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KENYA SOIL SURVEY

PRELIMINARY EVALUATION OF THE SOIL CONDITIONS ON THE EAST BANK OF THE LOWER TANA (BURA-EAST AREA) FOR LARGE-SCALE IRRIGATION DEVELOPMENT.

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W.G. Sombroek, J.P. Mbuvi and R.A. Leyder

with an Addendum

by

B.J.van der Pouw

SITE EVALUATION REPORT

No 21, June 1975

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1. Introduction

At the request of the Tana River Development Authority (TRDA), a site evaluation was carried out of to determine the irrigation potential of the East bank of the Lower Tana river ("Bura-east area"). The request was made in view of the proposal to start a major irrigation scheme in the area, as a complementary to the Bura (-west) scheme of 14.000 ha, which is already in an advanced stage of planning.

In an earlier KSSP site evaluation report (no. 14, Sombroek et al, 1974) it was already indicated that a sizeable tract of land east and south of Bura village might be moderately to marginally suited for large-scale irrigation of field crops.

Recent computer-based hydrological studies by TRDA technical staff have revealed that at the moment the amount of low-season Tana river water available for irrigation in the Lower Tana region would serve 20.000 ha. The available water would however increase substantially if one or more extra storage dams would be constructed in the upper Tana region for additional power generation. Since a weir is to be constructed in the Tana river near Nanigi, for the intake of the irrigation feeder canal for the Bura-west scheme, it was wondered whether the same structure might be used for a similar canal on the East bank.

Preparatory photo interpretation of an area of ± 375.000 ha was executed in March-April 1974, using aerial photographs scale 1:80.000 of 1963 or earlier (R.A.F/Survey of Kenya). Three short periods of fieldwork were involved: one week in April 1974 (Messrs Sombroek, Okwaro, Ngari and Leyder), two weeks in July 1974 (Messrs Mbuvi, Ngari and Kibe), and two days in November 1974 (Messrs Sombroek and Mbuvi). About 36 representative soil profile pits were described and tested for pH and electrical conductivity with portable equipment, while also observations on the vegetation were carried out. Samples of all pits were also analysed at the National Agricultural Laboratories in Nairobi, under supervision of Mr. Leyder. Because of pressure of other analytical work, notably on soil samples from the Bura-west feasibility study by Ilaco Co., the results of the laboratory analysis were substantially delayed. Using the same 1:80.000 photography, also the Hola area on the westbank was studied. This allowed a comparison of the photo interpretation pattern of the East bank with soil-topography conditions in the area of the Hola pilot irrigation scheme, which is already in existance for some ten years and on which (semi) detailed soil surveys have been carried out by Ilaco Co.

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Two advance notes on the findings of the site evaluation were forwarded to TRDA, on 25-5-74 and 26-2-75 respectively, the latter including a draft map with a delineation of the most suitable area and a suggested alignment of a feeder canal.

It should be stressed that the present mapping and suitability evaluation is very preliminary. A full-scale feasibility study should be preceded by a proper semi-detailed soil and topographical survey (see section 5, "suggested follow-up).

2. Environmental Conditions

2.1. Location and Communications

The study area of about 375.000 ha. forms part of Garissa District in North-Eastern province and is located on the East bank of the Lower Tana river. It stretches (see map attached) from the villages of Jara (39°50'E, 0° 45'S) and Hola (40°.00'E, 1°.30'S), both on the Tana river, till longitude 40°.20'E. Bura and Masabubu are the only villages nowadays existing on the East bank itself (Nanigi having been deserted during the "shifta" troubles). Bura village is connected with Garissa in the North by two roads, one passing over a relatively high lying plain and a lower one right alongside the Tana floodplain. It is also connected with Kolbio (now called Hulugho) near the Somali border in the east via Galma Galla. It is further connected via Ijara with Lamu on the ocean coast. All these roads are without any surfacing and are at present in quite poor condition, not permitting car traffic during the short but often intense rainy seasons. On the topographic maps of the area (1:50.000 and 1:250.000, Survey of Kenya) several "cut-lines" are indicated, that were prepared for a Shell-BP oil exploration programme around 1960. At present these cutlines are however difficulty discernable in the field and are hardly motorable.

The area can be reached overland only via Garissa (or Lamu); no connection with the West bank exist, except for a dug-out canoe crossing at Bura village. The village has however air communication through a landing strip for small aircraft. It contains a police post, a D.O.'s office and a few small shops (dukas), but hardly any other facilities.

2.2. Geology and geomorphology, altitudes and drainage

As regards geology, the area is composed of unconsolidated Late Tertiary and Quarternary sediments which are partly marine and partly fluviatile/ lacustrine.

The Tertiary sediments (unit Tpl, "Pliocene sands and clays" of the unpublished maps and reports of Matheson, 1961) consist of pebbly sandy clays that are strongly saline and alkali and therefore very liable to gully erosion (badlands, mapping unit Sb of attached map). Apart from the Tana floodplain, which consists of recent river alluvium, all other sediments are of Pleistocene (or Early Holocene) age, of fluviatile and lacustrine deposition. It apparently often concerns only a re-sorting and re-deposition of the older marine sediments (which accounts for the abundance of saline-alkali soils in the area). In Matheson's draft maps these Pleistocene sediments figure as Qg ("grey sandy clays"; main part of the study area), as Qr ("red sandy soils"; some stretches, mainly in the northwestern part) and as Qb ("black-cotton soil", mainly in the south-east of the study area). In contrast with the situation in the Garissa area, these denominations do not always match well with the geomorphologic levels (see below) nor is the description always very adequate. The "red sandy soils" in the study area are certainly not identical to those of the higher-level sedimentary plain, or "red-sand plain", of Garissa-Wajir (cf. unit Sp 3 of Sombroek et al 1974) because the sandy aspect continuous only till a few decimeters depth (see units Sp 2d and Sp1d as described below). Also the pattern appears not always correct (Mateson's mapping in this particular area was nearly exclusively based on photo interpretation).

Geomorphologically, the area appears to consist of two levels of regional sedimentary flattening:

a) an older plain in the north (units Sp2), that is characterised by a very clear pattern of tiny white dots on the aerial photographs: "intermediate-level, white-dot plain";

b) a younger plain in the central and southern part of the area (units Sp1), with only a vague dot or ripple pattern or a homogeneously light greyish aspect on the aerial photo's: "lower-level, grey-clay plain". The latter unit contains a number of parallel-running low ridges, that are infact transitional to the older plain. In both main units a number of equally parallel-running narrow depressional strips occur, that have a homogeneously dark grey tone on the aerial photographs (units Sp2v and Sp1v of the attached map). The upper plain is at about 450 feet* altitude (135m), which is about 100 feet (30m) above the local level of the Tana river and has a gentle gradient of about 1.5m/km towards the south-east. Where the plain is touched by the Tana floodplain, a valley side occurs, with irregular, partly scarp-like, slopes of about 5-10m/km (units Sb and Ss).

The lower plain is situated at about 300 feet altitude (90m), which near Bura village is only about 15 feet (5m) above the Tana floodplain; further downstream the relative height gradually increases to about 75 feet (25m) above the floodplain. The terrain has a very gentle gradient/slope in south-eastern direction of 0.5 - 0.1m/km, with similarly gentle secondary gradients towards the parallel depressional strips mentioned above.

* all height indications on the existing topo-maps are still given in feet.

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Also this level has a valley side where touched by the Tana river, but in this case with more gentle slopes (average 6 m/km).

Drainage: Apart from the relatively small stretches of valley sides, which drain into the Tana, the drainage of all the land is very systematically away from the river to the south-east, following the parallel depressional strips (units Sp2v, Sp1v). The relief differences are however so gentle-and the substratum of the land apparently so impermeable - that much of the land is imperfectly so poorly drained. Apart from the Tana river on the western boundary, there are no permanent or even ephemeral streams. After heavy rains much water accumulates in the Sp1v and Sp2v strips for considerable time.

The physiography of the area as a whole is quite distinct from the situation on the West bank. On the East bank the soil-topography pattern concerns broad, apparently homogeneous and largely parallel stretches. The West bank however shows a very intricate pattern. With a few notable exceptions like the "Camborthid" area, there are distinct differences in soils and (meso-) topography at short distances and such in a quite irregular pattern. This is not only exemplified by Ilaco's reconnaissance/semi-detailed soil maps of the West bank (see references), but is also apparent from even a quick comparison of the images on the 1:80.000 photo's of the East bank with those of the West bank. It seems that the broad (Pleistocene) geomorphologic/ hydrologic NW to SE pattern of the East bank has remained practically unaltered, but that a similar pattern on the West bank (still visible from the air in patches located some 40 kms west of the river) was broken up by a subsequent W to E drainage, and sediment re-deposition in a "braiding" pattern by a number of ephemeral streams coming from as far as the Kitui escarpment (some 200 kms away). Their large catchment area must have resulted, during some time(s) in the past, in a strong erosional and depositional force.

2.3. Climate

Climatic conditions in the study area should by all means be comparable with those of the West bank. On the latter the various Ilaco reports give substantial information. Therefore only a summary is given here:

The climate is hot and semi-arid. Total annual rainfall should be in the order of 450 mm, with a bi-modal pattern; most rain falls in April (±80 mm) and in November-December (also ± 80mm/month). These rainy seasons are however quite unreliable. On the one hand years may occur when there is practically no rainfall at all; on the other hand very heavy downpours may take place - also outside the rainy seasons. They result in high run-off and strong sheet (and locally gully) erosion, especially on those areas where the soils are liable to surface sealing (units Sp2d, Sp1d, Sb and Ss).

Temperatures are high throughout the year (25-30°C, monthly averages),

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which results in a high potential evaporation of approximately 190-200 mm per month. The following table may illustrate the situation.

(Table 1)

Rainfall (from EAMD 1973), mm

		J	F	M	A	M	J	J	A	S	O	N	D	Year
91.39000	13 yrs	17	6	52	102	22	8	7	4	8	23	107	88	443
91.4005	12 yrs	27	18	46	71	36	33	19	16	37	31	95	52	481

Mean air temperature (°C) and potential evaporation (mm) at Hola (from Woodhead, 1968).

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Temperature	28	29	29	28	27	26	25	25	26	27	28	28	
ntial Evapor.	200	200	220.	190	190	170	170	180	190	200	190	190	2290

It is obvious that climatic conditions are such that rainfed arable farming is impossible and that any agricultural development beyond extensive ranging has to be realised through the introduction of irrigation. With such provision, however, the growing season is all-year around.

2.4. Vegetation and land use, and population and wildlife

The vegetation consists of a deciduous bushland or bushed grassland, of varying density and species composition (see legend of map), but with *Acacia* species (*A. reficiens*, *A Zanzibarica*) and *Commiphora* species often predominant. The grass cover is poor on the higher terrain parts (units Sp2d, Sp1d), fair to good on the lower terrain parts (especially units Sp1(r) Sp1r, and Sp1v).

The land use is for extensive grazing only (cattle, sheep, goats, camels), by the local Somali herdsmen, moving freely over the area. Overall population density is about 2 inhabitants per Km^2. Only on the Tana river bank some itinerant cropping takes place, making use of the receding flood waters. A small patch of floodplain near Bura village is being developed for a minor irrigation scheme (see site evaluation report no. 14).

The area has quite a population of game, both large (elephants) and small. A species unique to the area of Bura-Kolbio-Ijara is the Hunter's hartebeest/antelope (*Damaliscus hunteri*, "hirola" in local language). For its preservation recently a game reserve was created ("Hirola Game Reserve", see Kenya Gazette of 1974). It is bound by the Bura-Ijara road in the East and the Tana river in the West, and it stretches from Masabubu in the North to somewhat beyond the study area in the South (see map).

Drinking water for man and animal is obtained largely from shallow water pans,

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found scattered over the plains, that are recharged with rain water. Towards the end of the dry season, however, they dry up and the Tana is then the only source of supply. All groundwater in the area is reportedly (Matheson, 1971) saline to varying degree, making it not suitable for human consumption and often also not suitable for cattle drinking.

3. The Soils

3.1. Introduction

The provisional mapping of the soils was done on physiographic basis, relying on aerial photointerpretation and a limited number (36) of field observations and testing. The exact location of these observation sites could not always be established accurately owing to the smoothness of the terrains, the gradual changes in vegetation, and local realignment of the tracks after the aerial photographs were taken. The description of the vegetation, in particular, is tentative since the scale and poor quality of the photographs do not permit a fair judgement of the representativeness of the few vegetation sampling sites. The description of the most important characteristics of the mapping units, as given in the legend of the map, represent averages; individual profiles are often somewhat divergent, both as regards field and laboratory data.

The above limitations have to be borne in mind when considering the following generalised descriptions. A full-scale survey may modify some aspects of the characterisations. The over-all pattern of soils is however unlikely to change substantially, also because of the very straightforward physiography.

3.2. The soils of the intermediate-level sedimentary plain (units Sp2)

This comprises two units, i.e. the general terrain (unit Sp2d) and the minor relatively low-lying stretches (unit Sp2v).

The unit Sp2d consists of flat to broadly and gently undulating land. About 37.000 ha are concerned.

The soils (see also unit Sp2 of site evaluation report 14) are imperfectly drained. A shallow topsoil, about 20cm on the average, has a fair to poor structure (subangular blocky to granular) and consists of brown (10YR 4/3), medium to coarse sandy loam with an appreciable percentage of silt. It is non-calcareous, non-saline and non-alkali, but overlies a pronounced hardpan (columnar structure, extremely hard when dry) or greyish brown (10YR 5/2) sandy clay loam to clay, which is slightly calcareous and non or slightly saline but often moderately alkali (ECe 4-8mmho/cm, ESP 12-25%, often high percentage of Mg): solodized Solonetz of solod/Natrargid.

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The topsoil is strongly sealing, and sheetflood accumulations of reddish coarse and rather angular sand are common (often choking road sides). The hardpan is impenetrable for roots and little permeable for water. The chemical fertility of the topsoil is fair, apart from nitrogen which is low (N 0.07%, C 0.4%, P 20ppm, K 0.2 meq%).

The vegetation is an open bushed grassland with Commiphora spp. and Acacia reficiens and a sparse grass-coverage. It shows a regular pattern of white dots, (10-20m, 50-100m apart) which is not always easily visible in the field, but very conspicuous on aerial photographs. These dots represent the nearly completely flattened remnants of fossil termite mounds. Their surface is nearly bare due to very poor soil structure right from the surface (and higher ECe and ESP values).

The structural development of the soils and their salinity/alkaliness make them non-suitable for irrigated arable cropping. The interspersing of the slightly raised white dots with their extremely poor soil conditions are an added limitation.

The unit Sp2v consists of parallel narrow stretches of flat land which is 1-3m below the level of Sp2d. The total acreage mapped is only about 3.500ha. The soil consists of poorly drained, very dark greyish brown , strongly cracking, heavy clay. No chemical analyses were carried out, but most likely the soils are both saline and alkali from some depth downwards: pellic Vertisol, (saline and) sodic phase/natric Grumaquert.

The vegetation is a regularly low bushed grassland, with Acacia species dominating, and a fair to good coverage with grass and woody herbs. The unit is considered non-suitable for large-scale irrigation because of its scattered occurrence, its poor drainage, its difficult management (swelling and shrinking), and the expected salinity/alkaliness and associated easy soil dispersion.

3.3. The soils of the lower-level sedimentary plain (units Sp1)

This plain contains a number of mapping units. In topographical sequence from high to low they are the following:

The unit Sp1d, comprising 28.000ha, consists of flat to gently undulating low-ridge terrain. The soils are imperfectly drained. A shallow topsoil of 10-20 cm. and of fair structure (subangular blocky) consists of mainly brown (10YR 4/3, sometimes 3/2) medium to coarse sandy clay loam (to sandy clay), which is predominantly non-calcareous, non-saline and non-alkali. This changes abruptly to a subsoil of which the upper part forms a pronounced hardpan (columnar structure, very to extremely hard when dry) and that consists of a dark greyish brown (10YR 4/2) sandy clay, strongly calcareous (common patches of soft lime), moderately to strongly saline and strongly alkali (ECe about 10 mmho/cm and ESP 25% in upper part, about 25mmho/cm and 35% respectively from about 60 cm): solodized Solonetz/Natrargid.

The topsoil is strongly sealing (a 2-5 mm thick,dense and platy capping), with local sheetflood accumulations of reddish coarse loose sand grains. The hardpan is nearly impenetrable for roots and little permeable for water. The chemical fertility of the topsoil is fair to moderately high, except for nitrogen (N 0.07%, C 0.5%, P 20ppm, K 0.2meq%).

The vegetation is a bushland or bushed grassland with Acacia species (notably A. reficiens), Commiphora species a.o., and a sparse grass cover (a.o. Chloris virgata and roxburghiana).
On aerial photographs there is a pattern of "white dots", though less pronounced than on unit Sp2d (see above). In the present case the dots often have a dark centre of vegetation, on still preserved rests of the fossil termite mounds.

The unit is considered non-suitable for large-scale irrigation development because of the structural characteristics of the soil (hardpan) combined with the high salinity/alkali levels in the subsoil, and the presence of the slightly raised white dots. The present arable layer is very shallow and leaching of the salts/Na and structural improvement of the subsoil is strongly hampered by the hardpan; reclamation would therefore be very difficult and expensive.
Unit Sp1(d), comprising 84.500 ha, consists of flat land of which the meso-relief is however somewhat irregular (differences of 50 cm or so) due to the presence of slight depressions (often forming a darker "ripple-pattern" on the aerial photo's) and/or the presence of slightly raised vague "white dots" (see above).
These patterns cause the soil profile development to be rather diverse. As a whole, however, the soils can be said to be imperfectly drained. A topsoil of 10-20 cm is fairly well structured (subangular blocky to crumbly), brown to dark brown (10YR 3-4/3), sandy clay loam to light clay, non-or slightly calcareous and mostly slightly saline and slightly alkali (ECe 5-10 mmho/cm; ESP about 20%). There is usually a clear transition to a subsoil of which the upper part forms a hardpan (often less pronounced than in unit Sp1d: more commonly prismatic or coarse angular blocky than columnar, and less hard when dry). This subsoil consists of dark (greyish) brown (10YR 4/2-3) sandy clay to clay, strongly calcareous (common patches of soft lime), strongly saline and strongly alkali (ECe 10-35 mmho/cm, ESP 20-50%; the higher figures occuring in the deeper subsoil): (solodized) Solonetz/natric Halorthid or Natrargid. The topsoil sealing varies from weak and thin to strong and thick, but there is little loose sand from sheetflood action. The hardpan is rather difficulty penetrable for roots and water. The chemical fertility of the topsoil is high, except for nitrogen (N- 0.05%, C 0.35%, P± 60ppm, K± 0.55 meq %).

The vegetation is varied. Often an open bushland or bushed grassland is concerned, with Acacia reficiens/mellifera, Commiphora species, Salvadora persica, Grewia species and often the low shrub Salsola dendroides. The grass cover varies substantially in both denseness and species composition (Chloris roxburghiana and virgata, Enteropogon, Eragrostis, Dactyloctenium, Andropogon and Chrysopogon species were observed).

The overall soil characteristics (claypan, salinity, alkaliness), combined with the short-distance variation in soil properties and meso-topography make the unit non-suitable for large-scale irrigation development of normal field crops. Relatively shallow rooting and salt-tolerant crops like cotton may however still give a fair yield (in USBR terminology: suitability class 4Csdt).

The unit Sp1(r), comprising 70.000 ha, consists of regular flat terrain with little or no "ripple" pattern or "white-dot" features on aerial photographs (see previous units); a rather homogenously grey tone prevails.

The soils are imperfectly drained and have a topsoil of about 15cm that is well structured (mostly crumbly), and consists of dark greyish brown (10YR 4/2 - 3/2) sandy clay to clay, mostly moderately calcareous and non-saline and non-alkali. There is a usually gradual transition to a subsoil of which the upper part does not form a clear hardpan (prismatic to coarse angular blocky). This subsoil consists of a dark grey (10YR 4/1) clay, that is strongly calcareous (abundant patches of soft lime; carbonate concretions lower-down) and both moderately to strongly saline and alkali (ECe 10-15 mmho/cm, ESP 15-40%, the higher values occurring lower-down): Solonchak, sodic phase/natric Halorthid.

The surface sealing of the soil is thin, if any, and there is little or no loose sand from sheetflood action. The subsoil is penetrable for roots and moisture; most roots of the natural vegetation are nevertheless restricted to the shallow topsoil. Subsoil and substratum have presummably a low horizontal hydraulic conductivity (no actual measurements). The chemical fertility of the topsoil is mostly high, except for nitrogen (N 0.08%, C 0.55%, P more than 5ppm, K about 0.6 meq%).

The vegetation is an open bushed grassland, often with Acacia zanzibarica, or even pure grassland, often with a characteristically dense grass coverage, notably of the Schoenefeldia transiens species.

The topography of the unit is quite favourable for irrigation development, but the salinity/alkaliness occurring at shallow depth, as well as the actual drainage condition and the limited scope to improve these drawbacks through deep drainage make the unit only (potentially) marginally suitable for large-scale irrigation development of climatically adapted field crops (in USBR terminology class 3 sd)

Unit Sp1r, comprising 69.000 ha, also consists of regular flat terrain, in this case with a quite homogenously grey tone on the available aerial photographs. The transition to the previous unit is however very gradual.
The soils are imperfectly drained with a topsoil of about 20 cm thickness that

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has a favourable structure (crumbly to subangular blocky) and consists of very dark grey/greyish brown (10YR 3/1-3/2) sandy clay to clay. This merges gradually into a subsoil without a clear hardpan (upper partly angular blocky to prismatic, not very hard when dry), consisting of a mostly dark greyish brown (10YR 4/2) clay. This subsoil, and sometimes also the topsoil, is moderately to strongly calcareous (abundant soft powdery lime, carbonate concretions lower down), but has little or no salinity or alkaliness (ECe about 4 mmho/cm or less, ESP less than 10%) till appreciable depth, 60 cm or so: haplic (gleyic) Xerosol/Camborthid.

The soil surface has little or no sealing or loose sand coverage and penetration of roots and moisture in the subsoil seems fairly easy. The horizontal hydraulic conductivity of the subsoil and the substratum should however be fair at the best (no actual measurements). The chemical fertility of the topsoil is good, though N and possibly also P fertilizing will be necessary right from the start of cultivation (N 0.06%, C 0.55%, $P^{\pm}$ 30ppm, $K^{\pm}$ 1.10 meq%).

The vegetation varies from low bushland to bushed grassland (or open grassland), with various species of shrubs (Cordia gharaf; Grewia, Commiphora and Acacia species) and a fair coverage of grass (observed were Enteropogon somaliensis, Chloris virgata and roxburghiana, Chrysopogon aucheri a.o.).

The mapping unit is considered to be moderately suitable for large-scale irrigation of climatically adapted field crops. The regular topography and the absence of salinity/alkaliness within normal rooting depth are favourable qualities, but the actual drainage condition is a drawback while deep drainage - also to avoid future salinisation by capillary rise from the deeper subsoil - will be difficult if feasible at all (in USBR terminology: class 2d)

Unit Sp1v, comprising 20.000 ha, consists of largely parallel running, narrow stretches of relatively low-lying flat land that is 1-3m above the level of units Sp1d and Sp1(d). The difference in level with units Sp1(r) and especially unit Sp1r seems however very small (0.5m or so), with a gradual transition. The aspect on the aerial photographs is homogeneously dark grey.

The soil consists of poorly drained, very dark grey/greyish brown (10YR 3/1 - 2/2), strongly cracking heavy clay. The topsoil is subangular blocky to to crumbyly, the subsoil coarse prismatic in structure. No clear hardpan character was observed. Only one site was tested chemically. It showed to be calcareous throughout, and to be slightly saline but strongly alkali from 60cm downwards (ECe 10-25 mmho/cm, ESP 50%): pellic Vertisol, sodic phase/natric Grumaquert. Similar levels of salinity and alkaliness are expected to predominate in most of the narrow stretches in the northern-central section of the area, especially where they band the areas of Sp1d or Sp1(d). The surface crusts, strongly cracks and may have a micro-relief of gilgay. The sub-soil is difficultly penetrable for roots and moisture (a.o. due to swelling and shrinking of the montmorillonitic clay), and the horizontal hydraulic conductivity of the subsoil is expected to be very low. The chemical fertility of the soil should however be very high.

The vegetation appears to consist predominantly of bushed grassland, with Acacia zanzibarica and Acacia reficiens as main shrubs, and a dense ground coverage of woody herbs and grasses like Sporobolus helvolus and Echinochloa. The narrow stretches should be considered as non-suitable for large-scale irrigation development, both because of the poor internal drainage, the position on natural drainage lines for the area as a whole, the salinity/alkaliness levels in the subsoil and the difficult physical soil management.

3.4. The soils of the valley sides

The valley sides were little studied in this area, because of their occurrence outside the main zone of interest. Also, they have been described in site evaluation report 14, from which the description below is largely copied.

The unit Ss (regular valley sides) are smoothly and regularly lowering towards the Tana floodplain (slopes 10m per km. or less). There is a vague pattern of "white dots" on aerial photographs. The mapped acreage is 5.500 ha.

The soils are moderately well drained with a topsoil till about 40 cm. depth of reddish brown-coarse sandy clay loam, non-calcareous, non-saline and non-alkali. The structure of this topsoil is rather poor (massive or granular) and the surface sealing is strong. It overlies abruptly a hardpan of brown, gravelly coarse sandy clay, containing high percentages of both lime (10-20%) and moderately high levels of salinity and alkaliness (ECe 6-14 mmho/cm, ESP 20-30%): solodized Solonetz/Natrargid.

The vegetation is a bushed grassland, with little grass coverage.

The hardpan character and salinity/alkaliness of the subsoil are unfavourable, and the average slope may be less than ideal, but the arable topsoil is relatively thick. Therefore the unit is classified as marginally suitable for large-scale irrigation development (in USBR terminology: class 3 st).

The unit Sb (irregular valley sides) is quite irregularly sloping towards the Tana river and often actively eroding, both by sheetwash and gullying: "badlands". The mapped acreage is 6.500 ha.

In most places the topsoil has been removed and the hard and very firm subsoil or substratum of gravelly (sand) clay is exposed. This clay appears to be strongly saline and strongly alkali, in the presence of lime concretions and free lime (EC 15-55 mmho/cm, ESP 35-50%, carbonates 2-15%).

The vegetation cover is very poor, consisting of low bushed grassland, with many patches of completely bare ground. The unit is definitely non-suitable for irrigation development.

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3.5. The soils of the low-terraces and alluvial fans

Also this group of mapping units is outside the main area of interest. The unit T (low-terrace land, 7.500 ha) consists of flat land, only a few meters above flooding. The soils are often moderately well drained, brown, slightly calcareous, non-saline and non-alkali and of sandy clay loam texture till 40-80 cm depth. Therebelow, a hardpan occurs of moderately to strongly calcareous, non- to slightly saline but moderately alkali sandy clay. These soils often support a wooded-bushed grassland with scattered Acacia tortilis as prominent feature.

Included are sizeable parts (30% or so) that are relatively low-lying and have a dense grassland cover. Their soils are imperfectly drained and clayey throughout, with substantially higher and shallower salinity and alkaliness. As a whole, the unit is considered only marginally suitable for large-scale irrigation (in USBR terminology: class 3 sdt).

The unit Tf (alluvial-fan land, 1.300 ha) is gently sloping, but often with many shifting drainage ways. The soils are mostly well drained. Till about 80 cm depth they are brown, slightly calcareous, non-saline and non alkali; of loamy sand to sandy loam texture. There below a hardpan occurs.

The sandyness of the arable topsoil, though deep, and the occurrence of many drainage gullies with their occasional torrential runoff from the higher lands make the unit non-suitable for large-scale irrigation.

3.6. The soils of the main floodplain

For description of this unit (F, comprising 43.000 ha) reference be made to the legend of the map, KSSP site evaluation report 14 and Ilaco's original soil survey of the West bank (Acres Ilaco,1967).

4. The irrigation potential

4.1. Crop performance on comparable irrigated West bank soils

In view of the existence of a successful pilot irrigation scheme at Hola, on which a fair amount of information on crop performances is available, a comparison of the soil conditions of East-and West bank is called for.

For that purpose a photointerpretation was carried out of the area around Hola, using the same old aerial photographs (1:80.000) and the same criteria as regards surface features.

The photo-interpretation pattern is indicated on the map attached (uncoloured). Comparison with Ilaco's original "semi-detailed" soil map of the whole West bank (Acres-Ilaco,1967), subsequent detailed mapping of Hola block I, II and III by Schroo (Ilaco,1968), the recent detailed survey of Hola Extension area, and the yield data recorded in the recent

Bura feasibility study (Ilaco, 1975), yields the following information:

- The present photo interpretation unit Sp1d coincides largely with the unit N_3 of Ilaco ("nazic Natrargids"). Within this unit, the Hola experimental fi[illegible] C is located. It was abandoned soon after its preparation, because of quite unsatisfactory yields of crops, including cotton. Hence the unit has been classified as "marginally suitable" by Ilaco. (class 4).

- The photo interpretation unit Sp1(d) appears to coincide with at last part of unit S2 of the Hola Extension area ("shallow Halorthid"). It has been demonstrated that with careful ridging cotton - a salt/alkali tolerant crop - does grow rather satisfactorily on this soil (average 2700 kg/ ha), but the period of experimentation is still too short (2-3 years) to allow definite conclusions as to its suitability for permanent commercial crop production. Trials with other crops have not yet been executed. Ilaco has tentatively classified the unit as "fairly suitable". (class 3).

- The photo interpretation unit Sp1(r) coincides with the unit S1 of Hola I-III blocks, which is described as "(non-shallow) Halorthid". It includes experimental field A, which has been in use for 10 years. Good yields of cotton have been obtained on this field (and the blocks in general), gradually increasing over the years (3000 kg/ha nowadays). Also subsistance growing of maize and trials with groundnuts as second crop have been encouraging. The results of experimentation with another main commercial crop, sugar cane (more sensitive to salinity and alkaliness) are as yet inclusive. There are indications that the salinity levels of the subsoils have decreased substantially as a result of leaching - though at the same time its alkaliness may have increased. With the above in mind, Ilaco has evaluated the soils as "suitable" for irrigation (class 2).

- Photo interpretation unit Sp1v coincides largely with Ilaco's units GU and GA ("Grumustert" and "Grumaquert"), which includes experimental field B. Unfortunately this field was abandoned after a few years; hence no definite data on its sustained suitability for cotton, let alone other crops like sugar cane, are available. Yields of cotton on GU-parts in the existing pilot scheme are definitely lower than those on the Halorthids of unit S1, and they are not increasing, possibly due to a larger tendency to dispersion of both top-and subsoil, which would prevent leaching. The soils are classified by Ilaco as "fairly suitable" (class 3).

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- Photo interpretation unit Sp1r, the most important one on the East bank, does not occur in the Hola area. It looks however rather comparable with the large stretch of mapping unit C("Camborthid") further north. These soils are considered "high suitable" for irrigation by Ilaco, not only for cotton but also for sugar cane and other climatically adapted fieldcrops (class 1). The latter is however not yet supported by yield data from experimental fields or a pilot scheme.

When comparing soil characteristics of the photo interpretation units of the East bank with those of comparable Ilaco mapping units on the West bank there is in general a good correlation. Also Ilaco's Halorthids and Grumusterts/aquerts have in fact appreciable levels of alkaliness, and often a hardpan character. The only systematic difference appears to be a difference in colour: the West bank soils are normally more reddish brown than greyish brown; apparently their (macro) drainage is somewhat better. It may also imply a somewhat better over-all structure stability of the West bank soils.

4.2. Summary of irrigation suitabilities

The tentative irrigation suitability assessment as given in chapter 3 is supported by the data of the West bank as given in chapter 4.1. The suitability rating for the East bank soils is however somewhat less optimistic. This is a reflection of the consideration that Ilaco's classification holds mainly for the tolerant cotton crop. A comprehensive and internationally acceptable suitability classification should also take into accound more sensitive crops, like sugar cane.

The poorer drainage conditions of the East bank soils and the possibly somewhat poorer structure stability, as reflected in greyer soil colours, has also been a factor in the scaling-down.

(Table 2)
Suitability for large-scale irrigation development

moderately suitable:	unit Sp1r	69.000 ha
marginally suitable:	unit Sp1(r)	70.000 ha
	unit Ss	5.500 ha
	unit T	7.500 ha
variable suitability:	unit F	43.000 ha
non-suitable:	units Sp2d, Sp2v, Sp1d, Sp1(d), Sp1v, Sb, Tf	
	total	180.000 ha
	grand total	375.800 ha

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Studying the attached map, it is obvious that from soils point-of-view the most suitable area for development of a complementary major irrigation scheme is located rather far away from the Tana river. The unit concerned, Sp1r, occurs on the Bura-Kolbio road at about 20 km East of Bura village, and stretches to the east and the southeast, at both sides of a major central interruption of non-suitable soils. Two solid blocks are concerned, totalling about 60.000 ha gross. On the topographic map this region is indicated with "Farena".

From studying ERTS-I satellite imagery of the area, it is likely that another 20.000 ha of these soils may occur directly east-south-east of the present map. They seem moreover to merge gradually into Vertisols, occuring further down as huge stretches rather than as narrow strips (unit Sp1v). The broadness of these stretches may make them marginally suitable rather than non-suitable.

Whether or not areas with Sp1(r) soils, evaluated as marginally suitable, should be included in a major scheme is debatable; more observations are required on the actual depth at which salinity and alkaliness occur in harmful concentrations. It will depend also on the results of the West bank scheme. It may however be obvious that the area already set aside as Hirola Game Reserve is not among the most suitable for any East bank scheme. Its grazing potential, at the same time, seems substantial (dense grass-coverage).

4.3. Engineering aspects

This section discusses the feasibility of bringing the irrigation water by gravity conduction through a primary canal from the Tana river to the two blocks of moderately suitable land mentioned before ("Farena scheme area"), the feasibility to lead this water over the scheme land through a secondary and tertiary network of irrigation and drainage canals, and the feasibility for the dislodging of excess water from the scheme area through a drainage outlet. It is a reflection of discussions with irrigation engineers of N.I.B. and Ilaco, and is based on the existing (poor) information on topography. The latter appears as "formlines", with intervals of 25 feet, and a few benchmarks on the Survey of Kenya 1:100.000 topographic maps. They have been copied on the provisional soil map, with local adjustments in accordance with the apparent physiography as borne out by the photo-interpretation.
It may go without saying that full discussion of engineering aspects can only be done when more reliable and more detailed topographic information becomes available.

4.3.a. The routing of the primary/feeder canal

The idea of an East bank complementary scheme originated when it became apparent that the proposed Nanigi weir in the Tana river for the inlet of the West bank canal might be used for the inlet of an East-bank canal as well. In general, the layout of the land on the East bank appears very favourable for such a proposition: it slopes away to the south-east, with an average gradient of 0.5-1.0m/km. A canal would run parallel to rather than cross the natural drainage ways (except for the first stretch near Nanigi), which is in contrast to the alignment of the West bank canal. If the irrigable area were located in a stretch right alongside the Bura-Ijara road, then no problem for the lay-out of the main canal would exist at all.

The best area is however found to occur further east. Though the absolute altitude of this Farena area is sufficiently below that of the weir (15m) and the distance as-the-crow-flies is not excessive (40 km), it is obvious that the occurrance of the parallel low-ridges of unit Sp1d and the parallel depressional strips of unit Sp1v form some kind of obstacle.

Taking into account a similar over-all gradient for the canal as at the West bank (about 30cm per km), there are five possibilities for its routing, as follows:

1) The canal takes-in water at the Nanigi weir by pumping, lifting it straight-away to the level of the intermediate-level plain (unit Sp2d) at the weir site; from there a short canal could lead the water by gravity straight to the scheme area.

The high pump-lifting involved (40m or so) and the vagaries of reliance on huge pumping machinery makes this not feasible. The over-all gradient of the intermediate-level plain (1.5m/km) may moreover be to steep to allow gravity conduction without scouring of the canal banks.

2) The weir at Nanigi is solidificated and raised, / forming a regular diversion dam across the floodplain; this would permit a rather short and straight gravity conveyance across the south-western tip of the intermediate-level plain.

The costs of such a diversion dam, and its macro-hydrological implications, will make also this alternative unattractive.

3) Construction of a second weir further upstream.
In view of the very gentle gradient of the Tana river in this area, this would have to be at Korokoro, or even further upstream. Since this would imply extra weir constructional works and an extra canal length of 20 km or so, precisely through the very difficult terrain of the Sb-unit, it is equally unattractive.

4) The canal takes-in water by gravity at the Nanigi weir and curves around the low-ridges of Sp1d without any major excavation.

This would make the total canal-length excessively long (up to 100km) and the water may then not reach the upper portions of the Farena scheme area.

5) By far the most economic solution appears to be to take-in water by gravity at the Nanigi weir site, lead it by gravity (via formlines 375-350) more or less parallel to the river until it reaches the Bura-Garissa upper road some 12-15 km north of Bura village; from thereon the canal would sway into about straightly eastern direction, more or less parallel to the Bura-Kolbio road, till it reaches the farthest block of the Farena area at formline 325, cutting through three low-ridges (Sp1d). and crossing several minor drainage ways ("luggas" of Sp1v). The cutting of the ridges will concern excavations of only a few meters depth (5m at the ridge rops?) over relatively short distances (3 times 2 km), and the construction of underpasses at the crossing of the luggas can be modest in view of their small catchment areas (the West bank canal crosses several major luggas!). The total length of the canal will then be about 55 km , i.e. of the same order of magnitude as the West bank canal.

On a few copies of the provisional soil map the proposed alignment of an East bank canal as outlined in alternative 5 is indicated.

4.3.b. <u>The secondary and tertiary network of canals within the scheme area.</u>

The two irrigable blocks of the Farena scheme have a regular slope of about 0.5m./km to the southeast, while both are banded by strips of the relatively low-lying Sp1v unit. This seems to allow for a simple fish-bone network of secondary and tertiary irrigation canals through the centre of the blocks, and drainage canals through the low-lying strips at the edges.

The obvious place for settlement of the scheme occupants and for the scheme headquarters is the stretch of Sp1d between the two blocks.

4.3.c. <u>The macro-drainage from the scheme area</u>

The dislodging of drainage water from the scheme (originating from both irrigation-cum-leaching and incidental heavy downpours during the rainy seasons) will require due attention. This holds especially because of the general flatness of the terrains, the presumed poor internal drainage of the soils and the substratum, and the salinity/alkaliness of the soils/substratum in the survey area as a whole.

Routing of this drainage water back to the Tana further downstream, with an outlet at e.g. Masalani (25km downstream of Hola) would require systematic excavation of a very long drainage canal (70km). It seems easier to use the sizeable stretches of relatively low land with Vertisols that occur directly south-east of the scheme area (ERTS-images, Matheson's geologic mapping, draft map on the Lamu hinterland of Dr. Gwynne of the Game Dept) as temporary storage basins for the scheme's drainage water. Ultimately however the water has to be conducted further, towards Lamu District and the Ocean. The obvious way of conduction appears to be the

Lagh Doi and Dodori (ephemeral) river system, starting south of Galma Galla. It may require the excavation of a short connection canal (10 km or so) as well as local cleaning-up of the river beds themselves.

An interesting side-effect of transport of the scheme's drainage water to the southeast is the possibility of concurrent construction of a number of watering places for cattle and wildlife in the passing-through area. This would avoid a trek to the Tana in times of drought (thereby also providing better protection for the Hirola Game Reserve).

5. Suggested follow-up

If indeed, on the basis of the above data, a large-scale irrigation development in the area is seriously considered, then an integrated soil-topography-(geo) hydrology-vegetation survey will have to be carried out as part of a (pre-) feasibility study.

It is suggested to include in such a survey all the area east of the Bura-Ijara road, from Bura village till at least its crossing with the cut-line opposite Hola, and extending some 45 km to the northeast (250.000 ha). Topographical and hydrological surveys will moreover be needed for the stretch between Bura and Nanigi, alongside the river, where the first portion of a feeder canal would be routed through (40.000 ha).

The survey would have to be preceeded by the cutting of a substantial number of penetration lines through the bushland ("cut-lines"), with benchmark sitings at regular distances that can also be identified from the air. Thereafter, the area has to be covered by detailed aerial photography (scale 1:10.000 or so). T he fieldwork for the various typesof survey should preferably be combined, the soil and vegetation surveyors following closely behind the topographic surveyor and utilizing the same base camps.

The soil survey part should be of the semi-detailed type (final mapping at scale 1:20,000). From experience on the West bank is its likely that little reliance can be made on vegetational differences for soil mapping at such a scale. This may hold still more so for the East bank where vegetational (and relief) differences are even more gradual. It will therefore be necessary to carry out a large number of actual soil observations, say 1 per 5 or 10 ha. Most of these observations will have to be on pit diggings rather than by augerings, since the occurrence and characteristics of any hardpan have to be noted carefully. Also, for all of the observation sites data on salinity/alkaliness will have to be obtained. It will be impossible to have this carried out by sending samples of each profile to the NAL routine laboratory in Nairobi. Portable equipment for measuring electrical conductivity and pH may be used, but it may be better to acquire a mobile field laboratory for the purpose ("labmobile", c.f. Driessen and DeMeester 1970), where samples can be analysed

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on the above aspects at the end of each day or week under more controlled conditions, and where also an indication of the soil structure stability (easiness of dispersion) can be obtained.

The interdisciplinary character of the required survey, the sheer size of the area to be covered (on the soils part alone 250 man-months would be required), may make it less advisable to have the survey carried out by the Kenya Soil Survey Project, both because of limitations of manpower, disciplines and equipment. Especially if the data would be required in the forthcoming one or two years, then it may be better to have the work carried out by technical personnel of the TRDA, or by way of a special Project under the umbrella of this authority. In that case, however, it has to be specified in the project-agreement what should be the requirements of the soils part of the work. In particular, it will have to be accepted that the soil surveyors will apply the standards of description and interpretation set by the Kenya Soil Survey and that (copies of) all original field and laboratory data will ultimately be made available to this Organisation for storage and future reference through its Data Storage and Retrieval system.

. Apart from the above integrated survey, it is recommended to start soonest with a programme of irrigation - agronomic experiments on some part of the most promising soils. In that way in-situ crop yield data will be available at the moment of a final decision on the execution of a scheme.

The required irrigation water for a 50-100 ha experimental plot might be pumped from the river bed at Bura village and conducted through a pipe line along the Bura - Kolbio road till a site at the nearest block of Sp1r soil (distance 20 km, total lift about 25m). Both cotton and sugarcane should be grown over a number of years, various drainage methods should be tried out and the changes in soil conditions should be carefully monitored.

For both the survey work and the agronomic experimentation, the construction of a vehicle ferry across the Tana at Bura village would be highly beneficial.

6. Conclusions and Recommendations

1. A preliminary study on soils and topography was carried out for an area of about 375,000 ha on the East bank of the Lower Tana river, to assess its potential for large-scale irrigation development.

2. The soils-topography pattern in the area is much more regular than at the West bank of the Lower-Tana. The various soils tend to occur in large homogeneous stretches, with a parallel arrangement in south-easterly direction.

3. Many of the soils are saline/alkali and contain a hardpan, making them

non-suitable for irrigation development.

4. About 30 km. east of Bura village and mostly near the Bura-Kolbio road (Farena area) there are however two sizeable blocks of level land where the soils appear moderately suitable for the irrigated growing of commercial field crops (mainly imperfectly drained and clayey haplic Xerosols/Camborthids, non-saline and non-alkali till about 60 cm depth and without a clear hardpan). The total acreage of these blocks is in the order of 60.000 ha within the area studied. Directly southeast of the study area at least another 20.000 ha of soils of similar suitability is expected to occur.

5. Mainly in the area of the Hirola Game Reserve directly west of the Bura-Ijara road, there are stretches of level land where the soils appear marginally suitable for irrigation development (mainly imperfectly drained clayey Solonchak, sodic phase/natric Halorthid; saline and alkali from shallow depth but without a clear hardpan layer). Within the study area about 70.000 ha is concerned.

6. The area of moderately suitable soils of the Farena area can be commanded by a feeder canal, of about 55 km length, having its intake by gravity at the proposed weir in the Tana river near Nanigi for the West bank canal (Bura irrigation scheme). Such a canal will have to cross three short stretches of low-ridgy terrain, where excavation will be necessary, and several minor drainage ways (luggas), where underpasses will have to be constructed.

7. In view of the gentle gradient of the land and a parallel natural drainage/ /to the south-east, the macro-drainage of an irrigation scheme in the Farena area should be preferably in that same direction, with through-connection to the Dodori river catchment south of Galma Galla.

8. A semi-detailed soil-topography-hydrology-vegetation survey will have to be carried out for an area of 250.000 - 300.000 ha, before the feasibility of an East bank scheme can accurately be established. Some specifications for such a survey are indicated.

9. It is also recommended to start soonest with a programme of irrigation-agronomic experimentation on a site some 20 km east of Bura village.

References

Acres/Ilaco 1967 "Survey of the irrigation potential of the Lower Tana river basin". Vol. I-VII. (esp. Vol. III. Agronomy). Ilaco-Arnhem.

Anon 1973 "Development of Lamu District (and contiguousparts of Garissa and Tana River districts)". Progress Report Working Party Ministry of Finance & Planning, Nairobi.

EAMD 1973 "Summary of rainfall in Kenya for the year 1971". E.A Meteorol. Dept., Nairobi.

Ilaco 1968 "Galole Pilot Demonstration and Training Project, Soil Survey 1:10.000". Ilaco Arnhem.

Ilaco 1975 "Bura irrigation scheme feasibility study". Vol. I and II. Ilaco - Arnhem (in press).

Matheson, F.J. 1961. "Geological reconnaissance of the Lamu-Galole area". Geological Survey of Kenya, draft report + maps (non-published).

Matheson, F.J. 1961 "Geological recconnaissance of the Garissa-Bura -Dakadima area". Geological Survey of Kenya, draft report and maps (non-published).

Patterson G.D. 1957 "Report on Lamu hinterland". Govnt. of Kenya, ALDEV., report LR/8., Nairobi.

Richards L.A. (ed) 1954. "Diagnosis and improvement of Saline and Alkaline Soils". USDA, Agric. Handbook 60, Washington D.C.

Sombroek, W.G., J.P. Mbuvi, J.M. Kibe and H.W. Okwaro 1974 " A preliminary evaluation of the irrigation suitability of the lands in the Middle-Lower Tana valley (Mbalambala - Garissa - Bura)". Site evaluation report 14, Kenya Soil Survey, Nairobi.

USBR 1953 "Bureau of Reclamation Mannual; Vol V, Irrigated Land Use; Part 2, Land classification". U.S. Dept. of the Interior, Bureau of Reclamation, Washington DC.

Woodhead, T. 1968 "Studies of potential evaporation in Kenya". E.A. Agric. and Forestry Research Org., Nairobi.

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ADDENDUM TO SITE EVALUATION REPORT NO. 21

1. Introduction:

The preliminary evaluation of the soil conditions on the east bank of the Lower Tana (Bura-East Area) for large scale irrigation development (KSS site evaluation report No. 21) indicates two large stretches of land as most suitable from a soils point-of-view. The lands concerned form two solid blocks in the northeastern part of the surveyed area. The soils belong to unit Sp1r (see provisional soil map attached to KSS site evaluation report No. 21). In order to obtain more detailed information on the soil characteristics in the two blocks a field trip was made from 27th June till 7th July (Messrs. Van der Pouw and Ngari). Dr. Sombroek joined the team during the first day of its fieldwork.

2. Working Method:

During the fieldwork emphasis was given to the occurrence of salinity and alkalinity. Special attention was also paid to the structural characteristics of the soils, especially to structures and structure transitions in the first 60 cm. of soil. Therefore small pits were dug (approximately 60cm. deep) which were then augered until approximately 100 cm. depth and comprehensively described. The pH and electric conductivity of the various horizons were measured in the field, using samples with a soil: water ratio of 1:5. The pH - measurements were done with a battery-operated portable WTW pH-meter and the electric conductivity was measured with a Cenco-L.F.T.D. portable conductivity meter.

A total of 27 profiles were thus described and tested. They are numbered 155-26 till 155-48 and 141-1 till 141-4. Their locations are given on the attached maplet which shows that part of the soil map of KSS site evaluation report <u>21</u> that contains the two large blocks of land belonging to soil unit Sp1r. As can be seen from the attached maplet various traverses were made. In the southeastern block (which hereafter will be called block I) there are three traverses, of which one along the road to Kolbio employing observations of former field trips (155-8 till 155-11). Also in the northeastern block of Sp1r soils (hereafter to be called block II) three traverses were made. Here observation 155-37 was the starting point of two traverses, of which one again runs along the road to Kolbio.

3. Results:

3.1. Salinity

The profile studies, especially the EC_5 measurements, revealed typical soil patterns closely related to the detailed physiography. To illustrate this, the EC_5 measurements along the various traverses are schematically represented in graphs (see Figs. 1-6). The distance between the observation numbers is plotted on the horizontal axis and corresponds with a scale of approximately 1: 100,000. On the same axis, below the observation numbers, the respective soil units are mentioned. The vertical axis shows the electric conductivity in micro- mhos x cm^{-1} at 25°C. Each figure represents one traverse and shows the electric conductivity (EC_5) of each soil horizon of the relevant profiles. Most profiles consist of four horizons, roughly corresponding with depths of 0-20 cm., 20-40 cm., 40-60 cm. and 60-100 cm. Few profiles showed three horizons, the second being approximately from 20-60 cm. In these cases the symbols for the 20-40 cm. and 40-60 cm. horizons are placed together at the same level (see for instance 155-8). For the conversion of the EC_5 - values to the ECe values, use is made of the relation $EC_e = r.EC_5$ and the factor "r" should be known. From previous investigations on similar soils (Acres/Ilaco, 1967) r was found to be approximately 2.5. Therefore it is assumed that an EC_5 - values of 1.6 mmhos x $cm.^{-1}$ (=1600 micro- mhos x cm^{-1}) corresponds to an EC_e - value of 4 mmhos x cm^{-1} which is regarded as the boundary between nonsaline and saline soil (Richards et al 1954). The various salinity degrees are tentatively defined as follows:

	EC_5
Moderately saline	1600 - 3200 micromhos x cm^{-1}
Strongly saline	3200 - 6400 "
Very strongly saline	more than 6400 "

As can be seen from the figures the soils of unit Sp1r show many differences in salt content. Figs. 2-4 show the existence of a gradual transition from the saline soils of surrounding units to the non-saline central parts in the two blocks of Sp1r-soils. The soils at the fringes of the two blocks are usually non-saline until a depth of about 60 cm. and moderately or strongly saline further downward. The large central parts are non-saline until a depth of at least 100 cm.

3.2. pH

The pH shows patterns closely related to the salt content. The soils which are non-saline until a depth of 60 cm. show a gradual increase of the pH from the top with usually a maximum between 40 and 60 cm. The deeper, saline subsoils showed lower pH-values. The maximum pH-values of the soils involved a range from about 8.5 to 9.0, indicating alkali conditions as well.

The pH in the non-saline central parts show a different pattern. Usually there is a gradual increase of the pH, from about 7.5 at the top to a maximum in the lowest horizon, varying approximately from 8.0 to 8.5.

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3.3. Structure :

A similar gradual change as shown for the salt content, can also be observed in the soil structure. The Splr-soils directly bordering unit Splv have soils which show (composed) prismatic structures in the B-horizon, starting at about 20 cm.),and crumb or subangular blocky structures in the A-horizon. The transition between these horizons is usually clear, or even abrupt. This, together with slight swelling and shrinking causes poor rooting characteristics. The central parts usually have B-horizons with angular blocky structures, occasionally with weak prismatic tendencies. The transition from the A-horizon, usually having crumb or subangular blocky structures, to the B-horizon is clear to gradual. The more favourable structure of the central parts is clearly expressed by deeper reaching and more uniformly distributed rooting systems.

3.4. Other data

A peculiar feature of the central part of Block I is the local occurrence of brown and reddish brown or dark reddish brown soils or soil horizons. An estimate of the area comprised cannot be given. Another special feature of block I is the occurrence of acid soils, observations 155-33 and 34. These profiles together with 155-35 show also a slight mesorelief with local differences in altitude of about 50 cm. over distances of about 200 m. The slightly higher soils (155-33 and -35) have sub-soils with angular blocky structures, whereas the lower soil (155-34) has a subsoil with prismatic tendencies, combined with a somewhat higher salt content (see Fig. 1). They be rather put with unit Spl(d) than Splr. The area involved comprises about 1000 ha. It is an eastward extension of the Spl(d) area already indicated in the northwestern tip of block I.

The descriptions of Splr soils given in Ch. 3.1 - 3.3 relate all to broad stretches of land. In those cases where rather narrow stretches of Splr soils occur, different conditions were encountered, especially in relation to salinity and alkalinity. These stretches namely (see for instance the areas covered by the traverses given in Fig. 5 and 6) have a saline subsoil that usually starts already at 40 cm. depth, with the highest salt concentration between 60 and 100 cm. The pH shows a familiar pattern. It increases gradually from the top to a maximum between 40-60 cm. (pH 8.7-8.9) and then drops again, thus indicating saline-alkali soils. These conditions, together with somewhat poor rooting characteristics (due to prismatic structure tendencies), and probably low hydraulic conductivity make these narrow parts of Splr soils unsuitable for irrigation. It is estimated that about 13.000 ha. of soils mapped as Splr, are involved.

3.4. Surrounding soils

The greater part of the two blocks are surrounded by narrow stretches of soils belonging to unit Splv. Three profiles were investigated. They were all calcareous throughout. They are moderately saline between 40-60 cm. and strongly saline from 60 cm. downwards (see 155-40 in Fig. 1, 155-37 in Fig. 4 and 155-48 in Fig. 6). The pH values varied from 7.2 to 8.7, the highest values being measured between 40 and 60 cm. indicating alkali conditions which further downward combine with high salt concentrations and therefore result in lower pH values.

The profiles belonging to units Spl(d) and Spld (see 155-11 and 155-1 in Fig. 1 and 155-47 in Fig. 6) show similar salinity and pH patterns as described for the profiles of unit Splv.

4. Over-all suitability of the blocks

The various traverses made confirming the over-all description of the soil units involved. They support also the general soil pattern as indicated on the attached part of the soil map from KSS site evaluation report No. 21. At the same time the results described in Ch. 3 allow for more detailed indications with respect to the suitability of Splr soils for irrigation. This can be based on the following subdivision of Splr - soils.

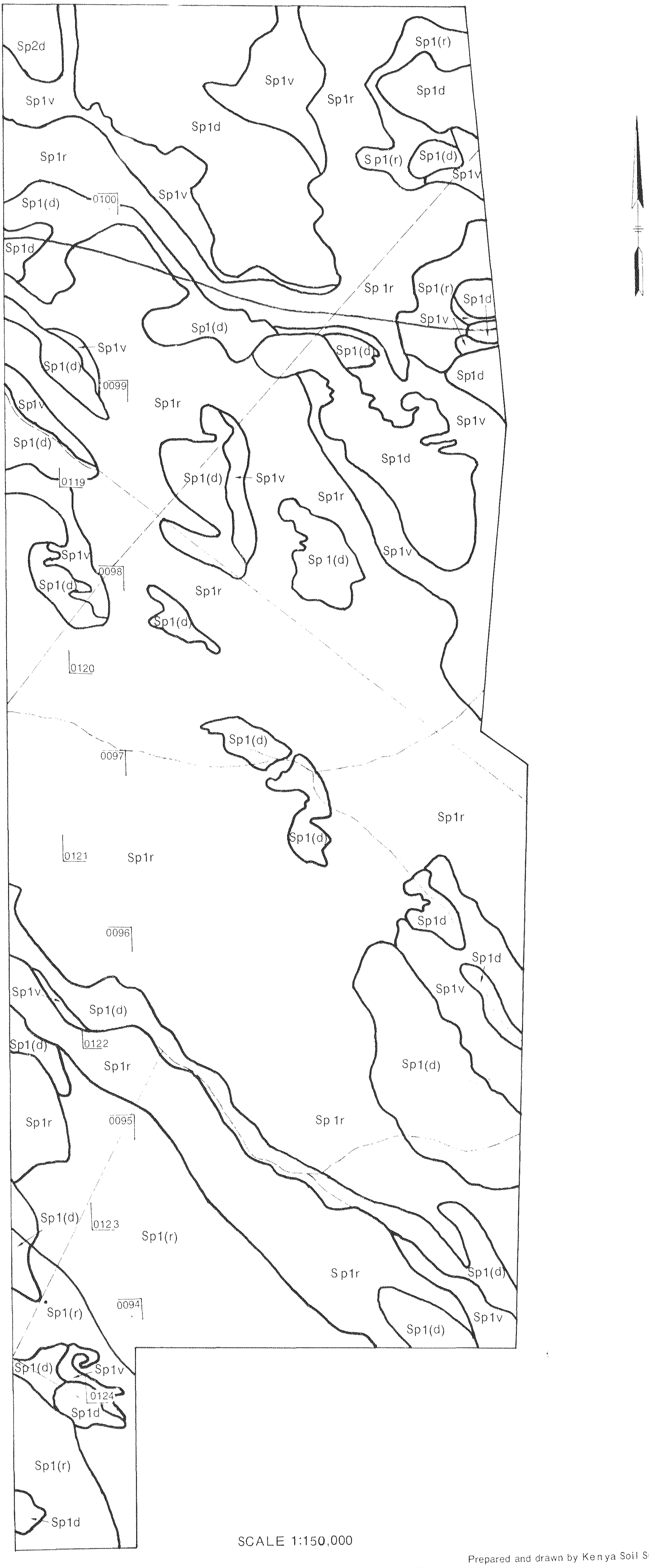
	acreage	suitability class
a) soils which are non-saline/non-alkali until a depth of at least 100 cm.	33.000 ha.	1-2
b) soils which are non-saline/non-alkali until a depth of 60 cm.	22.000 ha.	2
c) soils which are non-saline/non-alkali until a depth of 40 cm. (usually in "narrow stretches")	13.000 ha.	3
d) soils which be rather put in unit Spl(d) than Splr	1.000 ha.	4
Total covered by the soil map of KSS site evaluation report No. 21	69.000 ha.	

Nairobi, 2-8-75

B.J. van der Pouw

Extension site evaluation No. 21 (Bura East)

2780a KE 1975.06



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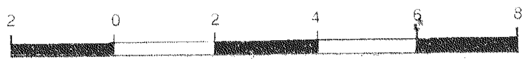
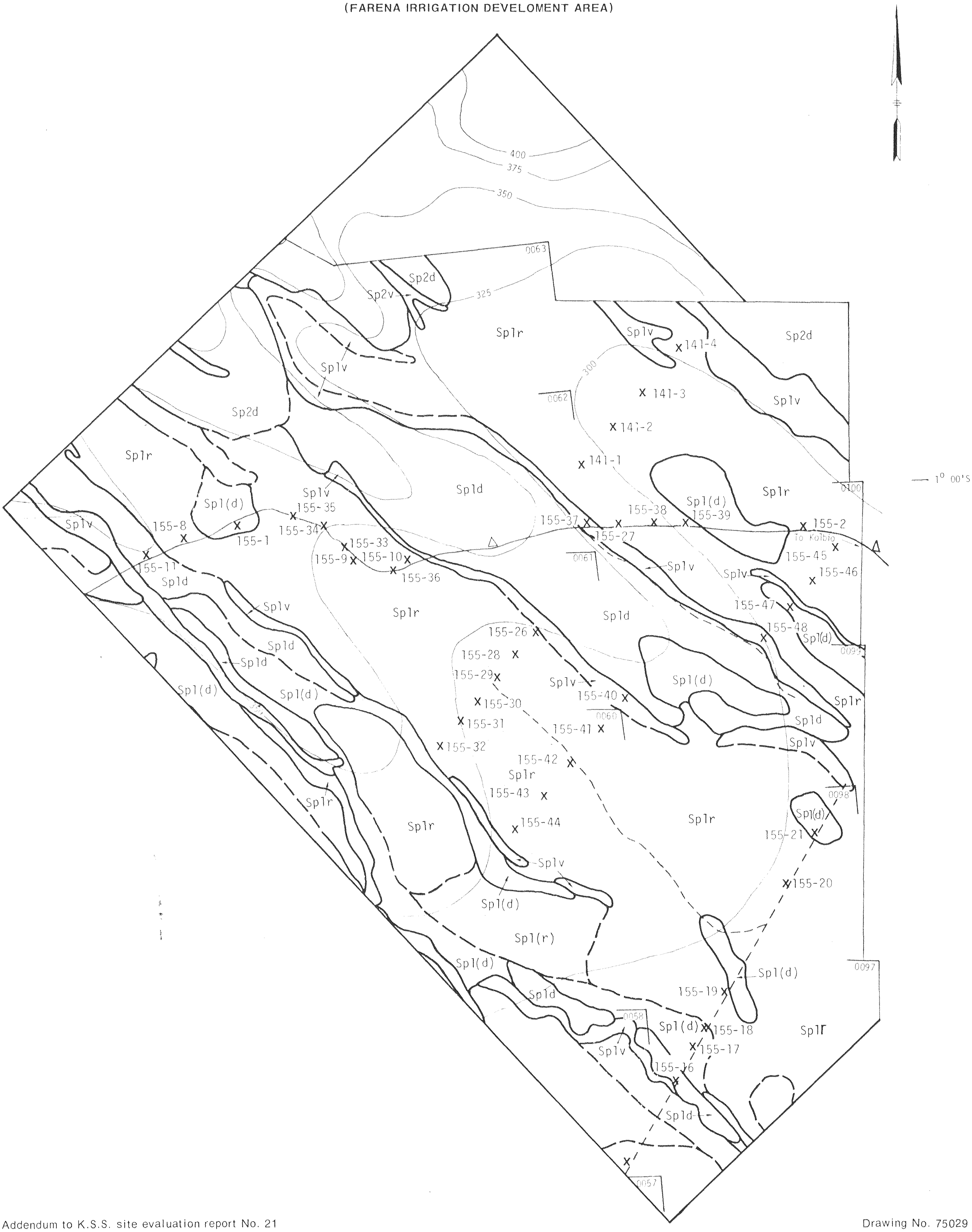


Prepared and drawn by Kenya Soil Survey, October 1975.

Drawing No. 75048

PART OF BURA - EAST PROVISIONAL SOIL MAP

(FARENA IRRIGATION DEVELOMENT AREA)



Addendum to K.S.S. site evaluation report No. 21

Drawing No. 75029