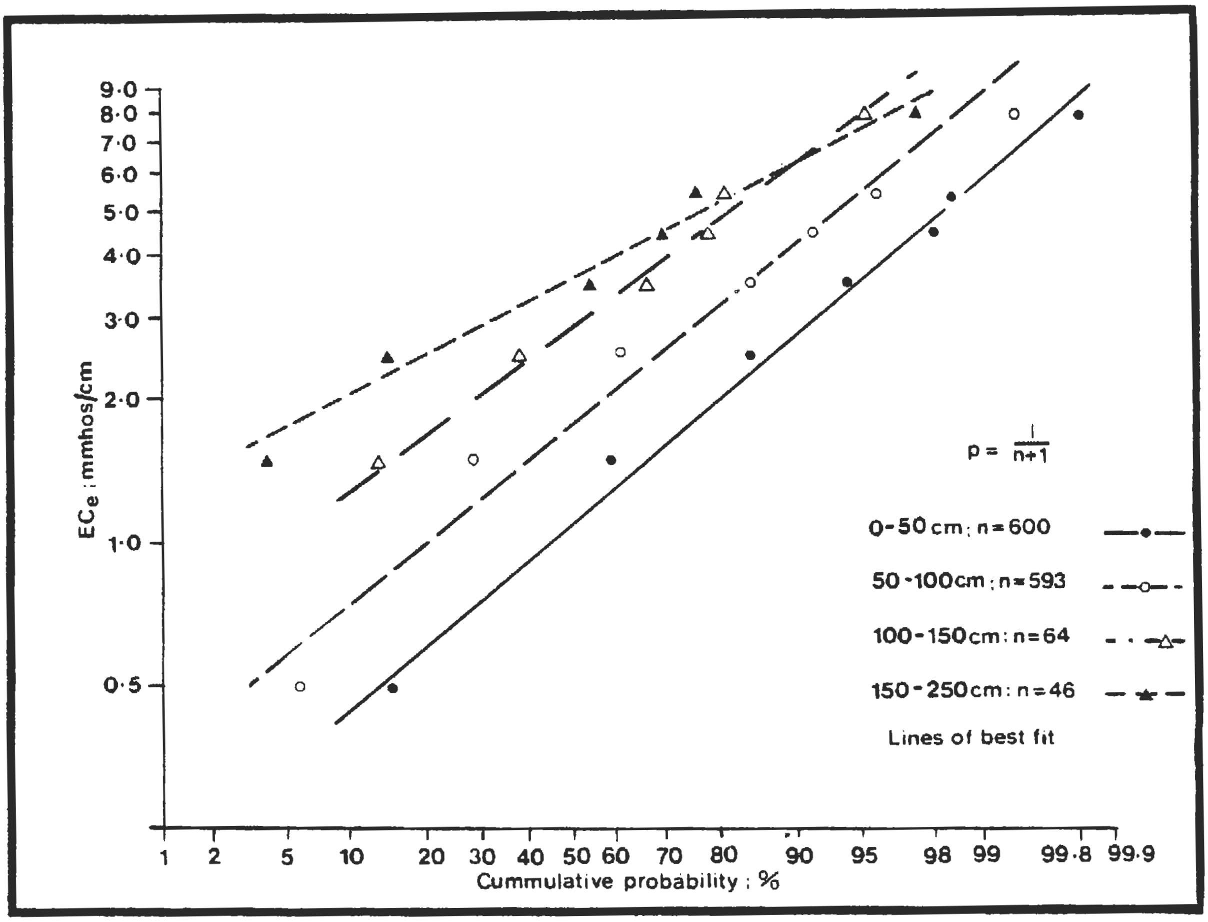
Salinity in Relation to Depth

Sampled depth (m)	Study Area			Project Area		
	Samples	Mean ECe	SE	Samples	Mean ECe	SE
0 - 0.5	600	2.0	0.06	300	1.8	0.05
0.5 - 1.0	593	2.9	0.12	299	2.5	0.09
1.0 - 1.5	64	4.1	0.95	38	3.7	0.46
1.5 - 2.5	46	4.5	0.57	14	4.1	1.11
2.5 - 3.5	43	4.8	0.33	-	-	-

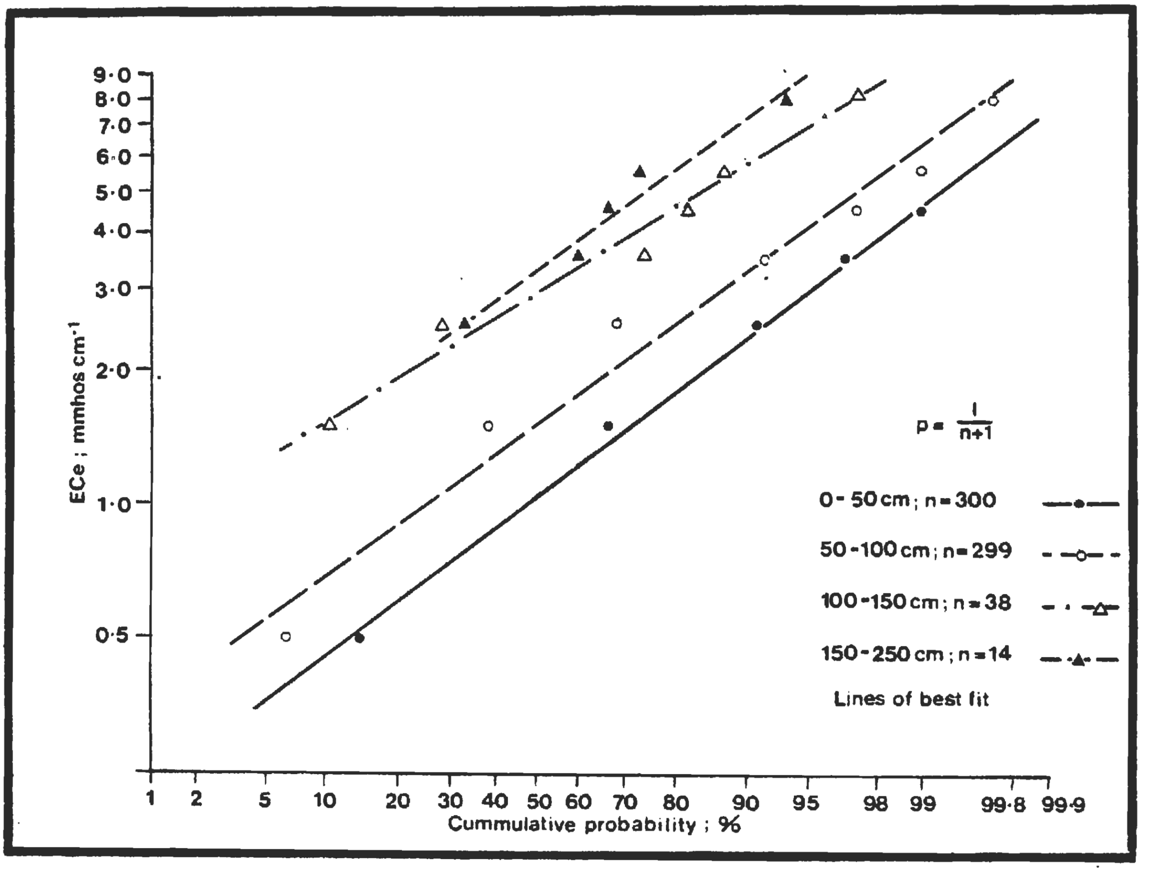
Note: Salinity values as ECe in mmho/cm
SE is the standard error of the mean

An analysis of the data for the principal series of the Study Area (Table 4.5) shows that there is no significant difference between salinity values in each of the three upper horizons, between the soils derived from old flood plain alluvium (Saruda and Golweyn series). The salinity in the upper 50 cm of soil in

PROBABILITY OF SALINITY - STUDY AREA



PROBABILITY OF SALINITY - PROJECT AREA



the Qoryooley series is also similar to these old alluvial soils. However, the salinities in Saruda and Golweyn series are significantly greater than those of Qoryooley series in the 50 to 100 cm and 100 to 150 cm horizons ($p = 0.01$ and 0.05, respectively).

TABLE 4.5

Salinity Profiles for Principal Series (ECe)

Series & depth (m)	Samples	Mean ECe	SE	Distribution by ECe classes (%) 0 - 1.0	1.1- 2.0	2.1- 3.0	3.1- 4.0	4.1- 5.0	5.1- 6.0	6.1- 15.0
Saruda (Sr)										
0 - 0.5	148	1.9	0.09	14.9	48.6	29.1	4.7	2.0	-	0.7
0.5 - 1.0	144	3.1	0.24	2.1	20.1	31.3	30.6	9.0	2.1	4.9
1.0 - 1.5	20	4.4	0.65	-	10.0	30.0	30.0	5.0	5.0	20.0
Golweyn (Gl)										
0 - 0.5	108	2.1	0.16	13.0	42.6	27.8	11.1	2.8	0.9	1.9
0.5 - 1.0	105	3.2	0.33	2.9	16.2	31.4	32.4	8.6	1.9	6.7
1.0 - 1.5	8	5.7	1.10	-	12.5	-	25.0	12.5	12.5	27.5
Qoryooley (Qr)										
0 - 0.5	162	1.8	0.09	17.3	53.1	18.5	6.8	3.7	-	0.6
0.5 - 1.0	165	2.3	0.14	12.1	32.1	34.5	13.9	3.0	2.4	1.8
1.0 - 1.5	15	2.8	0.21	-	13.3	53.3	26.7	6.7	-	-

(b) Salinity Hazard

Salinity hazard classes were established using published data (FAO, 1976) for salinity tolerance of the principal crops under consideration, there being no locally obtained data available. Critical ECe limits for the five classes of salinity hazard adopted are shown in Table 4.6. The value of 2.5 mmho/cm was selected as representing the optimum maximum acceptable limit for the principal crop, maize, and also for grapefruit. The 5.0 mmho/cm value corresponds to the upper limit for 10 to 25% yield reduction in maize and rice: at around 7.5 mmho/cm, 50% yield reductions can be expected in these two crops. The upper limit of 10.0 mmho/cm represents the 10% yield reduction level of cotton, an important potential crop.

Salinity data for all sites examined were classified according to the criteria in Table 4.6, using ECe values for the upper 100 cm profile (Table 4.7). On this basis the soils are seen to have low to negligible salinity hazard; in the Study Area 91% of all sites examined are rated Class I or II, whereas the equivalent figure for the Project Area is 97%.

TABLE 4.6

Salinity Hazard Class Limits

Class	Salinity hazard	Class limit (ECe)
I	Negligible	2.4
II	Low	4.9
III	Moderate	7.4
IV	High	9.9
V	Very high	more than 9.9

TABLE 4.7

Salinity Hazard Classification

Class	Study Area Sites	Study Area %	Project Area Sites	Project Area %
I	221	36.2	120	40.0
II	333	54.5	171	57.0
III	41	6.7	9	3.0
IV	13	2.1	0	0
V	3	0.5	0	0
TOTAL	611	100.0	300	100.0

A comparison of salinity hazard classifications for individual series (Table 4.8) shows that soils derived from old alluvium have a marginally greater hazard than those derived from semi-recent and recent alluvium. Only 6.4% of the latter group of soils have salinity of Class III or higher as compared with 12.5% of the soils derived from old alluvium. However, this apparent trend may be partly accounted for by differences in land use; a relatively higher proportion of the uncultivated lands comprise soils derived from old flood plain alluvium and slightly higher salinity hazards occur on this land as compared with irrigated land (Table 4.9), indicative of the effects of leaching.

TABLE 4.8

Salinity Classes of Soil Series

Soil series	n	Frequency occurrence by classes (%) I	II	III	IV	V/VI
Old Alluvium						
Saruda (Sr)	145	31.0	60.7	5.5	2.1	0.7
Dhoblow (Db)	6	50.0	33.3	16.7	-	-
Golweyn (Gl)	106	25.5	63.2	6.6	3.8	0.9
Majabto (Mt)	9	22.2	22.2	44.5	-	11.1
Shalambood (Sh)	30	26.7	50.0	13.3	10.0	-
Sub-total	296	28.7	58.8	8.1	3.4	1.0
Semi-recent & Recent Alluvium						
Madhuulow (Mw)	24	16.7	75.0	8.3	-	-
Qoryooley (Qr)	171	49.7	45.6	4.7	-	-
Mukoy Dumis (Mc)	58	44.8	46.6	5.2	3.4	-
Buulo Mareerta (Bm)	20	30.0	45.0	20.0	5.0	-
Gayweerow (Gw)	35	42.9	57.1	-	-	-
Faraxaane (Fx)	7	-	100.0	-	-	-
Sub-total	315	43.2	50.4	5.4	1.0	-
TOTAL (all soils)	611	36.2	54.5	6.7	2.1	0.5

Note: Data for all routine survey sites in Study Area.

TABLE 4.9

Salinity in Relation to Land Use

Land use category	Salinity hazard classes (% occurrences) I	II	III	IV	V/VI
1. Uncultivated	35.5	46.4	11.8	4.5	1.8
2. Marginal arable	32.5	59.8	5.1	2.6	-
3. Irrigated annuals	38.2	54.0	6.8	0.7	0.3
4. Irrigated perennials	35.0	59.9	1.3	3.8	-

Source: Data for all Study Area routine sites

(c) Composition of Soluble Salts

In the soil solution salts dissociate into their constituent ions. Analyses were performed on samples from 25 profiles to determine the principal cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and anions ($CO_3^{=}$, HCO_3^{-}, Cl^{-},$SO_4^{=}$); the complete results of these analyses are shown in Appendix C, Section C.2. Figures 4.5, 4.6 and 4.7 illustrate the distribution of soluble ions within selected profiles under different forms of land use.

The dominant soluble ions in the soils are calcium and sulphate with lesser amounts of magnesium and potassium being recorded only in minor amounts in soils derived from channel remnant alluvium. In relatively saline soils (ECe more than 5.0) the proportion of sodium and chloride is greater; the salt sodium chloride has a very high solubility (264 g/l) and is probably responsible for the high salinities in these soils. Indeed, highly significant positive linear correlations were established between chloride ion and ECe ($r = 0.76$, $n = 101$, $p = 0.001$) and between sodium ion and ECe ($r = 0.94$, $n = 72$, $p = 0.001$).

Soluble salt composition bears little relation to soil series but can be linked to differences in land use. An examination of the chloride to sulphate ratio, which is a guide to the degree of leaching, shows that ratios are low for all soils. However, the means of ratios for the upper horizons (0 to 50 cm) of uncultivated soils are significantly (p less than 0.01) greater at 1.3 than those for cultivated/irrigated soils (0.4). No significant difference exists between ratios of the 100 to 150 cm horizons. This suggests that the effects of leaching are confined to the upper layers, consistent with the permeability characteristics of these soils. On the other hand, some of the reduction in Cl : SO_4 ratios is due to deposition of $SO_4^{=}$ from the irrigation water rather than due to leaching of chlorides. This is particularly apparent under irrigated bananas (see Figure 4.6) where a relative increase in sulphate ions is evident in the sub-surface horizons.

The relative mobility of the individual ions is shown by the analyses of a salt efflorescence which formed on the face of Profile R37 (Majabto series). Comparison between analyses of the ions in the efflorescence and those in the soil horizon from which they were derived (Appendix C, Section C.2) shows that Mg^{++}, Na^{+} and Cl^{-} ions are most mobile whereas Ca^{++} and $SO_4^{=}$ values are almost unchanged. The Cl : SO_4 ratio in the soil horizon was 0.8 as compared with 1.8 in the efflorescence, accompanied by a change in ECe from 7.5 to 13.9.

With the exception of the Majabto profile and some subsoils, the soils examined have a relatively low proportion of toxic ions such as Na^+ and Cl^-. In view of the high proportions of soluble Ca^{++} and $SO_4^=$ and the low exchangeable sodium percentages, leaching should not present any serious problems in terms of monovalent-divalent ion balance. Levels of soil gypsum are favourable (0 to 2.0%) as shown in Appendix C, Section C.2, and gypsum crystals occur in many profiles.

(d) Exchangeable Sodium

High levels of exchangeable sodium on the cation exchange complex can result in deflocculation and reduced permeability as soils are leached. All routine samples were therefore tested for exchangeable sodium percentage (ESP).

The results of these analyses (Appendix C, Section C.3) show that very few soils have ESP values in excess of 5, the upper limit for favourable physical properties in Vertisols (Dudal, 1965) and only one site has a value of more than 15, indicative of alkalinisation (Table 4.10). The soils therefore present no sodium hazard. Similarly, the low sodium adsorption ratios (SAR) (Appendix C, Section C.2) indicate that there will be negligible alkalinisation hazard should irrigation be intensified. Although overall SAR values are low, the mean value for soils derived from old alluvium (4.16) is significantly ($p = 0.001$) greater than the mean SAR of 2.22 for soils derived from recent and semi-recent alluvium. A low alkalinisation hazard was also shown by Citaco (1974) in their study of the Buulo Mareerta area; ESP values were reported to be slightly higher than in the present study (mean = 2.8, SE = 0.22) but within the Class A limit.

TABLE 4.10

Exchangeable Sodium Hazards

Class	ESP limits (maxima)	Study Area		Project Area	
		Sites	%	Sites	%
A - Negligible	5	575	93.8	257	97.3
B - Low	10	29	4.7	5	1.9
C - Moderate	15	8	1.3	2	0.8
D - High	20	1	0.2	-	-
TOTAL		613	100.0	264	100.0

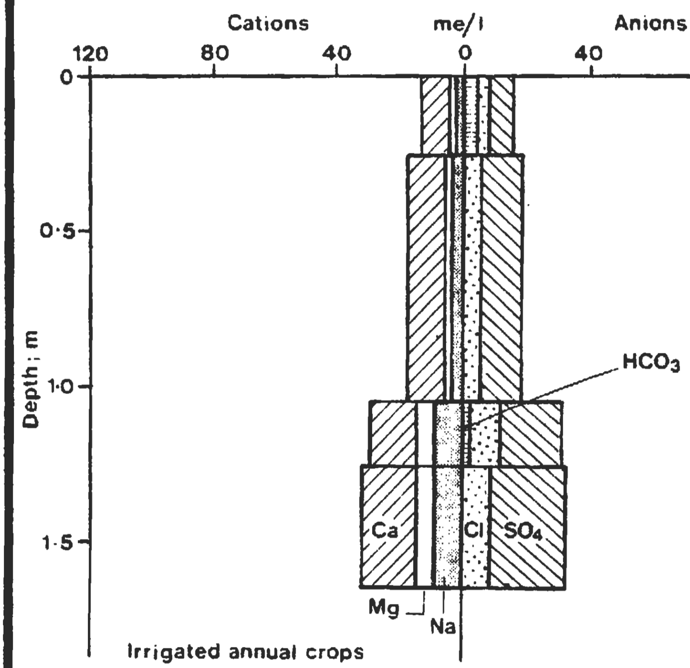
(e) Control of Salinity under Irrigation

As discussed earlier, the salinity values reported in this chapter refer to the present conditions and are susceptible of change with changes in land use. In order to maintain or reduce soil salinity under irrigation, it is necessary to apply sufficient water, in excess of crop requirements, to allow downward leaching and removal of soluble salts from the profile. This process can be expressed in the following equation:-

FIGURE 4.5

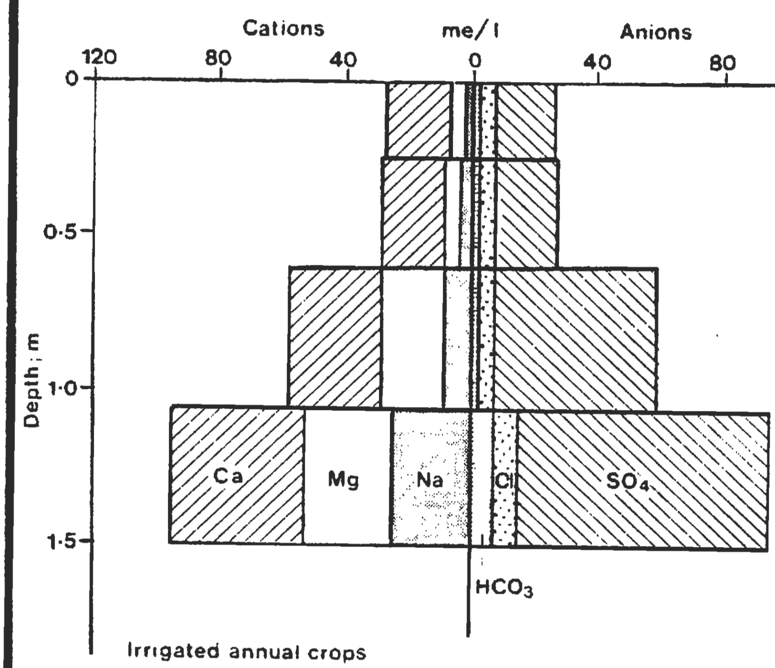
SOLUBLE ION DISTRIBUTION - IRRIGATED SOILS

QORYOOLEY SERIES R17



ECe	ESP	Cl/SO4	SAR
1·4	0·85	0·5	1·1
1·7	1·31	0·2	1·6
1·9	1 44	0·5·	3·0
2·6	1 11	0·3	2 7

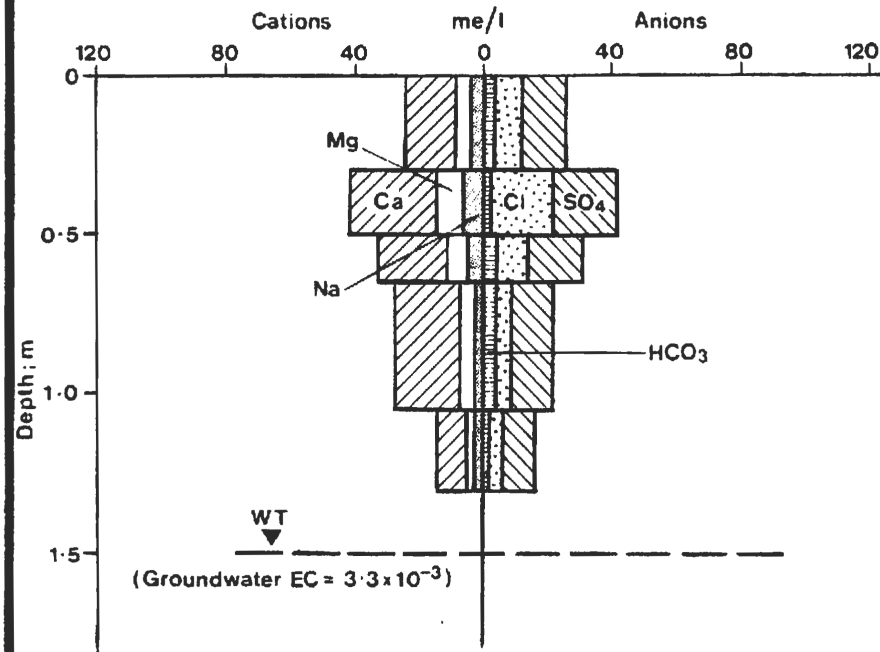
SARUDA SERIES R35



ECe	ESP	Cl/SO4	SAR
1·9	0·7	0·3	0·8
2·2	1·5	0 3	1·1
3·5	1·1	0·1	1 8
5·0	3·0	0 1	4·2

SOLUBLE ION DISTRIBUTION - IRRIGATED SOILS

C. MUKOOYE DUMIS SERIES R33

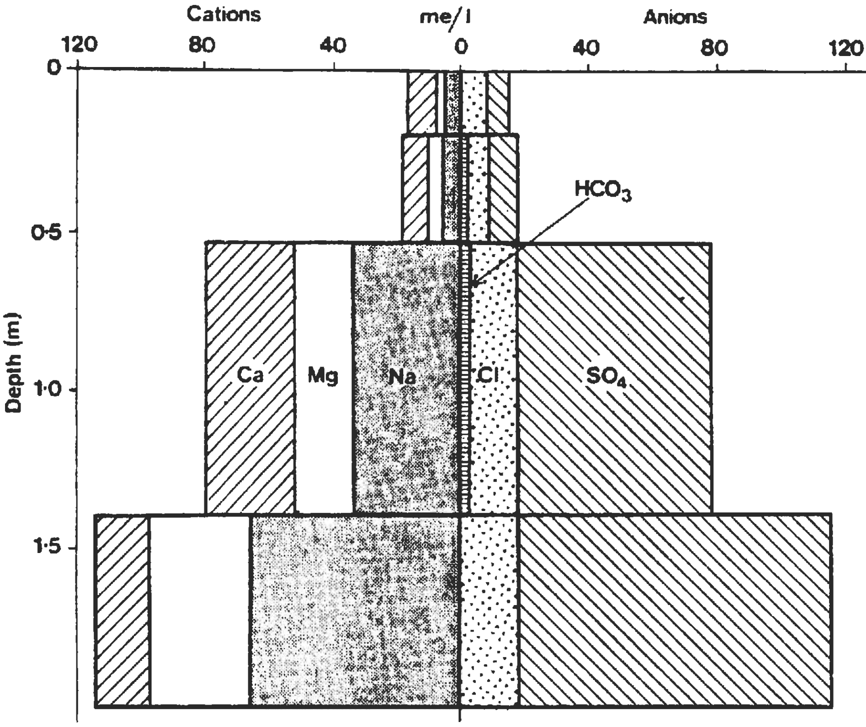


ECe	ESP	Cl/SO_4	SAR
2·2	1·12	0·7	1·1
2·0	0·66	0·8	1·4
2·3	1·15	0·6	1·2
1·8	0·23	0·3	0·7
1·2	0·79	0·4	0·8

Irrigated perennial crops ; bananas

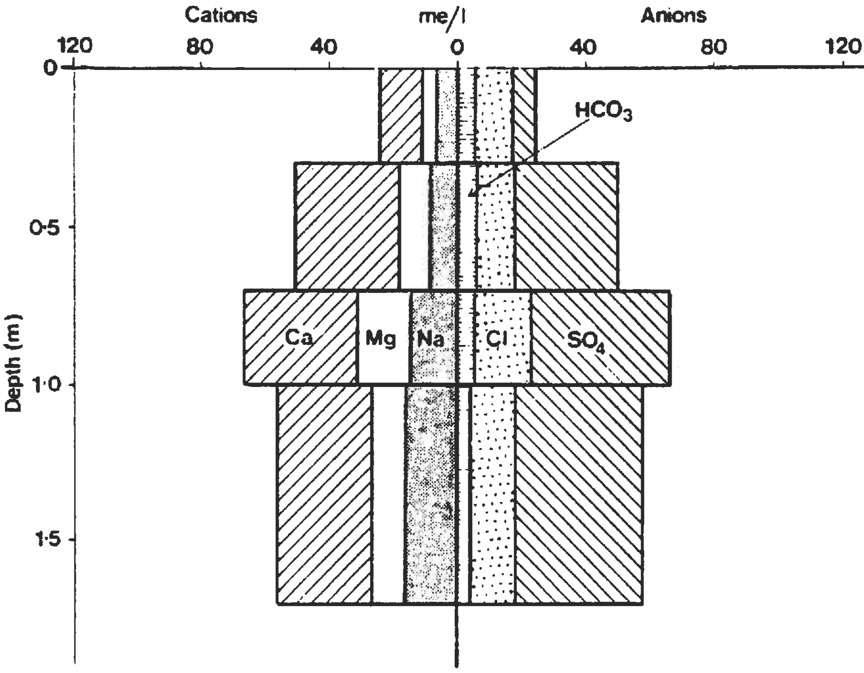
SOLUBLE ION DISTRIBUTION - UNCULTIVATED SOILS

SARUDA SERIES R 10



ECe	ESP	Cl/SO_4	SAR
1·6	1·48	1·1	1·9
1·7	1·77	0·6	2·4
5·6	4·34	0·2	1·2
8·0	7·69	0·2	13·1

MUKOY DUMIS SERIES R 27



ECe	ESP	Cl/SO_4	SAR
2·6	1·47	2·0	2·1
3·7	1·28	0·4	2·0
4·8	0·87	0·4	3·0
4·2	4·18	0·3	3·6

$$LR/In = ECiw/f(5.33 . ECe - 2.667 . ECiw)$$

where LR/In is the fraction of leaching water (LR) compared to the net irrigation application (In)

ECiw is the average electrical conductivity of the irrigation water

ECe is the electrical conductivity of the soil saturated extract

f is the leaching efficiency, representing the efficiency of the leaching water in actually removing soluble salts from the root zone.

The derivations and applications of this equation are described in Annex VI; in the present chapter brief consideration is given to the soil aspects of leaching requirements and efficiency.

The results of the soil analyses indicate that the present salinity hazard is low to negligible for most crops although some loss of yield can be expected for sensitive crops such as grapefruit. This situation could change, however, with more intensive irrigation, a rise in water tables or an increasing use of saline groundwater. The need for a leaching fraction in the irrigation water applications is therefore self-evident if a salt balance is to be maintained.

The feasibility of leaching is a more problematic topic. Subsoil hydraulic conductivities are slow and the effects of leaching are at present confined mainly to the upper 50 cm of the soil profile. Indeed, under traditional subsistence irrigated agriculture there is no hydraulic connection between the root zone and the deep subsoil, down which leaching water could pass. Such connections currently occur only under perennially irrigated banana crops although in future it is probable that hydraulic connections with the deeper subsoil will be established under annual cropping, if improved methods of irrigation are implemented.

In terms of soil chemistry, leaching should present no serious problems. The sodium and chloride ions, which account for much of the soil salinity, are mobile. The soils themselves contain considerable reserves of gypsum and exchangeable calcium and have low sodium adsorption ratios indicating that leaching of sodium ions should not have any adverse effect on soil permeability.

An exact quantification of the leaching efficiency factor, f, must remain a subject for detailed research. Van der Molen (1973) has proposed the adoption of a value of 0.3 for clay soils. This is based on the assumption that downward percolating water passes between peds rather than through the soil mass, thus effectively removing only those salts present on the ped faces. In the soils of the Study Area, soil structure has been observed to disintegrate on saturation, especially in soils derived from the old flood plain alluvium, which would suggest that any water able to percolate downwards would leach most of the soil mass and achieve an efficiency of more than 0.3. Soils derived from semi-recent and recent alluvium appear to have a greater aggregate stability, which is considered to assist downwards movement, but as a result the efficiency of leaching can be expected to be lower and nearer to the figure of 0.3 quoted by Van der Molen (1973). Further information on the efficiency of leaching is likely to be obtained from the results of drainage trials currently in progress at the Jowhar sugar estate (MMP, 1978).

4.5.2 Soil Fertility

The most accurate indication of soil fertility can be obtained only by field experimentation: nevertheless general aspects of the fertility can be inferred from the soil analyses presented in Appendix C.

(a) Nutrient Retention Capacity

All the soils have relatively high clay contents (Table 4.1) in which 2 : 1 lattice montmorillonitic clay minerals predominate. Consequently, they have high cation exchange capacities (Appendix C, Section C.3) and therefore a favourable capacity for the retention of mineral nutrients against leaching.

(b) Presence and Availability of Major Plant Nutrients

The major nutrients are nitrogen (N), phosphorus (P) and potassium (K).

(i) Nitrogen

The mean value for total nitrogen in the surface horizons of the 24 profiles tested is 0.08% (SD = 0.019). As a value of less than 0.10% is considered to be very low, the soils are seen to be deficient in this nutrient and would be likely to respond well to applications of fertiliser nitrogen. Ammonium sulphate would be a suitable source of N. Present nitrogen levels are uniformly low with no detectable difference between land use and soil series. Organic carbon contents are less than 1.2% and the mean C : N ratio is 11 : 5, indicating a high degree of mineralisation of organic nitrogen.

(ii) Phosphorus

This nutrient was determined as the 'available' form. The considerable variation which occurs between samples tested appears to be partially related to land use. Despite the limited number of results available, the data in Table 4.11 suggest that higher levels of P occur under banana plantations, probably due to applications of fertiliser P. The somewhat higher phosphorus values for soils under subsistence agriculture as compared with uncultivated land, could be the result of incorporation of crop residues.

TABLE 4.11

Available Phosphorus in Surface Horizons

Land use	Samples	Available phosphorus (ppm) Mean	SE
Uncultivated	8	2.3	1.04
Irrigated annual crops	12	3.1	0.47
Irrigated bananas	4	6.6	2.34
All samples	24	3.4	0.62

Available phosphorus levels of less than 2.6 ppm are considered to be deficient, therefore most soils in the area can be expected to require application of phosphorus fertiliser. This is normal in Vertisols with a moderately alkaline reaction, in which phosphorus is usually present as the non-available tricalcium salt.

(iii) Potassium

Most available potassium in soils occurs as the exchangeable form, adsorbed to the cation exchange complex. In addition, in saline soils, K ions can exist in the soil solution but these are included in the measurements for exchangeable potassium. Potassium ions can also be added via the irrigation water and contribute to the overall availability of this nutrient.

An examination of the data for exchangeable potassium (Appendix C, Section C.1) shows values to be reasonably consistent throughout profiles with no detectable difference between soil series and land use, although values are slightly higher in the surface horizons. The mean exchangeable potassium value for all 24 profiles tested, comprising 97 individual horizons, is 1.17 meq/100 g (SE = 0.061). This represents the equivalent of 55.1 meq/100 g and, therefore, in terms of exchangeable potassium, the soils do not appear to be deficient in this nutrient. However, in view of the relatively high levels of exchangeable calcium and magnesium in the soils, giving high (Ca + Mg) : K ratios, there are likely to be problems of reduced potassium availability, which may indicate a need for fertiliser K. In terms of application of potassium in irrigation water, assuming a mean content of 7.0 ppm K and an application rate of 1.5 m of water per year, a total of some 10 kg/ha of K could be applied to the land.

(c) Soil Reaction (pH)

Values for pH, as measured in the 1 : 2.5 aqueous extract, are very uniform; the means for each soil series range from 8.1 to 8.4. If expressed in terms of pH of the saturation extract these values would be expected to be in the order of 7.5 to 7.8, indicating negligible alkalinity hazard, as is confirmed by the very low exchangeable sodium values (Appendix C, Section C.3). However, even with these pH levels some reduction in nutrient availability can be anticipated, specifically of phosphorus and the micronutrients such as iron and manganese.

(d) Boron

This micronutrient was measured as hot water soluble boron. The results (Appendix C, Section C.1) show a mean value for all 76 horizons tested as being 1.15 ppm which is above the 0.5 ppm critical value for deficiency. However, tests for boron are often unreliable and considerable variation in boron contents was recorded between batches of samples analysed.

CHAPTER 5

LAND SUITABILITY CLASSIFICATION

5.1 Objectives and Classification Procedure

The purpose of land suitability classification is to rank lands according to their suitability for the types of agriculture appropriate to an area. The primary objective of the present study is to increase the agricultural productivity of the area through improvement of existing irrigated agriculture and expansion of irrigation into new areas. This objective is to be achieved in the context of limited irrigation water supplies, and it is envisaged that the annual crops, maize, upland rice, cotton and sesame, will predominate in the developments. Consequently, a system of land suitability classification was required to show suitability for irrigated annual crop production.

As required by the Terms of Reference, the system adopted is based on the United States Bureau of Reclamation (USBR, 1954) classification for irrigated land use, which ranks land according to its anticipated repayment capacity under irrigation. The main USBR classes are defined briefly as follows:-

Class 1 - Arable:

"Lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops. These lands potentially have a relatively high payment capacity."

Class 2 - Arable:

"Lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity, adapted to a somewhat narrower range of crops. They are not so desirable nor of such high value as lands of Class 1 because of certain correctible or non-correctible limitations. They have intermediate payment capacity."

Class 3 - Arable:

"Lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics than described for Class 2 lands. They are expected to have adequate payment capacity."

Class 4 - Special use or limited arable:

"Lands which are more suitable for irrigation only if used for special crops or systems of irrigation. Class 4 lands may have a range in payment capacity greater than that for associated arable lands."

Class 5 - Non-arable:

"Lands in this class are non-arable under existing conditions."

Class 6 - Non-arable:

"Lands considered non-arable under the existing project because of failure to meet the minimum requirements for the other classes of land. The lands do not have sufficient payment capacity to warrant consideration for irrigation."

These USBR classes provide a convenient basis on which to classify land but it is also essential to accommodate the special attributes and requirements of an area under consideration.

Irrigation agriculture has been practised in the Shabeelle Flood Plain for nearly 50 years and has been proved feasible, but present and predicted yields (Table 5.1) are generally low, due largely to management and agronomic deficiencies. Current land development costs are high at US $ 3 750 per hectare. Insufficient data are available to classify adequately the different land units in terms of their payment capacity, although the yield figures indicate that overall values will be moderate to low. Estimates of land quality have therefore had to be based solely upon the physical characteristics of topography, soils and drainage. Economic aspects, such as bush clearance requirements and proximity to water supplies, are not considered in the classification.

TABLE 5.1

Predicted Crop Yields

Crop	Yield (kg/ha)
Upland rice	1 800
Maize	3 500
Sesame	800
Cotton (seed)	2 000
Groundnuts (unshelled)	2 000

Note: Yield predictions for Qoryooley Project Area (see Annex IV)

5.2 Methods of Classification

Four land suitability classes were defined for use in the Study Area, based on the principles of the USBR system and designed to rank land according to its suitability for annual crops - specifically maize, sesame and upland rice - grown under surface irrigation. The four classes include the equivalent of the USBR arable Classes 1, 2 and 3 and non-arable Class 6, which for ease of interpretation are here termed highly suitable, suitable, moderately suitable and unsuitable respectively. The minimum physical requirements for these classes (Table 5.2) were defined largely on the basis of previous experience in Somalia (FAO/Lockwood, 1968; HTS Ltd., 1969; Citaco, 1974; HTS Ltd., 1977).

Classification is based on the identification of the limitations of each unit of land in terms of its physical features and ranking according to the specifications in Table 5.2. These limitations are broadly divisible into relatively permanent deficiencies, such as soil profile characteristics, and rectifiable deficiencies, such as micro-relief, soil salinity and flood hazard. In the final classification the deficiencies appropriate to a unit of land are indicated as sub-class suffixes to the main land suitability class. Permanent and rectifiable deficiencies are denoted separately.

The criteria of classification are described below, drawing on the information contained in Chapter 4.

5.2.1 Soil Factors

As described earlier, the soils are predominantly Vertisols. Such soils have distinctive characteristics in terms of texture, morphology and soil-water relations which need to be recognised in the land suitability classification. Vertisols are widely and successfully used for irrigation but, as stated by Dudal (1965), problems common to all irrigation farming are more acute on these soils. Water entry and movement through the profile are the principal problems in these soils; the soil factors selected for the classification therefore reflect these soil-water relation aspects.

(a) Profile Factors (p)

Three principal characteristics of the soils are considered, namely soil texture, infiltration and available water capacity. These factors are considered to be 'permanent'.

(i) Soil texture. Preference is given in the classification to soils with loam to friable clay textures; soils dominated by montmorillonitic clays are therefore automatically downgraded to Class 2 or 3, depending on the permeability of their structure. Profiles with significant depths of medium textured horizons in the upper 1.0 m are acceptable for Class 1.

(ii) Infiltration. The time required to infiltrate a depth of 100 mm of water is used as the basis for this criterion, classifying solely in terms of increasing slowness of infiltration as excessively rapid rates do not occur in this area. A range of 1.5 to 8.0 hours is adopted for Class 1, 8 hours being the length of a normal working day.

(iii) Available water capacity. This criterion is considered in terms of the total available water capacity (AWC) and the easily available water capacity (EAWC), each based on the upper 100 cm of the profile. The Class 1 minimum values of 120 and 65 mm for total AWC and EAWC, respectively, are intended to ensure sufficient moisture reserves to allow flexibility in irrigation interval design.

TABLE 5.2

Land Suitability Classification - Minimum Requirements for Classes

Criteria	Class 1 Highly suitable	Class 2 Suitable	Class 3 Moderately suitable	Class 6 Unsuitable
1. Soil Factors				
(a) Profile factors - (p)				
Texture and structure in upper 1.0 m	Loam to friable clay	Sandy loam to permeable clay (at least 50 cm)	Loamy sand or clay	Lands which fail to meet the minimum requirements of the other classes
Infiltration; time for 100 mm to enter	1.5 to 8.0 hours	8.0 to 20.0 hours	20 to 40 hours	
Total available water capacity in upper 1.0 m - AWC	120 mm +	80 - 120 mm	50 - 80 mm	
- EAWC	65 mm +	30 - 65 mm	Less than 30 mm	
(b) Drainability (d) Hydraulic conductivity				
- upper 1.0 m	0.30 - 1.00 m/d	0.10 - 1.00 m/d	Less than 0.30 m/d	
- subsoil	0.30 - 1.00 m/d	0.10 - 0.30 m/d	Less than 0.10 m/d	
(c) Salinity hazard(s)	Class I (less than 2.5 mmho/cm)	Class II (less than 5.0 mmho/cm)	Classes III - IV (less than 10.0 mmho/cm)	
2. Topographic Factors Micro-relief (t)	None	Very weakly undulating; gilgai features	Weakly undulating or slightly dissected	
3. Flood Susceptibility (f)	None	None or slight brief superficial flooding	Extended periods of flooding necessitating surface drainage measures	

(b) Drainability (d)

This factor is based on a combination of observed soil profile characteristics and measured values for horizontal and vertical hydraulic conductivity. The limits for classes (Table 5.2) refer to horizontal hydraulic conductivity values in the upper metre and in the subsoil; they provide guidelines within each soil unit assessed. Deficiencies in this factor are considered to be 'permanent'.

Particular emphasis in this study is placed on the drainability criterion in view of the increasing seriousness of drainage problems which have been encountered under similar soil conditions at the Jowhar sugar estate (MMP, 1976 and 1978).

(c) Salinity (s)

Soil salinity is classified according to the hazard classes defined in Section 4.5. This factor is considered to be 'rectifiable' with leaching and is therefore denoted separately. However, where a Class 3 salinity hazard occurs on soils with Class 3 drainability limitations, the possibilities of effectively and economically removing the salts are considered remote and the land is downgraded to Class 6.

The soils are virtually free of exchangeable sodium hazard and therefore this factor is not included in the classification.

5.2.2 Topography (t)

The lands of the Study Area are, with the exception of minor areas of channel remnants, flat to almost flat. The topographic limitation is therefore mainly used in the context of micro-relief. This is a 'rectifiable' deficiency of the land, demanding more levelling than required under normal land preparation operations.

5.2.3 Susceptibility to Flooding (f)

Flooding in this context includes any superficial inundation by water for extended periods, either derived directly from the river or derived from accumulations of surface run-off which are unable to drain into the river due to its seasonally high water level. Such flooding is not tolerated in Class 1 but brief periods of inundation are accepted in Class 2. The flood hazard is 'rectifiable' and its seriousness depends on the year under consideration. The limits of flooding recorded in the present study refer to a year of high rainfall and riverflows.

In addition to superficial flooding, consideration has been given to the depth to water table, as being an indication of regional drainage hazard. However, water table levels can fluctuate and as insufficient comparable data were available for the upper 3.0 to 4.0 m layers, this factor was not used in the detailed classification. The approximate extent of land with a water table within 2.5 m of the surface is shown on Map 1B.

5.3 Land Suitability Mapping

5.3.1 Representation of Units

Following the methods outlined above, each soil mapping unit was classified in terms of the soil factors (Table 5.3) and then compared with the relevant salinity hazard data in Appendix C, the survey site location maps (Maps 1C and 2C) and recorded information on topography and flood hazard. This procedure enabled the delineation of land suitability classes and sub-classes which are shown at 1 : 50 000 (Map 1B) and 1 : 25 000 (Map 2B) for the Study Area and Qoryooley Project Area, respectively.

TABLE 5.3

Land Suitability Characteristics of Soil Mapping Unit

Mapping unit	Class levels of deficiencies: Profile Factors (p) Texture	Infil-tration	Avail-able water	Drain-ability factor (d)	Basic sub-class	Topo-graphic factor (t)
Saruda (Sr)	3	3	2	3	3pd	1
Dhoblow (Db)	2	2	2	3	3pd	2
Golweyn (G)	3	3	2	3	3pd	1
Majabto (Mt)	2	2	2	2	2pd	1 - 3
Shalambood (Sh)	2	3	2	2	3pd	3 - 6
Madhuulow (Mw)	2	2	2	2	2pd	1
Qoryooley (Qr)	2	2	2	2	2pd	1
(Qr-s)	2	2	2	3	3pd	1
Mukoy Dumis (Mc)	1	1	1	2	2d	1
Buulo Mareerta (Bm)	1	1	1	2	2d	2
Faraxaane (Fx)	1	1	1	2	2d	1 - 2
Gayweerow (Gw)	1	1	1	2	2d	1 - 2

Note: Soil complexes are classified either according to the dominant series or the series with least favourable characteristics.

The land is mapped at the class level of its most limiting characteristics; consequently a unit of land with Class 1 level soil and topographic features, Class 2 level salinity and drainability and Class 3 flood susceptibility would be mapped as Class 3d/sf. In order to assess the potential of the land if, for example, flood control measures were to be implemented, it would be essential to determine the class levels of each limitation. This could be achieved by reference to Appendix C, to determine the soil salinity levels, and by reference to the soil map and Table 5.3 to assess the drainability of the soil unit in the area.

Moreover, should there be a need to introduce a crop with different soil requirements, such as grapefruit which is sensitive to salinity, the salinity class level of any land suitability unit can be checked against the soil salinity data. Similarly, for paddy rice the present land suitability classification could be re-interpreted with the aid of the soils and survey site location maps, the Appendix C salinity data and Table 5.3, to identify lands with the poor drainability and fine textures which are required by this crop.

It is important to emphasise that the accuracy of the land suitability mapping is considered to be acceptable for the map scale employed. This accuracy could not be guaranteed if the maps were to be enlarged beyond their original scale unless accompanied by an appropriate amount of additional field surveys.

5.3.2 Study Area Mapping Units

Table 5.4 summarises the proportions of land suitably classes, and shows that some 90% of the Study Area is irrigable, divided approximately equally between Classes 2 and 3. The remaining areas (10%) are rated Class 6 as being unsuitable for irrigation.

TABLE 5.4

Summary of Land Suitability Class Areas

Class		Study Area		Project Area	
		ha	%	ha	%
1	Highly suitable	-	-	-	-
2	Suitable	28 852	42.4	1 131	19.6
3	Moderately suitable	32 424	47.3	4 252	73.7
4	Unsuitable	6 134	10.3	386	6.7
TOTAL		67 410	100.0	5 769	100.0

A detailed breakdown of the proportions of individual land suitability sub-classes is given in Table 5.5. The principal characteristics of the classes are described below:

(a) Class 1: Land Highly Suitable for Irrigation

No Class 1 land is recognised due to the poor drainability characteristics of the subsoils. These comprise clays of the old flood plain alluvium which are encountered within the upper 3.0 m of soil profiles throughout the Study Area.

Although the upper soil horizons of recent or semi-recent alluvium may have drainability characteristics acceptable for Class 1, the low hydraulic conductivities of the subsoils could be expected to represent a considerable constraint on any future artificial drainage operations.

(b) Class 2: Land Suitable for Irrigation

This class is mapped extensively in the areas of soils derived from semi-recent and recent alluvium. The lands are broadly divisible into two groups:-

(i) Lands with Class 2d permanent deficiencies. These include areas of Gayweerow, Faraxaane, Buulo Mareerta and Mukoy Dumis series and their complexes, which have profile characteristics of Class 1 quality, due to significant depths of medium textured horizons, but have overall Class 2 drainability deficiencies due to the low hydraulic conductivities in the subsoils. Most of these soils also have rectifiable deficiencies, such as uneven topography along minor channel remnants and Class 2 salinity hazard, resulting in downgrading to Classes 2d/t, 2d/s and 2d/st. These lands occur principally in the south-west as moderately extensive units. In addition, soils of otherwise Class 2 quality are downgraded to Classes 3d/f, 3d/ft or 3d/fst due to flooding hazard and/or topographic constraints of Class 3 proportions and are mapped as minor units of land, particularly on Gayweerow series, adjacent to the Shabeelle river.

(ii) Lands with Class 2pd permanent deficiencies. These lands have qualities slightly inferior to the Class 2d lands of the previous group but are suitable for irrigation. They occur as extensive areas of soils derived from semi-recent alluvium (Qoryooley and Madhuulow series) which have moderately permeable clay texture horizons in the upper 1.0 m, resulting in profile deficiencies of Class 2 proportions in addition to the overall drainability deficiencies. Extensive areas are rated Class 2pd/s due to salinity hazard and some areas in the south-west are also affected by uneven topography (2pd/st).

Minor units of land adjacent to the Shabeelle river of otherwise Class 2pd limitations are further downgraded due to flood hazard (3pd/fs or 3pd/f).

TABLE 5.5

Land Suitability Classes of Study Area

Class/sub-class		Area ha	%
Class 1		-	-
Class 2:	2d	1 732	2.6
	2d/t	350	0.5
	2d/s	800	1.2
	2d/st	835	1.2
	2pd	11 557	17.1
	2pd/s	12 105	18.0
	2pd/t	180	0.3
	2pd/st	1 021	1.5
	Sub-total	28 580	42.4
Class 3:	3d/f	89	0.1
	3d/s	137	0.2
	3d/st	178	0.3
	3d/sf	-	-
	3d/fst	1 942	2.9
	3d/ft	485	0.7
	3pd	6 256	9.3
	3pd/s	19 973	29.7
	3pd/st	838	1.2
	3pd/f	137	0.2
	3pd/fs	1 846	2.7
	Sub-total	31 881	47.3
Class 6:		6 949	10.3
	Sub-total	6 949	10.3
	TOTAL	67 410	100.0

(c) Class 3: Land Moderately Suitable for Irrigation

This class is mapped principally in areas occupied by soils derived from the old flood plain alluvium, mainly Saruda and Golweyn series. These soils have relatively impermeable clay profiles with poor aggregate stability and slow infiltration rates which result in Class 3 deficiencies of both profile (p) and drainability (d) characteristics. In addition, extensive areas have Class 2 salinity hazard and are mapped as Class 3pd/s. Both the Class 3pd and 3pd/s lands are moderately suitable for irrigation but they will require more specialised management than Class 2 lands if sustained agricultural production is to be achieved. The fine clay textures and slow infiltration rates could limit their flexibility of use in terms of tillage operations and length of irrigation interval.

Artificial drainage is likely to be very difficult to achieve as will be the leaching of soluble salts from lands with a Class 3pd/s rating. Until such time as leaching can be shown to be effective on these soils, any lands with both drainability and salinity hazard deficiencies of Class 3 proportions have been automatically downgraded to Class 6.

In addition to the lands with permanent Class 3pd deficiencies, minor areas of land with basically Class 2 deficiencies (2pd, 2d) have been downgraded to Class 3 on the basis of rectifiable flooding hazard and/or topography, as described above. A small area of the Channel Remnant (CR) soil unit has been mapped on Class 3pd/st due to only minor topographic limitations; elsewhere this unit is placed in Class 6.

(d) Class 6: Land Unsuitable for Irrigation

This class includes all lands which, under present project conditions, are not considered to be irrigable. They comprise channel remnant areas, which are excluded principally on topographic grounds, and some areas of Saruda, Golweyn and Majabto series which have a combination of poor drainability and moderate to high salinity.

5.3.3 Qoryooley Project Area

Almost 93% of the land in the Qoryooley Project Area is mapped as being irrigable (Table 5.4); of this approximately 20% is Class 2 and 80% Class 3. The remaining areas are rated unsuitable for irrigation (Class 6). Consequently there is a lower proportion of Class 2 land than in the Study Area as a whole but it should be explained that the land covered by the soil survey extends beyond the limits of the proposed Qoryooley project. The additional lands which are not scheduled for inclusion in the project lie remote from the river in areas mapped exclusively as Class 3 (see Map 2B) and therefore the proportion of Class 2 lands within the boundaries covered by the feasibility study will be greater than those shown in Table 5.4.

The proportions of individual land suitability sub-classes as mapped are shown in Table 5.6. The class characteristics are essentially similar to those mapped over the Study Area as a whole although fewer sub-classes were recognised in the Qoryooley area.

(a) Class 1: Land Highly Suitable for Irrigation

No Class 1 was recognised due to the inferior drainability characteristics of the subsoils.

(b) Class 2: Land Suitable for Irrigation

These lands are divisible into those with the permanent deficiencies of drainability (2d) and those limited by both profile and drainability features (2pd). The former occur near the river and along the main overflow channels on Gayweerow and Mukoy Dumis soils; they mostly have minor topographic deficiencies and/or salinity hazard. The lands with a basic 2pd classification occur on the level areas of Qoryooley and Madhuulow series immediately beyond the main levee of the river. Some of these lands have a salinity hazard of Class 2 proportions.

(c) Class 3: Land Moderately Suitable for Irrigation

Very extensive areas of Class 3 land occupy the Saruda, Golweyn and Golweyn-Majabto soil complex. These areas are principally classified as either 3pd or 3pd/s depending on the salinity hazard. In addition, Qoryooley shallow phase is given a Class 3pd rating due to the proximity to the surface of a poorly drainable subsoil.

Areas of land which would otherwise be rated Class 2d/s or 2pd/s have been mapped in Class 3pd/sf or 3d/sf due to the hazard of flooding, especially in the south-east of the area.

(d) Class 6: Land Unsuitable for Irrigation

This includes land with uneven relief associated with the main channel remnant complex in the south-east of the area and adjacent areas of Golweyn-Majabto complex which, due to poor drainability and moderately high salinity, have been downgraded from Class 3. These areas are also locally downgraded to Class 6 on the basis of flood hazard and high water tables. A small area of Saruda soils with Class 3 salinity hazard and drainability deficiency has also been placed in Class 6.

TABLE 5.6

Land Suitability Classes of Qoryooley Project Area

	Class/sub-class	Area ha	%
Class 1:		-	-
Class 2:	2d	30	0.5
	2d/t	76	1.3
	2d/st	57	1.0
	2pd	474	8.2
	2pd/s	494	8.6
	Sub-total	1 131	19.6
Class 3:	3d/sf	139	2.4
	3pd	1 777	30.8
	3pd/s	2 287	39.6
	3pd/sf	49	0.9
	Sub-total	4 252	73.7
Class 6:		386	6.7
	Sub-total	386	6.7
TOTAL		5 769	100.0

CHAPTER 6

COMPARISONS WITH PREVIOUS SOIL AND LAND CLASSIFICATION STUDIES

6.1 Methods of Classification

Several land classification studies have been carried out which cover the present Study Area (FAO/Lockwood, 1968; Citaco, 1974; Hunting Technical Services Ltd., 1977) or adjacent areas of similar soils (Hunting Technical Services Ltd., 1969) and have been reviewed in Chapter 2.5. Each of these studies was conducted at a different scale of mapping but all have had as their primary objective the ranking of land according to its suitability for surface irrigation of annual crops. The purpose of this section of the report is to attempt to correlate the various classification systems of these earlier surveys with that of the present study.

In each of these surveys, with the exception of the FAO/Lockwood (1968) study, the USBR (1954) system was used as a basis for land classification. It is therefore against the USBR system that each method of classification is compared. Table 6.1 shows that the classes defined by each study are broadly similar, the exceptions being mainly in the nature and level of deficiencies which are used to define classes. In particular, the Citaco (1974) system does not use salinity as a criterion of classification because measured salinity values were very low and were not considered to be limiting even to grapefruit. However, it is advisable to emphasise that the Citaco salinity measurements were determined as the EC of the 1 : 2 soil/water extract ($EC_{1:2}$) and yet they were compared with the normally accepted and more reliable values for EC of the saturation extract (ECe) in their classification standards. During the present study (Appendix E) ECe values have been shown to be about double the $EC_{1:2}$ values. On this basis, therefore, the validity of the quoted salinity limits and indeed the land class mapping of the Citaco study are highly questionable.

6.2 Interpretation of Soil Suitabilities

Direct comparisons between the different surveys are very difficult as each has adopted different soil mapping units which, although usually based on the original FAO/Lockwood soil units, inevitably have been modified to suit the level of survey and mapping. Using the FAO/Lockwood soil units as a basis, the following comparisons are possible:-

(a) Saruda Soil Unit

This soil was classed as marginal for irrigation by the original study (FAO/Lockwood, 1968), downgraded largely as being difficult to manage. In the review of this mapping (HTS Ltd., 1977) the Saruda unit was upgraded to Class II solely on the basis of soil and micro-relief considerations. The Saruda unit was adopted for the Hunting Technical Services Ltd. (1969) surveys and mapped at Balcad, where it was rated as a complex of Classes 2 and 3, in view of poor profile and salinity characteristics. The soil unit does not occur within the area mapped by

TABLE 6.1

Correlation between Land Suitability Classification Systems used in Lower Shabeelle Flood Plain

USBR (1954) basic system for use in USA		Janaale-Buulo Mareerta study (1978)-annual crops		FAO/Lockwood (1968)		Hunting Technical Services Inter-riverine study (1977)		Citaco, Buulo Mareerta area (1974)-annual crops and grapefruit		Hunting Technical Services Afgooye-Balcad study (1969)	
Class	Description	Class	Description	Class	Description	Class	Description	Class	Description	Class	Description
1	Arable: highly suitable for wide range of crops.	1	Highly suitable (accommodated but not mapped).			I	Soils suited to very wide range of crops.	1	Highly suitable	1	Highly suitable
2	Arable: somewhat inferior to Class 1 and more limited range of crops.	2	Suitable: drainability, soil profile, salinity hazard deficiencies, locally topographic limitation.	A	Suitable	II	Suited to wide range of crops: drainage or soil limitations.	2	Suitable: drainage and texture deficiencies.	2	Moderately suitable: minor soil and micro-relief limitations.
3	Arable: Suitable but approaching marginality. Limited range of crops.	3	Moderately suitable: drainability, profile, salinity and locally topographic deficiencies and/or flooding hazard.	B	Marginal: salinity and alkalinity hazard and/or beyond irrigation command.	III	Suited to limited range of crops: soil (available water and texture), drainage and salinity deficiencies.	3	Marginal suitability: drainage and texture deficiencies	3	Moderately to suitable: soil profile and salinity
4	Special use or limited arable: suitable for special crops or method of irrigation.	-	(not used)	-	(no equivalent)	IV	Marginal for cropping: severe drainage and salinity/alkalinity hazard requiring extensive reclamation.	-	(no equivalent)	-	Limited suitability: severe limitations of soil texture, salinity, micro-relief and alkalinity
5	Non-arable under existing conditions	-	(not used)	-	(no equivalent)			-	(no equivalent)	-	(not used)
6	Non-arable: fails to meet minimum requirements for arable classes.	6	Unsuitable: extreme deficiencies of soils, drainage, salinity, topography.	C	Unsuitable: salinity/alkalinity hazard, soil depth and erosion hazard.	VI	Unsuited: extreme deficiencies of topography, salinity/alkalinity, shallow profile, erosion.	6	Unsuitable: deficiencies of topography	6	Non-arable: extreme deficiencies of soil profile, salinity/alkalinity, topography.

Citaco but is shown as being widespread in the north of the present Study Area; this has now been confirmed and the Saruda unit has been redefined as a soil series (Sr). In addition, it has also been mapped extensively to the south-east of the Shabeelle river. The Saruda series has been rated as Class 3pd or 3pd/s, depending on salinity hazards, and locally as Class 6.

(b) Goluen Soil Unit

This soil unit was rated Class A by FAO/Lockwood (1968) as being suitable for irrigation but as Class II by Hunting Technical Services Ltd. (1977) on the basis of fine textures and salinity hazard. In the Afgooye and Balcad surveys (HTS Ltd., 1969) the Goluen soil unit was recognised and mapped mainly as a complex of Classes 2 and 3, as for the Saruda unit, but locally Goluen soils were rated Class 2 and even Class 1.

The Goluen soil unit is mapped as occurring extensively in the Janaale-Buulo Mareerta area but during the present study is was re-defined as Golweyn series, within much narrower limits than the original soil unit and confined to soils of the old alluvium flood plain with 7.5YR hue colours. As such, the Golweyn series is rated Class 3pd or 3pd/s on the basis of profile, drainage and/or salinity hazard. The remaining areas are mapped as a range of series derived from semi-recent and recent alluvium parent materials which were not identified during the reconnaissance studies by FAO/Lockwood (1968). These soils are here placed mainly in Class 2 in recognition of their more favourable profile and drainability characteristics as compared with the strictly defined Golweyn series. Some of these soils also have a Class 2 salinity hazard. It is probable that those areas of the Goluen soil unit mapped in the Afgooye survey (HTS Ltd., 1979) as being Class 1 or Class 2 are comparable with the semi-recent and recent alluvial soils series of the present study.

The area of the Citaco (1974) survey lies wholly within the Goluen soil unit as originally mapped and occupies the south-west part of the present Study Area. Citaco classified the land approximately equally between Classes 1, 2 and 3 with only 1% in Class 6. This compares with a predominantly Class 2 rating for the area in the present study. This difference arises from three sources: first, in the current study greater emphasis has been placed on drainability with the result that many areas which would otherwise meet Class 1 standards (e.g. Mukoy Dumis series) have been downgraded to Class 2d. Secondly, although some soils of the semi-recent alluvium are clay textured, and placed in Class 3 by Citaco as being unsuitable for grapefruit, the soil structure here is considered sufficiently permeable to retain the soils in Class 2pd for the production of annual crops. Thirdly, owing to their use of non-comparable salinity measurements, Citaco did not see the need to employ salinity hazard as a criterion in their classification.

In conclusion, there is a reasonable similarity between the various surveys, although anomalies inevitably occur due to the different scales of mapping and purposes of the individual study. In the present study there has been greater emphasis placed on drainability as a criterion of classification, resulting in irrigable land being mapped in Classes 2 and 3 but not Class 1.

APPENDIX A

SOIL SERIES DESCRIPTIONS

A.1 Methods of Description

In this appendix the eleven soil series identified and mapped during the field surveys are defined in terms of their profile characteristics and physiography. Detailed profile descriptions for sites representative of each series, referred to in Section A.2, are included in Section A.3.

The method of description follows the principles of the FAO (1968) Guidelines. Soil colours are described in the most moist state using the Munsell notation. Soil classification is according to the FAO/UNESCO legend (1974). In the detailed descriptions, horizons are described in terms of the ABC nomenclature although for Vertisols this system tends to be difficult to apply. Soil morphology is described in the dry or slightly moist state as most structure in Vertisols disintegrates when the profile is wetted. Complete soil chemical and physical data are provided in Appendices C and D; sample numbers in the descriptions refer to detailed (D) or routine salinity (S) analyses. Soil reaction is given as the pH of the 1 : 2.5 soil/water suspension.

A.2 Soil Series Definitions

The series are described in order according to the principal parent material within which each is formed. These parent materials and the alluvial sequence are described in Chapter 2.1.

A.2.1 Soils derived from Old Flood Plain Alluvium

(a) Saruda Series (Sr)

Classification: Chromic Vertisols.

Location and physiography: The soils are formed in the fine textured alluvium of the old meander flood plain (1c and 1d) and occur extensively throughout the northern and south-eastern parts of the Study Area. Gilgai micro-relief occurs locally but mostly the land is level.

Land use: Much of the area mapped as Saruda series has been cleared for irrigated subsistence agriculture although large areas south-east of the river have subsequently been abandoned. A small area of banana plantation is located on Saruda soils near Janaale. Along the northern boundary of the area natural scrub vegetation persists on these soils. Saruda series accounts for some 50% of the soils of the Project Area.

Profile characteristics: Profiles are deep and moderately well drained with clay textures and dark greyish brown colours throughout. In the dry state the soils crack to a depth of at least 1.0 m (see Description No. 1). The upper horizon (20 to 25 cm) has medium to fine angular blocky structure and carries a thin (5 to 10 mm) friable mulch at the surface. The second horizon typically has prismatic structure with coarse aggregates and intervening vertical cracks. This horizon merges at a depth of 50 to 70 cm into a zone of compact blocky-wedge structure in which large slickensides are prominent. The colours in these horizons are uniformly dark to very dark greyish brown (10YR 4/2-3/2) and textures are clay. Below a depth of between 120 and 150 cm a browner (10YR 4/3) coloured horizon often occurs which has weakly developed structure and silty clay loam textures. This corresponds to the older 1d alluvium. The soils are calcareous throughout the profile; fine (1 to 3 mm) white $CaCO_3$ nodules and shell fragments are common in most profiles and gypsum crystals occur in the lower horizons. Small (1 to 2 mm) manganese coated nodules were observed in many soils. Shells and shell fragments are usually present at the soil surface. Porosity is very low except for the vertical and inter-ped cracks which form in the dry state. Plant roots are usually concentrated within the upper 50 cm of Saruda soils but roots of perennial plants do penetrate deeper.

Associated soils: The series is similar to the Saruda soil unit described by FAO/Lockwood (1967), but is mapped over a larger area than in the earlier survey. Saruda series is associated with Golweyn series from which it is distinguished by the dominance of colours of the 10YR hue. Discrete channel remnants (CR), characterised by Shalambood series, occur within the areas mapped as Saruda series and locally Saruda soils are complexed with Dhoblow series. Near to the Shabeelle river the Saruda soil parent materials are overlain by more recent alluvium and the soils are juxtaposed with Qoryooley series, which has colours in the 5YR hue. In general the Saruda soils have very uniform profiles and are readily distinguished by their dark greyish brown colours, clay textures and Vertisol morphology.

(b) Dhoblow Series (Db)

Classification: Vertic Cambisols

Location and physiography: These soils are formed in mixed fine and medium textured alluvium (1c and 1d) associated with minor channel remnants and meander scars in the old flood plain. The terrain is often weakly undulating and gilgai and sink hole micro-relief is common. The soils are mapped locally in the south and east of the Study Area, complexed with Saruda series.

Land use: The soils are either under sparse remnant natural vegetation or used for low intensity rainfed and irrigated cropping.

Profile characteristics: The profiles are varied, reflecting differences in alluvial origin; textures are predominantly silty but are interstratified with clay loam, loam and clay. The Vertisol characteristics of cracking and blockwedge structures are weakly developed in the upper horizons but large wedges and slickensides are often present in the subsoil. Soil colours range from very dark greyish brown (10YR 3/20 to brown (7.5YR 4/4). The Dhoblow soils are strongly calcareous, containing nodules and soft flecks of $CaCO_3$ and shell fragments throughout the profile. The medium textured horizons are moderately porous. Roots of perennial plants extend down to at least 1.0 m (see Description No. 2).

Associated soils: Dhoblow soils are mapped only as a complex with Saruda series, which lacks the texture variation. The soils resemble Shalambood series but have darker colours and are associated with only minor channel remnants within the main flood plain.

(c) Golweyn Series (Gl)

Classification: Chromic Vertisols

Location and physiography: Golweyn soils are developed within the fine textured dark brown clays (1a) of the old flood plain. They are mapped extensively on the level flood plain throughout the central and south-eastern parts of the Study Area and locally to the north of the Shabeelle river.

Land use: Most of the areas mapped as Golweyn series have been cleared and are used for irrigation of annual and perennial crops.

Profile characteristics: The soils are moderately well drained with predominantly clay textures and brown (7.5YR 4/2) colours. A thin mulch forms at the surface in the dry state and cracks form to a depth of 75 to 100 cm (see Description No. 3). The upper horizon of 20 to 25 cm is normally clay textured, with sub-angular blocky structure and brown colours (7.5YR 4/2) but where the soils are overlain by more recent alluvium the surface horizon may be more silty and redder in colour. Below 20 to 25 cm depth the Vertisol characteristics of prismatic and blocky-wedge structure predominate, textures are clay and colours are predominantly brown (7.5YR 4/2). Soil colours become increasingly greyish brown (10YR 4/2) below 100 cm as the parent material merges with the older dark greyish brown Saruda clays (1c).

The soils are strongly calcareous throughout the profile and $CaCO_3$ nodules are common below 25 cm depth. Gypsum crystals are often present in the lower horizons. Roots are normally confined to the less compact horizons in the upper 75 cm of the profile.

Associated soils: The series is similar to the Golweyn soil unit described by FAO/Lockwood (1967) but for the purposes of this study has been re-defined to include only those soils derived from the brown coloured old flood plain alluvium (1a). The redder coloured soils derived from more recent alluvium, but previously included within the Golweyn unit (FAO/Lockwood, 1967) have been assigned to separate series. The Golweyn series comprises a range of profile types, varying between those with a shallow depth of brown alluvium overlying Saruda series, to those in which an overlay of semi-recent reddish brown alluvium predominates. Consequently, the series is associated with Saruda series at one extreme and Qoryooley series at the other.

(d) Majabto Series (Mt)

Classification: Vertic Cambisols

Location and physiography: These soils are formed in medium to fine textured alluvium (1a and 1d) of mixed flood plain and channel remnant origin. They occur locally on the level to slightly depressional terrain associated with the major channel remnant of the right bank of the Shabeelle river near Tawakal.

Land use: Most of the Majabto soils have been used for low intensity irrigated agriculture but some areas have reverted to sparse scrub or thickets of Acacia woodland.

Profile characteristics: Majabto soils are two layered, comprising an upper layer of clay or clay loam with brown (7.5YR 4/2) colours and Vertisol characteristics and a subsoil of brown (10YR hue) silt loams and silty clay loams with friable single-grained structure. The upper horizons are similar to Golweyn series; they are at least 50 cm thick and often extend down to a depth of 1 m (see Description No. 4).

The soils are moderately well drained in the upper profile but a water table was frequently encountered between 100 and 150 cm depth. Porosity is low in the upper horizons but increases in the silty layers of the subsoil. Profiles are strongly calcareous and $CaCO_3$ nodules are common throughout the profile: gypsum crystals and salt efflorescences occur in the lower horizons. Fine flakes of mica (muscovite) are characteristic of the subsoil alluvium. Roots are mostly confined to the upper 50 to 70 cm of the profile.

Associated soils: Majabto soils are mapped in a complex with Golweyn series, from which they are distinguished by the presence of a silt loam to silty clay loam layer within the 50 to 100 cm depth range. Majabto soils merge laterally with Shalambood series of the main channel remnants.

(e) Shalambood Series (Sh)

Classification: Vertic Cambisols - Eutric Cambisols.

Location and physiography: Shalambood soils are formed in stratified levee alluvium of the channel remnants of the old meander flood plain. They are mapped within the Channel Remnant (CR) complex as narrow strips of land, seldom wider than 300 m, associated with former river channels and occur mainly in the left bank area of the Shabeelle river. The terrain varies from almost level, where the old channels have been infilled, to undulating and uneven where a main channel and levee still persist.

Land use: Apart from local areas of low intensity irrigated agriculture, the channel remnants carry a cover of scrub and thicket vegetation which is used for fuelwood supplies and livestock browse. Swampy areas occur locally which are colonised by aquatic vegetation.

Profile characteristics: Shalambood soils are typically formed in stratified clay, silt loam and silty clay alluvium but range from predominantly silt loam profiles to those which are almost entirely clay textured. They are well to moderately well drained and have dark yellowish brown to brown (10YR 4/4-4/3, 7.5YR 4/2) colours (see Description No. 5).

The Shalambood profiles have only weakly developed Vertisol characteristics; cracks are usually shallow and prismatic or wedge structures occur only in the clay textured lower horizons. Porosity is low and the soils are often very compact, especially below a depth of 50 cm. Roots are concentrated in the upper horizons but tree roots can be traced down to 100 to 125 cm depth. The soils are strongly calcareous and $CaCO_3$, either as discrete 2 to 5 mm nodules or soft white flecks, is common throughout the profile; gypsum crystals occur in the subsoil horizons.

Associated soils: Laterally the Shalambood soils merge with the clay soils of Saruda and Golweyn series on the main flood plain. Within the Channel Remnant complex (CR) they are often associated with darker brown clay textured soils of the old channel beds. The soils often resemble Majabto series, from which they are distinguished by their greater textural stratification and their location along old levees and channels. Shalambood soils are less dark coloured and more silty textured than Dhoblow series.

A.2.2 Soils Derived from Semi-recent Alluvium

(a) Madhuulow Series (Mw)

Classification: Chromic Vertisols.

Location and physiography: These soils are derived from clay textured semi-recent alluvium (2b) and are mapped moderately extensively on the level flood plain in the west of the Study Area near to the Shabeelle river.

Land use: The soils are almost exclusively used for irrigated agriculture, mainly by small-scale subsistence farmers.

Profile characteristics: Madhuulow soils are clay textured, moderately well drained and have predominantly reddish brown (5YR 4/2-3) colours. Vertisol characteristics are strongly developed in the form of deep cracking, a surface mulch and the presence of slickensides in the lower horizons. These lower horizons typically have a conchoidal blocky structure and faint grey mottling to the surface of the peds (see Description No. 6).

The surface horizon is usually friable when moist, with sub-angular blocky structure and reddish brown colours (5YR 4/3) although some profiles have browner (10YR 4/2) colours. This overlies an horizon of fine blocky to wedge structure at 20 to 25 cm depth which is more compact; the surfaces of the peds often have faint greyish brown mottles but the dominant colour remains 5YR 4/2-4/3. Below a depth of 50 to 75 cm the structure is stronger and coarser with discrete, dense conchoidal blocky aggregates which have greyish brown mottles and coatings to their surfaces. Gypsum crystals and white $CaCO_3$ filaments often occur in this horizon. Below a depth of 100 to 125 cm the colours become darker (7.5YR 4/2 - 5YR 4/2), the structure is weaker and predominantly wedge shaped in many profiles. Within the conchoidal blocky horizons there often occurs a thin (5 to 10 cm) layer of very dark grey (10YR 3/1) clay containing many shell fragments. In the dry state cracks extend down to at least 100 cm depth and minor cracks occur between individual peds in the lower horizons. Tubular pores (1 mm) occur in the conchoidal blocky structure, often grey mottled in their interior; these probably represent former root channels.

The soils are strongly calcareous but $CaCO_3$ nodules and filaments are confined to the lower horizons. Roots are concentratd in the upper, friable horizons but some penetrate between peds to nearly 100 cm.

Associated soils: Madhuulow soils are associated with Qoryooley series, which also has reddish brown colours but lacks the mottling in the lower horizons. The seies merges with Gayweerow, Mukoy Dumis and, locally, with Faraxaane series, along minor channel remnants in the recent and semi-recent flood plain but is distinguished from these soils by the lack of silty loam and fine sand horizons.

(b) Qoryooley Series (Qr)

Classification: Chromic Vertisols

Location and physiography: Qoryooley soils are formed in fine-textured alluvium of the semi-recent flood plain (2c) but overlie the darker coloured clays of the old flood plain (1c). The soils are mapped extensively in the Study Area, principally to the south and south-west of the Shabeelle river. The terrain is level but slight micro-relief caused by sink holes and gilgai occurs locally in areas which have not been cultivated.

Profile characteristics: Profiles are deep and moderately well drained with predominantly clay textures and crack deeply in the dry state. The upper 50 to 100 cm comprises reddish brown (5YR 4/3) clay which overlies brown (10YR 4/2-4/3) clay (see Description No. 7). The upper 20 to 25 cm of the profile consists of reddish brown (5YR 4/3) friable, sub-angular blocky clay. This overlies a more dense horizon of reddish brown to dark reddish brown (5YR 4/3-4/2) clay or locally silty clay, with fine conchoidal blocky to weak prismatic structure which extends down to a depth of at least 100 cm and very rarely includes thin lenses (2 to 5 cm) of silt loam and silty clay loam. Below this there usually occurs a transitional horizon (10 to 20 cm) of very dark grey (N 3/0 - 10YR 3/1) clay with many shell fragments, which abruptly overlies the brown to dark greyish brown (10YR 4/3-4/2) clay subsoil. This subsoil comprises old flood plain alluvium similar to Saruda series: it has weakly developed wedge structure and contains shell fragments and fine $CaCO_3$ nodules.

The soils are strongly calcareous throughout their depth. Porosity is low but in the dry state the soils crack deeply and considerable inter-ped porosity occurs between the conchoidal blocky structural units. Roots are most common in the upper 75 cm but some were observed down to nearly 200 cm in some profiles.

In many of the Qoryooley profiles examined, the transition to the compact darker coloured subsoil occurred at between 50 and 100 m depth; such profiles were classed as Qoryooley shallow phase, Qr-s (see Description No. 8). Only in the detailed mapping of the Project Area was this phase mappable as a separate unit.

Associated soils: Qoryooley soils are closely associated with Mukoy Dumis series, which has a significant horizon of silty loam textures, and the two soils are mapped extensively as a complex. In some areas this complex also includes Buulo Mareerta series, which occurs on minor recent channel remnants within the semi-recent flood plain. Elsewhere Qoryooley series is complexed with Gayweerow series. In many cases the distinction between Qoryoolow shallow phase and the red phase of Golweyn series proved to be difficult to make and consequently areas mapped as Qoryooley series may contain significant inclusions of Golweyn series. Although superficially similar to Madhuulow series, the Qoryooley soils lack the mottling of the peds in the middle horizons.

(c) Mukoy Dumis (Mc)

Classification: Chromic Vertisols - Vertic Cambisols.

Location and physiography: This series is formed in fine textured alluvium of the semi-recent flood plain (2a) overlain by fine and medium textured materials of recent alluvial origin (3a and 3b). The soils occur extensively in the south-west of the Study Area and locally in the vicinity of the Shabeelle river. The terrain is level.

Land use: Large areas of Mukoy Dumis soils are used for irrigated banana production and small scale irrigated cropping but sparse scrub and grassland vegetation persists in the extreme south-west.

Profile characteristics: Profiles are well drained and predominantly reddish brown in colour (5YR 4/3). They are characterised by distinct textural stratifications in which clay or clay loam (3a) overlies loam or silt loam (3b) which in turn overlies clay of semi-recent alluvium (2a) (see Description No. 9). Vertisol features are well developed - cracking, mulch and slickensides - but due to the medium textured sub-surface horizons they are classed as intergrades to Vertic Cambisols.

Surface horizons are usually clay textured with reddish brown colours (5YR 3/2 -4/4) and crack to form sub-angular blocky structure. These grade fairly abruptly into medium textures (silt loam, loam or clay loam) with thin clay lenses, at a depth of 30 to 50 cm, rarely as deep as 100 cm, in which colours are brown (10YR 4/3 - 7.5YR 4/4) and the structure is weak sub-angular blocky with a friable consistence. This sub-surface medium textured horizon in turn abruptly overlies a clay subsoil, usually within 75 cm of the surface, which has compact conchoidal blocky structure and reddish brown colours (5YR 4/3-4/4). The deeper subsoil comprises dark greyish brown (10YR 4/2-4/2) or brown (7.5YR 4/2) clays of the old flood plain alluvium, and occurs at depths usually in excess of 150 cm.

The soils are strongly calcareous throughout the profile but $CaCO_3$ nodules occur only in the deeper subsoil. The medium textured sub-surface horizons are porous but few pores occur in the clay horizons except as inter-ped and vertical cracks in the conchoidal blocky horizon. Roots are concentrated in the surface and sub-surface horizons although some penetrate to a depth of 100 cm.

Associated soils: Mukoy Dumis soils are mapped extensively as complexes with either Qoryooley or with Qoryooley and Buulo Mareerta series; they are also mapped locally as a complex with Gayweerow series, especially in the Project Area. The Mukoy Dumis soils are distinguished from Qoryooley series by presence of a medium textured sub-surface horizon and from Gayweerow by their less sandy textures, shallower depth of recent alluvium and their location remote from the present course of the Shabeelle river.

(d) Buulo Mareerta Series (Bm)

Classification: Eutric Cambisols

Location and physiography: These soils are formed in stratified alluvial deposits of the minor channel remnants in the semi-recent flood plain. The terrain is very weakly undulating to undulating along the main channel remnants and meander scars in the extreme south-west of the Study Area, where Buulo Mareerta soils are most common.

Land use: Buulo Mareerta soils are largely under natural scrub woodland or grassland although some subsistence irrigated agriculture is practised where irrigation command is feasible.

Profile characteristics: The soils are characterised by alternating layers of silty clay loam, silt loam and silty clay. They are well drained and range in colour from dark yellowish brown (10YR 4/4) in the medium textured horizons to brown or reddish brown (7.5YR 4/2 - 5YR 3/2-4/3) in the finer textured layers (see Description No. 10).

The sequence and depth of each horizon is very varied, reflecting frequent changes in original deposition of the alluvium. The surface horizon is normally of silty clay loam texture and has crumb structure. This is underlain, at a depth of some 25 cm, by a horizon of silt loam with weak blocky structure. This in turn overlies a silty clay horizon, at 50 to 60 cm depth, which has strongly developed conchoidal blocky structure. This sequence of silt loam and conchoidal blocky silt clay horizons is repeated down to a depth of some 150 cm. Cracking is confined to minor inter-ped cracks in the conchoidal blocky horizons. The soils are strongly calcareous; filamentous and nodular $CaCO_3$ occurs from a depth of 25 to 50 cm downwards. Roots occur principally in the surface horizon but some penetrate to 100 cm depth.

Associated soils: Buulo Mareerta soils are mapped either individually or in association with Mukoy Dumis and Qoryooley series, where they occupy minor channel remnants within the flood plain which are not separately mappable. Buulo Mareerta soils are distinguished from Qoryooley series by their silt loam horizons and from Mukoy Dumis by the alternating textural layers. Some Buulo Mareerta profiles resemble Gayweerow series, but the latter are confined to the recent alluvial deposits of the Shabeelle river.

A.2.3 Soils Derived from Recent Flood Plain Alluvium

(a) Faraxaane Series (Fx)

Classification: Eutric Cambisols

Location and physiography: Faraxaane soils are formed in recent medium textured alluvium (3b) overlying semi-recent flood plain alluvium (2a). The soils occur locally in the central part of the Study Area on minor ridges which represent former minor overflow channels of the Shabeelle river system. The terrain is level but the ridges are slightly raised above the main flood plain.

Land use: Faraxaane soils are used mainly for small scale irrigation of annual crops. Fruit trees, such as mangoes and guavas, are frequently grown along the slight channel ridges.

Profile characteristics: Faraxaane series has a distinct two layered profile in which at least 50 cm of loam and silt loam materials overlies a compact dark reddish brown (5YR 3/2) clay horizon of semi-recent alluvium. The upper profile is well drained but drainage is only moderate in the subsoil (see Description No. 11).

The upper horizon is brown (10YR 4/3-4/4) with loamy texture, friable consistence and sub-angular blocky structure. This overlies, at a depth of 20 to 30 cm, a horizon of loam, silt loam or silty clay loam with similar colours and structure. This in turn is underlain by a transitional horizon of clay loam texture, dark brown colours (7.5YR 4/4) and sub-angular blocky structure which grades into the subsoil of reddish brown (5YR 4/4) compact conchoidal blocky clay. This horizon is encountered at within 50 to 100 cm of the surface. The upper horizons are porous and roots extend down to at least 100 cm depth.

The profile is strongly calcareous, $CaCO_3$ is common throughout the profile as soft patches and filamentous deposits. Mica flakes occur in the upper horizons and between the peds in the subsoil.

Associated soils: Faraxaane soils are usually associated with Mukoy Dumis series, with which they are complexed for mapping purposes. They are distinguished from the latter by their deep medium textured surface horizons and lack of a superficial clay horizon.

(b) Gayweerow (Gw)

Classification: Vertic Cambisols.

Location and physiography: Gayweerow soils are formed in recent alluvium (3a and 3b) on the levees of the Shabeelle river and its main overflow channels. The land is generally flat with only very slight slope downwards away from the river and along the overflow channels. In the immediate vicinity of the river, relief is often more irregular, largely due to construction of bunds against flooding. Gayweerow soils are mapped in a narrow belt along the Shabeelle river.

Land use: Gayweerow soils are used for a wide range of purposes. Areas adjacent to the river are often swampy and colonised by aquatic grasses and large trees; more freely drained areas carry grass swards which are grazed by livestock. Irrigated agriculture, both small scale and banana plantations, is practised along the back slope of the levee. Fruit trees, such as mango and guava, are planted along the levees and channel ridges.

Profile characteristics: A relatively wide range of profile types are included within Gayweerow series, differing according to the thickness and texture of each layer in the depositional sequence. Most profiles show a well defined stratified sequence of horizons varying from loamy very fine sand, silt loam to clay (see Description No. 12). In other cases the clay textures predominate with only minor lenses of medium textures being present. Similarly the soils vary from moderately well drained along the levee and ridge crests to imperfectly drained along the back slope of the levee. In the latter situation, the water table is often within the upper 1.0 m of the soil and the area is prone to flooding during periods of peak rainfall and high river flow.

Gayweerow soils are mainly reddish brown to brown (5YR 4/3 - 7.5YR 5/4) in the medium textured horizons. Soil structure is varied: weak sub-angular blocky to single grain structure is typical of the medium textured layers whereas moderate sub-angular blocky and conchoidal blocky structure occurs in the clay and silty clay layers. Vertisol characteristics are poorly expressed although deep cracking occurs in the finer textured profiles; the soils are porous especially in the loam and silt loam horizons. The soils are strongly calcareous throughout and fine $CaCO_3$ nodules occur below 150 cm depth. Fine flakes of mica are a common feature of these soils.

Roots are concentrated in the upper 25 cm of the profile but individual tree roots were observed down to almost 150 cm depth.

Associated soils: Gayweerow soils are associated with Qoryooley, Mukoy Dumis and Madhuulow soils along the boundary between the recent levee alluvium and the semi-recent flood plain alluvium; in some cases the series is mapped in complexes with these soils. Some Gayweerow profiles are similar to those of Mukoy Dumis series, especially along the margins of minor overflow channels.

A.3 Detailed Site and Soil Profile Descriptions

Descriptions are presented for representative sites of each of the eleven series mapped. The location of each site is shown on the soil map (Map 1A). The following profiles are described:

Description No.	Soil series			Profile No.
1	Saruda	-	Sr	R10
2	Dhoblow	-	Db	R20
3	Golweyn	-	Gl	R22
4	Majabto	-	Mt	R37
5	Shalambood	-	Sh	R18
6	Madhuulow	-	Mw	R63
7	Qoryooley	-	Qr	R17
8	Qoryooley (shallow phase)	-	Qr-s	R14
9	Mukoy Dumis	-	Mc	R33
10	Buulo Mareerta	-	Bm	R28
11	Faraxaane	-	Fx	R40
12	Gayweerow	-	Gw	R47

Description No. 1

Soil series: Saruda (Sr)

Site No.: R10

Classification: Chromic Vertisol

Land suitability: 3pd/s

Date of description: 14th June 1977

Author: K.J. Virgo

Location: 5 km north of Qoryooley on Farsooley road; map grid ref: 36,000 N - 12,500 E, approximately 1°50' N - 44°33' E

Site Features:

(a) Elevation: 68 m.

(b) Physiographic position: Shabeelle Meander Flood Plain, site on old flood plain north of the present river.

(c) Refief: Level with slight gilgai formations.

(d) Parent material: Meander Flood Plain alluvium, 'old' alluvial deposits, clay textured.

(e) Soil surface: Dark brown powdery mulch, occasional cracks and sink holes, shell fragments.

(f) Vegetation and land use: Open scrub woodland, including Salvadora, Boscia, Acacia and Dichrostachys spp.

Brief Description of Profile:

A deep moderately well drained clay textured profile with dark greyish brown colours. The upper horizons are well cracked to a depth of 55 cm, with sub-angular blocky structure overlying weakly developed prismatic structure. Below 55 cm the profile is compact and very firm with weakly developed wedge structures and slickensides. Roots penetrate to 55 cm depth. The profile is very strongly calcareous throughout and gypsum crystals are common in the lower horizons. This soil has a Class II salinity hazard and is placed in land Class 3pd/s due to profile deficiencies such as low infiltration, hydraulic conductivity and available water capacity.

Profile Description:

Horizon	Depth (cm)	Description
A1	0 to 20	Dark greyish brown to brown (10YR 4/2-4/3) clay; moderate medium sub-angular blocky structure; slightly hard dry; common vertical cracks, few fine pores; few $CaCO_3$ nodules (2 to 5 mm), strongly calcareous, pH 8.5; many fine roots; gradual smooth boundary. Sample 1D.
B21	20 to 55	Dark greyish brown (10YR 4/2) clay; weak coarse prismatic to moderate medium blocky; hard dry; few vertical cracks (10 to 15 mm), no visible pores; few $CaCO_3$ nodules and black Mn coated nodules, strongly calcareous, pH 8.5; common fine and medium roots; gradual smooth boundary.Sample 2D.
B22	55 to 140	Dark greyish brown (10YR 4/2) clay; weak medium blocky to wedge; very firm slightly moist; few cracks (5 to 10 mm), no visible pores; frequent gypsum crystals; strongly calcareous, pH 8.4; no roots; gradual smooth boundary. Sample 3D.
C	140 to 200	Dark brown (10YR 3/3) clay; very hard dry; weak medium blocky to wedge; few fine cracks; no visible pores; frequent clusters of gypsum crystals, strongly calcareous, pH 8.5; no roots. Sample 4D.

Description No. 2

Soil series: Dhoblow (Db)

Site No.: R20

Classification: Vertic Cambisol

Land suitability: 3pd/s

Date of description: 18th July 1977

Author: K.J. Virgo

Location: 3 km south-east of Golweyn; map grid ref: 15,500 N - 19,500 E; approximately $1^{o}37'$ N - $44^{o}37'$ E.

Site Features:

(a) Elevation: 64 m.

(b) Physiographic position: Shabeelle Meander Flood Plain near foot of coastal dunes.

(c) Relief: Weakly undulating due to macro-gilgai development (50 cm elevation variation); site on slight crest.

(d) Parent material: Meander Flood Plain alluvium; 'old' alluvial deposits of fine texture but including medium textured layers.

(e) Soil surface: Compact brown surface with 10 mm powder mulch. Cracks visible at centres of gilgai. Scattered shell fragments.

(f) Vegetation and land use: Non-cultivated; sparse bush cover of Dichrostachys and Acacia species.

Brief Description of Profile:

Deep alluvial profile with prominent horizon differences due to different alluvial origin. Predominant texture is silty clay but includes a layer of loam at 45 cm depth. Colours are very dark greyish brown to brown. The soil is moderately well drained but very compact in the lower horizons; roots extend to 65 cm but penetrate to 125 cm between ped faces along minor cracks. The profile is strongly calcareous. Moderately well drained. This soil has a Class II salinity hazard and is placed in land Class 3pd/s on the basis of this salinity and profile deficiencies.

Profile Description:

Horizon	Depth (cm)	Description
A1	0 to 25	Very dark greyish brown (10YR 3/2) silty clay loams; strong medium subangular blocky; friable moist; many fine pores; few $CaCO_3$ nodules and shell fragments, strongly calcareous, pH 8.3; many fine roots; clear smooth boundary. Sample 1D.
B21	25 to 45	Dark greyish brown (10YR 4/2) silty clay; moderate medium subangular blocky; hard dry; many fine pores; few $CaCO_3$ nodules and shell fragments, strongly calcareous, pH 8.1; many fine roots; abrupt smooth boundary. Sample 2D.
II B22	45 to 65	Yellowish brown (10YR 5/4) loam; hard dry; weak fine blocky to single grain; many fine tubular pores; many soft flecks of $CaCO_3$, strongly calcareous, pH 8.0; few fine and medium roots; abrupt smooth boundary. Sample 3D.
III B3	65 to 125	Brown to reddish brown (7.5YR 4/4 to 5YR 4/3) with few fine distinct strong brown mottles; clay; moderate very coarse prismatic to fine blocky; hard dry; few 5 mm vertical cracks and pores; many soft $CaCO_3$ efflorescences, strongly calcareous, pH 8.1; few medium and fine roots along ped faces; clear smooth boundary. Sample 4D.
IV C	125 to 150	Very dark grey (10YR 3/1) clay loam; moderate medium wedge; very hard dry; few gypsum crystals; common $CaCO_3$ nodules, slightly calcareous, pH 8.1; no roots. Sample 5D.

Description No. 3

Soil series: Golweyn (Gl)

Site No: R22

Classification: Chromic Vertisol

Land suitability: 3pd/s

Date of description: 19th July 1977

Author: K.J. Virgo

Location: 2.5 km WNW of Shalambood near road to Qoryooley; map grid ref: 22,250 N - 27,000 E; approximately 1°42' N - 44°' E.

Site Features:

(a) Elevation: 66 m asl.

(b) Physiographic position: Shabeelle Meander Flood Plain, main alluvial plain.

(c) Relief: Flat and level, some bunds for irrigation.

(d) Parent material: Meander Flood Plain alluvium; 'old' alluvial deposits of fine clay textures.

(e) Soil surface: Brown, fine mulch obscuring cracks.

(f) Land use and vegetation: Former irrigated subsistence agriculture now abandoned; few low shrubs.

Brief Description of Profile:

A deep moderately well drained alluvial profile with brown colours. Moderate medium blocky and wedge structure occurs down to 55 cm, below which the structure is more compact and prismatic. The profile shows evidence of pronounced cracking but cracks were poorly developed at time of sampling due to moist state of profile. The soil is strongly calcareous throughout, gypsum crystals are abundant in the subsoil. Roots are concentrated in the upper 55 cm but some penetrate along ped faces to 100 cm depth. The soil is clay textured to 4.5 m. The profile has deficiencies in terms of slow infiltration, hydraulic conductivity and high clay contracts which downgrade it to Class 3pd: the Class II salinity values put the soil into unit 3pd/s.

Profile Description:

Horizon	Depth (cm)	Description
Ap	0 to 20	Brown (7.5YR 4/2) silty clay; moderate medium subangular blocky; friable moist; few fine pores; strongly calcareous, pH 8.1; many fine roots; clear smooth boundary. Sample 1D.
A3	20 to 55	Brown (7.5YR 4/2) clay; moderate medium angular blocky; firm moist; few 5 mm wide vertical cracks and few fine pores; strongly calcareous, pH 8.1; few fine roots; gradual smooth boundary. Sample 2D.
B2	55 to 90	Brown (7.5YR 4/2) clay; moderate coarse prismatic with fine wedge component; moist firm; few fine slickensides; few narrow cracks and fine pores; few fine $CaCO_3$ nodules; strongly calcareous, pH 8.2; rare fine roots; gradual smooth boundary. Sample 3D. (Between 80 to 90 cm few non-continuous lenses of fine sand 5 to 10 mm thick).
C1	90 to 170	Brown to dark greyish brown (7.5YR 4/2 - 10YR 4/2) with few medium distinct grey and black mottles; clay; moderate medium wedge and blocky; hard dry; rare narrow vertical cracks; no pores visible; few gypsum crystals; strongly calcareous, pH 8.3, few fine $CaCO_3$ nodules. Sample 4D.
II C2	170 to 350	Dark greyish brown (10YR 4/2) with few medium distinct strong brown mottles; clay; very firm slightly moist; common $CaCO_3$ nodules and gypsum crystals. Samples 4S: 140 - 250 cm, 5S: 250 -350 cm.
II C3	350 to 450	Brown (10YR 4/3) clay; slightly moist; many gypsum crystals.

(170 to 450 cm in auger)

Description No.4

Soil series: Majabto (Mt)

Site No.: R37

Classification: Vertic Cambisol

Land suitability: 3pd/s

Date of description: 18th August 1977

Author: K.J. Virgo

Location: 3 km east of Gayweerow village;
map grid ref: 2,870 N - 19,250 E,
approximately 1°45' N - 44°32' E.

Site Features:

(a) Elevation: 66 m asl.

(b) Physiographic position: Shabeelle Meander Flood Plain near to channel remnant.

(c) Relief: Level; bunded for irrigation.

(d) Parent material: Meander Flood Plain alluvium; 'old' clay and silty textured deposits.

(e) Soil surface: Brown with friable mulch and few cracks.

(f) Vegetation and land use: recently cultivated prior to controlled flood irrigation of simsim.

Brief Description of Profile:

A two layered alluvial soil with 70 cm of moderate prismatic structured clay horizons overlying weakly structured silty and silty clay loam material. A water table was encountered at 180 cm. The upper horizons crack when the soil is dry. Below 70 cm the soil is friable and moist and efflorescences of salt accumulated on the pit sides, indicating a high salinity. The profile is calcareous throughout. Roots are confined to the upper 70 cm zone. Upper profile is moderately well drained. The soil has limitations of high water table, poor textural characteristics and Class IV salinity, resulting in it being placed in Class 3pd/s.

Profile Description: Description

Horizon	Depth (cm)	Description
Ap	0 to 20	Brown (7.5YR 4/2) clay loam; moderate coarse subangular blocky; friable moist; few fine pores; strongly calcareous, pH 8.3; many fine roots; gradual smooth boundary. Sample 1D.
B2	20 to 70	Brown (7.5YR 4/2) clay; moderate very coarse prismatic to strong medium wedge; very firm moist; few 5 mm wide vertical cracks, few tubular pores; few fine $CaCO_3$ nodules and efflorescence of salts on pit face, strongly calcareous, pH 8.2; few medium and fine roots; clear smooth boundary. Sample 2D.
II B3	70 to 150	Dark brown (7.5YR 4/4) silt loam with few thin sand veins; weak coarse blocky to single grain; friable moist; common fine tubular pores; few gypsum crystals and efflorescences of salt, strongly calcareous, pH 8.5; mica flakes; no roots; abrupt boundary. Sample 3D.
II C1	150 to 175	Brown (10YR 4/3) silty clay; weak medium blocky to single grain; friable moist; many fine pores; strongly calcareous, pH 8.3; no roots. Sample 4D.
III C2	175 to 300	Dark greyish brown (10YR 4/2 - 4/3) clay to silty clay; friable moist; few $CaCO_3$ nodules and mica flakes: Sample 4S. 175 - 250 cm.
III C3	300 to 400	As previous horizon but with few medium distinct strong brown mottles and few gypsum crystals. Sample 5S: 250 to 350 cm.
IV C4	400 to 450	Brown (10YR 4/3) fine sandy loam; wet non-plastic, non-sticky; mica flakes.

(175 to 450 cm in auger)

Description No.5

Soil series: Shalambood (Sh) — Site No.: R18

Classification: Vertic Cambisol — Land suitability: 6

Date of description: 13th July 1977 — Author: K.J. Virgo

Location: 5.5 km NE of Golweyn;
map grid ref: 21,000 N - 20,500 E;
approximately $1^{o}42'$ N - $44^{o}32'$ E.

Site Features:

(a) Elevation: 66 m

(b) Physiographic position: Shabeelle Meander Flood Plain - Channel Remnant, site located on levee position of former major drainage line.

(c) Relief: Level, little influence from channel.

(d) Parent material: Levee alluvium, mainly silty clay materials of 'old' Meander Flood Plain deposits.

(e) Soil surface: Reddish colour, compact with slight fine powdery mulch, no visible cracks.

(f) Vegetation and land use: Bare ground with irrigated subsistence cultivation of maize adjacent.

Brief Description of Profile:

Deep moderately well drained dark brown to dark yellowish brown profile with alternating silty clay, silty clay loam and clay horizons. Upper horizons of Channel Remnant origin overlying Meander Flood Plain deposits at 180 cm. Moderately well developed structure in upper horizons but low porosity and few cracks. Very compact below depth of 50 cm. Profile is strongly calcareous throughout, $CaCO_3$ occurs in all horizons and gypsum crystals are common in the subsoil. Roots penetrate to 115 cm depth. Although the profile has agricultural potential, it lies close to an area of broken relief in an old channel and is therefore placed in land Class 6.

Profile Description:

Horizon	Depth (cm)	Description
A1	0 to 15	Dark yellowish brown (10YR 4/4) silty loam; moderate coarse subangular blocky; slightly hard dry; few 5 mm vertical cracks and many fine tubular pores; few fine $CaCO_3$ nodules, strongly calcareous, pH 8.5; common fine roots; gradual smooth boundary. Sample 1D.
B21	15 to 50	Dark brown (7.5YR 4/4) silty clay; moderate coarse blocky to strong medium angular blocky; firm slightly moist; few 5 mm vertical cracks, few fine tubular pores; common fine $CaCO_3$ nodules, strongly calcareous, pH 8.6; few fine roots; gradual smooth boundary. Sample 2D.
II B22	50 to 115	Dark yellowish brown (10YR 4/4) clay; moderate coarse blocky, very firm moist; few 5 mm vertical cracks, rare fine pores; common fine $CaCO_3$ nodules, strongly calcareous, pH 8.4; few fine roots; clear smooth boundary. Sample 3D.
III B3	115 to 150	Dark yellowish brown (10YR 4/4) with common fine distinct light brown mottles; silty clay loam; weak medium blocky to wedge; firm slightly moist, few fine inter-ped cracks and visible pores; few fine $CaCO_3$ and Mn coated nodules, strongly calcareous, pH 8.2; few gypsum crystals; no roots; clear smooth boundary. Sample 4D.
IV C	150 to 180	Brown (10YR 4/3) with common medium distinct dark grey mottles; silty clay; weak medium blocky; very firm slightly moist; no visible pores; slickensides; frequent pockets of gypsum crystals; strongly calcareous, pH 8.1; no roots. Sample 5D.

Description No.6

Soil series: Madhuulow (Mw)

Site No.: R63

Classification: Chromic Vertisol

Land suitability: 2pd

Date of description: 31st October 1977

Author: K.J. Virgo

Location: 400 m east of Jasiira village near road to Gayweerow; map grid ref: 30,750 N - 14,200 E; approximately 1^{o} 46' N - 44^{o}33' E.

Site Features:

(a) Elevation: 66 m.

(b) Physiographic position: Shabeelle Meander Flood Plain, 800 m from river on recent flood plain.

(c) Relief: Flat with slight slope upwards to the river.

(d) Parent material: Meander Flood Plain alluvium; recent and semi-recent clay deposits.

(e) Soil surface: Reddish brown, moist after irrigation.

(f) Vegetation and land use: Irrigated subsistence agriculture, sweet potatoes and tomatoes.

Brief Description of Profile:

A deep reddish brown, moderately well drained, fine textured profile. The upper 75 cm are friable, with fine blocky structure and fine slickensides. Below 75 cm the soil is more compact, structure is prismatic but with a conchoidal blocky component comprising very dense structural aggregates. Greyish brown colouring to surface of peds in lower horizons is typical of series. Gypsum and filamental calcium carbonate occur at below 100 cm. Soil recently irrigated and therefore no cracking visible at surface but inter-ped cracks occur at below 150 cm. Roots are confined to the upper 75 cm. The soil has moderate deficiencies in terms of clay textures and slow infiltration/hydraulic conductivity; salinity is Class I and the land is given a Class 2pd rating.

Profile Description:

Horizon	Depth (cm)	Description
Ap	0 - 25	Reddish brown (5YR 4/3) clay to silty clay; moderate medium subangular blocky; friable moist; few fine pores; few medium and fine roots; strongly calcareous, pH 8.1, gradual smooth boundary. Sample ID.
B1	25 to 75	Reddish brown (5YR 4/3 - 4/4) clay; moderate fine blocky wedge; friable moist; many fine slickensides; few fine pores; strongly calcareous, pH 8.1; rare fine roots; clear smooth boundary. Sample 2D.
B2	75 to 105	Reddish brown (5YR 4/3) with frequent medium distinct greyish brown mottles and coatings to ped surfaces; clay; moderate coarse prismatic to strong medium conchoidal blocky; firm moist; rare fine tubular pores; few gypsum crystals and rare fine $CaCO_3$ nodules; strongly calcareous, pH 8.0; no roots; gradual boundary. Sample 3D.
B3	105 to 160	Reddish brown (5YR 4/4) with common coarse distinct greyish brown mottles to ped faces; clay; weak coarse prismatic to moderate medium conchoidal blocky; very firm moist; few 5 mm wide cracks and rare very fine pores; few pockets of gypsum crystals; few fine $CaCO_3$ nodules, strongly calcareous, pH 8.1; no roots. Sample 4D.

Description No.7

Soil series: Qoryooley (Qr) — Site No.: R17

Classification: Chromic Vertisol — Land suitability: 2pd

Date of description: 13th July 1977 — Author: K.J.Virgo

Location: 4 km SE of Gayweerow village, near Asayle canal;
map grid ref: 27,250 N - 20,000 E;
approximately 1°45' N - 44°33' E.

Site Features:

(a) Elevation: 68 m asl.

(b) Physiographic position: Shabeelle Meander Flood Plain, recent flood plain close to present course of river.

(c) Relief: Level; recently ploughed.

(d) Parent material: Meander Flood Plain alluvium; recent and semi-recent clays overlying old alluvium.

(e) Soil surface: Reddish brown with crumb mulch.

(f) Vegetation and land use: Cultivated prior to irrigation of annual crops - maize and simsim.

Brief Description of Profile:

A deep reddish brown clay profile, moderately well drained, overlying brown older alluvium with clay textures and imperfect drainage. The upper profile, to 105 cm depth, has moderately well developed conchoidal blocky structure with weak prisms and deep cracking. There is an abrupt boundary with the older alluvium at 105 cm; this alluvium is wedge structured and contains shell fragments and $CaCO_3$ nodules. The whole profile is strongly calcareous. Roots penetrate to the upper boundary of the brown alluvium but some extend to 160 cm. Water table at 270 cm. Fine sandy textures below 360 cm probably form the upper strata of the Fluvio-marine alluvium. The soil is given a Class 2pd rating, downgraded on account of fine textures, low infiltration rates and slow hydraulic conductivity. Salinity Class I.

Profile Description:

Horizon	Depth (cm)	Description
Ap	0 to 25	Reddish brown (5YR 4/3) clay; moderate coarse subangular blocky; slightly hard dry; few fine vertical cracks, common fine pores; common fine fibrous roots; strongly calcareous, pH 8.2; gradual smooth boundary. Sample ID.
B21	25 to 105	Reddish brown to dark reddish brown (5YR 4/3 - 3/2) clay; weak coarse prismatic to fine wedge and conchoidal blocky; firm moist; few 10 to 20 mm vertical cracks, few visible pores; strongly calcareous, pH 8.1; few medium roots; abrupt smooth boundary. Sample 2D.
I C1	105 to 125	Very dark grey (N 3/0) clay; moderate coarse blocky; very firm moist; few 10 mm vertical cracks and fine tubular pores; many fine $CaCO_3$ nodules and shell fragments, strongly calcareous, pH 8.1; few fine roots; clear smooth boundary. Sample 3D.
II C2	125 to 360	Brown (10YR 4/3) clay; moderate coarse wedge; firm moist; rare fine vertical cracks, common fine tubular pores; few fine white $CaCO_3$ nodules and Mn coated nodules, few shell fragments, strongly calcareous, pH 8.1; rare fine roots. Samples 4D : 125 - 265 cm, 4S: 150-250 cm, 5S: 250-350 cm.
III C3	360 to 450	Brown (10YR 4/3) very fine sandy loam; wet non-sticky slightly plastic; many fine mica flakes.

(165 to 450 cm auger)

Description No.8

Soil series: Qoryooley, Shallow Phase (Qr-s)

Site No.: R14

Classification: Chromic Vertisol.

Land suitability: 2pd

Date of description: 12th July 1977

Author: K.J. Virgo

Location: 7.5 km WNW of Shalambood near road to Golweyn; map grid ref: 24,020 N - 22,100 E; approximately $1^{o}42'$ N - $44^{o}37'$ E.

Site Features:

(a) Elevation: 66 m.

(b) Physiographic position: Shabeelle Meander Flood Plain on main flood plain near to present river course.

(c) Relief: Level, bunded for irrigation.

(d) Parent material: Shabeelle Flood Plain alluvium; recent and semi-recent clays overlying old clay deposits.

(e) Soil surface: Red, with friable mulch and crumb structure following cultivation; occasional cracks.

(f) Vegetation and land use: Irrigated area, fallow with weed cover at time of description.

Brief Description of Profile:

A deep moderately well drained clay textured profile showing an abrupt change at 95 cm between upper horizons of reddish brown alluvium and a subsoil of dark greyish brown alluvium. The upper horizons are moderately well structured and show evidence of vertical cracking. Roots penetrate to 95 cm. The whole profile is strongly calcareous, with many $CaCO_3$ nodules and shell fragments present in the subsoil older alluvium. The land is given a Class 2 pd rating.

Profile Description:

Horizon	Depth (cm)	Description
Ap	0 to 15	Reddish brown (5YR 4/3) clay, moderate medium crumb to subangular blocky; friable, slightly moist; many fine pores; strongly calcareous, pH 8.3; common roots; clear smooth boundary. Sample 1D.
B21	15 to 55	Reddish brown (5YR 4/4) clay; moderate very coarse prismatic to strong medium blocky; firm, slightly moist; few fine pores; rare shell fragments; strongly calcareous, pH 8.3; common fine roots; clear smooth boundary. Sample 2D.
B22	55 to 95	Reddish brown (5YR 4/3) clay; moderate fine conchoidal blocky; very firm, moist; few fine (5 mm) vertical cracks; few fine (1 mm) $CaCO_3$ nodules, strongly calcareous, pH 8.3; few fine roots; abrupt smooth boundary. Sample 3D.
II C	95 to 160	Dark grey (10YR 3/1) with few fine distinct reddish brown mottles; clay; strong coarse blocky wedge with slickensides; very firm slightly moist; rare fine pores; many fine $CaCO_3$ nodules and shell fragments; strongly calcareous, pH 7.9; rare fine roots. Sample 4D.

Description No.9

Soil series: Mukoy Dumis (Mc)

Site No.: R33

Classification: Chromic Vertisol

Land suitability: 2d/s

Date of description: 14th August 1977

Author: K.J. Virgo

Location: 7.5 km NW of Shalambood near Golweyn-Janaale road;
map grid ref: 26,100 N - 23,100 E;
approximately 1°45' N - 44°38' E

Site Features:

(a) Elevation: 66 ml asl.

(b) Physiographic position: Shabeelle Meander Flood Plain, recent flood plain near to river.

(c) Relief: Levelled for irrigation.

(d) Parent material: Meander Flood Plain alluvium; recent and semi-recent clays and silt loams over old clay deposits.

(e) Soil surface: Reddish brown, ploughed.

(f) Vegetation and land use: Irrigated bananas.

Brief Description of Profile:

A deep well drained profile showing alternating layers of alluvial deposition. The upper horizon comprises friable reddish brown clay loam, which overlies B horizons of friable, brown silt loam and loam. At 65 cm there occurs a horizon of more compact reddish brown clay with a conchoidal blocky and wedge structure; this horizon shows evidence of former vertical cracking. Older Meander Flood Plain clay alluvium occurs below 130 cm depth. The soil is strongly calcareous throughout. Roots are well developed in the porous and friable upper 65 cm. A perched water table occurs at 150 cm; below 340 cm the soil appears to be dry. The soil has a high potential for irrigation, limited only by the low hydraulic conductivities in the lower horizons and a Class II salinity hazard. The high water table is an added limitation. The soil is given a Class 2d/s rating.

Profile Description:

Horizon	Depth (cm)	
Ap	0 to 30	Reddish brown (5YR 4/3) clay loam; moderate medium crumb; friable moist; many fine pores; strongly calcareous, pH 8.2; many fine roots; clear smooth boundary. Sample 1D.
II B1	30 to 50	Brown (10YR 4/3) loam; weak fine subangular blocky; very friable moist; many fine pores; strongly calcareous, pH 8.1; many medium and fine roots; clear smooth boundary. Sample 2D.
II B21	50 to 65	Brown (7.5YR 4/4) silt loam with thin bands (5 to 10 mm) of clay; moderate subangular blocky; friable moist; many fine tubular pores; strongly calcareous, pH 8.1; common fine roots; abrupt smooth boundary. Sample 3D.
III B22	65 to 105	Reddish brown (5YR 4/3) clay; strong fine conchoidal blocky to wedge; firm moist; few fine pores, infilled cracks visible; spherical slickensides; strongly calcareous, pH 8.1; rare fine roots; abrupt smooth boundary. Sample 4D.
III B3	105 to 130	Reddish brown (5YR 4/4) clay; weak coarse blocky to moderate very fine wedge; firm moist; strongly calcareous, pH 8.2; roots; abrupt smooth boundary. Sample 5D.
IV C1	130 to 160	Dark grey (10YR 4/1) clay; strong fine wedge; firm moist; shell fragments; no roots.
IV C2	160 to 350	Greyish brown (2.5YR 5/2) with many medium distinct light olive brown mottles; clay; wet and plastic. Sample 4S (150-250 cm).

(160 to 350 cm in auger)

Description No.10

Soil series: Buulo Mareerta (Bm)

Site No.: R28

Classification: Eutric Cambisol

Land suitability: 2d/t

Date of description: 1st August 1977

Author: K.J. Virgo

Location: 1.5 km east of Buulo Mareerta village beside road to Golweyn; map grid ref: 14,500 N - 11,750 E: approximately 1°36' N - 44°32' E.

Site Features:

(a) Elevation: 65 m.

(b) Physiographic position: Shabeelle Meander Flood Plain, situated on small levee of channel remnant.

(c) Relief: Slight slope to south, level surface.

(d) Parent material: Meander Flood Plain alluvium; recent and semi-recent clays and silty deposits.

(e) Soil surface: Reddish brown, dry soft mulch with no visible cracks.

(f) Vegetation and land use: Sparse shrubs and grasses, grazing land.

Brief Description of Profile:

A well drained profile showing prominent alluvial stratification in which clay or silty clay horizons overlie silt loam horizons. The upper horizons have moderate to well developed blocky structure with filamentous deposits of $CaCO_3$ to the peds. The whole profile is strongly calcareous. Roots are well developed down to 55 cm. The profile was dry to 170 cm when described. The soil is given a Class 2d/t rating, downgraded due to low subsoil hydraulic conductivity and minor topographic deficiencies.

Profile Description:

Horizon	Depth (cm)	Description
A1	0 to 25	Brown to reddish brown (7.5YR 4/2 - 5YR 4/3) silty clay loam; strong fine crumb; slightly hard dry; common medium and fine pores; strongly calcareous, pH 8.6; many fine and medium roots and few faunal tunnels; clear smooth boundary. Sample 1D.
II B21	25 to 55	Dark yellowish brown (10YR 4/4) with few medium distinct strong brown patches; silt loam; moderate medium blocky; slightly hard dry; few fine tubular pores; few filamentous $CaCO_3$ deposits, strongly calcareous, pH 8.4; common fine and medium roots; abrupt smooth boundary. Sample 2D.
III B22	55 to 90	Dark reddish brown (5YR 3/2) silty clay; weak medium blocky to strong fine conchoidal blocky; hard dry; rare fine pores; many $CaCO_3$ filaments, strongly calcareous, pH 8.0; abrupt smooth boundary. Sample 3D.
IV B21	90 to 110	Yellowish brown (10YR 5/4) with few medium distinct strong brown mottles; silt loam; structureless to weak medium blocky; hard dry; common fine tubular pores; common soft $CaCO_3$ deposits, strongly calcareous, pH 8.2; rare medium roots; abrupt smooth boundary. Sample 4D.
V B32	110 to 150	(as III B22 horizon).
VI C	150 to 170	Dark yellowish brown (10YR 4/4) silt loam; moderate coarse blocky; hard dry; common fine tubular pores; few soft $CaCO_3$ deposits.

Description No.11

Soil series: Faraxaane (Fx) | Site No.: R40

Classification: Eutric Cambisol | Land suitability: 2d/st

Date of description: 24th August 1977 | Author: K.J. Virgo

Location: 2.5 km ESE of Faraxaane village; map grid ref: 26,700 N - 13,400 E; approximately $1^{o}45'$ N - $44^{o}33'$ E.

Site Features:

(a) Elevation: 65 m.

(b) Physiographic position: On small channel remnant levee within Shabeelle Meander Flood Plain.

(c) Relief: Level but with very slight slope away from centre of ridge. Bunded for irrigation.

(d) Parent material: Meander Flood Plain alluvium; loamy recent alluvium over clay textured semi-recent alluvium.

(e) Soil surface: Reddish brown with fine powder mulch.

(f) Vegetation and land use: Irrigation of maize on subsistence farmer scale. Occasional mango trees.

Brief Description of Profile:

A prominently two layered, well drained alluvial profile. The upper layer is loamy textured with brown to dark yellowish brown colours, single grained to weak structure and very porous. This layer is well drained. The lower horizon, below 60 cm comprises reddish brown clay, with strong blocky to wedge structure in which, in the dry state, the peds are discrete and separated by numerous small cracks. A transitional zone occurs between the two layers where coarse textured material has fallen down the cracks into the lower layer. The whole profile is calcareous and $CaCO_3$ filaments are common below 20 cm. Roots extend freely to the 60 cm depth. The soil is given a Class 2d/st rating, downgraded due to the poor drainage characteristics of the subsoil, Class II salinity and weakly undulating relief.

Profile Description:

Horizon	Depth (cm)	Description
A1	0 to 20	Brown (10YR 4/3) loam; single grain to weak medium subangular blocky; friable moist; few fine cracks and pores; few soft $CaCO_3$ deposits; strongly calcareous, pH 8.1; many fine roots; gradual smooth boundary. Sample 1D.
B21	20 to 60	Dark yellowish brown (10YR 4/4) silt loam; moderate medium subangular blocky; soft dry; few 2 to 3 mm wide vertical cracks, common fine tubular pores; common soft $CaCO_3$ deposits, strongly calcareous, pH 8.2; common fine roots; clear smooth boundary. Sample 2D.
II B22	60 to 100	Dark brown (7.5YR 4/4) clay loam; moderate medium subangular blocky; very firm slightly moist; few 3 to 5 mm vertical cracks, few medium and fine tubular pores; mica flakes; common soft and filamentous $CaCO_3$ streaks to ped faces, strongly calcareous, pH 8.3; few fine and medium roots; clear wavy boundary where sandy material intermixed with clay. Sample 3D.
II B3 to C1	100 to 250	Reddish brown (5YR 4/4) with frequent medium distinct grey mottles to ped faces; clay; strong medium blocky to wedge with dense conchoidal clay peds; few 5 mm wide vertical cracks, no visible pores; mica flakes between peds; common filaments of $CaCO_3$, strongly calcareous, pH 8.2; no roots. Samples 4D: 100 to 160 cm, 4S: 160 to 250 cm.
II C	250 to 450	Dark grey to very dark greyish brown (10YR 4/1 - 3/2) clay; very firm slightly moist; common $CaCO_3$ nodules; few gypsum crystals and shell fragments. Sample 5S: 250 to 350 cm.

(160 to 450 cm auger)

Description No.12

Soil series: Gayweerow (Gw) — Site No.: R47

Classification: Vertic Cambisol — Land suitability:

Date of description: 21st September 1977 — Author: K.J. Virgo

Location: 1 km NW of Janaale;
map grid ref: 33,300 N - 29,200 E;
approximately $1^{o}47'$ N - $44^{o}42'$ E.

Site Features:

(a) Elevation: 70 m asl.

(b) Physiographic position: Shabeelle Meander Flood Plain, 800 m from river on slight levee.

(c) Relief: Levelled for irrigation.

(d) Parent material: Meander Flood Plain alluvium; recent clays and silty materials over semi-recent and old clay deposits.

(e) Soil surface: Compacted but cracks visible locally.

(f) Vegetation and land use: Recently abandoned irrigated bananas; weed growth.

Brief Description of Profile:

A deep imperfectly drained profile with alternating textural horizons. Reddish brown to brown friable recent alluvium of clay, silty loam and silty clay textures extend down to 150 cm. These horizons show evidence of alluvial stratification, including sand lenses and thin bands of conchoidal blocky clay. Clay textures occur below the 150 cm depth and a water table was encountered at 145 cm. Roots are present down to 80 cm. The whole profile is strongly calcareous and $CaCO_3$ nodules and gypsum occur in the deep subsoil. Cracking is confined to the upper 35 cm clay textured horizon. The soil is downgraded to land Class 2 due to moderate profile drainage limitations such as low hydraulic conductivity in the subsoil and Class II salinity hazard, but is further downgraded to Class 3d/fs on account of a flooding hazard.

Profile Description:

Horizon	Depth (cm)	Description
Ap	0 to 35	Reddish brown (5YR 4/3) silty clay; weak medium subangular blocky; very friable moist; common fine tubular pores; strongly calcareous, pH 8.1; many fine and medium roots; abrupt smooth boundary. Sample 1D.
II B1	35 to 65	Yellowish brown (10YR 5/4) loam; single grained with horizontal striations; very friable moist; many fine mica flakes; many fine pores; strongly calcareous, pH 7.9; few fine roots; abrupt smooth boundary. Sample 2D.
II B2	65 to 80	Brown (7.5YR 4/4) silt loam; weak medium subangular blocky with thin layers of conchoidal blocky clay; friable moist; common medium tubular pores; many fine mica flakes; strongly calcareous, pH 8.1; rare fine roots; clear smooth boundary. Sample 3D.
II B3	80 to 150	Brown (7.5YR 4/2) silty loam; weak medium subangular blocky with layers of conchoidal blocky clay; plastic non-sticky wet; common fine mica flakes; common fine pores; strongly calcareous, pH 8.1. Sample 4D.
III C1	150 to 240	Reddish brown (5YR 4/3) clay; firm moist; few fine $CaCO_3$ nodules, strongly calcareous. Sample 4S.
IV C2	240 to 450	Brown (10YR 4/3) with few medium distinct grey mottles; clay; moist friable to plastic and sticky wet; few gypsum crystals, few $CaCO_3$ nodules. Sample 5S, 250 to 350 cm.

(150 - 450 cm in auger)

APPENDIX B

METHODS OF LABORATORY ANALYSIS

Analyses of soil samples were performed at the Hunting Technical Services Ltd. Environmental Chemistry Laboratory in the United Kingdom. The methods of analysis employed are described briefly in this appendix; these derive from the USDA Handbook 60 (USDA, 1954) and the FAO Soils Bulletin 10 (FAO, 1970).

Sample Preparation

Each soil sample was air-dried and sieved to pass a 2 mm screen before being despatched to the laboratory. This fine earth fraction was used in subsequent analysis. No particles coarser than 2 mm were recorded. A sub-sample of the fine earth fraction of each surface horizon was ground in a mechanical mortar to pass an 80 mesh sieve for use in determinations of carbon, nitrogen and phosphorus.

Particle Size Analysis

40 g of soil were dispersed by shaking overnight with sodium hexametaphosphate and water. The suspension was then transferred to a one litre cylinder, made up to volume and stirred. A Bouyoucos hydrometer, calibrated in grams of soil per litre, was used to take readings of the density of the soil suspension at the following settling times:

(i) 46 seconds to give silt + clay content

(ii) 5 hours to give clay content.

The density readings were corrected for temperature variations and dispersing agent content. The soil suspension was then washed through an 80 mesh (0.2 mm) sieve and the coarse sand fraction weighed after drying. Finer divisions within the sand fraction were measured on selected samples using different sieve sizes.

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 then measured and the results expressed in mmho/cm as the electrical conductivity of the saturation extract (ECe).

Electrical Conductivity of 1 : 2 Soil/Water Extract

40 ml of deionised water were added to 20 g of soil and shaken vigorously for one hour. The soil/water suspension was centrifuged to obtain a clear extract and the electrical conductivity of this extract was measured and expressed as the $EC_{1:2}$ in mmho/cm.

pH of 1 : 2.5 Extract

50 ml of deionised water were added to 20 g of soil. The suspension was stirred and allowed to settle. After one hour the pH of the supernatant liquid was measured, using a combined glass/calomel electrode.

Cation Exchange Capacity - Bascombe's Method

Two grams of soil were shaken twice with triethanolamine-buffered barium chloride solution (pH 8.2), in order to replace all exchangeable cations with barium. Excess barium was removed by shaking with water. The sample was then shaken with a solution of magnesium sulphate of known concentration. This replaced the exchangeable barium by magnesium, at the same time removing barium from solution by precipitating barium sulphate. Magnesium remaining in solution was determined by titration. The cation exchange capacity is derived from the difference between the amount of magnesium added and the amount remaining in solution.

Exchangeable Bases

Four grams were extracted by shaking with 20 ml of N ammonium acetate solution, buffered at pH 7.0. Calcium and magnesium were determined by atomic absorption spectroscopy using strontium chloride as a releasing agent to overcome interference by aluminium or phosphate. Sodium and potassium were also determined using atomic absorption methods, utilising strontium chloride as an ionisation buffer. The exchangeable cation values were corrected to allow for soluble salts.

Soluble Cations in Saturation Extract

Soluble calcium, magnesium, sodium and potassium were measured in the saturation extract, utilising atomic absorption techniques in the presence of strontium chloride.

Soluble Anions in Saturation Extract

(i) Carbonate and Bicarbonate

An aliquot was titrated against dilute hydrochloric acid using phenolphthalein as indicator. When the pink colour had been discharged the amount of acid was measured, methyl orange indicator added and the titration continued to the end point.

(ii) Chloride

Chloride was measured using an EEL chloride meter, which automatically titrates the chloride against silver ions.

(iii) Sulphate

The sulphate was precipitated as barium sulphate in the presence of a stabilised gel. The opaque suspension was then measured using a nephelometer.

Boron

Boron was determined as 'hot water soluble boron'. 10 g of air-dried fine earth was refluxed with 20 ml of deionised water for five minutes, and the resulting slurry was centrifuged to obtain a clear extract. An aliquot of this extract was taken and the boron content determined by the Curcumin method. Aliquots of the river water samples were determined for boron by the same method.

Gypsum

Calcium was determined in saturation extract and also in a 1 : 5 soil/water extract. Knowing the saturation percentage of the soil, the increased solubility of calcium in the 1 : 5 extract was used to calculate gypsum content.

Total Nitrogen Content

A weighed sample of finely ground soil was digested with concentrated sulphuric acid containing potassium sulphate, to raise the temperature, and selenium as a catalyst. After digestion the sample was made alkaline and the ammonia released was steam-distilled into boric acid containing bromocreosol green/methyl red indicator. After distillation, the ammonia dissolved in the boric acid was back-titrated against standard sulphuric acid, and the rest expressed as per cent total nitrogen.

Available Phosphorus

A weighed sample of soils was extracted by shaking for 0.5 hour with 0.5 molar sodium bicarbonate solution at pH 8.5. The extract was decolourised with activated charcoal and filtered to obtain a clear solution; phosphorus was determined colourimetrically by the molybdenum blue method.

Organic Carbon Content (Walkly-Black Method)

A weighed sample of finely ground soil was digested with a known amount of potassium dichromate and concentrated sulphuric acid. Excess dichromate, remaining after digestion was complete, was titrated against standard ferrous ammonium sulphate using ferroin as indicator. In the calculation of the result, expressed as per cent organic carbon, it was assumed that only 77% of the organic carbon present had been oxidised.

Moisture Retention Characteristics

Undisturbed soil cores 50 mm in diameter were collected in the field using a special sampling device. The dry weight of the undisturbed soil in the core was determined and the bulk density calculated. The cores were saturated with water and their moisture content measured. They were then placed on the porous plate apparatus and subjected to a suction of 7.6 cm of mercury (0.1 bar). When the moist sample reached equilibrium with the suction and water ceased to flow from the chamber, the sample was removed and weighed to determine the moisture content. The determination was repeated at suctions of 25.4 cm of mercury (0.3 bar) and at 76 cm of mercury (1.0 bar). The samples were then transferred to the high pressure chamber (pressure plate) and the soil moisture content determined when in equilibrium with a suction of 15 bar.

APPENDIX C

CHEMICAL ANALYSIS RESULTS

For convenience of presentation the analytical results are divided as follows:

(a) Detailed analyses of representative profiles

(b) Soluble salt analyses of representative profiles

(c) Salinity and exchangeable sodium analyses for all survey sites

(d) Electrical conductivity analyses for shallow groundwater

(e) Mineralogical analyses.

C.1 Detailed Analyses

Detailed analyses were performed on samples collected from the major horizons of profile pits representative of each of the soil series identified. The complete results for the 24 profiles analysed are given in Table C.1, listed according to soil series. An explanation of the scheme of analyses and the units of measurement used in the table are given below and methods of analysis are described in Appendix B.

(a) Soil Particles (%)

Results of mechanical analysis are expressed in percentage terms, based on the air-dry fine earth fraction; textures are according to the FAO Guidelines (FAO, 1968).

Coarse sand	(CoS)	2.00 - 0.20 mm
Fine sand	(fs)	0.20 - 0.05 mm
Silt	(Si)	0.05 - 0.002 mm
Clay	(C)	Less than 0.002 mm

(b) pH

Soil reaction measured on the 1 : 2.5 aqueous extract.

(c) ECe

Electrical conductivity of the saturation extract, expressed in mmho/cm.

(d) Exchangeable Cations (meq/100 g)

Values are given in milliequivalents per 100 g of air-dried soil for calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na). The cation exchange capacity (CEC) is expressed in the same units.

TABLE C.1

Results of Detailed Analyses

Profile & depth (cm)	Soil particles (%) CoS	FS	Si	C	Texture	pH 1:2.5	ECe (mmho/cm)	Exchangeable cations (meq/100 g) Ca	Mg	K	Na	CEC	ESP (%)	Available P (ppm)	Total N (%)	Organic C (%)	Soluble B (ppm)
Saruda (Sr)																	
R10																	
0-20	10	12	37	41	C	8.5	1.6	23.5	6.1	1.6	0.4	25.0	1.6	0.6	0.08	0.86	0.36
20-55	11	9	30	50	C	8.5	1.7	22.9	8.3	1.1	0.5	28.2	1.8	-	-	-	0.62
55-140	7	8	32	53	C	8.4	5.6	53.1*	7.7	1.2	1.3	29.0	4.5	-	-	-	1.28
140-200	10	10	30	50	C	8.5	8.0	54.4*	12.9	0.7	2.0	26.0	7.7	-	-	-	2.38
R16																	
0-25	5	7	33	55	C	8.4	1.8	28.7	5.7	1.4	0.2	26.0	0.8	0.4	0.06	0.62	0.29
25-75	10	10	25	55	C	8.7	1.3	27.0	6.5	1.0	0.9	27.0	3.3	-	-	-	0.26
75-130	9	11	27	53	C	8.5	2.7	29.1	7.6	1.1	1.5	22.3	6.7	-	-	-	0.33
R35																	
0-25	7	23	35	35	CL	8.2	1.9	28.6	4.6	1.5	0.2	30.1	0.7	3.0	0.09	1.21	-
25-60	6	21	23	50	C	8.3	2.2	23.2	6.6	0.8	0.5	34.3	1.5	-	-	-	-
60-105	5	22	23	50	C	8.2	3.5	25.9	10.9	1.0	0.4	37.7	1.1	-	-	-	-
105-150	3	22	22	53	C	8.2	4.7	76.9*	10.8	0.9	1.1	36.9	3.0	-	-	-	-
R64																	
0-20	4	21	36	39	CL	8.2	1.9	27.5	5.6	1.2	0.2	31.5	0.6	2.6	0.10	1.19	-
20-50	4	11	32	53	C	8.2	1.3	23.3	7.1	0.8	0.2	29.3	0.7	-	-	-	2.4
50-120	2	6	32	60	C	8.1	2.9	25.6	10.1	0.8	0.3	32.5	0.9	-	-	-	3.8
120-160	1	9	37	53	C	8.3	1.9	20.9	10.1	0.6	0.4	31.0	1.3	-	-	-	2.4
Dhoblow (Db)																	
R20																	
0-25	1	11	52	36	SiC	8.3	2.4	24.6	4.1	1.5	0.4	24.9	1.4	1.0	0.08	1.10	0 .22
25-45	4	15	45	36	SiC	8.1	3.5	75.6*	2.7	0.8	0.2	25.6	0.7	-	-	-	0.45
45-65	6	31	50	13	L	8.0	4.0	75.0*	2.2	0.8	0.2	3.2	5.3	-	-	-	0.63
65-125	6	31	22	41	C	8.1	5.6	71.3*	7.6	1.2	0.4	10.7	3.9	-	-	-	0.86
125-150	5	37	20	38	CL	8.1	7.0	84.7*	18.3	1.6	0.9	14.0	6.3	-	-	-	1.14

TABLE C.1 (cont.)

Profile & depth (cm)	Soil particles (%) CoS	FS	Si	C	Texture	pH 1:2.5	ECe (mmho/cm)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	CEC	ESP (%)	Available P (ppm)	Total N (%)	Organic C (%)	Soluble B (ppm)
Golweyn (Gl)																	
R22																	
0-20	2	10	42	46	SiC	8.1	4.0	35.6*	10.7	3.0	0.8	32.5	2.6	2.0	0.09	0.86	0.27
20-55	2	10	35	53	C	8.1	5.2	24.8	8.5	1.6	1.6	29.0	5.5	-	-	-	0.39
55-90	1	16	32	51	C	8.2	6.0	46.3*	6.7	0.9	1.5	31.9	4.5	-	-	-	0.55
90-140	1	11	32	56	C	8.3	8.0	61.3*	11.8	0.9	2.8	36.8	7.7	-	-	-	0.71
R25																	
0-26	1	6	32	61	C	8.3	2.3	32.0	7.5	2.6	0.5	36.4	1.3	1.6	0.09	1.10	0.76
20-60	0	7	25	68	C	8.2	4.2	32.9	6.6	1.1	0.6	33.0	1.7	-	-	-	0.73
60-160	3	9	25	63	C	8.0	4.0	46.3*	6.1	1.0	0.2	35.0	0.6	-	-	-	0.32
R66																	
0-20	2	21	49	28	CL	7.8	2.7	30.6*	2.5	1.6	0.1	28.7	0.3	2.6	0.06	0.67	1.74
30-60	1	16	40	43	C	7.8	3.7	50.6*	5.8	1.4	0.1	33.5	0.3	-	-	-	2.65
60-130	1	14	35	50	C	8.1	5.3	111.2*	8.5	1.5	0.6	34.3	1.8	-	-	-	4.38
130-160	2	15	31	52	C	8.3	7.7	36.6	10.0	1.5	0.3	34.5	0.9	-	-	-	4.40
Majabto (Mt)																	
R37																	
0-20	2	18	40	40	CL	8.3	3.1	21.6	5.1	1.6	0.4	28.8	1.3	5.8	0.09	1.31	-
20-70	1	14	40	45	C	8.2	6.1	60.6*	5.4	1.3	1.5	33.7	4.4	-	-	-	-
70-150	0	15	60	25	SiL	8.5	7.5	22.5	5.5	0.8	1.5	29.8	4.9	-	-	-	-
150-165	0	10	45	45	SiC	8.3	2.9	21.0	5.4	0.7	0.3	29.4	1.0	-	-	-	-
Shalambood (Sh)																	
R51																	
0-25	3	13	64	10	SiL	8.2	1.6	18.8	3.6	1.6	0.1	24.3	0.4	3.4	0.11	1.03	2.3
25-50	2	14	64	20	SiL	8.3	1.5	17.8	4.4	0.6	0.2	24.3	0.8	-	-	-	2.2
50-125	1	10	67	22	SiL	8.4	2.4	19.3	7.1	0.4	0.4	23.0	1.7	-	-	-	2.0
125-170	0	8	44	48	SiC	8.3	3.2	19.4	11.0	0.5	0.9	28.5	3.2	-	-	-	2.7

TABLE C.1 (cont.)

Profile & depth (cm)	Soil particles (%) CoS	FS	Si	C	Texture	pH 1:2.5	ECe (mmho/cm)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	CEC	ESP (%)	Available P (ppm)	Total N (%)	Organic C (%)	Soluble B (ppm)
Shalambood (cont.)																	
R18																	
0-15	6	14	54	26	SiL	8.5	2.1	19.6	3.7	2.4	0.4	21.8	1.7	9.2	0.09	0.90	0.13
15-65	4	11	44	41	SiC	8.6	3.0	10.7	4.5	1.8	1.2	22.8	5.3	-	-	-	0.23
55-115	2	13	39	46	C	8.4	5.0	21.9	6.1	2.0	4.6	28.5	16.3	-	-	-	0.46
115-150	1	16	45	38	SiCL	8.2	10.0	62.5*	8.7	1.7	4.6	28.5	16.0	-	-	-	0.61
150-180	2	20	42	46	SiC	8.1	8.0	59.4*	8.0	1.8	5.5	31.8	17.3	-	-	-	0.66
Madhuulow (Mw)																	
R25																	
0-20	0	14	25	61	C	8.3	4.8	61.9*	11.0	1.1	0.7	35.8	197	0.4	0.04	0.58	0.50
20-70	1	16	27	56	C	8.0	3.7	66.9*	6.2	0.9	0.3	35.3	0.7	-	-	-	0.53
70-140	2	18	32	48	C	8.0	3.3	21.3	4.3	1.0	0.1	29.0	0.2	-	-	-	0.29
140-170	7	23	24	46	C	8.1	6.5	18.4	7.7	1.2	0.9	30.3	2.9	-	-	-	0.37
R34																	
0-20	0	22	35	43	C	8.1	2.6	27.6	5.2	1.6	0.3	33.3	1.0	2.2	0.09	1.00	-
20-65	0	17	28	55	C	8.2	2.9	27.3	6.8	1.2	0.4	33.7	1.2	-	-	-	-
65-135	2	5	28	65	C	8.1	3.6	20.9	8.8	1.0	0.4	35.5	1.1	-	-	-	-
135-160	0	10	20	70	C	8.1	3.7	19.8	8.2	1.1	0.3	36.0	0.8	-	-	-	-
R63																	
0-25	0	18	29	53	C	8.1	1.9	31.4	6.2	1.7	0.4	36.8	1.1	3.2	0.07	0.83	4.2
25-75	0	8	29	73	C	8.1	2.0	29.0	7.0	1.0	0.3	36.3	0.8	-	-	-	-
75-105	0	1	26	73	C	8.0	3.2	30.9	6.4	1.0	0.4	38.0	1.1	-	-	-	4.0
105-160	0	10	10	80	C	8.1	3.2	50.0*	5.7	1.1	0.3	34.8	0.9	-	-	-	3.9
Qoryooley (Qr)																	
R51																	
0-20	1	11	45	43	SiC	8.2	2.0	23.4	5.9	0.9	0.2	25.5	0.7	11.3	0.08	0.76	0.16
20-801	16	40	43	SiC	8.1	3.0	19.0	4.7	0.6	0.2	25.5	0.3	-	-	-	-	0.11
80-165	1	13	23	63	C	8.1	2.0	29.5	5.8	0.7	0.3	42.8	0.7	-	-	-	0.28

TABLE C.1 (cont.)

Profile & depth (cm)	Soil particles (%) CoS	FS	Si	C	Texture	pH 1:2.5	ECe (mmho/cm)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	CEC	ESP (%)	Available P (ppm)	Total N (%)	Organic C (%)	Soluble B (ppm)
Qoryooley (cont.)																	
R17																	
0-25	0	6	36	58	C	8.2	1.4	28.2	6.0	2.1	0.3	29.3	0.9	5.7	0.10	1.00	0.32
25-105	0	9	23	68	C	8.1	1.7	37.8	7.1	0.8	0.5	41.3	1.3	-	-	-	0.31
105-125	1	16	32	51	C	8.1	1.9	27.4	4.6	0.8	0.4	28.5	1.4	-	-	-	0.32
125-165	4	15	33	48	C	8.1	2.6	19.2	4.2	0.9	0.4	34.3	1.1	-	-	-	0.30
R21																	
0-20	3	9	50	38	SiCL	8.3	2.2	23.6	5.5	2.4	0.2	24.9	0.8	10.0	0.09	0.90	0.24
20-55	2	12	38	48	C	8.3	3.3	21.0	6.0	1.3	0.2	27.5	0.6	-	-	-	0.25
55-130	1	8	35	56	C	7.9	1.5	42.2*	3.1	1.6	0.1	19.8	0.4	-	-	-	0.04
130-160	1	13	30	56	C	8.1	3.4	30.3	5.7	1.4	0.1	37.0	0.3	-	-	-	0.19
R14 (Qr-s)																	
0-15	1	8	38	53	C	8.3	2.1	28.8	4.7	2.1	0.2	32.5	0.6	3.9	0.09	0.90	0.27
15-55	1	10	33	56	C	8.3	1.6	23.4	4.8	1.5	0.3	33.3	0.9	-	-	-	0.26
55-95	0	11	21	68	C	8.3	1.5	24.8	5.5	1.1	0.5	41.8	1.1	-	-	-	0.26
95-160	2	19	23	56	C	7.9	1.9	23.1	4.4	0.9	0.4	31.8	1.3	-	-	-	0.27
Mukoy Dumis (Mc)																	
R27 0-30	0	17	37	46	C	8.2	2.6	29.1	6.0	1.7	0.4	27.8	1.5	1.5	0.08	0.86	0.16
30-70	0	15	32	33	CL	8.1	3.7	30.6*	4.8	1.5	0.3	23.5	1.3	-	-	-	0.66
70-100	0	17	62	21	SiL	8.1	4.8	28.4	5.5	0.6	0.2	20.8	0.9	-	-	-	0.83
100-170	0	15	44	41	SiC	8.0	4.2	51.9*	8.1	1.1	1.4	33.0	4.2	-	-	-	0.46
R33																	
0-30	1	21	45	33	CL	8.2	2.2	23.8	5.8	1.4	0.3	25.1	1.1	2.6	0.10	1.05	2.54
30-50	0	27	48	25	L	8.1	2.9	19.1	5.0	0.5	0.1	21.3	0.7	-	-	-	-
50-65	2	8	65	25	SiL	8.1	2.3	21.6	4.8	0.5	0.3	25.3	1.1	-	-	-	-
65-105	0	15	30	55	C	8.1	1.8	30.8	6.0	0.8	0.1	35.1	0.2	-	-	-	-
105-130	0	10	28	62	C	8.2	1.2	26.0	6.3	0.8	0.3	36.5	0.8	-	-	-	-

TABLE C.1 (cont.)

Profile & depth (cm)	Soil particles (%) CoS	FS	Si	C	Texture	pH 1:2.5	ECe (mmho/cm)	Exchangeable cations (meq/100g) Ca	Mg	K	Na	CEC	ESP (%)	Available P (ppm)	Total N (%)	Organic C (%)	Soluble B (ppm)
Buulo Mareerta (Bm)																	
R28																	
0-25	0	17	45	38	SiCL	8.6	2.3	18.0	3.0	1.5	0.3	14.3	2.1	1.0	0.03	0.40	0.35
25-55	1	16	60	23	SiL	8.4	2.0	21.5	4.4	4.1	0.2	23.0	0.8	-	-	-	0.30
55-90	0	12	40	48	SiC	8.0	4.4	30.5*	5.7	0.7	0.9	27.8	3.3	-	-	-	0.53
90-110	0	30	54	16	SiL	8.2	7.5	17.8	3.3	0.3	0.4	17.8	2.4	-	-	-	0.30
Faraxaane (Fx)																	
R40																	
0-20	1	29	47	13	L	8.1	3.3	15.6	1.6	0.8	0	19.3	0.2	4.6	0.09	1.05	-
20-60	0	27	55	18	SiL	8.2	3.7	38.8*	4.3	0.5	0.2	22.8	0.8	-	-	-	-
60-100	0	22	50	28	CL	8.3	4.3	56.9*	5.1	0.6	0.2	27.6	0.7	-	-	-	-
100-160	0	15	20	65	C	8.2	4.4	66.3*	9.2	0.9	0.1	33.8	0.4	-	-	-	-
Gayweerow (Gw)																	
0-25	0	15	31	54	C	8.1	2.6	28.1	6.3	1.1	0.3	28.3	1.1	1.0	0.07	0.86	0.34
25-40	0	7	52	41	SiC	8.2	2.0	22.1	4.6	0.7	0.5	22.5	2.1	-	-	-	0.37
40-85	0	17	22	61	C	8.1	2.3	24.6	5.2	0.7	0.5	28.3	1.7	-	-	-	0.30
85-140	0	14	20	66	C	8.1	4.2	28.6	7.1	0.9	1.4	33.2	4.1	-	-	-	0.27
140-180	1	21	24	54	C	8.0	5.6	16.9	6.6	0.9	1.3	27.0	4.9	-	-	-	0.21
R47																	
0-35	0	13	47	40	SiC	8.1	3.7	19.1	5.6	0.8	0.2	28.8	0.7	2.6	0.09	0.92	3.3
35-65	0	47	43	10	L	7.9	3.8	12.9	2.3	0.3	0.1	15.5	0.6	1.4	0.03	0.44	1.92
65-800	0	11	64	25	SiL	8.1	3.6	16.6	3.6	0.4	0.1	19.3	0.5	-	-	-	4.0
80-150	0	16	61	23	SiL	8.1	3.7	15.4	3.6	0.4	0.2	18.5	1.1	-	-	-	3.5

Notes: - No test performed

* Exchangeable calcium excessively high due to interference from calcium ions (from gypsum and calcium carbonate) dissolved by the sodium acetate solution.

(e) ESP

Exchangeable sodium percentage is given as the calculated value of Na/CEC x 100.

(f) Available P (ppm)

Available phosphorus is expressed in terms of elemental phosphorus in parts per million.

(g) Total N (%)

Nitrogen is given as the percentage of total N in the air-dry soil.

(h) Organic C (%)

Organic carbon percentage in the air-dry soil.

(i) Soluble B (ppm)

Values for hot water soluble boron are given in parts per million for the saturation extract.

C.2 Soluble Salt Analyses

All samples on which detailed analyses were performed (Appendix C.1) were also tested for soluble salts in terms of soluble cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and soluble anions (HCO_3^{-}, $CO_3^{=}$, Cl^{-}, $SO_4^{=}$). The results for these analyses are presented in Table C.2; no soluble $CO_3^{=}$ ions were detected, so this anion is not included. In addition, two samples collected from salt efflorescences, one at the surface and one on the face of a profile pit, were tested for soluble ions (Table C.3) to assess the relative mobility of the different ions under the influence of evaporation from the soil surface. In the case of Sample R37-A, which relates to an efflorescence of salt formed on the surface of Profile R37 at a depth of 70 to 150 cm, the analyses for the adjacent in situ horizon are included for comparison. Sample R61-A was collected from an efflorescence formed on a field irrigation bund.

Table C.4 shows the results of tests for gypsum, performed on samples from selected profiles. Methods of analysis are described in Appendix B.

TABLE C.2

Soluble Ions in Saturation Extract (meq per litre)

Soil series/ Site No.	Land use category (1)	Depth of sample (cm)	ECe (2)	Soluble cations				Soluble anions			Cl/SO4 (3)	SAR (4)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}		
Saruda (Sr)												
R10	1	0 - 20	1.6	8.6	2.8	4.5	0.5	7.5	6.7	1.0	1.1	1.9
		20 - 55	1.7	7.9	3.5	5.8	0.2	5.6	8.9	2.0	0.6	2.4
		55 - 140	5.6	27.5	18.1	34.6	0.3	14.4	61.2	3.0	0.2	1.2
		140 - 200	8.0	18.9	32.0	66.0	0.2	17.5	98.2	1.0	0.2	13.1
R16	1	0 - 25	1.8	8.9	2.6	3.6	0.4	9.3	3.1	1.0	3.0	1.5
		25 - 75	1.3	3.4	1.4	5.6	0.1	5.0	4.1	2.0	1.2	3.6
		75 - 130	2.7	6.8	3.5	12.9	0.2	10.7	9.7	2.0	1.1	5.7
R35	3	0 - 25	1.9	20.0	3.6	2.8	0.5	5.4	18.8	2.0	0.3	0.8
		25 - 60	2.2	16.4	5.7	3.5	0.2	5.1	19.6	2.0	0.3	1.1
		60 - 105	3.5	30.0	19.0	9.1	0.3	5.6	51.8	2.0	0.1	1.8
		105 - 150	4.7	41.9	27.5	25.0	0.3	7.6	79.5	7.0	0.1	4.2
R64	2	0 - 20	1.9	15.0	3.5	3.2	0.3	5.1	16.3	2.0	0.3	1.1
		20 - 50	1.3	8.6	2.8	2.4	0.2	3.1	8.9	2.0	0.3	1.0
		50 - 120	2.9	25.0	11.5	5.0	0.2	2.0	37.9	3.5	0.1	1.2
		120 - 160	1.9	11.9	6.2	5.3	0.2	2.0	19.8	3.0	0.1	1.7
Dhoblow (Db)												
R20	1	0 - 25	2.4	17.4	3.3	5.8	0.7	10.6	12.3	4.0	0.9	1.8
		25 - 45	3.5	43.1	6.4	5.8	0.3	14.4	36.9	4.0	0.4	1.2
		46 - 65	4.0	47.5	15.6	16.4	0.5	13.0	62.7	4.0	0.2	2.9
		65 - 125	5.6	33.8	27.5	22.5	0.8	16.3	63.5	4.0	0.3	4.1
		125 - 150	7.0	31.3	40.4	37.4	0.9	20.0	84.9	6.0	0.2	6.2

TABLE C.2 (cont.)

Soil series/ Site No.	Land use category (1)	Depth of sample (cm)	ECe (2)	Soluble cations				Soluble anions			Cl/SO4 (3)	SAR (4)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}		
Golweyn (Gl)												
R22	2	0 - 20	4.0	11.0	5.5	4.0	0.1	6.4	12.2	3.0	0.5	1.4
		20 - 55	5.2	17.0	10.6	21.3	0.5	21.2	26.5	3.0	0.8	5.7
		55 - 90	6.0	16.8	15.6	33.3	0.4	17.2	47.7	1.0	0.4	8.3
		90 - 140	8.0	14.3	22.4	44.4	0.3	32.1	49.5	1.0	0.6	10.4
R25	3	0 - 20	2.3	12.4	3.6	4.0	1.0	5.9	14.2	2.0	0.4	1.4
		20 - 60	4.2	28.8	6.8	11.2	0.3	12.1	29.2	3.0	0.4	2.7
		60 - 160	4.0	30.0	13.0	11.8	0.3	14.1	40.8	2.0	0.3	2.5
R66	3	0 - 20	2.7	35.0	4.3	2.5	0.8	2.0	37.5	2.5	0.1	0.6
		20 - 60	3.7	32.5	14.1	11.2	0.8	3.8	50.8	2.0	0.1	2.3
		60 - 130	5.3	29.4	25.0	29.1	1.0	3.9	79.2	2.0	0	5.6
		130 - 160	7.7	27.5	38.5	61.6	1.0	15.2	113.8	2.0	0.1	10.7
Majabto (Mt)												
R37	3	0 - 20	3.1	26.3	6.8	10.3	0.8	15.9	20.3	7.0	0.8	2.5
		20 - 70	6.1	48.8	21.5	50.0	0.7	44.7	70.4	5.0	0.6	8.4
		70 - 150	7.5	39.4	32.9	57.3	0.8	53.6	69.8	6.0	0.8	9.5
		150 - 165	2.9	31.3	9.1	5.6	0.4	9.1	32.6	5.0	0.3	1.2
Shalambood (Sh)												
R51	1	0 - 25	1.6	10.4	2.5	3.0	0.8	5.2	8.1	2.5	0.6	1.2
		25 - 50	1.5	8.9	2.5	4.0	0.2	3.1	10.0	3.0	0.3	1.7
		50 - 125	2.4	11.9	5.2	8.3	0.2	8.5	16.3	2.0	0.5	2.8
		125 - 170	3.2	15.0	9.7	15.4	0.2	10.1	28.8	3.0	0.4	4.4

TABLE C.2 (cont.)

Soil series/ Site No.	Land use category (1)	Depth of sample (cm)	ECe (2)	Soluble cations				Soluble anions			Cl/SO$_4$ (3)	SAR (4)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO$_4^{=}$	HCO$_3^{-}$		
Shalambood (cont.)												
R18	2	0 - 15	2.1	6.0	2.7	6.1	1.1	8.2	5.8	2.0	1.4	2.9
		15 - 55	3.0	5.5	3.1	16.4	0.6	13.5	12.3	1.6	1.1	7.9
		55 - 115	5.0	11.3	8.3	31.9	1.3	20.4	30.5	1.0	0.7	10.2
		115 - 150	10.0	15.5	33.8	58.8	2.8	43.2	63.5	3.0	0.7	11.8
		150 - 180	8.0	11.5	28.5	37.4	2.0	30.8	48.3	2.0	0.6	8.4
Madhuulow (Mw)												
R26	3	0 - 20	4.8	30.0	22.4	21.3	0.3	7.6	61.9	5.0	0.1	4.2
		20 - 70	3.7	31.3	16.5	6.9	0.3	6.9	44.5	4.0	0.2	1.4
		70 - 140	3.3	33.8	12.1	4.5	0.3	6.6	38.4	5.0	0.2	0.9
		140 - 170	6.5	30.0	21.5	41.3	0.4	17.5	68.8	7.0	0.3	8.1
R34	3	0 - 20	2.6	28.8	4.7	3.6	0.5	4.6	29.6	2.0	0.2	0.9
		20 - 65	2.9	31.3	7.7	4.8	0.3	5.8	35.6	3.0	0.2	1.1
		65 - 135	3.6	30.0	12.5	11.2	0.3	5.9	45.1	3.0	0.1	2.4
		135 - 160	3.7	27.5	14.9	12.3	0.4	6.2	46.2	3.0	0.1	2.7
R63	3	0 - 25	1.9	14.5	3.3	3.3	0.5	4.2	15.0	2.5	0.3	1.1
		25 - 75	2.0	15.8	4.7	4.3	0.2	2.0	20.8	2.0	0.1	1.3
		75 - 105	3.2	28.0	10.6	6.4	0.4	10.9	31.3	2.0	0.3	1.5
		105 - 160	3.2	30.0	11.3	6.9	0.4	2.8	45.0	3.0	0.1	1.5
Qoryooley (Qr)												
R13	4	0 - 20	2.0	11.5	0.5	0.5	0.3	6.5	10.3	3.0	0.6	1.3
		20 - 80	3.0	35.0	7.1	4.8	0.2	5.1	36.9	4.0	0.1	1.0
		80 - 165	2.0	13.0	3.5	4.0	0.1	5.6	15.1	1.0	0.4	2.9
R17	3	0 - 25	1.4	9.3	2.0	2.7	0.5	3.7	7.4	4.0	0.5	1.1
		25 - 105	1.7	11.3	2.7	4.3	0.1	2.5	14.5	1.0	0.2	1.6
		105 - 125	1.9	15.8	4.7	9.5	0.2	9.3	19.5	2.0	0.5	3.0
		125 - 165	2.6	17.0	5.4	8.9	0.3	7.0	24.1	1.0	0.3	2.7

TABLE C.2 (cont.)

Soil series/ Site No.	Land use category (1)	Depth of sample (cm)	ECe (2)	Soluble cations				Soluble anions			Cl/SO4 (3)	SAR (4)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}		
Qoryooley (cont.)												
R21	4	0 - 20	2.2	12.4	4.5	4.8	1.2	9.0	12.0	3.0	0.8	1.7
		20 - 55	3.3	30.0	4.7	5.0	0.7	8.4	31.7	1.0	0.3	1.2
		55 - 130	1.5	7.5	2.8	3.6	0.4	4.6	9.2	2.0	0.5	1.6
		130 - 160	3.4	26.3	11.9	5.0	0.6	6.8	32.9	5.0	0.2	1.1
R14	3	0 - 15	2.1	15.8	3.1	4.5	0.8	7.9	13.5	3.0	0.6	1.5
		15 - 55	1.6	10.4	2.5	3.7	0.4	5.6	9.5	3.0	0.6	1.5
		55 - 95	1.5	9.3	2.5	4.3	0.2	5.9	8.9	2.0	0.7	1.8
		95 - 160	1.9	10.6	2.8	5.3	0.2	8.5	8.6	2.0	1.0	2.0
Mukoy Dumis (Mc)												
R27	2	0 - 30	2.6	14.5	3.6	6.4	0.5	12.7	6.2	5.0	2.0	2.1
		30 - 70	3.7	33.8	8.1	9.1	0.5	11.7	32.1	6.0	0.4	2.0
		70 - 100	4.8	35.5	15.5	15.4	0.3	18.3	42.2	5.0	0.4	3.0
		100 - 170	4.2	30.0	11.0	16.4	0.2	13.7	39.5	4.0	0.3	3.6
R33	4	0 - 30	2.2	15.8	4.8	3.5	0.6	8.8	13.4	3.5	0.7	1.1
		30 - 50	2.9	27.5	8.3	6.1	0.2	18.7	22.1	2.0	0.8	1.4
		50 - 65	2.3	21.3	6.2	4.5	0.2	9.8	17.5	4.0	0.6	1.2
		65 - 105	1.8	20.0	4.7	2.4	0.1	5.2	18.4	4.0	0.3	0.7
		105 - 130	1.2	9.3	2.7	1.9	0.1	4.1	10.7	2.0	0.4	0.8
Buulo Mareerta (Bm)												
R28	1	0 - 25	2.3	12.1	2.7	8.3	1.5	9.9	10.6	4.0	0.9	3.1
		25 - 55	2.0	8.9	2.4	4.0	2.4	7.9	2.0	7.0	4.0	1.7
		55 - 90	4.4	33.8	9.3	17.1	0.2	10.7	44.2	5.0	0.2	3.7
		90 - 110	7.5	38.6	18.6	44.4	0.2	36.1	58.7	6.0	0.6	8.3

TABLE C.2 (cont.)

Soil series/ Site No.	Land use category (1)	Depth of sample (cm)	ECe (2)	Soluble cations				Soluble anions			Cl/SO_4 (3)	SAR (4)
				Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	$SO_4^=$	HCO_3^-		
Faraxaane (Fx)												
R40	3	0 - 20	3.3	43.1	10.9	5.0	0.9	9.2	48.6	2.0	0.2	1.0
		20 - 60	3.7	31.3	36.4	16.1	0.3	8.4	69.8	5.0	0.1	2.8
		60 - 100	4.3	48.8	32.0	7.5	0.3	5.4	75.0	7.0	0.1	1.2
		100 - 160	4.4	30.0	34.5	18.5	0.3	11.0	67.7	6.0	0.2	3.3
Gayweerow (Gw)												
R24	3	0 - 25	2.6	23.8	6.4	5.3	0.3	5.4	28.5	3.0	0.2	1.4
		25 - 40	2.0	14.5	4.1	5.6	0.2	4.2	17.5	3.0	0.2	1.8
		40 - 85	2.3	17.0	4.8	6.4	0.1	3.7	22.2	3.0	0.2	1.9
		85 - 140	4.2	30.0	8.7	14.5	0.2	13.8	36.4	3.0	0.4	3.3
		140 - 180	5.6	35.5	18.0	21.3	0.3	17.2	54.2	3.0	0.3	4.1
R47	4	0 - 35	3.7	28.0	10.1	12.9	0.3	3.4	46.3	3.0	0.1	3.0
		35 - 65	3.8	32.5	9.9	13.8	0.2	5.4	51.0	1.8	0.1	3.0
		65 - 80	3.6	30.0	9.1	11.5	0.2	4.5	45.0	2.5	0.1	2.6
		80 - 150	3.7	32.5	8.9	12.1	0.3	5.6	46.3	3.0	0.1	2.7

Notes: (1) Land use categories:

1 - uncultivated
2 - marginal annual crops
3 - irrigated annual crops
4 - irrigated perennial crops

(see Annex IV)

(2) ECe in mmho/cm

(3) Chloride to sulphate ratio

(4) Sodium adsorption ratio

TABLE C.3

Salt Efflorescence Analysis

Sample No.	ECe	Soluble cations (meq/l)				Soluble anions (meq/l)		
		Ca	Mg	Na	K	Cl	SO_4	HCO_3
R37-A	13.9	37.0	59.5	100.0	1.0	126.8	71.3	1.0
R37-3	7.5	39.4	32.9	57.3	0.8	53.6	69.8	6.0
R61-A	3.7	52.0	11.9	11.8	0.1	31.2	39.2	2.0

TABLE C.4

Soil Gypsum Content

Series	Profile No.	Depth (cm)	Gypsum (%)
Saruda	R64	0 - 20	*
		20 - 50	0.02
		50 - 120	0.08
		120 - 160	0.04
Shalambood	R51	0 - 25	0.03
		25 - 50	0.01
		50 - 125	0.01
		125 - 170	0.01
Madhuulow	R63	0 - 25	0.03
		25 - 75	0.07
		75 - 105	0.87
		105 - 160	1.17
Gayweerow	R47	0 - 35	0.09
		35 - 65	-
		65 - 80	0.22
		80 - 150	0.08

Note: * Indicates values less than 0.01.

C.3 Routine Salinity Analyses

Analyses were carried out to determine electrical conductivity of the saturation extract (ECe) and exchangeable sodium percentage (ESP). These analyses were performed on samples collected from the 0 to 50 and 50 to 100 cm horizons of all auger sites and all profile pits which had not already been sampled for detailed chemical analysis. Tests for ECe were also performed on samples from deeper horizons at selected sites. In addition, some tests for EC were made on the 1 : 2 soil to water extract ($EC_{1:2}$) to establish a relationship between ECe and $EC_{1:2}$ (see Appendix E).

Details of the number of samples and types of analyses are listed in Table C.5. Complete data are presented in Tables C.6 to C.9. Site locations in the Study Area and Qoryooley Project Area are shown in Maps 1C and 2C, respectively.

TABLE C.5

Salinity Analysis Samples: Numbers and Locations

Type of analysis	and depth (m)	Profile pits	Auger sites: Study Area	Auger sites: Project Area	Auger sites: Sample areas	Totals
ECe &	0 - 0.5	72	541	264	16	893
ESP	0.5 - 1.0	72	541	264	16	893
ECe	1.0 - 1.5	54	11	21	-	86
	1.5 - 2.5	37	9	5	-	51
	2.5 - 3.5	36	9	5	-	50
ECe,	0 - 0.5	-	-	-	30	30
$EC_{1:2}$ & ESP	0.5 - 1.0	-	-	-	30	30
ECe & $EC_{1:2}$	1.0 - 1.5	-	-	-	15	15

The following explanatory notes are provided for use with Tables C.6 to C.9.

(a) ECe and $EC_{1:2}$ values are given in mmho/cm. Classes are as defined in Chapter 4, viz:

Class	Salinity level	ECe limits (maxima)
I	Negligible	0 - 2.4
II	Low	2.5 - 4.9
III	Moderate	5.0 - 7.4
IV	High	7.5 - 9.9
V	Very high	10.0 +

(b) ECe and ESP values for profiles which were sampled for detailed chemical analysis are given as the weighted means of the values for natural horizons.

(c) CEC and exchangeable sodium (Na+) values are expressed in meq/100 g. ESP classes are as defined in Chapter 4, viz:-

Class	Sodium hazard	ESP limits (maxima)
A	Negligible	4.9
B	Low	5.0 - 9.9
C	Moderate	10.0 - 14.9
D	High	15.0+

(d) Symbols used in tables:

(i) Analysis not performed -

(ii) Analysis for which data available for natural horizon (Section C.1) +

(e) Land use categories are as defined in Annex IV, viz:-

1 - Uncultivated
2 - Marginal cultivation of annual crops
3 - Irrigated annual crops
4 - Irrigated perennial crops.

C.4 Water Analyses

At survey sites where a water table was encountered, samples were collected and tested for electrical conductivity, using an electric conductivity meter. The results (Table C.10) show that high salinities can occur in the groundwater, often within the root zone of the crops. The mean EC for 16 samples is calculated at 7 642 micromho/cm (SD = 5 394); no significant relationship was recorded between depth of water sample and salinity.

The majority of samples were collected from sites which are used for irrigation of either perennial crops (mainly bananas) or annual crops, reflecting the tendency for high water tables to occur under areas where irrigation water application and canal seepage is greatest.

TABLE C.6

Routine Analysis Results (Study Area)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R101	-1	0-50	Qr	1.7	II	34.5	0.23	0.7	A	2
	-2	50-100		2.8		37.5	0.37	1.0		
R102	-1	0-50	Gl	1.7	I	33.3	0.24	0.7	A	3
	-2	50-100		2.4		39.8	0.30	0.8		
R103	-1	0-50	Qr	3.7	II	33.0	0.44	1.3	A	4
	-2	50-100		2.4		35.8	0.59	1.7		
R104	-1	0-50	Qr	1.2	I	26.5	0.37	1.4	A	3
	-2	50-100		1.6		35.3	0.86	2.4		
R105	-1	0-50	Sh	1.9	IV	24.3	0.35	1.4	B	3
	-2	50-100		8.5		20.5	1.03	5.0		
R106	-1	0-50	Gl	2.6	II	27.5	0.15	0.6	A	3
	-2	50-100		3.4		31.5	0.26	0.8		
R107	-1	0-50	Sr	1.0	II	29.5	0.52	1.7	A	2
	-2	50-100		3.4		32.3	0.50	1.6		
R108	-1	0-50	Gl	1.7	II	28.0	0.20	0.7	A	2
	-2	50-100		2.9		26.8	0.20	0.8		
R109	-1	0-50	Sr	1.3	III	35.3	1.13	3.2	C	1
	-2	50-100		5.1		37.5	4.73	12.6		
R110	-1	0-50	Sh	1.2	III	32.3	0.86	2.7	C	1
	-2	50-100		5.2		33.5	4.07	12.2		
R111	-1	0-50	Sh	2.3	IV	30.3	0.60	2.0	A	1
	-2	50-100		8.9		24.0	0.75	3.1		
R112	-1	0-50	Sr	1.4	III	35.5	0.85	2.4	A	1
	-2	50-100		6.1		37.3	0.25	0.7		
R113	-1	0-50	Sr	0.9	II	36.0	0.35	1.0	A	3
	-2	50-100		3.5		40.5	0.95	2.4		
R114	-1	0-50	Sr	1.6	I	30.5	0.18	0.6	B	2
	-2	50-100		2.0		35.0	1.98	5.7		
R115	-1	0-50	Gl	1.5	II	31.0	0.15	0.5	A	2
	-2	50-100		3.2		36.3	0.24	0.7		
R116	-1	0-50	Gw	1.2	I	33.8	0.24	0.7	A	2
	-2	50-100		2.4		28.3	0.64	2.3		
R117	-1	0-50	Qr	2.5	II	34.8	0.30	0.9	A	3
	-2	50-100		1.6		35.5	0.31	0.9		
R118	-1	0-50	Qr	1.0	I	36.8	0.27	0.7	A	3
	-2	50-100		1.1		39.3	0.40	1.0		
R119	-1	0-50	Mw	2.0	II	30.0	0.24	0.8	A	3
	-2	50-100		2.8		38.0	0.26	0.7		
R120	-1	0-50	Mc	2.1	II	28.5	0.27	1.0	A	3
	-2	50-100		2.9		34.3	0.30	0.9		
R121	-1	0-50	Qr	1.0	I	35.0	0.16	0.5	A	3
	-2	50-100		2.3		37.5	0.31	0.8		
R122	-1	0-50	Mc	3.1	II	29.8	0.13	0.4	A	3
	-2	50-100		3.4		35.5	0.43	1.2		
R123	-1	0-50	Qr	1.8	II	35.3	0.35	1.0	A	3
	-2	50-100		2.9		32.5	0.17	0.5		
R124	-1	0-50	Qr	2.7	II	37.3	0.53	1.4	A	3
	-2	50-100		2.1		38.3	0.45	1.2		
R125	-1	0-50	Gl	1.3	I	36.3	0.56	1.5	A	3
	-2	50-100		3.1		36.8	0.41	1.1		
R127	-1	0-50	Qr	1.3	I	38.0	0.41	1.1	A	1
	-2	50-100		2.2		38.5	0.50	1.3		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R128	-1	0-50	Sh	1.4	II	26.3	0.19	0.7	A	3
	-2	50-100		2.6		33.3	0.28	0.8		
R129	-1	0-50	Sr	1.6	II	30.5	0.29	1.0	A	1
	-2	50-100		3.0		32.8	0.30	0.9		
R130	-1	0-50	Db	2.9	II	21.3	0.34	1.6	A	2
	-2	50-100		3.4		7.3	0.12	1.6		
R131	-1	0-50	Db	2.1	II	25.5	0.48	1.9	A	2
	-2	50-100		3.6		30.5	0.29	0.9		
R132	-1	0-50	Gl	1.0	II	33.5	1.00	3.0	A	2
	-2	50-100		2.6		37.8	0.50	1.3		
R133	-1	0-50	Sr	0.8	I	31.5	0.07	0.2	A	1
	-2	50-100		2.4		34.0	0.15	0.4		
R134	-1	0-50	Sh	3.1	II	29.8	0.18	0.6	A	2
	-2	50-100		3.5		37.5	0.29	0.8		
R135	-1	0-50	Sr	2.8	II	38.8	0.16	0.4	A	2
	-2	50-100		3.8		37.8	0.29	0.8		
R136	-1	0-50	Sh	2.2	I	21.8	2.47	11.3	C	4
	-2	50-100		1.8		19.0	0.03	0.2		
R137	-1	0-50	Qr	2.7	II	33.5	0.09	0.3	A	4
	-2	50-100		1.2		38.8	0.43	1.1		
R138	-1	0-50	Qr	1.1	I	32.3	0.29	0.90	A	2
	-2	50-100		1.2		39.3	0.43	1.1		
R139	-1	0-50	Qr	1.3	I	29.3	0.22	0.8	A	3
	-2	50-100		1.2		38.8	0.41	1.1		
R140	-1	0-50	Qr	1.0	I	34.5	0.20	0.6	A	3
	-2	50-100		1.1		35.3	0.20	0.6		
R141	-1	0-50	Gl	1.0	II	22.8	0.26	1.1	A	3
	-2	50-100		3.3		33.5	0.15	0.5		
R142	-1	0-50	Db	1.3	I	24.0	0.29	1.2	A	1
	-2	50-100		1.2		25.0	0.15	0.6		
R143	-1	0-50	Sr	1.9	II	35.3	0.14	0.4	A	3
	-2	50-100		3.4		38.3	0.20	0.5		
R144	-1	0-50	Gl	2.3	I	30.5	0.16	0.5	A	1
	-2	50-100		2.1		29.3	0.56	1.9		
R145	-1	0-50	Sr	0.8	II	36.0	0.23	0.6	A	2
	-2	50-100		2.5		40.8	0.23	0.6		
R146	-1	0-50	Gl	2.5	II	37.3	0.11	0.3	A	2
	-2	50-100		3.4		40.8	1.14	2.8		
R147	-1	0-50	Sr	0.9	II	25.8	0.34	1.3	A	1
	-2	50-100		2.5		32.3	0.33	1.0		
R148	-1	0-50	Sr	0.7	I	30.5	1.45	4.8	A	1
	-2	50-100		0.8		39.8	0.57	1.4		
R149	-1	0-50	Gl	1.2	I	32.5	0.27	0.8	A	2
	-2	50-100		1.3		38.5	0.25	0.6		
R150	-1	0-50	Gl	1.2	I	32.3	0.21	0.7	A	3
	-2	50-100		1.9		36.8	0.43	1.2		
R151	-1	0-50	Gl	2.4	III	29.8	1.04	3.5	A	2
	-2	50-100		5.4		36.8	0.98	2.7		
R153	-1	0-50	Db	1.7	I	11.5	0.04	0.4	A	1
	-2	50-100		2.2		36.0	0.03	0.1		
R154	-1	0-50	Sr	1.7	II	41.0	0.39	1.0	A	2
	-2	50-100		4.2		36.8	1.12	3.0		

Note: 126 and 152 outside area.

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na+	ESP	Class	
R155	-1	0-50	Gl	1.4	II	43.3	0.24	0.6	A	2
	-2	50-100		2.5		34.0	0.23	0.1		
R156	-1	0-50	Qr	1.8	I	36.3	0.53	1.5	A	2
	-2	50-100		2.1		39.1	0.63	1.6		
R157	-1	0-50	Sr	1.2	II	34.0	0.24	0.7	A	3
	-2	50-100		2.8		39.8	0.48	1.2		
R158	-1	0-50	Qr	1.0	I	31.0	0.14	0.5	A	2
	-2	50-100		1.5		36.3	0.25	0.7		
R159	-1	0-50	Mc	2.6	II	38.3	0.32	0.8	A	3
	-2	50-100		4.2		24.5	0.58	2.4		
R160	-1	0-50	Mc	1.2	I	28.5	0.29	1.0	A	1
	-2	50-100		0.7		26.3	0.24	0.9		
R161	-1	0-50	Mc	0.8	I	29.5	0.28	1.0	A	2
	-2	50-100		0.7		24.5	0.39	1.6		
R162	-1	0-50	Qr	0.6	I	36.8	0.30	0.8	A	3
	-2	50-100		0.6		37.5	0.58	1.6		
R163	-1	0-50	Mc	3.1	II	22.0	34.0	1.6	A	1
	-2	50-100		3.1		37.3	0.23	0.6		
R164	-1	0-50	Mc	0.9	I	29.0	0.26	0.9	A	1
	-2	50-100		1.1		19.0	0.30	1.6		
R165	-1	0-50	Mc	1.0	I	30.5	0.29	1.0	A	1
	-2	50-100		1.3		35.8	0.30	0.8		
R166	-1	0-50	Qr	1.0	I	34.0	0.38	1.1	A	4
	-2	50-100		1.0		37.3	0.30	0.8		
R167	-1	0-50	Qr	1.0	I	26.3	0.27	1.0	A	1
	-2	50-100		2.4		29.5	0.49	1.7		
R168	-1	0-50	Gl	2.1	I	39.5	0.28	0.7	A	1
	-2	50-100		2.3		45.8	0.20	0.4		
R169	-1	0-50	Sh	2.6	II	36.3	0.14	0.4	A	1
	-2	50-100		4.3		34.0	0.98	2.9		
R171	-1	0-50	Sh	1.0	II	31.3	0.26	0.8	A	3
	-2	50-100		3.5		36.5	0.75	2.1		
R172	-1	0-50	Gl	4.8	IV	31.5	0.27	0.9	A	1
	-2	50-100		8.3		35.0	0.42	1.2		
R173	-1	0-50	Gl	2.6	II	35.5	0.31	0.9	A	3
	-2	50-100		2.0		36.3	0.34	0.9		
R174	-1	0-50	Qr	3.4	II	34.3	0.37	1.1	A	4
	-2	50-100		1.8		37.5	0.30	0.8		
R175	-1	0-50	Gl	3.3	II	34.5	0.11	0.3	A	4
	-2	50-100		4.3		29.3	0.25	0.9		
R176	-1	0-50	Qr	2.1	I	24.8	0.13	0.5	A	3
	-2	50-100		1.8		32.2	0.13	0.4		
R177	-1	0-50	Qr	2.8	II	34.0	0.16	0.5	A	4
	-2	50-100		4.1		35.5	0.55	1.6		
R178	-1	0-50	Qr	2.6	II	35.0	0.19	0.5	A	3
	-2	50-100		3.2		37.8	0.35	0.9		
R179	-1	0-50	Mw	2.3	II	33.5	0.25	0.8	A	3
	-2	50-100		2.7		41.9	0.38	0.9		
R180	-1	0-50	Mw	2.5	II	31.0	0.08	0.3	A	1
	-2	50-100		2.6		31.5	0.10	0.3		
R181	-1	0-50	Mw	2.6	II	35.9	0.15	0.4	A	3
	-2	50-100		3.2		38.8	0.33	0.9		

Note: No R170

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R182	-1	0-50	Mw	4.0	III	38.9	0.50	1.3	A	3
	-2	50-100		5.1		38.0	0.44	1.2		
R183	-1	0-50	Bm	3.9	II	23.9	0.23	1.0	A	3
	-2	50-100		2.0		28.3	0.32	1.1		
R184	-1	0-50	Gw	0.9	II	29.0	0.34	1.2	A	1
	-2	50-100		2.9		35.7	0.55	1.5		
R185	-1	0-50	Mt	1.7	I	26.1	0.22	0.8	A	3
	-2	50-100		1.8		25.7	0.25	1.0		
R186	-1	0-50	Mt	3.0	II	36.5	0.32	0.9	A	3
	-2	50-100		2.5		31.5	0.11	0.4		
R187	-1	0-50	Gl	1.5	II	30.5	0.22	0.7	A	3
	-2	50-100		3.7		32.3	0.28	0.9		
R188	-1	0-50	Gl	1.2	II	31.6	0.18	0.6	A	3
	-2	50-100		2.8		32.1	0.20	0.6		
R189	-1	0-50	Qr	1.1	II	32.0	0.06	0.2	A	3
	-2	50-100		2.8		36.0	0.35	1.0		
R190	-1	0-50	Gl	1.4	II	31.3	0.33	1.1	A	3
	-2	50-100		3.6		36.8	0.38	1.0		
R191	-1	0-50	Gl	20.9	VI	27.2	1.38	5.1	B	1
	-2	50-100		19.1		27.8	0.70	2.5		
R192	-1	0-50	Sr	2.9	II	33.4	0.25	0.8	B	3
	-2	50-100		4.4		36.9	2.74	7.4		
R193	-1	0-50	Sr	2.8	II	34.9	0.27	0.8	A	3
	-2	50-100		4.4		36.5	0.53	1.5		
R194	-1	0-50	Sr	2.8	II	36.0	0.30	0.8	A	3
	-2	50-100		4.2		35.5	0.65	1.8		
R195	-1	0-50	Sr	3.0	II	34.5	0.25	0.7	A	3
	-2	50-100		4.0		39.9	0.63	1.6		
R196	-1	0-50	Sr	1.7	III	28.0	0.89	3.2	B	1
	-2	50-100		6.6		36.3	2.13	5.9		
R197	-1	0-50	Sh	3.1	IV	27.3	0.93	3.4	A	1
	-2	50-100		9.2		36.5	1.12	3.1		
R198	-1	0-50	Sh	2.3	I	28.8	0.46	1.6	A	2
	-2	50-100		1.5		32.3	0.42	1.3		
R199	-1	0-50	Sr	2.0	I	31.7	0.33	1.0	A	4
	-2	50-100		2.3		40.8	0.46	1.1		
R200	-1	0-50	Qr	2.0	II	26.0	0.33	1.3	A	4
	-2	50-100		3.0		35.8	0.50	1.4		
R201	-1	0-50	Qr	2.7	II	31.7	0.34	1.1	A	3
	-2	50-100		1.0		32.0	0.44	1.4		
R202	-1	0-50	Gl	1.2	II	25.6	0.13	0.5	A	2
	-2	50-100		2.9		29.5	0.35	1.2		
R203	-1	0-50	Gl	2.8	II	34.1	0.25	0.7	A	2
	-2	50-100		3.3		30.6	0.29	1.0		
R204	-1	0-50	Sr	2.7	II	32.3	0.13	0.4	A	3
	-2	50-100		4.4		26.0	0.54	2.1		
R205	-1	0-50	Sr	3.3	II	35.0	0.23	0.7	A	2
	-2	50-100		4.7		25.7	0.28	1.1		
R206	-1	0-50	Sh	1.2	II	26.7	0.45	1.7	A	1
	-2	50-100		3.6		31.6	0.38	1.2		
R207	-1	0-50	Gl	0.6	I	33.0	0.48	1.5	A	1
	-2	50-100		0.6		31.8	1.32	4.2		
R208	-1	0-50	Gl	1.1	II	29.0	0.65	2.2	A	1
	-2	50-100		3.9		31.9	0.80	2.5		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R209	-1	0-50	Sh	0.8	II	27.1	0.53	2.0	A	1
	-2	50-100		3.2		28.7	0.93	3.2		
R210	-1	0-50	Sr	1.1	I	29.6	0.65	2.2	A	1
	-2	50-100		1.7		34.1	1.50	4.4		
R211	-1	0-50	Gl	1.1	I	36.0	0.53	1.5	A	1
	-2	50-100		2.4		37.7	0.71	1.9		
R212	-1	0-50	Sh	2.8	II	24.0	0.04	0.2	A	1
	-2	50-100		2.8		25.8	0.05	0.2		
R213	-1	0-50	Sr	2.7	II	36.5	0.16	0.4	A	2
	-2	50-100		3.0		29.5	0.26	0.9		
R214	-1	0-50	Sr	1.1	I	32.9	0.30	0.9	A	3
	-2	50-100		1.8		31.8	0.46	1.5		
R215	-1	0-50	Sr	2.5	II	33.5	0.10	0.3	A	3
	-2	50-100		3.2		31.6	0.26	0.8		
R216	-1	0-50	Sr	0.8	I	30.5	0.58	1.9	A	1
	-2	50-100		0.7		31.8	0.95	3.0		
R217	-1	0-50	Gl	0.8	II	34.8	0.46	1.3	A	1
	-2	50-100		3.2		39.3	0.31	0.8		
R218	-1	0-50	Sr	1.4	I	28.7	0.19	0.7	A	3
	-2	50-100		1.7		34.1	0.50	1.5		
R219	-1	0-50	Qr	1.8	II	34.4	0.36	1.1	A	4
	-2	50-100		2.6		39.5	0.71	1.8		
R220	-1	0-50	Mc	1.4	II	30.6	0.30	1.0	A	4
	-2	50-100		2.7		29.3	0.19	0.7		
R221	-1	0-50	Qr	1.6	II	33.3	0.33	1.0	A	4
	-2	50-100		2.9		39.0	0.51	1.3		
R222	-1	0-50	Qr	1.4	I	24.3	0.31	1.3	A	4
	-2	50-100		1.5		34.0	0.38	1.1		
R223	-1	0-50	Qr	1.6	II	27.1	0.18	0.7	A	2
	-2	50-100		2.9		35.5	0.26	0.7		
R224	-1	0-50	Qr	4.4	III	38.9	1.09	2.8	A	2
	-2	50-100		5.1		35.6	0.41	1.2		
R225	-1	0-50	Qr	1.6	II	36.4	0.50	1.4	A	1
	-2	50-100		4.8		41.6	0.82	2.0		
R226	-1	0-50	Sr	4.7	V	25.5	0.36	1.4	A	3
	-2	50-100		10.9		25.9	0.85	3.3		
R227	-1	0-50	Sh	0.9	I	22.4	0.11	0.5	A	3
	-2	50-100		2.4		32.3	0.11	0.3		
R228	-1	0-50	Qr	1.5	II	36.2	0.38	1.1	A	3
	-2	50-100		2.5		42.0	0.50	1.2		
R229	-1	0-50	Gl	3.0	II	36.0	0.43	1.2	A	2
	-2	50-100		3.0		42.0	0.50	1.2		
R230	-1	0-50	Sh	0.9	I	29.9	0.13	0.4	A	1
	-2	50-100		2.4		27.2	0.14	0.5		
R231	-1	0-50	Mc	2.7	II	26.2	0.59	2.3	A	4
	-2	50-100		2.6		23.6	0.14	0.6		
R232	-1	0-50	Mc	4.4	III	30.0	0.89	3.0	A	3
	-2	50-100		7.3		21.8	0.55	2.5		
R233	-1	0-50	Qr	1.7	II	26.9	0.33	1.2	A	2
	-2	50-100		3.6		35.8	0.05	0.1		
R234	-1	0-50	Qr	1.2	I	36.6	0.29	0.8	A	3
	-2	50-100		1.3		42.0	0.41	1.0		
R235	-1	0-50	Qr	2.8	II	35.9	0.66	1.8	A	4
	-2	50-100		2.2		38.3	0.60	1.6		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R236	-1	0-50	Qr	0.9	I	30.3	0.28	0.9	A	3
	-2	50-100		1.0		34.7	0.53	1.5		
R237	-1	0-50	Qr	1.3	II	41.7	0.44	1.1	A	3
	-2	50-100		2.8		43.0	0.35	0.8		
R238	-1	0-50	Sh	1.6	I	22.9	0.16	0.7	A	2
	-2	50-100		1.2		27.8	0.19	0.7		
R239	-1	0-50	Qr	1.2	I	36.3	0.29	0.8	A	3
	-2	50-100		1.0		35.9	0.50	1.4		
R240	-1	0-50	Bm	-	I	-	-	-	A	2
	-2	50-100		2.4		24.7	0.42	1.7		
R241	-1	0-50	Qr	0.9	I	33.8	0.31	0.9	A	3
	-2	50-100		1.0		36.1	0.50	1.4		
R242	-1	0-50	Gl	1.2	II	26.7	0.23	0.9	A	1
	-2	50-100		3.4		36.2	0.33	0.9		
R243	-1	0-50	Sh	7.3	III	30.3	0.68	2.2	A	
	-2	50-100		7.1		37.3	0.08	0.2		
R244	-1	0-50	Gl	1.3	II	33.3	0.44	1.3	A	1
	-2	50-100		3.8		38.3	0.31	0.8		
R245	-1	0-50	Gl	2.8	II	31.3	0.16	0.5	A	1
	-2	50-100		3.4		14.3	0.27	1.9		
R246	-1	0-50	Qr	1.3	II	35.8	0.45	1.3	A	4
	-2	50-100		3.3		40.5	0.63	1.6		
R247	-1	0-50	Bm	0.9	I	22.0	0.16	0.7	A	3
	-2	50-100		1.7		19.3	0.63	3.3		
R248	-1	0-50	Qr	3.0	II	26.8	0.49	1.8	A	2
	-2	50-100		1.7		38.8	0.69	1.8		
R249	-1	0-50	Gl	3.8	II	37.0	0.38	1.0	A	2
	-2	50-100		2.3		29.3	0.54	1.8		
R250	-1	0-50	Gl	1.1	I	30.5	0.41	1.3	A	1
	-2	50-100		1.2		38.3	0.98	2.6		
R251	-1	0-50	Qr	1.1	II	33.7	0.32	1.0	A	4
	-2	50-100		3.9		36.7	0.55	1.5		
R252	-1	0-50	Gl	2.7	II	25.9	0.20	0.8	A	4
	-2	50-100		1.9		26.5	0.21	0.8		
R253	-1	0-50	Qr	1.7	I	35.6	0.41	1.2	A	3
	-2	50-100		1.6		40.9	0.66	1.6		
R254	-1	0-50	Qr	1.2	I	33.0	0.33	1.0	A	4
	-2	50-100		2.0		38.5	0.53	1.4		
R255	-1	0-50	Bm	0.8	I	26.1	0.11	0.4	A	1
	-2	50-100		0.8		21.8	0.16	0.7		
R256	-1	0-50	Sh	1.4	I	27.2	0.21	0.8	A	3
	-2	50-100		1.2		30.7	0.31	1.0		
R257	-1	0-50	Qr	1.3	I	30.5	0.34	1.1	A	4
	-2	50-100		1.1		34.7	0.52	1.5		
R258	-1	0-50	Mc	2.7	II	38.4	0.49	1.3	A	3
	-2	50-100		2.4		34.7	0.66	1.9		
R259	-1	0-50	Qr	1.1	II	36.3	0.29	0.8	A	4
	-2	50-100		2.5		35.7	0.45	1.3		
R260	-1	0-50	Gl	2.6	II	29.5	0.20	0.7	A	2
	-2	50-100		2.2		29.5	0.39	1.3		
R261	-1	0-50	Sr	1.9	I	29.5	0.31	1.1	A	3
	-2	50-100		1.7		35.6	0.42	1.2		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R262	-1	0-50	Mc	1.3	I	28.8	0.46	1.6	A	4
	-2	50-100		1.5		23.0	0.26	1.1		
R263	-1	0-50	Sr	1.0	II	30.5	0.42	1.4	A	3
	-2	50-100		2.7		37.7	0.84	2.2		
R264	-1	0-50	Sr	2.4	II	38.7	0.33	0.9	A	1
	-2	50-100		2.8		36.6	0.44	1.2		
R265	-1	0-50	Sr	0.8	I	29.9	0.19	0.6	A	1
	-2	50-100		2.4		30.1	0.29	1.0		
R266	-1	0-50	Sr	2.3	II	37.5	0.24	0.6	A	1
	-2	50-100		2.6		38.2	0.22	0.6		
R267	-1	0-50	Sh	0.7	II	29.1	0.29	1.0	A	1
	-2	50-100		2.7		28.9	0.25	0.9		
R268	-1	0-50	Gl	1.3	II	27.4	0.27	1.0	A	1
	-2	50-100		2.7		32.1	0.34	1.1		
R269	-1	0-50	Sr	2.6	II	33.0	0.23	0.7	A	1
	-2	50-100		3.2		32.7	0.38	1.2		
R270	-1	0-50	Gl	3.2	II	28.8	0.43	1.5	A	4
	-2	50-100		3.7		32.0	0.21	0.7		
R271	-1	0-50	Gl	1.8	I	28.2	0.48	1.7	A	1
	-2	50-100		-		-	-	-		
R272	-1	0-50	Sr	1.5	I	29.6	0.39	1.3	A	2
	-2	50-100		1.2		31.3	0.92	2.9		
R273	-1	0-50	Sr	1.1	II	32.7	0.28	0.9	A	2
	-2	50-100		2.6		28.6	0.19	0.7		
R274	-1	0-50	Mc	1.0	II	28.9	0.16	0.6	A	3
	-2	50-100		2.6		23.4	0.11	0.5		
R275	-1	0-50	Mw	0.8	II	24.7	0.15	0.6	A	3
	-2	50-100		2.7		15.8	0.09	0.6		
R276	-1	0-50	Sr	2.9	II	33.1	0.35	1.1	A	3
	-2	50-100		3.9		27.9	0.59	2.1		
R277	-1	0-50	Sr	1.6	II	34.6	0.48	1.4	A	4
	-2	50-100		3.9		28.3	0.31	1.1		
R278	-1	0-50	Sh	3.9	III	32.1	1.10	3.4	B	3
	-2	50-100		6.5		31.8	2.48	7.8		
R279	-1	0-50	Mw	3.5	III	35.8	0.35	1.0	A	3
	-2	50-100		6.0		29.3	0.34	1.2		
R280	-1	0-50	Sr	1.5	II	36.4	0.55	1.5	A	4
	-2	50-100		2.9		39.7	0.54	1.4		
R281	-1	0-50	Sr	1.6	I	30.7	0.45	1.5	A	3
	-2	50-100		2.3		31.2	0.99	3.2		
R282	-1	0-50	Gl	2.6	II	34.0	0.40	1.2	A	3
	-2	50-100		3.2		35.0	0.68	1.9		
R283	-1	0-50	Gl	2.2	II	37.8	0.26	0.7	A	3
	-2	50-100		3.7		37.3	0.93	2.5		
R284	-1	0-50	Sh	2.5	II	23.9	0.24	1.0	A	4
	-2	50-100		1.3		23.3	0.19	0.8		
R285	-1	0-50	Gl	3.6	III	34.9	1.09	3.1	C	3
	-2	50-100		5.3		30.3	3.09	10.2		
R286	-1	0-50	Sh	1.8	I	25.0	0.15	0.6	A	3
	-2	50-100		1.9		29.7	0.44	1.5		
R287	-1	0-50	Sr	2.6	II	36.5	0.28	0.8	A	3
	-2	50-100		3.4		35.6	0.39	1.1		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R288	-1	0-50	Gl	1.4	I	35.3	0.27	0.8	A	3
	-2	50-100		1.2		37.1	0.26	0.7		
R289	-1	0-50	Gl	2.8	II	30.7	0.44	1.4	A	3
	-2	50-100		3.3		30.2	0.85	2.8		
R290	-1	0-50	Gl	1.3	II	35.4	0.19	0.5	A	3
	-2	50-100		2.6		36.3	0.10	0.3		
R291	-1	0-50	Gl	1.1	I	35.3	0.45	1.3	A	3
	-2	50-100		2.4		35.5	0.90	2.8		
R292	-1	0-50	Sh	2.6	II	24.5	0.07	0.3	A	2
	-2	50-100		3.8		27.7	0.06	0.2		
R293	-1	0-50	Gl	2.2	II	29.9	0.33	1.1	A	2
	-2	50-100		2.9		34.7	0.54	1.6		
R294	-1	0-50	Mw	2.8	II	35.5	0.88	2.5	A	4
	-2	50-100		-		-	-	-		
R295	-1	0-50	Mc	1.0	I	31.5	0.16	0.5	A	3
	-2	50-100		1.6		19.5	0.13	0.7		
R296	-1	0-50	Mc	2.5	II	34.3	0.29	0.9	A	3
	-2	50-100		2.7		30.5	0.59	1.9		
R297	-1	0-50	Qr	1.2	I	31.7	0.40	1.3	A	3
	-2	50-100		2.4		34.2	0.60	1.8		
R298	-1	0-50	Qr	2.2	II	34.5	0.18	0.5	A	3
	-2	50-100		3.1		32.3	0.19	0.6		
R299	-1	0-50	Qr	1.4	I	33.6	0.37	1.1	A	4
	-2	50-100		2.3		34.8	0.59	1.7		
R300	-1	0-50	Sr	0.9	I	28.9	0.26	0.9	A	3
	-2	50-100		2.2		32.3	0.15	0.5		
R301	-1	0-50	Gw	1.1	I	25.0	0.21	0.8	A	4
	-2	50-100		1.6		30.5	0.39	1.3		
R302	-1	0-50	Sr	1.1	I	32.2	0.43	1.3	A	2
	-2	50-100		1.2		34.1	0.25	0.7		
R303	-1	0-50	Sr	2.3	I	38.3	0.40	1.0	A	3
	-2	50-100		1.1		34.4	0.47	1.4		
R304	-1	0-50	Sr	1.2	I	33.0	0.26	0.8	A	3
	-2	50-100		1.2		32.7	0.56	1.7		
R305	-1	0-50	Sr	2.5	II	35.7	0.21	0.6	A	1
	-2	50-100		2.4		37.5	0.38	1.0		
R306	-1	0-50	Sr	1.9	II	32.0	0.21	0.7	A	2
	-2	50-100		2.5		34.2	0.39	1.1		
R307	-1	0-50	Db	1.3	I	30.3	0.34	1.1	A	1
	-2	50-100		2.3		29.9	0.72	2.4		
R308	-1	0-50	Sr	1.6	I	31.2	0.31	1.0	A	4
	-2	50-100		2.4		34.0	0.33	1.0		
R309	-1	0-50	Sr	2.1	II	34.1	0.43	1.3	A	3
	-2	50-100		2.5		34.7	0.37	1.1		
R310	-1	0-50	Mc	1.3	I	22.5	0.24	1.1	A	3
	-2	50-100		1.1		16.6	0.09	0.5		
R311	-1	0-50	Qr	2.2	II	25.5	0.22	0.9	A	4
	-2	50-100		2.5		29.1	0.37	1.3		
R312	-1	0-50	Qr	1.1	II	33.4	0.53	1.6	A	4
	-2	50-100		2.5		32.6	0.54	1.7		
R313	-1	0-50	Qr	1.4	I	27.9	0.40	1.4	A	4
	-2	50-100		2.2		28.6	0.39	1.4		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na+	ESP	Class	
R314	-1	0-50	Qr	2.6	II	32.6	0.24	0.7	B	4
	-2	50-100		3.4		34.8	2.64	7.6		
R315	-1	0-50	Qr	2.8	II	26.5	0.22	0.8	A	4
	-2	50-100		2.6		31.6	0.10	0.3		
R316	-1	0-50	Gw	1.9	II	28.5	0.12	0.4	A	3
	-2	50-100		3.5		28.4	0.18	0.6		
R317	-1	0-50	Gw	2.0	I	32.3	0.17	0.5	A	3
	-2	50-100		1.6		34.1	0.27	0.8		
R318	-1	0-50	Gl	1.8	I	31.2	0.39	1.3	A	3
	-2	50-100		2.4		34.5	0.52	1.5		
R319	-1	0-50	Qr	1.2	I	39.1	0.60	1.5	A	4
	-2	50-100		0.9		35.8	0.29	0.8		
R320	-1	0-50	Qr	0.5	I	34.2	0.29	0.9	A	1
	-2	50-100		0.9		34.5	0.39	1.1		
R321	-1	0-50	Mc	1.6	III	25.0	0.19	0.8	A	1
	-2	50-100		5.5		22.9	0.23	1.0		
R322	-1	0-50	Mc	1.7	II	33.5	0.50	1.5	A	1
	-2	50-100		3.3		29.9	0.66	2.2		
R323	-1	0-50	Mc	2.6	II	36.2	0.24	0.7	A	2
	-2	50-100		2.8		32.2	0.17	0.5		
R324	-1	0-50	Bm	3.1	III	27.8	0.11	0.4	A	1
	-2	50-100		7.0		28.3	0.14	0.5		
R325	-1	0-50	Qr	0.7	I	34.2	0.23	0.7	A	1
	-2	50-100		1.4		36.2	0.54	1.5		
R326	-1	0-50	Qr	1.2	II	36.6	0.16	0.4	A	3
	-2	50-100		2.8		36.4	0.19	0.5		
R327	-1	0-50	Qr	2.7	II	39.0	0.08	0.2	A	1
	-2	50-100		3.0		31.3	0.03	0.1		
R328	-1	0-50	Bm	1.6	II	27.4	0.34	1.2	A	1
	-2	50-100		3.1		28.1	0.18	0.6		
R329	-1	0-50	Mc	1.7	I	36.2	0.44	1.2	A	3
	-2	50-100		1.5		50.2	0.39	0.8		
R330	-1	0-50	Qr	1.1	I	32.1	0.16	0.5	A	1
	-2	50-100		1.0		32.1	0.43	1.3		
R331	-1	0-50	Mc	2.0	II	29.4	0.19	0.7	A	2
	-2	50-100		3.7		31.2	1.28	4.1		
R332	-1	0-50	Mc	1.0	I	33.6	0.18	0.5	A	1
	-2	50-100		2.2		27.5	0.58	2.1		
R333	-1	0-50	Qr	1.0	I	37.5	0.35	0.9	A	1
	-2	50-100		0.8		34.2	0.39	1.1		
R334	-1	0-50	Mc	1.3	II	34.8	0.16	0.5	A	1
	-2	50-100		3.2		29.1	0.17	0.6		
R335	-1	0-50	Mc	1.1	I	38.1	0.27	0.7	A	3
	-2	50-100		1.2		31.4	0.30	1.0		
R336	-1	0-50	Mc	7.5	IV	28.5	1.03	3.6	A	4
	-2	50-100		4.4		23.4	0.28	1.2		
R337	-1	0-50	Mc	2.1	I	33.0	0.24	0.7	A	3
	-2	50-100		2.4		28.3	0.27	1.0		
R338	-1	0-50	Qr	4.3	II	34.5	0.65	1.9	A	4
	-2	50-100		2.8		33.5	0.25	0.8		
R339	-1	0-50	Mc	1.9	I	35.8	0.16	0.5	A	3
	-2	50-100		1.0		23.3	0.18	0.8		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R340	-1	0-50	Qr	3.6	II	30.8	0.38	1.2	A	3
	-2	50-100		2.2		31.7	0.38	1.2		
R341	-1	0-50	Bm	1.1	II	20.4	0.16	0.8	A	3
	-2	50-100		2.6		28.8	0.18	0.6		
R342	-1	0-50	Bm	1.3	I	33.5	0.13	0.4	A	2
	-2	50-100		2.0		26.5	0.12	0.5		
R343	-1	0-50	Sh	2.2	II	27.2	0.06	0.2	A	1
	-2	50-100		3.0		29.4	0.03	0.1		
R344	-1	0-50	Mc	0.9	I	37.7	0.27	0.7	A	1
	-2	50-100		0.8		28.9	0.30	1.0		
R345	-1	0-50	Qr	0.6	I	30.6	0.18	0.6	A	1
	-2	50-100		0.6		29.0	0.14	0.5		
R346	-1	0-50	Qr	1.6	I	35.0	0.05	0.1	A	4
	-2	50-100		1.0		35.5	0.28	0.8		
R347	-1	0-50	Qr	0.9	II	34.6	0.22	0.6	A	4
	-2	50-100		2.6		37.0	0.09	0.2		
R348	-1	0-50	Mc	1.4	I	23.2	0.08	0.3	A	4
	-2	50-100		0.9		19.5	0.12	0.6		
R349	-1	0-50	Mc	2.0	I	33.2	0.40	1.2	A	4
	-2	50-100		2.4		31.7	0.38	1.2		
R350	-1	0-50	Gl	2.9	II	29.5	0.12	0.4	B	3
	-2	50-100		4.3		33.0	1.68	5.1		
R351	-1	0-50	Gl	0.9	II	29.3	0.14	0.5	A	3
	-2	50-100		2.8		32.7	0.18	0.6		
R352	-1	0-50	Gl	2.1	III	25.3	0.15	0.6	A	3
	-2	50-100		5.0		29.6	0.60	2.0		
R353	-1	0-50	Gl	1.4	II	26.4	0.19	0.7	A	3
	-2	50-100		2.8		32.8	0.17	0.5		
R354	-1	0-50	Gl	2.5	II	36.2	0.08	0.2	A	3
	-2	50-100		2.9		35.6	0.12	0.3		
R355	-1	0-50	Fx	3.6	II	24.3	0.09	0.4	A	3
	-2	50-100		2.6		23.6	0.03	0.1		
R356	-1	0-50	Fx	2.7	II	22.8	0.17	0.8	A	3
	-2	50-100		3.5		23.8	0.15	0.6		
R357	-1	0-50	Qr	2.4	III	31.6	0.93	2.9	C	3
	-2	50-100		5.2		16.8	2.38	14.2		
R358	-1	0-50	Sh	3.7	II	25.5	0.18	0.7	A	1
	-2	50-100		4.5		23.5	0.25	1.1		
R359	-1	0-50	Sr	3.4	II	34.8	0.20	0.6	A	3
	-2	50-100		2.8		36.3	0.19	0.5		
R360	-1	0-50	Sr	1.9	II	30.4	0.09	0.30	A	3
	-2	50-100		2.7		29.9	0.05	0.2		
R361	-1	0-50	Qr	0.8	I	31.3	0.33	1.1	A	4
	-2	50-100		0.8		31.6	0.59	1.9		
R362	-1	0-50	Bm	3.9	II	14.7	0.12	0.8	A	1
	-2	50-100		4.1		9.7	0.15	1.5		
R363	-1	0-50	Mc	2.4	II	22.9	0.09	0.4	A	2
	-2	50-100		2.7		20.9	0.08	0.4		
R364	-1	0-50	Bm	2.4	II	28.6	0.26	0.9	A	3
	-2	50-100		2.9		16.5	0.16	1.0		
R365	-1	0-50	Gl	3.3	II	16.6	0.22	1.3	A	4
	-2	50-100		2.7		33.0	0.33	1.0		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R366	-1	0-50	Bm	3.4	III	24.2	0.37	1.5	A	3
	-2	50-100		5.8		30.9	0.85	2.8		
R367	-1	0-50	Qr	0.9	I	33.2	0.32	1.0	A	3
	-2	50-100		1.3		36.0	0.56	1.6		
R368	-1	0-50	Mc	1.2	I	28.6	0.20	0.7	A	3
	-2	50-100		1.3		29.2	0.24	0.8		
R369	-1	0-50	Mw	2.2	II	34.8	0.09	0.3	A	3
	-2	50-100		3.0		36.5	0.22	0.6		
R370	-1	0-50	Qr	0.8	I	36.3	0.47	1.3	A	3
	-2	50-100		1.1		36.3	0.71	2.0		
R371	-1	0-50	Mc	3.0	II	29.9	0.53	1.8	A	3
	-2	50-100		3.1		28.3	0.51	1.8		
R372	-1	0-50	Qr	2.9	II	30.2	0.43	1.4	A	3
	-2	50-100		2.1		34.6	1.13	3.3		
R373	-1	0-50	Mc	4.0	II	27.2	1.06	3.9	A	2
	-2	50-100		2.3		15.5	0.75	4.8		
R374	-1	0-50	Bm	1.8	II	22.8	0.29	1.3	A	1
	-2	50-100		2.9		23.5	0.56	2.4		
R375	-1	0-50	Qr	1.2	II	34.9	0.23	0.7	A	3
	-2	50-100		2.7		37.2	0.29	0.8		
R376	-1	0-50	Sr	3.5	II	39.2	0.64	1.6	A	3
	-2	50-100		4.4		33.8	0.42	1.2		
R377	-1	0-50	Fx	4.1	II	25.6	0.30	1.2	A	3
	-2	50-100		2.5		24.2	0.09	0.4		
R378	-1	0-50	Mw	1.1	I	39.2	0.24	0.6	A	3
	-2	50-100		1.3		33.5	0.29	0.9		
R379	-1	0-50	Qr	0.8	II	35.6	0.39	1.1	A	3
	-2	50-100		2.7		38.8	0.62	1.6		
R380	-1	0-50	Qr	2.0	I	35.1	0.25	0.7	A	3
	-2	50-100		1.3		36.5	0.31	0.8		
R381	-1	0-50	Qr	1.3	I	33.5	0.36	1.1	A	3
	-2	50-100		1.9		37.4	0.51	1.4		
R382	-1	0-50	Fx	3.4	II	21.5	0.38	1.8	A	3
	-2	50-100		3.2		23.7	0.48	2.0		
R383	-1	0-50	Qr	1.3	I	32.6	0.34	1.0	A	3
	-2	50-100		1.3		34.4	0.43	1.5		
R384	-1	0-50	Qr	1.1	I	33.4	0.44	1.3	A	3
	-2	50-100		1.6		34.6	0.48	1.4		
R385	-1	0-50	Mw	1.1	I	30.6	0.31	1.0	A	2
	-2	50-100		1.0		33.1	0.33	1.0		
R386	-1	0-50	Mc	1.2	I	30.2	0.21	0.7	A	3
	-2	50-100		1.1		30.3	0.15	0.5		
R387	-1	0-50	Qr	1.5	I	33.7	0.30	0.9	A	3
	-2	50-100		1.9		35.7	0.24	0.7		
R388	-1	0-50	Qr	1.1	I	31.8	0.30	0.9	A	3
	-2	50-100		1.9		36.6	0.47	1.3		
R389	-1	0-50	Fx	4.4	II	19.7	0.23	1.2	A	3
	-2	50-100		1.9		12.6	0.11	0.9		
R390	-1	0-50	Fx	4.2	II	19.0	0.28	1.5	A	2
	-2	50-100		4.5		21.3	0.55	2.6		
R391	-1	0-50	Bm	0.9	I	23.8	0.13	0.5	A	3
	-2	50-100		1.1		23.6	0.32	1.4		
R392	-1	0-50	Mw	1.4	II	33.5	0.27	0.8	A	4
	-2	50-100		2.6		38.8	0.28	0.7		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R393	-1	0-50	Mw	0.9	II	32.9	0.18	0.5	A	2
	-2	50-100		2.6		38.4	0.15	0.4		
R394	-1	0-50	Sr	2.3	II	31.8	0.16	0.5	A	3
	-2	50-100		3.8		35.9	1.10	3.1		
R395	-1	0-50	Qr	0.9	I	32.9	0.36	1.1	A	3
	-2	50-100		1.8		33.9	0.32	0.9		
R396	-1	0-50	Qr	0.7	I	32.1	0.18	0.6	A	3
	-2	50-100		1.7		35.7	0.35	1.0		
R397	-1	0-50	Qr	1.0	I	31.9	0.19	0.6	A	3
	-2	50-100		1.0		34.1	0.29	0.9		
R398	-1	0-50	Qr	1.0	I	34.5	0.36	1.0	A	3
	-2	50-100		1.2		37.2	0.27	0.7		
R399	-1	0-50	Sr	4.4	III	35.6	0.87	2.4	A	3
	-2	50-100		6.5		36.2	0.63	1.7		
R400	-1	0-50	Sr	2.5	II	27.7	0.10	0.4	A	2
	-2	50-100		2.7		37.2	0.17	0.5		
R401	-1	0-50	Mw	2.1	II	37.1	0.18	0.5	A	3
	-2	50-100		2.5		37.9	0.36	0.9		
R402	-1	0-50	Qr	1.5	III	33.3	0.35	1.1	A	3
	-2	50-100		6.8		35.5	1.65	4.6		
R403	-1	0-50	Qr	1.2	I	33.4	0.24	0.7	A	4
	-2	50-100		1.0		33.7	0.31	0.9		
R404	-1	0-50	Qr	1.6	I	34.8	0.28	0.8	A	4
	-2	50-100		1.2		38.4	0.52	1.4		
R405	-1	0-50	Mc	1.5	I	24.3	0.25	1.0	A	4
	-2	50-100		0.9		30.2	0.30	1.0		
	-3S	100-150		2.7		-	-	-		
	-4S	150-250		3.8		-	-	-		
	-5S	250-350		3.5		-	-	-		
R406	-1	0-50	Qr	3.5	II	31.3	0.75	2.4	A	4
	-2	50-100		4.7		39.0	0.84	2.2		
	-3S	100-150		4.4		-	-	-		
	-4S	150-250		3.8		-	-	-		
	-5S	250-350		3.5		-	-	-		
R407	-1	0-50	Mc	5.5	III	25.3	0.66	2.6	A	4
	-2	50-100		3.2		37.2	0.63	1.7		
R408	-1	0-50	Sr	1.1	II	31.3	0.35	1.1	A	3
	-2	50-100		2.8		37.1	0.32	0.9		
	-3S	100-150		3.9		-	-	-		
	-4S	150-250		4.0		-	-	-		
	-5S	250-350		4.8		-	-	-		
R409	-1	0-50	Qr	1.3	I	33.8	0.25	0.7	A	3
	-2	50-100		1.2		38.1	0.35	0.9		
	-3S	100-150		3.4		-	-	-		
	-4S	150-250		3.2		-	-	-		
	-5S	250-350		2.4		-	-	-		
R410	-1	0-50	Qr	1.2	II	35.1	0.34	1.0	A	3
	-2	50 100		3.9		36.7	0.50	1.4		
R411	-1	0-50	Qr	1.4	II	38.5	0.53	1.4	A	4
	-2	50-100		2.8		44.5	0.58	1.3		
	-3S	100-150		3.7		-	-	-		
	-4S	150-250		4.5		-	-	-		
	-5S	250-350		6.2		-	-	-		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R412	-1	0-50	Gl	1.5	II	35.0	0.50	1.4	A	3
	-2	50-100		3.6		40.3	0.53	1.3		
R413	-1	0-50	Qr	1.0	I	36.2	0.44	1.22	A	1
	-2	50-100		1.3		45.3	0.78	1.7		
	-3S	100-150		3.4		-	-	-		
	-4S	150-250		3.9		-	-	-		
	-5S	250-350		4.9		-	-	-		
R414	-1	0-50	Qr	1.8	I	37.3	0.48	1.3	A	3
	-2	50-100		2.2		34.8	0.42	1.2		
	-3S	100-150		2.4		-	-	-		
	-4S	150-250		2.6		-	-	-		
	-5S	250-350		2.0		-	-	-		
R415	-1	0-50	Sr	2.5	II	32.5	0.24	0.7	A	2
	-2	50-100		2.4		31.4	0.30	1.0		
	-3S	100-150		2.9		-	-	-		
R416	-1(a)	0-50	Sr	1.7	II	33.8	0.26	0.8	A	2
	-2(a)	50-100		3.0		30.0	0.16	0.5		
	-3(a)	100-150		3.0		-	-	-		
R417	-1	0-50	Sr	1.8	I	34.5	0.38	1.1	A	3
	-2	50-100		2.0		29.0	0.22	0.8		
R418	-1	0-50	Qr	4.7	II	28.9	0.65	2.3	A	4
	-2	50-100		3.0		30.7	0.32	1.0		
R419	-1	0-50	Qr	2.0	II	30.5	0.32	1.0	A	2
	-2	50-100		3.3		32.8	0.13	0.4		
R420	-1	0-50	Qr	3.5	II	35.8	0.38	1.1	A	2
	-2	50-100		0.8		33.4	0.20	0.6		
R421	-1	0-50	Qr	3.0	II	34.5	0.24	0.7	A	3
	-2	50-100		2.0		31.7	0.33	1.0		
R422	-1	0-50	Qr	1.2	III	33.4	0.34	1.0	A	2
	-2	50-100		5.7		33.6	1.26	3.8		
R423	-1	0-50	Gl	2.6	II	30.9	0.30	1.0	A	3
	-2	50-100		4.5		34.5	0.40	1.2		
R424	-1	0-50	Gl	9.1	IV	27.5	1.88	6.8	B	2
	-2	50-100		7.3		31.0	0.63	2.0		
R425	-1	0-50	Mt	3.7	II	29.3	0.40	1.4	A	3
	-2	50-100		4.9		22.5	0.28	1.2		
R426	-1	0-50	Gw	1.0	I	11.5	0.07	0.6	A	4
	-2	50-100		0.7		2.8	0.06	2.1		
R427	-1	0-50	Qr	1.1	II	33.1	0.31	0.9	A	2
	-2	50-100		2.7		36.3	0.28	0.8		
R428	-1	0-50	Gw	1.5	I	32.8	0.29	0.9	A	4
	-2	50-100		1.4		10.8	0.12	1.1		
R429	-1	0-50	Mc	1.0	I	25.5	0.16	0.6	A	4
	-2	50-100		1.7		20.0	0.16	0.8		
R430	-1	0-50	Sr	2.5	II	31.9	0.16	0.5	A	2
	-2	50-100		3.1		35.8	0.11	0.3		
R431	-1	0-50	Qr	1.3	I	33.5	0.26	0.8	A	2
	-2	50-100		1.4		36.5	0.66	1.8		
R432	-1	0-50	Gw	3.3	II	18.0	0.25	1.4	A	2
	-2	50-100		1.4		33.8	0.50	1.5		
R433	-1	0-50	Mc	2.9	II	19.5	0.58	3.0	A	3
	-2	50-100		3.0		29.5	0.32	1.1		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R434	-1	0-50	Qr	3.7	II	34.8	0.38	1.1	A	3
	-2	50-100		3.8		34.3	0.70	2.0		
R435	-1	0-50	Qr	2.2	I	32.3	0.28	0.9	A	2
	-2	50-100		2.2		37.9	0.19	0.5		
R436	-1	0-50	Gw	1.5	I	24.5	0.16	0.7	A	3
	-2	50-100		1.5		19.5	0.14	0.7		
R437	-1	0-50	Sr	1.7	II	29.5	0.25	0.9	A	3
	-2	50-100		4.2		36.5	0.15	0.4		
R438	-1	0-50	Qr	1.8	II	32.3	0.34	1.1	A	4
	-2	50-100		3.3		33.6	0.31	0.9		
R439	-1	0-50	Gl	3.5	II	33.5	0.13	0.4	A	3
	-2	50-100		3.1		37.2	0.14	0.4		
R440	-1	0-50	Gl	2.0	II	32.2	0.30	0.9	A	3
	-2	50-100		3.2		36.2	0.16	0.4		
R441	-1	0-50	Gl	2.6	II	38.2	0.44	1.2	A	4
	-2	50-100		2.9		29.7	0.43	1.5		
R442	-1	0-50	Qr	1.2	I	37.2	0.32	0.9	A	2
	-2	50-100		1.0		38.7	0.31	0.8		
R443	-1	0-50	Gw	1.1	I	30.1	0.26	0.9	A	3
	-2	50-100		1.3		18.1	0.24	1.3		
R444	-1	0-50	Qr	1.4	I	36.4	0.36	1.0	A	4
	-2	50-100		2.1		40.2	0.44	1.1		
R445	-1	0-50	Gw	0.9	I	30.1	0.20	0.7	A	3
	-2	50-100		1.2		23.0	0.21	0.9		
R446	-1	0-50	Gw	0.9	I	30.7	0.18	0.6	A	4
	-2	50-100		0.8		21.7	0.16	0.7		
R447	-1	0-50	Qr	1.6	I	33.7	0.95	2.8	A	2
	-2	50-100		2.1		32.7	0.63	1.9		
R448	-1	0-50	Qr	3.2	II	36.5	0.25	0.7	A	3
	-2	50-100		2.6		36.5	0.17	0.5		
R449	-1	0-50	Qr	1.5	II	30.5	0.34	1.1	A	2
	-2	50-100		2.8		30.2	0.56	1.9		
R450	-1	0-50	Sr	1.3	I	27.7	0.20	0.7	A	3
	-2	50-100		2.8		28.0	0.37	1.3		
R451	-1	0-50	Sr	2.7	II	36.3	0.16	0.4	A	1
	-2	50-100		2.7		21.5	0.05	0.2		
R452	-1	0-50	Sh	3.6	III	28.6	0.27	0.9	A	2
	-2	50-100		5.9		35.2	0.44	1.3		
R453	-1	0-50	Sr	1.5	II	36.7	0.26	0.6	A	3
	-2	50-100		2.9		41.2	0.40	1.0		
R454	-1	0-50	Gl	1.2	II	29.2	0.23	0.8	A	2
	-2	50-100		3.0		34.7	0.08	0.2		
R455	-1	0-50	Sr	2.8	II	40.0	0.17	0.43	A	1
	-2	50-100		3.7		38.7	0.22	0.6		
R456	-1	0-50	Qr	3.8	III	32.7	0.46	1.4	A	3
	-2	50-100		6.0		30.2	0.56	1.9		
R457	-1	0-50	Qr	1.9	II	34.2	0.45	1.3	A	3
	-2	50-100		3.2		40.0	0.53	1.3		
R458	-1	0-50	Qr	1.6	II	35.8	0.23	0.6	A	3
	-2	50-100		3.2		43.6	0.19	0.4		
R459	-1	0-50	Sr	2.8	II	17.0	0.11	0.7	A	2
	-2	50-100		-		-	-	-		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R460	-1	0-50	Sr	2.9	II	28.7	0.13	0.5	A	1
	-2	50-100		3.1		36.2	0.23	0.6		
R461	-1	0-50	Gl	3.0	II	34.0	0.25	0.7	A	2
	-2	50-100		4.7		35.5	0.55	1.6		
R462	-1	0-50	Gl	1.5	II	32.7	0.41	1.3	A	1
	-2	50-100		2.5		34.7	0.86	2.5		
R463	-1	0-50	Sr	2.7	II	37.5	0.34	0.9	A	2
	-2	50-100		3.1		36.7	0.46	1.3		
R464	-1	0-50	Sr	2.7	II	30.7	0.16	0.5	A	3
	-2	50-100		3.0		37.5	0.14	0.4		
R465	-1	0-50	Gl	1.3	II	33.8	0.44	1.3	A	3
	-2	50-100		3.7		37.0	0.53	1.4		
R466	-1	0-50	Qr	4.3	III	32.0	0.55	1.7	B	3
	-2	50-100		7.3		34.4	1.8	5.4		
R467	-1	0-50	Gw	1.2	II	29.0	0.26	0.9	A	3
	-2	50-100		2.7		32.5	0.46	1.4		
R468	-1	0-50	Gw	3.2	II	26.3	0.32	1.2	A	2
	-2	50-100		3.3		33.5	0.36	1.1		
R469	-1	0-50	Gl	2.9	II	35.8	0.30	0.8	A	2
	-2	50-100		4.0		35.4	0.36	1.0		
R470	-1	0-50	Gw	1.1	I	31.5	0.14	0.4	A	4
	-2	50-100		0.9		29.8	0.16	0.5		
R471	-1	0-50	Qr	3.6	II	30.0	0.36	1.2	A	4
	-2	50-100		2.8		31.5	0.43	1.4		
R472	-1	0-50	Qr	3.6	II	34.6	0.50	1.5	A	4
	-2	50-100		3.5		32.8	0.13	0.4		
R473	-1	0-50	Ar	1.7	II	34.0	0.69	2.0	A	3
	-2	50-100		3.1		33.3	0.32	1.0		
R474	-1	0-50	Sr	1.3	II	32.5	0.27	0.8	A	3
	-2	50-100		3.1		35.5	0.27	0.8		
R475	-1	0-50	Sr	2.9	II	16.9	0.07	0.4	A	3
	-2	50-100		3.4		13.8	0.23	1.7		
R476	-1	0-50	Sr	6.4	III	35.8	2.50	7.0	B	3
	-2	50-100		4.1		29.5	0.15	0.5		
R477	-1	0-50	Sr	2.9	II	32.4	0.14	0.4	A	3
	-2	50-100		3.2		35.0	0.34	1.0		
R478	-1	0-50	Mt	1.7	I	22.4	0.13	0.6	A	4
	-2	50-100		5.5		15.8	0.28	1.8		
R480	-1	0-50	Sr	1.4	I	34.7	0.35	1.0	A	2
	-2	50-100		3.1		38.5	0.41	1.1		
R481	-1	0-50	Mt	8.4	V	31.0	1.30	4.2	B	1
	-2	50-100		10.1		32.4	2.50	7.7		
R482	-1	0-50	Gl	5.3	III	36.0	1.99	5.5	B	1
	-2	50-100		3.1		37.0	0.19	0.5		
R483	-1	0-50	Sr	2.3	II	34.1	0.16	0.5	A	2
	-2	50-100		3.5		34.4	0.34	1.0		
R484	-1	0-50	Sh	1.3	II	29.5	0.16	0.5	A	3
	-2	50-100		2.6		27.9	0.46	1.7		
R485	-1	0-50	Sr	1.5	I	30.3	0.28	0.9	A	1
	-2	50-100		2.1		32.3	0.45	1.4		
R486	-1	0-50	Sr	0.8	II	34.9	0.29	0.8	A	3
	-2	50-100		3.1		38.3	0.35	0.9		

Note: No R479

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R487	-1	0-50	Sr	1.0	II	32.3	0.23	0.7	A	3
	-2	50-100		2.5		35.9	0.44	1.2		
R488	-1	0-50	Sr	1.2	I	38.6	0.11	0.3	A	3
	-2	50-100		2.0		34.5	0.57	1.7		
R489	-1	0-50	Sr	1.4	I	32.3	0.30	0.9	A	3
	-2	50-100		2.2		38.0	0.42	1.1		
R490	-1	0-50	Gl	0.8	II	31.3	0.26	0.8	A	3
	-2	50-100		3.0		33.6	0.30	0.9		
R491	-1	0-50	Gl	1.8	II	36.4	0.39	1.1	A	1
	-2	50-100		3.3		38.1	0.34	0.9		
R492	-1	0-50	Sr	1.7	II	40.9	0.44	1.1	A	3
	-2	50-100		3.8		41.4	0.93	2.3		
R493	-1	0-50	Mt	5.0	III	27.8	0.60	2.2	A	3
	-2	50-100		6.7		26.5	0.90	3.4		
R494	-1	0-50	Mt	3.1	III	29.8	0.43	1.4	A	3
	-2	50-100		5.4		30.0	0.73	2.4		
R495	-1	0-50	Sr	1.6	II	33.0	0.54	1.6	A	3
	-2	50-100		3.1		33.4	0.69	2.1		
R496	-1	0-50	Sr	1.5	II	33.2	0.32	1.0	A	2
	-2	50-100		3.3		35.2	0.35	1.0		
R497	-1	0-50	Sr	2.8	II	33.4	0.16	0.5	A	3
	-2	50-100		4.3		28.2	0.66	2.3		
R498	-1	0-50	Sr	1.3	I	25.7	0.11	0.4	A	3
	-2	50-100		1.2		28.8	0.20	0.7		
R499	-1	0-50	Sr	1.7	II	36.2	0.36	1.0	A	3
	-2	50-100		3.3		39.3	0.34	0.9		
R500	-1	0-50	Sr	1.0	II	28.7	0.24	0.8	A	3
	-2	50-100		2.6		30.0	0.32	1.1		
R501	-1	0-50	Sr	3.2	II	27.4	0.16	0.6	A	3
	-2	50-100		3.8		25.3	0.60	2.4		
R502	-1	0-50	Gl	1.6	II	32.4	0.65	2.0	C	1
	-2	50-100		4.3		34.3	3.63	10.6		
R503	-1	0-50	Gl	1.1	I	35.4	0.24	0.7	A	3
	-2	50-100		1.6		33.8	0.57	1.7		
R504	-1	0-50	Gl	1.4	I	31.3	0.43	1.4	A	3
	-2	50-100		2.2		32.7	0.73	2.2		
R505	-1	0-50	Gl	0.9	II	36.7	0.77	2.1	B	3
	-2	50-100		2.8		36.0	2.60	7.2		
R506	-1	0-50	Gl	1.5	II	30.5	0.20	0.7	A	1
	-2	50-100		3.1		35.2	0.26	0.7		
R507	-1	0-50	Sr	2.9	II	34.0	0.20	0.6	A	3
	-2	50-100		3.9		35.5	0.40	1.1		
R508	-1	0-50	Gl	1.6	II	33.5	1.21	3.6	B	1
	-2	50-100		3.7		39.5	3.26	8.3		
R509	-1	0-50	Qr	1.3	I	37.2	0.22	0.6	A	3
	-2	50-100		1.3		36.6	0.42	1.5		
R510	-1	0-50	Qr	1.2	I	35.1	0.48	1.4	A	2
	-2	50-100		1.2		32.7	0.35	1.1		
R511	-1	0-50	Gw	2.7	II	35.4	0.22	0.6	A	3
	-2	50-100		2.3		32.0	0.52	1.6		
R512	-1	0-50	Qr	1.1	I	34.2	0.26	0.8	A	3
	-2	50-100		2.2		36.8	0.46	1.3		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R513	-1	0-50	Qr	1.1	I	33.3	0.20	0.6	A	3
	-2	50-100		1.2		34.0	0.30	0.9		
R514	-1	0-50	Qr	0.7	I	33.8	0.14	0.4	A	3
	-2	50-100		1.1		33.2	0.23	0.7		
R515	-1	0-50	Gw	1.0	I	17.0	0.05	0.3	A	2
	-2	50-100		2.1		21.9	0.15	0.7		
R516	-1	0-50	Qr	0.8	II	34.9	0.25	0.7	A	3
	-2	50-100		2.6		37.0	0.22	0.6		
R517	-1	0-50	Sr	1.0	I	33.1	0.23	0.7	A	3
	-2	50-100		1.8		35.7	0.32	0.9		
R518	-1	0-50	Sr	1.1	I	32.9	0.20	0.6	A	3
	-2	50-100		1.8		34.7	0.39	1.1		
R519	-1	0-50	Sr	0.9	II	28.2	0.15	0.5	A	3
	-2	50-100		3.2		29.1	0.16	0.6		
R520	-1	0-50	Sr	2.3	II	29.5	0.31	1.1	A	2
	-2	50-100		3.4		33.3	0.21	0.6		
R521	-1	0-50	Gw	1.9	II	30.0	0.19	0.6	A	3
	-2	50-100		3.3		20.9	0.29	1.4		
R522	-1	0-50	Qr	1.8	I	30.5	0.15	0.5	A	3
	-2	50-100		1.8		35.3	0.42	1.2		
R523	-1	0-50	Sr	1.2	I	27.7	0.14	0.5	A	2
	-2	50-100		1.9		29.2	0.75	2.6		
R524	-1	0-50	Sr	1.4	I	30.0	0.15	0.5	A	3
	-2	50-100		1.4		31.9	0.16	0.5		
R525	-1	0-50	Sr	1.3	I	17.5	0.04	0.2	A	2
	-2	50-100		1.1		19.8	0.07	0.4		
R526	-1	0-50	Qr	1.2	I	36.1	0.35	1.0	A	3
	-2	50-100		1.5		35.2	0.33	0.9		
R527	-1	0-50	Sr	1.4	I	33.0	0.46	1.4	A	3
	-2	50-100		1.3		33.1	0.34	1.0		
R528	-1	0-50	Sr	1.0	I	36.2	0.28	0.8	A	3
	-2	50-100		1.7		34.7	0.39	1.1		
R529	-1	0-50	Gl	2.1	I	33.7	0.39	1.2	A	3
	-2	50-100		1.7		34.1	0.45	1.3		
R530	-1	0-50	Sr	0.9	II	34.2	0.20	0.6	A	3
	-2	50-100		3.7		31.6	0.46	1.5		
R531	-1	0-50	Gl	1.0	I	31.1	0.20	0.6	A	2
	-2	50-100		1.3		31.0	0.38	1.2		
R532	-1	0-50	Mc	1.2	I	26.0	0.20	0.8	A	3
	-2	50-100		1.6		23.2	0.26	1.1		
R533	-1	0-50	Mc	1.1	I	23.2	0.14	0.6	A	3
	-2	50-100		1.2		23.7	0.29	1.2		
R534	-1	0-50	Gw	1.8	I	18.6	0.16	0.9	A	3
	-2	50-100		1.5		13.7	0.10	0.7		
R535	-1	0-50	Gl	1.5	I	27.2	0.32	1.2	A	2
	-2	50-100		0.9		35.0	0.49	1.4		
R536	-1	0-50	Qr	1.4	II	34.7	0.33	1.0	A	1
	-2	50-100		3.0		35.5	0.35	1.0		
R537	-1	0-50	Gw	1.1	II	25.5	0.14	0.6	A	3
	-2	50-100		2.7		24.2	0.06	0.3		
R538	-1	0-50	Gl	1.2	II	35.7	0.53	1.5	A	3
	-2	50-100		3.4		36.4	0.60	1.7		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R538	-1	0-50	Gl	1.2	II	35.7	0.53	1.5	A	3
	-2	50-100		3.4		36.4	0.60	1.7		
R539	-1	0-50	Gl	2.0	II	35.7	0.45	1.3	A	1
	-2	50-100		3.2		39.4	0.41	1.0		
R540	-1	0-50	Sr	2.6	II	34.2	0.16	0.4	A	3
	-2	50-100		2.9		38.9	0.35	0.9		
R541	-1	0-50	Sh	3.7	II	21.1	0.23	1.1	A	1
	-2	50-100		3.6		22.0	0.28	1.3		
R542	-1	0-50	Gl	1.1	II	33.0	0.34	1.0	A	3
	-2	50-100		3.0		31.7	0.34	1.1		
R543	-1	0-50	Gl	2.7	II	30.5	0.20	0.7	A	3
	-2	50-100		3.0		28.8	0.31	1.1		
R544	-1	0-50	Gw	0.9	II	27.7	0.37	1.3	A	3
	-2	50-100		3.9		32.6	0.38	1.2		
R545	-1	0-50	Qr	3.7	II	24.2	0.35	1.5	A	3
	-2	50-100		3.0		33.2	0.56	1.7		
R546	-1	0-50	Qr	1.3	I	32.7	0.34	1.0	A	3
	-2	50-100		1.4		34.7	0.49	1.4		
R547	-1	0-50	Gl	0.8	I	32.5	0.31	1.0	A	3
	-2	50-100		1.0		33.4	1.44	4.3		
R548	-1	0-50	Gl	1.0	I	32.7	0.29	0.9	A	2
	-2	50-100		1.6		32.8	0.50	1.5		
R549	-1	0-50	Gl	0.9	II	32.0	0.45	1.4	A	3
	-2	50-100		2.8		33.5	0.93	2.8		
R550	-1	0-50	Gl	1.2	II	30.7	0.25	0.8	A	3
	-2	50-100		3.1		33.0	0.36	1.1		
R551	-1	0-50	Gl	1.7	I	32.7	0.23	0.7	A	3
	-2	50-100		1.2		32.2	0.82	2.6		
R552	-1	0-50	Gl	1.7	I	30.0	0.15	0.5	A	3
	-2	50-100		1.7		32.1	0.19	0.6		
R553	-1	0-50	Mw	0.7	II	36.4	0.23	0.6	A	3
	-2	50-100		2.9		33.0	0.14	0.4		
R554	-1	0-50	Mw	1.3	I	31.7	0.27	0.9	A	3
	-2	50-100		1.2		33.2	0.30	0.9		
R555	-1	0-50	Qr	1.2	II	29.0	0.22	0.8	A	3
	-2	50-100		2.8		34.5	0.19	0.6		
R556	-1	0-50	Qr	2.0	I	32.0	0.28	0.9	A	3
	-2	50-100		2.1		34.4	0.33	1.0		
R557	-1	0-50	Gl	1.0	I	32.0	0.20	0.6	A	2
	-2	50-100		1.2		34.5	0.35	1.0		
R558	-1	0-50	Gw	0.9	I	33.4	0.15	0.5	A	3
	-2	50-100		1.2		33.5	0.46	1.4		
R559	-1	0-50	Qr	1.3	II	35.7	0.22	0.6	A	2
	-2	50-100		2.7		34.2	0.19	0.6		
R560	-1	0-50	Gw	2.4	II	25.9	0.05	0.2	A	4
	-2	50-100		2.9		34.6	0.14	0.4		
R561	-1	0-50	Mw	1.1	I	32.2	0.24	0.7	A	3
	-2	50-100		1.4		32.5	0.48	1.5		
R562	-1	0-50	Gw	1.6	II	14.4	0.12	0.8	A	3
	-2	50-100		2.7		26.1	0.41	1.6		
R563	-1	0-50	Gw	4.1	II	23.0	0.13	0.6	A	3
	-2	50-100		3.5		14.1	0.18	1.3		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R564	-1	0-50	Mw	1.1	II	33.1	0.27	0.8	A	2
	-2	50-100		2.8		39.9	0.40	1.0		
R565	-1	0-50	Sr	1.2	II	35.5	0.71	2.0	B	2
	-2	50-100		2.8		40.6	3.13	7.7		
R566	-1	0-50	Sr	1.1	IV	33.5	1.31	3.9	A	2
	-2	50-100		7.5		37.5	1.38	3.7		
R567	-1	0-50	Sr	3.4	II	39.3	0.34	0.9	B	2
	-2	50-100		4.1		41.5	3.32	8.0		
R568	-1	0-50	Sr	1.3	I	30.5	0.70	2.3	B	1
	-2	50-100		2.4		36.1	2.23	6.2		
R569	-1	0-50	Sr	0.9	I	34.2	0.14	0.4	A	1
	-2	50-100		0.9		37.4	0.62	1.7		
R570	-1	0-50	Gl	0.4	IV	32.1	1.4	4.3	B	1
	-2	50-100		7.6		39.6	3.3	8.3		
R571	-1	0-50	Sh	0.8	II	30.7	0.36	1.2	A	1
	-2	50-100		3.0		36.7	0.37	1.0		
R572	-1	0-50	Gl	0.9	II	34.2	1.24	3.6	C	1
	-2	50-100		3.7		38.9	4.41	11.3		
R573	-1	0-50	Sr	2.0	II	34.6	0.56	1.6	B	1
	-2	50-100		3.1		32.6	2.68	8.2		
R574	-1	0-50	Sr	3.4	II	45.5	0.39	0.9	A	2
	-2	50-100		4.1		41.5	0.60	1.5		
R575	-1	0-50	Sr	1.3	II	42.0	0.43	1.0	A	1
	-2	50-100		3.7		40.5	0.48	1.2		
R576	-1	0-50	Sr	2.4	I	40.7	0.98	2.4	A	2
	-2	50-100		2.4		36.0	0.36	1.0		
R577	-1	0-50	Sr	1.5	I	41.6	0.41	1.0	A	2
	-2	50-100		2.1		41.5	0.54	1.3		
R578	-1	0-50	Sr	1.8	I	37.2	0.74	2.0	A	3
	-2	50-100		1.6		36.7	0.42	1.1		
R579	-1	0-50	Sr	1.8	II	40.2	0.43	1.1	A	3
	-2	50-100		3.5		42.0	0.50	1.2		
R580	-1	0-50	Sr	2.9	II	37.2	0.17	0.5	A	3
	-2	50-100		3.6		34.9	0.35	1.0		
R581	-1	0-50	Sr	1.6	II	35.0	0.26	0.7	A	3
	-2	50-100		3.0		40.0	0.46	1.2		
R582	-1	0-50	Sr	1.5	I	39.5	0.31	0.8	A	2
	-2	50-100		1.3		39.7	0.84	2.1		
R583	-1	0-50	Sr	1.0	II	30.6	0.15	0.5	A	3
	-2	50-100		2.6		28.3	0.20	0.7		
R584	-1	0-50	Sr	1.7	III	37.0	1.30	3.5	C	1
	-2	50-100		5.0		42.4	4.25	10.0		
R585	-1	0-50	Sr	2.4	IV	30.6	0.96	3.1	B	2
	-2	50-100		8.1		42.7	2.63	6.2		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
M101	-1	0-50	Gl	4.0	II	28.6	0.48	1.7	A	3
	-2	50-100		4.4		31.8	0.14	0.4		
M102	-1	0-50	Qr	2.6	II	30.8	0.50	1.6	A	3
	-2	50-100		3.1		38.4	0.43	1.1		
M103	-1	0-50	Qr	2.8	II	35.0	0.38	1.1	A	3
	-2	50-100		1.7		34.6	0.48	1.4		
M104	-1	0-50	Gw	4.0	II	28.2	0.40	1.4	A	3
	-2	50-100		4.9		33.1	0.55	1.7		
M105	-1	0-50	Gw	2.8	II	28.4	0.20	0.7	A	3
	-2	50-100		3.3		34.2	0.19	0.6		
M106	-1	0-50	Mw	2.8	II	27.0	0.25	0.9	A	3
	-2	50-100		3.8		36.3	0.57	1.6		
M107	-1	0-50	Sr	3.0	II	38.3	0.20	0.5	A	3
	-2	50-100		3.2		39.8	0.11	0.3		
M108	-1	0-50	Sr	1.6	I	34.4	0.21	0.6	A	3
	-2	50-100		2.1		39.6	0.27	0.7		
M109	-1	0-50	Sr	1.6	II	34.1	0.22	0.7	A	3
	-2	50-100		2.7		40.4	0.56	1.4		
M110	-1	0-50	Sr	0.9	I	35.7	0.31	0.9	A	2
	-2	50-100		2.4		40.5	0.57	1.4		
M111	-1	0-50	Sr	1.5	I	28.9	0.68	2.4	B	2
	-2	50-100		2.0		30.3	1.98	6.5		
M112	-1	0-50	Sr	1.2	II	35.0	0.68	1.9	C	2
	-2	50-100		3.6		36.3	4.25	11.7		
M113	-1	0-50	Sr	1.8	II	31.2	0.42	1.4	B	1
	-2	50-100		2.2		31.6	2.38	7.5		
M201	-1	0-50	Qr	1.5	I	29.6	0.36	1.2	A	2
	-2	50-100		1.2		32.2	0.57	1.8		
M202	-1	0-50	Qr	6.4	III	35.1	1.65	4.7	B	3
	-2	50-100		4.1		39.5	3.05	7.7		
M203	-1	0-50	Qr	1.2	I	35.6	0.35	1.0	A	3
	-2	50-100		2.0		38.9	0.69	1.8		
M204	-1	0-50	Qr	2.3	I	27.6	0.16	0.6	A	3
	-2	50-100		1.9		35.7	0.36	1.0		
M205	-1	0-50	Qr	2.6	II	33.4	0.58	1.7	A	3
	-2	50-100		3.2		34.2	0.34	1.0		
M206	-1	0-50	Qr	0.9	I	34.2	0.27	0.8	A	2
	-2	50-100		1.0		36.3	0.41	1.1		
M207	-1	0-50	Qr	1.3	I	32.1	0.34	1.1	A	3
	-2	50-100		2.1		38.1	0.51	1.3		
M208	-1	0-50	Gl	2.3	I	38.5	0.20	0.5	A	3
	-2	50-100		2.1		27.7	0.10	0.4		
M209	-1	0-50	Qr	1.6	I	31.3	0.21	0.7	A	3
	-2	50-100		1.3		33.8	0.25	0.7		
M210	-1	0-50	Qr	1.0	I	36.1	0.16	0.4	A	3
	-2	50-100		1.0		38.2	0.28	0.7		
M211	-1	0-50	Qr	1.5	I	35.0	0.30	0.9	A	3
	-2	50-100		2.1		36.3	0.45	1.2		
M212	-1	0-50	Qr	1.9	I	32.0	0.29	0.9	A	3
	-2	50-100		1.9		36.3	0.56	1.5		
M213	-1	0-50	Gw	0.7	I	28.1	0.18	0.6	A	3
	-2	50-100		0.9		19.9	0.19	1.0		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na+	ESP	Class	
M214	-1	0-50	Qr	2.3	I	32.9	0.13	0.4	A	3
	-2	50-100		2.4		33.9	0.18	0.5		
M215	-1	0-50	Qr	3.0	II	23.2	0.02	0.1	A	3
	-2	50-100		3.7		38.4	0.40	1.0		
M301	-1	0-50	Qr	3.0	II	26.2	0.12	0.9	A	4
	-2	50-100		4.0		31.8	0.24	0.8		
M302	-1	0-50	Qr	2.0	II	26.0	0.32	1.2	A	4
	-2	50-100		2.7		38.7	0.50	1.3		
M303	-1	0-50	Qr	4.0	III	29.4	0.60	2.0	A	3
	-2	50-100		7.3		35.5	0.55	1.6		
M304	-1	0-50	Qr	4.4	II	26.4	0.15	0.6	A	2
	-2	50-100		4.2		21.4	0.18	0.8		
M305	-1	0-50	Gl	4.7	IV	28.6	0.25	0.9	B	4
	-2	50-100		8.0		38.2	2.02	5.3		
M306	-1	0-50	Sr	2.7	II	29.4	0.20	0.7	A	3
	-2	50-100		3.2		35.9	0.15	0.4		
M307	-1	0-50	Gl	3.2	III	36.4	0.94	2.6	A	3
	-2	50-100		6.4		36.0	1.33	3.7		
M308	-1	0-50	Qr	2.1	II	30.4	0.31	1.0	A	3
	-2	50-100		3.5		29.2	0.30	1.0		
M309	-1	0-50	Qr	2.8	II	23.0	0.09	0.4	A	3
	-2	50-100		3.6		35.5	0.03	0.1		
M310	-1	0-50	Sr	3.5	II	29.3	0.26	0.9	A	2
	-2	50-100		3.4		33.3	0.54	1.6		
M311	-1	0-50	Gl	2.4	II	24.4	0.39	1.6	A	2
	-2	50-100		4.5		38.4	1.39	3.6		
M312	-1	0-50	Gl	1.6	II	27.5	0.11	0.4	A	3
	-2	50-100		3.3		34.7	0.07	0.2		
M313	-1	0-50	Gl	1.7	I	22.6	0.25	1.1	A	3
	-2	50-100		1.2		24.6	0.88	3.6		
M401	-1	0-50	Qr	1.6	II	27.7	0.28	1.0	A	3
	-2	50-100		2.5		28.8	0.35	1.2		
M402	-1	0-50	Mc	1.7	I	28.9	0.28	1.0	A	2
	-2	50-100		1.8		23.3	0.20	0.9		
M403	-1	0-50	Bm	2.7	II	13.2	0.07	0.5	A	2
	-2	50-100		3.4		22.4	0.05	0.2		
M404	-1	0-50	Qr	1.1	I	32.2	0.24	0.8	A	3
	-2	50-100		2.3		33.9	0.46	1.4		
M405	-1	0-50	Mc	3.2	II	22.2	0.22	1.0	A	3
	-2	50-100		4.0		29.8	0.43	1.4		
M406	-1	0-50	Bm	1.9	IV	22.0	0.09	0.4	B	3
	-2	50-100		9.5		29.1	1.49	5.1		
M407	-1	0-50	Mc	3.6	II	26.6	0.20	0.8	A	3
	-2	50-100		3.2		38.3	0.35	0.9		
M408	-1	0-50	Mc	2.5	II	26.2	0.09	0.3	A	3
	-2	50-100		2.1		15.0	0.09	0.6		
M409	-1	0-50	Qr	1.9	I	33.8	0.28	0.8	A	3
	-2	50-100		1.7		37.4	0.50	1.3		
M410	-1	0-50	Mc	1.3	I	17.8	0.14	0.8	A	3
	-2	50-100		2.2		34.5	0.45	1.3		
M411	-1	0-50	Mw	1.9	II	32.7	0.18	0.6	A	3
	-2	50-100		3.2		36.3	0.32	0.9		

TABLE C.6 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R412	-1	0-50	Sr	2.9	II	38.3	0.07	0.2	A	3
	-2	50-100		3.6		36.1	0.14	0.4		
M413	-1	0-50	Mw	2.9	II	32.5	0.04	0.1	A	3
	-2	50-100		3.3		38.2	0.11	0.3		
M415	-1	0-50	Qr	0.7	I	31.2	0.14	0.5	A	3
	-2	50-100		2.2		35.2	0.35	1.0		
M416	-1	0-50	Qr	1.4	II	38.7	0.26	0.7	A	3
	-2	50-100		3.4		35.7	0.32	0.9		
M417	-1	0-50	Gw	2.9	II	22.1	0.06	0.3	A	4
	-2	50-100		3.0		35.7	0.11	0.3		
	-3S	100-150		2.2		-	-	-		
	-4S	150-250		2.9		-	-	-		
	-5S	250-300		3.9		-	-	-		
M418	-1	0-50	Gw	2.6	II	31.4	0.20	0.6	A	4
	-2	50-100		2.1		31.0	0.26	0.8		

Note: No M414

TABLE C.7

Routine Analysis Results (Profile Pits)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R10	-(D)	0-50	Sr	1.7	III	+	+	1.7	A	1
		50-100		5.2		+	+	4.2		
		100-150		6.1		+	+	5.1		
R11	-1	0-50	Qr	1.4	I	39.3	0.45	1.2	A	2
	-2	50-100		1.7		21.5	0.31	1.4		
	-3S	100-150		2.7		-	-	-		
	-4S	150-250		3.4		-	-	-		
	-5S	250-350		3.3		-	-	-		
R13	(D)	0-50	Qr	2.6	II	+	+	0.8	A	4
		50-100		2.6		+	+	0.8		
		100-150		2.0		+	+	0.7		
	-4S	150-250		3.9		-	-	-		
	-5S	250-350		3.0		-	-	-		
R14	(D)	0-50	Qr	1.8	I	+	+	0.8	A	2
		50-100		1.6		+	+	1.1		
		100-150		1.9		+	+	1.3		
R15	-1	0-50	Sr	2.5	II	35.3	0.16	0.5	A	3
	-2	50-100		3.1		38.3	0.37	1.0		
	-3S	100-150		3.7		-	-	-		
	-4S	150-250		3.7		-	-	-		
	-5S	250-350		3.5		-	-	-		
R16	(D)	0-50	Sr	1.6	I	+	+	2.1	B	1
		50-100		2.0		+	+	5.0		
		100-150		2.7		+	+	6.7		
	-4S	150-250		4.0		-	-	-		
	-5S	250-350		4.0		-	-	-		
R17	(D)	0-50	Qr	1.6	I	+	+	1.1	A	3
		50-100		1.7		+	+	1.3		
		100-150		2.2		+	+	1.0		
	-4S	150-250		3.6		-	-	-		
	-5S	250-350		3.9		-	-	-		
R18	(D)	0-50	Sh	2.7	II	+	+			2
		50-100		4.8		+	+	16.3		
		100-150		8.5		+	+	16.0		
R19	-1	0-50	Gl	2.7	II	25.8	0.20	0.8	A	4
	-2	50-100		2.0		25.3	0.26	1.0		
R20	(D)	0-50	Db	3.0	III	+	+	1.1	A	1
		50-100		5.1		+	+	4.3		
		100-150		6.3		+	+	5.1		
R21	(D)	0-50	Qr	2.9	II	+	+	0.7	A	4
		50-100		1.7		+	+	0.4		
		100-150		2.3		+	+	0.4		
	-4S	150-250		2.9		-	-	-		
	-5S	250-350		3.0		-	-	-		
R22	-(D)	0-50	Gl	4.7	III	+	+	4.3	B	2
		50-100		6.3		+	+	5.2		
		100-150		8.0		+	+	7.7		
	-4S	150-250		6.7		-	-	-		
	-5S	250-350		7.0		-	-	-		

TABLE C.7 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R23	-1	0-50	Qr	4.4	II	26.8	0.38	1.4	A	4
	-2	50-100		4.0		25.0	0.28	1.1		
	-3S	100-150		2.5		-	-	-		
	-4S	150-250		3.1		-	-	-		
	-5S	250-350		3.1		-	-	-		
R24	(D)	0-50	Gw	2.4	II	+	+	1.5	A	2
		50-100		2.9		+	+	2.4		
		100-150		4.5		+	+	4.9		
	-4S	150-250		7.0		-	-	-		
R25	(D)	0-50	Gl	3.4	II	+	+	1.5	A	2
		50-100		4.0		+	+	0.8		
		100-150		4.0		+	+	0.6		
	-4S	150-250		3.9		-	-	-		
	-5S	250-350		4.5		-	-	-		
R26	(D)	0-50	Mw	4.1	II	+	+	1.2	A	3
		50-100		3.5		+	+	0.4		
		100-150		3.9		+	+	0.7		
R27	(D)	0-50	Mc	3.0	II	+	+	1.4	A	2
		50-100		4.4		+	+	1.1		
		100-150		4.2		+	+	4.2		
	-4S	150-250		4.2		-	-	-		
	-5S	250-350		4.6		-	-	-		
R28	(D)	0-50	Bm	2.2	II	+	+	1.5	A	1
		50-100		4.2		+	+	2.9		
		100-150		7.5		+	+	2.4		
R29	-1	0-50	Gl	1.8	I	29.7	0.37	1.2	A	4
	-2	50-100		2.4		36.1	1.69	4.7		
	-3S	100-150		11.6		-	-	-		
	-4S	150-250		4.6		-	-	-		
	-5S	250-350		9.2		-	-	-		
R30	-1	0-50	Bm	5.2	III	19.5	0.13	0.7	A	3
	-2	50-100		3.7		22.5	0.53	2.4		
R31	-1	0-50	Gl	2.2	I	25.0	0.30	1.2	A	3
	-2	50-100		1.6		29.3	0.35	1.2		
	-3S	100-150		4.8		-	-	-		
	-4S	150-250		5.1		-	-	-		
	-5S	250-350		4.9		-	-	-		
R32	-1	0-50	Qr	1.1	II	31.0	0.34	1.1	A	3
	-2	50-100		2.7		33.2	0.46	1.4		
	-3S	100-150		3.9		-	-	-		
	-4S	150-250		3.2		-	-	-		
	-5S	250-350		2.9		-	-	-		
R33	(D)	0-50	Mc	2.9	II	+	+	0.9	A	4
		50-100		2.0		+	+	0.5		
		100-150		1.3		+	+	0.8		
	-4S	150-250		1.7		-	-	-		
R34	(D)	0-50	Mw	2.8	II	+	+	1.1	A	3
		50-100		3.4		+	+	1.1		
		100-150		3.6		+	+	1.0		
	-4S	150-250		4.4		-	-	-		
	-5S	250-350		4.6		-	-	-		

TABLE C.7 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R35	(D)	0-50	Sr	2.1	II	+	+	1.1	A	3
		50-100		3.2		+	+	1.2		
		100-150		4.6		+	+	2.8		
	-4S	150-250		5.8		-	-	-		
	-5S	250-350		2.5		-	-	-		
R36	-1	0-50	Bm	2.2	I	24.8	0.19	0.8	A	3
	-2	50-100		1.2		36.1	0.38	1.1		
	-3S	100-150		1.8		-	-	-		
	-4S	150-250		2.9		-	-	-		
	-5S	250-350		3.5		-	-	-		
R37	(D)	0-50	Mt	4.9	III	+	+	3.2	A	3
		50-100		6.9		+	+	4.7		
		100-150		7.5		+	+	4.9		
	-4S	150-250		6.8		-	-	-		
	-5S	250-350		7.5		-	-	-		
R38	-1	0-50	Sr	1.0	II	31.8	0.21	0.7	A	3
	-2	50-100		2.9		36.9	0.49	1.3		
	-3S	100-150		4.0		-	-	-		
	-4S	150-250		7.0		-	-	-		
	-5S	250-350		9.4		-	-	-		
R39	-1	0-50	Gl	3.5	II	27.1	0.34	1.3	A	4
	-2	50-100		3.6		31.4	0.41	1.3		
	-3S	100-150		3.8		-	-	-		
	-4S	150-250		4.0		-	-	-		
	-5S	250-350		4.4		-	-	-		
R40	(D)	0-50	Fx	3.5	II	+	+	0.6	A	3
		50-100		4.2		+	+	0.7		
		100-150		4.4		+	+	0.4		
	-4S	150-250		4.9		-	-	-		
	-5S	250-350		5.4		-	-	-		
R41	-1	0-50	Qr	2.9	II	30.4	0.50	1.6	A	1
	-2	50-100		3.6		36.5	0.70	1.9		
	-3S	100-150		2.1		-	-	-		
	-4S	150-250		3.1		-	-	-		
	-5S	250-350		3.2		-	-	-		
R42	-1	0-50	Sr	1.7	III	36.0	0.89	2.5	B	1
	-2	50-100		5.6		37.9	2.60	6.9		
	-3	100-150		9.0		-	-	-		
	-4S	150-250		9.5		-	-	-		
	-5S	250-350		6.0		-	-	-		
R43	-1	0-50	Sr	4.9	IV	30.8	1.20	3.9	A	1
	-2	50-100		9.5		28.4	1.33	4.7		
	-3S	100-150		13.7		-	-	-		
	-4S	150-250		9.8		-	-	-		
	-5S	250-350		11.2		-	-	-		

TABLE C.7 (cont.)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
R44	-1	0-50	Qr	2.4	I	27.9	0.22	0.8	A	3
	-2	50-100		1.7		24.3	0.15	0.6		
	-3S	100-150		2.9		-	-	-		
	-4S	150-250		3.3		-	-	-		
	-5S	250-350		3.3		-	-	-		
R45	-1	0-50	Mw	2.7	II	37.3	0.15	0.4	A	3
	-2	50-100		3.0		39.1	0.06	0.2		
	-3S	100-150		3.9		-	-	-		
	-4S	150-250		4.4		-	-	-		
	-5S	250-350		6.7		-	-	-		
R46	-1	0-50	Sr	1.6	II	25.7	0.19	0.7	A	3
	-2	50-100		2.8		38.2	0.24	0.6		
	-3S	100-150		3.0		-	-	-		
	-4S	150-250		3.4		-	-	-		
	-5S	250-350		4.1		-	-	-		
R47	(D)	0-50	Gw	3.7	II	+	+	0.7	A	4
		50-100		3.7		+	+	0.6		
		100-150		3.7		+	+	1.1		
	-4S	150-250		3.9		-	-	-		
	-5S	250-350		4.5		-	-	-		
R48	-1	0-50	Sr	1.0	I	37.2	0.29	0.8	A	3
	-2	50-100		1.4		35.0	0.26	0.7		
	-3S	100-150		2.7		-	-	-		
	-4S	150-250		3.0		-	-	-		
	-5S	250-350		3.7		-	-	-		
R49	-1	0-50	Sr	1.9	II	35.6	0.27	0.8	A	3
	-2	50-100		3.6		38.8	0.63	1.6		
	-3S	100-150		3.9		-	-	-		
	-4S	150-250		5.5		-	-	-		
R50	-1	0-50	Gl	3.2	II	30.5	0.16	0.5	A	4
	-2	50-100		3.7		35.5	0.40	1.1		
	-3S	100-150		5.9		-	-	-		
	-4S	150-250		6.6		-	-	-		
	-5S	250-350		6.8		-	-	-		
R51	(D)	0-50	Sh	1.6	I	+	+	0.6	A	1
		50-100		2.4		+	+	1.7		
		100-150		2.8		+	+	2.5		
	-4S	150-250		4.2		-	-	-		
	-5S	250-350		5.7		-	-	-		
R52	-1	0-50	Sr	1.7	I	31.8	0.27	0.9	A	4
	-2	50-100		1.3		39.0	0.66	1.7		
	-3S	100-150		1.4		-	-	-		
	-4S	150-250		1.5		-	-	-		
	-5S	250-350		1.2		-	-	-		
R53	-1	0-50	Sr	1.7	I	27.5	0.23	0.8	A	2
	-2	50-100		1.7		41.8	1.13	2.7		
	-3S	100-150		6.8		-	-	-		
	-4S	150-250		7.8		-	-	-		
	-5S	250-350		4.5		-	-	-		

TABLE C.7 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na+	ESP	Class	
R54	-1	0-50	Sr	2.1	I	34.3	0.35	1.0	A	3
	-2	50-100		1.4		42.0	0.55	1.3		
	-3S	100-150		5.9		-	-	-		
	-4S	150-250		7.0		-	-	-		
	-5S	250-350		7.6		-	-	-		
R55	-1	0-50	Sr	2.0	II	30.5	0.91	3.0	B	1
	-2	50-100		2.8		40.0	2.68	6.7		
	-3S	100-150		1.3		-	-	-		
	-4S	150-250		7.8		-	-	-		
	-5S	250-350		9.4		-	-	-		
R56	-1	0-50	Qr	1.2	I	39.0	0.29	0.7	A	3
	-2	50-100		1.6		33.8	0.42	1.2		
R57	-1	0-50	Mc	2.1	II	33.0	0.39	1.2	A	2
	-2	50-100		3.1		33.3	0.26	0.8		
	-3S	100-150		3.7		-	-	-		
R58	-1	0-50	Gw	1.2	II	25.8	0.16	0.6	A	2
	-2	50-100		2.6		36.3	0.44	1.2		
	-3S	100-150		1.4		-	-	-		
R59	-1	0-50	Qr	1.3	I	36.5	0.28	0.8	A	3
	-2	50-100		0.9		32.5	0.14	0.4		
	-3S	100-150		2.9		-	-	-		
R60	-1	0-50	Gl	1.7	I	38.5	0.23	0.6	A	3
	-2	50-100		1.6		41.0	0.23	0.6		
	-3S	100-150		1.2		-	-	-		
R61	-1	0-50	Sr	1.4	I	37.5	0.21	0.6	A	3
	-2	50-100		1.7		43.8	0.38	0.9		
	-3S	100-150		3.3		-	-	-		
R62	-1	0-50	Sr	1.8	II	31.1	0.38	1.2	A	3
	-2	50-100		3.1		38.0	0.46	1.2		
	-3S	100-150		3.2		-	-	-		
R63	(D)	0-50	Mw	1.9	II	+	+	1.0	A	3
		50-100		2.6		+	+	1.0		
		100-150		3.2		-	-	-		
R64	(D)	0-50	Sr	1.5	II	+	+	0.7	A	2
		50-100		2.9		+	+	0.9		
		100-150		2.3		-	-	-		
R65	-1	0-50	Gl	1.7	I	40.2	0.42	1.0	A	3
	-2	50-100		2.0		41.5	0.51	1.2		
R66	(D)	0-50	Gl	3.3	III	+	+	0.3	A	2
		50-100		5.0		+	+	1.8		
		100-150		6.3		+	+	1.3		
R67	-1	0-50	Sr	2.8	II	41.0	0.24	0.6	A	3
	-2	50-100		3.4		37.9	0.41	1.1		

TABLE C.7 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na^+	ESP	Class	
R68	-1	0-50	Gl	2.7	II	28.3	0.37	1.3	A	3
	-2	50-100		2.2		32.2	0.36	1.1		
R69	-1	0-50	Sr	1.9	I	39.5	0.44	1.1	A	2
	-2	50-100		1.1		34.0	0.34	1.0		
R70	-1	0-50	Mc	1.8	II	31.1	0.20	0.6	A	1
	-2	50-100		2.3		27.6	0.26	0.9		
	3S	100-150		1.9		-	-	-		
R71	-1	0-50	Gw	1.3	I	33.2	0.50	1.5	A	3
	-2	50-100		2.4		34.6	0.16	0.5		

TABLE C.8

Routine Analysis Results (Project Area)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Exchangeable Sodium Na^+	Exchangeable Sodium ESP	Exchangeable Sodium Class	Land use
D101 -1	0 - 50	Mc	1.2	II	36.4	0.33	0.9	A	3
-2	50 - 100		3.2		29.6	0.32	1.1		
D102 -1	0 - 50	Qr-s	1.0	II	33.8	0.25	0.7	A	3
-2	50 - 100		2.8		32.6	0.25	0.8		
D103 -1	0 - 50	Qr-s	1.1	I	27.7	0.28	1.0	A	2
-2	50 - 100		2.4		36.2	0.53	1.5		
D104 -1	0 - 50	Gl	1.6	II	36.3	0.54	1.5	A	2
-2	50 - 100		2.9		35.2	0.40	1.1		
D105 -1	0 - 50	Gl	1.2	I	30.0	0.21	0.7	A	2
-2	50 - 100		0.9		31.2	0.21	0.7		
D106 -1	0 - 50	Gl	0.9	I	31.4	0.18	0.6	A	3
-2	50 - 100		1.1		31.7	0.24	0.8		
D107 -1	0 - 50	Sr	1.1	I	31.3	0.29	0.9	A	3
-2	50 - 100		0.9		30.4	0.21	0.7		
D108 -1	0 - 50	Sr	1.1	I	24.8	0.14	0.6	A	3
-2	50 - 100		1.1		24.7	0.19	0.8		
D109 -1	0 - 50	Sr	1.0	I	33.6	0.34	1.0	A	3
-2	50 - 100		2.1		36.4	0.31	0.9		
D110 -1	0 - 50	Sr	1.0	I	29.4	0.19	0.7	A	3
-2	50 - 100		1.4		31.2	0.39	1.3		
D111 -1	0 - 50	Sr	1.0	I	28.7	0.25	0.9	A	3
-2	50 - 100		1.0		30.1	0.16	0.5		
D112 -1	0 - 50	Sr	1.0	I	28.6	0.21	0.7	A	2
-2	50 - 100		2.3		31.6	0.26	0.8		
D113 -1	0 - 50	Sr	1.0	I	27.3	0.16	0.6	A	3
-2	50 - 100		1.0		27.4	0.16	0.6		
D114 -1	0 - 50	Sr	1.3	I	34.9	0.31	0.9	A	3
-2	50 - 100		0.8		35.6	0.75	2.1		
D115 -1	0 - 50	Sr	2.7	II	29.6	0.34	1.2	A	3
-2	50 - 100		1.5		34.1	0.58	1.7		
D116 -1	0 - 50	Sr	0.8	I	28.0	0.19	0.7	A	3
-2	50 - 100		1.3		31.5	0.43	1.4		
D117 -1	0 - 50	Sr	1.0	II	29.5	0.15	0.5	A	3
-2	50 - 100		2.5		31.3	0.15	0.5		
D118 -1	0 - 50	Sr	1.2	I	32.5	0.40	1.2	A	3
-2	50 - 100		1.3		31.4	0.44	1.4		
D119 -1	0 - 50	Sr	0.7	II	31.0	0.27	0.87	A	3
-2	50 - 100		2.9		38.9	0.46	1.18		
D120 -1	0 - 50	Sr	3.6	II	36.7	0.66	1.8	A	3
-2	50 - 100		1.1		32.8	0.79	2.4		
D121 -1	0 - 50	Gw	2.0	I	25.8	0.27	1.1	A	2
-2	50 - 100		1.3		27.5	0.20	0.7		
D122 -1	0 - 50	Gw	1.2	I	29.2	0.29	1.0	A	2
-2	50 - 100		1.2		32.4	0.35	1.1		
D123 -1	0 - 50	Gw	1.1	I	28.3	0.34	1.2	A	3
-2	50 - 100		1.2		31.0	0.25	0.8		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Exchangeable Sodium Na+	Exchangeable Sodium ESP	Exchangeable Sodium Class	Land use
D124 -1	0 - 50	Qr	1.0	I	32.2	0.24	0.7	A	2
-2	50 - 100		1.0		33.3	0.42	1.3		
D125 -1	0 - 50	Qr	1.1	I	31.8	0.21	0.7	A	2
-2	50 - 100		1.2		33.1	0.26	0.8		
D126 -1	0 - 50	Qr	0.9	I	31.3	0.16	0.5	A	3
-2	50 - 100		0.8		28.7	0.24	0.8		
D127 -1	0 - 50	Qr	1.0	I	31.5	0.24	0.8	A	2
-2	50 - 100		2.3		32.0	0.24	0.8		
D128 -1	0 - 50	Gl	1.4	II	20.2	0.11	0.5	A	3
-2	50 - 100		2.7		25.7	0.07	0.3		
D129 -1	0 - 50	Sr	1.6	II	34.2	0.39	1.1	A	2
-2	50 - 100		4.1		38.8	0.69	1.8		
D130 -1	0 - 50	Sr	1.1	I	31.2	0.21	0.7	A	2
-2	50 - 100		1.6		32.5	0.19	0.6		
D131 -1	0 - 50	Sr	1.6	I	26.4	0.11	0.4	A	2
-2	50 - 100		1.4		28.6	0.16	0.6		
D132 -1	0 - 50	Sr	1.0	I	32.5	0.14	0.4	A	3
-2	50 - 100		2.0		36.5	0.19	0.5		
D133 -1	0 - 50	Sr	1.3	I	35.4	0.27	0.8	A	3
-2	50 - 100		1.6		36.1	0.52	1.4		
D134 -1	0 - 50		3.3	II	30.3	0.32	1.1	A	1
-2	50 - 100		3.4		33.6	0.44	1.3		
D135 -1	0 - 50	Sr	1.1	I	34.2	0.40	1.2	A	2
-2	50 - 100		1.7		32.6	0.30	0.9		
D136 -1	0 - 50	Sr	1.6	I	28.8	0.23	0.8	A	2
-2	50 - 100		1.0		33.9	0.43	1.3		
D137 -1	0 - 50	Sr	0.8	I	30.5	0.16	0.5	A	3
-2	50 - 100		2.4		36.6	0.08	0.2		
D138 -1	0 - 50	Sr	1.3	I	31.0	0.14	0.5	A	2
-2	50 - 100		0.9		33.6	0.25	0.7		
D139 -1	0 - 50	Sr	1.1	I	31.8	0.32	1.0	A	3
-2	50 - 100		0.9		36.6	0.38	1.0		
D140 -1	0 - 50	Sr	2.3	I	36.6	0.09	0.2	A	3
-2	50 - 100		2.3		40.4	0.06	0.2		
D141 -1	0 - 50	Mw	1.3	I	34.6	0.31	0.9	A	3
-2	50 - 100		1.6		34.0	0.46	1.4		
D142 -1	0 - 50	Qr	1.1	II	31.3	0.31	0.8	A	2
-2	50 - 100		2.6		31.8	0.28	0.9		
D143 -1	0 - 50	Qr	1.5	I	31.6	0.29	0.9	A	2
-2	50 - 100		1.3		35.6	0.33	0.9		
D144 -1	0 - 50	Qr	1.3	I	32.0	0.33	1.0	A	3
-2	50 - 100		1.4		36.2	0.51	1.4		
D145 -1	0 - 50	Mw	1.2	I	31.8	0.32	1.0	A	3
-2	50 - 100		1.3		30.8	0.44	1.4		
D146 -1	0 - 50	Mw	1.1	I	28.7	0.33	1.2	A	3
-2	50 - 100		1.4		30.7	0.39	1.3		
D147 -1	0 - 50	Mw	0.9	II	32.3	0.29	0.9	A	3
-2	50 - 100		2.8		35.0	0.38	1.1		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
			ECe	Class	CEC	Na^+	ESP	Class	
D148 -1	0 - 50	Mw	1.0	I	30.9	0.29	0.9	A	3
-2	50 - 100		1.3		32.0	0.52	1.6		
D149 -1	0 - 50	Mw	1.3	I	30.8	0.39	1.3	A	3
-2	50 - 100		1.6		37.0	0.48	1.3		
D150 -1	0 - 50	Mw	1.4	I	33.8	0.25	0.7	A	3
-2	50 - 100		1.5		36.4	0.44	1.2		
D151 -1	0 - 50	Mw	2.0	II	33.7	0.36	1.1	A	3
-2	50 - 100		2.5		41.4	0.63	1.5		
D152 -1	0 - 50	Mw	1.3	I	31.1	0.34	1.1	A	3
-2	50 - 100		1.1		34.5	0.40	1.2		
D153 -1	0 - 50	Mw	1.2	I	34.3	0.34	1.0	A	2
-2	50 - 100		2.2		35.8	0.19	0.5		
D154 -1	0 - 50	Mw	2.3	II	33.0	0.19	0.6	A	2
-2	50 - 100		2.5		35.5	0.22	0.6		
D155 -1	0 - 50	Qr	2.3	II	31.3	0.22	0.7	A	3
-2	50 - 100		2.7		32.3	0.20	0.6		
D156 -1	0 - 50	Sr	2.4	II	34.2	0.21	0.6	A	3
-2	50 - 100		2.7		36.5	0.25	0.7		
D157 -1	0 - 50	Sr	1.5	II	37.4	0.18	0.5	A	3
-2	50 - 100		2.8		41.0	0.28	0.7		
D158 -1	0 - 50	Sr	2.3	II	34.0	0.16	0.5	A	3
-2	50 - 100		3.0		37.8	0.38	1.0		
D159 -1	0 - 50	Sr	1.0	II	33.0	0.26	0.8	A	3
-2	50 - 100		3.3		39.8	0.55	1.4		
D160 -1	0 - 50	Sr	1.2	II	30.8	0.18	0.6	A	3
-2	50 - 100		3.0		39.3	0.40	1.0		
D161 -1	0 - 50	Gl	2.5	II	31.9	0.48	1.5	A	3
-2	50 - 100		3.5		35.2	0.50	1.4		
D162 -1	0 - 50	Gl	0.7	I	30.7	0.34	1.1	A	2
-2	50 - 100		1.0		37.3	0.62	1.7		
D163 -1	0 - 50	Mt	1.7	II	20.4	0.18	0.9	A	3
-2	50 - 100		2.7		26.1	0.31	1.2		
D164 -1	0 - 50	Sh	1.5	II	19.4	0.16	0.8	A	3
-2	50 - 100		2.5		27.5	0.09	0.3		
D165 -1	0 - 50	Mt	1.3	II	23.9	0.26	1.1	A	3
-2	50 - 100		2.8		30.5	0.28	0.9		
D166 -1	0 - 50	Gl	1.2	I	29.8	0.20	0.7	A	3
-2	50 - 100		2.0		31.3	0.36	1.2		
D167 -1	0 - 50	Gl	1.2	I	31.0	0.37	1.2	A	2
-2	50 - 100		1.7		36.5	0.63	1.7		
D168 -1	0 - 50	Sr	1.9	I	22.7	0.24	1.1	A	3
-2	50 - 100		2.1		30.4	0.27	0.9		
D169 -1	0 - 50	Gl	3.8	II	41.5	0.50	1.2	A	3
-2	50 - 100		3.4		39.3	0.75	1.9		
D170 -1	0 - 50	Gl	2.5	II	29.8	0.16	0.5	A	3
-2	50 - 100		4.0		17.0	0.42	2.5		
D171 -1	0 - 50	Gl	5.6	III	33.8	1.64	4.9	A	2
-2	50 - 100		1.4		33.5	0.18	0.5		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Exchangeable Sodium Na+	Exchangeable Sodium ESP	Exchangeable Sodium Class	Land use
D172 -1	0 - 50	Sr	2.1	II	26.8	0.34	1.3	A	3
-2	50 - 100		4.1		31.0	0.7	2.2		
D173 -1	0 - 50	Sr	1.4	II	26.8	0.30	1.1	A	2
-2	50 - 100		3.3		38.2	0.23	0.6		
D174 -1	0 - 50	Sr	1.5	II	34.3	0.24	0.7	A	1
-2	50 - 100		3.3		38.6	0.13	0.3		
D175 -1	0 - 50	Sr	2.7	II	30.0	0.56	1.9	A	3
-2	50 - 100		4.7		40.6	0.74	1.8		
D176 -1	0 - 50	Sr	3.0	III	34.1	0.17	0.5	A	3
-2	50 - 100		5.2		42.3	0.47	1.1		
D177 -1	0 - 50	Sr	1.2	II	30.9	0.21	0.7	A	2
-2	50 - 100		2.7		40.9	0.35	0.9		
D178 -1	0 - 50	Sr	2.5	II	41.1	0.16	0.4	A	3
-2	50 - 100		2.9		35.8	0.29	0.8		
D179 -1	0 - 50	Sr	1.6	II	29.1	0.23	0.8	A	3
-2	50 - 100		3.4		35.6	0.02	0.1		
D180 -1	0 - 50	Sr	1.0	II	35.5	0.29	0.8	A	3
-2	50 - 100		2.9		38.6	0.40	1.0		
D181 -1	0 - 50	Sh	2.1	I	24.3	0.20	0.8	A	3
-2	50 - 100		2.0		19.6	0.30	1.5		
D182 -1	0 - 50	Gl	2.3	II	28.6	0.23	0.8	A	3
-2	50 - 100		3.2		39.1	0.24	0.6		
D183 -1	0 - 50	Gl	2.6	II	36.6	0.28	0.8	A	3
-2	50 - 100		1.2		32.8	0.18	0.6		
D184 -1	0 - 50	Gl	1.9	II	35.8	0.41	1.2	A	3
-2	50 - 100		2.9		40.9	0.29	0.7		
D185 -1	0 - 50	Sr	2.8	II	29.1	0.16	0.6	A	3
-2	50 - 100		3.8		12.6	0.48	3.8		
D186 -1	0 - 50	Sr	2.7	II	28.6	0.15	0.5	A	2
-2	50 - 100		3.4		37.3	0.29	0.8		
D187 -1	0 - 50	Sr	2.7	II	30.9	0.22	0.7	A	3
-2	50 - 100		2.6		26.3	0.15	0.4		
D188 -1	0 - 50	Sr	0.9	II	27.1	0.14	0.5	A	3
-2	50 - 100		2.8		29.7	0.25	0.8		
D189 -1	0 - 50	Sr	2.4	II	23.9	0.07	0.3	A	3
-2	50 - 100		3.0		19.4	0.24	1.2		
D190 -1	0 - 50	Sr	1.4	II	29.2	0.29	1.0	A	3
-2	50 - 100		3.2		39.3	0.35	0.9		
D191 -1	0 - 50	Sr	1.1	II	29.5	0.28	1.0	A	2
-2	50 - 100		3.0		39.6	0.28	0.7		
D192 -1	0 - 50	Sr	1.5	II	33.0	0.35	1.1	A	3
-2	50 - 100		3.7		41.3	0.63	1.5		
D193 -1	0 - 50	Sr	1.2	II	32.0	0.23	0.7	A	2
-2	50 - 100		2.7		36.7	0.15	0.4		
D194 -1	0 - 50	Sr	1.1	II	28.5	0.29	1.0	A	3
-2	50 - 100		3.4		32.8	0.03	0.1		
D195 -1	0 - 50	Sr	1.3	II	29.3	0.26	0.9	A	3
-2	50 - 100		3.0		39.7	0.35	0.9		
D196 -1	0 - 50	Sr	2.3	II	33.5	0.19	0.6	A	2
-2	50 - 100		3.0		38.8	0.21	0.5		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D197 -1	0 - 50	Sr	1.4	II	31.5	0.18	0.6	A	2
-2	50 - 100		3.0		37.1	0.19	0.5		
D198 -1	0 - 50	Sr	1.1	I	23.8	0.10	0.4	A	3
-2	50 - 100		1.0		33.9	0.22	0.7		
D199 -1	0 - 50	Sr	1.5	I	28.3	0.16	0.6	A	3
-2	50 - 100		1.4		47.9	0.27	0.7		
D200 -1	0 - 50	Sr	1.7	I	30.8	0.20	0.7	A	3
-2	50 - 100		1.5		32.3	0.27	0.8		
D201 -1	0 - 50	Sr	3.4	II	33.8	0.21	0.6	A	2
-2	50 - 100		3.8		40.3	0.05	0.1		
D202 -1	0 - 50	Gw	3.8	II	22.3	0.23	1.0	A	2
-2	50 - 100		1.5		21.3	0.13	0.6		
D203 -1	0 - 50	Gw	2.0	I	22.0	0.22	1.0	A	2
-1	50 - 100		1.5		23.0	0.30	1.3		
D204 -1	0 - 50	Mw	1.1	II	32.3	0.18	0.6	A	2
-2	50 - 100		2.7		35.8	0.37	1.0		
D205 -1	0 - 50	Mw	2.0	II	29.8	0.25	0.8	A	1
-2	50 - 100		2.7		32.9	0.23	0.7		
-3S	100 - 150		3.3		-	-	-		
-4S	150 - 250		3.5		-	-	-		
-5S	250 - 350		4.4		-	-	-		
D206 -1	0 - 50	Sh	2.1	II	19.8	0.11	0.6	A	1
-2	50 - 100		3.9		23.9	0.50	2.1		
-3S	100 - 150		4.0		-	-	-		
-4S	150 - 250		2.7		-	-	-		
-5S	250 - 350		2.6		-	-	-		
D207 -1	0 - 50	Fx	2.9	II	21.3	0.02	0.1	A	2
-2	50 - 100		3.2		17.5	0.05	0.3		
-3S	100 - 150		3.3		-	-	-		
D208 -1	0 - 50	Mw	1.6	II	34.8	0.28	0.8	A	2
-2	50 - 100		3.2		39.5	0.35	0.9		
-3S	100 - 150		3.2		-	-	-		
D209 -1	0 - 50	Mc	1.0	I	29.3	0.11	0.4	A	1
-2	50 - 100		1.4		23.8	0.07	0.3		
-3S	100 - 150		1.1		-	-	-		
-4S	150 - 250		2.7		-	-	-		
-5S	250 - 350		2.8		-	-	-		
D210 -1	0 - 50	Qr	1.3	II	36.9	0.15	0.4	A	2
-2	50 - 100		3.6		42.8	0.31	0.7		
-3S	100 - 150		2.9		-	-	-		
D211 -1	0 - 50	Sr	2.6	II	34.3	0.10	0.3	A	2
-2	50 - 100		3.2		38.5	0.11	0.3		
-3S	100 - 150		3.3		-	-	-		
D212 -1	0 - 50	Sr	3.0	II	37.5	0.09	0.2	A	2
-2	50 - 100		3.6		37.6	0.18	0.5		
-3S	100 - 150		3.7		-	-	-		
-4S	150 - 250		3.9		-	-	-		
-5S	250 - 350		4.4		-	-	-		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D213 -1	0 - 50	Sr	2.2	II	32.6	0.15	0.5	A	3
-2	50 - 100		3.3		41.8	0.30	0.7		
-3S	100 - 150		3.3		-	-	-		
D214 -1	0 - 50	Sr	1.4	I	37.8	0.27	0.7	A	2
-2	50 - 100		2.4		43.0	0.34	0.8		
-3S	100 - 150		3.4		-	-	-		
D215 -1	0 - 50	Mw	1.0	II	32.5	0.18	0.6	A	2
-2	50 - 100		2.7		41.8	0.17	0.4		
D216 -1	0 - 50	Mw	2.1	II	32.5	0.20	0.6	A	3
-2	50 - 100		3.1		38.5	0.30	0.8		
D217 -1	0 - 50	Gw	1.4	II	33.0	0.19	0.6	A	3
-2	50 - 100		3.2		38.6	0.21	0.5		
D218 -1	0 - 50	Mw	1.3	I	35.0	0.27	0.8	A	2
-2	50 - 100		1.8		29.7	0.27	0.9		
D219 -1	0 - 50	Qr	2.0	I	34.8	0.45	1.3	A	2
-2	50 - 100		2.4		36.4	0.37	0.8		
D220 -1	0 - 50	Qr	2.5	II	33.8	0.63	1.9	A	2
-2	50 - 100		1.1		33.4	0.26	0.8		
D221 -1	0 - 50	Fx	2.8	II	14.8	0.02	0.1	A	2
-2	50 - 100		1.5		7.8	0.04	0.5		
D222 -1	0 - 50	Mw	2.7	II	35.8	0.38	1.1	A	1
-2	50 - 100		2.7		36.8	0.19	0.5		
D223 -1	0 - 50	Sr	1.7	I	34.5	0.33	1.0	A	2
-2	50 - 100		2.1		41.0	0.42	1.0		
D224 -1	0 - 50	Gl	1.6	II	34.0	0.23	0.7	A	2
-2	50 - 100		3.0		29.0	0.10	0.3		
D225 -1	0 - 50	Gl	1.0	I	33.9	0.26	0.8	A	2
-2	50 - 100		1.3		36.2	0.18	0.5		
D226 -1	0 - 50	Sr	1.3	II	29.7	0.21	0.7	A	1
-2	50 - 100		2.5		35.0	0.24	0.7		
D227 -1	0 - 50	Sr	1.7	II	32.6	0.26	0.8	A	1
-2	50 - 100		3.4		39.0	0.58	1.5		
D229 -1	0 - 50	Sr	1.9	II	35.3	0.33	0.9	A	3
-2	50 - 100		3.4		36.8	0.41	1.1		
D230 -1	0 - 50	Sr	1.2	I	24.4	0.09	0.4	A	3
-2	50 - 100		0.8		29.2	0.13	0.5		
D231 -1	0 - 50	Sr	1.3	II	33.3	0.18	0.5	A	3
-2	50 - 100		3.4		40.3	0.16	0.4		
D232 -1	0 - 50	Sr	1.5	I	27.5	0.18	0.7	A	3
-2	50 - 100		1.2		34.5	0.21	0.6		
D233 -1	0 - 50	Sr	1.4	I	35.2	0.28	0.8	A	3
-2	50 - 100		1.0		35.8	0.75	2.1		
D234 -1	0 - 50	Sr	0.8	II	31.5	0.53	1.7	A	3
-2	50 - 100		2.5		38.7	0.13	0.3		
D235 -1	0 - 50	Sr	1.3	II	28.4	0.80	2.8	C	2
-2	50 - 100		3.3		36.0	5.01	13.9		
D236 -1	0 - 50	Gl	2.0	II	27.3	0.22	0.8	A	3
-2	50 - 100		3.2		33.3	0.33	1.0		

Note: No site 228

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D237 -1	0 - 50	Gl	1.7	I	25.3	0.18	0.7	A	1
-2	50 - 100		1.9		34.9	0.39	1.1		
D238 -1	0 - 50	Gl	2.6	II	23.2	0.09	0.4	A	3
-2	50 - 100		3.7		29.8	0.07	0.2		
D239 -1	0 - 50	Gl	1.7	I	31.4	0.23	0.7	A	3
-2	50 - 100		1.7		40.5	0.24	0.6		
D240 -1	0 - 50	Sr	3.2	II	27.7	0.28	1.0	A	3
-2	50 - 100		4.5		34.5	0.25	0.7		
D241 -1	0 - 50	Sr	2.6	II	24.5	0.16	0.7	A	2
-2	50 - 100		3.8		31.7	0.32	1.0		
D242 -1	0 - 50	Sr	2.6	II	30.0	0.33	1.1	A	3
-2	50 - 100		3.6		40.5	0.08	0.2		
D243 -1	0 - 50	Sr	3.0	II	35.3	0.29	0.8	A	2
-2	50 - 100		4.6		40.8	0.94	2.3		
D244 -1	0 - 50	Sr	2.7	II	31.7	0.19	0.6	A	3
-2	50 - 100		4.3		38.7	0.82	2.1		
D245 -1	0 - 50	Mc	1.2	I	34.5	0.19	0.6	A	3
-2	50 - 100		1.2		11.3	0.04	0.4		
D246 -1	0 - 50	Qr	1.5	I	33.0	0.21	0.6	A	2
-2	50 - 100		1.3		32.7	0.27	0.8		
D247 -1	0 - 50	Qr	1.4	I	32.5	0.24	0.7	A	2
-2	50 - 100		1.7		35.9	0.30	0.8		
D248 -1	0 - 50	Mw	3.0	II	34.3	0.11	0.3	A	3
-2	50 - 100		1.9		28.9	0.22	0.8		
D249 -1	0 - 50	Qr	3.3	II	38.0	0.09	0.2	A	3
-2	50 - 100		1.8		38.0	0.22	0.6		
D250 -1	0 - 50	Mc	1.6	I	28.3	0.18	0.6	A	3
-2	50 - 100		1.4		22.0	0.12	0.6		
D251 -1	0 - 50	Mw	1.3	I	33.3	0.20	0.6	A	3
-2	50 - 100		1.1		39.9	0.27	0.7		
D252 -1	0 - 50	Qr	1.2	I	33.3	0.23	0.7	A	2
-2	50 - 100		1.4		33.9	0.26	0.8		
D253 -1	0 - 50	Mw	2.2	I	34.5	0.32	0.9	A	3
-2	50 - 100		1.8		34.3	0.24	0.7		
D254 -1	0 - 50	Qr-s	2.2	II	33.8	0.09	0.3	A	3
-2	50 - 100		2.9		32.2	0.14	0.4		
D255 -1	0 - 50	Sr	2.6	II	32.5	0.19	0.6	A	3
-2	50 - 100		3.8		37.8	0.88	2.3		
D256 -1	0 - 50	Gl	2.9	II	38.0	0.20	0.5	A	2
-2	50 - 100		3.7		40.7	0.37	0.9		
D257 -1	0 - 50	Sr	1.6	I	25.1	0.09	0.4	A	3
-2	50 - 100		1.6		32.3	0.14	0.4		
D258 -1	0 - 50	Sr	1.2	II	25.8	0.16	0.6	A	3
-2	50 - 100		3.0		32.5	0.19	0.6		
D259 -1	0 - 50	Sr	4.8	II	28.8	0.55	1.9	A	3
-2	50 - 100		3.2		41.5	0.35	0.8		
D260 -1	0 - 50	Sr	2.8	II	35.5	0.30	0.9	A	2
-2	50 - 100		2.9		38.7	0.11	0.3		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D261 -1	0 - 50	Sr	1.3	II	35.5	0.20	0.6	A	3
-2	50 - 100		2.6		43.3	0.45	1.0		
D262 -1	0 - 50	Sr	1.1	I	30.5	0.23	0.8	A	2
-2	50 - 100		1.6		36.5	0.26	0.7		
D263 -1	0 - 50	Sr	1.8	II	35.8	0.20	0.6	A	3
-2	50 - 100		3.5		39.3	0.38	1.0		
D264 -1	0 - 50	Sr	1.1	II	31.4	0.20	0.6	A	3
-2	50 - 100		3.0		35.6	0.23	0.7		
D265 -1	0 - 50	Sr	1.7	I	31.8	0.39	1.2	A	3
-2	50 - 100		-		-	-	-		
D266 -1	0 - 50	Sr	1.7	I	33.9	0.30	0.9	A	3
-2	50 - 100		1.1		30.8	0.16	0.5		
-3S	100 - 150		3.0		-	-	-		
D267 -1	0 - 50	Sr	1.2	II	36.0	0.29	0.8	A	3
-2	50 - 100		3.0		40.3	0.22	0.6		
D268 -1	0 - 50	Sr	1.6	II	35.3	0.15	0.4	A	3
-2	50 - 100		3.0		39.3	0.22	0.6		
-3S	100 - 150		3.2		-	-	-		
D269 -1	0 - 50	Sr	1.7	II	30.9	0.31	1.0	A	3
-2	50 - 100		3.6		34.0	0.15	0.4		
-3S	100 - 150		5.3		-	-	-		
D270 -1	0 - 50	Sr	1.3	I	23.3	0.11	0.5	A	3
-2	50 - 100		1.4		29.0	0.11	0.4		
D271 -1	0 - 50	Sr	1.0	I	29.4	0.16	0.5	A	3
-2	50 - 100		1.7		36.2	1.62	4.5		
D272 -1	0 - 50	Sr	1.2	II	28.0	0.23	0.8	A	3
-2	50 - 100		3.7		34.9	0.02	0.1		
-3S	100 - 150		4.0		-	-	-		
D273 -1	0 - 50	Gl	1.5	I	26.3	0.37	1.4	A	1
-2	50 - 100		2.4		33.0	1.62	4.9		
-3S	100 - 150		2.0		-	-	-		
D274 -1	0 - 50	Sr	1.0	I	31.3	0.27	0.9	A	1
-2	50 - 100		1.6		35.8	0.23	0.6		
-3S	100 - 150		3.1		-	-	-		
D275 -1	0 - 50	Sr	1.8	I	37.0	0.57	1.5	A	3
-2	50 - 100		1.8		38.4	1.63	4.2		
D276 -1	0 - 50	Sr	1.3	II	36.6	0.63	1.7	A	1
-2	50 - 100		3.2		22.3	0.20	0.9		
D277 -1	0 - 50	Sr	1.9	I	29.9	0.30	1.0	A	1
-2	50 - 100		2.4		37.5	1.75	4.7		
-3S	100 - 150		5.0		-	-	-		
D278 -1	0 - 50	Sr	2.4	II	21.1	0.20	1.0	A	1
-2	50 - 100		4.2		31.8	0.35	1.1		
D279 -1	0 - 50	Sr	1.5	II	28.6	0.36	1.3	B	1
-2	50 - 100		3.7		33.4	1.75	5.2		
D280 -1	0 - 50	Sr	1.3	I	35.7	0.28	0.8	A	3
-2	50 - 100		1.3		34.7	0.06	0.2		
D281 -1	0 - 50	Sr	1.4	I	36.4	0.23	0.6	A	3
-2	50 - 100		1.4		41.9	0.50	1.2		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
			ECe	Class	CEC	Na+	Class		
D282 -1	0 - 50	Sr	1.3	I	35.5	0.32	0.9	A	3
-2	50 - 100		1.4		37.5	0.05	0.1		
D283 -1	0 - 50	Sr	1.0	I	26.8	0.07	0.3	A	3
-2	50 - 100		1.0		30.0	0.28	0.9		
D284 -1	0 - 50	Sr	1.1	I	33.0	0.47	1.4	A	3
-2	50 - 100		2.1		38.3	1.75	4.6		
D285 -1	0 - 50	Sr	1.0	I	33.0	0.64	1.9	B	3
-2	50 - 100		1.8		35.0	3.03	8.7		
D286 -1	0 - 50	Sr	1.0	II	31.8	0.70	2.2	B	3
-2	50 - 100		3.3		36.5	2.29	6.3		
D287 -1	0 - 50	Sr	1.6	I	30.8	0.89	2.9	A	3
-2	50 - 100		0.9		32.9	0.20	0.6		
D288 -1	0 - 50	Sr	1.0	II	32.8	0.57	1.7	A	3
-2	50 - 100		3.9		35.5	0.69	1.9		
D289 -1	0 - 50	Sr	1.9	I	28.2	0.75	2.7	A	3
-2	50 - 100		1.9		31.3	0.22	0.7		
D290 -1	0 - 50	Sr	1.0	I	33.2	0.19	0.6	A	3
-2	50 - 100		1.3		39.3	0.30	0.8		
D291 -1	0 - 50	Sr	1.2	I	34.0	0.29	0.9	A	3
-2	50 - 100		1.8		39.7	0.67	1.7		
D292 -1	0 - 50	Sr	1.3	I	31.2	0.26	0.9	A	3
-2	50 - 100		1.4		33.3	0.57	1.7		
D293 -1	0 - 50	Sr	1.0	I	30.8	0.23	0.8	A	3
-2	50 - 100		1.0		30.0	0.59	2.0		
D294 -1	0 - 50	Sr	2.7	II	33.3	0.28	0.8	A	3
-2	50 - 100		1.5		38.3	0.78	2.0		
D295 -1	0 - 50	Sr	1.3	I	29.6	0.53	1.8	A	3
-2	50 - 100		2.2		37.3	1.09	2.9		
D296 -1	0 - 50	Sr	1.3	II	35.3	1.8	5.2	C	3
-2	50 - 100		3.0		36.3	5.14	14.2		
D297 -1	0 - 50	Sr	1.1	II	31.8	0.68	2.1	A	3
-2	50 - 100		3.8		36.2	1.26	3.5		
-3S	100 - 150		6.0		-	-	-		
D298 -1	0 - 50	Sr	3.9	II	31.2	0.42	1.4	A	3
-2	40 - 100		2.8		27.0	0.48	1.8		
-3S	100 - 150		7.0		-	-	-		
D299 -1	0 - 50	Gl	1.8	I	30.5	0.91	3.0	B	1
-2	50 - 100		0.6		34.0	2.35	6.9		
-3S	100 - 150		7.3		-	-	-		
D300 -1	0 - 50	Mw	1.5	II	34.1	0.27	0.8	A	3
-2	50 - 100		2.6		35.3	0.30	0.9		
-3S	100 - 150		2.5		-	-	-		
-4S	150 - 250		3.0		-	-	-		
-5S	250 - 350		3.9		-	-	-		
D301 -1	0 - 50	Mw	1.2	I	34.0	0.32	0.9	A	3
-2	50 - 100		1.8		35.7	0.40	1.1		
-3S	100 - 150		3.0		-	-	-		
D302 -1	0 - 50	Mw	1.1	II	30.7	0.35	1.1	A	3
-2	50 - 100		2.7		31.5	0.39	1.2		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D303 -1	0 - 50	Mc	1.8	II	30.8	0.42	1.4	A	3
-2	50 - 100		3.1		31.8	0.37	1.2		
D304 -1	0 - 50	Gw	2.2	I	32.8	0.14	0.4	A	3
-2	50 - 100		1.7		28.1	0.47	1.7		
D305 -1	0 - 50	Gw	2.9	II	20.0	0.22	1.1	A	3
-2	50 - 100		2.3		31.6	0.31	1.0		
D306 -1	0 - 50	Mw	1.3	I	33.8	0.29	0.9	A	3
-2	50 - 100		1.1		39.0	0.44	1.1		
D307 -1	0 - 50	Mw	1.3	I	31.3	0.27	0.9	A	3
-2	50 - 100		1.5		34.3	0.40	1.2		
D308 -1	0 - 50	Gw	3.9	II	39.5	0.54	1.4	A	2
-2	50 - 100		0.9		27.0	0.20	0.7		
D309 -1	0 - 50	Mw	0.8	I	31.0	0.23	0.7	A	2
-2	50 - 100		1.1		34.5	0.41	1.2		
-3S	100 - 150		2.3		-	-	-		
D310 -1	0 - 50	Qr	1.2	I	31.3	0.29	0.9	A	3
-2	50 - 100		1.6		29.3	0.33	1.1		
D311 -1	0 - 50	Gw	1.1	I	23.0	0.30	1.3	A	1
-2	50 - 100		1.4		21.5	0.26	1.2		
D312 -1	0 - 50	Mt	3.3	II	21.3	0.23	1.1	A	3
-2	50 - 100		3.7		26.5	0.44	1.7		
D313 -1	0 - 50	Gl	4.9	II	27.8	0.55	2.0	A	3
-2	50 - 100		1.7		24.8	0.57	2.3		
D314 -1	0 - 50	Qr-s	1.6	I	31.8	0.25	0.8	A	2
-2	50 - 100		1.8		27.5	0.22	0.8		
D315 -1	0 - 50	Qr-s	2.4	II	35.8	0.23	0.6	A	3
-2	50 - 100		3.1		36.5	0.15	0.4		
D316 -1	0 - 50	Mw	2.6	II	32.3	0.28	0.9	A	3
-2	50 - 100		3.2		38.0	0.30	0.8		
D317 -1	0 - 50	Qr-s	1.1	II	33.5	0.26	0.8	A	3
-2	50 - 100		3.0		35.5	0.21	0.6		
D318 -1	0 - 50	Qr-s	2.7	II	38.0	0.14	0.4	A	3
-2	50 - 100		1.1		33.8	0.23	0.7		
D319 -1	0 - 50	Qr-s	1.1	I	35.0	0.23	0.7	A	2
-2	50 - 100		2.4		34.3	0.19	0.6		
D320 -1	0 - 50	Qr-s	3.0	II	40.5	0.28	0.7	A	3
-2	50 - 100		1.7		35.0	0.32	0.9		
D321 -1	0 - 50	Sr	1.8	II	33.5	0.23	0.7	A	2
-2	50 - 100		2.9		41.8	0.19	0.5		
D322 -1	0 - 50	Sr	2.5	II	33.8	0.28	0.8	A	3
-2	50 - 100		4.2		40.3	0.25	0.6		
D323 -1	0 - 50	Sr	3.0	II	31.3	0.19	0.6	A	3
-2	50 - 100		3.7		39.8	0.09	0.2		
D324 -1	0 - 50	Sr	1.5	I	26.3	0.16	0.6	A	3
-2	50 - 100		1.5		29.5	0.16	0.5		
D325 -1	0 - 50	Sr	1.4	I	35.0	0.20	0.6	A	3
-2	50 - 100		1.4		37.8	0.18	0.5		
D326 -1	0 - 50	Sr	1.2	II	33.0	0.20	0.6	A	3
-2	50 - 100		3.1		37.8	0.27	0.8		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity Ece	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
D327 -1	0 - 50	Sr	2.9	II	32.0	0.19	0.6	A	3
-2	50 - 100		3.0		37.0	0.22	0.6		
D328 -1	0 - 50	Sr	2.7	II	38.0	0.19	0.5	A	3
-2	50 - 100		3.4		39.0	0.34	0.9		
D329 -1	0 - 50	Sr	1.6	I	28.5	0.20	0.7	A	3
-2	50 - 100		2.1		36.3	0.30	0.8		
D330 -1	0 - 50	Sr	1.2	I	30.5	0.18	0.6	A	3
-2	50 - 100		2.3		38.8	0.27	0.7		
D331 -1	0 - 50	Sr	2.8	II	41.5	0.19	0.5	A	3
-2	50 - 100		1.5		40.3	0.20	0.5		
D332 -1	0 - 50	Sr	3.9	III	23.0	0.32	1.4	A	3
-2	50 - 100		6.0		29.0	0.28	0.9		
D333 -1	0 - 50	Sr	3.7	II	35.8	0.25	0.7	A	3
-2	50 - 100		2.6		37.0	0.15	0.4		
D334 -1	0 - 50	Sr	2.6	II	40.5	0.37	0.9	A	3
-2	50 - 100		4.5		41.3	0.28	0.7		
D335 -1	0 - 50	Sr	4.6	II	32.5	0.29	0.8	A	3
-2	50 - 100		4.6		39.9	0.63	1.6		
D336 -1	0 - 50	Sr	1.5	I	31.4	0.16	0.5	A	3
-2	50 - 100		1.4		36.8	0.20	0.5		
D337 -1	0 - 50	Sr	3.2	II	36.7	0.27	0.7	A	3
-2	50 - 100		1.1		40.0	0.24	0.6		
D338 -1	0 - 50	Sr	1.6	II	24.5	0.23	0.9	A	3
-2	50 - 100		3.0		32.9	0.17	0.5		
D339 -1	0 - 50	Sr	1.1	I	36.3	0.28	0.8	A	3
-2	50 - 100		2.1		43.0	0.38	0.9		
D340 -1	0 - 50	Mt	1.0	I	31.0	0.16	0.5	A	3
-2	50 - 100		1.8		36.8	0.32	0.9		
D341 -1	0 - 50	Gl	1.2	II	31.8	0.29	0.9	A	3
-2	50 - 100		3.3		37.3	0.28	0.8		
D342 -1	0 - 50	Gl	1.8	II	35.0	0.30	0.9	A	3
-2	50 - 100		3.3		38.3	0.31	0.8		
D343 -1	0 - 50	Gl	0.9	II	34.0	0.40	1.2	A	2
-2	50 - 100		3.2		33.8	0.24	0.7		
D344 -1	0 - 50	Gl	1.2	II	32.0	0.38	1.2	A	3
-2	50 - 100		2.5		35.5	0.48	1.4		
D345 -1	0 - 50	Gl	2.3	III	35.0	0.57	1.6	A	2
-2	50 - 100		5.9		36.0	0.88	2.4		
D346 -1	0 - 50	Gl	2.6	II	27.5	0.33	1.2	A	2
-2	50 - 100		4.9		34.5	0.73	2.1		
D347 -1	0 - 50	Sh	3.5	III	30.5	0.20	0.7	A	3
-2	50 - 100		5.1		33.3	0.42	1.3		
-3S	100 - 150		4.4		-	-	-		
D348 -1	0 - 50	Gl	3.7	II	33.0	2.50	7.6	B	3
-2	50 - 100		2.7		37.8	0.47	1.24		
D349 -1	0 - 50	Gl	0.8	I	25.3	0.11	0.4	A	3
-2	50 - 100		1.3		25.5	0.19	0.8		
D350 -1	0 - 50	Sh	4.9	III	34.3	0.69	2.0	A	3
-2	50 - 100		5.1		35.3	1.20	3.4		

TABLE C.8 (cont)

Site number	Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Exchangeable Sodium Na^+	Exchangeable Sodium Class		Land use
D351 -1	0 - 50	Mt	1.6	II	26.5	0.14	0.5	A	3
-2	50 - 100		3.8		32.5	0.29	0.9		
D352 -1	0 - 50	Mt	2.9	II	30.5	0.16	0.5	A	2
-2	50 - 100		4.4		26.3	0.42	2.6		
D353 -1	0 - 50	Qr-s	1.6	II	37.0	0.36	1.0	A	2
-2	50 - 100		3.2		38.8	0.34	0.9		
D354 -1	0 - 50	Qr	0.9	I	34.5	0.24	0.7	A	2
-2	50 - 100		0.9		34.8	0.53	1.5		
D355 -1	0 - 50	Qr	1.4	II	27.8	0.22	0.8	A	2
-2	50 - 100		2.5		40.3	0.82	2.0		
D356 -1	0 - 50	Qr	1.7	II	33.8	0.46	1.4	A	2
-2	50 - 100		3.1		41.3	0.65	1.6		
D357 -1	0 - 50	Qr	1.6	I	32.5	0.31	1.0	A	2
-2	50 - 100		1.7		35.5	0.50	1.4		
D358 -1	0 - 50	Gw	1.8	II	31.5	0.27	0.9	A	4
-2	50 - 100		2.9		41.5	0.75	1.8		
D359 -1	0 - 50	Gw	0.7	I	27.5	0.24	0.9	A	4
-2	50 - 100		1.9		32.8	0.30	0.9		
D360 -1	0 - 50	Gw	1.2	II	37.8	0.24	0.6	A	1
-2	50 - 100		2.6		28.5	0.40	1.4		
D362 -1	0 - 50	Gl	6.0	III	33.0	0.43	1.3	A	3
-2	50 - 100		1.1		28.5	0.65	2.3		
D363 -1	0 - 50	Gl	1.5	II	33.0	0.29	0.9	A	3
-2	50 - 100		3.0		37.3	0.38	1.0		
D364 -1	0 - 50	Gl	3.0	II	35.5	0.30	0.9	A	3
-2	50 - 100		1.7		31.3	0.25	0.8		
D365 -1	0 - 50	Gl	1.5	II	26.1	0.23	0.9	A	3
-2	50 - 100		3.2		34.5	0.24	1.0		
-3S	100 - 150		4.0		-	-	-		
D366 -1	0 - 50	Gl	2.0	I	30.3	0.26	0.9	A	2
-2	50 - 100		1.2		37.5	0.69	1.8		
-3S	100 - 150		3.5		-	-	-		

Note: No site 361

TABLE C.9

Routine Analysis Results (Sample Areas)

Site number		Sample depth (cm)	Series	Salinity ECe	Salinity Class	Exchangeable Sodium CEC	Na+	ESP	Class	Land use
Sample Area 1										
S101	-1	0-50	Gl	2.1	II	32.8	0.33	1.0	A	
	-2	50-100		3.6		38.8	0.13	0.3		
S102	-1	0-50	Gl-r	1.6	II	31.8	0.38	1.2	A	
	-2	50-100		2.9		37.8	0.58	1.5		
S103	-1	0-50	Gl	1.9	II	35.5	0.45	1.3	A	
	-2	50-100		3.3		39.5	0.63	1.6		
S104	-1	0-50	Gl-r	1.9	II	32.5	0.36	1.1	A	
	-2	50-100		2.9		39.0	0.55	1.4		
S105	-1	0-50	Gl	1.8	II	32.5	0.29	0.9	A	
	-2	50-100		2.7		39.0	0.22	0.6		
S106	-1	0-50	Gl-r	2.4	II	33.8	0.15	0.4	A	
	-2	50-100		2.8		37.8	0.17	0.4		
S107	-1	0-50	Gl	1.3	II	36.8	0.35	1.0	A	
	-2	50-100		3.3		40.8	0.50	1.2		
S108	-1	0-50	Gl	1.3	II	34.8	0.35	1.0	A	
	-2	50-100		2.9		42.5	0.49	1.2		
S109	-1	0-50	Gl-r	1.4	II	33.5	0.52	1.6	A	
	-2	50-100		3.2		40.8	0.49	1.2		
S110	-1	0-50	Gl-r	4.3	II	30.8	1.25	4.1	A	
	-2	50-100		3.3		39.3	0.43	1.1		
S111	-1	0-50	Gl-r	1.4	1	34.8	0.31	0.9	A	
	-2	50-100		2.1		39.8	0.30	0.8		
S112	-1	0-50	Gl	2.7	II	36.0	0.27	0.8	A	
	-2	50-100		3.6		40.8	0.23	0.6		
S113	-1	0-50	Qr-s	1.6	II	34.5	0.35	1.0	A	
	-2	50-100		3.1		37.5	0.76	2.0		
S114	-1	0-50	Gl	1.4	II	33.3	0.30	0.9	A	
	-2	50-100		3.1		39.0	0.35	0.9		
S115	-1	0-50	Qr-s	2.5	11	35.5	0.27	0.8	A	
	-2	50-100		3.0		37.5	0.15	0.4		
S116	-1	0-50	Gl-r	2.2	II	33.8	0.21	0.6	A	
	-2	50-100		2.9		38.0	0.20	0.5		
Sample Area 2										
S202	-1	0-50	Mc	2.7	II	25.3	0.10	0.4	A	1.9
	-2	50-100		3.4		30.3	0.26	0.9		1.9
S202	-1	0-50	Gl	1.4	II	24.2	0.14	0.6	A	0.6
	-2	50-100		3.0		33.0	0.31	0.9		1.7
S203	-1	0-50	Mc	1.7	II	21.9	0.19	0.9	A	0.7
	-2	50-100		2.5		29.5	0.39	1.3		1.1
S204	-1	0-50	Qr	2.3	I	22.5	0.31	1.4	A	0.5
	-2	50-100		1.4		26.5	0.37	1.4		0.4
S205	-1	0-50	Qr-s	1.5	II	23.4	0.14	0.6	A	0.5
	-2	50-100		2.5		31.0	0.30	1.0		1.4
	-3S	100-150		3.4		-	-	-		
	-4S	150-250		4.4		-	-	-		
	-5S	250-350		4.8		-	-	-		

TABLE C.9 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na^+	ESP	Class	
S206	-1	0-50	Gl	1.4	I	28.5	0.28	1.0	A	0.7
	-2	50-100		1.7		31.2	0.30	1.0		0.7
S207	-1	0-50	Gl	1.6	II	28.5	0.29	1.0	A	0.5
	-2	50-100		2.9		31.2	0.42	1.3		0.9
S208	-1	0-50	Qr	1.7	I	25.8	0.18	0.7	A	0.5
	-2	50-100		1.5		29.8	0.32	1.1		0.6
S209	-1	0-50	Gl	1.2	I	38.8	0.42	1.1	A	0.7
	-2	50-100		1.2		29.3	0.23	0.8		0.6
S210	-1	0-50	Qr-s	2.4	I	24.1	0.19	0.8	A	0.9
	-2	50-100		1.1		30.2	0.23	0.8		0.6
S211	-1	0-50	Gl	2.5	II	29.9	0.28	0.9	A	1.0
	-2	50-100		2.1		31.0	0.36	1.2		0.8
S212	-1	0-50	Gl	2.2	I	28.7	0.32	1.1	A	0.9
	-2	50-100		2.1		34.2	0.39	1.1		0.9
S213	-1	0-50	Gl	1.6	I	28.8	0.23	0.8	A	0.8
	-2	50-100		1.2		32.6	0.38	1.2		0.7
S214	-1	0-50	Qr-s	1.7	I	30.0	0.29	1.0	A	0.8
	-2	50-100		1.9		36.7	0.53	1.4		0.8
S215	-1	0-50	Qrs-r	2.3	II	29.4	0.34	1.2	A	0.6
	-2	50-100		2.8		36.8	0.40	1.1		
SampleArea 3										
S301	-1	0-50	Sr	1.4	II	30.7	0.18	0.6	A	0.7
	-2	50-100		3.0		38.5	0.20	0.5		2.0
	-3	100-150		3.4		-	-	-		3.0
S302	-1	0-50	Sr-g	1.8	II	33.7	0.03	0.1	A	1.0
	-2	50-100		3.8		38.2	0.36	0.9		3.3
	-3	100-150		3.3		-	-	-		2.5
S303	-1	0-50	Sr-g	1.3	II	34.5	0.23	0.7	A	0.7
	-2	50-100		3.4		35.0	0.31	0.9		2.1
	-3	100-150		4.0		-	-	-		3.4
S304	-1	0-50	Sr-g	1.6	II	-	-	-	A	-
	-2	50-100		3.5		37.0	0.37	1.0		3.1
	-3	100-150		4.2		-	-	-		3.9
S305	-1	0-50	Sr-g	4.1	II	40.3	0.38	0.9	A	3.2
	-2	50-100		3.2		36.0	0.38	1.1		2.2
	-3	100-150		2.2		-	-	-		1.2
S306	-1	0-50	Sr	1.4	I	30.8	0.19	0.6	A	0.6
	-2	50-100		1.5		35.3	0.23	0.7		0.9
	-3	100-150		1.4		-	-	-		0.7
S307	-1	0-50	Sr	0.9	I	32.9	0.21	0.6	A	0.5
	-2	50-100		1.5		36.2	0.40	1.1		0.8
	-3	100-150		1.1		-	-	-		0.6
S308	-1	0-50	Sr	1.3	II	33.5	0.26	0.8	A	0.6
	-2	50-100		3.6		38.7	0.42	1.1		2.6
	-3	100-150		4.0		-	-	-		3.5
S309	-1	0-50	Sr-g	2.7	II	32.9	0.27	0.8	A	2.2
	-2	50-100		3.3		34.6	0.23	0.7		3.0
	-3	100-150		2.4		-	-	-		1.4

TABLE C.9 (cont.)

Site number		Sample depth (cm)	Series	Salinity		Exchangeable Sodium				Land use
				ECe	Class	CEC	Na^+	ESP	Class	
S310	-1	0-50	Sr-g	1.2	II	31.5	0.25	0.8	A	0.6
	-2	50-100		3.3		39.0	0.32	0.8		2.6
	-3	100-150		4.1		-	-	-		3.5
S311	-1	0-50	Sr	1.2		32.1	0.16	0.5	A	0.6
	-2	50-100		1.2		32.3	0.19	0.6		0.6
	-3	100-150		2.0		-	-	-		1.0
S312	-1	0-50	Sr	1.1	I	32.5	0.18	0.6	A	0.6
	-2	50-100		1.3		35.8	0.31	0.9		0.7
	-3	100-150		1.4		-	-	-		0.8
S313	-1	0-50	Sr	1.8	I	-	-	-		0.7
	-2	50-100		1.4		-	-	-		0.8
	-3	100-150		3.5		-	-	-		2.9
S314	-1	0-50	Sr-g	1.8	I	-	-	-		0.9
	-2	50-100		2.1		-	-	-		-
	-3	100-150		3.4		-	-	-		3.1
S315	-1	0-50	Sr	1.1	I	-	-	-		0.6
	-2	50-100		1.0		-	-	-		0.6
	-3	100-150		-		-	-	-		-

TABLE C.10

Groundwater Salinity[1]

Soil series and site no.	Depth of water table (cm)	Electrical conductivity (micromho/cm)	Land use category[2]
Golweyn			
R29	198	23 000	4
R39	140	7 800	4
R50	50	5 550	4
D362	50	9 600	3
Majabto			
D366	60	14 890	2
R37	180	14 000	3
D312	100	4 420	3
Qoryooley			
R32	250	2 600	3
R17	270	7 200	3
R23	160	6 200	4
R11	360	4 100	2
R13	280	3 820	4
R406	100	4 800	4
Gayweerow			
R47	140	4 950	4
R24	60	5 400	3
D360	50	3 940	1

Notes: (1) Samples collected from auger holes at water table level.

(2) Categories as in Annex IV: 1 - uncultivated, 2 - marginal annual crops, 3 - irrigated annual crops, 4 - irrigated perennial crops.

C.5 Mineralogical Analyses

Analyses were performed on subsoil samples from profiles of Madhuulow and Saruda series to determine the mineralogical composition of the two principal soil parent materials, namely semi-recent and old alluvium.

The analyses were carried out by staff of the Rothamsted Experimental Station, Harpenden, UK. Ground whole samples from the 100 to 150 cm horizons of profiles R63 (Madhuulow series) and R64 (Saruda series) were examined by X-ray diffraction in the air dry condition, after treatment with ethylene glycol and heating at 360°C and 520°C.

The results of the analyses showed that the parent materials are essentially similar in their principal components, which comprise calcite, quartz and clay minerals. The semi-recent alluvium sample also contained gypsum. Similarly, both samples contain the same suite of clay minerals, namely interstratified illite-smectite (in which 50 to 70% comprises smectite layers), illite and kaolinite with a trace of chlorite. However, the relative proportions of the clay minerals differ between samples. The Madhuulow subsoil clay contains more illite and kaolinite and less illite-smectite than the old alluvium of Saruda series.

Smectite (or montmorillonite) and illite are both 2 : 1 lattice clay minerals but smectite has weak bonding between layers which results in its ability to expand and contract in response to addition and loss of moisture. Expansion and contraction are prevented by stronger cation linkages between layers in the case of illite and by the rigid 1 : 1 lattice structure in kaolinite. The more stable conchoidal blocky structure observed in the lower horizons of soils derived from semi-recent alluvium may, therefore, be due to the higher proportions of non-expanding - lattice clays in this alluvium.

The derived CEC values for the clays in each sample (Table C.11) are consistent with the differing clay mineralogy. Smectite typically has CEC values in the range 80 to 150 meq/100 g as compared with 10 to 40 for illite and 3 to 15 for kaolinite. The relatively low CEC values of the clay in profile R63, as compared with the total clay content, are probably a consequence of the higher proportions of illite and kaolinite. The higher CEC values of the clay in profile R64 can be related to the higher proportions of smectite in this soil.

TABLE C.11

Clay and CEC Values

Sample	Series	Percentage clay	CEC of clay (meq/100 g)
R63	Madhuulow	80	43.5
R64	Saruda	53	58.5

APPENDIX D

SOIL PHYSICAL TEST RESULTS

D.1 Moisture Retention and Available Water

D.1.1 Introduction

The available water capacity (AWC) of a soil is defined as that portion of the total water holding capacity which is available to roots to sustain plant life. To absorb water from the soil, the plant has to overcome the matric suction forces which hold the water in the soil. These forces increase with decreasing soil moisture content, from the point where water is freely available, the lower limit of availability, to the point where the plant is no longer able to extract moisture rapidly enough to sustain life, the permanent wilting point or upper limit of availability. The difference between soil moisture contents at these two limits provides an estimate of the AWC of the soil. The limits are usually expressed in terms of the suction head against which the water is held in the soil, measured in bars (1.0 bar is equivalent to a head of 10 m of water or 0.76 m of mercury).

The preceding definitions refer to the moisture contents retained against soil matric suctions and take no account of the additional retention forces due to osmotic suction arising from dissolved salts in the soil solution. The presence of soluble salts effectively reduces moisture availability in proportion to the level of salinity at the prevailing moisture content. In general, the osmotic suction is about 0.36 bar for every 1.0 mmho/cm of EC; moreover, as moisture contents in the soil decrease so the EC of the soil solution increases. For example, in the soils under study, an ECe of 2.5 mmho/cm could contribute an additional osmotic suction of nearly 1.0 bar at saturation (0 bar matric suction) but at a matric suction of 15 bar the EC could be expected to increase by 40 to 45%, due to the concentration of salts causing an additional osmotic suction of 1.3 bar at permanent wilting point.

D.1.2 Definition of AWC Parameters

In order to estimate the AWC of a soil it is first necessary to define the upper and lower limits of availability. The upper suction limit, or permanent wilting point, is generally accepted as being the moisture retained against a suction of 15 bar. The lower limit is more difficult to define, especially in fine textured Vertisols. This limit is conventionally defined as field capacity (FC), being the moisture content at which a previously saturated soil ceases to drain under gravity. However, the concept of field capacity is not applicable to Vertisols (Fox, 1964; Farbrother, 1972) as there is no distinct point at which depletion of moisture under gravity ceases. On the basis of studies of the behaviour of soils in the Sudan Gezira, Farbrother (1972) recommended the acceptance of 0.0 bar (saturation) as the lower limit of availability in Vertisols, giving AWC as the difference between 15 bar and 0.0 bar retentions.

Tests carried out during the present study confirmed the absence of a clearly defined FC moisture content (Section D.1.4); the 0.0 bar retention values were therefore adopted as the low limit of moisture availability. For soils other than Vertisols, the conventional limit of 0.1 bar retention was used.

Having defined the available water limits it should also be stressed that moisture is not equally available to plants over the whole range. At higher suctions, usually above 1.0 bar, it becomes increasingly difficult for the roots to extract water at a rate sufficient to maintain active growth; similarly, at low suctions, below 0.1 bar, aeration of the soil is progressively reduced and root growth restricted, resulting in reduced rates of uptake by the plant.

Pidgeon (1972) proposed the use of easily available water capacity (EAWC) to indicate the range over which moisture stress is least and optimal growth can be expected. The EAWC is defined as the moisture held between suctions of 0.1 and 1.0 bar.

D.1.3 Results of Moisture Retention Tests

These tests were conducted in the laboratory using the methods described in Appendix B. A total of 40 samples were collected from the major horizons of 12 profile pits representative of the principal soil series. Complete results are given in Table D.1.

The data in Table D.1 are expressed as gravimetric soil moisture contents; to assess the quantity of water available for plant growth and for the determination of irrigation intervals it is essential to know the volume of water available. In 'normal' soils this conversion can be achieved by multiplying the gravimetric percentage by the bulk density to give the volumetric percentage (or cm per metre of soil). However, in Vertisols the bulk density of the soil varies with the moisture content (Fox 1964; Farbrother, 1972; Fadl and Ali, 1977) and consequently no single volume can be used to calculate volumetric moisture contents. Farbrother (1972) proposed the use of standard bulk density values for different moisture contents and depths in the profile. However, Farbrother's bulk density values are significantly lower than those for the present Study Area. Similarly, provisional data for Shabeelle Flood Plain Vertisols at the Jowhar sugar estate (MMP, 1978) indicate that bulk densities at different moisture contents are consistently higher than in Sudanese Vertisols. Increasing Farbrother's values by a factor of 10% provides more realistic bulk density values which are comparable with the Jowhar results and more compatible with the values in Table D.1 in relation to the probable moisture contents at which they were sampled. Conversion factors, increased by 10%, are given in Table D.2.

The AWC and EAWC characteristics of the soils tested have been calculated on a volumetric basis (Table D.3) using the conversion factors in Table D.2 and the gravimetric moisture retention percentages (Table D.1). It should perhaps be emphasised that the conversion from gravimetric to volumetric moisture contents in Vertisol clays is only approximate. To assist in the interpolation between values in Table D.2, a set of curves was drawn relating bulk density, moisture content (w/w) and depth in the profile. The results presented in Table D.3 are therefore approximate values for volumetric moisture content based on considerable interpolation but they are probably more realistic than values calculated from a single bulk density value. For horizons in which expanding lattice clays do not predominate, silt loams, clay loams, loams, volumetric values were calculated according to the conventional method, using the single measured bulk density figure and the 0.1 bar retention as the lower limit of moisture availability.

Moisture release curves have been drawn for four representative profiles and are included in the main text (Figure 4.1).

TABLE D.1

Moisture Retention Percentages (w/w)

Series profile and depth (cm)		Bulk density (g/cm^3)	Moisture retention %w/w					Soil texture
			0 bar	0.1 bar	0.3 bar	1.0 bar	15 bar	
Saruda								
R 38	0 - 20	1.33	55.1	36.8	33.0	30.8	26.8	C
	20 - 95	1.49	44.5	35.2	33.2	31.7	25.7	C
	95 - 160	1.24	42.5	37.4	36.0	34.6	27.9	C
R 62	0 - 35	1.47	40.6	34.6	31.3	28.7	22.4	C
	35 - 90	1.52	40.7	34.2	31.1	28.6	24.6	C
	90 - 140	1.48	40.6	35.0	33.3	31.1	25.0	C
Golweyn								
R 50	0 - 35	1.37	46.0	35.2	31.4	28.7	21.5	C
	35 - 90	1.54	37.3	33.7	31.2	28.9	23.3	C
	90 - 150	1.65	35.2	33.2	31.8	30.2	25.5	C
R 39	0 - 20	1.41	47.8	33.0	28.8	26.8	21.7	C
	20 - 50	1.63	36.2	30.2	28.4	26.8	22.6	C
	50 - 150	1.49	43.5	37.3	35.9	34.0	27.2	SiC
Majabto								
R 37	0 - 20	1.28	53.7	37.1	30.6	28.0	23.2	CL
	20 - 70	1.58	41.4	34.0	32.5	30.9	28.3	C
	70 - 150	1.43	42.2	35.6	33.7	31.8	23.0	SiL
Madhuulow								
R 63	0 - 25	1.30	58.3	44.2	36.9	34.0	26.9	C
	25 - 75	1.40	54.2	42.6	40.6	38.4	31.2	C
	75 - 105	1.54	45.5	39.4	37.7	36.0	30.9	C
	105 - 160	1.55	43.7	39.4	38.2	36.5	30.1	C
Qoryooley								
R 56	0 - 25	1.37	47.5	39.6	35.1	32.9	25.6	C
	25 - 70	1.43	46.6	37.2	35.2	33.5	28.1	C
	70 - 110	1.58	36.6	32.4	30.3	28.0	25.5	C
R 13	0 - 20	1.63	40.2	34.2	32.2	30.4	25.3	SiC
	20 - 85	1.60	43.1	35.1	32.8	31.5	25.3	SiC
	85 - 200	1.72	44.5	41.4	40.5	38.8	34.4	C
	85 - 200	1.67	44.8	41.8	40.6	38.7	34.3	C

TABLE D.1 (cont.)

Series profile and depth (cm)		Bulk density (g/cm³)	Moisture retention % w/w 0 bar	0.1 bar	0.3 bar	1.0 bar	15 bar	Soil texture
Qoryooley (cont.)								
R 17	0 - 25	1.46	46.7	40.7	36.6	34.4	28.8	C
	25 - 105	1.47	49.8	40.5	39.1	37.8	38.9	C
	105 - 125	1.51	42.7	40.8	40.2	39.5	34.7	C
	125 - 150	1.86	34.2	31.9	30.3	29.8	23.9	C
R 21	0 - 20	1.21	59.8	41.7	35.5	31.6	21.8	SiCL
	20 - 55	1.43	43.0	32.0	29.3	27.8	21.5	C
	55 - 130	1.49	41.8	34.1	31.5	30.3	23.1	C
Mukoy Dumis								
R 33	0 - 30	1.27	50.0	34.9	29.7	27.6	20.2	CL
	30 - 105	1.44	38.8	33.1	30.9	29.2	19.2	SiL-L
	105 - 130	1.58	43.6	39.0	37.8	36.7	28.2	C
Gayweerow								
R 47	0 - 35	1.61	39.4	33.7	31.5	29.7	21.8	SiC
	35 - 65	1.51	32.5	27.5	20.2	13.8	7.6	L
	65 - 80	1.38	36.9	32.9	31.1	28.6	19.3	SiL
	80 - 150	1.46	33.1	29.2	25.0	20.6	11.6	SiL

TABLE D.2

Bulk Density Values for Vertisols

Percentage moisture (w/w)	Depth of sample (cm) 0 to 40	40 to 60	60 to 80	80 to 100	100 to 200
50	1.22	1.24	-	-	-
40	1.27	1.31	1.38	1.42	1.43
30	1.31	1.39	1.45	1.52	1.54
20	1.35	1.45	1.61	1.68	1.69
10	1.38	1.49	1.68	-	-
0	1.38	-	-	-	-

TABLE D.3

Soils Available Water Capacity

Soil series and profile no.	Sample depth (cm)	AWC Horizon (%)	AWC Upper 1.0 m (mm)	EAWC Horizon (%)	EAWC Upper 1.0 m (mm)
Saruda (Sr)					
R 38	0 - 20	30.2	226	6.8	44
	20 - 95	20.9		3.9	
	95 - 160	18.6		3.0	
R 62	0 - 35	21.5	197	6.9	65
	35 - 90	18.7		6.6	
	90 - 140	18.6		4.2	
Golweyn (Gl)					
R 50	0 - 35	28.4	202	7.8	59
	35 - 90	16.7		5.2	
	90 - 150	11.1		3.2	
R 39	0 - 20	29.7	204	7.3	46
	20 - 50	16.2		4.2	
	50 - 150	19.2		3.7	
Majabto (Mt)					
R 37	0 - 20	17.8	163	11.7	58
	20 - 70	14.8		3.7	
	70 - 150	17.9		5.4	
Madhuulow (Mw)					
R 63	0 - 25	33.3	237	11.5	60
	25 - 75	22.5		4.3	
	75 - 105	16.6		4.0	
	105 - 160	15.4		2.6	
Qoryooley (Qr)					
R 56	0 - 25	24.4	194	7.5	52
	25 - 70	20.8		4.0	
	70 - 110	13.1		5.2	

TABLE D.3 (cont.)

Soil series and profile no.	Sample depth	AWC		EAWC	
		Horizon	Upper 1.0 m	Horizon	Upper 1.0 m
	(cm)	(%)	(mm)	(%)	(mm)
Qoryooley (cont.)					
R 13	0 - 20	17.5	182	4.6	39
	20 - 85	20.1		3.9	
	85 - 200	11.2		3.1	
R 17	0 - 25	19.4	189	6.6	38
	25 - 105	18.7		2.9	
	105 - 125	9.2		1.5	
	125 - 150	12.8		2.2	
R 21	0 - 20	23.3	229	11.1	39
	20 - 55	24.6		4.9	
	55 - 130	21.5		1.6	
Mukoy Dumis (Mc)					
R 33	0 - 30	18.6	197	9.2	68
	30 - 105	20.6		5.7	
	105 - 130	17.9		1.8	
Gayweerow (Gw)					
R 47	0 - 35	19.2	237	6.5	119
	35 - 65	30.0		20.7	
	65 - 80	18.8		5.9	
	80 - 150	25.7		12.5	

Note: AWC = Available water capacity

EAWC = Easily available water capacity.

Values are in volumetric terms.

D.1.4 Field Capacity Tests

Tests were conducted to ascertain whether field capacity is a valid concept in these soils. Two test sites were selected, one on Saruda series (R62) and the other on Qoryooley series.

The soil surface was bunded (1.5 x 1.5 m) and about 1 000 litres of water was applied to the basin so formed, ensuring complete saturation of the upper profile. The surface was then covered with polythene sheeting and allowed to drain. The polythene eliminated upward evaporative movement of moisture so that all subsequent changes in soil moisture could be attributed to movements in response to gravity and hydraulic gradients. Using an auger, soil samples were collected at two-day intervals following saturation of the basin, and moisture contents were determined gravimetrically. Field capacity is considered to be the moisture content to which an initially saturated soil drains under gravity. In the current tests there was no inflection in the moisture depletion curves (Figure D.1) that could be associated with a field capacity value, showing that there is no apparent transition from 'gravity' to 'hydraulic gradient' drainage in these soils.

D.2 Aggregate Stability

D.2.1 Introduction

The stability of soil structural aggregates when wet can affect significantly the water intake characteristics of a soil. The soils of the Study Area are either Vertisols or show the Vertisol properties of cracking when dry and forming prominent blocky, wedge or prismatic structural aggregates. The soils derived from recent and semi-recent alluvium have especially strongly developed conchoidal blocky structural units in their sub-surface horizons.

Tests were conducted to assess the degree of stability of the soil structure when wet and also to compare the stability of aggregates from the old alluvium soils with those from soils derived from younger alluvium.

D.2.2 Methods

The method of wet sieving dry aggregates was used (Kemper and Koch, 1966). Bulk samples of aggregates (1.0 to 1.5 kg) were collected from dry soil profiles at fixed depths (0 to 50, 50 to 100, 100 to 150 cm). Three profiles were selected from the old alluvium soils (R67 and R62, Saruda; R66, Golweyn series) and three derived from younger alluvium, displaying conchoidal blocky structure (R70 and R57, Mukoy Dumis; R63, Madhuulow series).

Samples were air-dried, weighed and then soaked with normal irrigation water for a period of five hours. Each sample was then transferred to a 2 mm sieve and washed to remove the fine material. The remaining coarse aggregates were air-dried and weighed to assess the percentage of aggregates remaining.

D.2.3 Results

On addition of water, virtually all structural aggregates disintegrated due to slaking. Attempts to measure remaining aggregates proved to be impossible as the slaked mass of the sample prevented effective washing of any remaining structural units.

The tests were therefore conclusive in confirming the very low aggregate stability of the soils and showed that individual structural units disintegrate rapidly when saturated and subjected to even minimal aggressive treatment. Similar observations have been reported in Kenya (Croon, 1978) where irrigation is practised on Vertisols. However, some differences were recorded between the two soil groups: samples of the Saruda and Golweyn series slaked completely and formed a near impermeable seal to the sieve, whereas the soils with conchoidal blocky structure retained a few fine blocky units and water was still able to penetrate through the sieve.

This rather tenuous evidence suggests that the soils derived from recent and semi-recent alluvium do have a marginally greater aggregate stability and better infiltration properties than the soils of the old flood plain alluvium, possibly resulting from higher proportions of non-expanding lattice clay contents (Appendix C, Section C.5). It is probable that drainage would be more efficient on the former but that mole drainage techniques are nowhere suitable.

Structure development in Vertisols is seen to be an ephemeral feature, dependent almost exclusively upon the moisture and pressure conditions in the profile. However, it should be emphasised that these tests were performed by wetting individual peds; expansion forces within the peds due to swelling of the clays was unrestrained by adjacent peds and slaking occurred. In the natural in situ condition, expansion would be limited by the surrounding soil volume, resulting in a build up of compression in the soil; slaking would occur only if this natural compression was relieved.

D.3 Infiltration

D.3.1 Methods

In soils which show the Vertisols characteristics of deep cracking in the dry state, reliable estimates of infiltration characteristics can be difficult to achieve as rates of water entry can be largely influenced by the volume of cracks and, consequently, the moisture content of the soil at the start of the test. Three methods of measurement were selected for use in the area:-

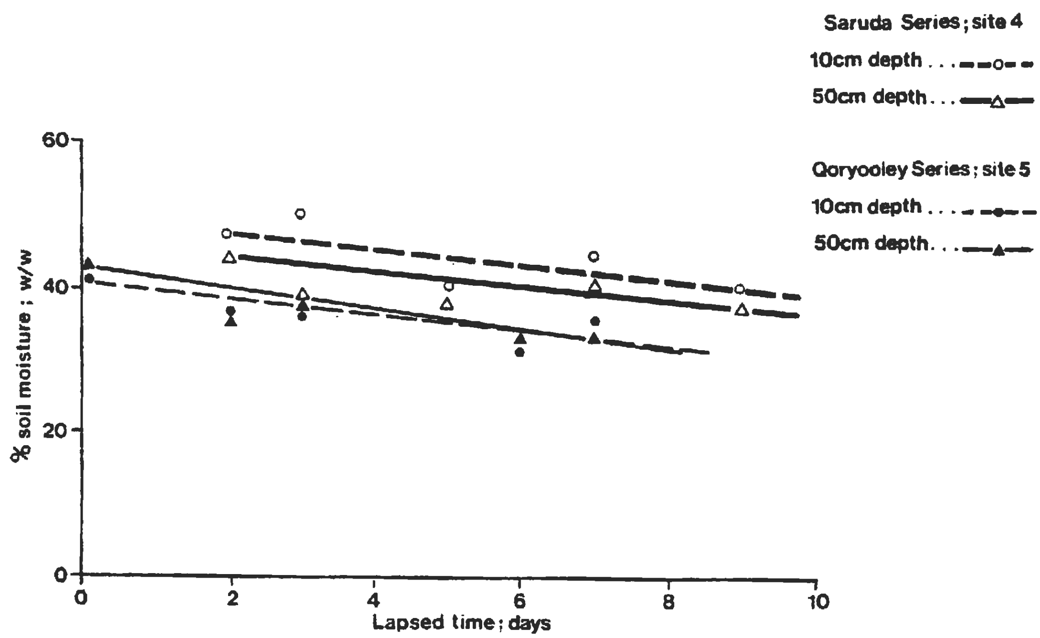
(a) Double-ring Infiltrometers

This method employs two metal cylinders of 300 and 600 mm diameter, arranged concentrically, and pushed into the soil surface to a depth of some 50 mm. Water was added to the inner and outer ring and records were kept of the volumes of water which were required to be added to the central ring to maintain a constant head of 100 mm. The water in the outer ring was maintained at the same level. Cumulative intake (mm) was recorded against time.

(b) Basin Tests

This method involves the flooding of a relatively large area of soil surface and recording the rate of entry of water over time. A wooden frame 1.8 x 1.7 m (approximately 3 m^2) was laid on the soil surface and a seal effected by embedding a strip of polythene sheeting into the soil beneath the frame. A bund was then constructed around the frame, some 60 cm remote from it, to form an outer basin. Water was applied to both the inner and outer basins and a record was then kept of the volume added to the central basin. Water flows via cracks between the inner and outer basins were assumed to be self-compensating and were ignored for the purposes of calculating the total additions of water over time.

FIELD CAPACITY TESTS



Note: Lapsed time after surface saturation and covering with plastic sheeting to prevent evaporation loses.

Once the main intake capacity of the soil was satisfied, the test continued by recording additions required to maintain the water level of the central basin at 50 mm depth. Infiltration was recorded as cumulative intake against time.

(c) 'Hill' Infiltrometers

The method employs small steel infiltrometer cylinders, 100 mm in diameter, which are forced a depth of 50 mm into the soil surface. These cylinders are fed with water from a plastic reservoir via a constant head device. The decline in level of water in the reservoir is proportional to the rate of intake of water into the soil (Hill, 1971) and expressed as cumulative intake against time.

D.3.2 Results and Discussion

The results obtained from each of the three test methods showed considerable variations, due largely to the variability of lateral flow losses via vertical cracks beneath the test site. The reliability of measurement therefore depends upon the effectiveness with which these lateral losses can be eliminated.

(a) Double-ring Infiltrometers

The use of the outer ring is intended to eliminate the lateral movement of water from the central ring and therefore provide a more accurate estimate of vertical intake. The method is widely used but on Vertisols the rings frequently can straddle vertical cracks, resulting in very considerable lateral losses of water from both rings. The results of tests on an initially dry, cracked soil of Qoryooley series (Figure D.2) indicate a cumulative intake of 150 to 190 mm over a seven hour period. However, a large proportion of the intake in the early stages of the tests resulted from lateral flow from both rings via sub-surface cracks and the results should therefore be used with caution.

(b) Basin Tests

By increasing the area of soil surface tested the method more closely simulates field conditions. However, without an effective deep seal around the test area, considerable lateral losses occurred, although flows between the central basin and outer basin are to some extent self-compensating. The test was performed on an initially dry and deeply cracked Saruda series soil (Site R62) and provided information on the method of water entry as well as an estimate of the total infiltration capacity of a dry soil.

Initial application of water resulted in flushing the surface mulch into the cracks, exposing several new cracks in the process. Considerable sub-surface flow occurred between the inner and outer basins as well as several metres outwards from the test area. Cracks became plugged at a depth of 25 to 30 cm and ceased to drain effectively after about 300 mm of water had been added. This represents the end of an initial phase of wetting, during which moisture entry occurs under gravity. Subsequently, the soil between the major cracks became wetted as part of a second stage of wetting, in which the rate of entry of water is dependent upon hydraulic gradients in the soil.

The test showed (Figure D.3) that some 490 mm of water infiltrated over a 27 hour period, of which 420 mm entered in the first five hours. It is probable that much of this initial entry represents net outward losses via cracks; a total of 250 to 300 mm would probably be a more realistic estimate of initial intake capacity. Once the soil was wetted, infiltration proceeded at the rate of some 50 mm over a seven hour period.

Figure D.4 shows that even these relatively large applications of water had little effect on the soil moisture content below a depth of 75 cm. Within this zone the available water capacity is calculated to be 150 mm (Section D.1); cracking evidently accounts for at least a further 100 mm of capacity in this depth.

(c) 'Hill' Infiltrometers

These tests are easy to perform and require little supervision. The standard correction curves for lateral seepage were developed for European soils and therefore may not be fully applicable to Vertisols. Nevertheless, the method produced consistent and reproducible results; it was therefore adopted for use in the study. Some 50 tests were performed on different soil series at 30 sites. Mean values for cumulative intake against time (Figures D.5 to D.7) show that the soils are capable of infiltrating about 75 to 95 mm of water over a seven hour period. In the case of the soils on old alluvium (Saruda and Golweyn) the rate of intake decreases to near zero after six hours but on the recent and semi-recent alluvial soils (Madhuulow, Qoryooley) the rate is still 5 to 10 mm/h at this stage.

These results are lower than those obtained by other tests but they are considered to represent more closely conditions prevailing under a normal irrigation regime, in which cracks would not be present to assist infiltration.

In conclusion, cumulative infiltration into a dry, cracked soil is estimated to be about 300 mm in five hours. Under a normal irrigation regime, in which soil cracking does not significantly aid infiltration, the eight hours intake capacity of the soils is 75 to 85 mm.

D.4 Soil Cracking Pattern

Under normal field conditions, Vertisols form deep vertical cracks as soil moisture is depleted, due to shrinkage of the constituent 2 : 1 lattice clays. These cracks permit rapid entry of irrigation water but as the soil moisture content rises so the clays re-expand and the cracks close. On subsequent drying the cracks re-form. For the purpose of irrigation and drainage, the formation of cracks is significant for three possible reasons:-

(a) Initial entry of irrigation water

(b) Aeration of the soil profile

(c) Improvement of profile drainage.

The tests reported in Section D.3 showed that the cracks are responsible for rapid entry of water under gravity into an initially dry profile and can absorb up to 300 mm of moisture. However, cracks have been observed to form only at moisture suctions near the upper limit of water availability (Section D.5) and therefore cannot be considered beneficial in a normal irrigation regime unless crops are allowed to suffer extreme moisture stress. They therefore can be expected to have minimal practical effect on soil aeration under irrigation.

FIGURE D.2

INFILTRATION - DOUBLE-RING TESTS

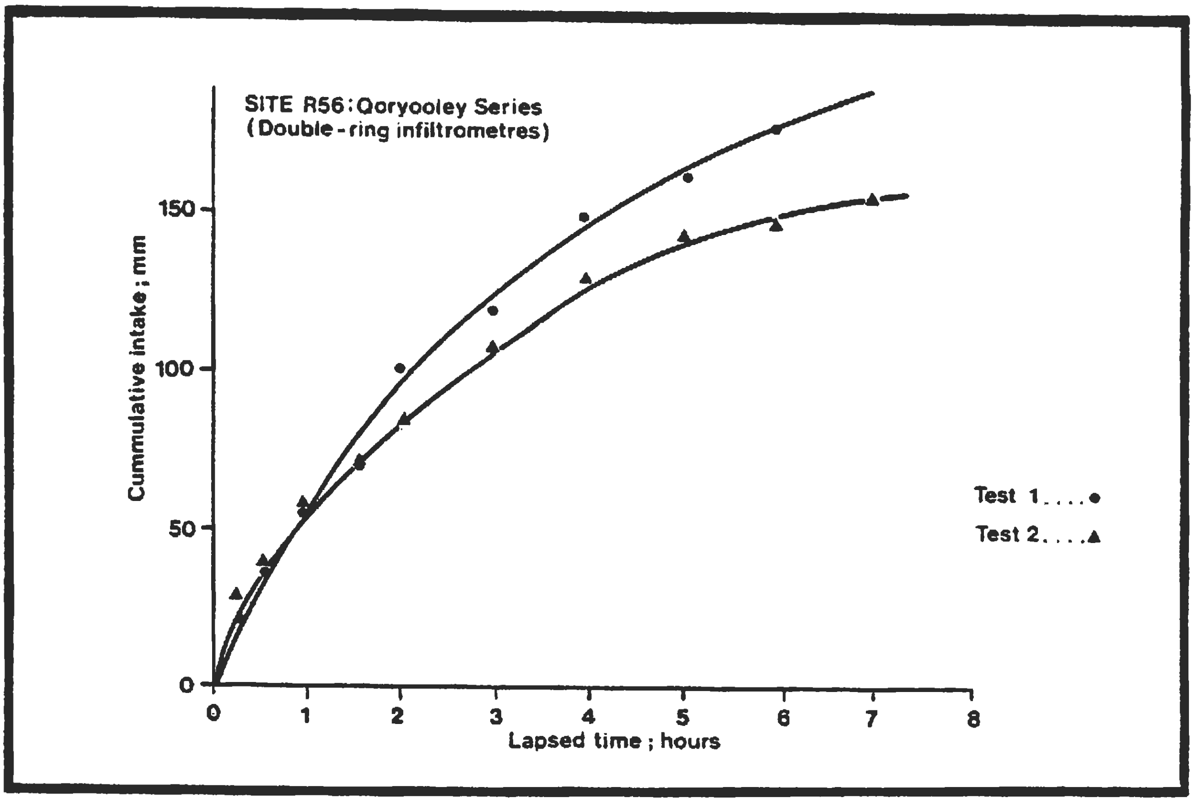
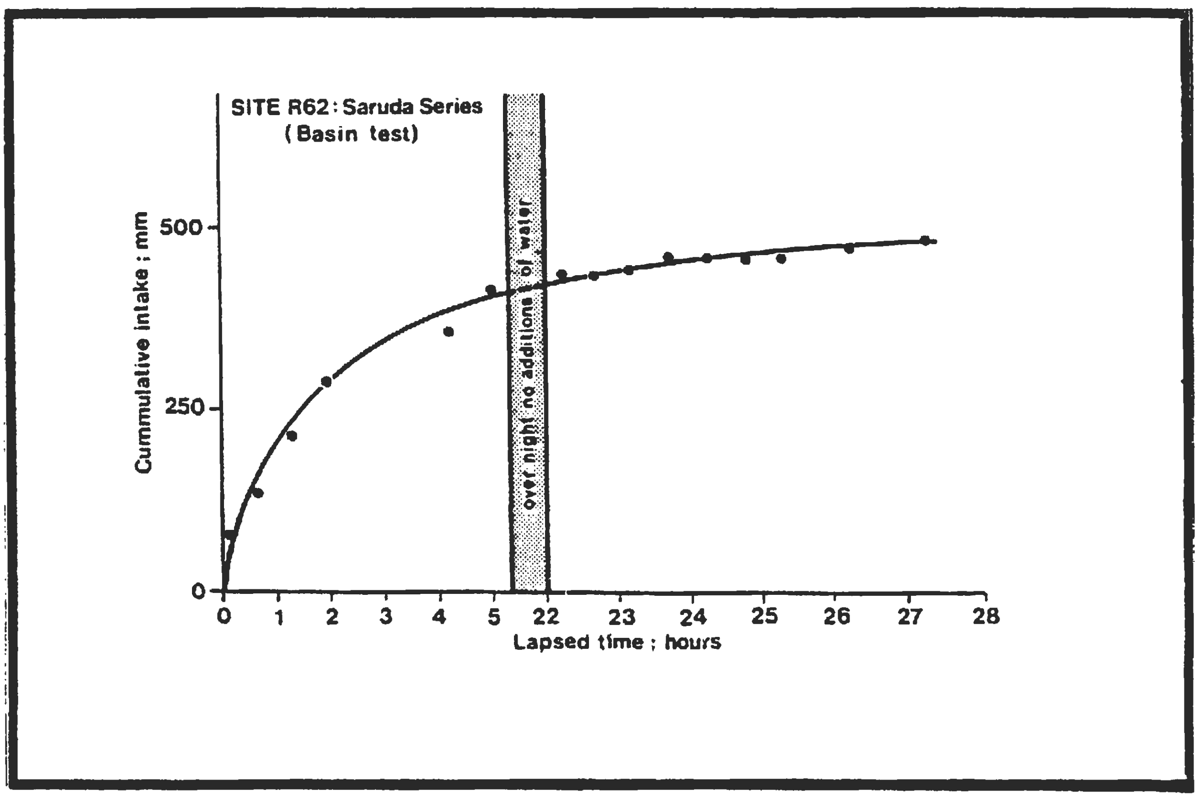
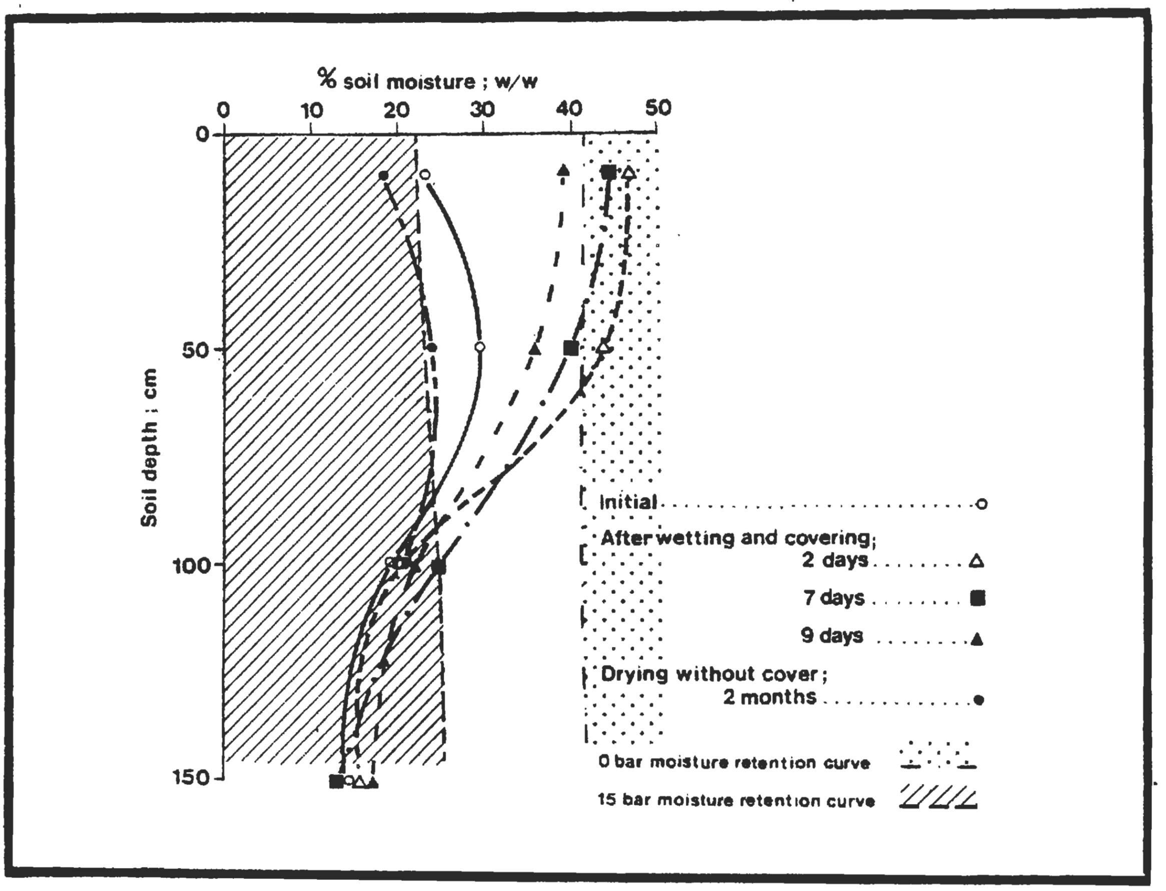


FIGURE D.3

INFILTRATION - BASIN TESTS

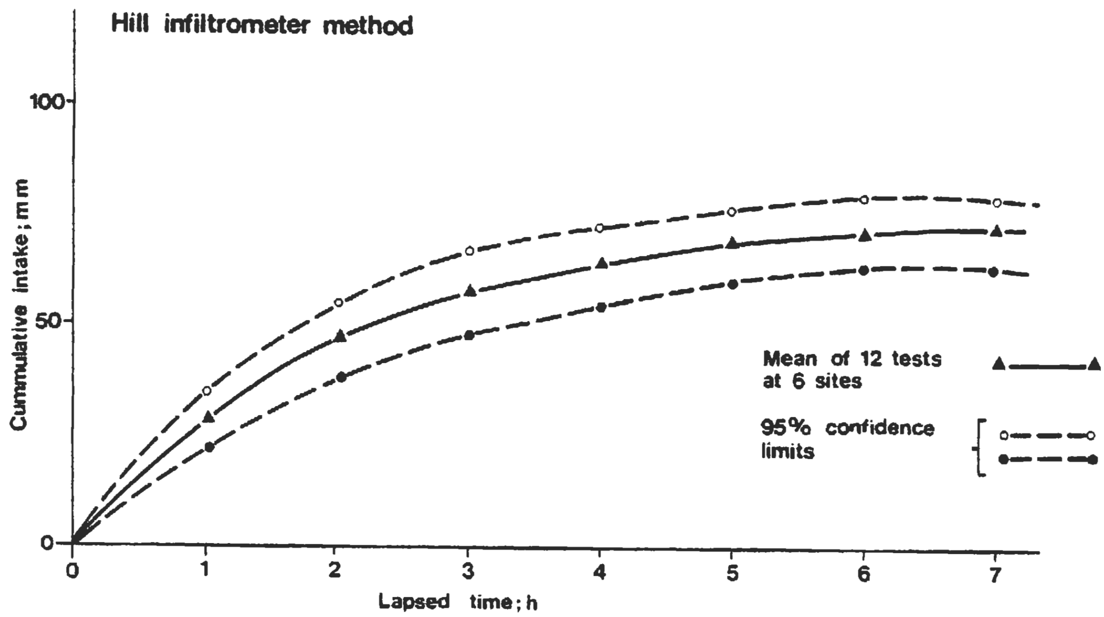


MOISTURE PENETRATION - BASIN INFILTRATION TEST



INFILTRATION – HILL METHOD

SARUDA SERIES



GOLWEYN SERIES

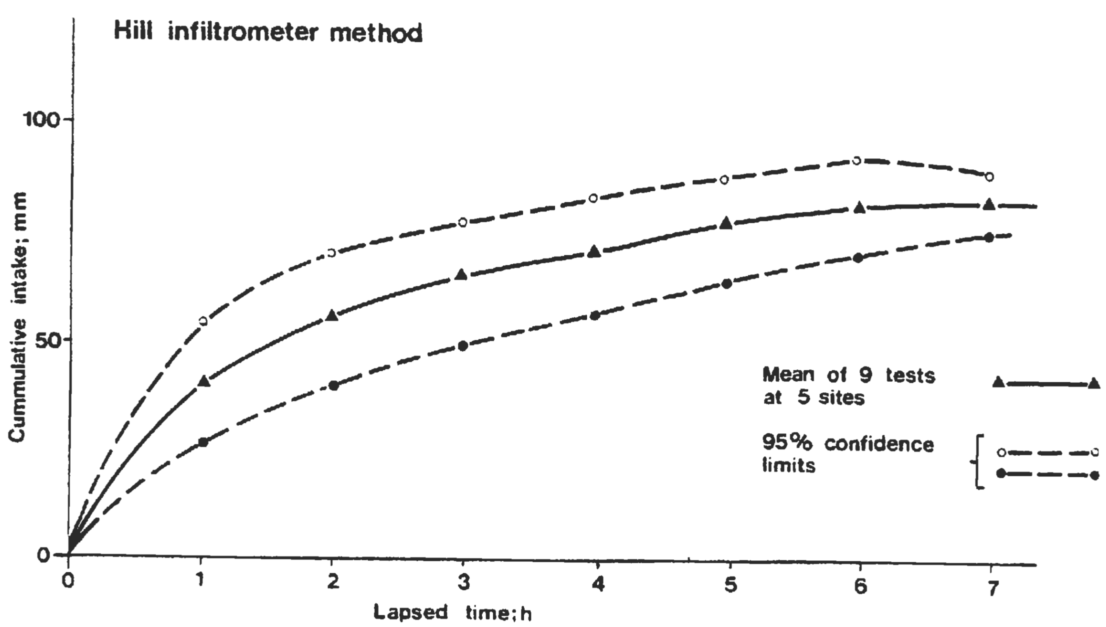
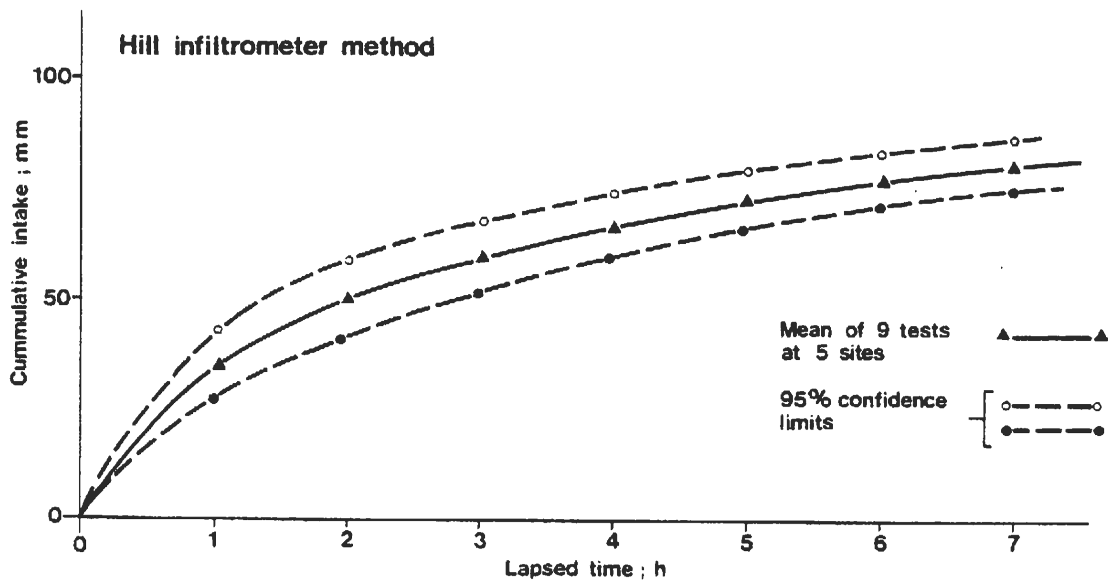


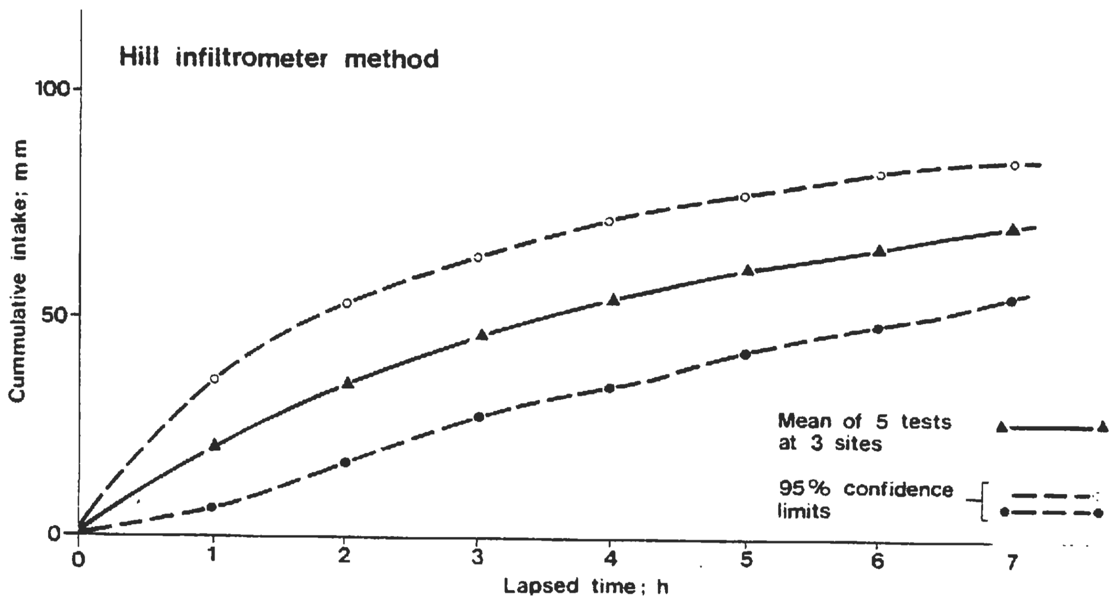
FIGURE D.6

INFILTRATION – HILL METHOD

QORYOOLEY SERIES

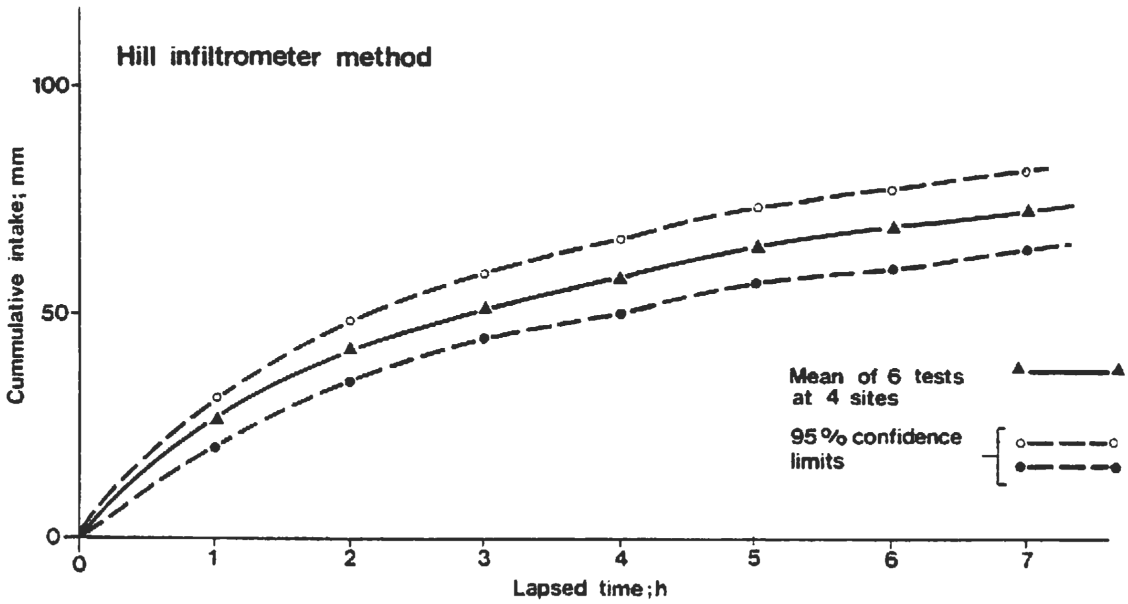


MADHUULOW SERIES

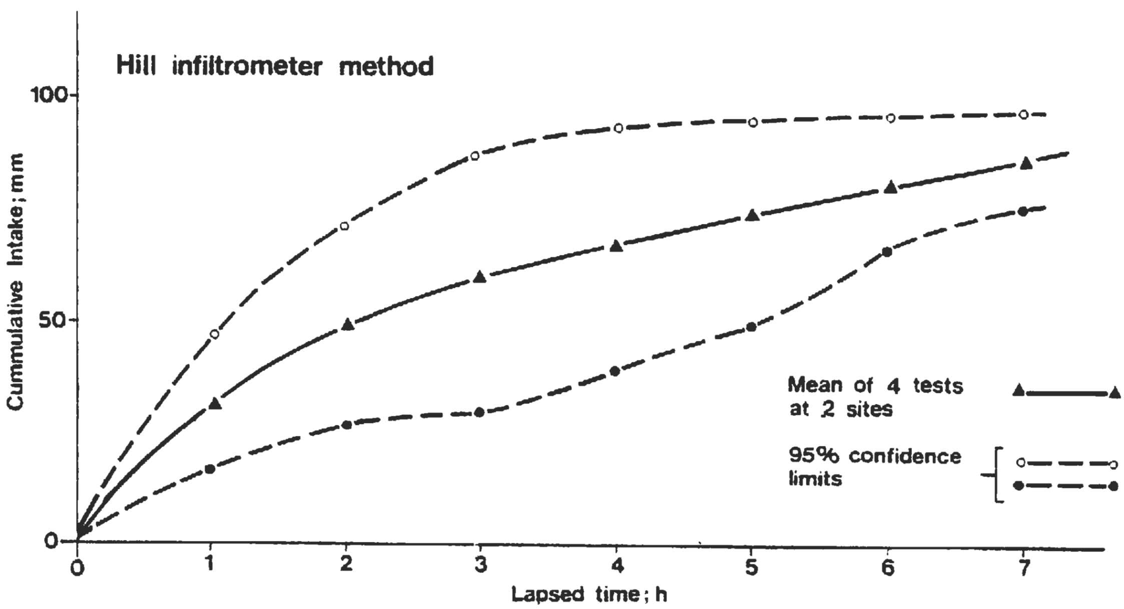


INFILTRATION – HILL METHOD

MUKOY DUMIS SERIES



GAYWEEROW SERIES



It has been suggested (Booker-McConnell, 1976) that the vertical cracks persist after saturation of the soil, to remain as minor fissures along which drainage can occur. As part of the current study, the cracking pattern before and after surface flooding was recorded and compared. For this purpose the basin infiltration test site was used (Section D.3).

The results, shown graphically in Figure D.8, show that cracking patterns are not constant; new patterns develop following a single wetting and drying cycle. This indicates that no sub-surface fissures or planes of weakness persist after saturation, a fact which is corroborated by the observation that the soils slake on saturation (Section D.2). Consequently, it is improbable that the cracking pattern has any influence on soil drainage in the saturated state.

D.5 Soil Moisture Monitoring

D.5.1 Methods

Soil moisture monitoring tests were conducted to determine the depth of moisture penetration under different forms of irrigation and, by comparison with moisture retention data, to assess the period during which the soil moisture is in the available range. Three sites on Qoryooley series soils were selected for the tests:-

(a) Site 1. Perennial crop irrigation - banana plantation near profile R13.

(b) Site 2. Annual crop irrigation - traditional small scale subsistence farming area near profile R56.

(c) Site 3. Controlled flood 'waska' irrigation basin between sites 1 and 2.

Within each field two sampling stations were selected some 20 m apart, from which replicate soil moisture samples were collected at regular intervals over the period September 1977 to February 1978. Samples were collected by auger from fixed depths of 5 to 10 cm, 45 to 50 cm, 95 to 100 cm and 145 to 150 cm. Samples were placed immediately into pre-weighed aluminium tins, weighed moist, oven dried and re-weighed. Moisture percentages were calculated on an oven-dry weight basis and expressed as mean values for replicates at each depth and sampling date.

D.5.2 Results

Selected results of the moisture programme are plotted graphically as moisture profiles and presented in the main text as Figure 4.2. The lower (0.0 bar) and upper (15 bar) suction limits of moisture availability are superimposed on the profiles to aid interpretation of the results.

(a) Perennial Crop Irrigation: Site 1

The banana crop is irrigated throughout the year. Moisture profiles were monitored on seven occasions from October to February and the results show that soil moisture was in the available range throughout the period. As this period included the main dry season, it can be assumed that the soils remain moist throughout the year. The water table at this site varied between 1.65 m, immediately following irrigation, and 2.80 m later in the cycle.

(b) Annual Crop Irrigation: Site 2

Monitoring commenced two days before initial irrigation (25/9/77) and continued at ten successive dates until early February. At the initial stage, soil moisture suctions are seen to be at or above wilting point throughout the profile. Following irrigation water application there is a rapid response in the upper horizons as moisture suctions decrease into the available range, followed by a decrease in the lower horizons. This is consistent with rapid initial entry via cracks and subsequent entry via hydraulic gradients into the deeper horizons (Section D.3). After 47 days, depletion of moisture resulted in suctions in the lower horizons returning to the unavailable range. This was rectified by the second irrigation after which the lower horizons remained moist for the rest of the period. Moisture levels in the surface, however, fell consistently over the period, showing a particularly rapid decline (from 43 to 25%) over the period 74 to 91 days. Soil cracking commenced at moisture contents 25 to 27%, near the permanent wilting point.

(c) Controlled Flood Irrigation of Maize: Site 3

Samples were collected immediately prior to flooding and at nine successive dates following the draining off of surplus water from the basin (11/10/77) until early February 1978. As at site 2, soil suctions were above wilting point at the initial sampling; following flooding, suctions fell rapidly throughout the profile but soil moisture remained within the available range for nearly 120 days after flooding. Cracks formed at the surface at a moisture content of about 30%.

D.6 Hydraulic Conductivity

D.6.1 Selection of Methods of Measurement

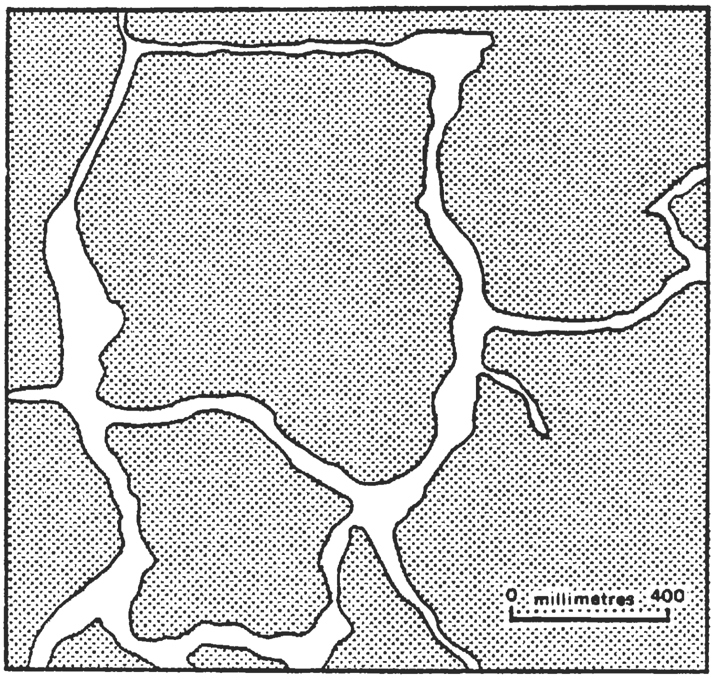
Three methods were adopted for the measurement of saturated hydraulic conductivity (k) of the soils:-

(a) The single auger hole method (Van Beers, 1963). This involves the measurement of the rate of rise of groundwater in an auger hole after initially pumping or bailing water out of the hole. A prerequisite for this test is a water table within the test depth.

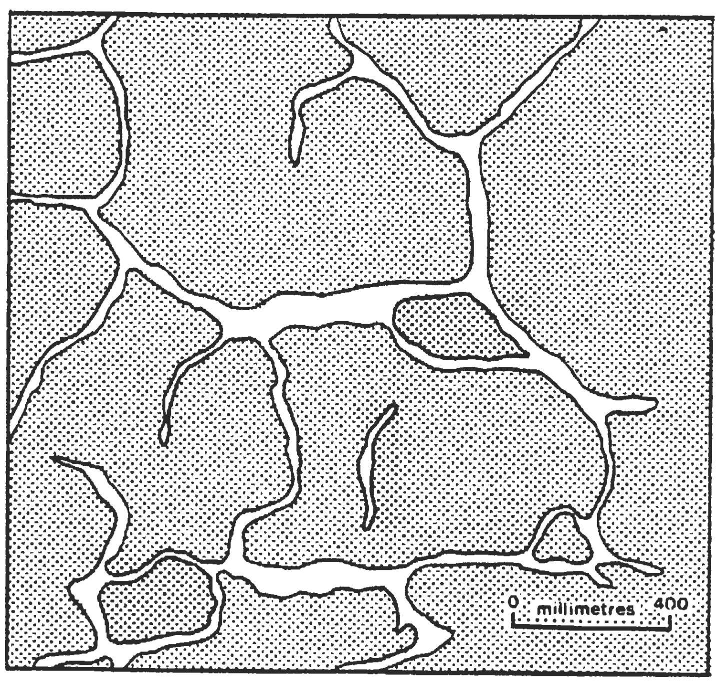
(b) The inversed auger hole method (Kessler and Oosterbaan, 1974). This technique is for use in soils above the saturated zone, water being added to an auger hole and the subsequent rate of fall in water level being used to calculate k.

SOIL CRACKING PATTERNS – SARUDA SERIES

a. October 30th 1977



b. January 11th 1978



Note: Test area cracks plotted 30.10.77; surface cultivated, saturated, allowed to dry and cracks replotted 11.1.78

(c) Infiltration tests (Kessler and Oosterbaan, 1974) in which the terminal infiltration rate is used as an approximation of hydraulic conductivity.

Of these three methods the pump-out single auger hole test proved to be the most reliable. The method provides a relatively simple way of measuring the horizontal hydraulic conductivity of a saturated soil under field conditions which closely resemble those which are likely to be encountered when a field drainage system is installed. The principal disadvantage of the pump-out test is that it requires the presence of a water table within the test depth, a feature which is not widespread in the Study Area.

The inversed auger hole method was employed where no water table existed but proved to be impractical as the auger holes rapidly collapsed due to soil slaking (Section D.2) and infilled soon after addition of water. This method was therefore abandoned at an early stage. The infiltration test method was used in the upper levels of the profile (0.5 and 1.5 m) at selected sites, using the double-ring infiltrometers; values obtained by this method were used as approximations of vertical hydraulic conductivity.

D.6.2 Methods and Results

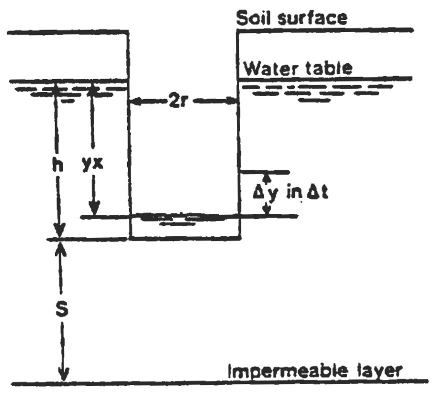
(a) Single Auger Hole Pump-out Method

The method involved the excavation of a 125 mm diameter auger hole to below the water table. Water was extracted from the hole using a hand pump. Immediately the removal of water was completed, the test commenced by measuring the rate of rise of the level of the water re-entering the hole from the surrounding soil. The rise of water in the hole was recorded against time until a steady value was obtained.

The actual measurement was achieved using a specially designed device comprising a length of electric cable attached to a weighted electrode (a two-pin plug) wired through a 4 volt dry cell battery and voltmeter. When the electrode was lowered into contact with the water, a current passed which was recorded by the voltmeter. The wire and electrode were then withdrawn a known distance from the hole by moving a peg, attached to the upper end of the wire, along one or more holes in a metal strip in which holes had been drilled at one centimetre intervals. The time taken for the water to rise and re-establish contact with the electrode was recorded by a stop-watch, the electrode was withdrawn further and the readings repeated. After a relatively fast initial recharge, the rate of rise usually stabilised and then slowly decreased as the dimensions of the cone of depression of the water table around the hole increased. On completion of the test, the time and depth to water level were recorded. Full details of the test were recorded on a pro forma and the water level in the hole was then allowed to regain equilibrium and the depth re-measured after about 24 hours. The general arrangement of the test is shown in Figure D.9.

FIGURE D.9

ARRANGEMENT OF HYDRAULIC CONDUCTIVITY TEST



The hydraulic conductivity (k) was calculated using the empirical formula derived by Ernst, applicable to homogeneous isotropic soils with no relatively impermeable layer within the close proximity to the test depth ($S > \frac{1}{2} h$). The Ernst formula is as follows:-

$$k = \frac{4\,000}{(20\ h/r)\ (2 - yx/h)} \quad \frac{r \Delta y}{yx \Delta t}$$

where Δy	=	rise of water surface in the auger hole during the time t
h	=	total depth of auger hole below the stable water level
yx	=	distance from stable water level to level of water in the hole at the time of the test
r	=	radius of the auger hole
k	=	hydraulic conductivity in m/d when the other factors are measured in centimetres and in seconds.

The results of the 18 tests are shown in Table D.4, differentiated according to the characteristics of the alluvium in the test zone. The clay textured alluvium is shown to have a lower hydraulic conductivity (mean 0.23 m/d; SE = 0.04) than alluvium with layers of silt loam and fine sandy loam (mean 0.76 m/d; SE = 0.14). The observed trend for hydraulic conductivities to decrease with increasing depth is illustrated in Figure D.10, compiled from data for reliable tests.

HYDRAULIC CONDUCTIVITY : RELATION TO DEPTH AND ALLUVIAL TYPE

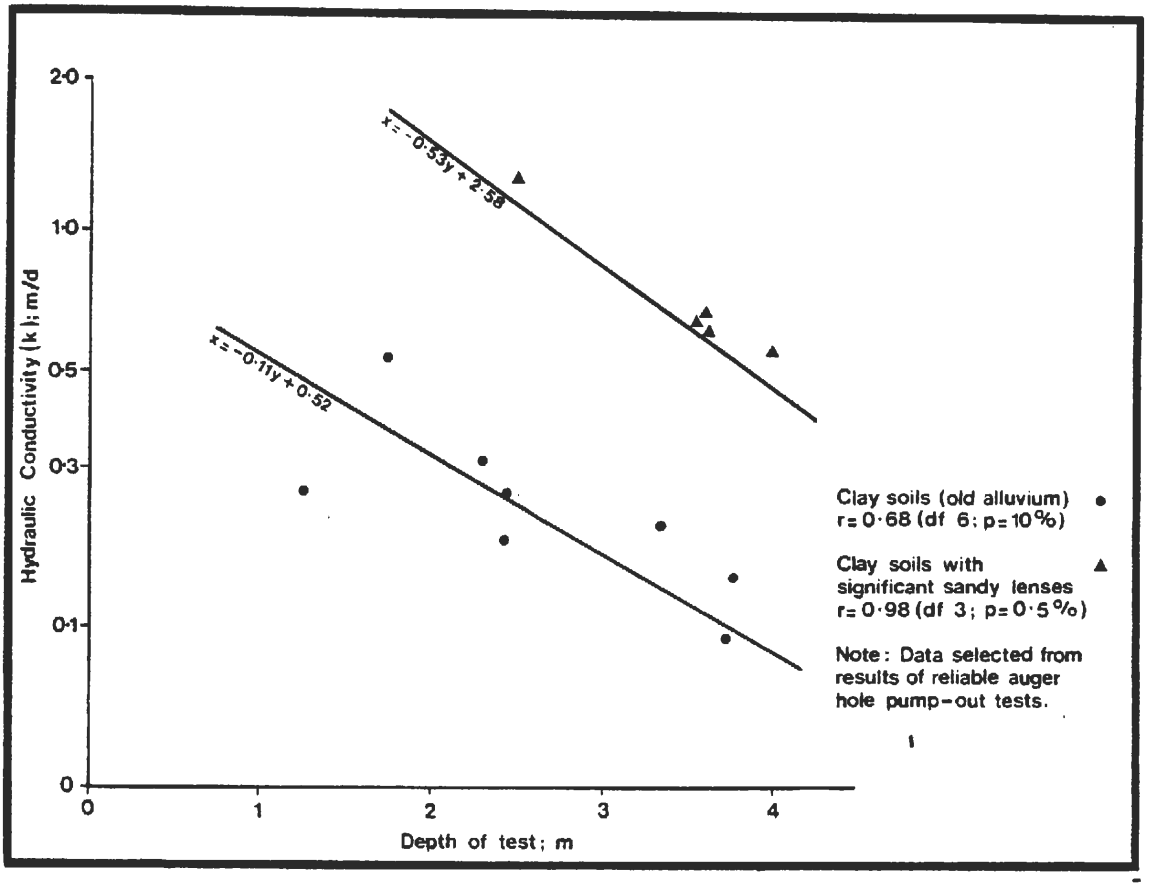


TABLE D.4

Hydraulic Conductivity (k)

Site	Depths (m) Stable water table	Initial test water level	Final test water level	Auger hole	Alluvium at depths of test	k (m/d)
R11	3.45	3.61	3.53	3.80	Fine sandy loam of	0.68
R17	2.70	3.55	3.15	4.25	Fluvio-marine alluvium (FM)	0.65
R13	2.75	3.72	3.62	3.75	Dark greyish brown	0.09
R406	1.00	2.40	2.22	2.80	clays of old flood plain	0.26
R33	1.50	1.74	1.64	2.25	alluvium (1c)	0.54
R37	1.80	2.30	2.25	2.31		0.31
R37	1.85	3.34	2.94	4.30		0.21
R47	1.45	3.77	3.48	4.35		0.15
R472	0.72	1.24	1.12	1.40		0.26
R50	1.00	1.71	1.41	1.83	Dark brown clays of	1.61*
R466	0.86	1.39	1.29	1.44	old flood plain alluvium (1a)	0.12
R468	0.22	0.60	0.46	1.20		0.25
R469	0.63	1.29	1.19	1.40		0.10
R29	1.40	3.98	3.53	4.35	Dark brown silty clay	0.56
R32	2.76	3.63	3.33	4.40	loam of old flood plain (1d)	0.62
R24	0.30	0.99	0.81	1.68	Reddish brown clay of	0.28
R47	1.45	2.41	2.13	2.50	semi-recent alluvium (2a)	0.19
R23	1.85	2.50	2.20	2.70	Dark brown sand and silt loam of semi-recent alluvium (2c)	1.30

Note: Results of pump-out auger hole tests using Ernst calculation

* Value influenced by nearby irrigation, excluded from later calculation.

(b) Infiltration Tests

Double-ring infiltrometers were used to measure terminal infiltration rates at depths of 0.5 and 1.5 m. Pits were excavated to the required depth, the base was cleared of loose soil and covered with sacking. Water was applied (200 to 300 litres) and allowed to infiltrate. After 48 hours the sacking and overlying sediment were removed and double-ring infiltrometers were installed. Water was applied to each ring and the rate of fall of the water level in the inner ring was recorded over a period of some six hours. The terminal infiltration rate was calculated as the mean rate for the final four hours.

As with all such pour-in methods, the accuracy of the results is limited by the tendency for fine soil particles to be washed into the pores and reduce permeability. In addition, several deep pits either collapsed when wetted or were infilled by rainwater and surface run-off.

A total of 14 tests were conducted. The results (Table D.5) tend to indicate that vertical hydraulic conductivity is greater (p = 0.05 to 0.10) in the soil horizons derived from semi-recent alluvium (mean 0.29 m/d; SE = 0.12) than those of the old alluvium (mean 0.07 m/d; SE = 0.01). The former soils are characterised by compact conchoidal blocky structure which has been shown to retain some degree of stability and permeability when saturated as compared with the blocky wedge structure of the old alluvium which slakes on saturation (Section D.2). No appreciable difference can be seen between recent and semi-recent alluvium. These results suggest that vertical moisture penetration will be more favourable on the recent and semi-recent soils than on those derived from old alluvium. The latter are also likely to have less favourable drainage characteristics which will reduce the effectiveness of any sub-surface drainage which may be installed.

TABLE D.5

Deep Infiltration Tests Results

Site No.	Soil series	0.5 m test depth: Alluvium	0.5 m test depth: Terminal rate (m/d)	1.0 m test depth: Alluvium	1.0 m test depth: Terminal rate (m/d)
Recent and Semi-recent Alluvium					
R58	Gw	3b-fine sand & silt	0.11	2a-clay	0.12
R13	Qr	2a-clay	0.10		-
R13	Qr	2a-clay	0.24		-
R63	Mw	3a-clay & silty clay	0.10	2a-clay	0.11
R57	Mc	3b-fine sand & silt	0.25	2a-clay	0.10
R79	Mc	3b-fine sand & silt	0.08	2a-clay	0.46
Semi-recent over Old Alluvium					
R59	Qr	2a-clay	0.91	1c-clay	0.07
R56	Qr	1c-clay	0.05		-
R14	Qr	2a-clay	0.07	1c-clay	0.12
Old Alluvium					
R60	Gl	1a-clay	0.07		-
R66	Gl	1a-clay	0.05	1c-clay	0.06
R64	Sr	1c-clay	0.03	1d-silty clay loam	0.02
R62	Sr	1c-clay	0.08	1d-silty clay loam	0.20
R67	Sr	1c-clay	0.07	1c-clay	0.04

Note: Symbols for alluvium are explained in Chapter 2.1, 3 = recent, 2 = semi-recent, 1 = old.

APPENDIX E

SAMPLE AREAS

E.1 Introduction

Three sample areas were examined to test the variability of soil characteristics within a field sized area. The three areas were located (see soil Map 1A) to cover three of the principal mapping units, namely, Qoryooley, Golweyn and Saruda series. Each area measured approximately 0.6 ha and the soils were examined by auger to a depth of 1.5 m on a 20 m x 20 m grid. Routine analyses were performed on samples from the 0 to 50 and 50 to 100 cm depths, with some additional salinity sampling and analyses in sample areas 2 and 3 (Appendix C). The survey results are shown graphically in Figures E.1, E.2 and E.3.

E.2 Sample Area 1

This area was located on land mapped as Golweyn series. At the time of sampling the land was in fallow after irrigated maize in the previous der season. The land was level except for irrigation bunds and channels. Although mapped in Golweyn series, the area lies near to the boundary with Qoryooley series, as is shown in Figure E.1. Qoryooley shallow phase (Qr-s) occurs within the area as well as a Golweyn red phase (Gl-r) which is defined as Golweyn series with a 20 to 50 cm reddish brown clay overlay resembling the upper horizon of Qoryooley series. All but two sites have salinity values of Class II with little apparent difference in ECe values over the area; ESP values are all low.

E.3 Sample Area 2

This area was located adjacent to the Primo Secondario canal on land which slopes very slightly to the south-east. The area was mapped as being the boundary between Golweyn and Qoryooley series. At the time of sampling the land was being used for irrigated tomato production.

The mapping (Figure E.2) confirmed the boundary between the Qr and Gl mapping units but also revealed an inclusion of Mukoy Dumis series near to the canal. The Qr unit comprised both modal and shallow phases. Although it is located adjacent to the main canal, from which some seepage occurs, the area does not appear to be affected in terms of salinity or exchangeable sodium levels. ECe values for the north-western portion, adjacent to the canal and subject to a fluctuating high water table, are not significantly different from the other parts of the sample area. The soils have salinities in the Class I range, except for the Mukoy Dumis and three Golweyn series sites which are salinity Class II. Samples from this area were tested for both ECe and $EC_{1:2}$. A significant correlation was established between ECe(x) and $EC_{1:2}$(y), in the forms:-

(i)	0 to 50 cm	$x = 0.80\ y + 1.26$	$r = 0.60$, $n = 15$, $P = 0.02$
(ii)	50 to 100 cm	$x = 1.47\ y + 0.66$	$r = 0.88$, $n = 14$, $P < 0.001$

E.4 Sample Area 3

This sample area lies within the Saruda mapping unit of the Project Area. The land is level and at the time of sampling was under a young crop of irrigated maize.

The detailed mapping enables a Saruda Gypsic phase to be defined and delineated; this soil has visible gypsum crystals within the upper 150 cm of the profile but in all other respects is similar to the modal phase. Gypsum, in the quantities present in these soils, has no adverse effect on crop growth and hence the phase division is of no practical value. The sample area confirmed the very uniform nature of the Saruda series in terms of structure, texture and colour and salinity levels (Figure E.3).

In addition to the normal routine analysis sampling from the 0 to 50 and 50 to 100 cm depths, these samples and additional samples from the 100 to 150 cm zone were tested for $EC_{1:2}$ in order to define the relationship between ECe and $EC_{1:2}$ and to assess the salinity levels in the deeper subsoil. Correlations were established between ECe(x) and $EC_{1:2}$(y) in the form:-

(iii)	0 to 50 cm	$x = 1.06\ y + 0.63$	$r = 0.97$, $n = 14$, $P<0.001$
(iv)	50 to 100 cm	$x = 1.02\ y + 0.67$	$r = 0.97$, $n = 14$, $P<0.001$
(v)	100 to 150 cm	$x = 0.88\ y + 0.89$	$r = 0.98$, $n = 14$, $P<0.001$

Exchangeable sodium values are low throughout the area and salinities are within Class I and II but show a trend towards increasing salinity values with depth.

E.5 Conclusions

The sample area mapping confirmed the morphological uniformity of Saruda series at field scale but indicated that within areas mapped as Golweyn series there may be considerable inclusion of Qoryooley shallow phase. In terms of salinity levels, the results show that within a particular field there can be considerable variation in ECe values but all within the limits of Classes I and II. The relationships established between ECe and $EC_{1:2}$ provide useful conversion factors for future determination of salinity using the more rapid $EC_{1:2}$ measurement.

SAMPLE AREA 1

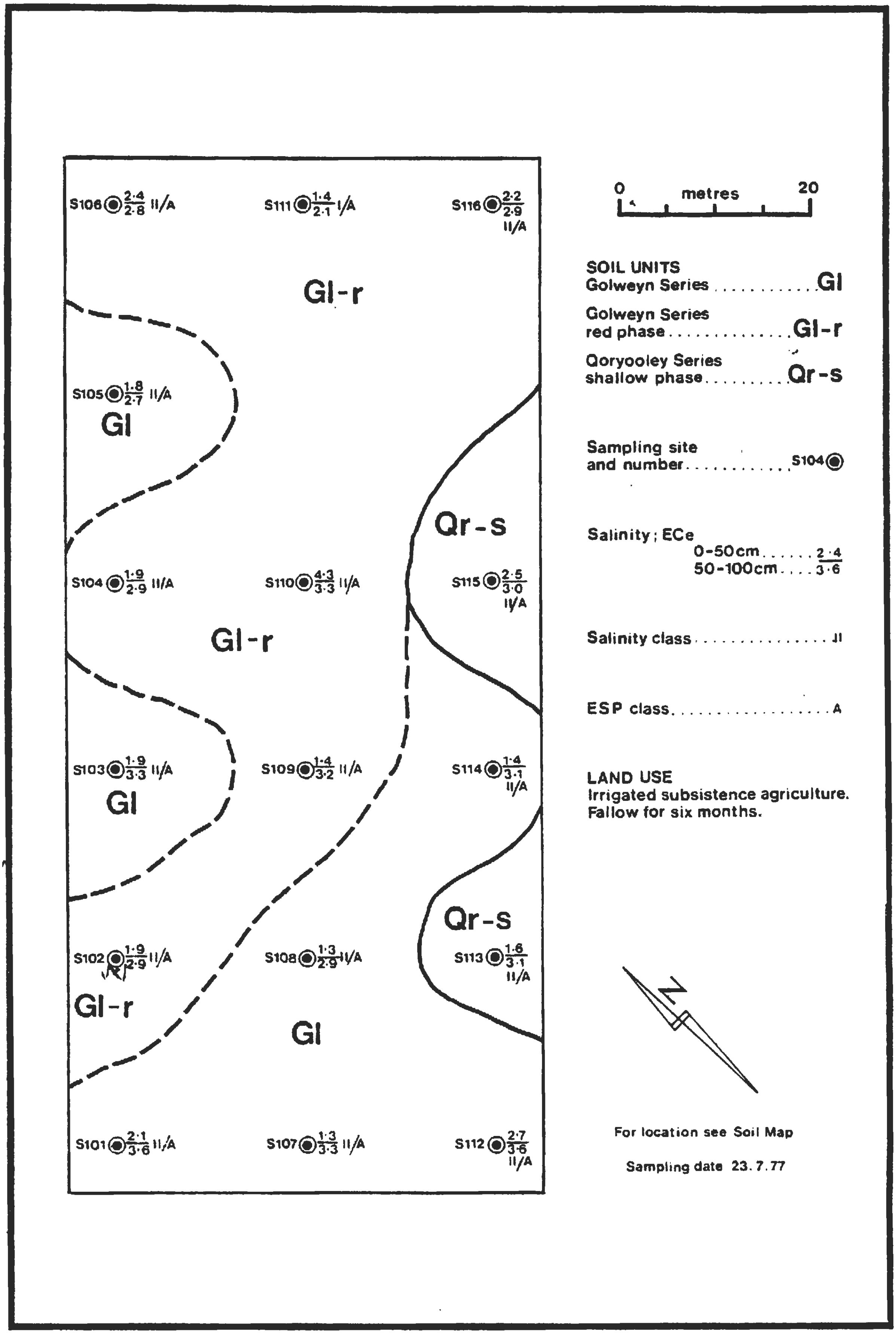
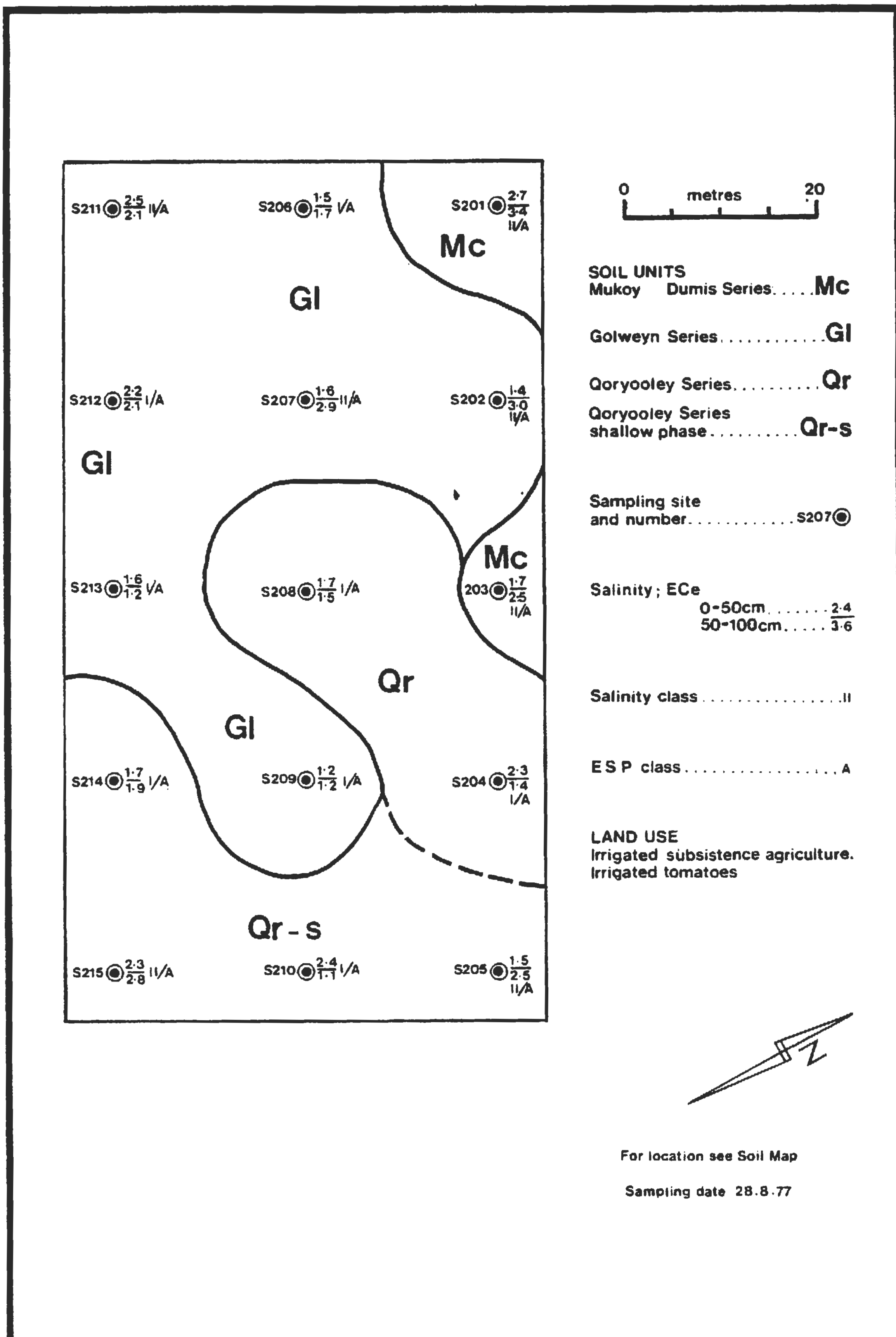
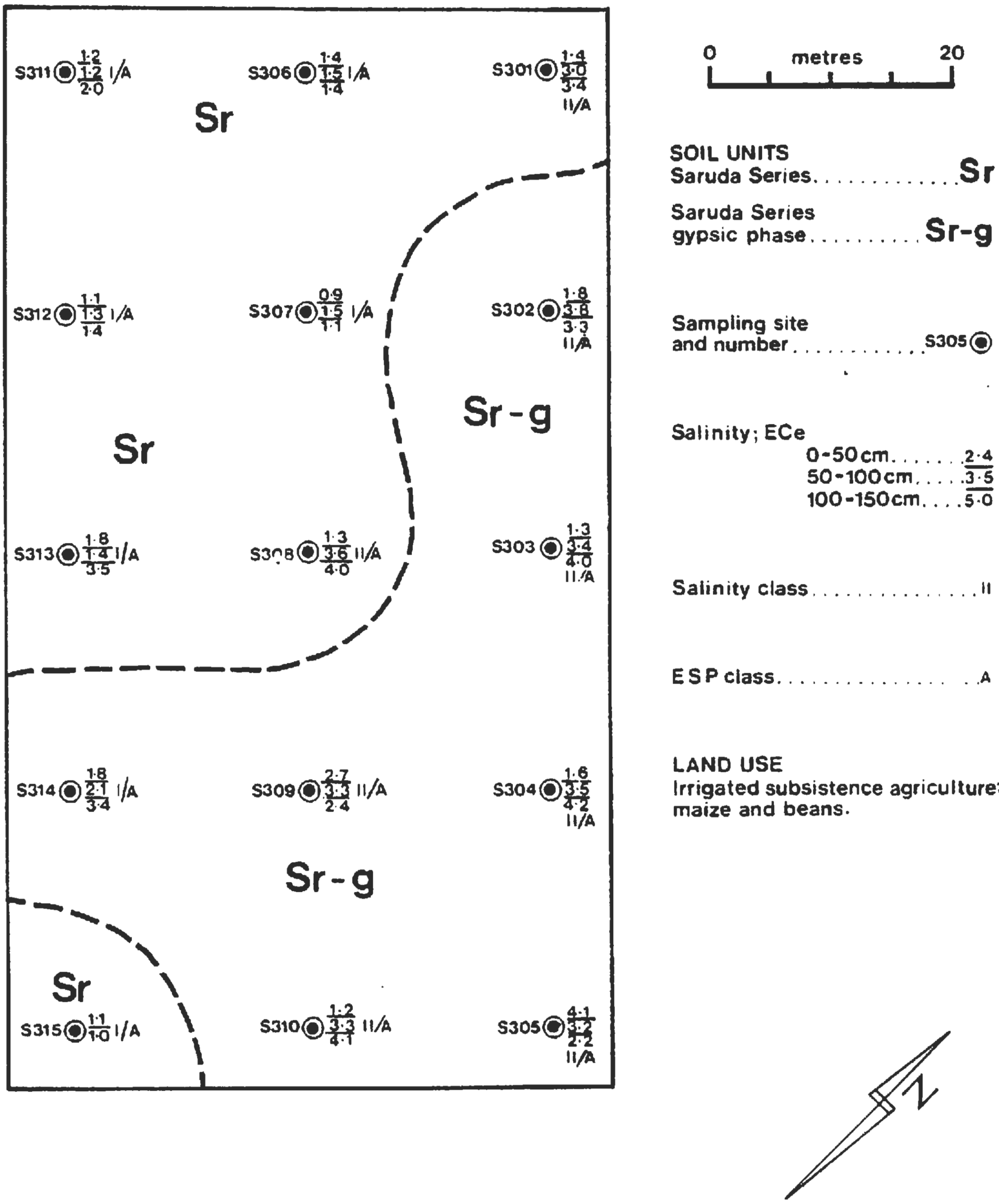


FIGURE E.2

SAMPLE AREA 2



SAMPLE AREA 3



For location see Soil Map

Sampling date 13.11.77

APPENDIX F

WIND EROSION AND DUNE STABILISATION

F.1 Introduction

The coastline of Southern Somalia is bounded by a belt of sand dunes some 3 to 10 km wide; these dunes carry an open woodland vegetation dominated by Acacia tortilis and A. bussei with A. seyal and A. mellifera locally and A. nilotica in the depressions. However, at certain points, usually related to the presence of a bay and an extensive area of beach sand, this natural vegetation has been swamped by blown sand, causing breaches in the formerly stable dunes. One such dune breach occurs in the Marka - Shalambood area. Most of the south-eastern boundary of the Study Area is now fringed by unstable dunes and is threatened by advancing windblown sand. Evidence for the steady advance of the dunes is provided by the submergence in sand of telephone lines, irrigation canals and tracks.

F.2 Dune Stabilisation Project

This project was implemented by the Range Agency as a result of the main Mogadishu-Shalambood road being threatened by the advance of the dunes. A programme of dune stabilisation commenced in 1973, with the aid of military and volunteer personnel.

The stabilisation methods used in the Dune Stabilisation Project (G. Booth, 1977, personal communication) comprised the exclusion of all livestock from the dunes and adjacent areas, the planting of drought tolerant plants on the dunes and the construction of 'hedges' of brush wood to reduce surface wind speeds. An initial attempt to seal the sand surface with clay from the flood plains was abandoned at an early stage when it was discovered that this reduced infiltration and initiated gully formation. In view of the immediate danger to the main road, stabilisation commenced from the inland side of the dunes and is currently progressing towards the coast. To date, a belt some 2 km wide has been stabilised adjacent to the main road.

The basic principle in preventing wind erosion involves the reduction of surface wind speeds to below the threshold speed at which detachment and subsequent transport of sand particles can occur. The soils of the present dunes consist of sands which have previously been sorted and transported by wind; they contain a very high proportion of particles in the range of 0.05 to 0.50 mm (Table F.1). Particles in this size range are the most susceptible to detachment and transport by wind, making the dune soils extremely vulnerable to wind erosion.

TABLE F.1

Particle Size Analysis of Dune Soil

Sample depth (cm)	Particle size distribution (%)					
	2.0 to 1.0 mm	1.0 to 0.5 mm	0.5 to 0.25 mm	0.25 to 0.05 mm	0.05 to 0.002 mm	Less than 0.002 mm
50 to 100	-	1.0	22.3	62.7	6.0	8.0

Source: Sample collected and analysed during present study.

The strongest winds along the Somali coast occur in December to March, coinciding with the period of driest soil conditions. This is therefore the period when maximum erosion occurs and accounts for the predominant south-westerly direction of movement. Maximum effect from windbreaks is therefore obtained if they are aligned south-east - north-east.

The technique of planting prickly pear (Opuntia sp.) between hedges around the dunes has been effective in excluding livestock. On the main dunes considerable success has been achieved with planting of Acacia cyanophylla, Cassurina equisetiofolia and Tamarix articulata. The A. cyanophylla has grown well and produces a dense protective bush cover within 18 months; it is also expected to provide a source of fuelwood and livestock fodder. Eucalyptus camaldulensis has been successful in some localities and will provide a supply of pole timber. Provided the trees are planted during one of the rainy periods, they can survive on moisture held in the sand. Indeed, during September free water was found at a depth of 1.3 m on one of the dune plateaux.

F.3 Future Requirements for Dune Stabilisation

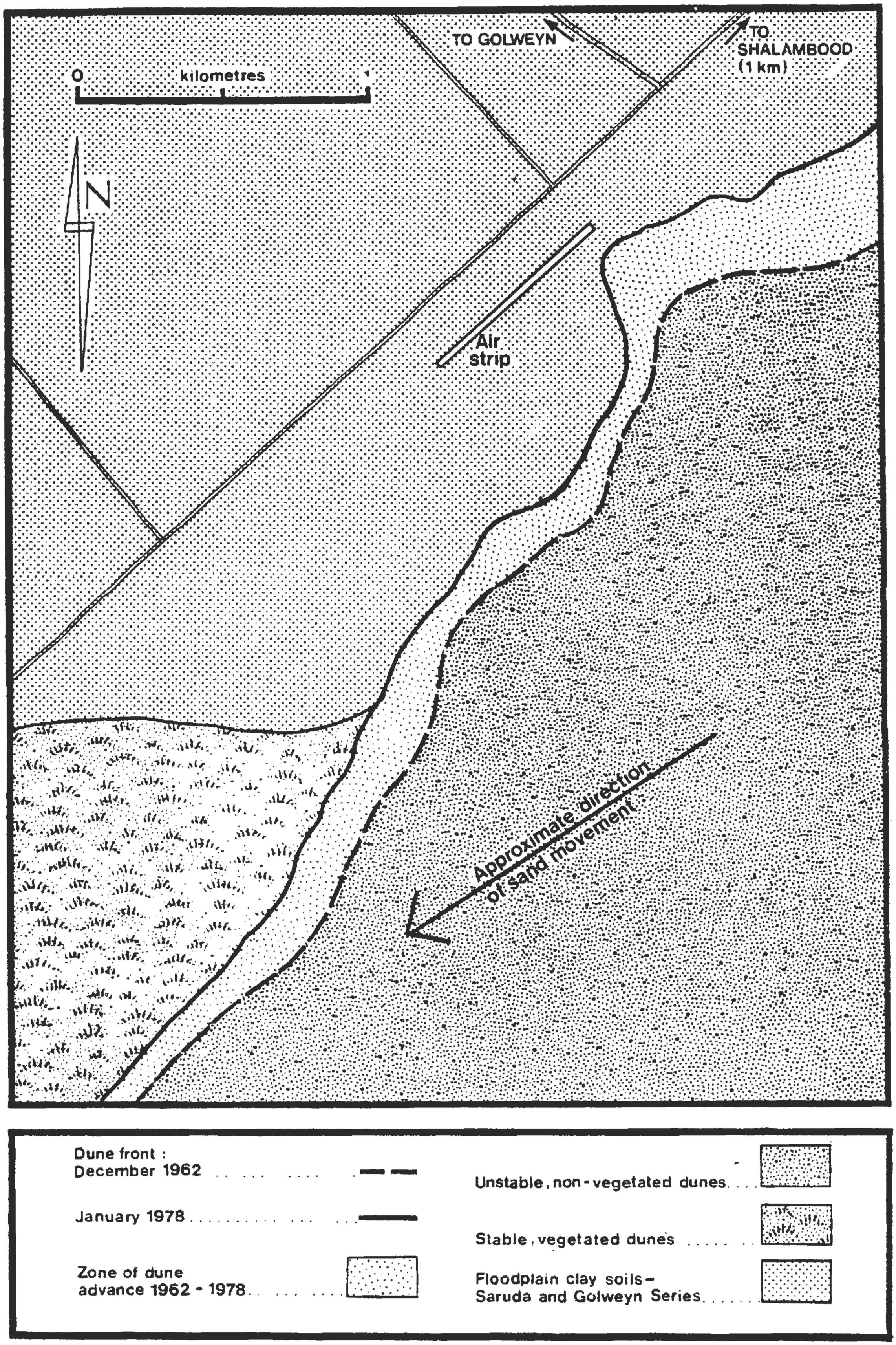
The results of the Buufo-Shalambood Dune Stabilisation Project prove that the advance of the dunes can be checked by relatively simple means. A close examination of the stabilised areas suggests that, in addition to the tree and cactus plantings and the construction of windbreaks, the exclusion of livestock has been a significant factor in reducing erosion; their exclusion has enabled a regeneration of natural herb and grass species which assist the stabilisation process.

The unstabilised dune front currently extends some 8 km along the south-east border of the Study Area. The eastern section is scheduled for stabilisation by the Range Agency but no plans have been made for the western section. The current rate of advance in this latter area was assessed by a comparison between the 1962 aerial photographs and the present day location of the dunes. As shown in Figure F.1, the dunes are advancing in a south-westerly direction at an average annual rate of 15 to 20 m. Under these circumstances there is little immediate danger to any currently irrigated areas or major roads, although the Shalambood airstrip will be inundated by sand within a few years.

Irrigable land of relatively low quality is currently being overrun at the rate of only some 40 ha per year. However, the loss of valuable Acacia woodland on the stable dunes ahead of the advancing dune front poses a potentially more serious threat. Not only is there a continuing loss of timber, grazing and ecological habitat but, as the extent of sands increases, so the rate of advance is likely to accelerate.

If it is considered to be worth instigating a stabilisation programme in this area, whether for economic or ecological reasons, the methods so far adopted by the Range Agency could be applied. In particular these methods should be designed to prevent the south-westerly movement of sand, which would involve commencement of stabilisation along a NW-SE line on the windward side of the dunes.

COASTAL DUNES : SHOWING CHANGES IN DUNE FRONT



APPENDIX G

VEGETATION

Plant specimens collected in the Study Area were identified by the staff of the Herbarium, Royal Botanic Gardens, Kew. The results are listed in this appendix.

Two separate areas were sampled:

(a) Abandoned Banana Plantation

This area, situated near Golweyn, was sampled to provide an indication of the commonest types of weed species colonising abandoned irrigated land. Included within this sampling are some exotic species which are used as windbreaks and hedge plants for dividing fields. Species identified are listed in Table G.1.

(b) Natural Scrub Woodland Vegetation

Specimens were collected from an area of scrub woodland in the extreme north of the Study Area, near the village of Tugarey. Apart from the removal of larger tree species (Acacia nilotica and Balanites aegyptica) for charcoal burning and low intensity cattle browsing, the area was relatively undisturbed and provided a reasonable representation of the natural vegetation of the region. The sampling provided an indication of species composition of trees, shrubs, herbs and grasses, but the list of identified species (Table G.2) should not be considered comprehensive.

TABLE G.1

Plant Species of Abandoned Arable Land

Grasses and Herbs	
Heliotropium cinerascens	Steud ex De
Cyperus rotundus	L
Brachiaria reptans	(L) Gardner and Hubbard
Echinochloa sp. aft. obtusiflora	Stapf.
Tragia sp.	
Psoralea corylifolia	L
Commelina pannosum	Webb
Lactuca capensis	Thunb
Sorghum arundinaceum	(Desv) Stapf.
Digataria sp.	
Cynodon plemfuensis	Vanderyst
Dalechampion scendens	L var cordofanus Mull. Arg.
Rottboellia exaltata	Lf
Achyranthes aspera	L
Ipomoea sp.	
Solanum nigrum	L
Cucumis melo	L
Vernonia cinerea	(L) Less
Euphorbia hypericifolia	L
Physalis peruviana	L
Phyllathus amarus	Schum and Thonn
Corchorus olitorius	L
Erlangea somalensis	O.Hoffm.
Lippia danensis	Chiov.
Aspilia mossambicensis	(Oliv.) Wild
Hibiscus sp.	
Monechria debilis	(Forsk.) Nees
Dichanthium annulatum	(Forsk.) Stapf.
Brachiaria deflexa	(Schumach.) C.E. Hubbard ex Ropyrs.
Setaria verticillata	(L) P. Beauv.
Cenchrus ciliaris	L
Urochloa panicoides	P. Beauv
Flaveria trinervia	(Spreng) Chiov.
Tribulus pterocarpus	Ehrenb. ex Koem.
Ocimum canum	Sims
Trees and Shrubs	
Conocarpus lancifolius	Engl.
Parkinsonia aculeata	L
Cassia occidentalis	L
Solanum sp.	
Thespesia danis	Oliv.

TABLE G.2

Plant Species of Shrub Woodland

Grasses and Herbs

Serra incana	Cav.
Barleria waggana	Rendle
Pupalia lappacea	(L) Juss
Rhynchosia minima	(L) De.
Ocimum spicatum	Defl.
Coleus sp. aff. barbatus	(Andr.) Benth.
Barleria orbicularis	T. Anders
Justicia flava	Vahl
Astipomea lachnosperma	(Choisy) Meeuse
Hibiscus sp.	
Hibiscus hildebrantii	Sprage and Hutch
Euphorbia agoenis	Hochst ex Boiss
Aloe sp.	
Melhania sp.	
Blepharis linariifolia	Pers.
Svensonia laeta	(Fenzl ex Walp.) Moldenka
Dactyloctenium scindicum	Boiss
Solanum somalense	Franch
Talinum portulacifolium	(Forsk.) Schweinf.
Vernonia sp.	
Zgleya pentandron	(L) Jeffrey
Celosia polystachia	(Forsk.) C.C. Townsend

Trees and Shrubs

Salvadora persica	L
Indigofera schimperi	Janb and Spach
Grewia tenax	(Forsk.) Fiori.
Acacia bussei	Harms
Premna resinosa	Schauer
Acacia ehrenbergiana	Hayne - New record
Acacia nubica	Benth.

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