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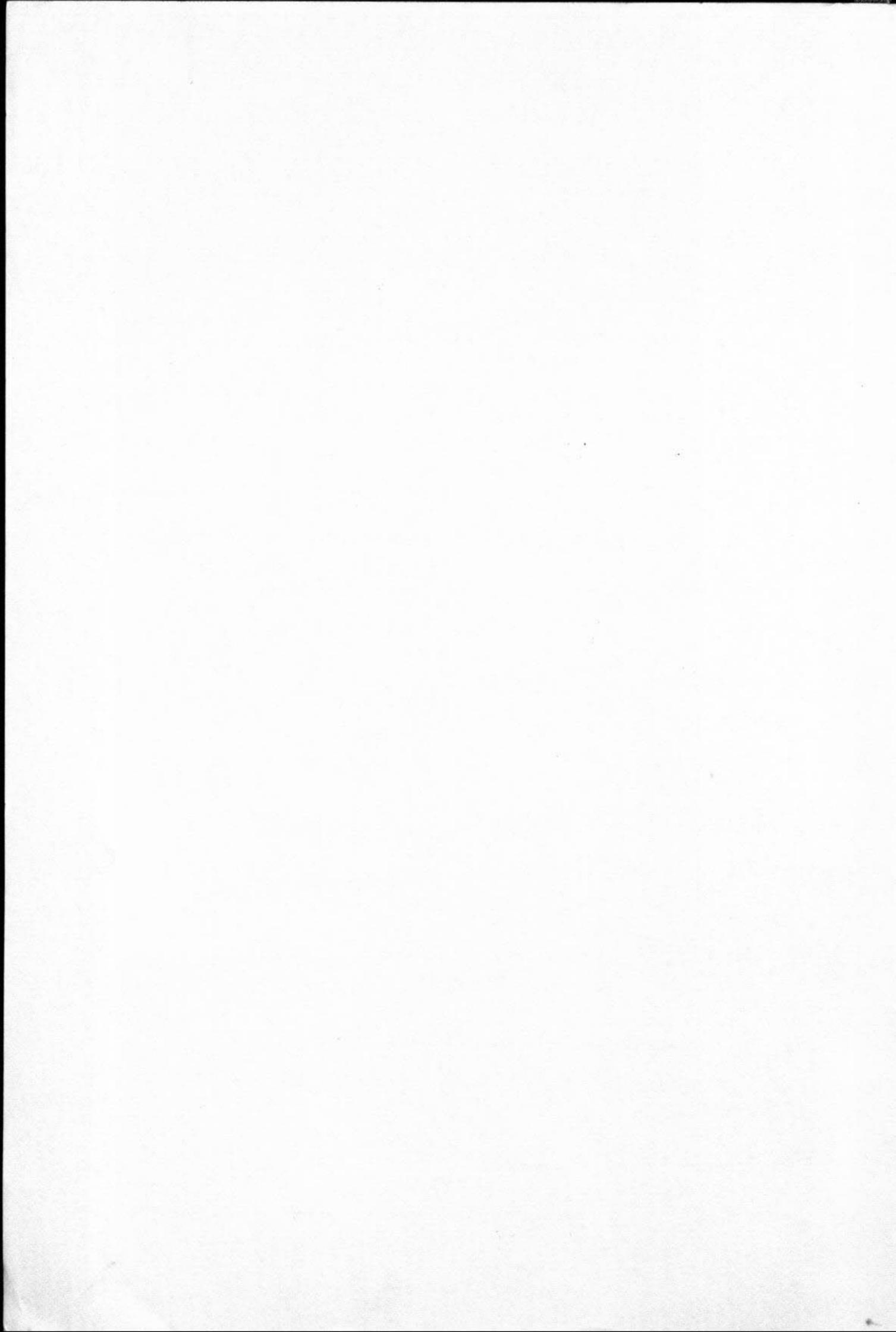
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**RAPID RECONNAISSANCE SOIL SURVEYS
OF PART OF TAVETA ESTATES,
KENYA**

**A REPORT PREPARED BY HUNTING TECHNICAL SERVICES LIMITED
FOR
COMMONWEALTH DEVELOPMENT CORPORATION**

SEPTEMBER 1987

SURVEYS: KENYA HUN



REFERENCES

APPENDICES

- A Soil Profile Description and Analytical Data
- B Field Auger Hole **RAPID RECONNAISSANCE SOIL SURVEYS
OF PART OF TAVETA ESTATES,
KENYA**
- C Preliminary Infiltration Test Data for Sites PR1 and PT8
- D Four-in Hydraulic Conductivity Test Data for Sites PT1 and PT8
- E Analytical Data from Water Samples

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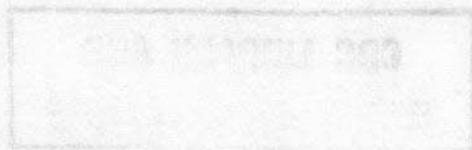
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RAISE PRODUCTION AND SURVIVAL
OF PART OF INDIAN STATES
KENYA

A REPORT PREPARED BY HUNTING TECHNICAL SERVICES LIMITED
FOR
COMMONWEALTH DEVELOPMENT CORPORATION

SEPTEMBER 1967



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1.1 INTRODUCTION

Rapid reconnaissance soil surveys of the proposed project area (1660 ha) at Taveta Estate were carried out between 7/8/87 and 13/8/87 to establish the availability of suitable land for surface irrigation development.

The Terms of Reference (ToR) for the reconnaissance soil surveys stipulate the following objectives:

- (a) Identify and describe the major soil types in the area and assess their overall suitability for surface irrigation.
- (b) Collect soil samples from modal profiles for physical and chemical analyses at the LRDC Tropical Soils Analysis Unit in Reading, England.
- (c) Determine the extent to which irrigation development could be constrained by potential soil salinity/alkalinity, and water logging problems.
- (d) Determine the base infiltration rate on each of the major soil types and carry out hydraulic conductivity tests to determine subsoil drainability.
- (e) Assess the area of land available for irrigated and rainfed cropping with due regard to tillage problems and likely trace element requirements.

Time constraints dictated that only a limited field programme could be completed to fulfil these objectives.

A cross-section of soil types were sampled for chemical analyses. Field infiltration and drainage characteristics require a more thorough evaluation than was possible in the given time period.

The following field sampling programme was completed:

- twenty-five routine auger observations to a depth of 1 m, or to the parent material;
- samples taken from auger borings for routine field EC and pH using a 1:5 soil water suspension (69 samples);
- seven profile pits excavated to a depth of 2 m for detailed analyses by horizon at the LRDC laboratories in the UK (24 samples);
- two infiltration and hydraulic conductivity tests on selected sites;
- collection of samples of irrigation water to determine sodium hazard and salinity.

In anticipation of salinity/sodicity being the principal constraint to development of the area a large number of samples were tested for field pH and EC using a 1:5 soil water suspension on air dried samples. Other chemical analyses completed are discussed in Section 4.

The fringes of the depression are more or less coincident with the 712 m (2350 ft) contour, as shown on the existing topo-map, with the better drained areas in the east and north of the project. Maximum slope gradient appears to be south, and south west into the depression.

SECTION 1

1.1 INTRODUCTION

Rapid reconnaissance soil surveys of the proposed project area (1000 ha) at Tazara
Banda were carried out between 1987 and 1988 to establish the suitability of various soils
for various irrigation developments.

The terms of Reference (TOR) for the reconnaissance soil survey are given in the following
annexure.

- (a) Identify and describe the major soil types in the area and assess their overall
suitability for various irrigation.
- (b) Collect soil samples from typical areas for physical and chemical analysis at
the IRDC Project Site and use them in planning irrigation.
- (c) Determine the soil water salinity and irrigation development could be considered as
potential soil salinity, alkalinity and water logging problems.
- (d) Determine soil water salinity and irrigation development could be considered as
potential soil salinity, alkalinity and water logging problems.
- (e) Assess the area of land available for irrigated and rainfed cropping with due
regard to the soil water salinity and irrigation development.

The constraints dictated that only a limited field programme could be completed to fulfil
these objectives.

A reconnaissance of soil types was carried out for chemical analysis, field irrigation and
irrigation characteristics to make a more thorough evaluation. This was possible in the given time
period.

The following soil sampling programme was completed:

- Twenty-five (25) soil samples were collected to a depth of 1 m or to the plough
depth.
- Samples taken from eight points for routine field EC and pH using a 1:2 soil
water suspension (10 samples).
- Seven profiles were excavated to a depth of 2 m for detailed analysis by horizon
at the IRDC waterworks in the IRDC area.
- The irrigation and hydrologic conductivity tests on selected sites.
- Collection of samples of irrigation water for detailed sodium hazard and
salinity.

In addition to soil salinity being the primary concern in development of the
area a large number of samples were tested for pH and EC using a 1:2 soil water suspension
on selected samples. Other chemical analyses completed are given in Section 2.

1.2 PREVIOUS WORK

A great deal of background information, some dating back to 1931, exists on the soil and water resources of Taveta District. Most of the reports and papers (some of which were not available for review) relate to areas close to the proposed project site or provide a general overview of the geology, soils and water resources.

There is no record of detailed soil surveys having been carried out in the project area though useful analytical data is provided for similar soils at the Kimala Irrigation Scheme (Kenya Soil Survey, 1976). The same report also furnishes information pertaining to leaching requirements, irrigation water requirements and irrigation frequencies, in addition to details of previous work and the history of irrigation development in Taveta District.

The Swynnerton report (1968) deals specifically with Taveta Estates and provides a rough sketch map of land with potential for irrigation which includes the proposed project area. Though rather short on detailed soils information the report summarises many of the soil related problems, including swamp encroachment from the south and the issue of a more regional approach to the drainage of the estate.

Most of the observations made in the Swynnerton report are still relevant to the present time, particularly in view of the fact that the project site lies on the periphery of swamp land where problems of salinity/alkalinity are most acute.

Papers prepared by A.E. Farrant (1966 and 1972) on drainage aspects of Taveta irrigation schemes were not available for review, though every effort should be made to obtain copies of these documents prior to implementation of the project.

Definitive description of the geology of the area is provided by Bear (see Section 1.3).

Michaelides Consultants provided useful drawings and some background information regarding soils and the location of old irrigation furrows.

1.3 GEOLOGY AND TOPOGRAPHY

The geology of the area is described in detail by Bear (1955). His map shows the project area as comprising mainly calcareous tuffaceous grits with outcrops of biotite garnet gneisses and quartzo-felspathic gneisses at Python and Reata Hills respectively. The latter form upstanding rocky hills with a well defined piedmont footslope.

The tuffaceous grits form a generally level plain with an elevation 710 m asl. The slope is barely discernible (<1%) with a southerly aspect. In the west of the area slopes are slightly steeper at 1-2 per cent. The soils are dominantly brown well structured clays with an overall depth of 120 cm to parent material.

The more elevated areas surrounding the gneissic hills are more limited in extent being confined to a narrow belt of land (piedmont) surrounding Python Hill in the south-centre of the project area. These parent materials impart a coarse texture to the piedmont fan soils. The main constituent is a yellowish red gritty sandy clay loam with a generally weak structure.

A shallow, poorly drained alluvial depression extending from west to east covers approximately 40-50 per cent of the project area. This depression is hydrologically related to the swamp areas west of the Kileo river, Toll Hill, and swamp areas immediately south of Python Hill. In the east and south east wetland areas associated with the Lumi river also extend into the area.

The fringes of the depression are more or less coincident with the 712 m (2,350 ft) contour, as shown on the existing topo-maps, with the better drained areas in the east and north of the project. Maximum slope gradient appears to be south, and south west into the depression.

A Great Deal of background information concerning the project is contained in the report of the previous work. This report of the previous work is a general overview of the project, and is intended to provide a general overview of the project, and is intended to provide a general overview of the project.

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General description of the project (as provided by the project sponsor)

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1.2 GEOLOGY AND TOPOGRAPHY

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Evaporation in the depression area exceeds the natural supply of water for leaching resulting in soils that are saline and alkaline. Natural drainage lines south into Lake Jipe are impeded by the gradual silting of channels and outlets resulting in the encroachment of swamp lands from the south into the project area. Surplus irrigation water has naturally contributed to high watertables in these areas with concomitant effects upon the soils.

1.4 NATURAL VEGETATION AND LAND USE

The existing vegetation reflects varying degrees of human interference and both natural and induced drainage problems. The distribution of vegetation associations and their composition does, however, provide a reliable indication of soil type, particularly with regard to salinity and drainage.

The natural vegetation of the area is an open savanna woodland with dominant *Acacia* tree species. Approximately 60 per cent of the project area has been subjected at some time in the past to clearing for the cultivation of sisal. The general decline in sisal production in recent years has resulted in regrowth of *Acacia* species of up to 20 years in age between the rows of sisal.

Natural plant species tolerant of high salinity (halophytes) are common on saline soils and depression areas, providing a means of identifying the limits of the poorly drained soils in the south and east of the project area.

Principal halophytic species include Doum Palms (*Hyphaene* spp.) and *Salvadora persica* (saltbush), associated with perennial grasses dominated by *Digitaria* spp., *Cyperus* spp. and *Cynodon* spp.

On more elevated better drained soils *Acacia mellifera* and *Acacia tortilis* are common, in association with *Aristida* spp. grasses.

Four main vegetation formations are identified. More detailed soil and land use surveys would provide a more reliable indication of their relationship to soil type, drainage and human interference.

Field procedures adopted at each site were typically similar, variations in size/number of samples being determined by complexity of soil distribution.

Vegetation formation	Soil type
- sisal with dense acacia regrowth	mostly on well drained
- sisal with mature (>20 years) regrowth	clays
- halophytic associations on depression alluviums	halomorphic depression soils
- mixed fringe vegetation on the periphery of the depression	fringe/marginal soils on edge of depression

Approximately 30 per cent of the area is currently cleared of natural bush and secondary regrowth in the centre of the project area for the cultivation of french seed beans using surface irrigation. The principal remaining areas of sisal with secondary regrowth are in the extreme west and east with halophytic associations occurring mainly in the south and east.

2.3 SAMPLING AND LABORATORY ANALYSIS

Samples were taken at all the sugar sites for analysis of pH and EC using 1:5 soil water suspension. The depth of the samples was, ordinarily, 0-25 cm, 25-50 cm, and 50-100 cm. This standard was occasionally varied according to circumstances.

The vegetation in the riparian zone consists of a natural sedge of water for leaching
 resulting in soft soil and some scattered shrubs that occur in the zone. The
 riparian zone is characterized by the presence of the riparian zone in the riparian zone
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1.4 NATURAL VEGETATION AND LAND USE

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Soil type	Vegetation formation
mostly on well-drained clays	mostly on well-drained clays
in some riparian zone	in some riparian zone
in some riparian zone on edge of riparian zone	in some riparian zone on edge of riparian zone

Approximately 10 per cent of the riparian zone is currently cleared of natural forest and vegetation
 for the purpose of the riparian zone. The riparian zone is characterized by the presence of the riparian zone
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SECTION 2

SURVEY METHODOLOGY

2.1 OFFICE METHODS

The ToR stipulate survey requirements consistent with those for detailed soil surveys. Because of the limited availability of field time some of the normal procedures used for detailed surveys had to be circumvented.

There was no general access to air photography of the area. Aerial reconnaissance in a light aircraft only proved to be of limited value.

2.4 FIELD SOIL TESTS

Base data mainly comprised a 1:50,000 scale topo map (1975), a 1:12,500 scale drawing provided by Michaelides Consultants, a small sketch map included in the Swynnerton report (1968) and the geological map by Bear (1955).

Maps and existing data were reviewed in the office in order to identify the principal landforms. Field observation sites were then located by ground checking; further observation/pit sites were located as the pattern of soil distribution within the area became evident.

Field observations were plotted onto the Michaelides map then transferred to the 1:50,000 scale topo maps enlarged to 1:30,000 scale on a photocopier for final inclusion in the report.

2.2 FIELD METHODS

Routine observations were made using a standard riverside, or five inch Jarrett auger head according to soil conditions. Dutch augers were used in the moist depression soils.

Field procedures adopted at each site were broadly similar, variations in observation density being a function of the complexity of soil distribution.

Detailed surveys normally require an observation density of 1 - 10 ha per site, which, for a 1660 ha site would require approximately 166 observations.

A total of twenty-five auger sites and seven profile pits were described. Auger sites were ordinarily completed to a depth of 1 m; profile pits were excavated to a depth of 2 m.

Sites were located on the ground using free survey techniques, involving the use of external features such as landforms and vegetation to identify the most representative areas. For detailed soil surveys controlled location on traverses will be required, particularly in dense thicket.

All sites were described on standard field proformas, recording colour, texture, structure, consistency, depth, root distribution and drainage characteristics. Supplementary information included geology, vegetation/land use, slope and parent material.

2.3 SAMPLING AND LABORATORY ANALYSIS

Samples were taken at all the auger sites for analysis of pH and EC using 1:5 soil water suspension. The depth of the samples was, ordinarily, 0-25 cm, 25-50 cm, and 50-100 cm. This standard was occasionally varied according to circumstances.

SECTION 2 SURVEY METHODOLOGY

2.1 OFFICE METHODS

The T&E stipulate survey implementation consistent with those for detailed soil surveys. Because of the limited resources available, a limited number of soil samples were collected for detailed surveys and to be representative.

There was no general access to the T&E reports of the area. Actual reconnaissance-type field notes only provide a general overview.

Base data were compiled from a 1:250,000 scale topographic map (T&E) and a 1:50,000 scale geologic map by the T&E. The T&E also provided a map of the area showing the location of the T&E reports and the geologic map by the T&E.

Maps and existing data were reviewed in the office in order to identify the general location of the T&E reports and to determine the general location of the T&E reports. The T&E reports were reviewed in the office in order to identify the general location of the T&E reports and to determine the general location of the T&E reports.

Field observations were made on the T&E reports and the T&E reports were reviewed in the office in order to identify the general location of the T&E reports and to determine the general location of the T&E reports.

2.2 FIELD METHODS

Field observations were made using a standard procedure of the T&E reports and the T&E reports were reviewed in the office in order to identify the general location of the T&E reports and to determine the general location of the T&E reports.

Field procedures followed at each site were generally similar, variations in observation being a function of the complexity of the situation.

Detailed surveys generally require an observation density of 1 - 10 per acre, which for a 1000 acre site would require approximately 100 observations.

A total of twenty-five sites were surveyed and seven profiles for each site were ordinarily completed to a depth of 1.0 m. Profile lengths were extended to a depth of 2 m.

Soils were located on the ground using the survey techniques involving the use of aerial features such as landmarks and vegetation to identify the most representative sites. For detailed soil surveys detailed location information was required, particularly in those areas.

All sites were described on standard field profiles, recording color, texture, structure, consistency, depth, soil distribution and drainage characteristics. Ecological survey information included geology, vegetation, and soil uses and soil moisture.

2.3 SAMPLING AND LABORATORY ANALYSIS

Samples were taken at all the sites for analysis of pH and EC using 1.5 soil water suspension. The depth of the sample was normally 0-25 cm, 25-50 cm, and 50-100 cm. The standard was occasionally varied according to circumstances.

Further samples were taken at six other stations in the study location for analysis of

- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- Electrical conductivity (EC)
- Ammonia nitrogen (NH₃-N)
- Nitrite nitrogen (NO₂-N)
- Nitrate nitrogen (NO₃-N)
- Total phosphorus (TP)
- Total organic carbon (TOC)
- Dissolved oxygen (DO)
- pH
- Temperature

All of the samples were processed and analyzed at the WPC laboratory at Foshan. Samples were also taken at a regular interval for monitoring of water quality and health.

2.4 FIELD WORK TESTS

Field water tests were carried out at sites 571 and 572 in the study area using a portable water testing kit.

Measurements of water quality parameters were taken using the portable water testing kit. The results of these tests are summarized and discussed in Section 3.

2.5 RESULTS

The results of the field water tests are presented in Table 2.1. The results show that the water quality is generally good, with only a few parameters exceeding the WHO guidelines. The most common parameter exceeding the guidelines is total dissolved solids (TDS), which is slightly above the recommended limit of 500 mg/L.

SECTION 3

GENERAL DESCRIPTION OF SOIL TYPES AND CLASSIFICATION

3.1 INTRODUCTION

The soils of the area are broadly divided into three distinctive types: the well drained reddish brown - brown calcareous clays developed over calcareous tuffaceous grits; the well drained yellowish red sandy clay loams derived from biotite garnet gneisses; and the poorly drained halomorphic soils of the central depression.

These soils are provisionally classified and mapped using the FAO system.

The main differentiating criteria for the soil mapping units are those properties most relevant to the proposed development, principally soil drainage, degree of salinity/alkalinity, soil texture and structure, and parent material.

3.2 REDDISH BROWN CALCAREOUS CLAYS (Chromic, calcic and vertic luvisols) Map Unit Lc/Lv

The principal soil types considered most suitable for development are the deep well drained strongly structured, dark reddish-brown - brown clays and silty clays developed over calcareous tuffaceous grits. (PT1, PT6 and PT7, Appendix A).

These soils occupy the most elevated part of the catenary sequence north and south of the main irrigation canal.

In the centre of the project area the soils have been surface irrigated to produce french seed beans. In the north west, north east and areas north of the canal the soils support a secondary regrowth, in old sisal fields, estimated to be 20 years in age.

Field observations in profile pits show differences in physical and chemical properties between irrigated (PT1) and non-irrigated (PT6 and PT7) soils. On irrigated land the soil has undergone some structural deterioration. Observation of the degree of aggregation suggests that after a number of years of surface irrigation there is a reduction in overall aggregate size and stability. There is also an increase in exchangeable sodium and salinity at depth.

Soils supporting a 20 year regrowth have a dry strongly structured subsoil with a relatively impermeable weakly structured horizon at 1 m depth.

The soils locally exhibit vertic properties indicating a clay fraction dominated by montmorillonitic clays. Surface cracking is evident in most years to varying degrees.

The soil reaction is very variable ranging from strongly alkaline (observation sites T19, 20 and 22, Appendix B), with very high pH values, to moderately alkaline, and, in places, slightly saline. pH generally increases with depth, lower horizons (50-100 cm) normally having a pH >8.0.

3.3 YELLOWISH RED SANDY CLAY LOAMS (Eutric Regosols) Map Unit Re

These soils occupy an elevated area south of the depression around Python Hill. They comprise a deep, well drained unconsolidated mantle of yellowish red (5YR 4/6) sandy clay loam derived from gneissic parent materials, (PT4, Appendix A). The soils are porous, though weakly structured with an erodible sandy loam topsoil. Poor aggregate stability in surface horizons is due

to the low clay content and low levels of organic matter. Soil pH is neutral (7-7.8) with very low field EC values.

This land is not commandable for surface irrigation but could be utilised for overhead methods.

3.4 WEAKLY STRUCTURED BROWN SILTY CLAY - CLAY LOAMS (Calcic Luvisols) Map Unit Lk

These soils occupy a limited area in the centre of the project site, comprising deep well drained brown (7.5YR 5/4) weakly structured silty clay - clay loams. Surface horizons comprise a very fine silty clay, forming a very fine weakly aggregated dry dust.

Though only occupying a limited area these soils do present special management problems with regard to furrow irrigation. Estate management reported severe difficulties forming ridges on these soils.

The lower permeability, caused by pore blocking, is demonstrated by the results of the field hydraulic conductivity tests. Both permeability and infiltration rates were less than half those on the better structured more porous brown clays.

3.5 HALOMORPHIC SOILS (Depression) (Mollic Solonetz, Sm; Vertic Solonetz, Sv) Map Unit Sm/Sv

The soils of the depression comprise mainly saline and saline alkali alluviums with properties influenced by the presence of soluble salts or sodium ions in the exchange complex, or both. Salinisation of the soil has occurred as a result of the accumulation of soluble salts in the profile by natural processes and the addition of saline drainage water.

The watertable lies within 2 m of the surface resulting in upward migration of salts to surface horizons. Horizons of maximum salt concentration may occur at depth, or at the surface depending on the local level of the watertable, or the degree of leaching.

On the periphery of the depression the soils are saline and very strongly alkaline throughout their depth even though a watertable may not be present. Profile moisture status is, however, influenced by natural seasonal fluctuations in the depth of the watertable within the depression, compounded by the addition of drainage water from surface irrigation upslope.

The saline-alkaline soils of the depression fringes (T13, T15, T16, T21, Appendix B and PT2, PT3, Appendix A) comprise deep moderately well-imperfectly drained clay loam with a black-very dark brown 10YR 2/1-2/2 topsoil, and a brown (7.5YR 5/4) subsoil. Surface horizons display varying degrees of sodium deflocculation which has also resulted in loss of permeability in the textural B horizon. Vertic properties are also present locally.

Field pH and EC values are generally very high, pH levels often exceeding 9.5 (very strongly alkaline) with EC values exceeding 4 mS/cm (1:5 soil water).

The prismatic structures in the B horizon and high exchangeable sodium percentage (ESP) qualifies these soils for the Solonetz order in the FAO classification system.

3.6 SOIL MAP LEGEND

The distribution of the respective soil types and the location of auger hole and pit sites is shown on the accompanying soil map (see Figure 3.6).

to the low clay content and low levels of organic matter. Soil pH is neutral (7.1-7.5) with very low field EC values.

This land is not recommended for pasture irrigation but could be utilized for overhead methods.

2.4 WEARLY STRATIFIED BROWN SILTY CLAY-LOAM
(Cecil-Lawson, Mm 10A1)

These soils occupy a broad area in the center of the project. The soil is a silty clay loam with a brown (7.5R) to dark brown (5YR 2/1) topsoil and a heavy clay subsoil. The soil is very fine-textured, having a very fine sandy loam texture.

Through only a few years of use, these soils are showing signs of soil compaction and erosion. Problems with waterlogging and soil erosion are noted. Several erosion gullies have formed on these soils.

The soil is moderately fertile by soil standards. It is characterized by the presence of the field horizon. The soil is moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils.

2.5 HAZARDOUS SOILS (Cecil-Lawson, Mm 10A1)

The soils of the depression comprise mainly silty clay and silty clay loam with a topsoil horizon. The soils are moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils. The soil is moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils.

The water table is within 2 m of the surface resulting in upward migration of salts to the surface. The soil is moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils.

On the periphery of the depression the soils are silty clay and silty clay loam. The soils are moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils.

The silty-clay soils of the depression (range P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P27, P28, P29, P30, P31, P32, P33, P34, P35, P36, P37, P38, P39, P40, P41, P42, P43, P44, P45, P46, P47, P48, P49, P50, P51, P52, P53, P54, P55, P56, P57, P58, P59, P60, P61, P62, P63, P64, P65, P66, P67, P68, P69, P70, P71, P72, P73, P74, P75, P76, P77, P78, P79, P80, P81, P82, P83, P84, P85, P86, P87, P88, P89, P90, P91, P92, P93, P94, P95, P96, P97, P98, P99, P100) are moderately fertile and information about soil fertility can be obtained from the soil analysis report on these soils.

Field pH and EC values are generally very high. EC values often exceeding 25 dS/m strongly indicate with EC values exceeding 4 dS/m (1:2 soil water).

The phenolic substances in the B horizon and high exchangeable sodium percentage (ESP) qualify these soils for the Sodic category in the PAC classification system.

2.6 SOIL MAP LEGEND

The distribution of the respective soil types and the location of sugar fields and pits are shown on the accompanying map (see Figure 2.6).

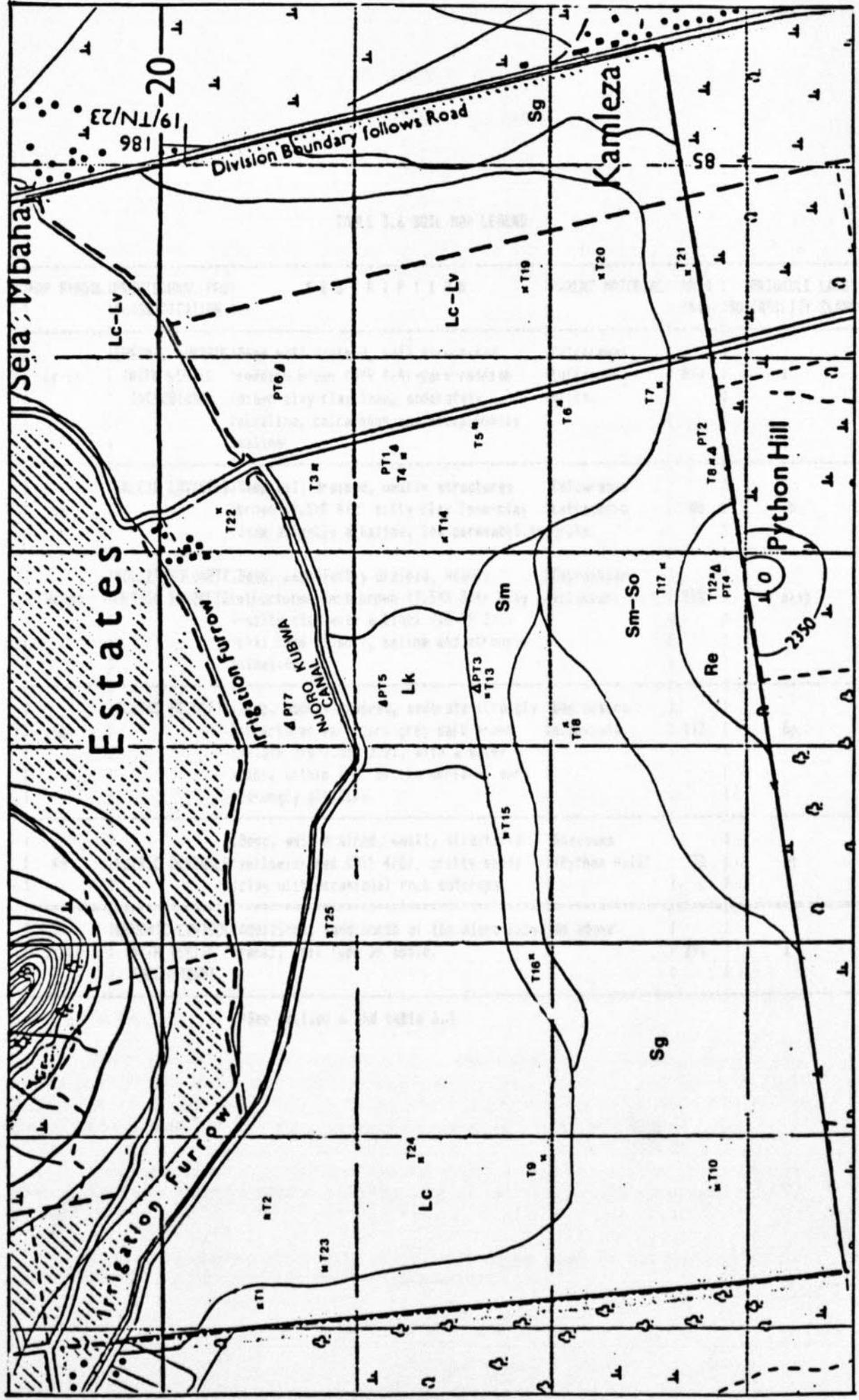


The soil legend is given on the adjoining page with a brief description of the main soil properties. Results of soil chemical analyses from auger hole and pit sites is given in Appendices A and B, and is discussed in detail in Section 4.

Scale 1:20,000

The first part of the report is a brief description of the main results. The second part is a detailed description of the methods used. The third part is a discussion of the results and their implications. The fourth part is a conclusion. The fifth part is a list of references.

FIGURE 3.6 RECONNAISSANCE SOIL MAP OF PROJECT AREA SHOWING LOCATION OF PROFILE PITS AND ROUTINE AUGER OBSERVATIONS



Scale 1:30,000

Scale 1:50,000



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SECTION 4

SOIL CHEMICAL CHARACTERISTICS

4.1 INTRODUCTION

TABLE 3.6 SOIL MAP LEGEND

MAP SYMBOL	PROVISIONAL FAO CLASSIFICATION	DESCRIPTION	PARENT MATERIAL	AREA (ha)	IRRIGABLE LAND SUITABILITY CLASS*
Lc/Lv	CHROMIC LUVISOL (WITH VERTIC INCLUSIONS)	Deep well drained, well structured reddish brown (5YR 4/4)-dark reddish brown clay-clay loam, moderately alkaline, calcareous and occasionally saline	Calcareous tuffaceous grits.	840	1
Lk	CALCIC LUVISOLS	Deep well drained, weakly structured brown (7.5YR 4/2) silty clay loam-clay loam slightly alkaline, low permeability	Calcareous tuffaceous grits.	80	3b
Sm/So	MOLLIC SOLONETZ ORTHIC SOLONETZ	Deep, imperfectly drained, weakly structured dark brown (7.5YR 3/4) clay -silty clay with a black (10 YR 2/1) clay loam topsoil, saline and strongly alkaline.	Depression alluviums	268	6axp
Sg	GLEYPIC SOLONETZ	Deep, poorly drained, moderate-strongly structured very dark grey-dark brown (7.5YR 3/0-7.5YR 3/2), with a water table within 1 m. of the surface, very strongly alkaline.	Depression alluviums	447	6p
Re	EUTRIC REGOSOLS	Deep, well drained, weakly structured yellowish red (5YR 4/6), gritty sandy clay with occasional rock outcrops.	Gneisses (Python Hill)	25	2t
Lc/Lv	CHROMIC LUVISOL (WITH VERTIC INCLUSIONS)	Additional land north of the Njoro Kubwa canal, soil type as above.	As above	290	1

*See section 6 and table 6.3

The program development is similar to that of the first two years as the principal crop for the project was maximum yields for maize variety 600 at 44 0.0 and some highest deficiencies are noted to be in some areas for nitrogen, phosphorus, potassium, calcium, sulfur, zinc, boron, copper, manganese, iron, and sodium. Some generally have soil salinization with the same range.

These deficiencies in pH values indicate results leading to acidic - strongly alkaline, with very strong acidic soils prevailing in the central depression area and the depression fringe soil.

In the well drained area (map unit Lk) pH values generally increase with depth, particularly in the sandy, weathered (7.5YR 4/2 and 5.5YR 4/2) aspects of

TABLE 1. (continued)

Year	Number of cases	Percentage of total cases	Age group	Sex	Occupation	Place of residence
1950	10	10.0	15-24	M	Farmer	Rural
1951	12	12.0	25-34	F	Teacher	Urban
1952	15	15.0	35-44	M	Engineer	Urban
1953	18	18.0	45-54	F	Homemaker	Rural
1954	20	20.0	55-64	M	Businessman	Urban
1955	22	22.0	65-74	F	Retired	Rural
1956	25	25.0	75-84	M	Farmer	Rural
1957	28	28.0	85-94	F	Homemaker	Rural
1958	30	30.0	95-104	M	Farmer	Rural
1959	32	32.0	105-114	F	Homemaker	Rural
1960	35	35.0	115-124	M	Farmer	Rural
1961	38	38.0	125-134	F	Homemaker	Rural
1962	40	40.0	135-144	M	Farmer	Rural
1963	42	42.0	145-154	F	Homemaker	Rural
1964	45	45.0	155-164	M	Farmer	Rural
1965	48	48.0	165-174	F	Homemaker	Rural
1966	50	50.0	175-184	M	Farmer	Rural
1967	52	52.0	185-194	F	Homemaker	Rural
1968	55	55.0	195-204	M	Farmer	Rural
1969	58	58.0	205-214	F	Homemaker	Rural
1970	60	60.0	215-224	M	Farmer	Rural
1971	62	62.0	225-234	F	Homemaker	Rural
1972	65	65.0	235-244	M	Farmer	Rural
1973	68	68.0	245-254	F	Homemaker	Rural
1974	70	70.0	255-264	M	Farmer	Rural
1975	72	72.0	265-274	F	Homemaker	Rural
1976	75	75.0	275-284	M	Farmer	Rural
1977	78	78.0	285-294	F	Homemaker	Rural
1978	80	80.0	295-304	M	Farmer	Rural
1979	82	82.0	305-314	F	Homemaker	Rural
1980	85	85.0	315-324	M	Farmer	Rural
1981	88	88.0	325-334	F	Homemaker	Rural
1982	90	90.0	335-344	M	Farmer	Rural
1983	92	92.0	345-354	F	Homemaker	Rural
1984	95	95.0	355-364	M	Farmer	Rural
1985	98	98.0	365-374	F	Homemaker	Rural
1986	100	100.0	375-384	M	Farmer	Rural
1987	102	102.0	385-394	F	Homemaker	Rural
1988	105	105.0	395-404	M	Farmer	Rural
1989	108	108.0	405-414	F	Homemaker	Rural
1990	110	110.0	415-424	M	Farmer	Rural
1991	112	112.0	425-434	F	Homemaker	Rural
1992	115	115.0	435-444	M	Farmer	Rural
1993	118	118.0	445-454	F	Homemaker	Rural
1994	120	120.0	455-464	M	Farmer	Rural
1995	122	122.0	465-474	F	Homemaker	Rural
1996	125	125.0	475-484	M	Farmer	Rural
1997	128	128.0	485-494	F	Homemaker	Rural
1998	130	130.0	495-504	M	Farmer	Rural
1999	132	132.0	505-514	F	Homemaker	Rural
2000	135	135.0	515-524	M	Farmer	Rural
2001	138	138.0	525-534	F	Homemaker	Rural
2002	140	140.0	535-544	M	Farmer	Rural
2003	142	142.0	545-554	F	Homemaker	Rural
2004	145	145.0	555-564	M	Farmer	Rural
2005	148	148.0	565-574	F	Homemaker	Rural
2006	150	150.0	575-584	M	Farmer	Rural
2007	152	152.0	585-594	F	Homemaker	Rural
2008	155	155.0	595-604	M	Farmer	Rural
2009	158	158.0	605-614	F	Homemaker	Rural
2010	160	160.0	615-624	M	Farmer	Rural
2011	162	162.0	625-634	F	Homemaker	Rural
2012	165	165.0	635-644	M	Farmer	Rural
2013	168	168.0	645-654	F	Homemaker	Rural
2014	170	170.0	655-664	M	Farmer	Rural
2015	172	172.0	665-674	F	Homemaker	Rural
2016	175	175.0	675-684	M	Farmer	Rural
2017	178	178.0	685-694	F	Homemaker	Rural
2018	180	180.0	695-704	M	Farmer	Rural
2019	182	182.0	705-714	F	Homemaker	Rural
2020	185	185.0	715-724	M	Farmer	Rural
2021	188	188.0	725-734	F	Homemaker	Rural
2022	190	190.0	735-744	M	Farmer	Rural
2023	192	192.0	745-754	F	Homemaker	Rural
2024	195	195.0	755-764	M	Farmer	Rural
2025	198	198.0	765-774	F	Homemaker	Rural
2026	200	200.0	775-784	M	Farmer	Rural
2027	202	202.0	785-794	F	Homemaker	Rural
2028	205	205.0	795-804	M	Farmer	Rural
2029	208	208.0	805-814	F	Homemaker	Rural
2030	210	210.0	815-824	M	Farmer	Rural

Source: Author's calculations.

SECTION 4

SOIL CHEMICAL CHARACTERISTICS

4.3 ALKALINITY

4.1 INTRODUCTION

Samples were collected from seven representative profile pits excavated to a depth of 2 m, and from routine auger hole observations dispersed throughout the project area.

Field analyses of texture, EC and pH are supplementary to samples collected (by horizon) from profile pits, and serve to identify soil chemical constraints to the development of irrigated agriculture in the project area. The sites from which samples were taken are marked on the accompanying soil map (Figure 3.6) and results of analyses given in Appendices A and B.

Soil chemical characteristics having the most relevance for irrigation development are:

- pH
- Alkalinity (ESP)
- Salinity (EC)
- Cation Exchange capacity (CEC)

Laboratory analyses also included; trace elements, copper manganese, zinc and boron, and tests for available phosphorus, potassium, total nitrogen and organic carbon.

4.2 SOIL pH

Soil pH (acidity/alkalinity) was measured in a 1:5 soil water suspension in the field using a portable pH meter, and in the laboratory (on profile pit samples only) using a 1:5 soil water suspension and 1:5 potassium chloride solution. The latter tends to yield values somewhat lower, of the order of 1.0 - 2.0 units.

Ranges used for the interpretation of pH data are:

Extremely acid	below 4.5	Neutral	6.6 - 7.3
Very strongly acid	4.5 - 5.0	Mildly alkaline	7.4 - 7.8
Strongly acid	5.1 - 5.5	Moderately alkaline	7.9 - 8.4
Medium acid	5.6 - 6.0	Strongly alkaline	8.5 - 9.0
Slightly acid	6.1 - 6.5	Very strongly alkaline	9.1 +

Soil pH affects the availability of nutrients to plants, though the tolerance limits of different crops varies greatly. For most crops a neutral range is the most suitable with pH values between 6.6 and 7.3.

The proposed development considers maize and french seed beans as the principal crop for the project area. Maximum yields for maize normally occur at pH 6.0 and above. Nutrient deficiencies are least likely to occur where the crop is grown for a maximum yield within the pH range 5.6 to not more than 7.5. Beans generally have a pH tolerance within the same range.

Field determinations of pH values yielded results tending towards the mildly - strongly alkaline, with very strongly alkaline soils occurring in the central depression area and the depression fringe soils.

In the well drained clays (map unit Lc) pH values generally increase with depth, particularly on recently irrigated land (T4, 5 and 6, Appendix B).

SECTION 4

SOIL CHEMICAL CHARACTERISTICS

4.1 INTRODUCTION

Soil samples were collected from seven representative locations along the length of the site and were analyzed for various chemical parameters. The results are presented in this section.

Field analyses of soil pH and electrical conductivity (EC) were conducted to provide preliminary information on soil characteristics. Soil pH values range from 4.5 to 7.5, and EC values range from 100 to 200 $\mu\text{mhos/cm}$. These results indicate that the soil is generally acidic and has a low to moderate salinity.

Soil chemical characteristics were analyzed for various parameters:

- pH
- Electrical Conductivity (EC)
- Cation Exchange Capacity (CEC)

Laboratory analyses were conducted for various chemical parameters including major and minor nutrients, trace metals, and organic carbon. The results are presented in this section.

4.2 SOIL pH

Soil pH (measured in water) was measured at 15 soil sampling locations. The pH values range from 4.5 to 7.5, with a mean value of 6.5. The pH values are generally acidic, which may affect the availability of nutrients and the growth of plants.

Range used for the interpretation of pH values:

Soil pH	Soil Condition	Soil Type	Soil Quality
4.5 - 5.5	Very strongly acidic	Acidic	Very poor
5.5 - 6.5	Strongly acidic	Acidic	Poor
6.5 - 7.5	Weakly acidic	Neutral	Fair
7.5 - 8.5	Weakly alkaline	Alkaline	Good
8.5 - 9.5	Strongly alkaline	Alkaline	Very good
9.5 - 10.5	Very strongly alkaline	Alkaline	Excellent

Soil pH affects the availability of nutrients to plants. In general, the availability of nutrients is highest at a pH of 6.5 to 7.5. For most crops, a pH range of 6.0 to 7.0 is considered optimal for growth.

The present investigation shows that the soil pH is generally acidic. This may affect the availability of nutrients and the growth of plants. It is recommended that the soil pH be adjusted to a range of 6.5 to 7.5 to improve soil fertility and crop production.

Field determination of soil pH was conducted using a portable pH meter. The results are presented in this section. The soil pH values are generally acidic, which may affect the availability of nutrients and the growth of plants.

In the field, soil pH was measured at 15 soil sampling locations. The pH values range from 4.5 to 7.5, with a mean value of 6.5. The pH values are generally acidic, which may affect the availability of nutrients and the growth of plants.

pH values greater than 8.5 indicate a high exchangeable sodium percentage, i.e. an exchange complex saturated with sodium ions, and an increasing alkali hazard. Field determinations of pH (Appendix B) provide a broad indication of the distribution of the alkali hazard throughout the project area.

4.3 ALKALINITY

The degree of alkalinity in soils is most commonly expressed in terms of exchangeable sodium percentage (ESP) as a measure of the percentage of the exchange complex occupied by exchangeable sodium. The main effect of high ESP values is the dispersion of clay, causing the soil to be dense and difficult to work, reducing the permeability and infiltration rates, and, in general, making it a poor medium for plant growth.

A soil is considered alkali when the ESP exceeds 15 per cent. Although widely quoted in the literature this value is somewhat arbitrary since the effects of increasing ESP are progressive, and the limit beyond which deterioration in soil structure occurs depends upon the type of clay mineral present.

ESP values obtained for the depression soils were very high (>50% PT2 and 3), and generally very low (<2% PT1, 5, 6 and 7) on the well drained clays. Alkalinity in the subsoil increases with depth on irrigated soils and progressively downslope with increasing drainage impedance. Increasing alkalinity is accompanied by observable changes in soil structure and colour (cf. PT 6 and PT3).

Suggested soil amendments for saline-alkali soils are discussed in Section 4.10.

4.4 SALINITY

The quantity, nature and distribution of soluble salts is perhaps one of the most important factors affecting irrigation development.

EC measured in a saturation extract most closely simulates salinity conditions in the root zone, however, this method was impractical for field conditions and the simpler method of determining EC using a 1:5 soil water solution was used. Since the soil solution is more dilute interpretation of field EC data must be multiplied upwards by a factor of approximately 6.4 to obtain an estimated equivalent saturated extract value.

Field and laboratory EC data results are supplied in Appendices A and B.

Both field and laboratory EC data yield very high values for the depression periphery soils in the south and south west of the project area. Profile pits PT2 and PT3 are moderately saline and strongly saline (ECe 8 mS/cm and 36 mS/cm respectively). Other profiles, notably sites T7, 15, 16, 17 and 21 also yielded relatively high values, using a field conductivity bridge. All of these sites are concentrated in or immediately adjacent to encroaching swamp lands.

In evaluating soils for sustained irrigation the importance of the initial level of salt varies according to the ease with which salts can be leached from the root zone. The presence of high salt contents in soils of limited permeability presents particular problems for leaching. In the project area the relatively fine textures occurring in juxtaposition to an extensive area of poorly drained soils will render reclamation difficult and costly.

There is some evidence of increases in subsoil salinity on more recently irrigated land (Site PT1) and sites adjacent to the depression (T7). This indicates that salinity levels are rising from the base of the profiles as groundwater levels within the depression encroach on the better drained soils.

the values greater than 0.5 indicate a high extractable soil percentage, i.e. an exchange complex associated with organic acids and an increasing alkali content. From the data of the 1950-51 season a broad indication of the direction of the alkali trends throughout the period was

4.2. ALKALINITY

The degree of alkalinity in soils is most commonly expressed in terms of exchangeable sodium percentage (ESP), as a measure of the percentage of the exchange complex occupied by sodium. The soil water content of ESP values is the percentage of clay, leaving the soil to be dried and divided in water. Although the ESP values are not directly related to the general salinity of the soil, they are

A soil water content of 20% when the ESP is 10% is a low soil. Although widely quoted in the literature, it is a statement of fact that the effect of increasing ESP, the percentage of the soil water content, is not the same in all soils. The soil water content depends upon the type of clay mineral present.

ESP values ranged from 0.5 to 1.0 in the 1950-51 season. ESP values were very high (ESP 1.0 and 2.0) and generally very low (ESP 0.5 and 1.0) on the west and east slopes. Alkalinity in the soil increases with depth in some soils and decreases in others. The soil water content and ESP values are related to the soil texture and the degree of soil salinity. ESP values of 0.5 and 1.0 are considered to be low and high respectively.

ESP values and soil water content are discussed in Section 4.10.

4.3. SALINITY

The degree of soil salinity is indicated by the electrical conductivity of the soil water. The soil water content of the soil is the most important factor in determining the degree of soil salinity.

The electrical conductivity of soil water is a measure of the degree of soil salinity. The degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil.

Field and laboratory EC data are given in Tables A and B.

Both field and laboratory EC data are given in Tables A and B. The degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil.

In evaluating soils for salinity, the degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil. The degree of soil salinity is determined by the amount of soluble salts in the soil.

There is some evidence of increased soil salinity in some recent irrigated soils (see 5.11) and also related to the depression (17). This indicates that salinity levels are high from the base of the profiles as groundwater levels within the depression are high. Salinity levels are also high in the soil.

Soils on more elevated sites, particularly the brown calcareous clays generally have very low salinity levels. Provided adequate drainage is provided to prevent salinisation of profiles these soils have very high development potential.

4.5 SALINE-ALKALI SOILS

The USDA (1954) define three soil groups with regard to salinity-alkalinity:

- saline soils
- saline-alkali soils
- non-saline alkali soils

Saline soils have a conductivity of the saturation extract of more than 4 mS/cm at 25°C and an ESP of less than 15. Ordinarily the pH is less than 8.5.

Saline-alkali soils are soils with a conductivity of the saturation extract greater than 4 mS/cm and an ESP >15%, pH is normally >8.5.

Non-saline alkali soils have a conductivity of the saturation extract less than 4 mS/cm and an ESP >15%; pH is in the range 8.5 - 10.0.

Except where appreciable quantities of gypsum are present in the soil the leaching of saline-alkali soils leads to the formation of non-saline alkali soils. This latter group of soils in time develops characteristic morphological features.

The soils of the central depression periphery fall into the saline-alkali group with mainly alkali soils occurring within the depression. Reference to field EC and pH data in Appendix B provides an indication of the distribution of salinity/alkalinity within the project area. More detailed surveys would define the precise soil boundaries of the saline-alkali soil groups.

4.6 EXCHANGEABLE CATIONS

(i) Cation Exchange Capacity

The cation exchange capacity (CEC) is a measure of the ability of the soil to adsorb and retain cations against leaching. It is dependent upon the amount of organic matter present, the type and amount of clay, and pH.

Ratings for the interpretation of CEC values are as follows:

CEC me/100 g of soil	rating
>40	Very high
25-40	high
15-25	medium
5-15	low
<5	very low

Values obtained for project area soils fall into the high-very high range, reflecting the high clay content.

Exchangeable forms of calcium magnesium and potassium constitute the major sources for plant nutrition. Calcium is the dominant cation followed by magnesium potassium and sodium, in descending order. The levels of exchangeable cations and their relationship to each other generally provide a more meaningful indication of fertility than the CEC value per se.

Soil of more elevated areas generally has lower clay content than soils of lower areas. This is probably due to the fact that the soil of lower areas is more likely to be eroded and deposited in lower areas.

4.2 SALINE/ALKALI SOILS

The USDA (1961) defines three soil types with respect to salinity/alkalinity:

- Saline soils
- Sodic soils
- Saline-sodic soils

Saline soils have a salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of less than 15. Sodic soils have a salinity of less than 0.5 at 5 cm and an EC_e of less than 15.

Saline-sodic soils have a salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of 15 or greater.

Saline soils have a salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of 15 or greater.

Soils with an apparent salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of less than 15 are considered to be saline soils. Soils with an apparent salinity of less than 0.5 at 5 cm and an EC_e of 15 or greater are considered to be sodic soils.

The soil of the study area is a saline soil. It has a salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of less than 15. The soil is also a saline-sodic soil because it has a salinity of 0.5 or greater (measured in dS/m) at 5 cm and an EC_e of 15 or greater.

4.3 EXCHANGEABLE CATIONS

The exchangeable cations in the soil are sodium, calcium, magnesium, and potassium. Sodium is the dominant cation in the soil. The exchangeable cations in the soil are measured in meq/100 g soil.

Results for the exchangeable cations are as follows:

Exchangeable Cation	meq/100 g soil
Very high	> 20
High	10-20
Medium	5-10
Low	2-5
Very low	< 2

When analyzed for percent cation exchange capacity (CEC), the soil is classified as a high CEC soil. This is due to the high sodium content of the soil.

Soils with a high CEC are generally more fertile than soils with a low CEC. This is because the high CEC soil can hold more nutrients in the soil. The soil of the study area is a high CEC soil. It has a CEC of 20 meq/100 g soil.

(ii) Exchangeable Calcium, Magnesium and Potassium

Exchangeable calcium levels in the project area are very high and reflect the calcareous nature of the parent material (Section 1.3). Levels of exchangeable potassium are also very high. Interpretation of absolute exchangeable Ca and Mg levels are, however, distorted by the presence of appreciable quantities of free carbonates, which are taken into solution.

Antagonisms may occur between nutrients if the Mg/K ratio is less than two, or the Ca/K ratio is less than five, due to excessive absorption of potassium by the plant.

All the soils in the project area, including the depression soils have exchangeable calcium levels in excess of 50 me/100 g.e.d.s. These values are considerably inflated by the presence of free carbonates, and estimates of possible nutrient imbalances induced by high levels of calcium are not, therefore, attainable.

The high proportion of free calcium in all the soils in the project area may render residual phosphates less available to plants by conversion of phosphate to calcium phosphate. Micronutrients may also be adversely affected, and growing crops should be examined for nutrient deficiency symptoms.

(iii) Exchangeable Sodium

The exchangeable sodium percentage (ESP) is calculated from the exchangeable sodium content as a percentage of the cation exchange capacity. Appreciable quantities of exchangeable sodium occur in the depression and depression fringe soils giving very high ESP values (PT2 and 3). These values would normally be expected to have adverse effects on soil structure.

4.7 ORGANIC CARBON AND NITROGEN

Soil nitrogen is frequently the most important single nutrient element limiting crop yields. The chief natural source of soil nitrogen is decaying organic matter. Clearance of natural forest vegetation and subsequent cultivation generally results in reductions in N necessitating the application of nitrogenous fertilisers.

Values obtained for project area topsoils are generally moderate in the well drained brown clays (0.17 - 0.21 per cent) to high in the depression soils.

Organic carbon levels in topsoils are low on the well drained soils (1.3 - 1.88 per cent) and low on the depression soils (2.01 - 3.44 per cent).

Carbon nitrogen ratios are of the order of 8 - 10 which are generally considered to be rather low.

4.8 AVAILABLE PHOSPHORUS

Phosphorus is second in importance only to nitrogen as a crop nutrient. Available phosphorus was measured on soil samples using the Bray and Olsen methods. The Olsen method is however more appropriate for soils with pH >7.0.

Established norms for the interpretation of available P data are as follows:

<5 ppm	extremely deficient
5-15 ppm	deficient
15-25 ppm	average
>25 ppm	adequate to high

4) **Extraneous Calcium, Magnesium and Potassium**
 Extraneous calcium in the project area may affect the calcium content of the soil. The level of extraneous potassium is also very low. The amount of absolute extraneous Ca and Mg levels are however detected by the amount of extraneous quantity of the carbonate which are in the soil.

Extraneous may occur between the two soils in the soil. The amount of extraneous calcium in the soil is less than two or three times the amount of calcium in the soil.

As the soil in the project area, including the depression soils have extraneous calcium in the soil. The level of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low.

The pH in the soil is low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low.

The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low. The amount of extraneous calcium is considered to be low.

4.3 ORGANIC CARBON AND NITROGEN

Soil nitrogen is generally the most important nutrient element for plant growth. The amount of soil nitrogen is generally the most important nutrient element for plant growth. The amount of soil nitrogen is generally the most important nutrient element for plant growth.

Values obtained for project area soils are generally moderate to the well defined brown class (1.7 - 2.21 per cent) in the depression soils.

Organic carbon levels in soils are low to the well defined soils (1.3 - 1.89 per cent) and low on the depression soils (2.01 - 2.44 per cent).

Carbon nitrogen ratio of the soils is 1 - 10 which are generally considered to be rather low.

4.4 AVAILABLE PHOSPHORUS

Phosphorus is second in importance only to nitrogen as a crop nutrient. Available phosphorus was measured on soil samples using the Bray and Kurtz method. The Bray method is however more appropriate for soils with pH > 7.5.

Established norms for the interpretation of available P data are as follows:

< 5 ppm	extremely deficient
5 - 15 ppm	deficient
15 - 25 ppm	average
> 25 ppm	adequate to high

Measured values on project area topsoils vary from deficient (PT5 and 7) to adequate-high (PT1, 2, 3 and 6). For maize these levels are generally considered to be adequate though under surface irrigation the application of phosphatic fertilisers will be required.

4.9 MICRONUTRIENTS

4.9.1 IRRIGATION WATER QUALITY

The soils were analysed for copper, manganese, zinc and boron, using DTPA extractant.

(i) Zinc:

Zinc deficiency is likely to occur when available levels are below 1 ppm. Zinc decreases in availability on soil flooding and disorders are common on calcareous soils with a high pH.

All the project area soils are deficient in zinc with values falling as low as 0.4 ppm in topsoils (PT5) to 0.2-0.3 ppm in the subsoil. Zinc deficiency in maize normally manifests itself in the form of chlorotic fading of the leaves with broad whitish areas. These may develop during early maturity.

(ii) Copper:

Maize is particularly sensitive to copper deficiency. Deficiencies are common in soils with less than 1 ppm. Values obtained for the project area soils are satisfactory though availability may be reduced with increasing pH. The range of values tends to be of the order of 2-3 ppm.

(iii) Manganese:

Available manganese not less than 10-15 ppm is essential for normal plant growth. Plant available manganese is dependent upon pH decreasing markedly at approximately pH 7.0 in calcareous soils.

Manganese levels in the project area are adequate in the top 0-50 cm but decrease markedly in the subsoil. Levels range from 18-29 ppm in the topsoil to as little as 2-3 ppm in some subsoils.

(iv) Boron:

Hot water extractable boron determinations were carried out on all profile pit samples. Toxic levels of boron are often present in saline-alkali soils and results show toxic concentrations in excess of 11 ppm in profile PT3 and potentially toxic concentrations in profile PT2. These levels are, however, confined to the lower half metre of subsoil. Levels of boron in the well drained soils are satisfactory for most crops.

4.10 SOIL AMENDMENTS

If reclamation of the saline-alkali soils of the depression and depression fringe is to be considered, certain soil physical and chemical amendments will be required.

Gypsum is the most commonly used amendment to replace sodium in the exchange complex, though irrigation water may sometimes dissolve sufficient calcium to decrease the sodium hazard appreciably. This process may be enhanced by adding acid or acid forming amendments such as sulphur or iron sulphate. These amendments have the overall effect of bringing calcium into the soil solution facilitating the replacement of sodium in the exchange complex.

Applications of gypsum should be accompanied by measures to maintain structure and permeability including deep ploughing, subsoiling and profile inversion. Saline alkali soils are generally flocculated and permeable at the start of reclamation whereas alkali soils are not. Soils within the depression are likely to require different treatments to those on the periphery.

Measurements of project area topsoils vary from depths (FTS and T) to depths
high (FTS and T) or more base levels are generally considered to be adequate through
under sulfate injection the application of phosphate fertilizers will be reduced.

SOIL AMENDMENTS

The soil was analyzed for copper, manganese, zinc and boron using DTPA extraction.

(i) Zinc
Zinc deficiency is likely to occur with available levels are below 1 ppm. Zinc deficiency
is available on soil testing and boron is common on calcareous soils with a pH
5.0.

(ii) Copper
Zinc and copper are deficient in soil with values below 0.5 ppm. In
topsoils (T) to 1-2 ppm. Zinc deficiency is likely to occur with available
levels in the form of zinc in the soil. The range of values tends to be
decreasing during early maturity.

(iii) Manganese
Manganese is particularly sensitive to copper deficiency. Deficiencies are common in soils with
less than 1 ppm. Values reported for the project area soils are satisfactory though
availability may be reduced with increasing pH. The range of values tends to be
order of 2-3 ppm.

(iv) Boron
Available manganese has been found to be essential for normal plant growth. Plant
available manganese is dependent upon pH decreasing markedly as soil pH increases
5.0 in calcareous soils.
Manganese levels in the project area are adequate in the top 0-20 cm for the duration
markedly in the subsoil. A range from 10-20 ppm in the topsoil to 20-30 ppm
in some subsoils.

(v) Sulfate
Hot water extractable boron determinations were carried out on all profile pit samples.
Toxic levels of boron are often present in calcareous soils and toxic boron
concentrations in excess of 1 ppm in soils. PFTs and potentially toxic concentrations
profile PFTs. These levels are however, confined to the lower soil water in subsoil. Levels
of boron in the soil are adequate for most crops.

SOIL AMENDMENTS

The reaction of the calcareous soil of the depression and depression fringe is to be
overland, certain soil physical and chemical amendments will be required.

Gypsum is the most commonly used amendment to replace sodium in the exchange
complex through higher water may, sometimes reduce sulfate calcium to decrease the
sodium hazard especially. This process may be enhanced by adding acid or acid forming
amendments such as sulfur or iron sulfate. These amendments have the overall effect of
changing calcium into the soil solution facilitating the replacement of sodium in the exchange
complex.

Applications of gypsum should be accompanied by measures to maintain soil structure and
generally including deep ploughing, subsoiling and profile location, where soil and
generally flocculated and permeable at the start of reclamation efforts with soil and
within the depression are likely to require different treatments to those on the periphery.

In addition to chemical amendments the only practical means of reducing soil salinity/alkalinity is by leaching. The depth at which the watertable should be maintained depends on the hazard of upward movement of salts; the range of depth recommended for maize and beans is 1.5-2.0 m.

4.11 IRRIGATION WATER QUALITY

Analysis of irrigation water from Homers and Njoro Kubwa springs gave results in the C2-S1 range using the USDA classification for irrigation water. This gives water of medium salinity hazard and low sodium hazard, which can be used if a moderate amount of leaching occurs. EC levels in profiles on existing irrigated lands show increased in EC with depth. Over a period of time these salts are likely to build up to harmful levels in the root zone unless provision is made for field drainage.

Analysis of drainage water at site T18 shows medium-high salinity drainage water with high levels of sodium. Results of the water analyses are given in Appendix E.

4.12 AGRONOMICS

The proposed development anticipates a maize culture followed by french seed beans using surface irrigation.

(i) Maize

Maize generally requires a more fertile soil for good yields than most other crops having a particularly high uptake of nutrients, particularly potassium. The most significant elements for nutrient availability to maize are pH, organic carbon, P(Olsen), exchangeable potassium and nitrogen.

Nitrogen is the most important nutrient though this may interact significantly with irrigation and plant populations. Ammonium ions are preferred over nitrate ions by the young maize plant but at a later stage nitrate ions are taken up much more readily, some from organic sources.

Because the maize plant uses nitrogen throughout its growth period applications of nitrogenous fertilisers will be required at Taveta at an approximate rate of 70 - 120 kg/ha.

Though P levels are adequate in some profiles maintenance applications of P_2O_5 are recommended under surface irrigation at a rate of 45-80 kg/ha. P responses in maize are, however, difficult to predict because of other interrelated factors. Large applications of P may induce zinc deficiency; P uptake may also be adversely affected by excessive levels of calcium.

Responses to applications of K_2O are not considered likely in view of the very high residual levels of potassium.

Generally, because of their high fertility status the brown clays are well suited to a maize culture. On the marginal soils subsoil waterlogging, salinity/alkalinity and boron toxicity will limit production.

(ii) French seed beans

Under irrigated conditions applications of N at a rate of approximately 70-80 kg/ha are recommended with 50-60 kg P_2O_5 per ha. Supplementary side dressings of N are recommended at a rate of 20-30 kg/ha. Nitrogen requirements can, however, be substituted by treating the seed with the correct race of RHIZOBIUM inoculant if available.

Full benefits from fertiliser applications will be accrued mainly from good seedbed preparation, favourable moisture conditions and efficient control of pests and weeds. For maize delayed planting before the rains tends to reduce yields significantly often leaving young plants growing in saturated soils.

SECTION 5

SOIL PHYSICAL PROPERTIES AND MANAGEMENT

The physical properties of the principal soil types identified were evaluated visually in the field according to FAO guidelines whilst workability was qualitatively assessed during pit excavation and infiltration tests.

Time constraints did not permit a detailed investigation of the physical properties of the soils in the field or the laboratory.

In order to facilitate evaluation of the soils for development of surface irrigation a number of assumptions are made using information extracted from standard tables and available technical literature. These are discussed below under separate but interrelated headings.

5.1 SOIL AGGREGATION

Soil aggregation is the process whereby a number of soil particles are held together to form units or peds of varying characteristic shapes. Stability of the aggregates is dependent upon clay content, organic matter and degree of cementation. The presence of sodium in appreciable quantities on the exchange sites weakens the bonding between clay particles causing deflocculation. Aggregates thus become soft floury and generally unstable on wetting dry soil.

Of the principal soil types, particularly around site PT3 (see Appendix A) and on the margins of the depression (T15 and T16, Appendix B) deflocculation of surface horizons is evident. Eluviation of clay particles into lower horizons has contributed to loss of pore space and a general deterioration of soil structure (PT3, PT5, Appendix A). Cultivation in very dry conditions thus results in the production of many dust particles.

The gradual decline in waterstable aggregates precipitated by this process is also evident when comparing profiles excavated on more recently irrigated land with profiles opened on later abandoned irrigated land.

5.2 SOIL STRUCTURE

Soil structure is the combination or arrangement of primary soil particles into secondary particles, units or peds. These units are characterised and classified on the basis of size, shape and degree of distinctness into classes, types and grades respectively. The solid structure of the peds or aggregates is less important than the spaces between them through which roots may penetrate.

Soil structure also determines the level of compaction with resultant effects upon the infiltration of applied moisture.

The strongly structured brown clays generally have favourable structural properties to a depth of 1 m with medium-coarse sized peds between which roots can easily penetrate. Cracks and surfaces of weakness that separate natural aggregates are generally well developed, and though the peds are relatively dense they readily absorb applied moisture.

Soil structure is poorly developed in the halomorphic soils (PT3, Appendix A). Distinct peds are almost absent on exposed soil faces and the soil contains many fine pores too small for root penetration which do not readily release soil moisture to plants.

SECTION 2
SOIL PHYSICAL PROPERTIES
AND MANAGEMENT

The physical properties of the different soil types described were evaluated mainly in the field according to FAO guidelines with, possibly, some laboratory assessment during the evaluation and after the test.

These considerations did not permit a detailed investigation of the physical properties of the soils in the field or in the laboratory.

In order to evaluate the soil for development of surface irrigation a number of parameters were used, selected from available tables and available technical literature. These are discussed below under separate but interrelated headings.

2.1 SOIL AGGREGATION

Soil aggregation is the process whereby a number of soil particles are held together to form units or aggregates of varying sizes. Stability of the aggregates is dependent on soil organic matter and degree of cementation. The presence of sodium in aggregates influences on the expansion and contraction of the soil particles causing disintegration. A good aggregate is one which is stable and gives a friable soil when dry.

Of the principal soil types, particularly in the PTB (see Appendix IV) and in the regions of the Indus (PTI and TII), Appendix (A) definition of surface horizons is evident. Evaluation of clay content and water content has contributed to loss of soil cohesion and a general deterioration of soil structure (PTI, PTII, Appendix A). Cultivation in very dry conditions has resulted in the production of many first grades.

The gradual decline of waterlogging, a negative process by this process is also evident when comparing results recorded in more recent irrigated lands with those covered on later abandoned irrigated land.

2.2 SOIL STRUCTURE

Soil structure is the arrangement or arrangement of primary soil particles into secondary particles, units or aggregates. These units are characterized and classified on the basis of size, shape and degree of cohesion, texture, type and grade respectively. The soil structure of the bulk of aggregates is less important than the space between them through which water and air pass.

Soil structure also determines the level of compaction with resultant effects upon the retention of applied moisture.

The strongly structured brown clayey soils have generally a structural proportion to a depth of 4 m with hard indurated clay beds between which roots pass easily. These soils are of a high degree of waterlogging and are generally well developed and through the roots are relatively close they readily accept applied moisture.

Soil structure is being developed for the brown soils (PTI, Appendix A). Districts in the most arid or exposed soil areas and the soil contains many fine roots and many are not penetrable which do not readily release soil moisture to plants.

In some areas however, these soils exhibit strong structure with polygonal cracking (vertic properties) in surface horizons.

Under surface irrigation topsoil structure is ephemeral and unstable, particularly if sodium is present in the soil. Whereas tillage practices aim to improve deficiencies in topsoil structure this can have the opposite effect resulting in enhanced dispersion and eluviation of clay particles. Soil aggregates become smaller, clog larger pores and reduce infiltration.

5.3 WORKABILITY

Workability is a function primarily of soil consistence, density, structure, moisture content and aggregate stability. Some of these attributes can be controlled directly or indirectly using surface irrigation.

The clayey soils of the project area have a generally sticky and plastic consistence rendering them difficult to manage when wet. Careful management of irrigation applications is therefore required to ensure that land preparation techniques minimise soil structural deterioration, principally through the effects of smearing when the soil is too wet.

Workability may also be limiting during and after the rains. Tillage during this period should be limited to days when the soil is moist (but not wet) and friable to achieve optimum working conditions.

In a moist condition the soils are firm - friable depending on clay content and levels of organic matter. Topsoils under mature regrowth generally tend to have more favourable workability characteristics.

Clayey soils are easily formed into ridges, though some soil structural deterioration is anticipated over time. On the calcareous soils with unstable topsoil structures maintenance of ridges will be more problematic (see section 3.4). Relatively low ridges (15 cm) are recommended to avoid accumulation of harmful salts on the apex of the ridge during the early growth stages. Field experimentation would be required to determine the optimum spacing but 80-90 cm may be used as a rule of thumb.

Timely subsoiling and/or ripping will help to alleviate panning and facilitate the downward penetration of applied moisture and leaching fractions.

5.4 MOISTURE RETENTION AND AVAILABILITY

The available water capacity (AWC) of a soil is that portion of the total waterholding capacity which is available to roots to sustain plant life. The principal forces which restrict the uptake of moisture are caused chiefly by surface tension within the soil pores and osmotic tension due to salts dissolved in the soil solution.

Laboratory data on available moisture at different suctions was not determined on the soils at Taveta. However, based on field texture and particle size class data, AWC was determined as a depth of water per unit depth of soil from standard tables.

Most of the soils in the Project area have high available water capacities. Indicative values for silty clay loam - clay loams are of the order of 150 - 170 mm/m of soil. Given that the textural profile is relatively uniform from the surface these values can be taken as indicative of all horizons with a clay loam - silty clay loam texture.

Because of a preponderance of smaller pores in some of the finer textured silty clay loams, which release water more slowly, drainable water capacity is reduced. This reduces the leachability of soils with less favourable macro and micro structural properties, particularly the halomorphic soils.

In some cases however, there will be a slight change in soil structure with polyacrylamide application (see section 2.1.1).

Under surface irrigation (sprinkler) systems, the soil is kept moist and the water content is high in the soil. Where large quantities of water are applied, the soil is kept moist and the water content is high in the soil. Where large quantities of water are applied, the soil is kept moist and the water content is high in the soil.

2.1.1 WATER AVAILABILITY

Water availability is a function of the soil moisture content, the soil texture, the soil structure, the soil depth, the soil temperature, the soil salinity, the soil acidity, the soil alkalinity, the soil organic matter, the soil inorganic matter, the soil nutrients, the soil micro-organisms, the soil fauna, the soil flora, the soil biota, the soil chemistry, the soil physics, the soil biology, the soil geology, the soil meteorology, the soil climatology, the soil hydrology, the soil pedology, the soil serology, the soil chronology, the soil stratigraphy, the soil geomorphology, the soil geology, the soil meteorology, the soil climatology, the soil hydrology, the soil pedology, the soil serology, the soil chronology, the soil stratigraphy, the soil geomorphology.

The clayey soils of the project area have a generally sticky and plastic consistency and are difficult to manage when wet. Careful management of irrigation applications is therefore required to ensure that the soil is not over-saturated and that the soil is not waterlogged through the effect of capillary rise from the water table.

Water availability may also be limited during and after the rain. This is due to the fact that the soil is often too wet and that the soil is often too dry to allow optimum working conditions.

In a moist condition the soil will be - sticky depending on clay content and levels of organic matter. Topsoil will generally have more available water than subsoil.

Clayey soils are often found in ridges, through some soil structure deterioration is expected over time. On the other hand, soils with high clay content will have a high water content and will be more plastic. Relatively low clay content (15-20%) will have a high water content and will be more plastic. Relatively low clay content (15-20%) will have a high water content and will be more plastic. Relatively low clay content (15-20%) will have a high water content and will be more plastic.

There is a need for irrigation during and after the rain. This is due to the fact that the soil is often too wet and that the soil is often too dry to allow optimum working conditions.

2.1.2 WATER RETENTION AND AVAILABILITY

The available water capacity (AWC) of a soil is the portion of the total water content which is available to roots to extract. The greater the AWC, the greater the water content of the soil. The greater the AWC, the greater the water content of the soil. The greater the AWC, the greater the water content of the soil.

Laboratory data on available moisture at different suction was not determined on the soils in Table 2.1. However, based on field observations and data, AWC was determined as a depth of water per unit depth of soil from standard tables.

Most of the soils in the Project area have high available water capacity. The values for clay loam - clay loam are of the order of 1.5 to 2.0 mmol/m³ of soil. The values for silty clay loam - silty clay loam are of the order of 1.5 to 2.0 mmol/m³ of soil. The values for silty clay loam - silty clay loam are of the order of 1.5 to 2.0 mmol/m³ of soil.

Because of a proportionate increase in the available water capacity of the soil, the available water capacity of the soil is reduced. This is due to the fact that the soil is often too wet and that the soil is often too dry to allow optimum working conditions.

From the point of view of irrigation management, it remains important that soil water tensions are kept low if crop moisture stress is to be maintained within reasonable limits. Laboratory determinations of available water capacity based on matric suctions in combination with osmotic suctions are required if this objective is to be achieved.

5.5 INFILTRATION

Infiltration refers to the vertical intake of water into a soil at the soil surface.

Ring infiltration tests can only provide a broad indication of soil behaviour under surface irrigation. Basic rates determined by this method can be expected to decrease with time with successive irrigations.

Ring infiltration test results are also often skewed with a greater chance occurrence of relatively high rates.

Two ring infiltration tests were conducted (in triplicate), using water from the main feeder canal, at pit sites PT1 and PT5. Site 1 was slightly moist, site 5 dry throughout.

The field methodology used is described in Appendix C and the results summarised and related to soil types and textures in Table 5.6. Curves of cumulative infiltration and intake rates are illustrated in Appendix C.

Basic infiltration rates $>6.5 \text{ cm h}^{-1}$ are normally considered marginal for surface methods. Measured rates at site PT1, which were in excess of 10 cm h^{-1} , would be expected to decrease with cropping. The FAO (1979a) cites an upper limit of $10\text{-}12 \text{ cm h}^{-1}$ for surface methods.

Excessive losses through deep percolation would not be considered problematic in this case and basic intake rates are considered to be within an acceptable range for surface methods.

Measured rates at test site PT1 were optimum for surface irrigation (3.5 cm h^{-1}).

Infiltration is aided by large pores and favourable soil structure and is therefore a particularly sensitive indicator of changes in soil structure and porosity. Variations in basic infiltration rates between individual tests and different soil types are, therefore, indicative of differences in texture, structure and porosity within the main soil groups. The slower rates at site PT5 compared to site PT1 reflect the generally weaker structural properties and reduced permeability.

Prior to development more detailed investigation of infiltration rate variation within and between the different soil types is recommended, particularly on the virgin calcareous brown clays and soils affected by sodium deflocculation.

5.6 SUBSOIL PERMEABILITY AND DRAINAGE CHARACTERISTICS

Soil permeability is that quality of a soil that enables it to transmit water or air. When defined quantitatively the term hydraulic conductivity (K) expressed in m/day is used as an indication of the drainability of the soil.

Within the depression the watertable lies within 2.0 m of the soil surface. In the south west standing water is present on the soil surface. Although locally distorted by irrigation the watertable is a natural feature related to swamp areas west of Toll Hill in the south west of the project area, and the Kimorigo irrigation scheme in the south east.

Detailed drainage investigations were not carried out at these sites but observation in auger hole and profile pit sites show the substratum to be comprised of heavy clay soils with a

From the point of view of irrigation management, it remains important that soil water tensions are kept low if crop moisture stress is to be minimized within reasonable limits. Laboratory determinations of available water capacity based on water suction in combination with climatic suction are useful if the objective is to be achieved.

2.2 INFILTRATION

Infiltration refers to the vertical intake of water into a soil at the soil surface.

Field infiltration tests can only provide a crude indication of soil behaviour under surface irrigation. Field tests determined by this method can be expected to decrease with time with successive irrigations.

Field infiltration test results are also often skewed with a greater chance occurrence of relatively high rates.

Two field infiltration tests were conducted in the field. In the first, water was applied from the main leader canal to plot area P1 and P2. The second was slightly more at the 2 day throughout.

The field methods used to determine infiltration in Appendix C and the results summarized and related to a flow rate in Table 2.2. Values of cumulative infiltration and intake rates are illustrated in Appendix C.

Basic infiltration rates of 0.2 cm/h are normally considered suitable for surface methods. However, rates at the P1 and P2 plots were in excess of 10 cm/h. It would be expected to decrease with depth. The P1 and P2 plots are upper half of 10-12 cm/h for these methods.

Excessive losses through deep percolation would not be considered problematic in this case and field intake rates are considered to be within an acceptable range for surface methods.

Measured rates at plot area P1 were optimum for surface irrigation (0.2 cm/h).

Infiltration is aided by large pores and favourable soil structure and is therefore a particularly sensitive indicator of changes in soil structure and porosity. Variations in field infiltration rates between individual tests and different soil types are therefore evidence of differences in field soil structure and porosity with the main soil groups. The lower rates at the P1E compared to the P1F reflect the generally weaker structural properties and reduced permeability.

Prior to development more detailed investigation of infiltration rate variation within and between the different soil types is recommended, particularly on the virgin calcareous brown clay and soils affected by sodic soil salinization.

2.3 SUBSOIL PERMEABILITY AND DRAINAGE CHARACTERISTICS

Soil permeability is that quality of a soil that enables it to transmit water or air. When defined quantitatively the term hydraulic conductivity (K) expressed in m/day is used as an indication of the quality of the soil.

Within the depression the water table was within 2.0 m of the soil surface in the south west area and water is present on the soil surface. Although locally drained by infiltration the water table is a natural feature related to excess water west of Toff Hill in the south west of the project area and the Kiriango irrigation scheme in the south east.

Detailed drainage level gaugings were not carried out at these sites after six operations in August 1968 and while the intention to be completed of heavy clay soils with a

TEST SITE	SOIL CLASS	TEXTURAL PROFILE	SOIL MOISTURE STATUS AT START OF TEST	AV. INF. RATE (cm/hr) AFTER 4 HRS	BAS. INF. RATE (cm/hr) AFTER 4 HRS	INFILT. CATEGORY	DEPTH OF MOISTURE PENETRATION (cm) AT TREATMENT TERMINATION OF TEST	SURFACE REMARKS	
PT1	Lc	10-25 S;C 25-70 S;C 70-125 S;C 125-170 S;C	SLIGHTLY MOIST SURFACE IRRIGATED 3 WEEKS BEFORE START OF TEST.	10.64	6.0	MOD. RAPID	102	LIGHTLY MOIST DUG WITH HOE BEFORE START OF TEST	MODERATELY WELL STRUCTURED POPULUS CLAYS ALLOWING GOOD MOISTURE PENETRATION
PT5	Lk	10-15 S;C 15-50 S;C 50-110 S;C 110-160 S;C	DRY SOFT IN SURFACE HORIZONS, DRY AND SLIGHTLY HARD IN LOWER HORIZONS	3.79	2.5	MOD.	62	LIGHTLY MOIST DUG WITH HOE BEFORE START OF TEST	WEAKLY STRUCTURED POPULUS SURFACE

Since the irrigation water is highly mineralized, the EC of the soil water will increase more concentrated as water percolates through the soil. This may result in a consequent rise in the EC of the soil water at the end of the test. This may be avoided by diluting the irrigation water by deionized water.

With regard to drainage, the drainage coefficient is calculated as follows:

Drainage coefficient = $\frac{\text{Infiltration rate} \times \text{depth of water table}}{\text{depth of water table} + \text{depth of soil profile}}$

For PT1, the drainage coefficient is calculated as follows:

TEST SITE	INITIAL PERMEABILITY (K. #/day)	CLASS	FINAL K. AFTER 180 MINS. (#/day)	CLASS
PT1	1.2	MODERATE	0.35	MOD. SLOW
PT5	0.8	MODERATE	0.16	SLOW

TABLE 5.6 SOIL INFILTRATION AND POUR-IN HYDRAULIC CONDUCTIVITY TEST RESULTS.

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CHICAGO, ILLINOIS 60607

1. Name of the donor: _____
2. Address: _____
3. City: _____ State: _____ Zip: _____
4. Name of the recipient: _____
5. Address: _____
6. City: _____ State: _____ Zip: _____

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CHICAGO, ILLINOIS 60607

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DEPARTMENT OF CHEMISTRY
57 SOUTH EAST ASIAN AVENUE
CHICAGO, ILLINOIS 60607

slow - moderately slow (0.05-0.5 m/day) K value. Detailed drainage studies would be required on these lands prior to reclamation.

LAND SUITABILITY FOR IRRIGATION

To determine the hydraulic characteristics of the better drained soils in the north of the project site where the watertable is absent, pour-in tests were carried out at sites PT1 and PT5. The results show a generally slow - moderately slow permeability (see Table 5.6) requiring relatively close drain spacings.

Under surface irrigation, even on more elevated lands, the slow subsoil permeabilities could produce associated drainage problems of the root zone, with watertables rising to unacceptable levels, particularly along the southern boundary of the project area.

There is no evidence in profile pits of subsoil waterlogging on existing irrigated areas though further investigation is recommended. However, it is considered likely that field drainage would be required on these lands to ensure waterlogging of the root zone, by temporary rise of watertables, would be avoided.

Since the irrigation water is slightly saline (250-400 $\mu\text{S}/\text{cm}$) the soil solution will become more concentrated as evapotranspiration depletes soil moisture below field capacity. As a consequence the EC of the soil water will rise and leaching will be required, necessitating removal of leaching water by drainage.

With regard to drainage, successful development of the area will be dependent upon:

- design of a suitable drainage system to prevent watertables rising in the more elevated soils in the north of the project site;
- design of a suitable system for removing surplus water through the depression area and beyond the estate boundaries. Without this the encroachment of swamp areas from the south into the project site can be expected to continue;
- monitoring of groundwater levels and subsoil salinity/alkalinity to ensure the continued maintenance of a favourable medium for plant growth;
- detailed topographic surveys: field evaluation of topography indicates the main drainageways will be south west and south east.

Class 2 Lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity. They are not so desirable nor of such high value as lands of Class 1 because of certain compensable or non-compensable limitations. The Class 2 lands have intermediate payment capacity.

Class 3 Lands that are suitable for irrigation development but are approaching insignificantly for irrigation and are of distinctly non-ideal suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics than those described for Class 2 lands. Under proper management Class 3 lands are expected to have adequate payment capacity.

Class 4 Lands are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive, specific deficiency or deficiencies susceptible of correction at high cost but are suitable for irrigation because of contemplated intensive cropping such as vegetables or fruits. In addition, they may have one or more excessive non-correctable deficiency thereby limiting their utility to meadow, pasture, orchard or other relatively permanent crops. Class 4 lands may have a range in payment capacity greater than that for the associated arable lands.

flow - moderately slow (3.0 to 5.0 ft/day). Detailed channel studies would be required on these areas (see Appendix A).

To determine the hydraulic characteristics of the better drained soils in the north of the project area where the water table is shallower, piezometer tests were conducted at sites P11 and P12. The results show a generally slow permeability (see Table 2.6) indicating that the soils are not well drained.

Lighter soils (silt loam) occur in some areas, but the slow natural permeabilities could produce localized drainage problems if the soil were to be waterlogged. This is particularly true in the vicinity of the project area.

There is no evidence in piezometer test results of surface water seepage into the project area. However, it is considered likely that this drainage would be required to remove water from the soil zone by means of a drainage system.

Drainage of the water table is slightly better (3.0 to 5.0 ft/day) in the soil which is more permeable as a result of the drainage system. This is particularly true in the area where the water table is shallow and the drainage system is required to remove water from the soil zone.

With regard to drainage systems, a drainage system is required in the area where the water table is shallow.

Design of a drainage system to prevent waterlogging is required in the area where the water table is shallow.

Design of a drainage system for removing surface water through the drainage system and prevent the soil becoming waterlogged. Without this drainage system, the soil could become waterlogged.

Design of a drainage system to prevent waterlogging in the area where the water table is shallow.

Design of a drainage system to prevent waterlogging in the area where the water table is shallow.

SECTION 6

LAND SUITABILITY FOR IRRIGATION

6.1 INTRODUCTION

Land classification is the systematic appraisal of lands and their designation into land classes on the basis of similar physical and economic characteristics. Within each land class there are subclasses which identify the deficiency or deficiencies.

Many land classification systems for irrigated agriculture are based on the comprehensive system developed by the United States Bureau of Reclamation (USDI, 1953) for the specific purpose of establishing the extent and degree of suitability of lands for sustained irrigation. Fundamental considerations are the productive capacity of the land, the costs of crop production and land development, associated with the physical factors of soil, topography and drainage.

It is not always appropriate, however, to apply this system rigidly to areas outside the US. It is often necessary to modify details of the physical and economic criteria adopted if the resulting land classification is to be of maximum value.

Provided the necessity for these modifications can be justified within the context of the project area, and that fundamental concepts of the land classification system are adhered to, the USBR system provides a valuable though flexible framework for irrigated land classification studies.

Its application is advocated at Taveta in anticipation of more detailed soil and land classification surveys being required in the future.

The definition of the land classes is summarised below:

- Class 1 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 Lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity. They are not so desirable nor of such high value as lands of Class 1 because of certain correctable or non-correctable limitations. The Class 2 lands have intermediate payment capacity.
- Class 3 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 those described for Class 2 lands. Under proper management Class 3 lands are expected to have adequate payment capacity.
- Class 4 Lands are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive, specific deficiency or deficiencies susceptible of correction at high cost, but are suitable for irrigation because of contemplated intensive cropping such as vegetables or fruits. In addition, they may have one or more excessive non-correctable deficiency thereby limiting their utility to meadow, pasture, orchard or other relatively permanent crops. Class 4 lands may have a range in payment capacity greater than that for the associated arable lands.

LAND SUITABILITY FOR IRRIGATION

INTRODUCTION

Land classification is the systematic appraisal of lands and their designation into land classes on the basis of natural physical and economic characteristics. Within each land class there are subclasses which identify the physical or economic factors.

Many land classification systems for irrigation agriculture are based on the components system developed by the United States Bureau of Reclamation (USBR) for the purpose of classifying the extent and degree of suitability of lands for various irrigation purposes. In the present study, the suitability of the land for the purpose of irrigation and land development is appraised with the physical factors of soil, topography and drainage.

It is not always appreciated, however, in applying this system, that it was devised for the US. It is not always necessary to modify the physical and economic factors adopted if the results of classification are to be used for similar purposes.

Provided the necessity for these modifications can be justified within the context of the project and the objectives of the study, the results of the system are applied to the USBR system. This provides a valuable framework for irrigation land classification studies.

The application is restricted to the extent of the data available and the results of classification are being reported in the following.

The definition of the land classes is summarized below.

Class 1 Lands not suitable for irrigation because of excessive salinity or other soil conditions which are relatively high water capacity and relatively high water table.

Class 2 Lands of moderate suitability for irrigation because of moderate salinity or other soil conditions. They are not so suitable for irrigation as lands of Class 1 because of certain deficiencies or non-suitability. The Class 2 lands have moderate water capacity.

Class 3 Lands that are suitable for irrigation development but are approaching unsuitability for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topography or drainage conditions. Class 3 lands are described for Class 2 lands under present management. Class 3 lands are expected to have moderate water capacity.

Class 4 Lands are not in the class only after special surveys and engineering studies have shown them to be suitable. They may have an excessive water capacity or other soil conditions of concern at high cost, but are suitable for irrigation because of certain deficiencies or non-suitability. In addition, they may have one or more desirable non-suitable conditions which are not considered in the present study. Class 4 lands may have a large or small water capacity. Class 4 lands may have a large or small water capacity. Class 4 lands may have a large or small water capacity.

Class 6 Lands that are considered non-arable under the existing project or project plan because of failure to meet the minimum requirements for the other classes of land. Class 6 lands do not have sufficient payment capacity to warrant consideration for irrigation.

6.2 LAND CLASS CRITERIA

The framework of the Land Classification System is based on the system developed by the United States Bureau of Land Reclamation (1953), modified where necessary to accommodate local conditions. The general soil conditions specified by the USBR for profitable sustained irrigation are used to classify the lands in the Project Area. However, only those conditions that are considered particularly limiting in the area are isolated as primary criteria and given a coding in the sub-class legend. Soils, for example, must have an adequate supply of plant nutrients and a favourable cation exchange capacity. The base status of the soil parent materials is adequate to maintain this nutrient supply in all the soils of the Study Area. Thus it is not considered necessary to isolate nutrient supply or inherent soil fertility as a limiting factor for irrigated agricultural development. Nevertheless, it is likely that yields from all soils would be improved if dressings of nitrogen and phosphate were applied. The primary criteria used to differentiate land subclasses are shown in Table 6.3 and described below in detail.

6.2.1 Soil

After reviewing the physical characteristics of the soils and their immediate environment, the following primary criteria were selected and given a letter or numerical subscript indicating the nature and degree of limitation.

Soil texture	s
profile drainage	p
effective depth	d
soil structure	b
alkalinity	a
salinity	x

(i) Soil texture (s)

Soil texture influences bulk density, pore space, permeability, profile drainage, structure, available moisture capacity and infiltration rate of a soil.

Textures in all the major soil groups are generally clayey with high water holding capacities. Soil texture is not therefore considered limiting.

(ii) Profile drainage (p)

This factor comprises entry into and passage through the soil by water, and is related to soil texture, structure and clay mineralogy. Where extensive wet season flooding occurs or where high groundwater levels occur the land is downgraded.

The soils in the project area are poorly drained in the south and east, passing into imperfectly drained on the depression periphery to well drained in the more elevated areas.

(iii) Effective depth (d)

The depth of soil that will allow adequate root expansion is an important factor to be considered in selecting land for irrigation.

Effective soil depth was determined from maximum limit of auger penetration, but was also assessed in profile pits.

Class 6 lands that are considered non-arable under the existing project or project plan. Factors of value to meet the minimum requirements for the other classes of land. Class 6 lands do not have sufficient payment capacity to warrant consideration for irrigation.

LAND CLASS CRITERIA

The framework of the Land Classification System is based on the system developed by the United States Bureau of Land Reclamation (USBR) modified where necessary to accommodate local conditions. The general soil conditions specified by the USBR for profiles contained in the classification are not used in this project. However, only those conditions that are considered suitable for irrigation in the area are retained as primary criteria. Given a coding in the soil classification, the soil is assigned a primary, secondary, or tertiary status and a suitability rating. For example, there may be an adequate supply of water, but the soil may be too saline for irrigation. The base status of the soil parent material is determined by the primary study of all the soils of the study area. This is not considered necessary to make a final decision on irrigation suitability. The primary study is intended to provide a general overview of the study area and to identify those soils that would be improved by irrigation. The primary study is intended to provide a general overview of the study area and to identify those soils that would be improved by irrigation. The primary study is intended to provide a general overview of the study area and to identify those soils that would be improved by irrigation.

Soil

After following the physical characteristics of the soil and their immediate environment, the following primary criteria were established and given a letter or numerical weighting indicating the nature and degree of limitation.

a	Soil texture
b	Profile drainage
c	Effective depth
d	Soil structure
e	Salinity
x	Alkalinity

(i) Soil texture
Soil texture influences soil density, pore space, compressibility, profile drainage, structure, available moisture capacity, and nutrient retention of a soil.
Texture is the major soil factor and generally varies with high water logging exposure. Soil texture is not however considered limiting.

(ii) Profile drainage
The factor comprises only two and passage through the soil by water and is related to soil texture, structure and clay mineralogy. Where drainage is related to soil texture, structure and clay mineralogy, it is not considered limiting. Where profile drainage is related to soil texture, structure and clay mineralogy, it is not considered limiting.

The soils in the project area are heavy textured in the root zone and, passing the property defined on the classification criteria, are considered in the main elevated areas.

(iii) Effective depth (d)
The depth of soil that will allow adequate root expansion is an important factor to be considered in selecting land for irrigation.

Effective soil depth was determined from maximum limit of sugar penetration but was also assessed in profile pits.

Two types of limiting layer are identified in the project area; tuffaceous grits and impermeable clay horizons.

Classes for soil depth to a limiting layer are given as:

Very deep	> 100 cm
deep	75 - 100
mod. deep	50 - 75
shallow	25 - 50
very shallow	< 25 cm

All the soils in the project area fall into the very deep (> 100 cm) category though parent material is present within 60 cm (mod. deep) of the surface on the north west side of the project area.

Relatively impermeable horizons (> 100 cm depth) in the brown clays (PT7) may present limitations for drainage.

(iv) Soil structure (b)

Soil structure is included as a possible limitation because of the adverse effects of sodium deflocculation. Where structural deterioration was observed land has been downgraded.

(vi) Alkali hazard (a)

The alkali hazard in soils is expressed in terms of exchangeable sodium percentage (ESP) and is the percentage of the cation exchange capacity occupied by exchangeable sodium.

Conventionally, a soil is considered to have an alkali hazard when ESP exceeds 15, although the threshold value of ESP for a decrease in permeability depends upon the type of clay mineral present.

Class limits for land classes 1, 2 and 3 were set at ESP values of 5, 10 and 15 respectively. In the final assessment ESP values were found to be very high though the limitations imposed are of varying severity.

(vii) Salinity (x)

Analyses of soil samples has shown that natural salinity levels in the project area are quite high. The quality of the irrigation water is slightly saline, and, provided sufficient water is applied to meet the leaching requirements, coupled with good drainage in the subsoil, then salinity build-up subsequent to irrigation should be reduced.

Class limits have been defined for each irrigable land suitability class although in practice salinity is correctable by leaching.

6.2.2 Topographic Factors

(i) Slope (t)

This factor refers to the slope at the investigation site in percent. The quantitative slope classes used are shown in Table 6.3.

Except for the area around Python Hill and a small area in the west slopes generally do not exceed 1 per cent. Slopes in the west of the project area are 2 per cent and around Python Hill 1-2 per cent >

Two types of limiting layer are identified in this project area. Lufuaceous glau and

Classes for soil depth to a limiting layer are given as

Very deep	> 100 cm
Deep	75 - 100
Intermediate	50 - 75
Shallow	25 - 50
Very shallow	< 25 cm

All the soils in this study are classified into the very deep (> 100 cm) category

Relative permeable horizons (> 100 cm depth) in the brown type (PT)

(vi) Soil structure (b)
Soil structure is included as a possible limitation because of the adverse effects

(vii) Alkali hazard (a)
The alkali hazard in soils is expressed in terms of exchangeable sodium

Consequently, a soil is considered to have an alkali hazard when ESP exceeds

Class limits for land classes 1, 2 and 3 were set at ESP values of 5, 10 and 15

(viii) Salinity (v)
Analyses of soil samples has shown that natural salinity levels in the project

Class limits have been defined for each physical and chemical class through

2.2.2 Topographic factors

(i) Slope (i)
This factor refers to the slope of the investigation site in percent. The

Except for the small area around Pylon Hill and a small area in the west slope

(ii) Flood hazard (f)

The flood hazard is most common in the east and south west of the Project Area where waterlogging in the surface is present. Flooding due to local seepage from the canal appears to be significant in some parts of the project area in addition to drainage water from smallholder irrigation plots.

(iii) Runoff, erosion hazard (e)

Erosion was virtually absent in the project area though the implementation of suitable conservation measures may be required during development.

6.2.3 Derived Characteristics

(i) Available water holding capacity (AWC)

AWC is a particularly important soil characteristic used in day to day irrigation scheduling and management. Detailed laboratory evaluation prior to development is, therefore, considered to be of paramount importance.

The soils of the project area are generally of relatively uniform texture (clay loam - silty clay loam) with favourable water retention characteristics. Coarser textured soils may present particular problems of deep percolation and excessive leaching of fertilisers. This may become a problem if soils derived from gneissic parent materials are utilised.

(ii) Subsoil permeability

Class limits for topsoil permeability have been set at 0.3 - 0.1 m/day. In the subsoil limits are set at 0.01 - 0.03 (slow - moderately slow conductivity classes). Detailed drainage investigations will be required to refine these limits further.

In the project area preliminary indications are that the generally clayey substratum in both the well drained and poorly drained soils will require relatively close drain spacings because of the low subsoil hydraulic conductivity.

(iii) Infiltration

Basic infiltration rates provide a useful indication of suitability for surface irrigation though only two tests were possible in the time available.

Class limits are set in Table 6.3 but require further field investigation. The FAO quotes 12.5 cm h⁻¹ as the upper limit for surface irrigation. Measured rates achieved upto 10.5 cm h⁻¹ on existing irrigated land.

6.3 ALLOCATION OF LAND SUITABILITY CLASSES

Land suitability classes based on the criteria discussed in Chapter 6 have been assigned to each of the soil mapping units.

Land suitability subclasses have been used and divisions are distinguished by the nature of the limitations.

The irrigable land suitability map is shown as Figure 6.3 and the proposed framework (Table 6.3) and accompanying legend is tentatively proposed for future more detailed soil survey and land classification work.

TABLE 6.3 PROVISIONAL LAND SUITABILITY SPECIFICATIONS FOR SURFACE IRRIGATION AT TAVETA ESTATES, KENYA.

LAND CHARACTERISTIC	SYMBOL	CLASS 1 HIGHLY SUITABLE	CLASS 2 MODERATELY SUITABLE	CLASS 3 MARGINALLY SUITABLE	CLASS 4	CLASS 6 NOT SUITABLE
SOIL						
Texture	t	Fine sandy loam to clay or medium texture	Med. sandy loam - permeable clay or better	Loamy sand (less than 15% clay) to slightly permeable clay	Variable loamy sand - permeable clay	Land which fails to meet the minimum requirements of other classes.
Profile drainage	p	Well-excessively well	Moderately well or better	Imperfect	Poor-very poor	-
Soil structure	b	Well structured	Well-moderately well	Moderately well	Serious problem with sodic hardpan	-
Effective depth (to rock or impermeable clay)	d	>0.9m	0.6 to 0.9m	0.3-0.6m	-	-
Alkalinity (exchangeable sodium percentage ESP)	a	0-5%	5-10% from 1m -1.5m	10-15% to 1.0m 15-25% from 1-1.5m	>15%	>15%
Salinity (ECe mS/cm sat extract)	s	<4mS/cm	4mS/cm to 1m, 4-8mS/cm 1-1.5m	4-8 mS/cm from 0.5-1.0m, 8 mS/cm from 1.0-1.5m	8-12 mS/cm	>8 mS/cm
TOPOGRAPHIC FACTORS						
Slope	t	<2%	<2%	<4%	Variable	-
Susceptibility to flooding	f	None	Slight	Periodic but relatively infrequent floods of short duration.	Serious	-
Runoff erosion hazard	e	None	Occasional	Frequent	Frequent	Frequent

TABLE 4.2. PROPOSED AND EXISTING SPECIFICATIONS FOR BRIDGE
PROJECT AT WETA RIVER, IOWA

Item	Proposed	Existing	Notes
1. Bridge Deck	Asphalt concrete on steel deck	Asphalt concrete on steel deck	
2. Bridge Girders	Steel I-beams	Steel I-beams	
3. Bridge Piers	Concrete	Concrete	
4. Bridge Abutments	Concrete	Concrete	
5. Bridge Approach	Asphalt concrete	Asphalt concrete	
6. Bridge Foundations	Cast-in-place concrete	Cast-in-place concrete	
7. Bridge Deck Slope	2.0%	2.0%	
8. Bridge Deck Width	20.0 ft	20.0 ft	
9. Bridge Deck Height	10.0 ft	10.0 ft	
10. Bridge Deck Length	100.0 ft	100.0 ft	
11. Bridge Deck Area	2000.0 sq ft	2000.0 sq ft	
12. Bridge Deck Volume	20000.0 cu ft	20000.0 cu ft	
13. Bridge Deck Weight	1000000.0 lbs	1000000.0 lbs	
14. Bridge Deck Cost	\$1000000.0	\$1000000.0	
15. Bridge Deck Life	20 years	20 years	
16. Bridge Deck Maintenance	Annual	Annual	
17. Bridge Deck Repairs	As needed	As needed	
18. Bridge Deck Replacement	As needed	As needed	
19. Bridge Deck Decommissioning	As needed	As needed	
20. Bridge Deck Disposal	As needed	As needed	
21. Bridge Deck Recycling	As needed	As needed	
22. Bridge Deck Reuse	As needed	As needed	
23. Bridge Deck Relocation	As needed	As needed	
24. Bridge Deck Restoration	As needed	As needed	
25. Bridge Deck Rehabilitation	As needed	As needed	
26. Bridge Deck Renovation	As needed	As needed	
27. Bridge Deck Reconstruction	As needed	As needed	
28. Bridge Deck Reconstruction	As needed	As needed	
29. Bridge Deck Reconstruction	As needed	As needed	
30. Bridge Deck Reconstruction	As needed	As needed	

TABLE 6.3 PROVISIONAL LAND SUITABILITY SPECIFICATIONS FOR SURFACE
(cont.) IRRIGATION AT TAVETA ESTATES, KENYA.

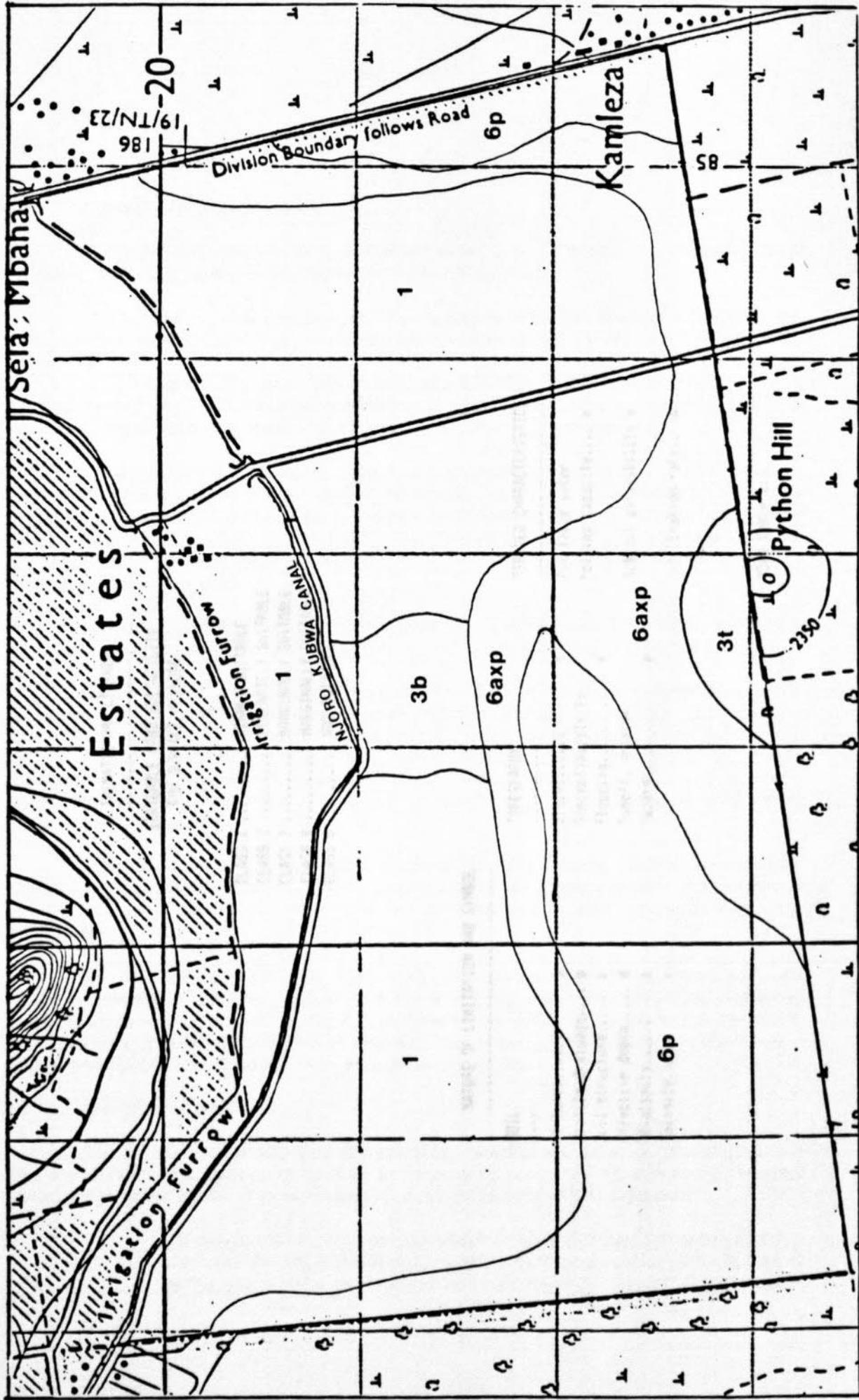
DERIVED CHARACTERISTICS						
Available water holding capacity (AWC) mm/m of soil	■	120	80-120	50-80	-	-
Permeability in upper 1.0m (m/day)	■	0.3-0.10	0.3-0.10	Less than 0.03	-	-
Permeability in subsoil (m/day)	■	0.03-0.10	0.01-0.03	Less than 0.01	-	-
Basic infiltration rate (cm/hr).	■	0.7-3.5	3.5-6.5	6.5-12.5	12.5-25.0	>25.0

STATE OF CALIFORNIA
 DEPARTMENT OF REVENUE

DATE	DESCRIPTION	AMOUNT	TOTAL
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FIGURE 63 PRELIMINARY IRRIGABLE SUITABILITY MAP FOR PROJECT AREA



DRILL HOLE



FIGURE 2. SOIL PROFILES AND TOPOGRAPHY OF THE STUDY AREA

SECTION 7

CONCLUSION

7.1 DEVELOPMENT POTENTIAL

The objective of field surveys at Taveta Estates was to reclassify and classify lands considered to have potential for development of surface irrigation.

The terms of reference emphasize, in particular, classification of areas considered into suitable for development due to high water tables and the associated problems of salinity/sodicity.

Table 3.6 gives the approximate areas of lands relatively suitable relative to soil type and, by reference to Table 3.3 the nature of the limitations. Appendix 3 contains the soil maps and preliminary irrigable suitability maps (Figures 3.6 and Figure 3.7).

These results show that of the 1,820 ha of common area approximately 840 ha (51 per cent) of the area is Class 1 (Highly Suitable) and 2 (Moderately Suitable) irrigable (as defined by profiles PT1, 8 and 7). Inclusion of areas under the old irrigation system adds a further 210 ha. This would be subject to the pumping of water to higher elevations. Similar areas further north are also suitable for cropping to be a panner.

THEMATIC MAP LEGEND*

IRRIGABLE LAND SUITABILITY FOR SURFACE METHODS

- CLASS 1 HIGHLY SUITABLE
- CLASS 2 MODERATELY SUITABLE
- CLASS 3 MARGINALLY SUITABLE
- CLASS 4 MARGINALLY SUITABLE
- CLASS 6 NOT SUITABLE

NATURE OF LIMITATION AND SYMBOL

SOIL

- Texture..... s
- Profile drainage.... p
- Soil structure..... b
- Effective depth..... d
- Alkalinity..... a
- Salinity..... x

TOPOGRAPHY

- Slope..... t
- Susceptibility to flooding..... f
- Runoff, erosion hazard..... e

DERIVED CHARACTERISTICS

- Available water holding capacity.... w
- Subsoil permeability .. m
- Infiltration rate... .. n

*See table 6.3

7.2 AREAS OF CONCERN

The description report (p. 20) accurately summarizes some of the existing and potential problems associated with, or likely to be associated with, the rehabilitation of irrigated agriculture at Taveta Estates. The more salient points may be summarised as follows:

The general rise in soil water levels backing up to an increasing extent from the south into the estate is well documented. The principal cause of this is seen to be the natural tilting of Lake Jipe, and inadequate drainage of irrigation water.

1950

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SECTION 7

CONCLUSION

7.1 DEVELOPMENT POTENTIAL

The objective of field surveys at Taveta Estates was to demarcate and classify lands considered to have potential for development of surface irrigation.

The terms of reference emphasise, in particular, identification of areas considered less suitable for development due to high watertables and the associated problems of salinity/alkalinity.

Table 3.6 gives the approximate areas of land suitability classes relative to soil type, and, by reference to Table 6.3 the nature of the limitations. Attention is also drawn to the soil map and preliminary irrigable suitability maps (Figure 3.6 and Figure 6.3 respectively).

These results show that of the 1,660 ha of commandable land south of the Njoro Kubwa canal approximately 840 ha (51 per cent) of the area is Class 1 land (highly suitable for surface irrigation) typified by profiles PT1, 6 and 7. Inclusion of similar soils between the existing canal and the old irrigation furrow adds a further 290 ha. This additional land, however, will necessitate the pumping of water to higher elevations. Similar sites further north should be investigated if the area for cropping is to be expanded.

The yellowish red soils around Python Hill, by virtue of their rather limited extent and topographic position, are not considered to have high development potential for surface irrigation.

The distribution of saline/alkali soils is determined by localised drainage impedence, local seepage from irrigation canals, small scale irrigation, and topographic position. The more poorly drained soils occur in the south west and east. Overall it is estimated that up to 715 ha of land is affected by salinity/alkalinity and/or high watertables. Approximately 260 ha of well-imperfectly drained soils appear to be severely affected by sodicity with resultant structural deterioration. Reclamation of these soils will be dependent upon provision of drainage for leaching and application of gypsum.

Principal soil chemical constraints to development are mainly confined to the poor-imperfectly drained soils in the south of the project site. These constraints are mainly related to salinity/alkalinity in depression fringe soils and alkalinity with a high watertable within the depression.

On the well drained clays high levels of calcium may render phosphate and micronutrients less available to plants and careful monitoring of nutrient deficiencies in growing crops will be required. These soils are otherwise considered highly fertile and well suited to the proposed development. Interpretation of chemical data must not however be considered as a static phenomenon but will change under the proposed land use.

7.2 AREAS OF CONCERN

The Swynnerton report (op. cit) accurately summarises some of the existing and potential problems associated with, or likely to be associated with, the rehabilitation of irrigated agriculture at Taveta Estates. The more salient points may be summarised as follows:

- The general rise in soil water levels backing up to an increasing extent from the south into the estate is well documented. The principal cause of this is seen to be the natural silting of Lake Jipe, and inadequate drainage of irrigation water.

SECTION 7
CONCLUSION

7.1 DEVELOPMENT POTENTIAL

The objective of this survey at Tavea Estate was to determine and classify lands considered to have potential for development or future expansion.

The terms of reference emphasize in particular identification of areas considered favorable for development due to their water-related and the essential physical characteristics.

Table 2 gives the approximate areas of land suitability classes relative to soil type, and by reference to Table 3 the status of the land. Attention is also drawn to the soil map and preliminary drainage suitability maps (Figures 2 and 3 respectively).

These results show that of the 1,200 ha of comparable land within the 2-10 m contour interval approximately 640 ha (53 per cent) of the area is Class 1 land (highly suitable for agriculture) (typical hydraulic conductivity between 0.1 and 0.2 m/day) and the balance is Class 2 land (moderately suitable). The additional land however, will require the pumping of water to further expansion. It will also require construction of levees and the area for cropping is to be excluded.

The yellowish red soils around Pithon Hill, by virtue of their limited extent and topographic position, are not considered to have high development potential for future expansion.

The distribution of water-saturated soils is determined by localized drainage depression. Local seepage from irrigation canals, small scale infiltration and topographic position. The most poorly drained soils occur in the south-west and east. Overall it is estimated that up to 15 per cent of the area is subject to waterlogging during high water table. Approximately 500 ha of waterlogging is estimated to be severely affected by saline water resulting from structural deterioration. Remediation of these soils will be a specialist task, involving a drainage for leaching and application of gypsum.

Pithon soil drainage conditions in development are mainly confined to the poor waterlogging soils in the south of the project site. These conditions are mainly related to salinity/alkalinity in expansion ridge soils and alkalinity with a high water table within the depression.

On the well drained areas high levels of calcium may cause phosphate and potassium deficiencies. It is suggested that careful monitoring of nutrient deficiencies in growing crops will be required. These soils are otherwise considered highly fertile and well suited to the proposed development. Intention of drainage is not intended to be considered as a status determination but we change under the proposed land use.

7.2 AREAS OF CONCERN

The swampland region (see 2.1) requires immediate attention in order to prevent the ground conditions associated with it from being associated with the rehabilitation of degraded agriculture at Tavea Estate. The more detailed plans may be summarized as follows:

The general rise in soil water levels backing up to an increasing extent from the south into the estate is well documented. The principal cause of this is seen to be the natural seepage of lake water and seepage through the irrigation water.

The relative contribution of these elements and the extent of encroachment in recent years warrants further investigation.

- As a consequence of rising watertables the development of salinity/alkalinity is seen as a major constraint to irrigated cropping in the south of the estate without the provision of field drainage.
- Utilisation of soils in the upper irrigable areas will further contribute to the problems on lower lying areas and in the depressions unless a suitable drainage system is designed.
- Implementation of a drainage scheme will undoubtedly have a major impact on small scale irrigation within and beyond the estate boundaries.

Successful implementation of the low cost irrigation scheme at Taveta Estates will, therefore, be dependent upon the design of an appropriate drainage system, and a high level of irrigation management. Swynnerton's proposals to overcome the existing and potential problems are reiterated here with some qualification based on recent field visits.

- It would be unwise to consider land which does not command sufficient elevation for deep main drainage or have sufficient gradient to be able to remove surplus water effectively from fields.
- Soils which do not command such a topographic position could be reclaimed by leaching, application of soil amendments such as gypsum, and provision of drainage to lower groundwater levels in depression areas. This solution may well prove to be not feasible on grounds of cost. However some provision must be made for drainage of depression areas in the south if surplus water from more elevated sites is to be removed.
- A more regional view of drainage is required if rising groundwater levels are not to have adverse affects in areas otherwise considered suitable for development. A detailed soil and topographic survey would identify potential problem areas.

To accomplish these objective will require:

- detailed soil surveys with particular emphasis on furrow tests, drainage design and classification of land for irrigation;
- detailed topographic survey and identification of main drainage lines;

The relative contribution of these elements and the extent of erosion are to be investigated further.

In a comparison of being water, the development of water resources is seen as a major constraint to further coping in the south of the state without the provision of land drainage.

Limitation of soils in the upper impinge area will further contribute to the problem of lower land area and in the theoretical unless a suitable drainage system is installed.

Implementation of a drainage system will undoubtedly have a major impact on the area's agriculture and beyond the estate boundaries.

Successful implementation of the low cost irrigation scheme at Tanya Estate will require the design of a drainage system and a high level of water management. Swynerton's proposals to overcome the existing drainage problems and to provide a drainage system based on recent and future.

It would be unwise to consider the area which does not contain sufficient drainage for crop production or have sufficient ground to be able to drain water with sufficient speed.

Soils which do not contain sufficient water could be retained by installing application of the drainage system as a system and provision of drainage to lower the water table in depression areas. This solution may well prove to be not feasible on grounds of cost. However, some provision may be made for drainage in depression areas in the south if surface water from more elevated areas is to be removed.

A more detailed view of drainage is required if being ground water levels are not to have serious effects in areas otherwise considered suitable for development. A detailed soil and topographic survey would be a very important preliminary step.

The drainage system will require

detailed soil surveys with contour mapping and drainage design and classification of land for irrigation.

detailed topographic survey and classification of land drainage level.

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- | | | |
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APPENDIX A
SOIL PROFILE DESCRIPTIONS AND
ANALYTICAL DATA

THE
HISTORICAL
AND
GEOGRAPHICAL
DESCRIPTION
OF
THE
COUNTY
OF
SURREY

PROFILE DESCRIPTION

OBS SITE PT1

TAVETA, KENYA

Map Unit: Lc
 Soil Classification: Chromic Luvisol (Lc)
 Irrigable Land Classification: 1
 Parent Material: Calcareous tuffs
 Topography: Generally level with 0-1% slope
 Micro Relief: Even
 Slope Gradient: 0-1% southern aspect
 Vegetation Land Use: Furrow irrigated french seed bean field
 Salinity/Alkalinity: Class O; none
 Drainage Class: Well drained

DESCRIPTION

Horizon	Depth (cm)	Description
Ap	0 - 25	Dark reddish brown (5YR 3/4) dry; 5YR 3/2 moist; <u>clay</u> ; moderate, medium-coarse subangular blocky; slightly hard (dry), firm (moist); sticky plastic; common fine pores; many fine roots, pH 8.0; diffuse boundary.
Bt1	25 - 70	Dark reddish brown (5YR 3/3) moist; <u>clay</u> ; moderate, medium-coarse subangular blocky; firm (moist), sticky and plastic; common very fine pores; common fine roots, pH 8.2; diffuse boundary.
Bt2	70 - 125	Dark reddish brown (5YR 3/3) moist; <u>clay</u> ; moderate, medium-coarse subangular blocky; firm (moist); sticky plastic; few common fine pores; common fine roots; pH 8.5; diffuse boundary.
C	125 - 170	Reddish brown (5YR 4/4) moist; gritty <u>clay</u> ; moderate medium-fine subangular blocky; firm (moist); sticky, plastic; few fine pores; few fine roots; pH 8.5; clear smooth boundary.
R	170 +	Soft calcareous tuffaceous grits.

Remarks:

- (i) Well structured soil allowing very good root penetration.
- (ii) Generally well drained, with no mottling present.
- (iii) Surface horizon generally dry - whole profile moist and firm throughout.

ANALYTICAL DATA PROFILE PT.1

Laboratory Number		7739	7740	7741	7742
Sample Identity		PT 1			
Moisture % o.d.s.		0-25	25-70	70-125	125-170
W/V Ratio g/cm ³ a.d.s.		11.4	11.9	11.9	11.5
pH 1:5 H ₂ O		1.06	0.94	1.02	1.08
E.C. me/cm 1:5 H ₂ O		8.0	8.2	8.5	8.5
pH 1:5 1M KCl		0.07	0.10	0.13	0.28
Calcium Carbonate %		6.7	7.3	7.6	7.7
Soluble Cations me/100 g a.d.s.			3.5	9.5	10.5
Exchangeable Cations me/100 g a.d.s. (1)	Na	0.1	0.2	0.9	3.1
	K	5.6	5.2	7.3	6.9
	Mg	10.0	13.7	18.8	22.9
	Ca(2)	29.7	>50.0	>50.0	>50.0
T.E.B. me/100 g a.d.s.		45.4	>69.1	>77.0	>82.9
C.E.C. me/100 g a.d.s.		41.5	36.8	34.7	34.3
Base Saturation %		100	100	100	100
Total N (3) %		0.17	0.08	0.08	0.06
Organic C (4) %		1.30	0.63	0.57	0.45
Hot Water Soluble B ppm		0.6	1.6	2.7	3.5
Available P (Bray) ppm		671	417	285	275
Available P (Olsen) ppm		29	6	17	24
DTPA Extract ppm	Cu	2.0	1.9	1.9	2.1
	Mn	20.6	12.1	9.3	7.5
	Zn	0.6	0.2	0.3	0.3
Saturation Extract % H ₂ O		67.1	70.6	65.9	68.9
E.C. Saturation Extract me/cm		0.83	0.65	1.32	3.73
Soluble Cations me/l	Na				
	K				
	Mg				
	Ca				
Available K ppm		2295	2172	2917	2795
Stones %					7
Particle Size Analysis (Percentages in dry mineral soil)	2000-50	15	15	16	14
	50-2	33	30	31	31
	<2mm	52	55	53	55
	Texture	C	C	C	C

ANALYTICAL DATA PROJECT

Sample No.	Time (min)	Area	Height	Retention Time (min)
1	1.2	150	1.5	1.2
2	2.5	300	3.0	2.5
3	4.8	600	7.5	4.8
4	7.2	1200	15.0	7.2
5	10.5	2400	30.0	10.5
6	15.0	4800	60.0	15.0
7	20.0	9600	120.0	20.0
8	25.0	19200	240.0	25.0
9	30.0	38400	480.0	30.0
10	35.0	76800	960.0	35.0
11	40.0	153600	1920.0	40.0
12	45.0	307200	3840.0	45.0
13	50.0	614400	7680.0	50.0
14	55.0	1228800	15360.0	55.0
15	60.0	2457600	30720.0	60.0
16	65.0	4915200	61440.0	65.0
17	70.0	9830400	122880.0	70.0
18	75.0	19660800	245760.0	75.0
19	80.0	39321600	491520.0	80.0
20	85.0	78643200	983040.0	85.0
21	90.0	157286400	1966080.0	90.0
22	95.0	314572800	3932160.0	95.0
23	100.0	629145600	7864320.0	100.0
24	105.0	1258291200	15728640.0	105.0
25	110.0	2516582400	31457280.0	110.0
26	115.0	5033164800	62914560.0	115.0
27	120.0	10066329600	125829120.0	120.0
28	125.0	20132659200	251658240.0	125.0
29	130.0	40265318400	503316480.0	130.0
30	135.0	80530636800	1006632960.0	135.0
31	140.0	161061273600	2013265920.0	140.0
32	145.0	322122547200	4026531840.0	145.0
33	150.0	644245094400	8053063680.0	150.0
34	155.0	1288490188800	16106127360.0	155.0
35	160.0	2576980377600	32212254720.0	160.0
36	165.0	5153960755200	64424509440.0	165.0
37	170.0	10307921510400	128849018880.0	170.0
38	175.0	20615843020800	257698037760.0	175.0
39	180.0	41231686041600	515396075520.0	180.0
40	185.0	82463372083200	1030792151040.0	185.0
41	190.0	164926744166400	2061584302080.0	190.0
42	195.0	329853488332800	4123168604160.0	195.0
43	200.0	659706976665600	8246337208320.0	200.0
44	205.0	1319413953331200	16492674416640.0	205.0
45	210.0	2638827906662400	32985348833280.0	210.0
46	215.0	5277655813324800	65970697666560.0	215.0
47	220.0	10555311626649600	131941395333120.0	220.0
48	225.0	21110623253299200	263882790666240.0	225.0
49	230.0	42221246506598400	527765581332480.0	230.0
50	235.0	84442493013196800	1055531162664960.0	235.0
51	240.0	168884986026393600	2111062325329920.0	240.0
52	245.0	337769972052787200	4222124650659840.0	245.0
53	250.0	675539944105574400	8444249301319680.0	250.0
54	255.0	1351079888211148800	16888498602639360.0	255.0
55	260.0	2702159776422297600	33776997205278720.0	260.0
56	265.0	5404319552844595200	67553994410557440.0	265.0
57	270.0	10808639105689190400	135107988821114880.0	270.0
58	275.0	21617278211378380800	270215977642229760.0	275.0
59	280.0	43234556422756761600	540431955284459520.0	280.0
60	285.0	86469112845513523200	1080863910568919040.0	285.0
61	290.0	172938225691027046400	2161727821137838080.0	290.0
62	295.0	345876451382054092800	4323455642275676160.0	295.0
63	300.0	691752902764108185600	8646911284551352320.0	300.0
64	305.0	1383505805528216371200	17293822569102704640.0	305.0
65	310.0	2767011611056432742400	34587645138205409280.0	310.0
66	315.0	5534023222112865484800	69175290276410818560.0	315.0
67	320.0	11068046444225730969600	138350580552821637120.0	320.0
68	325.0	22136092888451461939200	276701161105643274240.0	325.0
69	330.0	44272185776902923878400	553402322211286548480.0	330.0
70	335.0	88544371553805847756800	1106804644422573096960.0	335.0
71	340.0	177088743107611695513600	2213609288845146193920.0	340.0
72	345.0	354177486215223391027200	4427218577690292387840.0	345.0
73	350.0	708354972430446782054400	8854437155380584775680.0	350.0
74	355.0	1416709944860893564108800	17708874310761169551360.0	355.0
75	360.0	2833419889721787128217600	35417748621522339102720.0	360.0
76	365.0	5666839779443574256435200	70835497243044678205440.0	365.0
77	370.0	11333679558887148512870400	141670994486089356410880.0	370.0
78	375.0	22667359117774297025740800	283341988972178712821760.0	375.0
79	380.0	45334718235548594051481600	566683977944357425643520.0	380.0
80	385.0	90669436471097188102963200	1133367955888714851287040.0	385.0
81	390.0	181338872942194376205926400	2266735911777429702574080.0	390.0
82	395.0	362677745884388752411852800	4533471823554859405148160.0	395.0
83	400.0	725355491768777504823705600	9066943647109718810296320.0	400.0
84	405.0	1450710983537555009647411200	18133887294219437620592640.0	405.0
85	410.0	2901421967075110019294822400	36267774588438875241185280.0	410.0
86	415.0	5802843934150220038589644800	72535549176877750482370560.0	415.0
87	420.0	11605687868300440077179289600	145071098353755500964741120.0	420.0
88	425.0	23211375736600880154358572800	290142196707511001929482240.0	425.0
89	430.0	46422751473201760308717145600	580284393415022003858964480.0	430.0
90	435.0	92845502946403520617434291200	1160568786830044007717928960.0	435.0
91	440.0	185691005892807041234868582400	2321137573660088015435857280.0	440.0
92	445.0	371382011785614082469737164800	4642275147320176030871714560.0	445.0
93	450.0	742764023571228164939474329600	9284550294640352061743429120.0	450.0
94	455.0	148552804714245632987894857600	18569100589280704123486858240.0	455.0
95	460.0	297105609428491265975789715200	37138201178561408246973716480.0	460.0
96	465.0	594211218856982531951579430400	74276402357122816493947432960.0	465.0
97	470.0	1188422437713965063903158860800	14855280471424563298789485760.0	470.0
98	475.0	2376844875427930127806317721600	29710560942849126597578971520.0	475.0
99	480.0	4753689750855860255612635443200	59421121885698253195157943040.0	480.0
100	485.0	9507379501711720511225270886400	118842243771396506390315886080.0	485.0

Retention Time (min)	Area	Height	Sample No.
1.2	150	1.5	1
2.5	300	3.0	2
4.8	600	7.5	3
7.2	1200	15.0	4
10.5	2400	30.0	5
15.0	4800	60.0	6
20.0	9600	120.0	7
25.0	19200	240.0	8
30.0	38400	480.0	9
35.0	76800	960.0	10
40.0	153600	1920.0	11
45.0	307200	3840.0	12
50.0	614400	7680.0	13
55.0	1228800	15360.0	14
60.0	2457600	30720.0	15
65.0	4915200	61440.0	16
70.0	9830400	122880.0	17
75.0	19660800	245760.0	18
80.0	39321600	491520.0	19
85.0	78643200	983040.0	20
90.0	157286400	1966080.0	21
95.0	314572800	3932160.0	22
100.0	629145600	7864320.0	23
105.0	1258291200	15728640.0	24
110.0	2516582400	31457280.0	25
115.0	5033164800	62914560.0	26
120.0	10066329600	125829120.0	27
125.0	20132659200	251658240.0	28
130.0	40265318400	503316480.0	29
135.0	80530636800	1006632960.0	30
140.0	161061273600	2013265920.0	31
145.0	322122547200	4026531840.0	32
150.0	644245094400	8053063680.0	33
155.0	1288490188800	16106127360.0	34
160.0	2576980377600	32212254720.0	35
165.0	5153960755200	64424509440.0	36
170.0	10307921510400	128849018880.0	37
175.0	20615843020800	257698037760.0	38
180.0	41231686041600	515396075520.0	39
185.0	82463372083200	1030792151040.0	40
190.0	164926744166400	2061584302080.0	41
195.0	329853488332800	4123168604160.0	42
200.0	659706976665600	8246337208320.0	43
205.0	1319413953331200	16492674416640.0	44
210.0	2638827906662400	32985348833280.0	45
215.0	5277655813324800	65970697666560.0	46
220.0	10555311626649600	131941395333120.0	47
225.0	21110623253299200	263882790666240.0	48
230.0	42221246506598400	527765581332480.0	49
235.0	84442493013196800	1055531162664960.0	50
240.0	168884986026393600	2111062325329920.0	51
245.0	337769972052787200	4222124650659840.0	52
250.0	675539944105574400	8444249301319680.0	53
255.0	1351079888211148800	16888498602639360.0	54
260.0	2702159776422297600	33776997205278720.0	55
265.0	5404319552844595200	67553994410557440.0	56
270.0	10808639105689190400	135107988821114880.0	57
275.0	21617278211378380800	270215977642229760.0	58
280.0	43234556422756761600	540431955284459520.0	59
285.0	86469112845513523200	1080863910568919040.0	60
290.0	172938225691027046400	2161727821137838080.0	61
295.0	345876451382054092800	4323455642275676160.0	62
300.0	691752902764108185600	8646911284551352320.0	63
305.0	1383505805528216371200	17293822569102704640.0	64
310.0	2767011611056432742400	34587645138205409280.0	65
315.0	5534023222112865484800	69175290276410818560.0	66
320.0	11068046444225730969600	138350580552821637120.0	67
325.0	22136092888451461939200	276701161105643274240.0	68
330.0	44272185776902923878400	553402322211286548480.0	69
335.0	88544371553805847756800	1106804644422573096960.0	70
340.0	177088743107611695513600	2213609288845146193920.0	71
345.0	354177486215223391027200	4427218577690292387840.0	72
350.0	708354972430446782054400	8854437155380584775680.0	73
355.0	1416709944860893564108800	17708874310761169551360.0	74
360.0	2833419889721787128217600	35417748621522339102720.0	75
365.0	5666839779443574256435200	70835	

PROFILE DESCRIPTION

OBS SITE PT2

TAVETA, KENYA

Map Unit: So
 Soil Classification: Orthic Solonetz
 Irrigable Land Classification: 6axp
 Parent Material: Calcareous tuffs
 Topography: Generally level; depression fringe soil
 Micro Relief: Even
 Slope Gradient: 1% south
 Vegetation Land Use: Assorted halophytes and palms
 Salinity/Alkalinity: Class 3; strongly affected
 Drainage Class: Moderately well - imperfect

DESCRIPTION:

Horizon	Depth (cm)	Description
Ap	0 - 15	Brown (10YR 5/3) dry, very dark greyish brown (10YR 3/2) moist; <u>silty clay</u> ; strong composite coarse prismatic angular blocky; slightly hard (dry) friable (moist); slightly sticky, slightly plastic; few fine pores; many fine roots; pH 7.8; clear wavy boundary.
Btnz ₁	15 - 50	Very dark greyish brown (10YR 3/1) dry (10YR 3/1) moist; <u>clay</u> , strong medium crumb; cracks 4 mm wide 15-30 cm depth; slightly hard (dry) firm (moist), very sticky, plastic; many fine pores; many fine few medium roots; pH 9.8; clear smooth boundary.
Btnz ₂	50 - 120	Dark brown (7.5YR 3/4) moist; <u>silty clay</u> ; moderate, medium subangular blocky; friable (moist) sticky plastic; common fine pores, very few fine roots; pH 10.6; clear smooth boundary.
BC	120 - 200	Yellowish red (5YR 4/6) moist; <u>clay</u> ; moderate, medium subangular blocky; friable (moist) sticky, plastic; common fine pores; no roots; pH 10.5.
C	200 +	Weathered rock.

Remarks:

- (i) Profile is in situ clayey soil developed over calcareous tuffs, overlain by a superficial layer of alluvial material.
- (ii) Very moist below 50 cm, possible subsoil waterlogging at certain times of the year.

Map Unit:

Soil Classification:

Sm

Medium Siltstone (Ss)

Ssnp

Deposited at the surface of the hill

ANALYTICAL DATA PROFILE PT.2

Laboratory Number	
Sample Identity	
Moisture	% o.d.s.
W/V Ratio	g/cm ³ a.d.s.
pH	1:5 H ₂ O
E.C.	me/cm 1:5 H ₂ O
pH	1:5 1M KCl
Calcium Carbonate %	
Soluble Cations me/100 g a.d.s.	Na
	K
Exchangeable Cations me/100 g a.d.s. (1)	Na
	K
	Mg
	Ca(2)
T.E.B. me/100 g a.d.s.	
C.E.C. me/100 g a.d.s.	
Base Saturation %	
Total N (3) %	
Organic C (4) %	
Hot water Soluble B ppm	
Available P (Bray) ppm	
Available P (Olsen) ppm	
DTPA Extract ppm	Cu
	Mn
	Zn
Saturation Extract %H ₂ O	
E.C Saturation Extract me/cm	
Soluble Cations me/l	Na
	K
	Mg
	Ca
Available K ppm	
Stones %	
Particle Size Analysis (Percentages in dry mineral soil)	2000-50
	50-2
	<2 μm
	Texture

7743	7744	7745	7746
PT 2			
0-15	15-60	50-100	100-120
10.3	13.3	12.8	12.8
1.07	1.05	0.92	0.93
7.8	9.8	10.6	10.5
0.13	0.91	0.66	0.61
7.2	7.9	8.9	8.8
	3.0	15.0	21.5
0.8	26.4	31.3	27.8
7.3	5.5	6.4	6.1
9.5	6.7	7.8	9.3
35.0	25.6	>50.0	>50.0
52.6	64.2	>95.5	>93.2
45.7	42.1	34.1	30.6
100	100	100	100
0.27	0.13	0.05	0.04
2.01	0.84	0.26	0.20
1.6	1.2	5.9	7.5
2049	1295	178	40
29	10	34	33
1.5	2.5	2.9	2.3
27.4	29.3	4.3	5.3
0.6	0.3	0.3	0.3
60.5	77.1	64.5	61.7
1.80	12.06	7.33	5.98
	110.0	70.0	60.0
	1.2	1.0	0.9
	0.9	0.1	0.1
	1.6	0.2	0.2
2907	2458	2734	2734
			12
13	12	11	10
51	31	42	40
36	57	47	50
ZyCl	C	ZyC	C

PROFILE DESCRIPTION

OBS SITE PT3

TAVETA, KENYA

Map Unit:

Sm

Soil Classification:

Mollic Solonetz (Sm)

Irrigable Land Classification:

6axp

Parent Material:

Depression alluvium overlying calcareous tuffs

Topography:

Level

Micro Relief:

Slightly uneven

Slope Gradient:

1% south

Vegetation Land Use:

Assorted halophytes on recently cleared land

Salinity/Alkalinity:

Class 3, strongly affected

Drainage Class:

Imperfect

DESCRIPTION:

Horizon

Depth (cm)

Description

Az

0 - 10

Black (10YR 2/1) moist; silty clay; weak, medium-fine subangular blocky; friable (moist); slightly sticky, slightly plastic; few fine pores; few fine roots; pH 8.0; diffuse boundary.

Btnz₁

10 - 45

Very dark brown (10YR 2/2) moist; silty clay; weak, medium-coarse subangular blocky; friable (moist); sticky, plastic; common fine pores; few fine roots; pH 9.9; clear smooth boundary.

Btnz₂

45 - 95

Dark brown (7.5YR 3/4) moist; silty clay; weak, medium-coarse subangular blocky; friable (moist); sticky, plastic; many fine pores; few fine roots; pH 10.7; diffuse boundary.

Btnz₃

95 - 160

Brown (7.5YR 4/4) moist; silty clay; weak medium-coarse subangular blocky; friable (moist); slightly sticky, slightly plastic; many fine pores; no roots; pH 10.6; clear smooth boundary.

C

160 - 200

Brown (7.5YR 4/4) moist; sandy clay loam comprised weathered rock; friable moist; many fine pores; no roots.

200 +

Weathered calcareous tuffs.

Remarks:

- (i) Very dry dusty surface.
- (ii) Generally weakly structured throughout.

Horizon	Depth (cm)	Description
A2	0-10	Black (10YR 2/1) moist silty clay weak medium-fine subangular blocky (moist) slightly sticky, slightly plastic. Very fine pores, few fine roots, pH 8.0, diffuse boundary.
B1p	10-45	Very dark brown (10YR 2/3) moist silty clay weak medium-fine coarse subangular blocky (moist) sticky, plastic. Common fine pores, few fine roots, pH 8.0, clear wavy boundary.
B2p	45-95	Dark brown (7.5YR 4/2) moist silty clay weak medium-coarse subangular blocky (moist) sticky, plastic. Many fine pores, few fine roots, pH 7.7, diffuse boundary.
B3p	95-160	Brown (7.5YR 4/4) moist silty clay weak medium-coarse subangular blocky (moist) slightly sticky, slightly plastic. Many fine pores, no roots, pH 7.8, clear smooth boundary.
B	160-200	Brown (7.5YR 4/4) moist sandy clay loam, decomposed. Weathered root (thistle root), many fine pores, no roots.
	200+	Weathered calcareous till.

Remarks:

- (i) Commonly weakly structured throughout.
- (ii) Very dry dusty surface.

ANALYTICAL DATA PROFILE PT.3

Laboratory Number	
Sample Identity	
Moisture	% o.d.s.
W/V Ratio	g/cm ³ a.d.s.
pH	1:5 H ₂ O
E.C.	me/cm 1:5 H ₂ O
pH	1:5 1M KCl
Calcium Carbonate %	
Soluble Cations me/100 g a.d.s.	Na
	K
Exchangeable Cations me/100 g a.d.s. (1)	Na
	K
	Mg
	Ca(2)
T.E.B. me/100 g a.d.s.	
C.E.C. me/100 g a.d.s.	
Base Saturation	%
Total N (3)	%
Organic C (4)	%
Hot Water Soluble	3 ppm
Available P (Bray)	ppm
Available P (Olsen)	ppm
DTPA Extract ppm	Cu
	Mn
	Zn
Saturation Extract	% H ₂ O
F.C. Saturation Extract me/cm	
Soluble Cations me/l	Na
	K
	Mg
	Ca
Available K	ppm
Stones %	
Particle Size Analysis (Percentages in dry mineral soil)	2000-50
	50-2
	< 2 μm
	Texture

7747	7748	7749	7750
PT 3			
0-10	10-45	45-95	95-100
13.7	10.7	10.8	10.3
0.80	0.84	0.86	0.95
8.0	9.9	10.7	10.6
4.64	1.22	1.00	0.63
7.5	8.2	9.3	9.3
6.5	12.0	24.0	33.0
22.6	19.0	21.1	16.5
10.9	13.1	14.3	12.5
9.9	6.8	8.0	7.9
>50.0	>50.0	>50.0	>50.0
>93.4	>88.9	>93.4	>86.9
44.5	38.5	30.5	23.2
100	100	100	100
0.40	0.21	0.09	0.06
3.44	1.62	0.64	0.34
2.4	1.5	11.9	11.9
1090	636	5	3
40	9	20	22
0.9	1.2	1.5	0.6
8.9	10.9	4.5	2.5
1.1	0.4	0.3	0.1
70.0	65.6	68.9	56.8
69.6	24.9	15.05	9.33
600.0	220.0	130.0	80.0
60.0	20.0	10.0	10.0
75.9	5.0	0.2	0.1
153.6	6.4	0.2	0.1
6346	6034	6555	5826
			8
13	12	9	19
49	50	47	54
38	38	44	27
ZyCL	ZyCL	ZyC	ZyL

PROFILE DESCRIPTION

OBS SITE PT4

TAVETA, KENYA

Map Unit: Rc
Soil Classification: Eutric Regosols
Irrigable Land Classification: 2t
Parent Material: Gneisses
Topography: Sloping piedmont footslope associated with gneissic outcrops
Micro Relief: Even
Slope Gradient: 2% north
Vegetation Land Use: Overgrazed acacia scrub
Salinity/Alkalinity: None
Drainage Class: Well drained - somewhat excessively well drained

DESCRIPTION:

Horizon	Depth (cm)	Description
Au	0 - 15	Yellowish red (5YR 4/6) dry, (5YR 4/6) moist; <u>sandy loam</u> ; weak fine-medium subangular blocky, soft (dry) friable (moist) non sticky, non plastic; many fine pores; many fine roots; pH 7.0; diffuse boundary.
Bt ₁	15 - 75	Yellowish red (5YR 5/8) dry, (5YR 3/2) moist; gritty, <u>coarse sandy clay loam</u> ; weak fine-medium subangular blocky; soft (dry), friable (moist); slightly sticky, slightly plastic; many fine pores; many fine roots; pH 7.8; diffuse boundary.
Bt ₂	75 - 120	Yellowish red (5YR 5/8) dry; (5YR 3/2) moist; gritty, <u>coarse sandy clay loam - sandy loam</u> ; weak, medium-fine subangular blocky, soft (dry), friable (moist); slightly sticky, slightly plastic; many fine pores; many fine roots; pH 8.0; diffuse boundary.
BC	120 - 200	Reddish brown (5YR 5/4) dry; (5YR 4/4) moist; <u>gritty sandy clay loam</u> ; weak medium-fine subangular blocky, soft (dry), friable (moist); slightly sticky, slightly plastic; many fine pores; few fine roots; weathered rock fragments.

Remarks

- (i) Horizons not sampled.
- (ii) 120 - 200 containing weathered gneiss.

- (i) Very powdery dusty surface
- (ii) Profile very dry throughout
- (iii) Aggregate stability in surface horizons low, therefore difficult to bond the soil to make furrows

PROFILE DESCRIPTION

OBS SITE PT5

TAVETA, KENYA

Map Unit: Lk
Soil Classification: Calcic Luvisol
Irrigable Land Classification: 3b
Parent Material: Calcareous tuffaceous grits
Topography: Generally level
Micro Relief: Even
Slope Gradient: 0 - 1%
Vegetation Land Use: Furrow irrigated field left fallow. Furrows somewhat denuded due to poor aggregate stability in surface horizons
Salinity/Alkalinity: Class O; none
Drainage Class: Well drained

DESCRIPTION:

Horizon	Depth (cm)	Description
Apk	0 - 15	Dark brown (7.5YR 4/2) dry, dark brown (7.5YR 3/2) moist; <u>silty clay</u> ; strong coarse angular blocky structure; slightly hard (dry), friable (moist); slightly sticky, slightly plastic; few fine pores, common fine roots; pH 8.5; diffuse boundary.
Btk ₁	15 - 50	Brown (7.5YR4/2) dry, (7.5YR 3/2) moist; <u>silty clay</u> ; moderate, medium-coarse subangular blocky; soft (dry), friable (moist); slightly sticky, slightly plastic; common fine pores; common fine few coarse roots; pH 8.7; clear smooth boundary.
Bntk ₂	50 - 110	Brown (7.5YR 5/4) dry, dark brown (7.5YR 3/2) moist; <u>silty clay</u> ; weak-moderate, medium subangular blocky; slightly hard (dry), firm (moist); slightly sticky, slightly plastic; few fine pores; very few fine roots; pH 8.9; clear smooth boundary.
BC	110 - 160	Strong brown (7.5YR 5/6) dry, (7.5YR 4/6) moist; <u>silty clay</u> ; containing fragments of weathered rock; weak-moderate subangular blocky; slightly hard (dry), firm (moist); slightly sticky, slightly plastic; few fine pores; no roots; pH9.2; diffuse boundary.
	160 - 200	Weathered calcareous tuffs.

Remarks:

- (i) Very powdery dusty surface.
- (ii) Profile very dry throughout.
- (iii) Aggregate stability in surface horizons low, therefore difficult to bund the soil to make furrows.

Map Unit:
Soil Classification:

Lo
Chromic Umbril

ANALYTICAL DATA PROFILE PT.5

Laboratory Number	
Sample Identity	
Moisture	% o.d.s.
W/V Ratio	g/cm ³ a.d.s.
pH	1:5 H ₂ O
E.C.	me/cm 1:5 H ₂ O
pH	1:5 1M KCl
Calcium Carbonate %	
Soluble Cations me/100 g a.d.s.	Na
	K
Exchangeable Cations me/100 g a.d.s. (1)	Na
	K
	Mg
	Ca(2)
T.E.B. me/100 g a.d.s.	
C.E.C. me/100 g a.d.s.	
Base Saturation %	
Total N (3) %	
Organic C (4) %	
Hot water Soluble B ppm	
Available P (Bray) ppm	
Available P (Olsen) ppm	
DTPA Extract PPM	Cu
	Mn
	Zn
Saturation Extract %H ₂ O	
E.C. Saturation Extract me/cm	
Soluble Cations me/L	Na
	K
	Mg
	Ca
Available K ppm	
Stones %	
Particle Size Analysis (Percentages in dry mineral soil)	2000-50
	50-2
	< 2µm
	Texture

7751	7752	7753	7754
PT 5			
0-15	15-50	50-110	110-160
10.9	11.2	10.9	10.1
1.01	0.96	1.00	1.10
8.5	8.7	8.9	9.2
0.11	0.11	0.17	0.20
7.7	7.7	7.8	8.0
8.5	16.5	18.0	26.0
0.3	0.7	0.9	1.4
6.4	5.6	10.8	13.1
15.3	19.2	22.1	20.2
>50.0	>50.0	>50.0	>50.0
>72.0	>75.5	>83.8	>84.7
41.2	34.9	32.7	26.6
100	100	100	100
0.19	0.12	0.09	0.05
1.85	1.07	0.74	0.27
1.0	1.1	1.4	2.4
4.7	2.7	10	5
11	5	6	6
1.7	1.7	1.5	1.5
14.8	12.1	4.8	3.5
0.4	0.1	0.1	0.1
62.6	68.3	63.3	56.5
0.59	0.74	1.41	1.87
2479	2162	4304	5324
			18
12	9	10	11
48	42	56	49
40	49	34	40
ZyC	ZyC	ZyCL	ZyC

ANALYTICAL DATA PROFILE P18

TIME	TEMP	TEMP	TEMP
0-10	00-00	00-00	00-00
10-20	00-00	00-00	00-00
20-30	00-00	00-00	00-00
30-40	00-00	00-00	00-00
40-50	00-00	00-00	00-00
50-60	00-00	00-00	00-00
60-70	00-00	00-00	00-00
70-80	00-00	00-00	00-00
80-90	00-00	00-00	00-00
90-100	00-00	00-00	00-00
100-110	00-00	00-00	00-00
110-120	00-00	00-00	00-00
120-130	00-00	00-00	00-00
130-140	00-00	00-00	00-00
140-150	00-00	00-00	00-00
150-160	00-00	00-00	00-00
160-170	00-00	00-00	00-00
170-180	00-00	00-00	00-00
180-190	00-00	00-00	00-00
190-200	00-00	00-00	00-00
200-210	00-00	00-00	00-00
210-220	00-00	00-00	00-00
220-230	00-00	00-00	00-00
230-240	00-00	00-00	00-00
240-250	00-00	00-00	00-00
250-260	00-00	00-00	00-00
260-270	00-00	00-00	00-00
270-280	00-00	00-00	00-00
280-290	00-00	00-00	00-00
290-300	00-00	00-00	00-00

ANALYTICAL PROFILE	ANALYTICAL PROFILE
0-10	00-00
10-20	00-00
20-30	00-00
30-40	00-00
40-50	00-00
50-60	00-00
60-70	00-00
70-80	00-00
80-90	00-00
90-100	00-00
100-110	00-00
110-120	00-00
120-130	00-00
130-140	00-00
140-150	00-00
150-160	00-00
160-170	00-00
170-180	00-00
180-190	00-00
190-200	00-00
200-210	00-00
210-220	00-00
220-230	00-00
230-240	00-00
240-250	00-00
250-260	00-00
260-270	00-00
270-280	00-00
280-290	00-00
290-300	00-00

PROFILE DESCRIPTION

OBS SITE PT6

TAVETA, KENYA

Map Unit: Lc
 Soil Classification: Chromic Luvisol
 Irrigable Land Classification: 1
 Parent Material: Calcareous tuffaceous grits
 Topography: Level clay plain
 Micro Relief: Even
 Slope Gradient: 0 - 1%
 Vegetation Land Use: Very mature secondary regrowth possibly up to 20 years old
 Salinity/Alkalinity: Class O; none
 Drainage Class: Well drained

DESCRIPTION:

Horizon	Depth (cm)	Description
A	0 - 20	Dark reddish brown (5YR 3/2) dry; (5YR 3/2) moist; <u>heavy clay loam</u> ; weak-moderate medium crumb; slightly hard (dry), friable (moist); very sticky, very plastic; many fine pores; many fine roots; pH 8.0; clear smooth boundary.
Bt ₁	20 - 80	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist; <u>clay</u> ; strong, coarse prismatic, with cracks 20 - 80 cm depth, 0.5 cm wide; hard (dry), firm (moist) very sticky very plastic; many fine pores; common fine roots; pH 8.2; clear smooth boundary.
Bt ₂	80 - 135	Reddish brown (5YR 4/4) dry, (5YR3/2) moist, <u>clay</u> ; moderate-strong medium, subangular blocky; hard (dry), firm (moist); very sticky plastic; few fine pores; few fine roots; pH 8.4; few hairline cracks to 120 cm depth; diffuse boundary.
BC	135 - 200	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist; <u>gritty clay</u> ; weak, fine-medium subangular blocky; hard (dry), firm (moist); sticky, plastic; few fine pores; few fine roots; pH 8.6; fragments of weathered rock.

Remarks:

- (i) Very well structured soil to 80 cm depth with moderate structure to 135 cm depth.
- (ii) Relatively impermeable layer at 135 cm depth to 200 cm.

JAVETA, KENYA

Obs Site #18

Profile Description

Very fine sandy loam, secondary growth, possibly up to 20 years old	0-10	Very fine sandy loam, secondary growth, possibly up to 20 years old
Class O, brown	10-15	Class O, brown
Well drained		Well drained

DESCRIPTION

Horizon	Depth (cm)	Description
A	0-20	Dark reddish brown (5YR 3/2) moist, heavy clay loam, weak-moderate structure, crumb, friable (dry), bases finely, very sticky, very plastic, many fine pores, many fine roots, pH 5.0, clear reaction to sodium
B ₁	20-30	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist, clay, strong dense prismatic, with cracks 20-30 cm (dry), 0.5 cm wide, (1-2) fine, fine, fine, very sticky, very plastic, many fine pores, common fine roots, pH 5.0, clear reaction to sodium
B ₂	30-100	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist, clay, moderate strong medium subangular blocky (dry), very plastic, very sticky, plastic, few fine roots, few fine pores, pH 5.0, few bases, a grain is 100 cm (dry), clear reaction to sodium
B ₃	100-200	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist, clay, clay, weak, fine-medium subangular blocky, and (dry), firm (moist), sticky, plastic, few fine roots, few fine pores, pH 5.0, fragments of weathered rock

Remarks

- (1) Very well structured soil to 20 cm depth with maximum structure to 100 cm depth.
- (2) Primary topsoil layer at 100 cm depth to 200 cm.

Map Grid

Soil Classification

Lc

Chromic Luvisol

ANALYTICAL DATA PROFILE PT.6

Calcareous sufficuous gres

Laboratory Number	
Sample Identity	
Moisture	% o.d.s.
W/V Ratio	g/cm ³ a.d.s.
pH	1:5 H ₂ O
E.C.	me/cm 1:5 H ₂ O
pH	1:5 1M KCl
Calcium Carbonate	%
Soluble Cations me/100 g a.d.s.	Na
	K
Exchangeable Cations me/100 g a.d.s. (1)	Na
	K
	Mg
	Ca (2)
T.E.B.	me/100 g a.d.s.
C.E.C.	me/100 g a.d.s.
Base Saturation	%
Total N (3)	%
Organic C (4)	%
Available P (Bray) ppm	
Available P (Olsen) ppm	
DTPA Extract ppm	Cu
	Mn
	Zn
Saturation Extract	%H ₂ O
E.C. Saturation Extract me/cm	
Soluble Cations me/l	Na
	K
	Mg
	Ca
Stones %	
Particle Size Analysis (Percentages in dry mineral soil)	2000-50
	50-2
	<2µm
	Texture

7755	7756	7757	7758
PT 6			
0-20	20-80	80-136	135-200
14.0	14.7	14.2	12.3
1.02	0.97	1.04	1.09
8.0	8.2	8.4	8.6
0.05	0.09	0.10	0.10
7.1	7.4	7.7	7.8
	2.0	7.0	18.0
0.2	0.3	0.5	0.4
6.6	5.8	7.1	6.8
14.2	16.8	24.4	24.4
31.5	47.9	750.0	750.0
52.5	70.8	82.0	81.6
49.5	47.0	41.1	34.7
100	100	100	100
0.17	0.13	0.06	0.05
1.38	1.05	0.55	0.37
1.0	0.6	0.7	0.9
465	1020	532	180
27	4	9	15
2.4	2.7	2.3	2.3
19.7	20.1	10.1	9.2
0.4	0.2	0.2	0.2
71.9	78.9	72.3	69.4
0.61	0.75	0.62	0.47
2642	2387	2754	2785
		5	15
9	7	8	10
31	29	29	27
60	64	63	63
C	C	C	C

PROFILE DESCRIPTION

OBS SITE PT7

TAVETA, KENYA

Map Unit: Lc
Soil Classification: Chromic Luvisol
Irrigable Land Classification: 1
Parent Material: Calcareous tuffaceous grits
Topography: Level
Micro Relief: Even
Slope Gradient: 0%
Vegetation Land Use: Recently cleared land north of the canal
Salinity/Alkalinity: Class O; none
Drainage Class: Well drained

DESCRIPTION:

Horizon	Depth (cm)	Description
A	0 - 25	Dark reddish brown (5YR 3/2) dry, (5YR 3/2) moist; <u>clay loam</u> ; strong, medium crumb; slightly hard (dry), friable (moist); very sticky, plastic; many fine pores; very many fine roots; pH 8.3; clear smooth boundary.
Bt ₁	25 - 75	Dark reddish brown (5YR 3/3) dry, (5YR 3/2) moist; <u>clay</u> ; strong medium-coarse composite subangular blocky, prismatic; hard (dry), firm moist; very sticky, plastic; many fine few medium pores; many fine roots; pH 8.4; diffuse boundary.
Bt ₂	75 - 135	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist; <u>clay</u> ; moderate, medium subangular blocky; very hard (dry), firm (moist); very sticky plastic; common fine pores; few fine roots; pH 8.5; diffuse boundary.
BC	135 - 200	Reddish brown (5YR 4/4) dry, (5YR 3/2) moist; <u>clay</u> ; moderate medium subangular blocky; very hard (dry), firm moist; very sticky, plastic; few fine pores; few fine roots; pH 8.6.

Remarks:

- (i) Reduced permeability with depth, particularly below 75 cm.
- (ii) Very well structured topsoil down to 75 cm depth.
- (iii) Peds very porous with well developed clay skins.
- (iv) Termite chambers below 1 m depth.
- (v) Good root penetration

ANALYTICAL DATA REPORT

TEST	UNIT	TEST	UNIT	TEST	UNIT
1	g	2	g	3	g
4	g	5	g	6	g
7	g	8	g	9	g
10	g	11	g	12	g
13	g	14	g	15	g
16	g	17	g	18	g
19	g	20	g	21	g
22	g	23	g	24	g
25	g	26	g	27	g
28	g	29	g	30	g
31	g	32	g	33	g
34	g	35	g	36	g
37	g	38	g	39	g
40	g	41	g	42	g
43	g	44	g	45	g
46	g	47	g	48	g
49	g	50	g	51	g
52	g	53	g	54	g
55	g	56	g	57	g
58	g	59	g	60	g
61	g	62	g	63	g
64	g	65	g	66	g
67	g	68	g	69	g
70	g	71	g	72	g
73	g	74	g	75	g
76	g	77	g	78	g
79	g	80	g	81	g
82	g	83	g	84	g
85	g	86	g	87	g
88	g	89	g	90	g
91	g	92	g	93	g
94	g	95	g	96	g
97	g	98	g	99	g
100	g	101	g	102	g

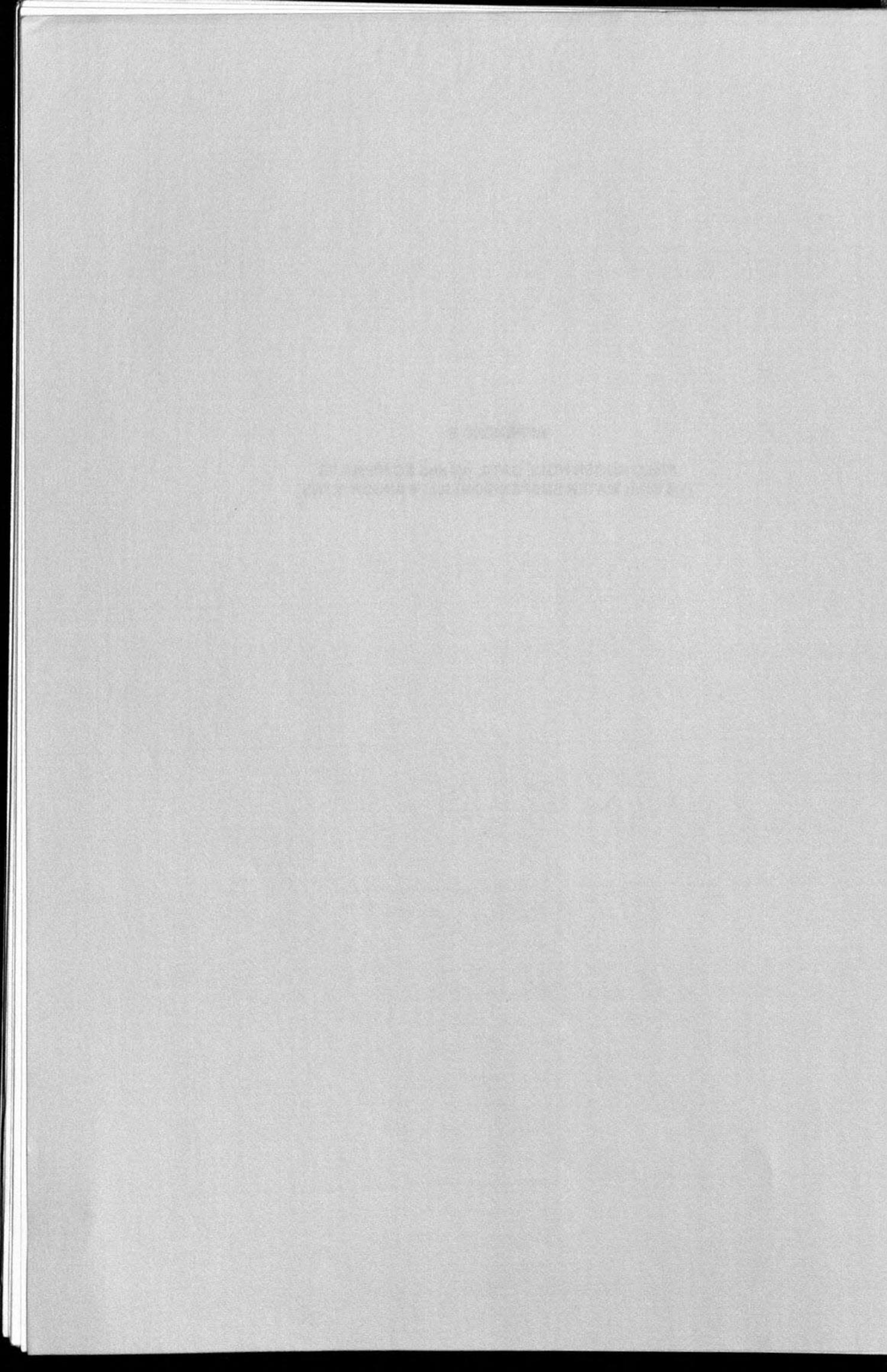
TEST	UNIT	TEST	UNIT	TEST	UNIT
1	g	2	g	3	g
4	g	5	g	6	g
7	g	8	g	9	g
10	g	11	g	12	g
13	g	14	g	15	g
16	g	17	g	18	g
19	g	20	g	21	g
22	g	23	g	24	g
25	g	26	g	27	g
28	g	29	g	30	g
31	g	32	g	33	g
34	g	35	g	36	g
37	g	38	g	39	g
40	g	41	g	42	g
43	g	44	g	45	g
46	g	47	g	48	g
49	g	50	g	51	g
52	g	53	g	54	g
55	g	56	g	57	g
58	g	59	g	60	g
61	g	62	g	63	g
64	g	65	g	66	g
67	g	68	g	69	g
70	g	71	g	72	g
73	g	74	g	75	g
76	g	77	g	78	g
79	g	80	g	81	g
82	g	83	g	84	g
85	g	86	g	87	g
88	g	89	g	90	g
91	g	92	g	93	g
94	g	95	g	96	g
97	g	98	g	99	g
100	g	101	g	102	g

LABORATORY ECe and pH RESULTS SITE T.18

Laboratory Number		7763	7764	7765
Sample Identity		T18		
Moisture % o.d.s.		0-10	10-40	40-80
W/V Ratio g/cm ³ a.d.s.				
pH 1:5 H ₂ O		8.5	9.8	10.5
E.C. me/cm 1:5 H ₂ O		0.10	0.36	0.72
pH 1:5 1M KCl		7.4	7.7	8.8
Calcium Carbonate %		0.5	3.0	6.5
Soluble Cations me/100 g a.d.s.	Na			
	K			
Exchangeable Cations me/100 g a.d.s. (1)	Na			
	K			
	Mg			
	Ca(2)			
T.E.B. me/100 g a.d.s.				
C.E.C. me/100 g a.d.s.				
Base Saturation %				
Total N (3) %				
Organic C (4) %				
Hot Water Soluble B ppm				
Available P (Bray) ppm				
Available P (Olsen) ppm				
DTPA Extract ppm	Cu			
	Mn			
	Zn			
Saturation Extract % H ₂ O		74.2	79.4	91.4
E.C. Saturation Extract mg/l		2.01	2.25	5.35
Soluble Cations mg/l	Na			
	K			
	Mg			
	Ca			
Available K ppm				
Stones %				
Particle Size Analysis (Percentages in dry mineral soil)	2000-50			
	50-2			
	<2µm			
	Texture			

APPENDIX B

**FIELD AUGER HOLE DATA, pH and EC RESULTS
(1:5 SOIL WATER SUSPENSION) for 25 AUGER SITES**



OBS No	Depth (cm)	Colour	Field Texture	EC ($\mu\text{S cm}^{-1}$ 1:5)	pH (1:5 Soil Water)	Profile Drainage Class
T1	0-30	10YR 3/2	Clay Loam (Heavy)	1200	9.6	Poor
T2	0-25	5YR 4/6	Sandy Clay Loam	160	7.38	Well
	25-50	5YR 4/6	Sandy Clay Loam	200	7.35	Well
T3	0-25	7.5YR 3/2	Silty Clay Loam	550	8.24	Mod. Alkaline
	25-50	7.5YR 4/4	Silty Clay Loam	600	8.10	Mod. Alkaline
	50-100	7.5YR 4/4	Silty Clay Loam	1050	8.20	Saline-Mod. Alkaline
T4	0-25	5YR 3/3	Clay Loam	180	8.06	Well
	25-50	5YR 3/3	Silty Clay Loam	180	8.80	Well
	50-100	5YR 3/3	Silty Clay Loam	300	8.60	Well
T5	0-25	5YR 4/6	Sandy Clay Loam	475	7.01	Well
	25-50	5YR 4/6	Clay Loam	900	7.80	Well
	50-100	5YR 4/6	Clay Loam	700	8.22	Well
T6	0-25	5YR 4/6	Fine Sandy Clay Loam	180	7.47	Well
	25-50	5YR 4/6	Fine Sandy Clay Loam	180	8.4	Well
	50-100	5YR 4/6	Fine Sandy Clay Loam	190	9.05	Well
T7	0-25	5YR 4/6	Fine Sandy Clay Loam	500	6.76	Moderately Well
	25-50	5YR 4/4	Silty Clay Loam	2600	6.75	Moderately Well
	50-100	5YR 3/3	Silty Clay Loam	1000	9.3	Moderately Well
T8	0-25	7.5YR 5/4	Fine Sandy Clay Loam	2100	7.55	Moderately Well
	25-50	7.5YR 3/4	Clay Loam	1500	9.5	Moderately Well
	50-100	7.5YR 3/4	Clay Loam (Heavy)	1100	>9.5	Moderately Well
T9	0-25	5YR 3/3	Sandy Clay Loam	150	7.6	Well
	25-50	5YR 4/6	Sandy Clay Loam	200	8.60	Well
T10	0-35	5YR 3/3	Clay Loam	100	>9.5	Poor
T11	0-25	5YR 4/6	Gritty Sand Clay Loam	1750	8.70	Well
	25-50	5YR 4/6	Gritty Sand Clay Loam	3500	9.55	Well
	50-100	5YR 4/6	Gritty Sand Clay Loam	4100	9.6	Well
T12	0-25	5YR 4/6	Sandy Loam	150	7.0	Well
	25-50	5YR 5/6	Sandy Clay Loam	125	7.8	Well
	50-100	5YR 5/8	Sandy Clay Loam	150	8.0	Well
T13	0-25	10YR 2/1	Silty Clay Loam	4000	8.90	Imperfect
	25-50	10YR 3/2	Silty Clay Loam	3000	>9.5	Imperfect
	50-100	10YR 4/3	Sandy Clay Loam	1400	>9.5	Imperfect
T14	0-25	5YR 3/3	Silty Clay Loam	200	8.95	Well
	25-50	5YR 3/2	Silty Clay Loam	375	9.6	Well
	50-100	5YR 3/2	Silty Clay Loam	900	>9.5	Well
T15	0-25	7.5YR 4/4	Sandy Clay Loam	1500	>9.5	Poor - Imperfect
	25-50	7.5YR 3/2	Clay Loam (Heavy)	1250	>9.5	poor - Imperfect
	50-75	7.5YR 3/2	Clay Loam (Heavy)	1150	>9.5	Poor - Imperfect
	75-100	7.5YR 3/2	Clay Loam (Heavy)	1050	>9.5	Poor - Imperfect
T16	0-25	7.5YR 4/4	Silty clay Loam	1100	8.95	Poor - Imperfect
	25-50	7.5YR 3/4	Clay Loam	2800	>9.5	Poor - Imperfect
	50-100	7.5YR 3/2	Clay Loam	3400	>9.5	Poor - Imperfect

Year	Value	Category	Value	Category	Value	Category	Value	Category
1950	100	...	100	...	100	...	100	...
1951	105	...	105	...	105	...	105	...
1952	110	...	110	...	110	...	110	...
1953	115	...	115	...	115	...	115	...
1954	120	...	120	...	120	...	120	...
1955	125	...	125	...	125	...	125	...
1956	130	...	130	...	130	...	130	...
1957	135	...	135	...	135	...	135	...
1958	140	...	140	...	140	...	140	...
1959	145	...	145	...	145	...	145	...
1960	150	...	150	...	150	...	150	...
1961	155	...	155	...	155	...	155	...
1962	160	...	160	...	160	...	160	...
1963	165	...	165	...	165	...	165	...
1964	170	...	170	...	170	...	170	...
1965	175	...	175	...	175	...	175	...
1966	180	...	180	...	180	...	180	...
1967	185	...	185	...	185	...	185	...
1968	190	...	190	...	190	...	190	...
1969	195	...	195	...	195	...	195	...
1970	200	...	200	...	200	...	200	...
1971	205	...	205	...	205	...	205	...
1972	210	...	210	...	210	...	210	...
1973	215	...	215	...	215	...	215	...
1974	220	...	220	...	220	...	220	...
1975	225	...	225	...	225	...	225	...
1976	230	...	230	...	230	...	230	...
1977	235	...	235	...	235	...	235	...
1978	240	...	240	...	240	...	240	...
1979	245	...	245	...	245	...	245	...
1980	250	...	250	...	250	...	250	...
1981	255	...	255	...	255	...	255	...
1982	260	...	260	...	260	...	260	...
1983	265	...	265	...	265	...	265	...
1984	270	...	270	...	270	...	270	...
1985	275	...	275	...	275	...	275	...
1986	280	...	280	...	280	...	280	...
1987	285	...	285	...	285	...	285	...
1988	290	...	290	...	290	...	290	...
1989	295	...	295	...	295	...	295	...
1990	300	...	300	...	300	...	300	...
1991	305	...	305	...	305	...	305	...
1992	310	...	310	...	310	...	310	...
1993	315	...	315	...	315	...	315	...
1994	320	...	320	...	320	...	320	...
1995	325	...	325	...	325	...	325	...
1996	330	...	330	...	330	...	330	...
1997	335	...	335	...	335	...	335	...
1998	340	...	340	...	340	...	340	...
1999	345	...	345	...	345	...	345	...
2000	350	...	350	...	350	...	350	...
2001	355	...	355	...	355	...	355	...
2002	360	...	360	...	360	...	360	...
2003	365	...	365	...	365	...	365	...
2004	370	...	370	...	370	...	370	...
2005	375	...	375	...	375	...	375	...
2006	380	...	380	...	380	...	380	...
2007	385	...	385	...	385	...	385	...
2008	390	...	390	...	390	...	390	...
2009	395	...	395	...	395	...	395	...
2010	400	...	400	...	400	...	400	...
2011	405	...	405	...	405	...	405	...
2012	410	...	410	...	410	...	410	...
2013	415	...	415	...	415	...	415	...
2014	420	...	420	...	420	...	420	...
2015	425	...	425	...	425	...	425	...
2016	430	...	430	...	430	...	430	...
2017	435	...	435	...	435	...	435	...
2018	440	...	440	...	440	...	440	...
2019	445	...	445	...	445	...	445	...
2020	450	...	450	...	450	...	450	...

1950-1959
 1960-1969
 1970-1979
 1980-1989
 1990-1999
 2000-2009
 2010-2019
 2020-2029

OBS No	Depth (cm)	Colour	Field Texture	EC (μ S cm ⁻¹ 1:5)	pH (1:5 Soil Water)	Salinity	Profile Drainage Class
T17	0-25	7.5YR 5/4	Sandy Clay Loam	5200	7.4	Saline	Well
	25-50	7.5YR 3/2	Sandy Clay Loam	4750	7.98	Saline	Well
	50-100	7.5YR 3/2	Sandy Clay Loam	660	9.46	Strongly Alkaline	Well
	100-150	7.5YR 3/2	Sandy Clay Loam	550	>8.5	Strongly Alkaline	Well
T18	0-10	7.5YR 4/2	Silty Clay Loam	225	8.95	Strongly Alkaline	Poor
	10-40	7.5YR 3/0	Silty Clay Loam	475	>9.5	Strongly Alkaline	Poor
	40-80	7.5YR 3/2	Silty Clay Loam	1100	>9.5	Strongly Alkaline	Poor
	80-100	7.5YR 5/6	Sandy Clay Loam	170	8.5	Strongly Alkaline	Well
T19	0-25	5YR 5/6	Clay Loam	200	8.53	Strongly Alkaline	Well
	25-50	5YR 5/6	Clay Loam	200	8.85	Strongly Alkaline	Well
	50-80	5YR 3/3	Sandy Clay Loam	220	8.48	Mod. Alkaline	Well
	80-100	5YR 4/6	Clay Loam	450	8.17	Mod. Alkaline	Well
T20	0-25	5YR 3/4	Sandy Clay Loam	875	7.6	Saline	Imperfect
	25-50	5YR 4/4	Clay Loam (Heavy)	1050	7.65	Saline	Imperfect
	50-80	5YR 4/4	Clay Loam (Heavy)	850	9.00	Strongly Alkaline	Imperfect
	80-100	5YR 3/4	Sandy Clay Loam	295	8.57	Strongly Alkaline	Well
T21	0-25	5YR 3/4	Clay Loam (Heavy)	325	8.50	Mod. Alkaline	Well
	25-50	5YR 3/4	Clay Loam (Heavy)	220	8.65	Strongly Alkaline	Well
	50-100	5YR 3/4	Sandy Clay Loam	175	7.6	Mod. Alkaline	Well
	100-150	5YR 3/6	Sandy Clay Loam	475	8.4	Saline - Mod. Alkaline	Well
T22	0-25	5YR 3/6	Sandy Clay Loam	1000	8.3	Saline - Mod. Alkaline	Well
	25-50	5YR 3/6	Sandy Clay Loam	140	7.97	Strongly Alkaline	Well
	50-90	5YR 3/4	Sandy Clay Loam	140	8.12	Strongly Alkaline	Well
	90-100	5YR 4/6	Sandy Clay Loam	140	7.7	Strongly Alkaline	Well
T23	0-25	5YR 3/4	Clay Loam	140	7.7	Strongly Alkaline	Well
	25-50	5YR 3/4	Clay Loam	175	7.45	Strongly Alkaline	Well
	50-90	5YR 4/6	Sandy Clay Loam	200	8.66	Strongly Alkaline	Well
	90-100	5YR 5/6	Sandy Clay Loam	200	8.66	Strongly Alkaline	Well

FIELD MEASUREMENTS AND INFILTRATION

At each site, two infiltration tests were conducted to a depth of 10 - 15 cm. The tests were conducted at different times of day to account for variations in soil moisture and depth of water table.

The infiltration rate was measured by a series of 10-minute tests. The results of these tests are presented in Table 1.

A total of 100 tests were conducted at the Project site. The results of these tests are presented in Table 2.

APPENDIX C

SITE #11
YAVOPI-ESTATES

PRELIMINARY INFILTRATION TEST DATA
FOR SITES PT1 AND PT5

DATE	TIME	DEPTH (cm)	INFLUX (cm/hr)	INFLUX (cm/hr)	INFLUX (cm/hr)
1	10:00	10	1.00	1.00	1.00
2	10:15	10	1.15	1.15	1.15
3	10:30	10	1.30	1.30	1.30
4	10:45	10	1.45	1.45	1.45
5	11:00	10	1.60	1.60	1.60
6	11:15	10	1.75	1.75	1.75
7	11:30	10	1.90	1.90	1.90
8	11:45	10	2.05	2.05	2.05
9	12:00	10	2.20	2.20	2.20
10	12:15	10	2.35	2.35	2.35
11	12:30	10	2.50	2.50	2.50
12	12:45	10	2.65	2.65	2.65
13	13:00	10	2.80	2.80	2.80
14	13:15	10	2.95	2.95	2.95
15	13:30	10	3.10	3.10	3.10
16	13:45	10	3.25	3.25	3.25
17	14:00	10	3.40	3.40	3.40
18	14:15	10	3.55	3.55	3.55
19	14:30	10	3.70	3.70	3.70
20	14:45	10	3.85	3.85	3.85
21	15:00	10	4.00	4.00	4.00
22	15:15	10	4.15	4.15	4.15
23	15:30	10	4.30	4.30	4.30
24	15:45	10	4.45	4.45	4.45
25	16:00	10	4.60	4.60	4.60
26	16:15	10	4.75	4.75	4.75
27	16:30	10	4.90	4.90	4.90
28	16:45	10	5.05	5.05	5.05
29	17:00	10	5.20	5.20	5.20
30	17:15	10	5.35	5.35	5.35
31	17:30	10	5.50	5.50	5.50
32	17:45	10	5.65	5.65	5.65
33	18:00	10	5.80	5.80	5.80
34	18:15	10	5.95	5.95	5.95
35	18:30	10	6.10	6.10	6.10
36	18:45	10	6.25	6.25	6.25
37	19:00	10	6.40	6.40	6.40
38	19:15	10	6.55	6.55	6.55
39	19:30	10	6.70	6.70	6.70
40	19:45	10	6.85	6.85	6.85
41	20:00	10	7.00	7.00	7.00
42	20:15	10	7.15	7.15	7.15
43	20:30	10	7.30	7.30	7.30
44	20:45	10	7.45	7.45	7.45
45	21:00	10	7.60	7.60	7.60
46	21:15	10	7.75	7.75	7.75
47	21:30	10	7.90	7.90	7.90
48	21:45	10	8.05	8.05	8.05
49	22:00	10	8.20	8.20	8.20
50	22:15	10	8.35	8.35	8.35
51	22:30	10	8.50	8.50	8.50
52	22:45	10	8.65	8.65	8.65
53	23:00	10	8.80	8.80	8.80
54	23:15	10	8.95	8.95	8.95
55	23:30	10	9.10	9.10	9.10
56	23:45	10	9.25	9.25	9.25
57	00:00	10	9.40	9.40	9.40
58	00:15	10	9.55	9.55	9.55
59	00:30	10	9.70	9.70	9.70
60	00:45	10	9.85	9.85	9.85
61	01:00	10	10.00	10.00	10.00
62	01:15	10	10.15	10.15	10.15
63	01:30	10	10.30	10.30	10.30
64	01:45	10	10.45	10.45	10.45
65	02:00	10	10.60	10.60	10.60
66	02:15	10	10.75	10.75	10.75
67	02:30	10	10.90	10.90	10.90
68	02:45	10	11.05	11.05	11.05
69	03:00	10	11.20	11.20	11.20
70	03:15	10	11.35	11.35	11.35
71	03:30	10	11.50	11.50	11.50
72	03:45	10	11.65	11.65	11.65
73	04:00	10	11.80	11.80	11.80
74	04:15	10	11.95	11.95	11.95
75	04:30	10	12.10	12.10	12.10
76	04:45	10	12.25	12.25	12.25
77	05:00	10	12.40	12.40	12.40
78	05:15	10	12.55	12.55	12.55
79	05:30	10	12.70	12.70	12.70
80	05:45	10	12.85	12.85	12.85
81	06:00	10	13.00	13.00	13.00
82	06:15	10	13.15	13.15	13.15
83	06:30	10	13.30	13.30	13.30
84	06:45	10	13.45	13.45	13.45
85	07:00	10	13.60	13.60	13.60
86	07:15	10	13.75	13.75	13.75
87	07:30	10	13.90	13.90	13.90
88	07:45	10	14.05	14.05	14.05
89	08:00	10	14.20	14.20	14.20
90	08:15	10	14.35	14.35	14.35
91	08:30	10	14.50	14.50	14.50
92	08:45	10	14.65	14.65	14.65
93	09:00	10	14.80	14.80	14.80
94	09:15	10	14.95	14.95	14.95
95	09:30	10	15.10	15.10	15.10
96	09:45	10	15.25	15.25	15.25
97	10:00	10	15.40	15.40	15.40
98	10:15	10	15.55	15.55	15.55
99	10:30	10	15.70	15.70	15.70
100	10:45	10	15.85	15.85	15.85

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FIELD MEASUREMENT OF INFILTRATION

SITE PT1
TAVETA ESTATES

At each site three infiltration rings were installed to a depth of 10 - 15 cm. An approximately constant head of water was maintained in each of the rings, and depth of water entering the soil recorded.

Infiltration rates were measured over a period of 5 hours. It was not practicable to continue the tests beyond five hours because of the difficulties of supplying water.

A total of two tests were carried out in the Project area. Curves of cumulative infiltration rates are given overleaf. A summary of data from the tests is given in Section 5.

SITE PT1
TAVETA ESTATES

Interval (min)	Cumulative time (min)	Intake (cm)	Cumulative (cm)	IR cm/hr	
				Immediate	Mean
2	2	2.23	2.23	66.9	66.9
3	5	1.13	3.36	22.6	40.32
5	10	1.56	4.92	18.72	29.52
5	15	1.3	6.22	15.6	24.88
5	20	1.26	7.48	15.0	22.44
5	25	1.13	8.61	13.56	20.66
5	30	1.16	9.77	13.92	19.54
5	35	1.06	10.83	12.72	18.56
5	40	1.0	11.83	12.0	17.74
5	45	1.06	12.89	12.72	17.18
5	50	1.0	13.89	12.0	16.67
5	55	0.96	14.85	11.52	16.2
5	60	0.90	15.75	10.8	15.75
5	65	1.0	16.75	12.0	15.46
5	70	1.0	17.75	12.0	15.21
5	75	0.83	18.58	9.96	14.86
5	80	0.9	19.48	10.8	14.61
10	90	1.8	21.28	10.8	14.18
10	100	1.76	23.04	10.56	13.82
10	110	1.56	24.6	9.36	13.42
10	120	1.46	26.06	8.76	13.03
10	130	1.4	27.46	8.4	12.67
10	140	1.46	28.92	8.76	12.39
10	150	1.36	30.28	8.16	12.112
10	160	1.4	31.68	8.4	11.88
10	170	1.4	33.08	8.4	11.67
10	180	1.33	34.41	7.98	11.47
10	190	1.3	35.71	7.8	11.28
15	205	2.0	37.71	8.0	11.03
15	220	2.0	39.71	8.0	10.83
15	234	2.0	41.71	8.0	10.64

FIELD MEASUREMENT OF RADIATION

As with the first radiation area, a depth of 10 - 12 cm. An exposure rate of 1.5 R/hr was measured in each of the two depth of water measurements.

Additional data were obtained over a period of 2 hours. It was not practical to measure the dose beyond the first several of the duration of exposure.

A total of 2000 R was obtained in the 10 - 12 cm. depth of exposure. This is a summary of data for the first two areas.

TABLE 1
RADIATION DATA

Interval (min)	Exposure Rate (R/hr)	Exposure (R)	Depth (cm)	Remarks
0-5	1.5	0.75	10	
5-10	1.5	1.5	10	
10-15	1.5	2.25	10	
15-20	1.5	3.0	10	
20-25	1.5	3.75	10	
25-30	1.5	4.5	10	
30-35	1.5	5.25	10	
35-40	1.5	6.0	10	
40-45	1.5	6.75	10	
45-50	1.5	7.5	10	
50-55	1.5	8.25	10	
55-60	1.5	9.0	10	
60-65	1.5	9.75	10	
65-70	1.5	10.5	10	
70-75	1.5	11.25	10	
75-80	1.5	12.0	10	
80-85	1.5	12.75	10	
85-90	1.5	13.5	10	
90-95	1.5	14.25	10	
95-100	1.5	15.0	10	
100-105	1.5	15.75	10	
105-110	1.5	16.5	10	
110-115	1.5	17.25	10	
115-120	1.5	18.0	10	
120-125	1.5	18.75	10	
125-130	1.5	19.5	10	
130-135	1.5	20.25	10	
135-140	1.5	21.0	10	
140-145	1.5	21.75	10	
145-150	1.5	22.5	10	
150-155	1.5	23.25	10	
155-160	1.5	24.0	10	
160-165	1.5	24.75	10	
165-170	1.5	25.5	10	
170-175	1.5	26.25	10	
175-180	1.5	27.0	10	
180-185	1.5	27.75	10	
185-190	1.5	28.5	10	
190-195	1.5	29.25	10	
195-200	1.5	30.0	10	

SITE PT5
TAVETA ESTATES

Interval (min)	Cumulative time (min)	Intake (cm)	Cumulative (cm)	IR cm/hr	Mean
				Immediate	Mean
5	5	1.5	1.5	18.00	18.0
5	10	0.56	2.06	6.72	12.36
5	15	0.5	2.56	6.0	10.24
15	30	0.86	3.42	3.44	6.84
15	45	1.23	4.65	4.92	6.2
15	60	0.93	5.58	3.72	5.58
15	75	1.03	6.61	4.12	5.28
15	90	0.83	7.44	3.32	4.96
15	105	0.86	8.3	3.44	4.74
30	135	1.7	10.0	3.4	4.44
30	165	1.76	11.76	3.52	4.27
30	195	1.76	13.52	3.52	4.16
30	225	1.63	15.15	3.26	4.04
30	255	1.63	16.78	3.26	3.94
30	285	1.25	18.03	2.50	3.79

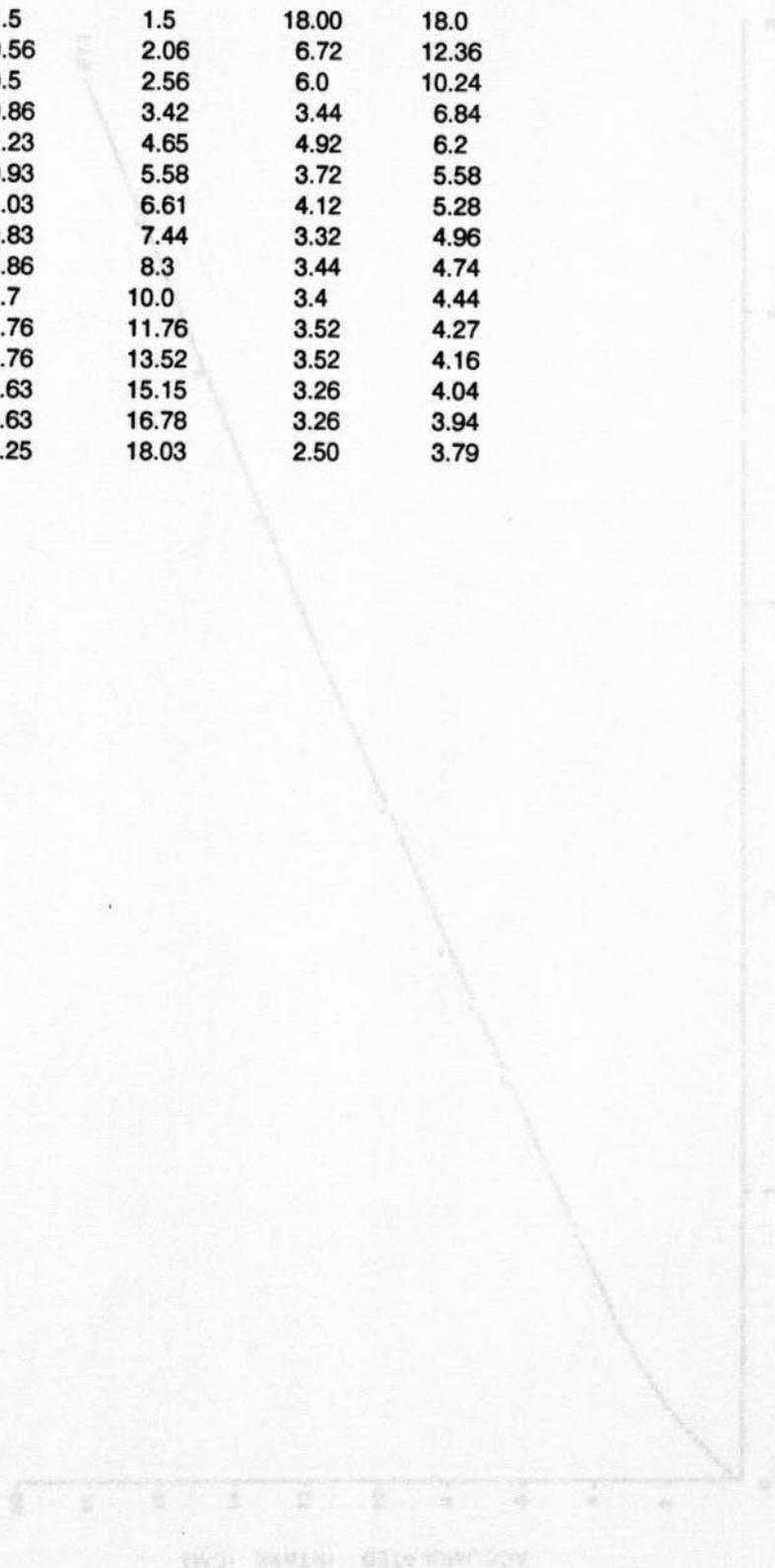
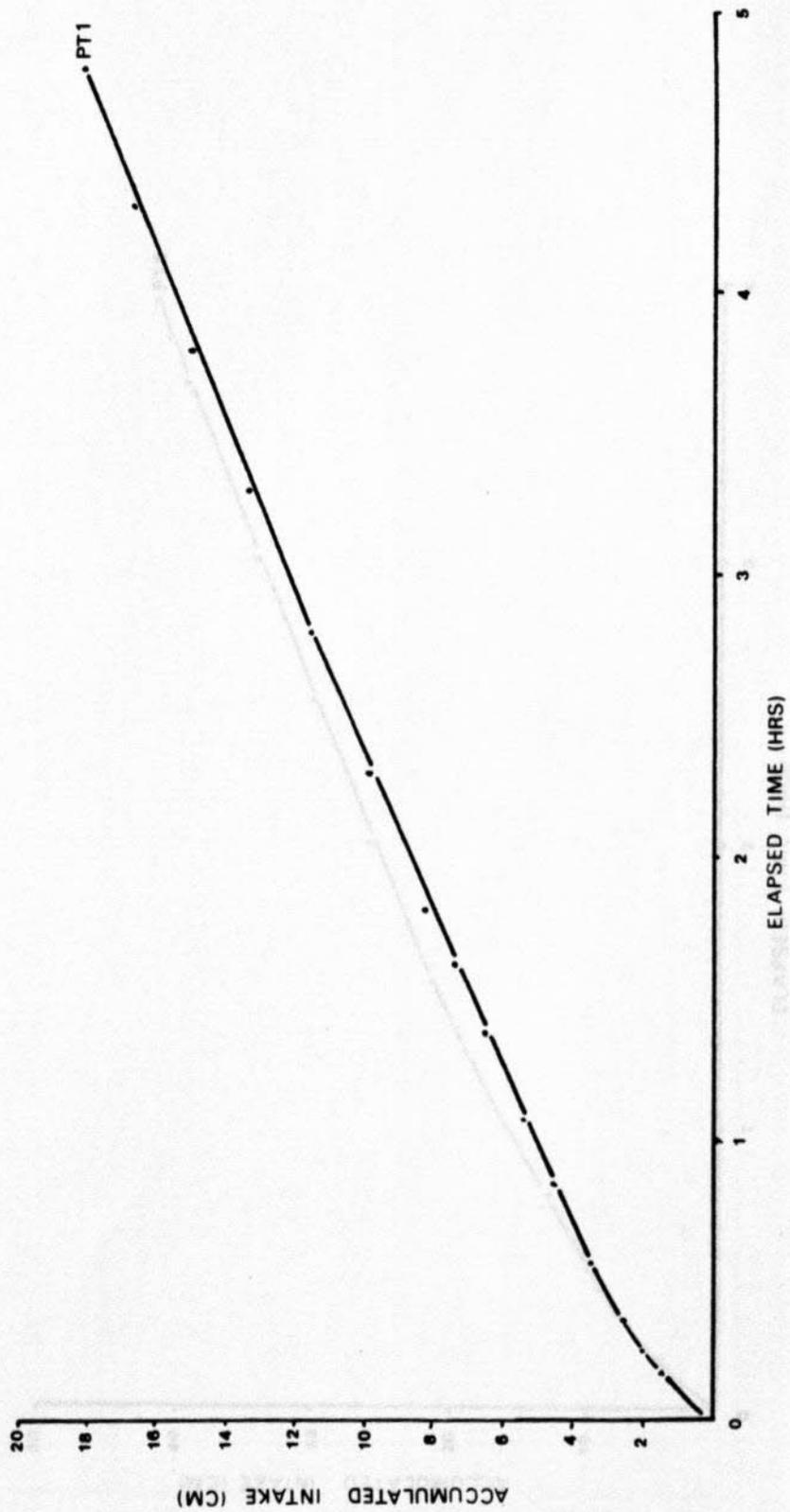


TABLE 1
 DATA

Time (min)	Concentration (mg/l)	Flow rate (l/min)	Volume (l)	Mass (mg)
0	0.00	1.00	0.00	0.00
10	0.05	1.00	0.10	0.05
20	0.10	1.00	0.20	0.10
30	0.15	1.00	0.30	0.15
40	0.20	1.00	0.40	0.20
50	0.25	1.00	0.50	0.25
60	0.30	1.00	0.60	0.30
70	0.35	1.00	0.70	0.35
80	0.40	1.00	0.80	0.40
90	0.45	1.00	0.90	0.45
100	0.50	1.00	1.00	0.50
110	0.55	1.00	1.10	0.55
120	0.60	1.00	1.20	0.60
130	0.65	1.00	1.30	0.65
140	0.70	1.00	1.40	0.70
150	0.75	1.00	1.50	0.75
160	0.80	1.00	1.60	0.80
170	0.85	1.00	1.70	0.85
180	0.90	1.00	1.80	0.90
190	0.95	1.00	1.90	0.95
200	1.00	1.00	2.00	1.00

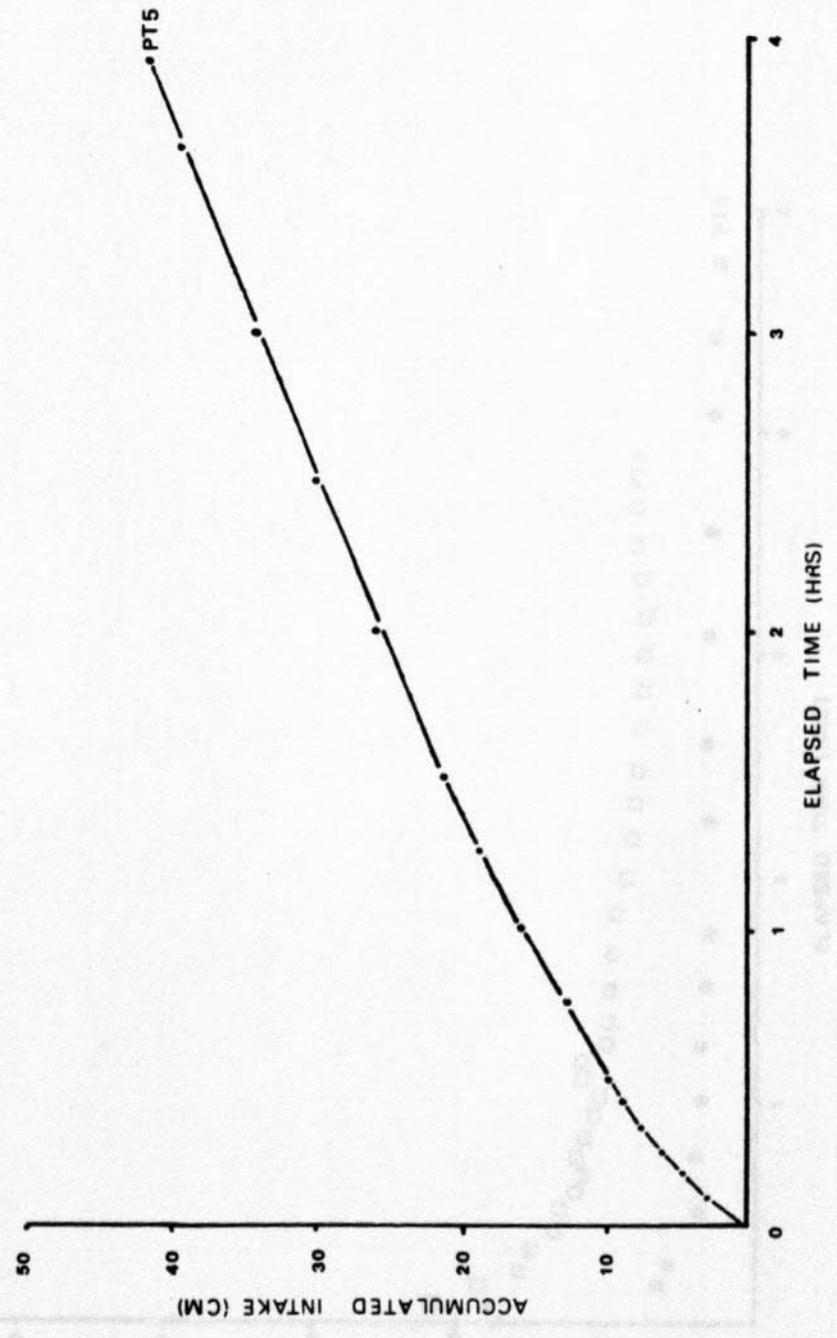


UNITED STATES



MILES PER HOUR

ACCUMULATED INTAKE AGAINST ELAPSED TIME FOR PROFILE PT.5

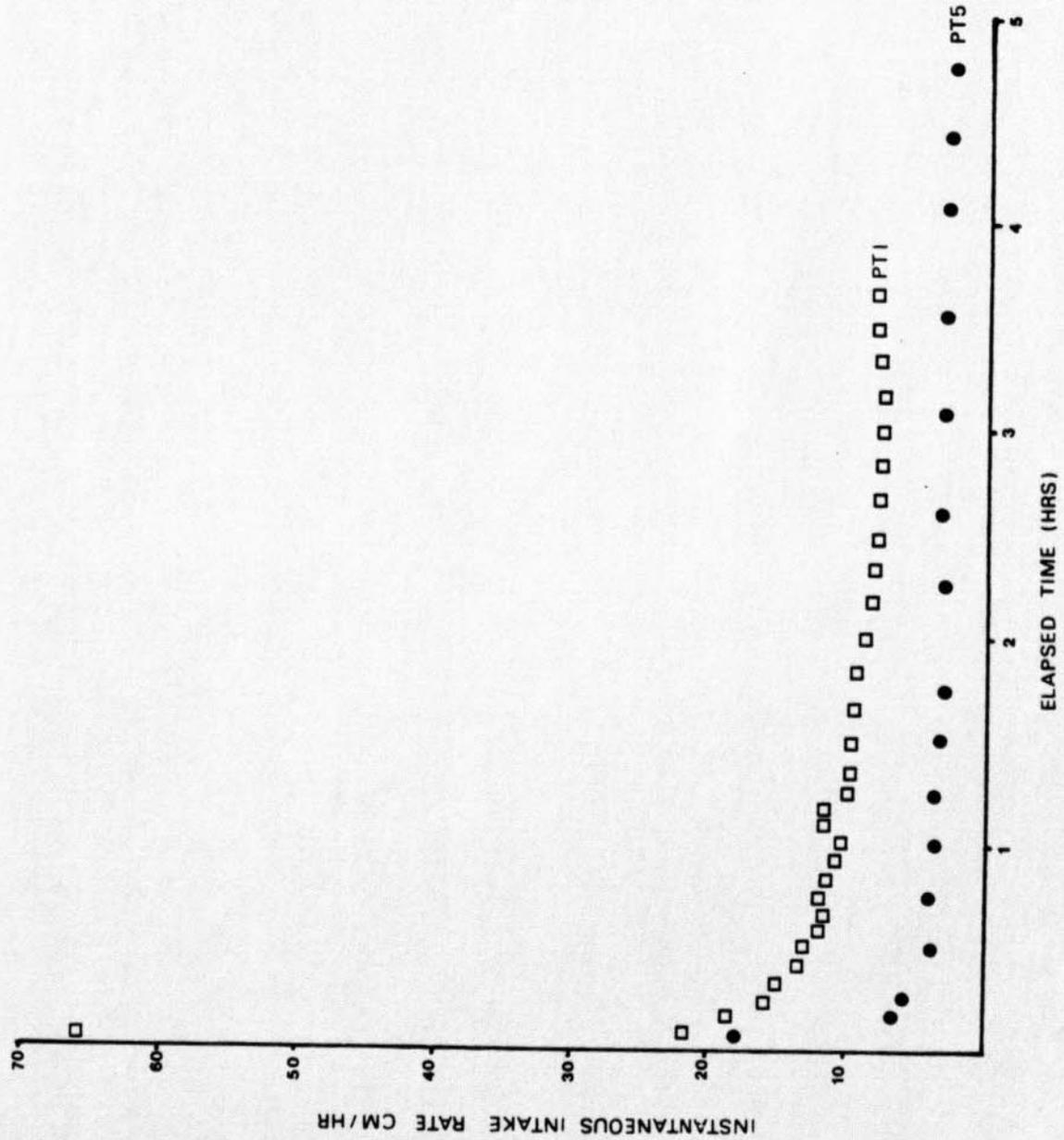


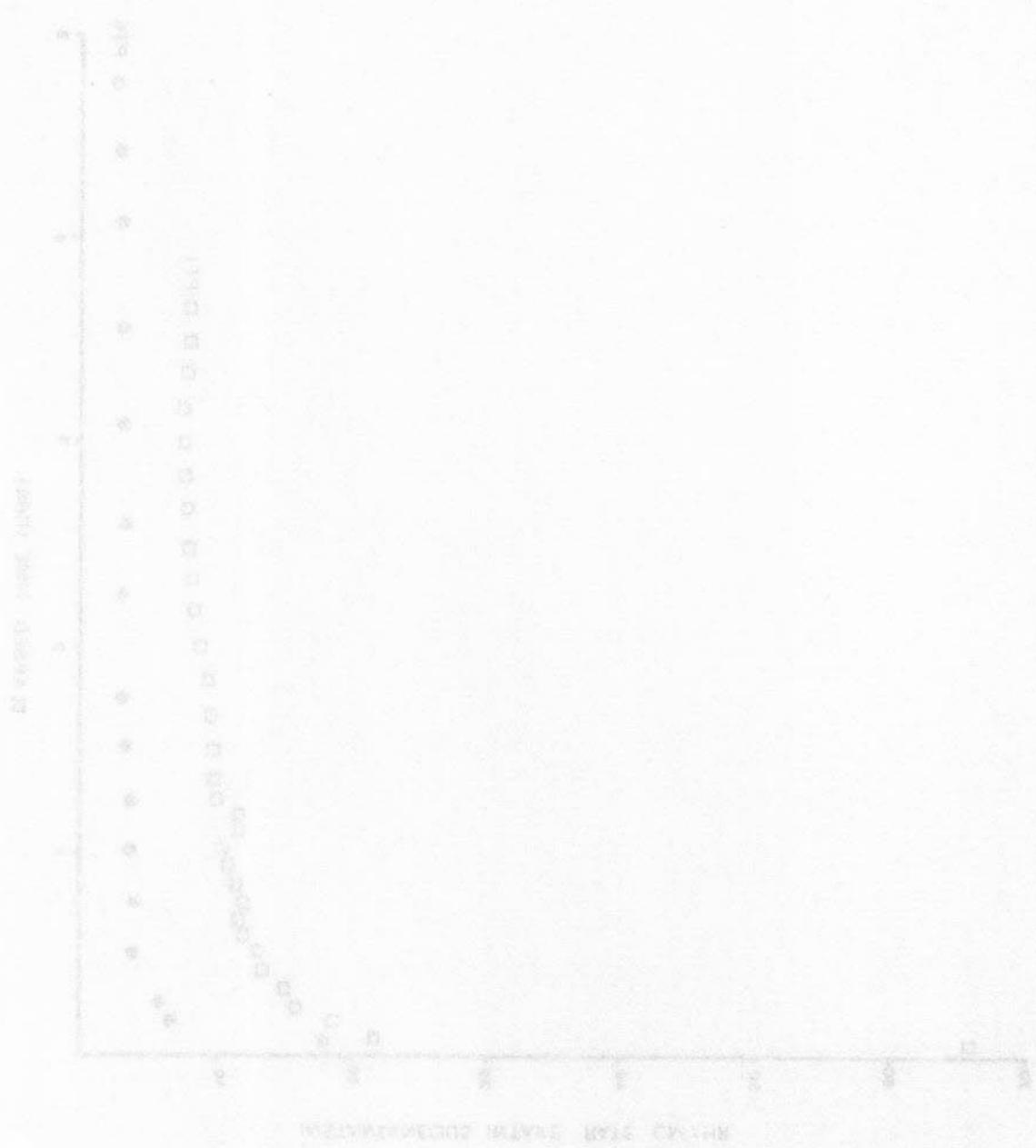


ACCUMULATED MILK YIELD (LITERS) VERSUS HYPER LIME INDEX

INSTANTANEOUS INTAKE RATE CM/HR AGAINST ELAPSED TIME FOR PROFILES PT.1 AND PT.5

APPENDIX B
FOUR-IN HYDRAULIC CONDUCTIVITY TEST DATA
FOR SITES PT.1 AND PT.5





THESE FIGURES ARE BASED ON THE ASSUMPTION THAT THE STOCK IS HELD FOR A PERIOD OF 12 MONTHS.

APPENDIX D
POUR-IN HYDRAULIC CONDUCTIVITY TEST DATA
FOR SITES PT1 AND PT5

APPENDIX

REPORT OF THE COMMISSIONER OF THE GENERAL LAND OFFICE
FOR THE YEAR 1881

**PROCEDURE USED IN DETERMINING HYDRAULIC
CONDUCTIVITY USING POUR-IN TEST**

Where a watertable was absent the pour-in method (shallow well test) was used. The procedure followed is similar to that described by USBR (1953).

An auger hole was bored to about 100 - 120 cm depth or according to layers present in the profile. The radius of the hole was 5.5 cm using a standard jarret auger head. A 2 cm diameter metal pipe was placed in the hole and the hole was then filled with gravel up to approximately 50 cm from the ground surface or until the gravel could be seen from the surface in normal daylight. Care was taken to ensure that the base of the pipe was clear of the bottom of the auger hole. Water was directed into the pipe using a finely adjustable aspirator, the hole being filled with water from below until water was visible at the gravel surface. The water level was then maintained at the surface of the gravel.

The percolation rate was measured in litres per second by maintaining a constant level of water in the hole over a period of 10 - 15 minutes, then directing the constant flow into a one litre measuring cylinder taking care not to alter the height of the tap throughout the measurements. While the flow rate was measured the constant level of water in the hole was maintained using a jug.

A number of readings were taken over a two hour period until a more or less constant rate was achieved.

Measurements made for obtaining hydraulic conductivity values at the Project site are given on the calculation sheets. Hydraulic conductivity was calculated by reference to nomograms given by USBR (1953).

Run	Elapsed Time (min)	Δ Time Secs	Ql min ⁻¹	Ql m ³ min ⁻¹	K m/day ²	Perm Class
1	5	21	1.43	0.00143	7.30	Moderate
2	10	27	1.11	0.00111	1.20	Moderate
3	15	30	1.07	0.00107	2.50	Moderate
4	20	31	0.96	0.00096	1.70	Moderate
5	25	36	0.84	0.00084	2.70	Moderate
6	30	45	0.66	0.00066	4.40	Mod. slow
7	45	44	0.90	0.00090	6.70	Mod. slow
8	50	52	0.58	0.00058	1.40	Mod. slow
9	55	60	0.5	0.00050	1.20	Mod. slow
10	70	61	0.49	0.00049	0.95	Mod. slow
11	85	69	0.35	0.00035	0.70	Mod. slow

PROCEDURES USED IN DETERMINING HYDRAULIC CONDUCTIVITY USING POINT TEST

When a well is to be drilled, the point test method (Latham well test) was used. The procedure followed is similar to the method by (Latham (1953)).

An auger hole was drilled to about 100 - 150 cm depth or according to the ground water table. The radius of the hole was 2.5 cm and a water level tap was fixed. A 2 cm diameter pipe was fixed in the hole and the hole was then filled with gravel up to approximately 50 cm from the ground surface and the gravel was then covered with a layer of normal daylight. Care was taken to ensure that the base of the pipe was clear of the bottom of the auger hole. Water was filtered into the pipe using a fine, cylindrical sintered, the hole being lined with water from below and water was added at the gravel surface. The water level was determined at the surface of the gravel.

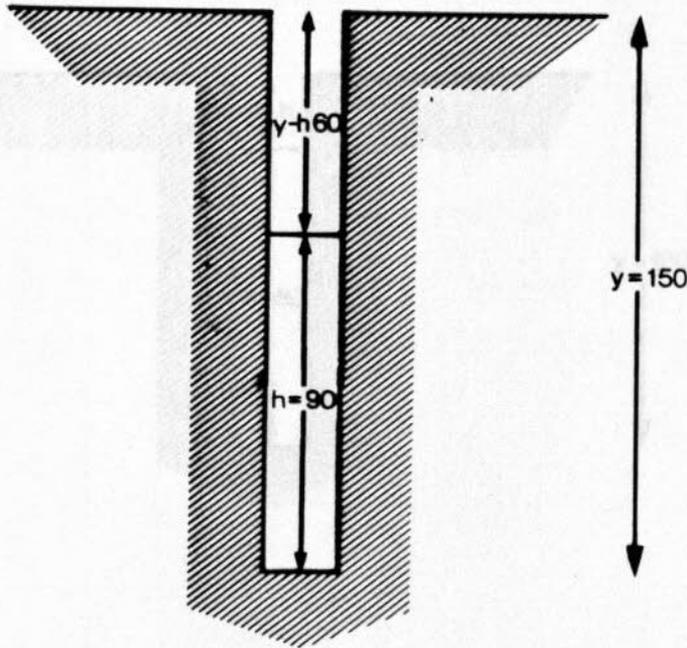
The discharge rate was measured in three per second by measuring a constant level of water in the test tank a period of 10 - 15 minutes, then dividing the constant flow into a one liter measuring cylinder taking care not to alter the height of the liquid. The measurement of the flow rate was repeated the constant level of water in the test tank was raised by using a

A number of readings were taken over a two hour period with a more or less constant discharge rate.

Measurements made for determining hydraulic conductivity values at the project site are given in the following table. Hydraulic conductivity was calculated by reference to nomograms given by (Latham (1953)).

HYDRAULIC CONDUCTIVITY TEST RESULTS (POUR-IN METHOD)

SITE PT1



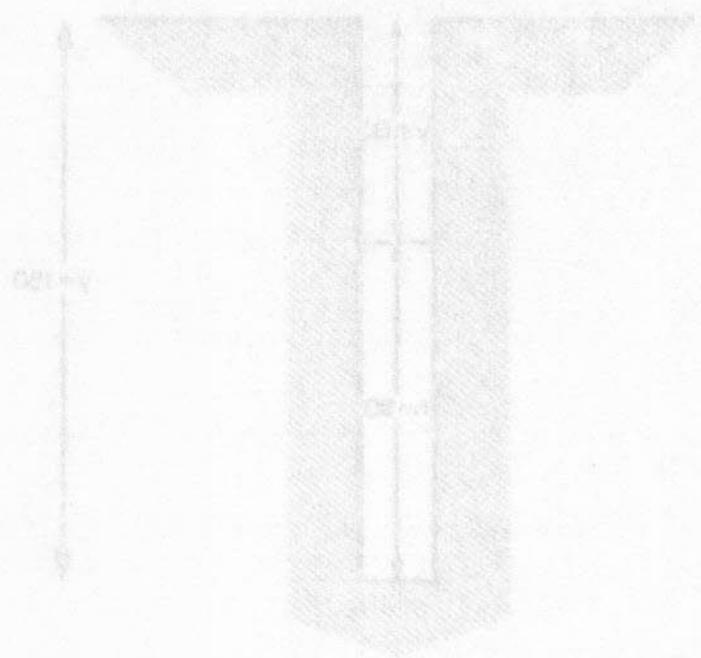
$h = 90 \text{ cm}$

$r = 5.25$

$\frac{h}{r} = 17.1 \text{ cm}$

Run	Elapsed Time (min)	Δ Time Secs	Ql min^{-1}	Q $\text{m}^3 \text{min}^{-1}$	K. m/day^{-1}	Perm Class
1	5	21	1.43	0.00143	1.20	Moderate
2	10	27	1.11	0.00111	1.00	Moderate
3	15	28	1.07	0.00107	0.90	Moderate
4	20	31	0.96	0.00096	0.70	Moderate
5	25	39	0.94	0.00094	0.70	Moderate
6	36	45	0.66	0.00066	0.40	Mod. slow
7	45	45	0.66	0.00066	0.40	Mod. slow
8	55	52	0.58	0.00058	0.40	Mod. slow
9	65	60	0.5	0.00050	0.35	Mod. slow
10	75	61	0.49	0.00049	0.35	Mod. slow
11	85	69	0.43	0.00043	0.35	Mod. slow

$r = 30 \text{ cm}$
 $r_w = 2.5 \text{ cm}$
 $h = 17.1 \text{ cm}$



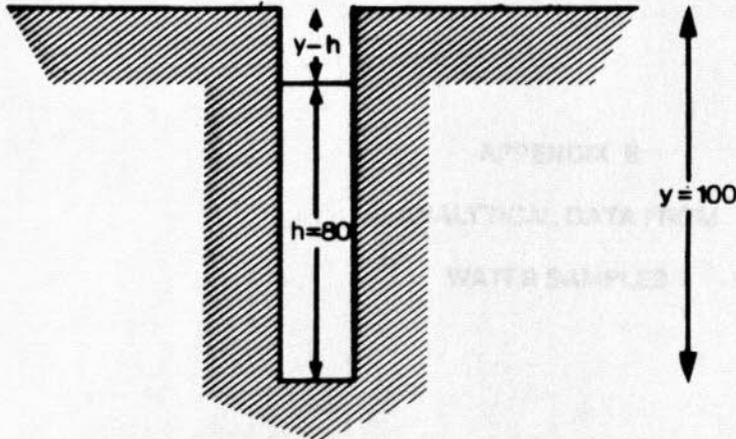
Run	Elapsed Time (min)	Δ Time (Sec)	Q (ml/min)	Q (m ³ /day)	K (m/day)	Flow Class
1	8	27	1.43	0.00748	1.20	Moderate
2	10	27	1.11	0.00711	1.00	Moderate
3	12	28	1.03	0.00707	0.90	Moderate
4	30	31	0.98	0.00698	0.70	Moderate
5	35	32	0.94	0.00694	0.73	Moderate
6	36	40	0.90	0.00685	0.40	Mod. slow
7	46	42	0.88	0.00688	0.46	Mod. slow
8	68	55	0.88	0.00688	0.30	Mod. slow
9	69	60	0.8	0.00680	0.28	Mod. slow
10	72	61	0.78	0.00678	0.25	Mod. slow
11	88	60	0.67	0.00648	0.25	Mod. slow

HYDRAULIC CONDUCTIVITY TEST RESULTS (POUR-IN METHOD)

SITE PT5

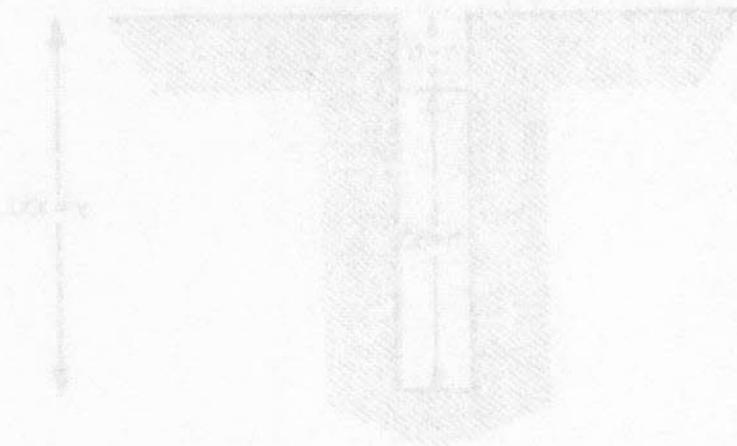
$h = 80 \text{ cm}$
 $r = 5.25$

$\frac{h}{r} = 15.23$



Run	Elapsed Time (min)	Δ Time Secs	Ql min^{-1}	Q $\text{m}^3 \text{min}^{-1}$	K m/day^{-1}	Perm Class
1	5	29.5	1.02	0.00102	0.80	Moderate
2	20	45	0.66	0.00066	0.40	Mod. slow
3	30	50	0.6	0.0006	0.36	Mod. slow
4	40	63	0.44	0.00044	0.30	Mod. slow
5	50	69	0.43	0.00043	0.30	Mod. slow
6	60	65	0.46	0.00046	0.30	Mod. slow
7	70	77	0.39	0.00039	0.28	Mod. slow
8	80	69	0.44	0.00044	0.30	Mod. slow
9	90	77	0.39	0.00039	0.28	Mod. slow
10	100	83	0.36	0.00036	0.16	Slow

$h = 80 \text{ cm}$
 $r = 2.52$
 $\frac{h}{r} = 31.75$



Run	Elapsed Time (min)	Flow Rate (cm ³ /min)	Flow Rate (m ³ /day)	Flow Rate (m ³ /day)	Flow Rate (m ³ /day)
1	2	1.00	0.00102	0.50	Medium
2	20	0.50	0.00509	0.25	Low
3	20	0.50	0.00509	0.25	Low
4	20	0.50	0.00509	0.25	Low
5	20	0.50	0.00509	0.25	Low
6	20	0.50	0.00509	0.25	Low
7	20	0.50	0.00509	0.25	Low
8	20	0.50	0.00509	0.25	Low
9	20	0.50	0.00509	0.25	Low
10	20	0.50	0.00509	0.25	Low

APPENDIX E
ANALYTICAL DATA FROM
WATER SAMPLES

THE
UNIVERSITY OF CHICAGO
PRESS

ANALYTICAL DATA WATER SAMPLES; TAVETA ESTATES

Laboratory Number		W189	W190	W191	W192				
Sample Identity		Njoro Kubwa Spring	Borehole Taveta Est	Drainage SITE T18	Homers Spring				
pH $\mu\text{S}/\text{cm}$		6.5	7.0	8.1	7.2				
E.C.		240	420	7610	400				
Soluble Cations me/L	Na	0.5	1.0	64.8	0.6				
	K	0.1	0.1	2.3	0.1				
	Mg	1.0	1.8	1.4	1.5				
	Ca	0.7	1.2	0.3	1.0				
Soluble Anions me/L	Cl	<0.5	<0.5	1.1	<0.5				
	SO ₄	0.0	0.0	0.3	0.0				
	CO ₃	0.0	0.0	23.4	0.0				
	HCO ₃	2.3	3.9	58.1	3.0				
Total Dissolved Solids g/L		0.32	0.21	4.93	0.23				
Total Undissolved Solids g/L				0.20					

