Socialist People's Libyan Arab Jamahiriya

Secretariat of Agricultural Reclamation and Land Development

FINAL REPORT

WADI AL-SHATTI DRAINAGE SURVEY

Cornelius-Brochier J. V.

November 1981

SOCIALIST PEOPLE'S
LIBYAN ARAB JAMAHIRIYA

SECRETARIATE OF AGRICULTURAL
RECLAMATION AND LAND DEVELOPMENT

FINAL REPORT

WADI SHATTI DRAINAGE SURVEY

NOVEMBER 1981

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1. Summary

Loss of yields or even crop failure are likely, if conditions of climate, topography, soil, and irrigation practice combine to cause waterlogging of the plant rootzone for extended periods. Saline groundwater aggravates this situation. The aim of drainage is therefore to remove surplus of water in order that soil structure and aeration are maintained or recovered and to control water tables which would otherwise rise to or near to the soil surface.

In the following the special problems in respect to surplus of water of Wadi Shatti Project are expounded and all basic data for the design of a complete drainage system resulting from field and laboratory investigations are described.

The drainage characteristics of the soil profiles are described by infiltration, internal drainage and land drainage. The soils are developed on unconsolidated sandy sediments, the profile is uniform in texture with weak structure. Salt efflorescences have been observed in certain farms in a limited scale, salt percent remains about 0.02 %. Moisture capacity and cation exchange capacity are very low due to the clean sandy texture. For all horizons the salinity level is below 4 mS/cm with pH reactions in the range of 7.7 through 8.2.

The soil surface salinity of the project area is in the range of 0.5 to about 15 mS/cm for the topsoil horizons. Few extreme values with its maximum of 54 mS (sample 148) and 40 mS (sample 8) were analysed in the western and central subarea. The northwestern part of the central area shows with an average of 11 mS/cm the highest salinity level. Occasionally a medium salinity of 5 - 10 mS/cm was analysed for some farms. Within the farm areas the level varies due to irrigation practices.

The infiltration tests showed no homogeneous distribution of intake values on the project area, the rates differed from low (20 cm/d) to very high (502 cm/d) with generally very high infiltration rates.

The internal drainage conditions, expressed by the hydraulic conductivity are in the range of 50 cm/d thru 2200 cm/d. The mean HC-values of the subareas are in the range of 440 cm/d in the eastern area, 720 cm/d in the central area and 550 cm/d in the western area. The permeability of the sandy soils is to be classified as high to excessively high with very high mean values in all subareas.

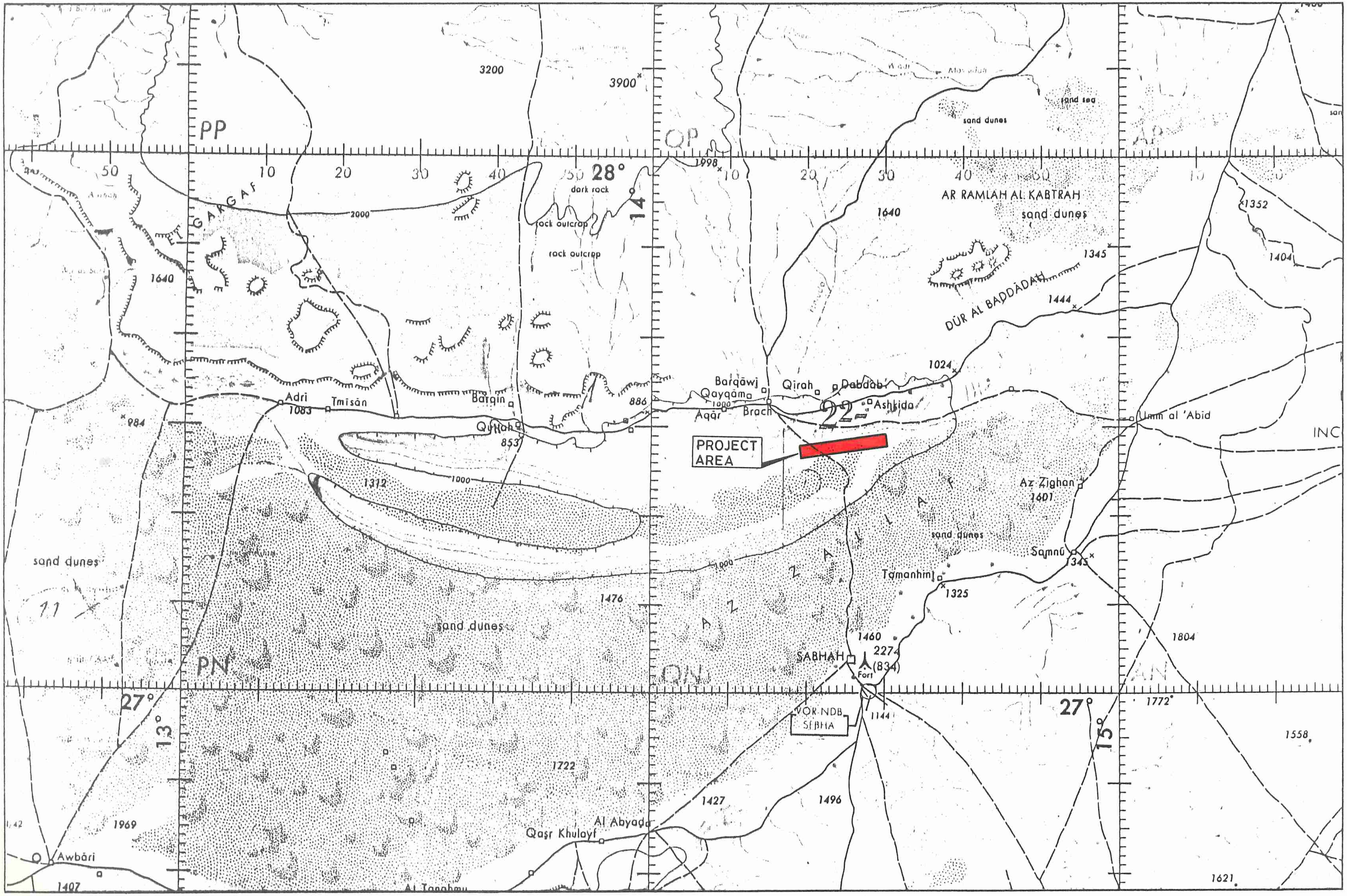
With a capillary rise of 0.5 cm/d at a suction of pF 2.5 the height of rise is 75 cm.

The annual irrigation quantity amounts to 1,668,760 m^3 with a corresponding irrigation rate of 0.44 l/sec · ha ≙ 3.80 mm/d per district (120 ha). The total irrigation efficiencies are about 0.57.

Salt content of drainage water ranges from 0.7 g/l to 6 g/l. With the performance of an effective drainage system the concentration will be reduced to a balanced status of 1.3 g/l to 1.6 g/l resulting from the low salinity level of irrigation water. The mean annual drainage water rate is per district 0.18 l/s · ha ≙ 1.55 mm/d with a monthly peak in summertime of 0.23 l/s · ha = 1.97 mm/d.

The monthly peak per irrigated farm area is 4.50 mm/d ≙ 0.52 l/s · ha.

In order to prevent salinization or reduce soil salinity leaching is required. For initial leaching the application of 50 to 80 mm irrigation water will be necessary to reduce the salinity level to about 1 mS/cm. The continuous leaching requirements are in range of 3 - 10 % of the consumptive use of crops.



PROJECT AREA
AR RAMLAH AL KABTRAH
sand dunes
DŪR AL BADDĀDAH
EL GARGAF
dark rock
rock outcrop
rock outcrop
Barqāwī
Qirah
Dabdab
Qayqām
Ashkida
Aqār
Brach
Adri
Tmīsān
Barqin
Quttah
Umm al 'Abid
Az Zighan
Samnū
Tamanhint
SABHAH
Fort
VOR NDB SEBHA
Awbāri
Qaşr Khulayf
Al Abyad
sand dunes
sand dunes
sand dunes
sand dunes
sand sea
PP
QP
PN
QN
28°
27°
13°
14
15°

2. Introduction

2.1 Background of Regional Development

The development of the Fezzan region is based on availability and access to groundwater resources. All inhabited land corresponds to zones of shallow water and the string of oases following the low lying terrain is the traditional settlement feature. Till the last years only few farm areas relied on deep groundwater exploitation, but these developments are strongly promoted recently.

Migration effects have influenced the regions population growth significantly. There is a considerable in-migration from Libya's southern neighbours, revealed by the fact, that more than 50 % of the population had their place of birth outside their present place of residence.

But the population inflow is more accentuated at the main settlements, especially the population drain from the rural surroundings towards the Fezzan capital Sebha. Not only the governmental facilities and services but also the private sector offers wage-earning job opportunities particularly to the age group of 15 to 25 years' male population.

The rapid growth of service employment and its favourable wage level has discouraged the incentive, people may have had to engage in agriculture. The present decline in agriculture throughout the Fezzan is more a result of the attractiveness of non-agricultural jobs than of the lack of agricultural potential.

The social status of agriculture, tending to become a part-time activity providing additional money to the family incomes, contrasts sharply with the fact that agriculture is still the economic basis of the region.

The high fragmentation of land, being reflected in the average holding size of half a hectar, prohibits investments in cultivation machinery and irrigation technology by the individual farmers. Furthermore, the farmers lack capital and are not in the position to invest and change from the present subsistence to market orientated production. Efforts to raise the productivity by improving farming practices and water management should also face the constraints of lowering and exhausting of the groundwater bearing strata as well as of salinization of soil surface.

A second constraint is the rising groundwater table in range of rooting depth so that great irrigated areas suffer from poor land drainage.

2.2 Project Objectives

On 23.03.1981 the Secretariate of Agricultural Reclamation and Land Development signed a contract with Messrs. Cornelius Brochier J.V. for the execution of the Drainage Project Wadi Shatti at Brak-Eshkeda in the S.P.L.A.J. (Libya). Before start of the construction of the drainage system a drainage survey within the project area shall be executed.

The drainage survey mainly consists of

- evaluation of available reports, maps and data
- soil surveys
  - physical and chemical properties
  - soil types
- infiltrometer measurements
- depth of groundwater table
- analyses of groundwater and drainage water
- hydraulic conductivities
- main drainage parameter
  - drainage survey discharge.
  - filter material
  - drainage areas
- leaching requirements
- re-use of drainage water

This report covers the activities with regard to the mentioned items which are executed so far and covers the results of evaluation of data, and all investigations.

2.3 Wadi Shatti Project Area

The project area of Wadi Shatti Project is located about 90 km northerly of Sebha, capital of the Fezzan Province. The area has about 3.000 ha, divided into the three subareas:

- Western Area
- Central Area
- Eastern Area

In accordance with the installed irrigation wells the area comprises 25 districts each with 12 farms, so that each well supplies water to 12 farms of 10 ha each. The farms are divided into two plots of 190 x 239 m each. Between the farm plots and around the farm windbreaks have been planted. The net area under irrigation and cultivation of each farm is about 8.3 ha. The Western Area has about 200 farms with a total area of about 2.000 ha. The Central Area has about 60 farms correspondingly 600 ha, the Eastern Area has 36 farms with a total of 370 ha.

Irrigation water pumped up from a deep aquifer (350 - 400 m) discharges into reservoirs, 2.400 m^3 each, from where it is pumped into the pipe irrigation scheme. Each farm is connected to this system by four hydrants.

The project implementation started in 1975 and is fully operational since the second half of 1976. It was said, that already one year later the first drainage problems became visible. Now, five years after beginning of project about one-third of the area suffers from surplus of water with a groundwater table occuring at a depth of less than 1.0 m. The existing salinity level of the top soils is not yet a major problem, because of the low salt content of irrigation water and groundwater.

The lay-out of the drainage scheme was designed in conformity with farm sizes, i.e. field size and irrigation scheme lay-out. Farm areas are surrounded by open drainage channels. Until now field drains don't exist. The General Map of the Drainage System, prepared by Italiana Lavori in June 1979, shows the lay-out of the drainage system. The conductor drains (main drains) are open channels which lead the surplus water to natural depressions (sabhkas) where it percolates or evaporates without any practical use.

In general the existing draining systems do not function properly due to the following reasons

1. maintenance of the channels is problematic because of the unstable sandy soils and proliferation of reeds the open drains gradually became wider and shallower resulting in insufficient outlet.
2. during the surveying check some difference in the topography as shown in the drawing, ITL Lavory,up to 3 m were detected at points important for the planning.
3. field drains and collector drains don't exist although their alignment are already mentioned by Italconsult.

For calculation of irrigation water demand related to climatic conditions, soil conditions, cropping pattern, water quality and irrigation method climatic data available from Sebha Station have been used.

Because of the high infiltration rates and the low values of available water capacity of the soils the main irrigation system is sprinkler irrigation. Only for some crops such as kinds of vegetables, orchards and during the first stage of project for windbreaks, furrow irrigation is applied.

? citrus ?

The main cultivated crops are alfalfa, wheat, water melon, tomatoes onions, vegetable pepper and fruit trees, i.e. pomegranate, grapes figs, dates and aprocots. With regard to the assessed cultivation units crop-rotation system can be classified as

Cereals-Ochards-Fodder-Vegetables.

For calculation of demand of irrigation water distinction was made between the growing periods of summer and winter.

3. Compilation of Results

3.1 Climatic Conditions

The climate of the project region is arid reflected in the landscape of desert.

Rainfall is almost zero and in regard to satisfying crop water requirements are insignificant. However, offshoots from wandering depressions may move from northwest as far south as the project region and clouds can bring some rain. Statistically the average rainfall is about 1 mm/month.

Some years and many summers are reported to be without any rain and there are some years when precipitation falls only during summer time.

The mean annual temperature is 22.4°C but there are distinct divergences between winter (14.3°C), and summer (28.5°C) with short transitional periods in March (18.1°C) and October (24.1°C). During winter time temperatures may fall below freezing point, so that the extremes of daily fluctuations can be limiting factor for plant growth.

But also maximum temperatures can reduce plant production either by direct influence or via high evapotranspiration requirements.

The relative humidity amounts from 40 to 50 % in winter, and falls to an average of 20 to 30 % in summer.

actually measured?

The mean annual sunshine hours are 9.6 per day, ranging from 7.8 hours in December to 12.2 hours in July.

How? calculated values seem to be high

Average wind speed from May to October is calculated to be 6.2 m/s, while from November to March it is 4.9 m/s. The annual average is 5.1 m/s. In case of

Frequency of occurrence

Ghibli wind speed may increase to 20 m/s causing excessive draughts and high temperatures.

ok

Climatological data shown in the following table refer to records from the meteo-station at Sebha, which is nearest to the project (at a distance of about 90 km) are taken as representative for the Wadi Shatti Drainage area.

Table 1: Climatological Data (Sebha-Station)

PARAMETER		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR TOTAL OR AVERAGE
rainfall	mm	1.6	1.0	0.4	0.5	1.6	0.5	0	0	0.4	1.4	1.2	1.0	9.6
temperature, mean	°C	11.5	14.0	18.1	23.2	27.4	30.8	30.2	30.4	28.7	24.1	18.1	12.8	22.4
temperature, absolute minimum	°C	-4.0	-4.4	-1.5	3.9	10.6	16.0	17.0	16.4	14.0	8.2	1.6	-2.5	-
temperature, absolute maximum	°C	29.2	36.2	39.2	43.1	44.9	45.6	46.5	44.0	46.2	40.5	35.6	34.1	-
temperature, mean daily min.	°C	4.5	7.0	10.2	15.3	19.7	23.2	22.7	22.5	21.4	16.8	10.6	5.8	15.0
temperature, mean daily max.	°C	18.8	22.0	26.1	31.1	35.4	38.9	38.1	37.9	35.9	31.2	25.6	19.9	30.1
relative humidity, mean	%	50	42	34	30	26	23	26	29	33	37	44	49	35
sunshine, hours per day		8.8	9.4	8.8	8.9	10.4	11.6	12.2	11.7	9.5	9.2	8.0	7.9	9.7
vapour pressure	mmHg	7.0	7.0	7.6	8.8	9.8	10.8	11.7	12.0	12.0	11.0	9.4	7.5	9.5
wind speed	m/s	3.8	4.3	5.7	6.0	6.0	5.7	5.2	5.0	5.1	4.9	4.4	5.0	5.1

3.2 Hydrogeology and Hydrology

A typical profile of the entire geological sequence in the Project Area is shown in Table 2 .

The groundwater used for the supply of the Eshkeda Project is contained in the sandstones of the Cambro-Ordovician formation. This Cambro-Ordovician aquifer representing the main aquifer forms on a regional scale a large system together with the Devonian sandstone representing a secondary aquifer. Groundwater stored in the two aquifers is mainly fossil water. Part of it may be water entrapped during the rock sedimentation, as the salt water in the carboniferous sandstones. Most of the groundwater probably is to attribute to the Pleistocene or perhaps to the latest Tertiary. Both aquifers are separated by intercalated Devonian shales representing a leaking aquiclude. In the Project Area the piezometric head of the two aquifers of approximately 2 bar is reported by Italconsult.[1)]

The Devonian aquifer is confined by shales of the Upper Devonian and Carboniferous formation. The average head of the Cambro-Ordovician and Devonian aquifer system in the Project Area was in 1975 about 30 to 40 m above ground level. It must be assumed that due to groundwater exploitation, the piezometric level has sunk considerably. This assumption was confirmed by the local authorities, however, quantitative data could not be obtained.

The Carboniferous shales are covered by young, alluvial and/or aeolian sediments of varying thickness. The thickness of these beds may range from about 10 m to almost zero. Exact data on the thickness of these deposits are not available. These young sediments contain groundwater. According to information obtained locally and to own observations, the table of this

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1) op cit. 1975.

groundwater is reaching the ground surface in places as indicated in map No.10.

This groundwater is not reported for the Eshkeda Project in the Italconsult reports. Sebkas, however, are mentioned in the Italconsult studies and are shown on the appurtenant maps. These Sebkas lie in the east of the Eshkeda area. It cannot be excluded that these Sebkas are related to the phreatic ground water in the young sediments. However, the source of recharge of this aquifer and the Sebkas is not definitely known. As mentioned previously the annual rainfall is almost zero. Statistically the average monthly rainfall is less than 1 mm, but occasionally once over many years significant downpours of up to 30 mm may occur. Those average rainfalls are negligible for groundwater recharge. Surface water from the northern hills (Djebel Gargaf), sporadic heavy rainfall, infiltrating irrigation water from old schemes (before 1975) may have contributed to the recharge of the Sebkas and the phreatic groundwater.

As mentioned in the Italconsult study, leakage water from the palaeozoic aquifer rising through fault zones may also have contributed to the Sebkas.

Following the observations of the REGWA-Study on the soils of the Eshkeda Project Area included in the Italconsult report, no groundwater table has risen to such an elevation below ground level that it could have an effect on the agricultural production in the Project Area. However, since irrigation in the Project Area has started, the phreatic groundwater table has risen, already influencing the crop production. From this observation it must be concluded that the infiltrating irrigation water is liable for the rise of the water table. Even if a certain amount of the phreatic groundwater may be recharged from deeper aquifers by upward leakage, this volume of water could not be only reason of the groundwater rise since the irrigation project started, because this leakage would have taken place already before the Project started. At that time, i.e. before groundwater extraction, the artesian head of the deep aquifer was definetely higher, which means that any leakage would have been higher than after project start, i.e. after groundwater expoitation.

Unfortunately, no regular observation of such a water table rise are available, for instance by piezometers. The proceeding statements, therefore, are based only upon verbal communications from the Project Authority and some local farmers. However, they seem to be reliable. In order to draw down the phreatic water table, drainage is required.

Table 2: Typical Geological Profile in the Eshkeda Project Area
Example Irrigation Well / W 18

Hydrogeol. characteristic		Depth (m) from	to	Lithology	Formation	
Phreatic aquifer		0	2	sand, fine to coarse, quartzitic, some sandstone, gravels, greyish to pinkish	-	Quaternary
		2	4	silt (90%), brownish, soft to medium hard, sand (10%) very fine to fine, light brownish		
Aquiclude		4	105	shale and clay, dark grey with rare fine grained sandstone interbedded	Mrar	Carboniferous
Leaking Aquiclude		105	139	alternating clay, claystone, light grey to brownish and light grey fine grained sand stone and siltstone	Shati	Devonian
Aquifer	secondary	139	185	sandstone, light grey, coarse grained with rare light grey clay interbedded	Awenat-Wenin	
	main	185	final depth (355m)	sandstone and quartzite, light grey, medium grained, hard to medium hard, kaolinitic	Hassouna (?)	Cambro-Ordovician

Source: Italconsult, Hydrogeological Survey, Part II, Rome, April 1975.

3.3 Drainage Characteristics of the Soil Profile and the Substratum

The use to which a soil can be put depends mainly on its water transmitting properties. The following agricultural qualities depend on the water movement:

- workability, resistance to erosion, surface sealing
- erodibility
- reclamation of saline and alkaline soils
- reclamation of soils with a high toxicity status
- oxygen availability to plants

The soil drainage status can be described by the

- Soil Drainage
  - Infiltration (cumulative intake and instantaneous intake)
  - Internal Drainage (Hydraulic Conductivity HC, saturated or unsaturated flow)
- Land Drainage (surface drainage, subsurface drainage).

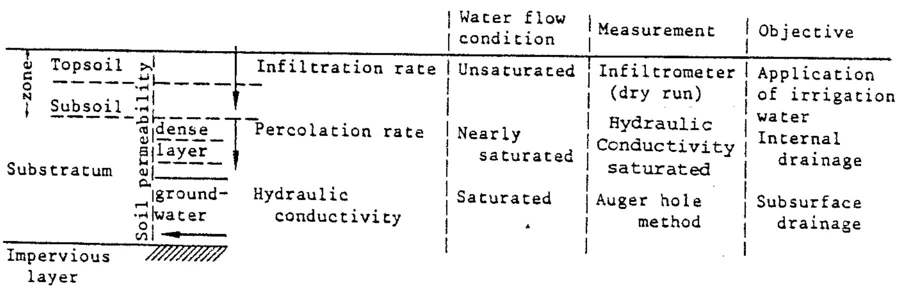

Figure 1 : Three aspects of soil permeability

Soil drainage means the ability of the solum to transmit water in a direction that is mainly vertical. This will take place in the upper 1.5 m of the soil profile normally. The components of soil drainage are infiltration, internal drainage and water storage above field capacity.

Land drainage covers both surface drainage (runoff) and subsurface drainage, in both of which the flow of water is mainly lateral. Subsurface drainage takes place in the upper 5-10 m of the profile depth, dependent on hydrogeological situation.

Hydromorphic properties of the soil profiles

Since certain morphological features of the profile will yield information on drainage status and ground-water conditions, the most important are described hereafter; many hydromorphic features and processes reflected in the profiles morphology after reaching an "equilibrium" state. The soils of the Eshkeda project are under irrigation since 3-4 years and therefore the current watertable cannot be assessed to be in a equilibrium state. Groundwater measurements are not available, but it is assumed that a slowly increase of the water table started since irrigation, showing also yearly fluctuations.

An irregular colour pattern, especially mottled and blotched areas, developed by the presence, translocation, and oxidation - reduction status of free iron oxides and manganese, had been observed occassionally in some pits, where the groundwater occurs within 1.5 m below the surface (e.g. pits No. E1, E27). These soils may develop as gleyic soils, whose grey colour developed by translocated and active reduction of iron to Fe^{2+}. Since gleyic soils do not develop during short periods of waterlogging, a permanent influence of reduced conditions within these layers is assumed. The bulk of soil profiles investigated in Eshkeda project shows no distinct features of hydromorphism although many of them have a water table within 2 m profile. The absence can be explained by the short time since starting irrigation.

An increase in soil salinity near to the surface which is a sign of a high water table in arid regions, was not found on irrigated areas, since there exist a water flow downward.

The evaluation of soil qualities relevant to water transmitting properties are shown for the surface infiltration (Table 3) and the hydraulic conductivity (Table 4).

Table 3 : Evaluation of Soil Surface Properties relevant to Infiltration

Soil Quality	Average Value	Range Value	Remarks
Texture	l'S	lS thru S	coarse textured, clean sand
Stratification	no	-	uniform solum
Structure	loose singular	-	no definite orderly arrangement of individual grains
Type of clay	-	-	not of importance since the clay percentage is less than 5 - 8 %
Surface sealing/ slaking	LL ÷ FC = > 2	1.5 - 3	no slaking will occur
Bulk Density	1.5-1.7 g/cm³	-	medium, typically for quartzitic sand
Porosity	44 - 35 Vol.%	-	no interped space, micropores limited
Aggregation	no	-	cohesionsless; no cementing agents are present like $CaCO_3$, $CaSO_4$, free iron oxided and clay domains.
Gradation	3 - 6 SW	-	mod.well graded coarse and medium sand, little fines;
Surface cover	vegetation	fallow;	density of vegetation cover depends on growth stage and is variable between crops
Evidence of crust	no	-	no crusting due to high $CaCO_3$, $CaSO_4$ and easily soluble salt percentages
Solution Composition and concentration	low EC; 2 - 100 ESP	high deviations of ESP	insensitive to variations due to low clay content, extremely low CEC and low EC.
Measured range of Infiltration			
wheat	177 cm/d	25 - 502	after harvesting, before tillage
alfalfa	140 cm/d	28 - 330	during irrigated final stage of growth
orchards, furrow	175 cm/d	22 - 475	permanently irrigated orchards
orchards, bare soil	154 cm/d	23 - 474	bare soil between furrows

Table 4 : Evaluation of Soil Properties (0 - 150 cm) relevant to Soil Conductivity to Water

	Deep sandy Haplic Yermosols	Sandy Haplic Yermosols overlying moderately deep clayey substratum
measured range of HC	200 - 2500 cm/d	200 - 2500, abrupt change to substratum
Texture	l'S - S	l'S or S above sandy clay or clay
Structure	loose singular	loose singular over blocky
Bulk density	medium	medium 1.4 - 1.75 g cm^{-3}
Structure stability	cohesionsless material	cohesionsless material above microaggregate clay
Consistence	soft to loose	soft
Mottling	no	occasionally greyish-blue
Layering	no within 2 m	clayey layers in various depth, generally below 1 m profile
Carbonates present	no	no
Gypsum present	few	few
Solution composition and concentration	low EC, mod.high ESP, CEC < 1 meq/ 100 g	mod. to high ESP
Clearage planes	no	no
Pores	micropores, limited	micropores, limited
Depth to bedrock or impervious base	above 2 m	within 1 thru 2 m profile

The gradation may be applied to seepage and drainage problems, since it allows a broadly defined estimate of permeability and unit weight, filter and grout design.
The following grain-size parameters were applied:

D_{10} size, which is an approximate measure of the void spaces in coarse grain soils

$D_u = D_{60}/D_{10}$, the coefficient of uniformity which indicates the relative broadness or narrowness of gradation.

The grain-size curve shows that the clean sands have a moderately range in grain sizes and substantial amounts of all intermediate particle sizes.

The coefficient of uniformity for the sandy soils is in the range of 3 - 6 due to the predominance of medium sand (0.2 to 0.63 µm). Soils having slightly higher contents of finer particles show a well gradation in the range of 15 - 20, whereas the impervious base of sandy clay loam has a broad gradation of > 300.

The structure and its stability against the action of water or compaction (wheel forces, animals) affects the water intake rate of the soil. Due to the clean sand[1] of the surface layers, no aggregation takes place and the soil constituents remains as cohesionless loose material. Cementing or bonding agents like $CaCO_3$ and $CaSO_4$ are not present in the Eshkeda soils. Therefore soil aggregation and its stability in the soils of Eshkeda depends on the adhesion of the single particles by the root system. Coarse pore systems are developed by roots, thus enlarging the infiltrability. On the other hand it was observed in the excessively drained Eshkeda soils, that an extensive root system and vegetation cover restrict the infiltration rate compared to a bare soil surface due to dense

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[1] A clean sand does not contain clay domains which may bond the sand particles to produce stable aggregates.

arrangement of mineral particles and extensive root development near the surface.

The deleterious effect of adsorbed sodium on the physical properties of most soils is clearly seen in the changes in the permeability of water through the soil. The permeability is a function of the square of the pore radii, so that any treatment which decreases the size of larger pores have effects on the permeability of the soil to water. Swelling of clay particles, by which the size of the large pores is decreased, and dispersion of the soil colloidal material, which can move and block pores in the soil, may both affect the intrinsic permeability of the soil. It may be deduced from the double layer theory that both swelling and particle dispersion increase as the concentration of salts in the soil solution decreases and the Na/Ca ratio in the solution increases.

The quantitative decrease in hydraulic conductivity with decreasing electrolyte concentration and increasing sodium adsorption ratio (SAR)[1] of the percolating solution is assessed for Eshkeda soils:

1. a low soluble salt percentage of 0.05 % of the irrigation water and the soil solution was determined

2. an extremely low cation exchange capacity CEC of less than 1 meq/100 g soil was analysed; often the value remain under the detectable limit

3. high deviations of the exchangeable sodium were calculated, due to a higher concentration of Na^+ in the solution compared to adsorbed Na^+ on

Exch. Na analyses in these sandy soils are of no value

1) the exchangeable sodium percentage (ESP)

the ion exchanger.

4. the soil constituents are loose cohesionless; the clean sand shows no aggregation and therefore swelling and dispersion phenomena are absent.

It follows that the effect of both, the total salt concentration as well as the composition of adsorbed ions has no essential influence on soil characteristics with regard to water transmitting properties.

3.4 Morphological Description of the Predominant Soil Types and their Range of Characteristics

(Soil Designation, Nomenclature and Classification,

The soils of Eshkeda project are developed on unconsolidaded sandy aeolian sediments which rest upon clayey carboniferous rocks. The topography is slightly undulating and reflects the irregularities of the underlying consolidaded rocks. The Eshkeda soils are deep, excessively drained clean sand and are characteristically reddish yellow to brownish yellow in colour with Ap and Bw[1] horizons. The epipedon horizon is still a ochric one, but there may develop a mollic epipedon during long continued use of the soil by men. The organic matter content is less than 1 percent throughout the thickness of mixed soil.

Structural development is weak and horizontation is ill defined. The soils were classified as sandy Haplic Yermosols Yh 2, under irrigated agriculture.

Typical Profile

The following profile was examined in a pit of the western farm area. At present the soil is used for cereal production; sprinkler irrigation was stopped after the harvest few weeks ago.

Information on the Site:

Location	=	western project area, pit No. E 14, Yh 2 - phreatic phase;
Altitude	=	328 m
Parent Material	=	quaternary sandy aeolian deposits overlying carboniferous shales (clay) in varying thickness
Physiography	=	southern slope of Wadi Shatti, covered by a convex sloped aeolian accumulation of some meter thickness

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1) Cambic Bw horizons, reflecting a slight weathering beneath the surface

Microtopography	= slightly undulating relief, the site was on a gentle convex summit
Moisture condition in the soil	= irrigated agriculture; under natural conditions having a aridic moisture regime
Drainage	= Excessively drained - water is removed from the soil very rapidly; the impervious base is below 5 m b.g.l.
Depth of groundwater	= below the profile at all times of the year
Evidence of Erosion	= none detected
Presence of salt and alkali	= none
Human influence	= strong due to irrigated agriculture

Cover		cereal - straw
Ap	0 - 25 cm	yellowish brown (10 YR 5/8) fine and medium sand; weak very thick platy structure in a soft consistence; friable when moist; no plasticity, no carbonates present; common continuous interstitial exped pores; no cutans detected; frequent medium roots, slightly moist, clear wavy boundary to
Bw	25 - 90 cm	yellow brown (10 YR 5/8) medium sand, structureless and non-coherent, loose consistence; no plasticity; no carbonates or gypsum present, few discontinuous interstitial pores, no cutans detected; few medium roots, diffuse boundary to
C	90 - 200 cm	yellow (10 YR 8/8) medium and coarse sand, structureless and non coherent; loose consistence, very similar to horizon above but very slightly paler in colour, no roots observed.

Brief description of the profile

Profile is very uniform in texture and has an almost uniform yellowish brown to yellow colour. Structure is weak in the ploughed Ap horizon and without aggregation in the B and C horizons. Carbonates, gypsum and salt efflorescences has not been observed; root distribution normal; profile reacts alkaline throughout; salt percent remains below 0.02 %; moisture capacity and cation exchange capacity are very low due to the clean sandy texture. Ecological properties of the profile are shown in Diagram.

Inferred characteristics of the soil

The soil is moderately suitable for irrigation; the extremely low natural fertility requires high fertilizer applications, leaching losses of fertilizers are high; the water retention is low and may be overcome by frequent irrigation intervals at low intensity level. Good aeration conditions favours root growth; the profile is excessively drained, making it difficult to distribute water uniformly; large quantities of water are wasted on the application side of the field when furrow irrigation is practiced.

Range of characteristics of Haplic Yermosols in Eshkeda project

a. Profile characteristics; dependent on their topographical position and the depth to the impervious clay layer in the substratum the soils are imperfectly drained or excessively drained. In 10 of the total 28 excavated pits within the project area, the groundwater table is 0.9 thru 1.5 m below the surface. Actually the moderately shallow groundwater is not reflected in the morphology of the the solum due to the short period since the rising groundwater (3 - 4 years). Some soils show weak hydromorphic properties, i.e. a dark greyish brown colour (10 YR 4/2) in the groundwater horizon, found on fracture phases.[1] Due to the lack of free iron (in the soil) and organic matter the typical features of gleyic soils remains weak. The horizontation is Ap - Bw - C - Cg or Ap - Bw - C also for the soils having a shallow watertable.

Texture and colour of the soils in Eshkeda are almost uniform. The clay + silt percentage is below 5 - 10 %; coarse fragments in gravel size were occasionally found in the soils of the eastern region and in few pits of the western area; the content of fines (< 0.05 mm) is slightly increased in the profiles of the eastern area. Profiles 6 thru 8 show medium to moderately coarse textured layers in variable depth. In profile No. 12 (district 4 of the western area) the upper part of the waterlogging layer of stL and sL in most soil comes near to the surface at 70 cm depth. The remaining observation pits show a very permeable loose sand down to 200 - 220 cm profile or at least down to the groundwater layer.[2]

Substantial differences with regard to physical or chemical properties had not been determined. The salinity level is below 4 mS/cm in most soil horizons; the reaction range is alkaline in the range of 7.7 thru 8.8 pH, with an average of 7.8 pH for the Ap horizon and 8.4 pH for the subsoil. The profiles of the eastern project area are slightly less alkaline in the subsoil, too. The carbonate percentage is below 1 % for all Eshkeda soils. Gypsum is present especially in the soils of the western area. Contents of 1 % $CaSO_4$ had been determined in the topsoil

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1) the Cg colouration is attributed to alteration of the original material by reduction and segregation of iron.

2) Auger hole borings determined the impervious base or shallow waterlogging layers at variable depth. Map shows the depth of loose soil to the impervious base or the presence of waterlogging layers for 298 farm areas.

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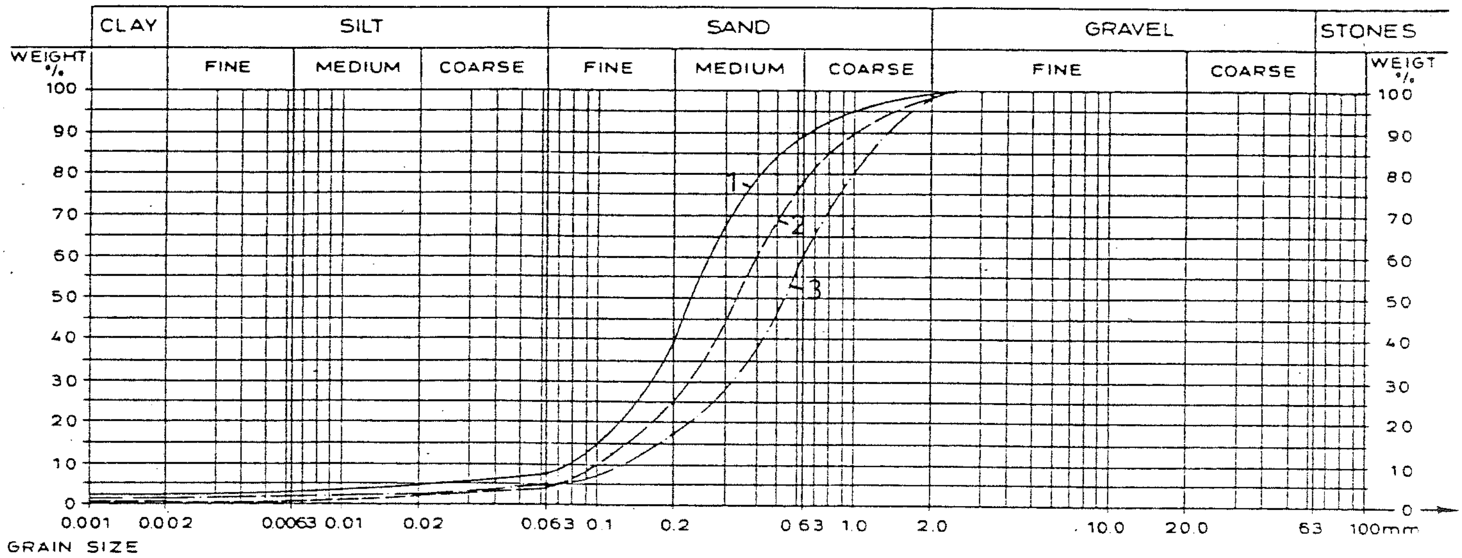

Figure 2 a: GRAIN SIZE DISTRIBUTION

Eshkeda project pit No. 14; 1 = 0- 25 cm
2 =90-120 cm
3 = 160-200 cm

D_u= 3.1→ 4.8
D_{10}= 0.08→ 0.12

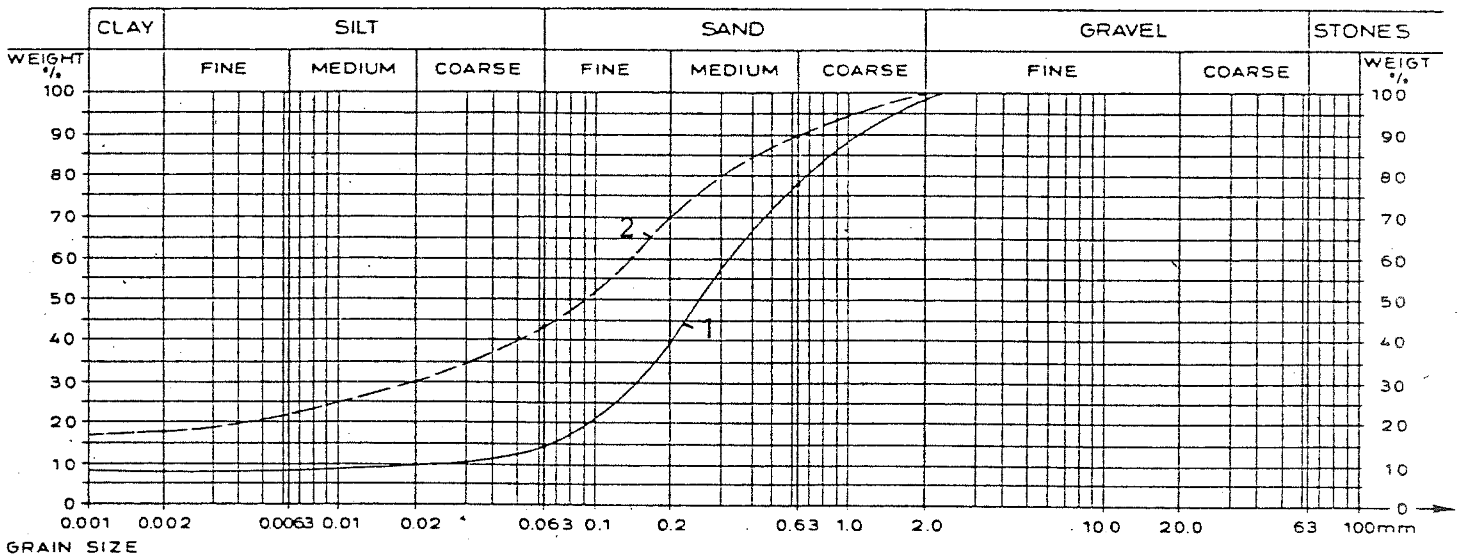

Figure 2b: GRAIN SIZE DISTRIBUTION

Eshkeda project pit No. 12 ; 1= 0-20 cm D_u= 16
2=95-120 cm D_u= > 300

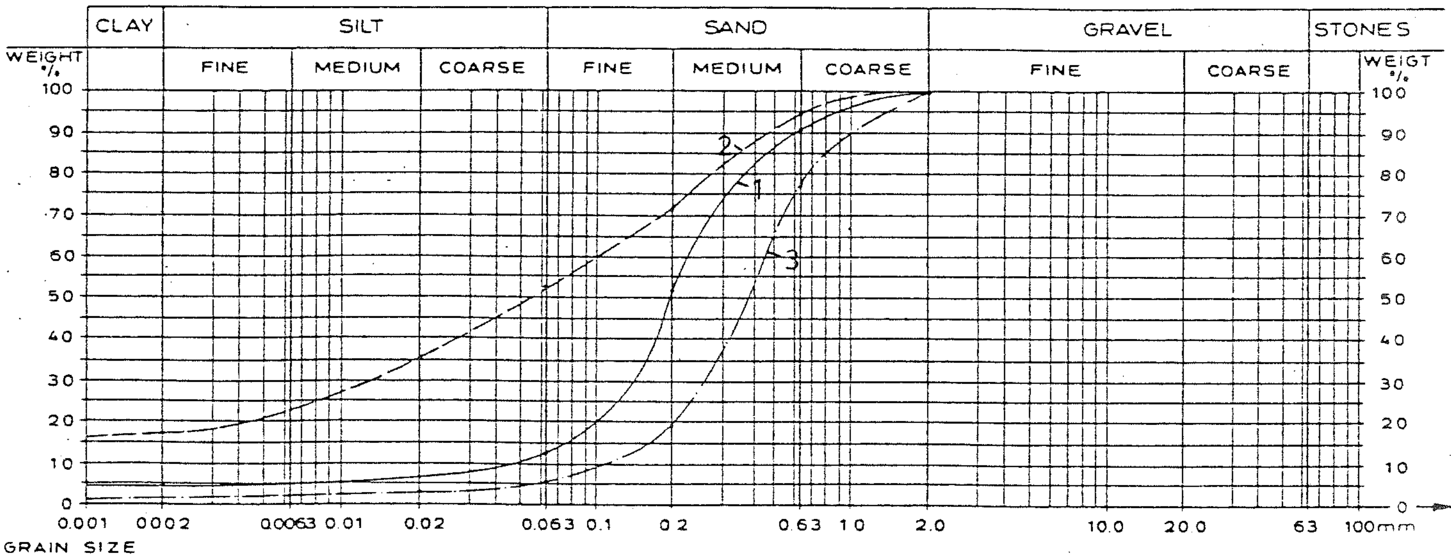

Figure 2c: GRAIN SIZE DISTRIBUTION

Eshkeda project pit No. 6 ; 1 = 0-25 cm D_u= 4;200;3
2 = 60-90 cm
3 = 150-200 cm

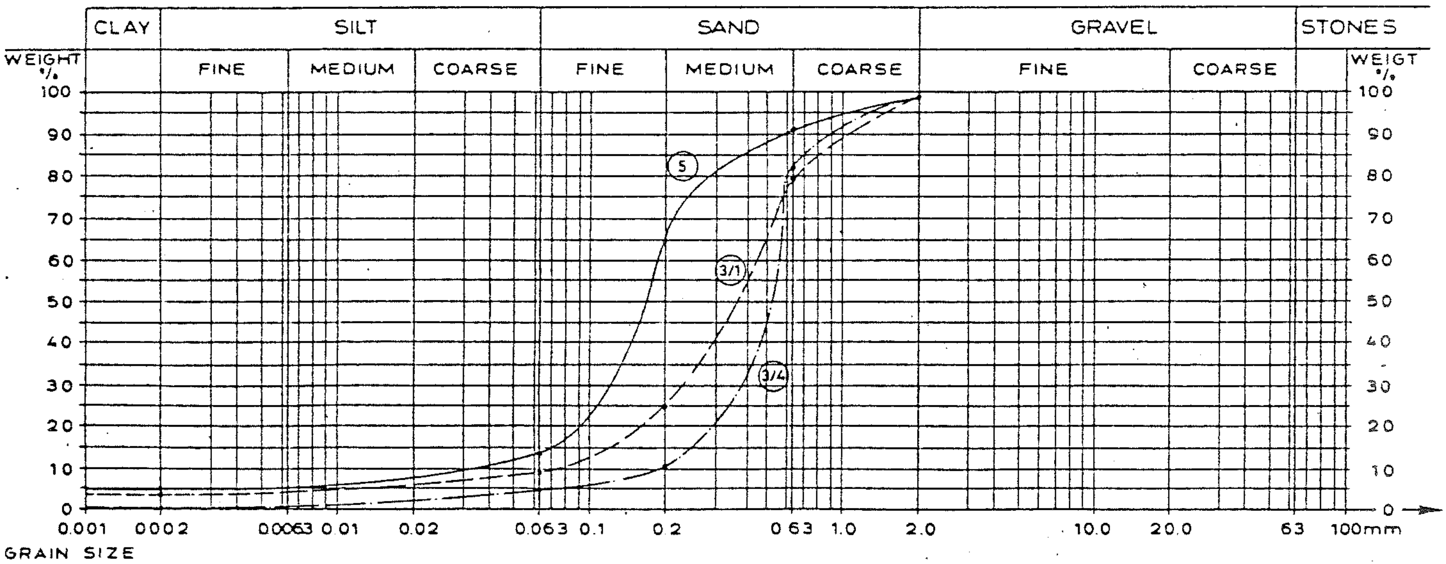

Figure 2d: GRAIN SIZE DISTRIBUTION

Eshkeda project pit No. 3 ; 1 = topsoil
2 = subsoil

Gleyic Cambisol (Berlin/Germany) pit No.5

horizons. The gypsum occurs also in the uncultivated soils of the surroundings; an Aa - By - C horizontation was mapped for these sites.[1] The salinity level is high in the gypsic B-horizon (20 mS/cm ≙ 0.28 % salt). Since the soils of the Eshkeda project are in general non-saline, the initial leaching of the soils prior to cultivation is not necessary and the leaching fraction (LR) is effective to keep the soluble salts out of the profiles.

b. Environmental characteristics. The soils occur in lower slope and summit sites and there appears to be no topographic influence on the development of the soil profile. The soils are derived exclusively from coarse grained aeolic accumulations of quaternaire geologic periods.

c. Associated soils. Soils of the Eshkeda project developed exclusively from the above mentioned aeolian deposits. The surrounding areas consists of pure clay or claystone, were Solonchaks with gypsic phases Zh 6-y developed.[2] Takyric features or vertic properties had not been identified on these sites. The salinity level is extremely high (2 - 3 % soluble salts) and petrosaline phases were frequently found. The surface of these soils seems to be within the capillary fringe zone of the watertable. The transitional zone between the sandy Eshkeda soils on higher topographical sites and the clayey Wadi Shatti soils consists of layered soils. Profile No. 32 is typical for these sites, where an essentially impermeable clay is covered by a coarse textured solum. The sandy cover may be derived from in-situ weathering of sandstone layers.

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1) (e.g. pit No. 29); ecological properties are shown in Diagram

2) e.g. pit Nos. 31 and 33.

Additional remarks. Biological activity is considered to play an increasing important part in the morphology of these soils. In many areas earthworm activity is very pronounced, the surface horizons being completely covered with wormcasts. Due to the infertile mineral matter, the organic matter will create improved conditions.

3.4.1 Soil Surface Salinity

The content of easily soluble salts (mainly NaCl) is in the range of 0.5 thru 53 mS/cm for the topsoil horizons (0 - 30 cm). The range of values are shown on Map 12 for the entire project area. The salinity level varies within the farm areas with regard to irrigation practices. Areas having a continued and uniform water application by sprinklers are less saline than areas where the water is distributed in furrows. The bare soil surface between the furrows has a slight salinity (4 - 8 mS/cm), due to the lateral through flow of water and solutes from the wet soil beneath the furrows.

The highest surface salinity level with an average of 11 mS/cm was analysed for the northwestern part of the Middle Zone. The eastern zone shows an average slightly salinity level of 2 - 4 mS/cm and 18 mS/cm for farm area which was left uncultivated until now (farm No. 10 district No. 25). Remaining farms in the western and central subareas are less saline and show EC values in the average range of 0.6 to 2 mS. Occasionally a medium salinity of 5 - 10 mS/cm was analysed for some farms; the deviations can be explained by variations of surface salinity between methods of irrigation, cropping pattern and preparation of land.

3.5 Soil Water Transmitting Properties

3.5.1 Infiltration Measurements

Infiltration describes the disappearance of water at the surface of the soil into the profile. If at any moment the rate of water application is so high that not all the water disappears at once, the infiltrability of the soil is exceeded. Thus, infiltrability is the most important soil property for planning irrigation systems and schedules. Upon it will depend, the rate at which water can be applied, the time necessary to apply an appropriate amount of water, and consequently the size and quantity of irrigation equipment to be used.

too simple.

The infiltration of a soil is not a constant. It decreases with time from the beginning of infiltration; it depends upon the initial water content distribution within the profile, and changes in the same way as the hydraulic conductivity which changes in the physiochemical properties of the soil, such as texture, structure, chemical composition and type of clay mineral present. The influence of texture is obvious as the water paths will generally be narrower, and thus resistance to water flow larger, when the percentage of small particles is higher. The packing density, uniformity of grain-size-distribution and aggregation modify the hydraulic conductivity towards a soil specific property.

The infiltration tests have been executed with a double-ring infiltrometer-set according to Schaffer/Collins. The infiltration rate is calculated by the falling-head method.

The process of infiltration can be characterized by the following quantities:

- the instantaneous infiltration rate (I_{inst}), which is the volume of water infiltrating through a horizontal unit area of soil surface at infinitely small period of time. It shows, in general, a rapid decline in the beginning, followed by a more stable, very slow decline after one hour of infiltration.

- the basic infiltration rate (I_{bas}), which is the relatively constant rate that developes after some hours. A good criterion of the term "relatively constant" would be a change in infiltration rate of less than 10 percent as compared with that of the preceeding hour, or $(I_t - I_{t+1}) < 0.1\ I_t$ (t expressed in hours). This is the physical quantity commonly used in hydrologic and runoff-erosion work. The (I_{inst})-time relationship is the basis for the design of sprinkler irrigation systems.

The following classification of basic infiltration rates is used:

Table 5 : <u>Classification of basic infiltration rates</u>

Class	Intake	Basic infiltration rate (cm/d)
0	very low	< 6
I	low	6 - 36
II	medium	36 - 67
III	high	67 - 127
IV	very high	> 127

Because of uniformity of soil type, change of the basic infiltration value depends on type of cultivation of the investigated area. Therefore infiltration rates were measured in almost each district on different areas cultivated with alfalfa, wheat, and in furrows resp. between furrows of orchards.

The following infiltration rates were observed in the project area:

Table 6 : Basic infiltration rate I_{bas} (cm/d)

Field No.	1 alfalfa		2 wheat		3 orchard in furrow		4 orchard between furrow	
	I_{bas} cm/d	class	I_{bas} cm/d	class	I_{bas} cm/d	class	I_{bas} cm/d	class
1.6 A							23	I
1.8 A					36	I/II		
2.3 A					74	III		
2.10A					63	II		
3.2 A	90	III						
3.10A							154	IV
4.6 A	277	IV						
4.9 A					23	I		
5.8 A	99	III	138	IV			323	IV
6.6 B			226	IV				
6.8 A	200	IV						
8.6 A					105	III		
8.8 A							186	IV
9.6 A					25	I	160	IV
10.5 B	105	III	102	III	182	IV	60	II
12.7 B	51	II	25	I	237	IV	474	IV
15.5 A	272	IV			315	IV		
15.6 A			264	IV	475	IV	123	III
16.5 A	136	IV	192	IV	295	IV	150	IV
17.3 A			176	IV	370	IV	172	IV
18.7 A	28	I	103	III	113	III	104	III
19.5 A	289	IV	187	IV	243	IV	135	IV
21.3 A	27	I	502	IV	22	I	66	II
22.5 A	114	III	156	IV	257	IV		
23.7 A					337	IV	142	IV
23.7 B	54	II	68	III				
24.5 A			63	II	79	III	69	III
24.5 B	330	IV						
25.7 A	30	I	278	IV	79	III	128	IV
average value	140	IV	177	IV	175	IV	154	IV

As shown, the infiltration rate differs from low (22 cm/d) to very high (502 cm/d) but is mostly very high.

Figure 3 shows the infiltrability for four typical measurement sites.

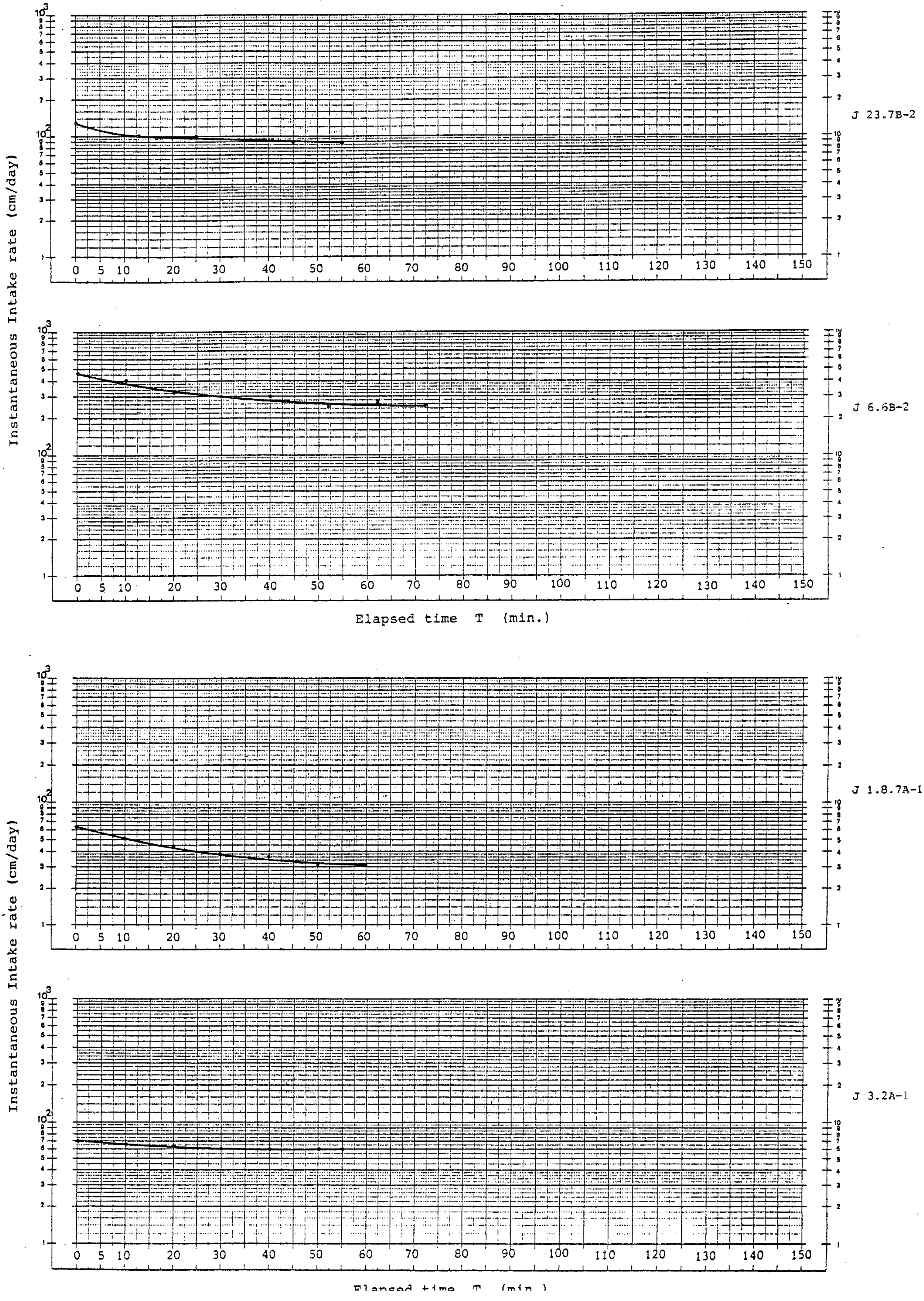
It can be seen that there is no homogeneous distribution of intake values on the project area. Also on equally cultivated farm areas different infiltration rate was measured.

It is to be assumed that local situation of irrigation status, soil structure, and root development is the reason of the very different infiltrability. In general it can be said that the infiltration of the whole project area is very high in average. Irrigation water infiltrates very fast and a high quantity of water reaches the phreatic groundwater table above the impervious layer.

and moisture retention is very low, therefore

Location measurement sites are shown in Drwg.No. 8 and the distribution of infiltration values are to be seen in Drawing No. 13.

Figure 3: Instantaneous Intake Rate



3.5.2 Soil Hydraulic Conductivity

The percolation rate or transmissivity of the soil profile is the most important soil property to be determined in regard of any possibility of perched water table conditions developing which may injure root crops (oxygen availability). The internal drainage conditions are expressed by the hydraulic conductivity (HC) of single horizons. In layered profiles with variating percolation rates the sequences of layers dertermine the internal drainage conditions.

The hydraulic conductivity mainly depends on the shape, size and quantity of pores in the soil. This relationship is described by the

Hagen-Poiseuille equation for liquid flow through a porous medium:

$$Q = \frac{r^4 \pi \Delta \psi}{8 \eta l},$$

in which

Q is the percolating water volume,

r the radii of the pores where water percolates,

$\Delta \psi$ is the hydraulic gradient,

η is the viscosity of the water and

l is the length of flow direction.

Since the pore radius strongly determines the percolation rate, in loose singular soils, the HC can be estimated by the use of the relation between pore-size-distribution and the grain-size curve. Hazen formula describes this relation as:

$$K \approx C d_{10}^2$$

where d_{10} is the diametre (cm) of grain-size which is found at 10 % in the grain size-curve. C is a empirical factor derived from the coefficient of uniformity

C_u and the bulk density (dry unit weight) d_s (gcm^{-3})

u \ d_s	1.5	1.6	1.7
1	150	127	111
5	113	96	82
10	101	84	69
15	98	78	63
20	93	75	61
25	92	74	59

Table 7 : C-value for calculation of the hydraulic conductivity K.

The C-value for the sandy soils in Eshkeda is in the range of 105 thru 69 with an average coefficient of 96. The average d_{10}-value of Eshkeda soils is 0.007 cm with an range of 0.01 thru 0.005 cm.

The sandy soils should have theoretically a saturated HC of 406 cm/d, with an range of 910 cm/d thru 150 cm/d for sandy soils. These theoretically values correlate quite well with the measured ranges of HC which are in the range of 120 cm/d thru 2400 cm/d, with an average range between 200 and 1200 cm/d. Therefore the permeability of the Eshkeda sandy soils is mainly a function of particle size.

Regardless of non universally acceptable minimum or maximum (economic use of scarce water resources) values for HC the following classes of HC were used to evaluate the soils for irrigation and drainage:

Classes	Saturated flow (cm/d)	HC-class
1	< 1	extremely low
2	1 - 10	low
3	10 - 40	moderately low
4	40 - 100	medium
5	100 - 300	high
6	300 - 1000	very high
7	> 1000	excessively high

The HC for Eshkeda soils is to be classified as high to excessively high. Topsoil horizons show a high percolation rate and occasionally medium values (pits No. 2, 6 and 7) when the sand contains more fine particles.

The subsoil horizons show very high to extremely high percolation rates.

The rather impervious clayey subsoil was found in one soil profile within 2 m depth (pit No. 12). The hydraulic conductivity of these layers is low (6 - 22 cm/d); a blocky structure favours the permeability where waterflow mainly takes place in the coarse macro-pores. The HC of the carboniferous substratum was additionally determined in a soil profile outside of the farm project area (pit No. 32). According to the Unified Soil Classification System the fine grained soil is classified as "inorganic clay of high plasticity (fat clays)" with a liquid limit greater than 50. The measured HC is for four replicate samples:

E.32/4-1	0.104 cm/d	=	1.2×10^{-6} cm/s
E.32/4-2	1.746 cm/d	=	2.0×10^{-5} cm/s
E.32/4-3	0.074 cm/d	=	8.6×10^{-7} cm/s
E.32/4-4	0.327 cm/d	=	3.8×10^{-6} cm/s
mean	0.563 cm/d	=	6.5×10^{-6} cm/s

L 5 mm/d

A layered profile is considered as impermeable if the K-ratio of the above layer and base layer is more than 100. For Eshkeda project this ratio is in the range of 500 thru 4000.

Hydraulic conductivity is a soil property that is highly dependent on the soil water content. The HC determined in the saturated material is expressed as

$$Jw = -K_w \frac{\Delta h}{\Delta z}$$

in which

Jw is the water flux density (cm/d),

K is the hydraulic conductivity (cm/d), and

Δ h is the difference in hydraulic potential (cm) between two points separated by a vertical distance Δ z (cm).

It is important to realize that the HC would be not the same at other water contents. In fact, HC of the soil decreases by several orders of magnitude as the water content changes from saturation to permanent wilting. The investigation program for Eshkeda project did not comprise the determination of the unsaturated flow in sandy profiles. Therefore an example is given to provide some informations on the quantitative changes in HC between saturated and unsaturated flow of sandy soils containing little fines.[1)]

horizon	Saturated flow cm/day	unsaturated flow (cm/d) at pF 1.7	2.0	2.3	2.7	2.85
Ah*	1990	200	60	0.2	0.05	0.002
Bv	800	20	0.1	0.001	0.0005	0.00007

Table 8 : Hydraulic Conductivity (HC) of a sandy soil at different moisture contents

1) The example of soil water properties of a sandy soil is derived from: Ökologisches Gutachten über den Ausbau und Betrieb der BAB Berlin auf den Großen Tiergarten; 1979; Sukopp, Blume, Horn, Petermann et.al.

* containing 2.5 % of organic matter

The grain size distribution is shown in Figure as No. 5, gleyic Cambisol (West-Berlin). The typical grain size curves of a sandy Yermosol in Eshkeda are plotted to compare the mineral constituent fraction of the soils.

The HC tremendously decreases even at low suctions in the range of 1.8 thru 2.5 pF (≙ 60 thru 220 cm water column). The volume water content at pF 1.8 and 2.3 are 28 % (Ah) and 17 % (Bv) resp. 18 % (Ah) and 6 % (Bv). At lower suction than pF 2.5 the unsaturated HC of a clean sandy soil is below the HC of silty or clayey soils. Therefore it is easy to understand why sandy soils are prone to draught, since the low HC does not permit sufficient water movement at a water content which is only slightly below the Field Capacity.

The capillary rise of the water from the shallow watertable is of importance for the determination of minimum drain depth required to keep the capillaries of the saline groundwater out of the lower rootzone. The capillary rise depends on

(1.) the water suction at the soil surface or the lower part of the rootzone and

(2.) on the unsaturated hydraulic conductivity of the zone between the groundwater table and rootzone.

Under steady state conditions the capillary rise can be determined by the use of the Darcy equation. The calculated rate of capillary rise for the sandy soil discussed above amounts is as follows:

	capillary rise (cm/d)								
	1	0.5	0.3	0.2	0.1	0.05	0.03	0.02	0.01
ψ cm	height of rise z (cm)								
30	28	29	29	29	29	29	29	29	29
60	50	54	56	57	58	59	59	59	59
100	61	70	76	81	87	92	95	96	98
300	65	77	87	95	111	130	145	158	182
600	66	78	88	96	113	132	149	164	192
1000	66	78	88	97	114	133	150	165	194
3000	66	79	89	97	114	134	151	166	196
10000	67	80	89	98	115	135	152	167	197
15000	67	80	89	98	115	135	153	168	198

Source: op cit., 1979

Table 9 : Relation of capillary rise and height of rise (z) dependent on the hydraulic gradient in the rootzone (Gleyic Cambisol)

From Table 9 the capillary rise of groundwater can be seen. At a suction of pF 2.5 (300 cm water column) and a capillary rise of 0.05 cm/day the height of rise is 130 cm. The value of 0.05 cm/day uprise is the lower limit of water movement which is ecologically relevant to plants. An average capillary rise of 0.5 cm/d is used as a sufficient rate[1]; at low suctions (pF 2.0 thru pF 2.8) an average capillary height of 70-78 cm was determined. These values are in agreement with the field observation in Eshkeda project, derived from the degrees of wetness of soil horizons above the groundwater table.

and Salinization!

1) according to soil-water standards of the "Bundesanstalt für Geowissenschaften und Rohstoffe", Hannover-West Germany

OK, but in non saline conditions

3.6 Description of Soil Auger Investigations

3.6.1 Impervious Layer

The carboniferous shales of the Mrar formation covered by alluvial and/or aeolian sediments with thickness from about 10 m to almost zero must be regarded as negative confining bed. This bottom of the phreatic groundwater mainly consists of clay and silty clay and is underlain by fine to coarse sand with interbedded gravels. The hydraulic conductivity of the layer is in range of about 6 - 22 cm/d and in comparison with the upper soil horizons absolutely impermeable. The results of field investigations for determining the depth of impervious layer are shown in Drawing 9. The relief of the layer is rather undulated and does not coincide with the topography of the soil surface. In the western area the base is quite deep and only in one plot the layer is uprising to the soil surface. But in general it is lying in depths of more than 4 m below soil surface. In the western part of the central area the layer comes up to the soil surface resp. is very shallow, whereas in the eastern part it only could be analysed on three plots. In the eastern area the depth of base is inhomogeneous changing from zero to more than four meter.

In conformity with the relief of the impervious base the table of groundwater is reaching the soil surface. Recharge of this upper groundwater horizon is given by surface water from northern hills, sporadic heavy rainfalls, infiltrating irrigation water and also by leackage water from the paleozoic aquifer rising through fault zones of the layer.

3.6.2 Determination of Groundwater Table

The project area is underlain by clay and siltstone of the Mrar formation, which has a thickness of 80 - 120 m. The hydraulic conductivity of this formation is very low compared with the overlaying sands. From point of view of land drainage the Mrar formation must be considered as "impervious layer".

By applying irrigation water in excess of crop requirements a general rise of the water table was the result. Where the water table has reached the root-zone already, capillary rise of salt-loaded water and the removal of water by evapotranspiration, leave behind a greatly increased concentration of salts in the root-zone and/or surplus of water.

Investigations with soil auger showed that the depth of shallow groundwater varied between 0.5 m to about 4.0 m, depending on the elevation of soil surface and on the impervious Mrar formation.

maybe

The field investigations were executed in August so that the results only can give instantaneous conditions of the actual situation and nothing can be said of the annual range of groundwater level. During winter months with reduced mean temperature, relative increase of rainfall and lower evaporation the groundwater table will rise. According to the local climatic conditions and the reduced evapotranspiration of plants the lowest groundwater table in general can be expected during July and August.

It can be stated, that in areas where the impervious layer is located at a depth of about 5 m the groundwater table can be found at a depth of 1.0 - 1.5 m. In these areas the high groundwater level is documented by soil surface salinity, mainly near windbreaks and channels with high evapotranspiration.

In the upper areas of the western area with also deep impervious base no groundwater was found (see Drawings 9 + 10) whereas in the central area inspite of variations of the impervious layer, mainly in the eastern part, the groundwater table is quite homogeneous till 2 m with only few exceptions. Contrary to the other areas the eastern area shows no shallow (0 - 1 m) groundwater table but the values are mainly in range of 1 m - 3 m and deeper.

In areas where the impervious layer is less than 2.0 m, the water table was found at a depth of 0.6 - 0.9 m. In these areas crops can not be grown profitably because of yield reduction. Even some farm plots have been infested with reeds and have been taken out of production. This progressive deterioration of worthfull arable land will now be stopped by adequate drainage.

Drawing No. 10.1 shows the Isopiestic Contour lines which are evaluated from the observed ground water table in auger holes.

3.6.3 Groundwater Properties

Water quality and drainage problems are very often interrelated and adequate control of a potentially damaging water table is recognized as an essential requirement to successful long term irrigated agriculture.

The quality of water can be assessed by the salinity, alkalinity and the content of Boron. According to the "International Standard Methods" of the Salinity Laboratory the electrolythe concentration measured as mS/cm is an index of the total salinity.

The total quantity of soluble salts in saline soils reduces crop yields or even makes crop production impossible. This limit is generally approx. 1 % salt in soil solution, although such reduction in relative yield can be observed at a level of 0.1 %.

Not all salts are equally harmful. Sodium salts, most chlorides and magnesium sulphates are more harmful than $CaCO_3$, bicarbonate or gypsum (less soluble salts).

The water quality is classified in four categories based on electrical conductivity values:

Electrical Conductivity µS/cm	Salinity assessment
< 250	low salinity
250 - 750	medium salinity
750 - 2250	high salinity
> 2250	very high salinity

Class I: This water can be used safely of most crops and on most soils

Class II: If a moderate amount of leaching is possible plants with moderate salt-tolerance can be cultivated.

Class III: Use is only possible on soils with adequate drainage and for crops with fair salt-tolerance, and provided management practices for salinity control are applied.

Class IV: Only salt-tolerant crops on permeable soils and with adequate management practices can be cultivated.

The electrical conductivity of the groundwater ranges in the project area from non saline to very high saline, most values are in the range of medium saline (see Drawing 14 and Annex 5). The level of salinity shows no homogeneous distribution within the project areas, because of different influences such as permeability resp. impermeability of soil, method and amount of irrigation, level of groundwater table.

?

For drawing the actual salinity level below the maximum allowable level of 1.2 mS leaching of salts out of the rootzone is required (see chapter 5.7).

With this foreseen ameliorative leaching it is aimed to remove the salinity as limiting factor so that future crop production will not be hampered.

Boron

This mineral is one of the essential elements for plant growth, but it is needed in relatively small amounts. At low concentrations it is beneficial but it is apt to accumulate in the soil following irrigation and may reach toxic concentrations. Water containing 1 mg/l of boron can still be considered as safe for most field crops; semi-tolerant crops, such as lima beans, oats, sorghum, barley, and cotton are sensitive to concentrations of 1 to 2 ppm, while lucerne, sugar-beets, and date palms can tolerate concentrations of 2 to 4 ppm, which is the upper permissible limit for all crops.

Values of about 20 - 100 ppm are in the toxic range and result in leaf burn.

Boron is well distributed through most arid soil profiles. But different soils have the ability to absorb or fix boron in varying amounts. The release of boron to soil solution from which it is absorbed by plants depends on the mechanism of fixation. In alkaline and clayey soils boron is less mobile and less readily removed from soil interfaces. In case of leaching larger quantities of water are required than are necessary for sodium salts, as boron is held more strongly by the soil.

The content of Boron ranges from 0.019 mg/l till 1.210 mg/l with an average value of 0.306 mg/l. Only the amount of sample No. 1 at farm No. 1 in district 18 (central area) has the high amount of 4.08 mg/l. This may result from the continuously high groundwater level in the water logged area. At this site also the salinity level is extremely high (8.33 mS/cm). But these extremely high values are not representative for the project area and will improve with the drainage and leaching measures.

As at 19 samples the boron content is below 0.75 mg/l, no specific problems for sensitive crops are to be expected.

sample	Boron mg/l
1	4.075
17	1.210
22	0.516
24	0.682
40	0.271
41	0.178
42	0.089
43	0.105
45	0.019
46	0.081
49	0.446
59	0.053
75	0.087
107	0.465
121	0.795
131	0.244
133	0.528
162	0.061
176	0.042
221	0.135

3.6.4 Field Measurement of Hydraulic Conductivity

With respect to the design of drainage systems it is neccessary to know the hydraulic conductivities of the subsoil and substratum. The auger hole method is a useful method for measuring permeability of the soil below the water table.

In accordance to the arranged investigation program boreholes were drilled on each farm in the project area. About 300 drillings of 2 1/2" diameter with "Minute man" drilling equipment and accompanying soil profile descriptions have been executed.

Because of the existing instable sandy soils in the Eshkeda area perforated tubes with diameters of 6.5 cm were inserted into the holes.

After pumping out water and mud from the hole the rise of the water level was measured with the standard equipment for auger hole measurements.

The sites of measurements are shown on Drawing No. 7.

In several farms no groundwater could be observed until 4 m depth below surface and therefore no measurement could be carried out.

In case of two different existing layers a second bore hole had to be drilled nearby to determine the hydraulic conductivity of the upper and lower layer.

Depth of groundwater level and if possible depth of impervious base was measured and can be seen on drawing No.9 and No. 10.

The following equations of Ernst/Hooghoudt can be used for computing the Hydraulic Conductivity:

for S > H $\qquad k = \dfrac{4000 r^2}{(H + 20r)\ (2 - \frac{y}{H}) y} \dfrac{\Delta y}{\Delta t}$ [m/d]

for S = o $\qquad k' = \dfrac{3600 r^2}{(H + 10r)\ (2 - \frac{y}{H}) y} \dfrac{\Delta y}{\Delta t}$ [m/d]

in which is k = hydraulic conductivity

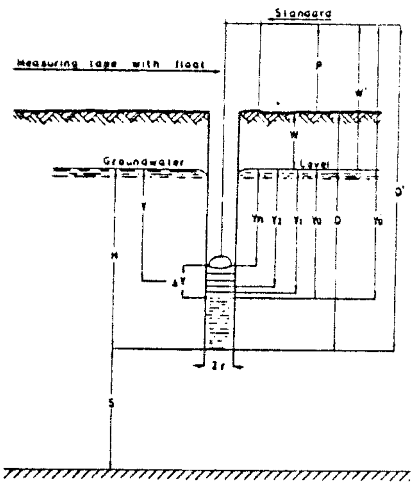
H = depth of hole below the groundwater table

y = distance between groundwater level and the average level of the water in the hole for the time interval t

r = radius of auger hole

S = depth of impermeable layer below the bottom of the hole.

Figure 4 : Scheme of Auger Hole Measurement



Normally 4 - 6 readings of Δy were taken for fixed intervals of time (Δt).

The data of field measurement can be seen from Map No. 14 which includes all irrigation districts of the Project Area. The values of the subareas are in range of about

Western Area:	50 cm/d thru 1900 cm/d
Central Area:	140 cm/d thru 2190 cm/d
Eastern Area:	70 cm/d thru 1150 cm/d

Following the classification of HC-values from chapter 3.5.2 the HC for the project area ranges from medium high to very high resp. excessively high.

The mean values of the subareas are in the range of 440 cm/d in the eastern area, 720 cm/d in the central area and 550 cm/d in the western area. According to these data it can be said that the topsoil horizons of Eshkeda soils in general have very high percolation rates.

The values of field measurement coincide very well with the percolation rates analysed in the laboratory which are in the average range from 200 to 1200 cm/d.

The hydraulic conductivities of single rather impervious clayey subsoil layers as mentioned in chapter 3.5.2 are superposed by the higher percolation rate of the topsoils so that the values of field measurement are in general more balanced than laboratory data.

On some farms of the project area field measurements were not possible. Either the groundwater table was not reached by the drillings or because of the quick entrance of mud into the holes inspite of using perforated tubes for reducing silty and clayey soil material.
The evaluated k-values are presented in Annex 5.

4. Irrigation

4.1 Methods

One district (12 farms) consist of one deep well, pumping station, and water reservoir of 2.400 m^3. From the reservoir the water is delivered by high pressure pumps through subsurface pipes to 4 hydrants of each farm. From the hydrants the water can be distributed to the whole farm area by means of quick-coupling movable aluminium pipes. In the fields water application depends on crop varieties: either surface irrigation (furrow, trickle) or overhead irrigation (sprinkler).

Trickle irrigation is no more practized and is replaced by furrow irrigation although water losses are much higher.

4.2 Irrigation Quantities

On paper!

The annual water volume per district amounts to 1.667.760 m³, in wintertime the monthly peak volume will be in March and amounts to 147.600 m³, in summertime (July / August) the amount will be 183.800 m³ (Annex, Monthly irrigation quantities).

These volumes correspond per district (120 ha gross area) to the

annual irrigation rate of 0.44 l/sec · ha ≙ 3.80 mm/d

monthly peak irrigation rate (winter)
0.46 l/sec · ha ≙ 3.97 mm/d

monthly peak irrigation rate (summer)
0.57 l/sec · ha ≙ 4.92 mm/d

At present time water is not only used for agricultural crops and fruit trees but also for furrow irrigation of windbreaks. When trees and shrubs of shelterbelts are grown up, they are able to supply themselves with groundwater so that no additional irrigation water will be necessary. Therefore the groundwater can be used in future for irrigation of agricultural crops only.

Besides from 3.90 ha perennial crops further 3.30 ha are cultivated in winter. The cultivated area for ephemeral crops will be reduced in summer to 0.50 ha vegetables only. The irrigated area is therefore in wintertime (without windbreaks) 7.20 ha, in summer (without windbreaks) 4.40 ha.

Accordingly the gross irrigation rate on the calculated farm areas is

$$\text{in winter:} \quad qi = \frac{147{,}600\ m^3 \cdot 1000\ l/m^3}{12 \cdot 7.2\ ha \cdot 31\ d \cdot 86400\ s/d} = 0.64\ l/s\ ha \triangleq 5.52\ mm/d$$

$$\text{in summer:} \quad qi = \frac{183{,}800\ m^3 \cdot 1000\ l/m^3}{12 \cdot 7.4\ ha \cdot 31\ d \cdot 86400\ s/d} = 1.30\ l/s\ ha \triangleq 11{,}23\ mm/d$$

4.3 Irrigation Efficiency

The irrigation system as a whole shows considerable losses. Unfortunately, no records about exact pump hours or quantities from well pumps and irrigation pumps are kept. Also no measurement about drainage water outflow from the project areas are available. Therefore no cross-check calculations are possible and the irrigation losses must be estimated. Any calculation of crop water requirements and comparison with the used volumes does not permit sufficient statistic figures to determine drainage water quantities. According to the irrigation practice the irrigation pumps and well pumps do not operate at night time. At the wells which are still under artesian pressure the water will continue to flow at a reduced discharge into the reservoirs. The field check has shown that this occurs to the deep lying wells in the western area (up to elevation 336 m) with estimated flows of about 10 l/s. In case of filled reservoirs at coming a overflow of reservoirs may occur for that reason. As the artesian pressure will be lowered in future these losses will be reduced accordingly. The estimate of the losses according to the international experience and compared to the irrigation practise at site will lead to more reasonable results.

Most of the deep wells show on the well heads considerable losses at pipe joints and valves. Up to 5 %, in average about 3 % of the well water is lost before reaching the balancing reservoir. Around many of the balancing reservoirs the soils show capillary rised water, which results mainly from reservoir leakage. In average per reservoir the losses are estimated to 4 %. From the irrigation pumps through the pipe distribution net to the field hydrants another 3.0 % may be lost. The field pipe system from hydrant to the sprinkler can be counted with about 5 % of losses.

From the water supplied from the sprinkler a loss of about 5 % will occur by evaporation before the water will reach the field surface. From the water reaching the field surface about 70 % will be used for evatranspiration but the other 30 % will occur as deep percolation loss contributing to the ground water.

Summarizing the different losses the following efficiencies will be reached:

deep well	loss	3 %	efficiency	0.97
balancing reservoir	loss	4 %	"	0.96
distribution net	loss	3 %	"	0.97
field pipe system	loss	5 %	"	0.95
sprinkler application	loss	5 %	"	0.95
field application (deep percolation)	loss	30 %	"	0.70

With these values the conveyance efficiency is
0.97 x 0.96 x 0.97 x 0.95 = 0.86

and the total irrigation efficiencies
0.86 x 0.95 x 0.70 = 0.57.

OK

This value is reasonable, comparing to other sprinkler irrigation projects in arid zones.

5. Drainage

5.1 Present Status of Drainage System

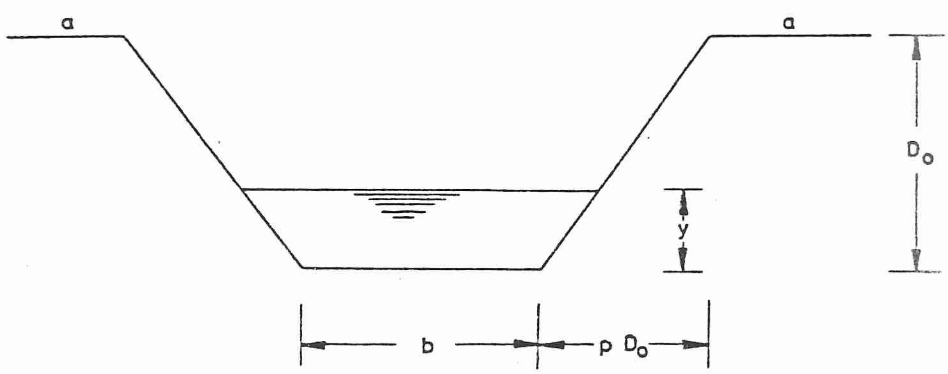
Excess of water in or on soils must be removed within the soil by downward or lateral flow through soil and substrata and/or by means of drainage. Water is "in excess" when the amount present adversely affects the production of crops by reducing the soil volume accessible to roots.

The lay-out of the drainage scheme was designed in conformity with farm sizes, i.e. field size and design of irrigation schemes. Farm districts are surrounded by open drainage channels.

Ditch drains are used because of their specific advantages, such as:

- receiving both groundwater and surface run-off
- required gradient for water transport can be much less than in pipe drains
- easy inspection and maintenance

The drainage system consists of 1 m to 4 m deep channels with relatively steep slopes. Standard cross-section of the ditch channels is:



Cross section of a ditch

a = berm : ~ 3 m

b = bottom width: 1 - 2 m

Do = total depth : 1.50 m - 3.50 m

y = depth of water: zero - 0.30 m

$Do/_{pDo}$ = side slopes, expressed as 1 : p =

$\frac{\text{vertical}}{\text{horizontal}}$: 1 : 1 (sandy soils) to 1 : 1.5 (unstable sands)

Length of ditches depends on length of fields and lay-out of project area. The total length of present drainage system is about

Western Area:	70 km
Central Area:	20 km
Eastern Area:	10 km

The actual condition of ditches is very different, mainly depending on soil condition, water keeping and wind direction. Ditches surrounding the project area are filled in some parts with aeolian sand. These channels are outside of the shelterbelts so that they are not protected against sand storms.

Within the project area ditches are of better condition and will operate in case of surplus of water. Channels that kept water at time of site inspection showed intensive growth of aquatic and terrestric plants. Discharge velocity is very slow < 0.20 m/s or nearly zero, which results from insufficient cleaning and insufficient outlet. Because of growing of reed at the slopes it can be stated, that these channels are containing water throughout the year. Partly the reed was 2 m high and also grew on the bottom of the ditches so that the transport of water will be strongly reduced.

and "dry" drains

Especially at the northern edge of the project insufficient out-let exists and permits intrusion of reeds not only in the drainage channels but also in the cultivation areas.

Actual problems with insufficient drainage could be seen in the following districts:

2, 3, 4, 5, 7, 9, 10, 11, 14, 17, 18, 19, 20, 21, 22 and 25.

Groundwater level in these areas reaches the soil surface while in most of the areas the water level is 0.7 m to 1.0 m and more below surface. This lower level in summertime results from high evapotranspiration rates and it is reported from wintertime that the groundwater table will reach in several districts the surface. In general it can be said, that the groundwater table increases from year to year. According to morphologic conditions the higher located farms are not or less concerned with drainage problems.

In order to draw down the phreatic water table a drainage system within the agricultural districts is required. Furtheron it deems important to take care for free flow conditions (weed control, maintenance) of the drainage outfalls.

Present status of drainage system see Drawing No. 2.

Table 10: Quality of Drainage Water at present time

(see Drawing No. 4)

Sample of Drainage / Well / Sabkha, wadi	EC(mS/cm) 25°	pH-value	Salt content (g/l)
D2	2.3	7.8	1.5
D3	2.94	8.1	1.9
D4	2.15	7.8	1.4
D5	9.72	8.1	6.2
D6	1.52	8.0	1.0
D7	2.48	8.0	1.6
D8	1.48	8.0	0.9
D9	3.66	7.7	2.3
D10	1.08	8.4	0.7
D11	3.92	7.9	2.5
D12	2.98	7.9	1.9
D13	1.66	8.0	1.1
D14	5.09	8.0	3.3
D15	2.11	7.9	1.4
D17	2.67	7.9	1.7
D18	4.95	7.9	3.2
D19	2.66	8.0	1.7
D20	1.13	7.7	0.7
D21	2.93	8.2	1.9
D22	2.21	7.9	1.4
D23	2.73	8.0	1.7
D24	1.88	7.9	1.2
D25	7.57	8.0	4.8
D26	5.25	8.0	3.3
D27	1.69	8.1	1.1
D28	1.71	8.1	1.1
D29	4.10	8.0	2.6
D32	6.47	8.2	4.1
D33	2.46	8.4	1.6
D34	4.55	8.0	2.9
W1	0.66	8.0	0.4
W5	0.63	7.9	0.4
W6	0.63	8.1	0.4
W7	0.70	7.8	0.4
W8	0.70	7.1	0.4
W9	0.66	7.8	0.4
E0	28.5	8.6	18.2
E6	5.2	8.2	3.3
E31	4.4	8.0	2.8

5.2 Whereabouts of Drainage Water

The actual drainage system only consists of open main drains collecting excess of water from farm plots from where it shall be discharged outside the project areas. Because of the undulated morphologic conditions not all water will drain into the channels. Excess water from the higher parts of the project areas follows to a certain amount the impervious layer below soil surface, aggravating the drainage problem in those lower parts. It also cannot be excluded that water from the open channels will infiltrate into surrounding soils from where it will rise in the upper horizons by capillarity. Dissolved salts are being transported as well. A closed drainage system with field drains and field collectors will therefore be required.

The solution proposed by ITL to execute different drainage outfalls from the districts to the Wadi does not fit with the topographical conditions. Especially the western part of the western area cannot be drained - even not temporarily - by ITL proposal. The only solution for the functioning drainage system efficiently is to collect the water by a main drainage channel (piped) along the northern border of the project area.

According to the lay-out of the main channels and the morphology of the area nearly all drainage water from the western zone and parts of the middle zone will be conducted to the depressions of Wadi Al Shatti which flows northerly along the border of the project area. The eastern zone and adjacent parts of the middle zone predominantly discharge into neighboured depressions (sebkhas) where it evaporates or percolates without any agricultural use. Because of the amount of drainage water and its continuous flow the re-use of the water is recommended.

5.3 Drainage Water Quality

The present salt content of the phreatic groundwater, i.e. from groundwater samples from pits at leaked sites shows values of about 0.7 g/l to 6 g/l. This wide range of salinity could only be found in the western area and expresses the salt problems resp. the importance and urgency of drainage.

The water in drainage canals shows values up to about 6 g/l. With the performance of an effective drainage system the concentration will be reduced reaching a balanced status in the range of 1.3 g/l to 1.6 g/l resulting from the low salinity level of the irrigation water (0.5 g/l).

As observed in most of the pits with medium textured soils the capillary zone shows values of about 0.7 m above phreatic water level. As mentioned above salt accumulation occurs whenever a deep horizon rich in salts becomes saturated with water. Accumulation is greatly accelerated when due to a high water table.

The critical depth of groundwater depends upon numerous environmental and technico-economic factors, but in general a correlation exists between the total salt content of the groundwater and the so-called critical depth. The higher the degree of mineralization, the greater the depth from which the groundwaters can salinize the soil and thereby reduce or even destroy crop production.

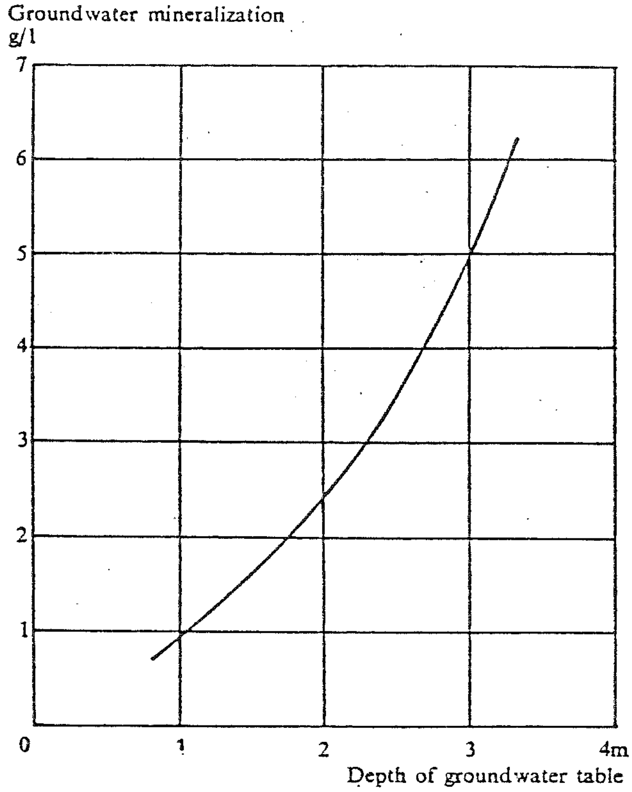


Figure 5: Relation between groundwater salt content and the critical groundwater level.

5.4 Effects of Salinity on Crops

Salts effect plants directly in two ways: by increasing osmotic pressure and by the specific toxicity of their ions. Indirect effects result from nutritional disturbances, from effects of salts on micro-organisms and on soil structure - the last mentioned often resulting in adverse physical conditions for plant growth. Depending on the susceptibility of crops these factors effect crop yields in various degrees (Figure 6).

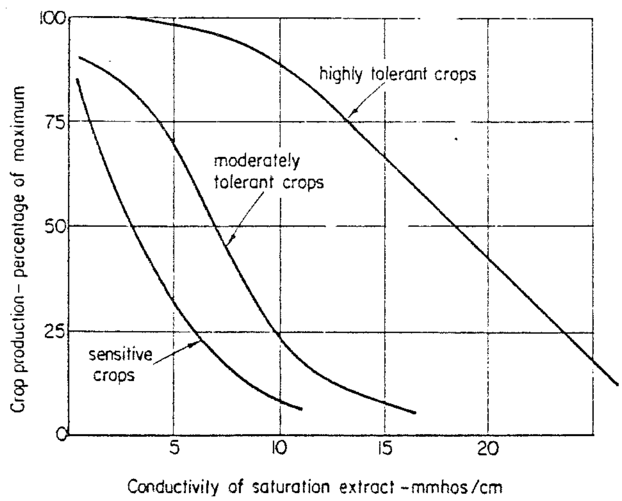


Figure 6: Relationship between Crop Production and Soil Salinity

With shallow water tables, salinity problems may also exist to upward movement of water and salts from groundwater as the water evaporates from the soil or is used by crops. This kind of salinity is related to high water tables and lack of drainage. To avoid salt accumulation to an excess level, they must be removed in amounts about equal to the salts applied (salt balance concept).

By withdrawing water from a salty solution and by evaporation soil dries out between irrigation intervals and salt concentration increases progressively. Plants are therefore submitted alternatively to an excess of salts, followed by a sudden excessively rapid uptake of water which occasionally cause the rupture and death of the cells.

Many ions which are harmless or even useful at relatively low concentrations may become toxic at high concentrations. Ions that are most likely to be toxic to plants are chloride, sodium, bicarbonate, sulphate, and boron. The excess of certain ions frequently has disturbing effect on the absorption of other ions. So, higher concentrations of sulphate generally decrease the uptake of calcium whilst promoting the uptake of sodium, thereby causing toxicity in susceptible crops. High concentrations of calcium may interfere with the uptake of potassium saline soil containing a high proportion of magnesium to calcium, may cause Ca deficiency in plants.

The increased pH, due to the increment of sodium carbonate, reduces the availability of P, Fe, Zn and Mn.

5.5 Amount of Drainage Water

Except the water lost from the sprinkler by evaporation to the air all other losses contribute to the groundwater recharge which has to be drained off from the project. Also the losses at wells and reservoirs feed the groundwater.

Therefore the drainage water recharge must be calculated as

$$1.00 - 0.86 \times 0.70 = 1.00 - 0.60 = 0.40$$

i.e. 40 % of the well discharge are subject to the drainage system.

Therefrom the drainage water rate is per district (120 ha gross)

annual average	0.40 x 0.44 l/s +ha = 0.18 l/s +ha $\hat{=}$ 1.55 mm/d
monthly peak (winter)	0.40 x 0.46 l/s +ha = 0.18 l/s +ha $\hat{=}$ 1.55 mm/d
monthly peak (summer)	0.40 x 0.57 l/s +ha = 0.23 l/s +ha $\hat{=}$ 1.97 mm/d

and per farm

monthly peak (winter)	0.40 x 0.64 l/s +ha = 0.26 l/s +ha $\hat{=}$ 2.22 mm/d
monthly peak (summer)	0.40 x 1.30 l/s +ha = 0.52 l/s +ha $\hat{=}$ 4.49 mm/d

The peak drainage rate of 4.5 mm/d results from the irrigation being constructed on 4.4 ha cultivated area. As the hydraulic conductivity of the subsoil is generally very high the percolating water from the cultivated plots will distribute relatively fast over the whole subsurface field size. From this point of view it is permissible to calculate the drainage water rate also in summer peak over the whole drained field size

40 % · 183,800 m³/ 12 · 7.6 ha · 31 d = 2.6 mm/d.

According to this value and considering a distribution margin it is recommended to calculate field drains and field collectors at a rate of 4.5 mm/d, see report on "Maindrainage system and Design Parameter" section 2.1.1, page 6.

Where farms are irrigated but not drained the drainage water shall be collected by catch drains at the lower site or by dimensioning the lower located drainage system at appropriate increased drainage water rates.

The main drainage system shall be dimensioned according to the connected gross irrigation area independent if field drainage system will be executed

at a rate of 2.5 mm/d.

This value covers the summer peak drainage rate at a 20 % safety margin.

If additional groundwater inflow occurs from outside areas or leakage from deeper aquifers, additional drainage measures are necessary.

5.6 Parameter of Drainage Design

5.6.1 General Design Principles

As a general rule, irrigation results in a significant rise in the level of the groundwater which is in arid regions usually much more saline than in humid regions. When the water table has reached the root-zone capillary rise of salt-loaded water and the removal of water by evapotranspiration leave behind a greatly increased concentration of salts in the root zone.

Subsurface drainage is used to

- control water tables which would otherwise rise to or near to the ground surface for extended periods
- improve the internal drainage and thus to permit the free movement of air and water
- leach the existing salts occuring in the orchard and vegetable farms

For practical reasons the lay-out of subsurface pipe drainage scheme will be designed in conformity to the irrigation scheme lay-out. It refers to the large scale project pattern itself as well as the gridiron system of the farm blocks. Besides this the lay-out includes the following main factors:

- drainage units with position of collector drains and direction of field drains in respect to slope
- depth and spacing of drains
- drain pipe diameter and gradient.

For drainage to be effective, it is necessary to lower the water table over a fairly large area. This cannot be achieved by the individual farmer so that the drainage lay-out has to include the whole project area.

The subsurface pipe drainage scheme consists of three types of drains:

1. Field drains

   Dependent on size of farm plots the length of field drains will be about 170 m or 220 m.

   The maximum hydraulic head of the field drain shall be 0.2 m, their depth below surface shall be 1.20 m to 1.80 m. In case of reduced soil thickness a lower depth can be expected, but if the impervious layer is at a depth of 0 - 1.00 m below surface the area will not be drainabel. These farm plots are unsuitable for irrigation.

   The minimum gradient of the field drains shall be

   $$s_{min} = 1 \text{ ‰}.$$

   The maximum slope of the drains is related to the permissible flow velocity in the drains and should not exceed $s_{max} = 8$ %.

   The feeder pipe diameter shall be at least 50 mm. Calculation of pipe diameter for 60 % of full flowing capacity is usual, see report on "Main-drainage system and Design parameter, section 2.1.5, page 7.

   Drain spacing and design data of the field drains are subject of the final design, for which the formula of Hooghoudt will be applicable.

   $$s = \sqrt{\frac{8 \cdot k_2 \cdot d \cdot h}{q} + \frac{4 \cdot k_1 \cdot h^2}{q}} \quad (m)$$

   s = drain spacing (m)

   k = hydraulic conductivity (m/d)

   d = the thickness of the so-called equivalent layer which depends on the distance D from drain depth to the impervious base, the drain spacing s and the wet perimeter of the drains.

   h = height of water table above the drain (m)

   q = specific flow to be drained (m/d)

For practical reasons drain spacing must be adapted to the size of plots and the existing agricultural use particularly on orchards.

Normally a gridiron system shall be designed for the field drainage scheme, but with respect to the topographical situation a herring-bone system is required in few farms.

To design the field drainage system in detail additional survey of topography is to be executed on site.

2. Collector drains

To collect drainage water from the field drains and to transport it to the main drains unperforated collector drains are designed along the boundaries of farms or across the farms. The pipe diameter of the collector drains must be calculated for hydraulic reasons and will be in the range of 100 - 200 mm normally. For checking and observing the field drainage system inspection chambers should be constructed on each farm plot.

3. Main drainage

The main drainage system should be designed with regard to the existing farm lay-out. The pipe diameter depends on the result of hydraulic calculation to be executed in final design.

Concerning the design parameters a separate report is submitted with this one.

4. Cleaning

5.6.2 Drainage Material

1. Field drainage system

Conditions governing performance of drain lines are

- water inlet openings in drain pipes
- hydraulic properties of filter material and backfill

The sandy soils of the irrigation project are quite unstable, particularly when saturated with water, so that transportation of sandy soil material into drain pipes could not be excluded.

For determining the hydrological properties of drainage material, the combination of pipes and filter material should be taken into account.

To minimize the entrance of sand particles the field pipes must be covered with filter material.

According to the contract for field drainage flexible, corrugated, and perforated PVC-pipes with an artificial filtermat of polypropylen around the pipes will be installed. The filter material is needed to diminish the entrance resistance of the pipes and to prevent silting up of pipes. This means that the material has to keep away the surrounding soil from the openings where velocity of flow is relatively high. That implies the need for the porous voluminous filter material. The chosen drainage filter must perform the following functions - separately or jointly:

- filter action, that is separation of soil particles of different sizes (> 0.02 mm); therefore the filter should allow the passage of finest soil particles (clay, fine silt);

- delay or prevention of active clogging of drains, that is of biochemical effects.

The drainage filter has to prevent that finest soil particles are caught on the surface of the filter, which seals, forming an impervious layer around the drain pipe.

The slot width for water entrance into the PVC drain pipes is dependent on soil class and drainage filter. For the soils of the project area it is recommended to use slot width of 1.2 - 1.7 mm. The grain size distribution curves of subsoils from pits of the western area have a $d_{60} : d_{40}$-ratio from about 1.2 thru 3.5 (see Figure 2). These ratios correspond very well with the demanded ratio of $d_{60} / d_{40} \leq$ 8 - 10 so that it can be said that the combination of selected slot width with drainage filter is most adapted and corresponds with the rule of filter stability.

In the highly pervious medium to coarse sandy soils and the reasonable permeable sandy soils of the project areas, the dominant function of the filter material will be, as mentioned above, the prevention of sand particles from entering into the drain pipe.

This demand will be fulfilled by the polypropylen filter (term: typar 68) so that no additional sand filter will be necessary. Field drains should be covered with this material simultaneously during the installation of pipes. Also in respect to durability, provided no chemical deposits of iron compounds are expected (because of low iron content unlikely) polypropylene mats are the most recommendable.

To our actual knowledge of soils of the project areas the simultaneous use of polypropylen filter and sand filter is superfluous and cannot be recommended.

2. Collector drains and Main drainage system

For collector pipes and main pipes unperforated PVC-pipes should be used.
Up to the diameter of 200 mm corrugated PVC-pipes are recommended, because trenchless installation is possible until a depth of about 2.00 m.

For pipes withdiameter 200 mm up to 600 mm smooth PVC-pipes should be used.

Corrugated and smooth PVC pipes will have to be imported and transported by trucks from Tripoli to Eshkeda. The risk of damage of pipes during the transport is unimportant when PVC-pipes are taken.

3. Manholes and Inspection Chambers

The manholes will be constructed of prefabricated asbestos cement elements according to the attached "Maindrainage system and Design Parameter".

5.6.3 Areas requiring field drainage

The main criteria for selecting the farms requiring field drainage are depth of the observed groundwater table and the depth of impervious base below ground surface.

The groundwater level was measured in auger holes before starting the measurement of hydraulic conductivity. These investigations were executed in summertime. According to the observation of water level in open drainage channels and sebhkas it is assumed, that the groundwater table is somewhat higher in wintertime because of the lower evapotranspiration losses. Unfortunately no observation data of groundwater table for a period of one year are available.

In parts of few farms of central and eastern sub-areas the impervious base is present close to the surface to a depth of 0 - 1.0 m.

Additional investigations should be executed immediately to delineate these areas in detail. Since a special work is needed to drain these areas which are not covered in the present contract, further negotiations with the Secretariat are necessary in order to agree upon payments to execute these areas which are about 90 hectares as specified in map no. 9.

There are 2 possiblities to drain these areas:

One is to install a drain system where the impermeable layer is removed from the drain trenches and gravel is filled instead.

The other possibility is to bring sand and fill these areas up to a total depth of about 1.4 m from the impermeable layer.

There is no need for drainage on about 315 ha cross area of the western zone and on 110 ha of the eastern zone.

Considering farms where drainage is required on parts only about 450 ha are to be excluded from drainage system.

The areas requiring field drainage are presented in Drawing No. 15.

5.7 Salt Balance and Leaching Requirement

In order to prevent salinization a balance must be maintained between the quantity of dissolved salts introduced into a rootzone, and that removed from the rootzone. The quantity of salts that accumulates in the rootzone during an irrigation season depends on the amount of irrigation water applied, and on its salt content. The amount of additional water which must pass through the rootzone in order to reduce soil salinity to a predetermined level, called "leaching requirement", is also dependent on the same two factors.

5.7.1 Continuous Leaching

The effect of a certain water application on the displacement of salts within or beyond rootzone may be calculated by the salt balance equation (Dieleman, FAO, 1971):

$$PC_u = JC_i$$

where C_u and C_i are concentration of the effluent and influent resp. P is the volume of water percolating beyond any given soil depth, and J is the volume of irrigation water per unit surface area, given by

$$J = E + P$$

in which E is the evaporation (consumption use).

If the calculation is based on complete mixing

$$C_u = C_s$$

where C_s is the average solutes concentration at field capacity soil moisture content; if it is assumed that part of the irrigation water will move downward through cracks, rootholes etc., it follows:

$$P = \frac{C_i}{f\ (C_s - C_i)} \cdot E$$

where f is the efficiency coefficient tentatively set as 0.9 for Eshkeda soils.

The maximum permissible salt content is variable at different levels of yield reduction for various crops:

Crop	EC_e mS/cm at yield reduction	
	0 %	10 %
Wheat	6.0	7.4
Alfalfa	2.0	3.4
Orchards*	2.7	3.8
Vegetables	1.6	2.3

*(figs, olives, grapes)

The maximum permissible salt content is substituted for C_s. Since this value is often twice for loamy soils and about 3- to 4-times for sandy soils[1)] the value of the saturation extract follows for typical sandy Eshkeda soils:

Crop	C_s-value for yield reduction	
	0 %	10 %
wheat	20	24
Alfalfa	7	11
Orchards	9	13
Vegetables	5	8

1) $EC_e \simeq \frac{W_{fc}}{W_e} EC_{FC}$; for water content at field capacity W_{FC} = 9 % and water content in the saturated paste $W_e = 20 \cdot 1.65 = 33$ it follows: $EC_e \approx 0.3\ EC_{FC}$

The leaching requirement results in

Wheat	P = 0.03 E
Alfalfa	P = 0.07 E
Orchards	P = 0.06 E
Vegetables	P = 0.10 E

The leaching requirement is therefore in the range of 3 - 10 % of the consumptive use, if a 10 % yield reduction is permitted. The net leaching fraction amounts to

$$\frac{ETcrop}{1 - LR} .$$

5.7.2 Initial Leaching

Saline soils are defined as soils containing enough soluble salts within the rootzone to decrease the growth of the crops to be grown. The reclamation process is aimed as removing this salinity as a limiting factor, so that the crop following it will not suffer any yield reduction.

Yes, but not required.

The ameliorative leaching is used for the desalinization of highly saline soils before beginning of their normal usage for irrigation. There are different models in calculating the quantity of water needed for efficient leaching.

The model used hereafter simulates quantitatively the process of solute movement through a porous medium. The single reservoir model with bypass and mixing is used for the calculation of desalinization of three series of soil layers:

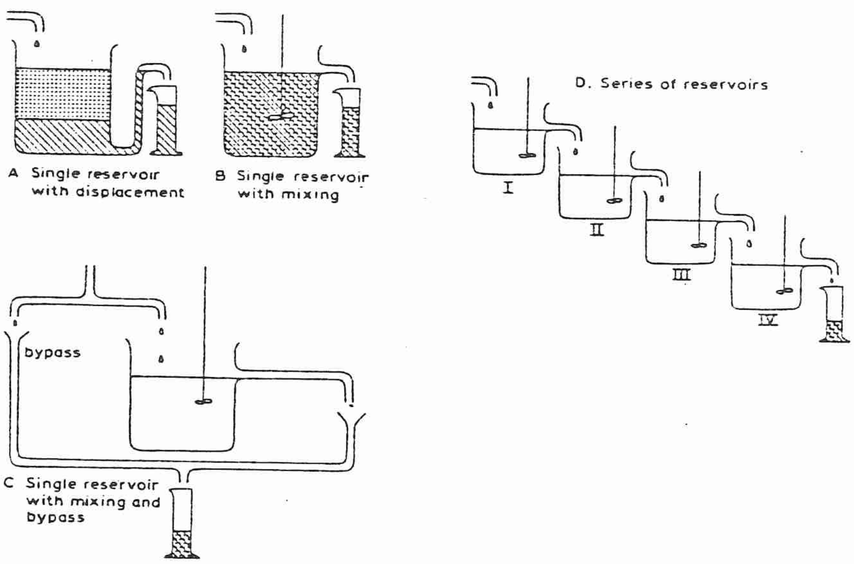


Figure 7: Theoretical models to illustrate the process of solute movement through porous materials

The following assumptions are made:

- there is no chemical or physical interaction between solute, solution and soil
- mixing takes place in the reservoir
- irrigation water is unlikely to mix completely with the solution, thus the soil can be regarded as a reservoir with bypass
- strong differences in salinity between successive layers
- the solum consists of three separate reservoirs, corresponding with the soil layers in 0 - 60, 60 - 120, and 120 - 180 cm depth
- the moisture content is approximately at field capacity (pF 2.2)
- each reservoir receives the outflow from the overlying one.

For irrigation water with the salt concentration (Ci), the original salt concentration in the reservoir solution (Co); a leaching efficiency (f), and t/T calculated from the irrigation water and the total amount of soil moisture in a layer of 60 cm,[1)] the following expressions are found for the salt concentration in three successive layers C_I to C_{III} equal volume:

1st reservoir: $C_I = C_i + (C_o - C_i)e^{-ft/T}$

2nd reservoir: $C_{II} = C_i + (C_o - C_i)\ (1 + \frac{ft/T}{T})e^{-ft/T}$

3rd reservoir: $C_{III} = C_i + (C_o - C_i)\ (1 + \frac{ft}{T} + \frac{f^2t^2}{2T^2})e^{-ft/T}$

1) T is the time of residence in the soil profile and can be expressed as volume of the system divided by the flux through the system (V/Q); since t/T equals Qt/W, we can calculate the values t/T from irrigation water and soil moisture.

The leaching efficiency is assumed as f = 0.9 for sandy soils having a very high hydraulic conductivity.[1] The initial salt concentration C_o of the soil profiles in the project area is shown on Map for the topsoil layers.

The salt content of the irrigation water C_i was analysed as 0.66 mS/cm.

The total amount of soil moisture at field capacity (FC) is uniform for the soils in Eshkeda:

50 mm/m for sandy soils
80 mm/m for sandy loamy soils.

The calculation for the desalinization is shown in Annex 2 for 30 representative soil profiles of Eshkeda project. The salinity level is determined after every 10 mm of irrigation water application for three soil layers C_t^{I}, C_t^{II}, C_t^{III}. The effect of leaching was determined till 100 mm were applied.

Since the salinity of the soil solution at Field Capacity (EC_{efc}) expected to develop after long term use of irrigation water of EC_w = 0.66 mS/cm is about 1.5 $EC_w \hat{=} EC_e$, we suppose an upper tolerant limit of total salinity of 1.0 to 1.2 mS/cm.

Due to the low or slight salinity status (< 4 mS/cm) most profiles require a low leaching amount only.

Therefore the desalinization of almost all soils in Eshkeda project is terminated after the application of 50 to 80 mm irrigation water. The typical desalinization rate of deep sandy profiles is shown in Figure 8 .

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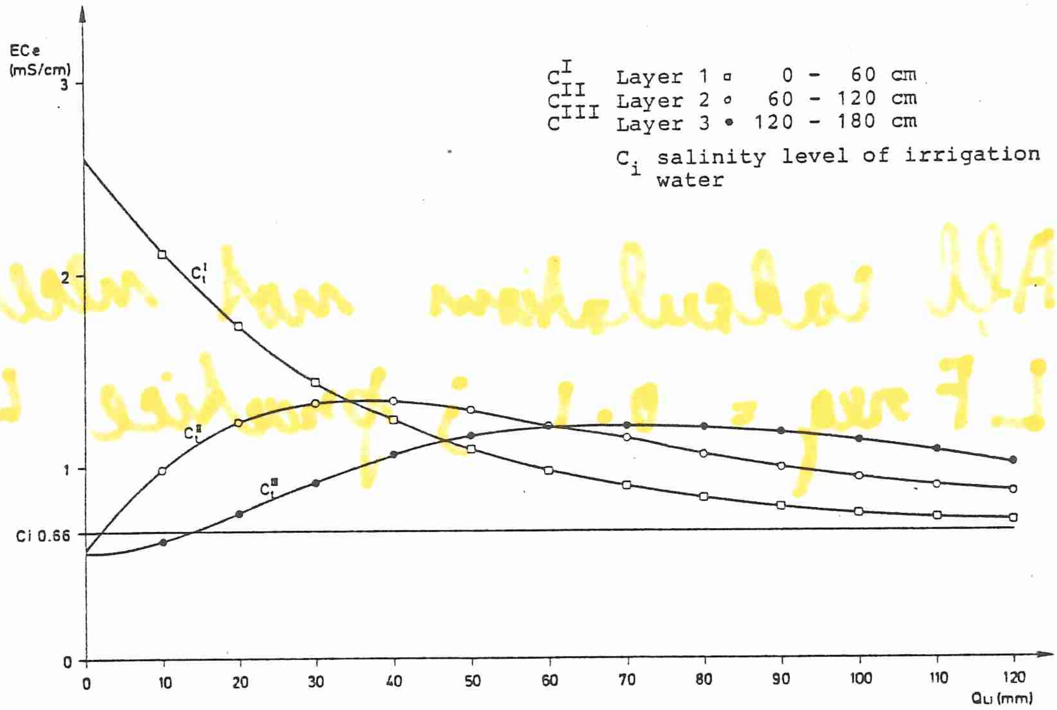
1) Jackson; FAO Soils Bulletin 21, p.103; loamy sandy soils of the eastern project area are slightly less permeable and show a aggregation; thus the leaching efficiency is slightly reduced to f = 0.85

Figure 8 : Salinity Level of Pit No. E 2 after Initial Leaching of for three Layers



It follows that for almost all sites on which alfalfa and wheat are grown no additional initial leaching is necessary to keep the salinity status below the maximum allowable level of 1.2 mS/cm. A single water application of 50 mm according to the normal sprinkler irrigation interval will reduce salinity. For a typical farm unit the following surface salinity (0 - 30 cm) data were determined:

farm unit 193	EC mS/cm before leaching	EC after leaching with 10	30	50	70	90 mm
alfalfa	2.20	1.5	0.9	0.7	0.7	0.7
wheat (after harvest)	3.46	2.2	1.1	0.8	0.7	0.7
orchards	5.60	3.4	1.5	0.9	0.7	0.7
bare soil between orchards	4.60	2.8	1.3	0.9	0.7	0.7

Even those sites showing a high salinity level of > 15 mS/cm need not to be initially leached due to the low net leaching demand:

farm unit 12	EC mS/cm before leaching	EC after leaching with					
		10	30	50	70	90	110 mm
orchards, between furrows	55.0	30	10	3.4	1.5	0.9	0.7

Under proper management practices and the application of adequate leaching fractions in addition to the crop water demand the salinity level of the rootzone will be kept at the 0 - 10 % yield decrement level.

The highest salinity value at farm 5 / district 5 with 53.37 mS/cm corresponds to the value above, showing that an adequate salinity level can already be reached under regular irrigation measures.

Figure 9: Salinity Levels of Typical Soils after Initial Leaching

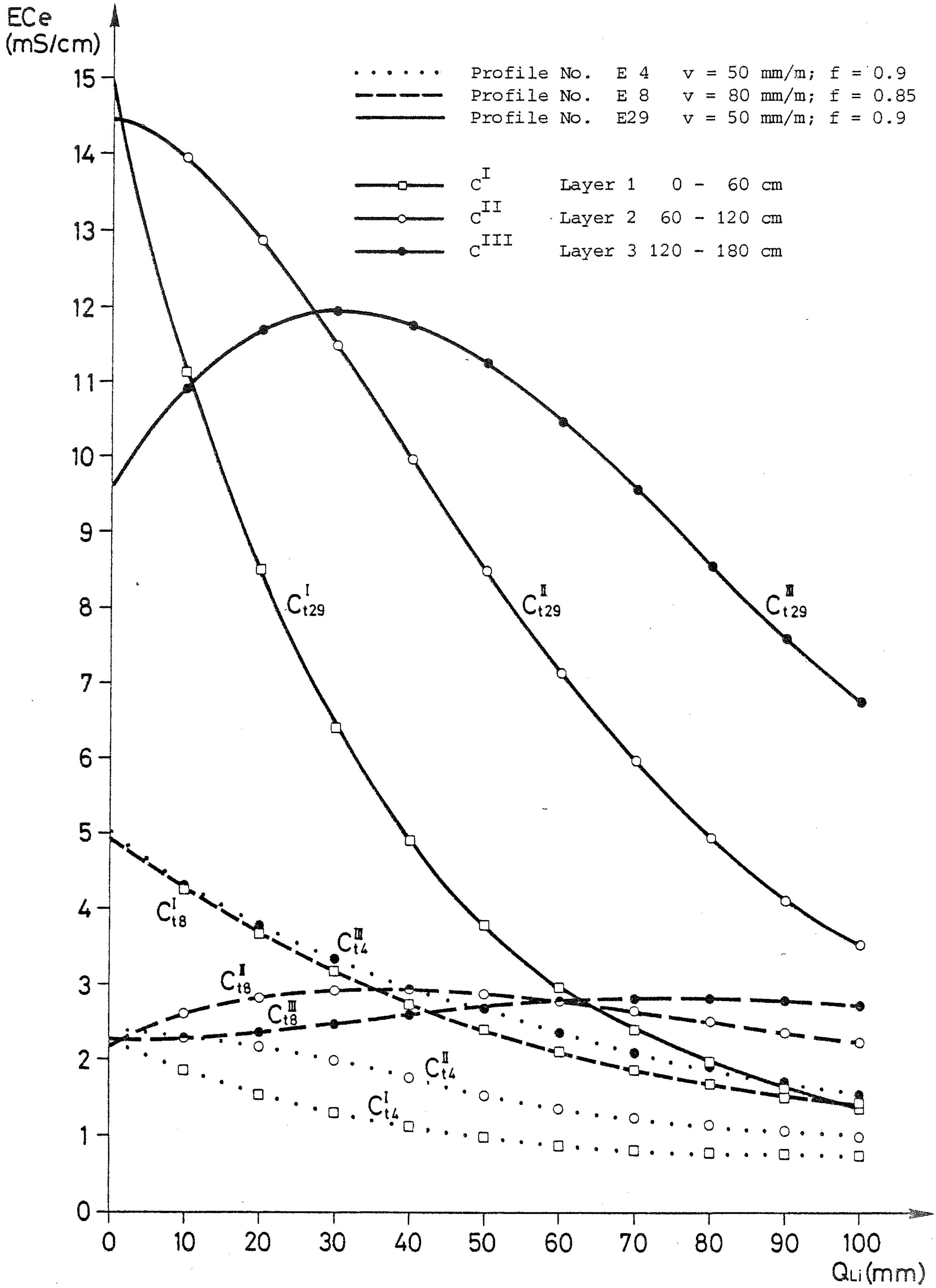
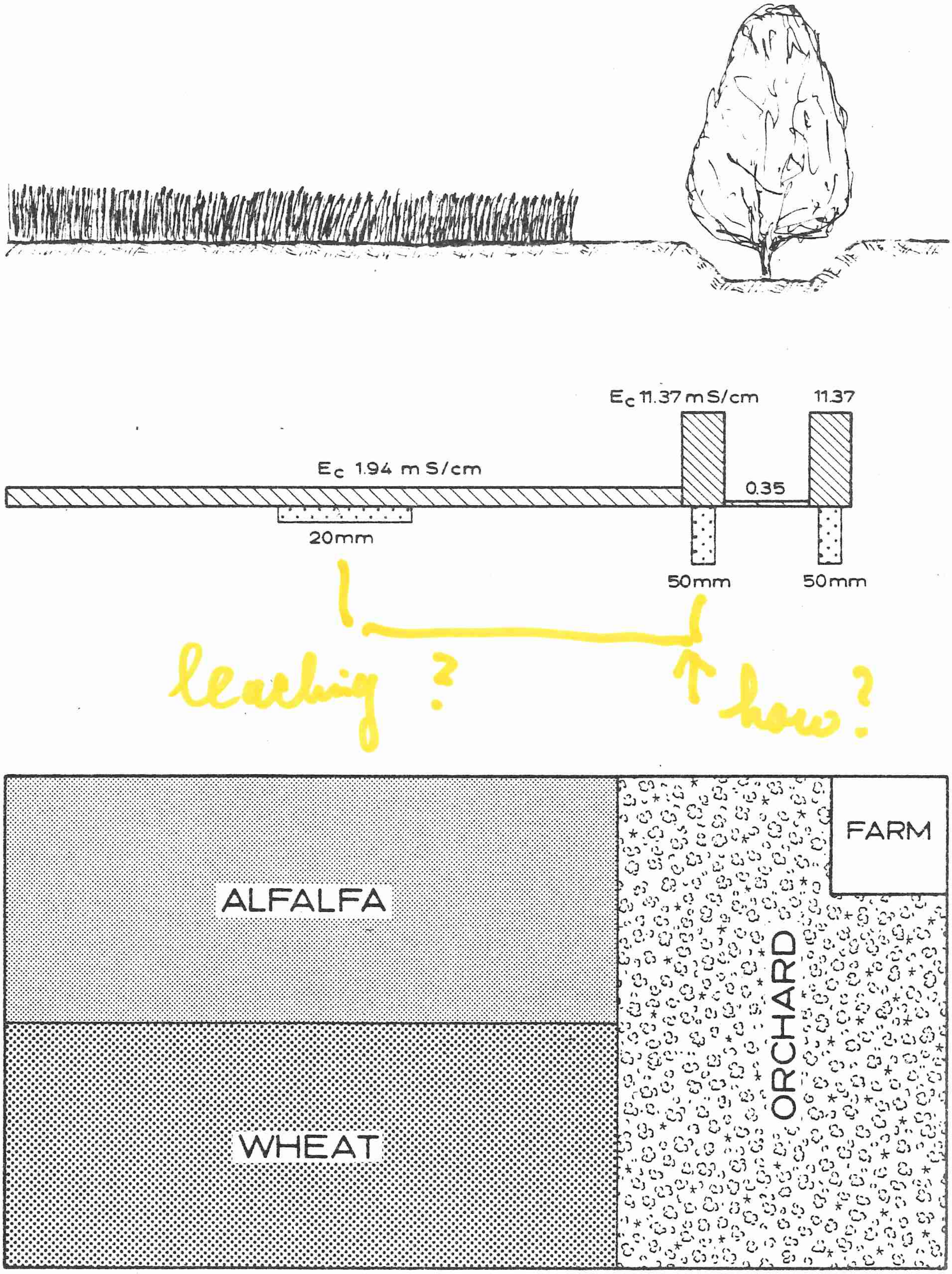


Figure 10: <u>Typical Distribution of Surface Salinity on Farm Areas</u>



5.8 Tentative Design of the Field Drainage System for 4 Typical Farm Plots

5.8.1 Hydraulic Calculation

Example No. 1 - Farm No. 23.12.B

Drain spacing:

q = 4.5 mm/d = 0,52 l/s/ha

k = 0,7 m/d

h = 0,20 m

D = 0,75 m

d = 0,72 m

$$s = \sqrt{\frac{8 \cdot 0{,}7 \cdot 0{,}72 \cdot 0{,}20}{0{,}0045} + \frac{4 \cdot 0{,}7 \cdot 0{,}20^2}{0{,}0045}}$$

S = 14.3 m

S = 15 m

Pipe Diameter:

DN = 50 mm

Di = 43,9 mm

s = 6,0 o/oo

Q = 0,4 · 60 % = 0,24 l/s

$$a = \frac{0{,}24}{0.52} = 0.46 \text{ ha} = 4600 \text{ m}^2$$

$$L = \frac{4600}{15} = 308 \text{ m} > \text{length of farm plot (234 m)}$$

<u>Example No. 2</u> - Farm No. 4.9.B

Drain spacing:

$$q = 4{,}5 \text{ mm/d} = 0{,}52 \text{ l/s/ha}$$

$$k = 0{,}9 \text{ m/d}$$

$$h = 0{,}20 \text{ m}$$

$$D = 2{,}50 \text{ m}$$

$$d = 1{,}77 \text{ m}$$

$$S = \sqrt{\frac{8.0{,}9.1{,}77.0{,}20}{0{,}0045} + \frac{4.0{,}9.0{,}20^2}{0{,}0045}}$$

$$S = 24{,}5 \text{ m}$$

$$\boxed{S = 25 \text{ m}}$$

Pipe Diameter:

$$DN = 65 \text{ mm}$$

$$Di = 58 \text{ mm}$$

$$s = 2 \text{ o/oo}$$

$$Q = 0{,}5 \cdot 60\ \% = 0{,}30 \text{ l/s}$$

$$a = \frac{0{,}30}{0{,}52} = 0{,}58 \text{ ha} = 5800 \text{ m}^2$$

$$L = \frac{5800}{25} = 232 \text{ m} \sim \text{length of farm plot (234 m)}$$

According to the contract between the Secretariate of Agricultural Reclamation and Land Development and the Cornelius-Brochier J.V. the pipe diameter of field drains is 50 mm.

So contract is wrong.

Using pipes ND 50 mm the required drain spacing will be:

$$Q = 0,20 \cdot 60\ \% = 0,12\ l/s$$

$$a = \frac{0,12}{0,52} = 0,23\ ha = 2300\ m^2$$

$$S = \frac{2300}{214} = 10,74\ m$$

$$\boxed{S = 10,0\ m}$$

Example No. 3 - Farm No. 18.4.B

Drain spacing:

$q = 4,5$ mm/d $= 0,52$ l/s/ha

$k = 4,8$ m/d

$h = 0,20$ m

$D = 0,50$ m

$d = 0,50$ m

$$S = \sqrt{\frac{8.4,8.0,50.0,20}{0,0045} + \frac{4.4,8.0,20^2}{0,0045}}$$

$$S = 39,2\ m$$

$$\boxed{S = 35,0\ m}$$

Pipe Diameter:

DN = 50 mm

Di = 43,9 mm

s = 6 o/oo

$$Q = 0,4 \cdot 60\ \% = 0,24\ l/s$$

$$a = \frac{0,24}{0,35} = 0,69\ ha = 6900\ m^2$$

$$L = \frac{6900}{35} = 197\ m$$ > width of farm plot (180 m)

<u>Example No. 4</u> - Farm No. 14.8.B

Drain spacing:

Considering the inflow from the undrained upper part of the farm the discharge increases to:

q = 9,0 mm/d = 1,05 l/s/ha
k = 3,8 m/d
h = 0,20 m
D = 3,00 m
d = 2,28 m

$$S = \sqrt{\frac{8.3{,}8.2{,}28.0{,}20}{0{,}009} + \frac{4.3{,}8.0{,}20^2}{0{,}009}}$$

S = 40,10 m

S = 40,0 m

Pipe Diameter:

DN = 50 mm
Di = 43,9 mm
s = 2 o/oo
Q = 0,2 · 60 % = 0,12 l/s

$$a = \frac{0{,}12}{1.05} = 0{,}114 \text{ ha} = 1140 \text{ m}^2$$

$$L = \frac{1140}{45} = 28.5\text{m}$$

length of farm plot (180 m)

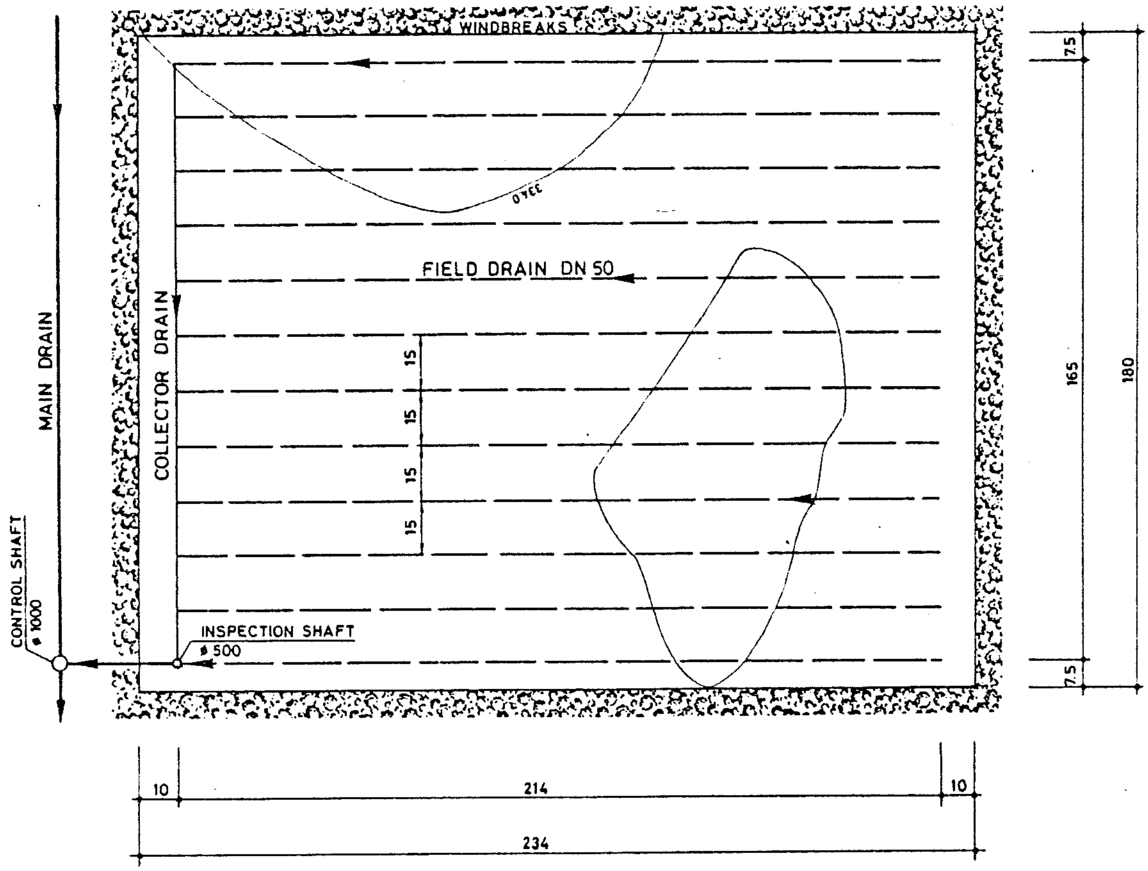
S = 10,0 m

$$L = \frac{1140}{10} = 114{,}0 \text{ m} < 180 \text{ m}$$

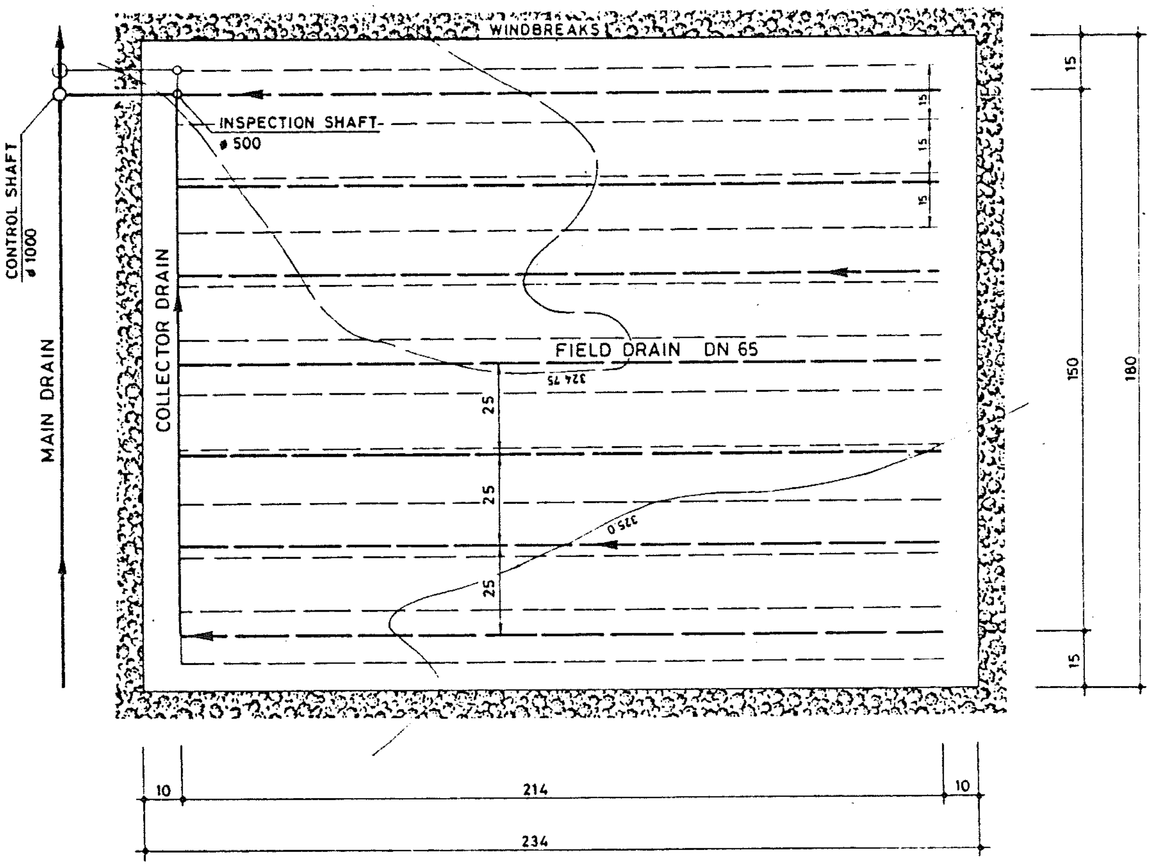
second field collector required.

5.8.2 Lay-out of Field Drainage System - Sample Farms

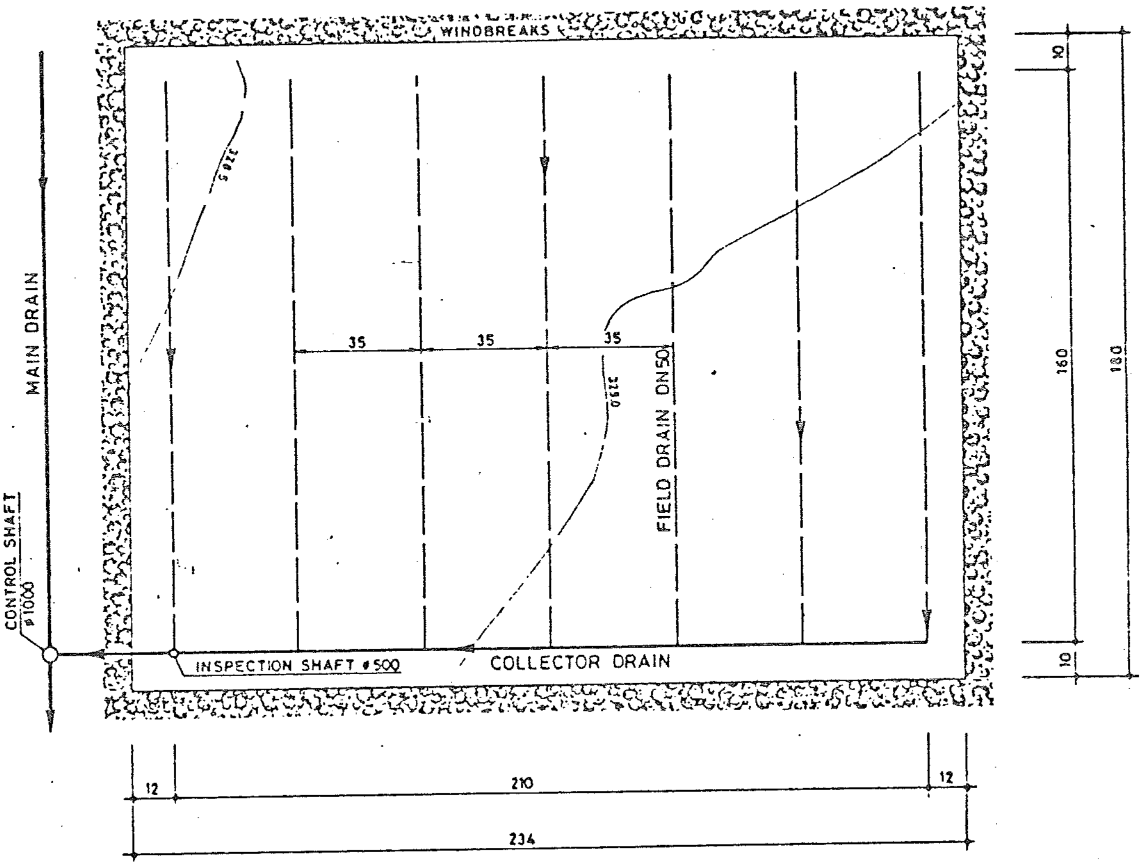
Example 1: Farm No. 23.12.B



Example 2: Farm No. 4.9.B



Example 3: Farm No. 18.4.B



Example 4: Farm No. 14.8.B

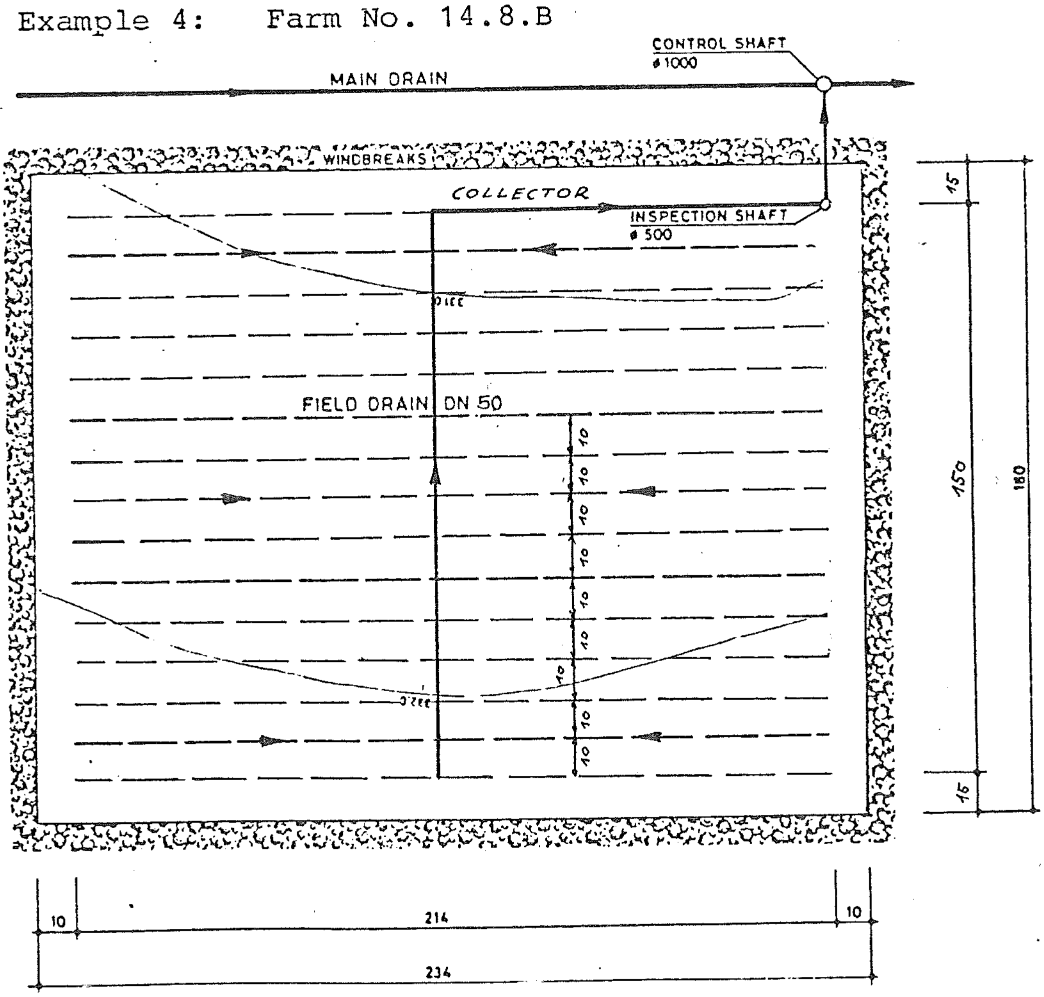
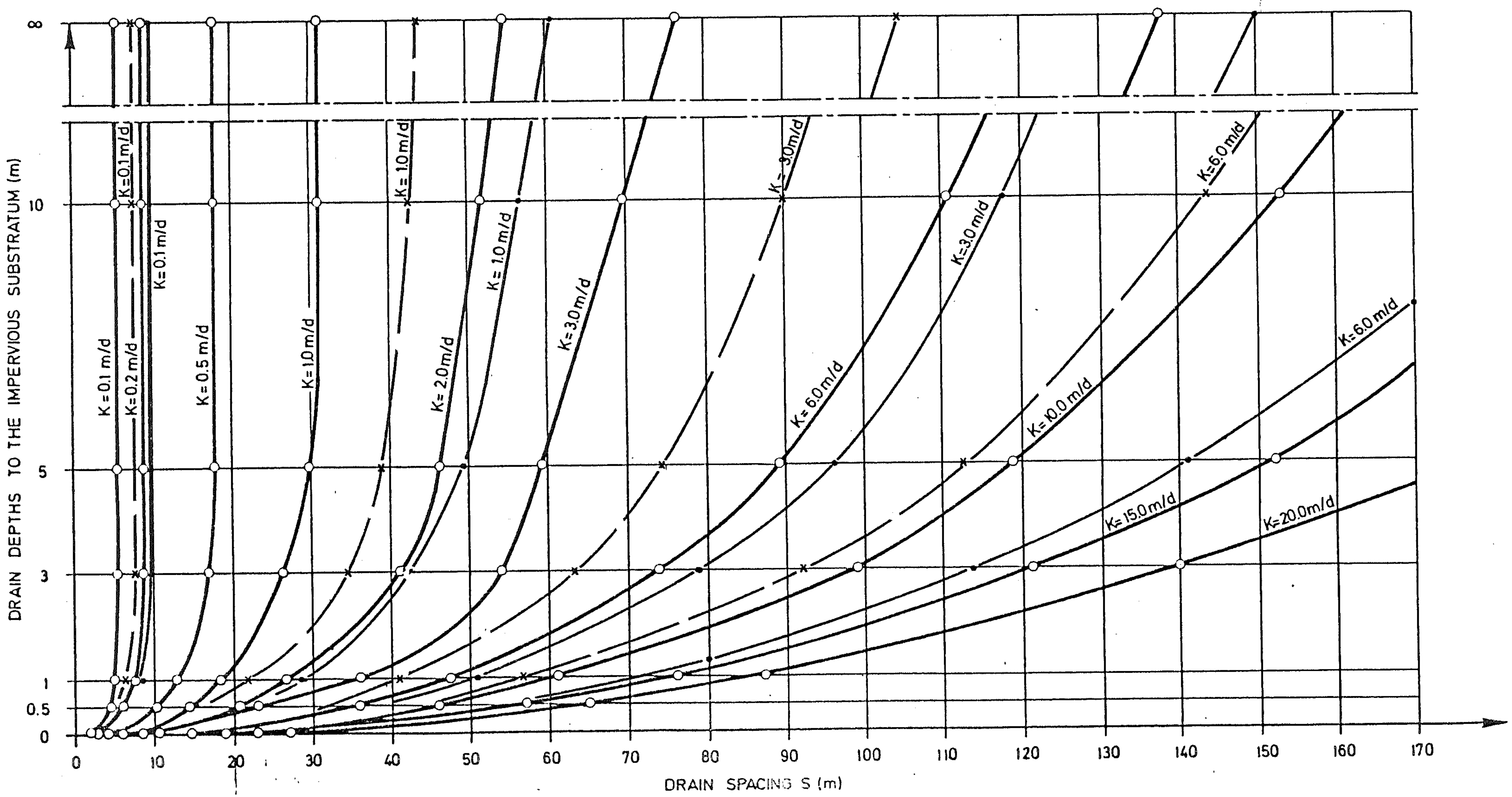


Figure : Drain Spacing (S) Plotted Against Drain Depth to the Impervious Substratum (D) at Hydraulic Conductivities between k = 0.1 m/d and 20.0 m/d, and at a Height of the Permissible Groundwater Table above the Drain of h = 0.2 m. The Maximum Discharge (q) to be Drained is calculated with 4.5 mm/day —o—
3.0 mm/day --x--
2.0 mm/day —•—



5.8.3 Symbols

q	mm/d	Precipitation to be drained
Q	l/s	Discharge capacity
s	o/oo	Slope of the drain
DN	mm	Nominal diameter
Di	mm	Internal diameter
a	ha	Potential acreage
L	m	Potential length of field drain
h	m/d	Hydraulic conductivity
S	m	Drain spacing
d	m	Thickness of equivalent layer
D	m	Depth of impervious layer below the drain
h	m	Height of water table above the drain

A N N E X E S

ANNEX 1

Monthly Irrigation Quantities

Monthly irrigation quantities per district (12 farms) incl. irrigation of windbreaks in 1979

No measured values!

month	irrigation quantities (m^3)
January	81.280
February	123.480
March	147.600
April	111.600
May	163.800
June	158.400
July	183.800
August	183.800
September	133.200
October	133.200
November	128.800
December	118.800

A N N E X 2

Calculation of Initial Desalinization of Soil Pits in Eshkeda

Calculation of Initial Desalinization of Soil Pits in Eshkeda

Key of Explanation

No.	-	No. of plot, total No.of plots is 50
C_o^I	-	EC_e of 1. layer (0 - 60 cm)
C_o^{II}	-	EC_e of 2. layer (60 - 120 cm)
C_o^{III}	-	EC_e of 3. Layer (120- 180 cm)
Q_{t1}	-	1. irrigation application of 10 mm, EC_i = 0.66 mS/cm
C_{t1}^I	-	EC_e after 1. water application; 1. layer
C_{t1}^{II}	-	EC_e after 1. water application; 2. layer
C_{t1}^{III}	-	EC_e after 1. water application; 3. layer
Qt_2	-	2. irrigation application of 10 mm; total 20 mm
C_{t2}^I	-	EC_e after 2. water application; 1. layer
C_{t2}^{II}	-	EC_e after 2. water application; 2. layer
C_{t2}^{III}	-	EC_e after 2. water application; 3. layer
Q_{t10}	-	17. irrigation application of 10 mm; total 100 mm
$C_{t\,10}^I$	-	EC_e after 10. water application; 1. layer
$C_{t\,10}^{II}$	-	EC_e after 10. water application; 2. layer
$C_{t\,10}^{III}$	-	EC_e after 10. water application; 3. layer

The following input data - calculation steps and output data are used

Example for the second column, plot 2; at the end of the column the data are printed as follows:

C_i ;	EC_w of irrigation water (mS/cm)
Q_{t10} ;	10. application rate each of 10 mm, where the program stopped
V ;	volume of the reservoir; Vol. % water
f	efficiency factor
C_o^I	initial salt concentration of 1. layer
C_o^{II}	initial salt concentration of 2. layer
C_o^{III}	initial salt concentration of 3. layer
$f \cdot Q_{t10}/v$	leaching factor
$f(Q_{t10}^2/2v^2)$	
$e^{-(Q_{t10}/v)f}$	
Q_t Stop	Programm stop, when water application amounts 100 mm
C_t Stop	Program steps
Start	Program steps
C_{t10}^I	concentration (mS/cm) of 1. layer after 100 mm leaching
C_{t10}^{II}	concentration (mS/cm) of 2. layer after 100 mm leaching
C_{t10}^{III}	concentration (mS/cm) of 3. layer after 100 mm leaching

N°	E 1		E 2		E 3		E 4		E 5		E 6	
c_o^I	2.80	***	2.60	***	0.78	***	2.29	***	0.68	***	2.68	***
c_o^{II}	1.75	***	0.57	***	0.29	***	2.35	***	1.68	***	11.63	***
c_o^{III}	1.86	***	0.52	***	0.33	***	5.03	***	2.00	***	2.42	***
Q_{t1}	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***
c_{t1}^I	2.25	***	2.10	***	0.75	***	1.87	***	0.67	***	2.35	***
c_{t1}^{II}	1.94	***	1.02	***	0.41	***	2.27	***	1.42	***	10.15	***
c_{t1}^{III}	1.67	***	0.61	***	0.34	***	4.33	***	1.88	***	3.79	***
Q_{t2}	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***
c_{t2}^I	1.83	***	1.72	***	0.73	***	1.55	***	0.67	***	2.08	***
c_{t2}^{II}	1.96	***	1.25	***	0.50	***	2.12	***	1.23	***	8.86	***
c_{t2}^{III}	1.91	***	0.77	***	0.37	***	3.79	***	1.73	***	4.73	***
Q_{t3}	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***
c_{t3}^I	1.53	***	1.45	***	0.71	***	1.32	***	0.67	***	1.85	***
c_{t3}^{II}	1.89	***	1.33	***	0.55	***	1.94	***	1.08	***	7.74	***
c_{t3}^{III}	1.94	***	0.93	***	0.41	***	3.35	***	1.58	***	5.32	***
Q_{t4}	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***
c_{t4}^I	1.30	***	1.24	***	0.70	***	1.15	***	0.67	***	1.65	***
c_{t4}^{II}	1.76	***	1.33	***	0.59	***	1.76	***	0.97	***	6.77	***
c_{t4}^{III}	1.93	***	1.05	***	0.46	***	2.98	***	1.44	***	5.65	***
Q_{t5}	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***
c_{t5}^I	1.14	***	1.09	***	0.69	***	1.02	***	0.66	***	1.49	***
c_{t5}^{II}	1.62	***	1.29	***	0.62	***	1.58	***	0.89	***	5.92	***
c_{t5}^{III}	1.89	***	1.14	***	0.50	***	2.66	***	1.31	***	5.78	***
Q_{t6}	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***
c_{t6}^I	1.01	***	0.98	***	0.68	***	0.93	***	0.66	***	1.36	***
c_{t6}^{II}	1.46	***	1.22	***	0.63	***	1.42	***	0.83	***	5.19	***
c_{t6}^{III}	1.82	***	1.19	***	0.53	***	2.37	***	1.19	***	5.76	***
Q_{t7}	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***
c_{t7}^I	0.92	***	0.90	***	0.67	***	0.86	***	0.66	***	1.24	***
c_{t7}^{II}	1.34	***	1.15	***	0.65	***	1.29	***	0.79	***	4.56	***
c_{t7}^{III}	1.73	***	1.20	***	0.56	***	2.12	***	1.09	***	5.63	***
Q_{t8}	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***
c_{t8}^I	0.85	***	0.84	***	0.67	***	0.81	***	0.66	***	1.15	***
c_{t8}^{II}	1.22	***	1.07	***	0.65	***	1.17	***	0.76	***	4.01	***
c_{t8}^{III}	1.63	***	1.19	***	0.58	***	1.90	***	1.01	***	5.43	***
Q_{t9}	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***
c_{t9}^I	0.88	***	0.79	***	0.67	***	0.77	***	0.66	***	1.07	***
c_{t9}^{II}	1.12	***	1.01	***	0.66	***	1.07	***	0.73	***	3.54	***
c_{t9}^{III}	1.52	***	1.16	***	0.60	***	1.70	***	0.94	***	5.18	***
Q_{t10}	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***
c_{t10}^I	0.77	***	0.76	***	0.67	***	0.74	***	0.66	***	1.00	***
c_{t10}^{II}	1.03	***	0.95	***	0.66	***	0.99	***	0.71	***	3.14	***
c_{t10}^{III}	1.42	***	1.12	***	0.62	***	1.54	***	0.88	***	4.90	***
c_1	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0
Q_{t10}	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1
v	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2	40.00	2
f	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3	0.85	3
c_o^I	2.80	4	2.60	4	0.78	4	2.29	4	0.68	4	2.68	4
c_o^{II}	1.75	5	0.57	5	0.29	5	2.35	5	1.68	5	11.63	5
c_o^{III}	1.86	6	0.52	6	0.33	6	5.03	6	2.00	6	2.42	6
$f \times Q_{t10}/v$	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7	1.77	7
$f(Q_{t10}^2/2v^2)$	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8	1.84	8
$e^{-(Q_{t10}/v)f}$	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9	0.17	9
Q_t Stop	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A
c_t Stop	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B
Start	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C
c_{t10}^I	0.77	D	0.76	D	0.67	D	0.74	D	0.66	D	1.00	D
c_{t10}^{II}	1.03	E	0.95	E	0.66	E	0.99	E	0.71	E	3.14	E
c_{t10}^{III}	1.42	I	1.12	I	0.62	I	1.54	I	0.88	I	4.90	I

Profile Nº	E 7		E 8		E 9		E 10		E 11		E 12	
c_o^{I}	3.05	***	4.96	***	1.50	***	0.73	***	0.50	***	2.21	***
c_o^{II}	3.08	***	2.19	***	1.72	***	0.55	***	0.49	***	0.97	***
c_o^{III}	3.63	***	2.21	***	0.75	***	1.19	***	0.64	***	0.77	***
Q_{t1}	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***
c_{t1}^{I}	2.66	***	4.26	***	1.28	***	0.71	***	0.54	***	1.81	***
c_{t1}^{II}	3.04	***	2.58	***	1.63	***	0.59	***	0.50	***	1.23	***
c_{t1}^{III}	3.54	***	2.25	***	0.99	***	1.03	***	0.60	***	0.87	***
Q_{t2}	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***
c_{t2}^{I}	2.34	***	3.68	***	1.12	***	0.70	***	0.57	***	1.51	***
c_{t2}^{II}	2.95	***	2.80	***	1.52	***	0.62	***	0.51	***	1.34	***
c_{t2}^{III}	3.47	***	2.35	***	1.15	***	0.92	***	0.58	***	0.99	***
Q_{t3}	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***
c_{t3}^{I}	2.07	***	3.19	***	1.00	***	0.69	***	0.59	***	1.29	***
c_{t3}^{II}	2.83	***	2.90	***	1.40	***	0.64	***	0.53	***	1.35	***
c_{t3}^{III}	3.40	***	2.47	***	1.24	***	0.85	***	0.56	***	1.10	***
Q_{t4}	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***
c_{t4}^{I}	1.84	***	2.78	***	0.91	***	0.68	***	0.61	***	1.13	***
c_{t4}^{II}	2.69	***	2.91	***	1.28	***	0.65	***	0.55	***	1.31	***
c_{t4}^{III}	3.31	***	2.58	***	1.27	***	0.80	***	0.55	***	1.18	***
Q_{t5}	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***
c_{t5}^{I}	1.65	***	2.43	***	0.85	***	0.68	***	0.62	***	1.01	***
c_{t5}^{II}	2.53	***	2.86	***	1.18	***	0.66	***	0.57	***	1.25	***
c_{t5}^{III}	3.22	***	2.68	***	1.27	***	0.76	***	0.55	***	1.22	***
Q_{t6}	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***
c_{t6}^{I}	1.49	***	2.15	***	0.80	***	0.67	***	0.63	***	0.92	***
c_{t6}^{II}	2.37	***	2.77	***	1.09	***	0.66	***	0.58	***	1.17	***
c_{t6}^{III}	3.12	***	2.74	***	1.24	***	0.74	***	0.56	***	1.23	***
Q_{t7}	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***
c_{t7}^{I}	1.35	***	1.90	***	0.76	***	0.67	***	0.64	***	0.85	***
c_{t7}^{II}	2.22	***	2.65	***	1.01	***	0.66	***	0.60	***	1.10	***
c_{t7}^{III}	3.01	***	2.78	***	1.20	***	0.72	***	0.57	***	1.22	***
Q_{t8}	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***
c_{t8}^{I}	1.24	***	1.70	***	0.74	***	0.67	***	0.65	***	0.80	***
c_{t8}^{II}	2.07	***	2.51	***	0.94	***	0.67	***	0.61	***	1.03	***
c_{t8}^{III}	2.90	***	2.79	***	1.14	***	0.70	***	0.57	***	1.19	***
Q_{t9}	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***
c_{t9}^{I}	1.15	***	1.53	***	0.72	***	0.66	***	0.65	***	0.76	***
c_{t9}^{II}	1.93	***	2.36	***	0.88	***	0.67	***	0.62	***	0.96	***
c_{t9}^{III}	2.77	***	2.78	***	1.09	***	0.69	***	0.58	***	1.15	***
Q_{t10}	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***
c_{t10}^{I}	1.07	***	1.39	***	0.70	***	0.66	***	0.65	***	0.74	***
c_{t10}^{II}	1.79	***	2.22	***	0.84	***	0.66	***	0.63	***	0.91	***
c_{t10}^{III}	2.65	***	2.73	***	1.03	***	0.69	***	0.59	***	1.10	***
c_i	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0
Q_{t10}	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1
v	40.00	2	40.00	2	30.00	2	30.00	2	30.00	2	30.00	2
f	0.85	3	0.85	3	0.90	3	0.90	3	0.90	3	0.90	3
c_o^{I}	3.05	4	4.96	4	1.50	4	0.73	4	0.50	4	2.21	4
c_o^{II}	3.08	5	2.19	5	1.72	5	0.55	5	0.49	5	0.97	5
c_o^{III}	3.63	6	2.21	6	0.75	6	1.19	6	0.64	6	0.77	6
$f \times Q_{t10}/v$	1.77	7	1.77	7	3.00	7	3.00	7	3.00	7	3.00	7
$f(Q_{t10}^2/2v^2)$	1.84	8	1.84	8	5.00	8	5.00	8	5.00	8	5.00	8
$e^{-(Q_{t10}/v)f}$	0.17	9	0.17	9	0.05	9	0.05	9	0.05	9	0.05	9
Q_t Stop	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A
c_t Stop	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B
Start	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C
c_{t10}^{I}	1.07	D	1.39	D	0.70	D	0.66	D	0.65	D	0.74	D
c_{t10}^{II}	1.79	E	2.22	E	0.84	E	0.66	E	0.63	E	0.91	E
c_{t10}^{III}	2.65	I	2.73	I	1.03	I	0.69	I	0.59	I	1.10	I

Profile Nº	E 13		E 14		E 15		E 16		E 17		E 18	
c_o^I	1.15	***	1.14	***	0.71	***	0.70	***	0.58	***	2.16	***
c_o^{II}	0.97	***	0.50	***	1.01	***	0.56	***	0.47	***	0.72	***
c_o^{III}	0.94	***	0.66	***	1.90	***	0.65	***	0.60	***	0.73	***
Q_{t1}	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***
c_{t1}^I	1.02	***	1.02	***	0.70	***	0.69	***	0.60	***	1.77	***
c_{t1}^{II}	1.00	***	0.65	***	0.93	***	0.59	***	0.58	***	1.04	***
c_{t1}^{III}	0.95	***	0.64	***	1.66	***	0.63	***	0.57	***	0.78	***
Q_{t2}	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***
c_{t2}^I	0.93	***	0.92	***	0.69	***	0.68	***	0.62	***	1.48	***
c_{t2}^{II}	0.99	***	0.73	***	0.87	***	0.62	***	0.53	***	1.19	***
c_{t2}^{III}	0.97	***	0.66	***	1.46	***	0.63	***	0.56	***	0.88	***
Q_{t3}	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***
c_{t3}^I	0.86	***	0.86	***	0.68	***	0.68	***	0.63	***	1.27	***
c_{t3}^{II}	0.97	***	0.77	***	0.82	***	0.63	***	0.55	***	1.23	***
c_{t3}^{III}	0.98	***	0.69	***	1.30	***	0.63	***	0.55	***	0.98	***
Q_{t4}	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***
c_{t4}^I	0.81	***	0.80	***	0.68	***	0.67	***	0.64	***	1.11	***
c_{t4}^{II}	0.93	***	0.79	***	0.78	***	0.64	***	0.57	***	1.22	***
c_{t4}^{III}	0.97	***	0.72	***	1.17	***	0.63	***	0.55	***	1.06	***
Q_{t5}	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***
c_{t5}^I	0.77	***	0.77	***	0.67	***	0.67	***	0.64	***	0.99	***
c_{t5}^{II}	0.89	***	0.78	***	0.75	***	0.65	***	0.59	***	1.18	***
c_{t5}^{III}	0.96	***	0.74	***	1.07	***	0.64	***	0.56	***	1.11	***
Q_{t6}	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***
c_{t6}^I	0.74	***	0.74	***	0.67	***	0.67	***	0.65	***	0.91	***
c_{t6}^{II}	0.86	***	0.78	***	0.73	***	0.66	***	0.60	***	1.12	***
c_{t6}^{III}	0.94	***	0.76	***	0.98	***	0.64	***	0.57	***	1.14	***
Q_{t7}	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***
c_{t7}^I	0.72	***	0.72	***	0.67	***	0.66	***	0.65	***	0.84	***
c_{t7}^{II}	0.82	***	0.76	***	0.72	***	0.66	***	0.62	***	1.05	***
c_{t7}^{III}	0.92	***	0.76	***	0.92	***	0.65	***	0.58	***	1.13	***
Q_{t8}	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***
c_{t8}^I	0.70	***	0.70	***	0.66	***	0.66	***	0.65	***	0.80	***
c_{t8}^{II}	0.79	***	0.75	***	0.70	***	0.66	***	0.63	***	0.99	***
c_{t8}^{III}	0.90	***	0.76	***	0.86	***	0.65	***	0.59	***	1.11	***
Q_{t9}	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***
c_{t9}^I	0.69	***	0.69	***	0.66	***	0.66	***	0.65	***	0.76	***
c_{t9}^{II}	0.77	***	0.74	***	0.69	***	0.66	***	0.63	***	0.94	***
c_{t9}^{III}	0.87	***	0.76	***	0.82	***	0.65	***	0.60	***	1.08	***
Q_{t10}	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***
c_{t10}^I	0.68	***	0.68	***	0.66	***	0.66	***	0.66	***	0.73	***
c_{t10}^{II}	0.75	***	0.72	***	0.68	***	0.66	***	0.64	***	0.89	***
c_{t10}^{III}	0.84	***	0.76	***	0.79	***	0.65	***	0.61	***	1.05	***
c_i	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0
Q_{t10}	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1
v	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2
f	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3
c_o^I	1.15	4	1.14	4	0.71	4	0.70	4	0.58	4	2.16	4
c_o^{II}	0.97	5	0.50	5	1.01	5	0.56	5	0.47	5	0.72	5
c_o^{III}	0.94	6	0.66	6	1.90	6	0.65	6	0.60	6	0.73	6
$f \times Q_{t10}/v$	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7
$f(Q_{t10}^2/2v^2)$	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8
$e^{-(Q_{t10}/v)f}$	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9
Q_t Stop	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A
c_t Stop	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B
Start	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C
c_{t10}^I	0.68	D	0.66	D	0.66	D	0.66	D	0.66	D	0.73	D
c_{t10}^{II}	0.75	E	0.72	E	0.68	E	0.66	E	0.64	E	0.89	E
c_{t10}^{III}	0.84	I	0.76	I	0.79	I	0.65	I	0.61	I	1.05	I

Profile N°	E 19		E 20		E 21		E 22		E 23		E 24	
c_o^I	2.19	***	1.13	***	1.57	***	0.89	***	0.69	***	0.64	***
c_o^{II}	3.03	***	0.31	***	0.45	***	0.79	***	1.02	***	0.28	***
c_o^{III}	3.15	***	0.27	***	0.63	***	0.95	***	1.07	***	0.33	***
Q_{t1}	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***
c_{t1}^I	1.79	***	1.01	***	1.33	***	0.83	***	0.68	***	0.65	***
c_{t1}^{II}	2.76	***	0.51	***	0.71	***	0.81	***	0.93	***	0.37	***
c_{t1}^{III}	3.09	***	0.31	***	0.62	***	0.91	***	1.04	***	0.33	***
Q_{t2}	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***
c_{t2}^I	1.50	***	0.92	***	1.16	***	0.79	***	0.68	***	0.65	***
c_{t2}^{II}	2.46	***	0.62	***	0.84	***	0.81	***	0.87	***	0.44	***
c_{t2}^{III}	2.97	***	0.36	***	0.67	***	0.89	***	1.01	***	0.35	***
Q_{t3}	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***
c_{t3}^I	1.28	***	0.85	***	1.03	***	0.75	***	0.67	***	0.65	***
c_{t3}^{II}	2.18	***	0.69	***	0.91	***	0.80	***	0.82	***	0.50	***
c_{t3}^{III}	2.82	***	0.46	***	0.74	***	0.87	***	0.96	***	0.38	***
Q_{t4}	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***
c_{t4}^I	1.12	***	0.80	***	0.93	***	0.73	***	0.67	***	0.65	***
c_{t4}^{II}	1.93	***	0.72	***	0.93	***	0.78	***	0.78	***	0.54	***
c_{t4}^{III}	2.64	***	0.53	***	0.79	***	0.85	***	0.92	***	0.42	***
Q_{t5}	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***
c_{t5}^I	1.00	***	0.76	***	0.86	***	0.71	***	0.67	***	0.66	***
c_{t5}^{II}	1.70	***	0.74	***	0.92	***	0.77	***	0.75	***	0.57	***
c_{t5}^{III}	2.44	***	0.59	***	0.84	***	0.83	***	0.88	***	0.45	***
Q_{t6}	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***
c_{t6}^I	0.91	***	0.74	***	0.81	***	0.70	***	0.66	***	0.66	***
c_{t6}^{II}	1.51	***	0.74	***	0.90	***	0.75	***	0.73	***	0.59	***
c_{t6}^{III}	2.23	***	0.63	***	0.86	***	0.82	***	0.84	***	0.49	***
Q_{t7}	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***
c_{t7}^I	0.85	***	0.72	***	0.77	***	0.69	***	0.66	***	0.66	***
c_{t7}^{II}	1.34	***	0.74	***	0.87	***	0.74	***	0.71	***	0.61	***
c_{t7}^{III}	2.03	***	0.66	***	0.86	***	0.80	***	0.81	***	0.52	***
Q_{t8}	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***
c_{t8}^I	0.80	***	0.70	***	0.74	***	0.68	***	0.66	***	0.66	***
c_{t8}^{II}	1.21	***	0.73	***	0.84	***	0.72	***	0.70	***	0.62	***
c_{t8}^{III}	1.85	***	0.68	***	0.88	***	0.78	***	0.78	***	0.54	***
Q_{t9}	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***
c_{t9}^I	0.76	***	0.69	***	0.72	***	0.68	***	0.66	***	0.66	***
c_{t9}^{II}	1.10	***	0.72	***	0.81	***	0.71	***	0.69	***	0.63	***
c_{t9}^{III}	1.67	***	0.70	***	0.87	***	0.77	***	0.76	***	0.56	***
Q_{t10}	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***
c_{t10}^I	0.74	***	0.68	***	0.71	***	0.67	***	0.66	***	0.66	***
c_{t10}^{II}	1.01	***	0.71	***	0.79	***	0.70	***	0.68	***	0.64	***
c_{t10}^{III}	1.52	***	0.71	***	0.85	***	0.75	***	0.74	***	0.56	***
c_1	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0
Q_{t10}	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1
v	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2
f	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3
c_o^I	2.19	4	1.13	4	1.57	4	0.89	4	0.69	4	0.64	4
c_o^{II}	3.03	5	0.31	5	0.45	5	0.79	5	1.02	5	0.28	5
c_o^{III}	3.15	6	0.27	6	0.63	6	0.95	6	1.07	6	0.33	6
$f \times Q_{t10}/v$	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7
$f(Q_{t10}^2/2v^2)$	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8
$e^{-(Q_{t10}/v)f}$	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9
Q_t Stop	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A
c_t Stop	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B
Start	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C
c_{t10}^I	0.74	D	0.68	D	0.71	D	0.67	D	0.66	D	0.66	D
c_{t10}^{II}	1.01	E	0.71	E	0.79	E	0.70	E	0.68	E	0.64	E
c_{t10}^{III}	1.52	I	0.71	I	0.85	I	0.75	I	0.74	I	0.58	I

Profile Nº	E 25		E 26		E 27		E 28		E 29		E 30	
c_o^I	0.62	***	0.52	***	1.65	***	2.12	***	14.78	***	6.35	***
c_o^{II}	0.79	***	0.53	***	1.19	***	3.48	***	14.42	***	5.92	***
c_o^{III}	0.91	***	1.00	***	1.30	***	4.07	***	9.62	***	11.24	***
Q_{t1}	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***	10.00	***
c_{t1}^I	0.63	***	0.56	***	1.39	***	1.74	***	11.12	***	6.36	***
c_{t1}^{II}	0.75	***	0.53	***	1.27	***	3.07	***	13.99	***	6.27	***
c_{t1}^{III}	0.87	***	0.68	***	1.29	***	3.57	***	10.88	***	9.95	***
Q_{t2}	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***	20.00	***
c_{t2}^I	0.64	***	0.58	***	1.20	***	1.46	***	8.41	***	4.88	***
c_{t2}^{II}	0.72	***	0.54	***	1.28	***	2.69	***	12.86	***	6.66	***
c_{t2}^{III}	0.84	***	0.79	***	1.29	***	3.62	***	11.65	***	9.04	***
Q_{t3}	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***	30.00	***
c_{t3}^I	0.64	***	0.60	***	1.06	***	1.25	***	6.40	***	3.79	***
c_{t3}^{II}	0.70	***	0.56	***	1.24	***	2.34	***	11.42	***	5.61	***
c_{t3}^{III}	0.80	***	0.73	***	1.30	***	3.35	***	11.92	***	8.29	***
Q_{t4}	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***	40.00	***
c_{t4}^I	0.65	***	0.62	***	0.96	***	1.10	***	4.91	***	2.98	***
c_{t4}^{II}	0.68	***	0.57	***	1.18	***	2.04	***	9.91	***	5.02	***
c_{t4}^{III}	0.77	***	0.68	***	1.28	***	3.06	***	11.73	***	7.68	***
Q_{t5}	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***	50.00	***
c_{t5}^I	0.65	***	0.63	***	0.88	***	0.99	***	3.61	***	2.38	***
c_{t5}^{II}	0.68	***	0.58	***	1.11	***	1.78	***	8.46	***	4.41	***
c_{t5}^{III}	0.75	***	0.65	***	1.26	***	2.77	***	11.20	***	6.95	***
Q_{t6}	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***	60.00	***
c_{t6}^I	0.65	***	0.64	***	0.82	***	0.90	***	2.99	***	1.55	***
c_{t6}^{II}	0.67	***	0.60	***	1.04	***	1.56	***	7.14	***	3.82	***
c_{t6}^{III}	0.73	***	0.64	***	1.22	***	2.50	***	10.44	***	6.26	***
Q_{t7}	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***	70.00	***
c_{t7}^I	0.66	***	0.64	***	0.78	***	0.84	***	2.39	***	1.60	***
c_{t7}^{II}	0.67	***	0.61	***	0.98	***	1.38	***	5.98	***	3.26	***
c_{t7}^{III}	0.71	***	0.63	***	1.17	***	2.24	***	9.53	***	100.56	***
Q_{t8}	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***	80.00	***
c_{t8}^I	0.66	***	0.65	***	0.75	***	0.79	***	1.94	***	1.36	***
c_{t8}^{II}	0.66	***	0.62	***	0.92	***	1.23	***	4.98	***	2.81	***
c_{t8}^{III}	0.70	***	0.62	***	1.12	***	2.01	***	8.57	***	5.00	***
Q_{t9}	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***	90.00	***
c_{t9}^I	0.66	***	0.65	***	0.73	***	0.76	***	1.61	***	1.18	***
c_{t9}^{II}	0.66	***	0.63	***	0.88	***	1.11	***	4.15	***	2.41	***
c_{t9}^{III}	0.69	***	0.62	***	1.07	***	1.80	***	7.60	***	4.42	***
Q_{t10}	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***	100.00	***
c_{t10}^I	0.66	***	0.65	***	0.71	***	0.73	***	1.36	***	1.04	***
c_{t10}^{II}	0.66	***	0.63	***	0.83	***	1.02	***	3.45	***	2.07	***
c_{t10}^{III}	0.68	***	0.62	***	1.02	***	1.61	***	6.68	***	3.89	***
c_i	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0	0.66	0
Q_{t10}	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1
v	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2	30.00	2
f	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3
c_o^I	0.62	4	0.52	4	1.65	4	2.12	4	14.78	4	6.35	4
c_o^{II}	0.79	5	0.53	5	1.19	5	3.48	5	14.42	5	5.92	5
c_o^{III}	0.91	6	1.00	6	1.30	6	4.07	6	9.62	6	11.24	6
$f \times Q_{t10}/v$	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7	3.00	7
$f(Q_{t10}^2/2v^2)$	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8	5.00	8
$e^{-(Q_{t10}/v)t}$	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9	0.05	9
Q_t Stop	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A	100.00	A
c_t Stop	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B	0.00	B
Start	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C	0.00	C
c_{t10}^I	0.66	D	0.65	D	0.71	D	0.73	D	1.36	D	1.04	D
c_{t10}^{II}	0.66	E	0.63	E	0.83	E	1.02	E	3.45	E	2.07	E
c_{t10}^{III}	0.66	I	0.62	I	1.02	I	1.61	I	6.68	I	3.89	I

A N N E X 3

Soil Designation, Nomenclature and Classification

Soil Designation, Nomenclature and Classification[1)]

The soils have been classified according to the modified and enlarged FAO-classification, used in the "Legend of the Soil Map of the World", FAO-UNESCO 1974. This system is structurally based on the use of a number of selected soil properties in differentiating classes although there are some "natural" soil units identified, which are based on all properties of a soil as an entity. Therefore the system preponderant is inductive, having some deductive elements, i.e. only objective and measurable soil properties are the basis of soil classification and soils showing comparable properties are groupes as isomorphic soil types. The highest classification level (soil units) is characterized by a small number of units which are classified deductively a priory, e.g. the soils occuring under aridic and semi-aridic climates are grouped as Yermosols and Xerosols, if the properties of Lithosols, Vertisols, Fluvisols and Solonchaks are not evident. This classification is based on the concept of genetic systems and the presumed or gin of the soil, defined on soil conformity factors. The middle and lower categories of the soil classifications are defined according to strictly defined soil properties which are relevant to both the pedogeneses and ecological-functional aspects:

1. Diagnostic epipedon horizons
2. Diagnostic subsurface horizons
3. Diagnostic properties
4. Soil Phases
5. Soil Variants, Site Variants
6. Textural Classes

These profile characteristics are used in the classification system dependent on the level, and the type of the soil mapping. Soil Phases and Variants are those properties which are of ecological relevance but which are not reflected by the primary diagnostic properties or which have no direct relation to the soils genetical development. The soil phases should be used in accordance to the specific use of the soil survey. Soil Variants are used for intensive soil surveys when diagnostic properties or soil phases should be specified more

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1) H.P. Blume and Th. Petermann, Classification of Arid Zone Soils, German Society of Soil Science, Conference 1981.

detailed. External soil qualities like slope, outcrops, micro-relief, soil erosion degradation and risk of flooding are considered as soil variants also if they are not of importance at a higher categoric level (soil catenas).

Summarizingly the structure of the soil classification system is polycategoric-hierarchic having several categories of classes of the higher-middle and lower niveau, which are explained on the basis of the following example:

UNIT	SOLONCHAK	Z	Saline Soil having an ochric A- and calcic B-horizon.
SUBUNIT	YERMIC SOLONCHAK	yZ	according to the actual aridic soil moisture regime = called Yermic Solonchak
SOIL TYPE	CALCIC YERMIC SOLONCHAK	yZk	A calcic B-horizon is the primary diagnostic property
SOIL SUBTYPE		yZk(dc1)	according to the non-calcareous parent material and the morphological development of a calcic Bck horizon having calcic nodules beginning in 0 - 50 cm profile depth
PHASES	gypsic, lithic	- yi	a weak gypsic horizon as Byz and lithic contact within 50 - 200 cm profile depth
VARIANTS		- yi3z3	differentiation according to the effective profile depth in 150 - 200 cm; and the type of salinization (z3) as chloridic.
SITE PHASES	slope	- yi3z3 / s	the site is different from similar profiles because of a knolly relief.
TEXTURAL CLASS	medium textured	yZk(dc1)3/04	sandy loamy topsoil (0 - 50 cm) overlying a fragmental silty loam in the lower rootzone and subsoil horizons.

Table 20: <u>Structure of the Soil Type Classification System</u>

Diagnostic horizons

ochric A epipedon	-	very weakly humous topsoil horizon (< 1 % humus at a sand/clay ratio of < 1; < 0.5 % humus at a sand/clay ratio of > 13 otherwise intermediate values), which does not have the properties of mollic, umbric, anthropic, plaggen or lithic epipedon horizons; often pale in colour but usually darker than the adjacent underlying horizons; it has a soil morphology aquired by soil formation.
anthropic epipedon	-	development of a topsoil (often ploughed) horizon as a result of long term irrigation; the diagnostic properties of an anthropic epipedon of humid climates must not be required.
gypsic horizon	-	secondary enrichment of $CaSO_4$ in the A- B- or C horizon; more than 15 cm thickness and > 5 % $CaSO_4$ than the parent material; indurated layers are classified as petrocalcic horizons.
calcic horizon	-	secondary enrichment of $CaCO_3$ in the A- B- or C horizon; more than 15 cm thickness, not less than 15 % $CaCO_3$ and at least 5 % more $CaCO_3$ as in the parent material; if there are secondary accumulations of $CaCO_3$ in the B-horizons of soils developed on calcareous material, the content of $CaCO_3$ must not decrease with depth. Indurated layers are classified as petrocalcic horizon;
argillic B horizon	-	clay illuvial horizon below an eluviation E horizon
cambic B horizon	-	a transitional subsurface horizon characterized by its colour and structural arrangement which is different from the underlying horizons or parent material; a cambic horizon may have lost sesquioxides at bases including carbonates through leaching; the alteration is characterized by the physical alteration by movement of soil particles, aggregation of soil particles into peds and the chemical alterations as the result of hydrolysis, reduction and segregation and solution and redistribution of soluble minerals. In arid regions often the cambic B horizon is characterized by its coarse prismatic structure which lies only a few centimeters below a platy surface horizon.

Diagnostic Properties

lithic	-	consolidated bedrock within 50 cm of the profile.
aridic moisture regime	-	natural soil moisture conditions to describe the soils accuring under warm-arid (YERMOSOLS, YERMIC SOLONCHAKS) and warm-semiarid (XEROSOLS) climatic conditions. The profile (30 cm for fine textured soils and 90 cm for light textured soils) should be not moist throughout for more than three consecutive months. Irrigated soils having an anthropic epipedon are designated by an anthropic phase. Groundwater-influenced soils having a high salinity are classified as Active Solonchaks.
high salinity	-	average electrical conductivity of the saturated soil extract exceeds 15 mS/cm within 1.25 m profile depth for heavy textured soils
takyric features	-	heavy textured soils which have deep polygonal cracks and a platy or massive surface crust when wet.
hydromorphic properties	-	in "gleysols" or "gleyic" soil subtypes; imperfectly drained soils showing a colouration of N or bluer than 10Y and signs of a seggregation of iron.

Phase z SALINE z 1-9 Variants	in the main rootzone (0-100 cm) a moderate salinization (4-15 mS/cm); single horizons may have a strong salinity level the type of salinity according to the predominant anion composition in (1) NO_3, (2) NO_3 + Cl, (3) Cl, (4) SO_4 + Cl, (5) Cl + SO_4, (6) SO_4, (7) SO_4 + soda, (8) soda, (9) Borate. A second number designates the predominant cation as (1) Ca, (2) Na, (3) Mg, (4) K;
Phase x STONY	coarse fragments (> 2 mm) in the main rootzone (0-50 cm) exceeds 35 %, thus limiting the workability and seed establishment.
Phase y GYPSIC	gypsic horizon in the profile which does not fullfil the requirements for diagnostic horizons
Phase k CALCIC	calcic horizon in the profile which does not fullfill the requirements of diagnostic horizons
Phase i LITHIC i1-3 Variants	consolidated bedrock within 50 - 200 cm profile depth according to the root penetrable soil depth in (1) 50 - 100 cm, (2) 100 - 150 cm, (3) 150 - 200 cm.
Phase m MOTTLED	blotched subsoil horizons, characterized by mottles of contrasting colours, mostly reddish-brown, rarely gray in a reddish-yellow or yellowish brown matrix; the blotches are not produced by lithological discontinuities. Relict hydromorphic processes i.e. segregation of iron were induced by fluctuating groundwater levels or waterlogging.
Phase l LUVIC	weak clay illuviation in the B-horizon without the characteristics of an argillic B horizon or where the illuviation occurs in the soils having a calcic or gypsic diagnostic horizon or lithic or takyric diagnostic properties.
Phase pz PETROSALINE Variants	saltpan or cemented salt layer below the surface having not less than 2 % of soluble salts and which is more than 2 cm thick, according to the depth of petrosaline layer in: (1) surface 0 - 20 cm, (2) shallow 20 - 50 cm, (3) moderately deep 50 - 100 and (4) deep 100 - 200 cm depth. A further subdivision is performed according to the quantity and thickness of the petrosaline layer in (1) Salt (%) x thickness (cm) < 10; (2) 10 - 60 and (3) > 60 and given as a second number; e.g. 2/1 = shallow layer with a salt x thickness product of 10 - 60.
Phase s SODIC	a sodic phase designates soils having not less than one horizon with an high ESP (> 15) and a CEC of > 5 me/100 g.
Phase d DURIC	soil having a petrocalcic horizon where the cementation is caused by additional silicates (quarzt, Chalcedon, Opal); synonymious with silicrete.
Phase a ANTHROPIC	soils with an anthropic epipedon which is characterized as an irrigated soil, whose soil development is strongly influenced by the additional water supply.
Phase q AQUIC	soils having a groundwater table within 1 m profile depth; as long as these soils are not classified as GLEYSOLS or SOLONCHAKS.
Phase p PHREATIC Variants	soils with a groundwater table within 1 - 5 m profile depth Soil Variants should be classified according to the actual salinity level of the groundwater in (p1) salt free < 1 mS/cm, (p2) moderately saline 1 - 3 mS/cm, and (p3) strongly saline > 3 mS/cm.
Phase e EXTERNAL	designation of a SOLONCHAK, whose solum is strongly saline up to the surface, opposite to internal SOLONCHAK with a non-saline epipedon (Kryptosolonchak according to Kubiëna).
Phase f FLUFFY	property of ACTIVE SOLONCHAKS having an extremely loose and dry surface, where the segregation of particles is induced by the accummulation of wedles shaped Na_2SO_4.
Phase b SABKHA	synonymious designation for ACTIVE SOLONCHAKS having an accummulation of hygroscopic salts which simulate a high plant available water quantity have a dark colour and seems to be ploughed.
Phase w WATER DEPOSITTS Variants	layered profile with a deposition of fluvial sediments upon the buried soil surface, the thickness does not exceed 50 cm, otherwise REGIT soil subtypes should be classified according to the thickness of the layers in (1) 0 - 20 cm, (2) 20 - 35 cm and (3) 35 - 50 cm.
Phase d DUNE-SHIFTING SAND DEPOSITS Variants	layered profile with an accummulation of aeolian sand upon the old soil surface; variants should be classified accordingly the thickness in (1) 0 - 20 cm, (2) 20 - 35 cm and (3) 35 - 50 cm.

Textural Classes

Particle size classes or substitutes are used to describe soil material of the upper 50 cm of the soil, which are important for tillage and various internal soil qualities. If there occurs strongly contrasting particle size classes within 150 cm from the surface or to a lithic contact or to a impenetrable horizon (petrocalcic phase, duripan) a second number is used: 05/02 or 02/04.

0	fragmental (>75% >2mm)	=	stones - cobbles - gravels
1	very coarse textured	=	sand
2	coarse textured	=	loamy sand
3	moderately coarse textured	=	sandy loam
4	medium textured	=	loam, silty loam, silt
5	moderately fine textured	=	sandy clayey loam, sandy clay
6	fine textured	=	clay, silty clay
7	ashy	=	volcanic ash, cinders, pumic
8	tixotropic	=	amorphous clays, fine earth is tixotropic

01 very coarse skeletal textured ;if fragments(>2mm) are >35%

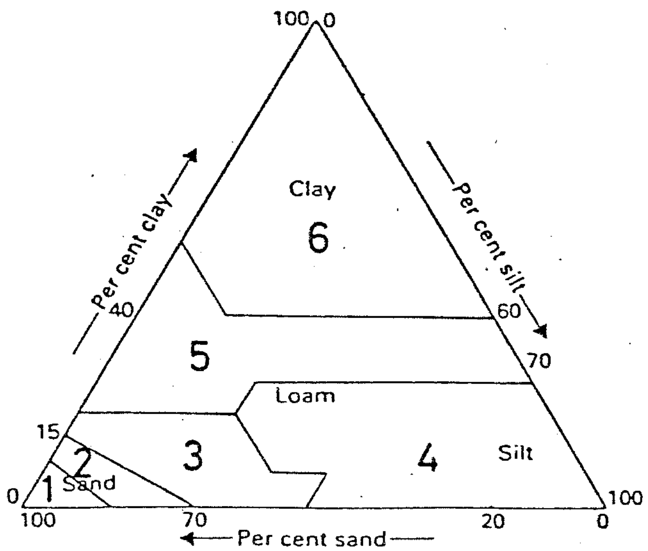
02 coarse skeletal textured

03 moderately coarse skeletal textured

04 medium skeletal textured

05 moderately fine skeletal textured

06 fine skeletal textured



At the higher categories the identification of taxonomic classes is performed by the use of the following key guide where the soil properties are defined:

Table 21:

Key Guide to Soil Units, Characterized by an "aridic moisture regime"

Diagnostic Characteristics	Designation
profile depth less than 10 cm	LITHOSOL (L)
other soils having > 30% clay, deep cracks, slickenslides, wedge-shaped or parallelepiped structural aggregates and gilgai micro relief.	VERTISOL (V)
other soils developed on recently alluvial deposits having no other diagnostic horizons than an ochric or umbric A, a histic H horizon or a sulferic horizon; receiving fresh material at regular intervals and showing stratification	FLUVISOLS (J)
other soils showing a "high salinity" and no other diagnostic horizon than an ochric A, H, cambic, calcic or gypsic horizon	SOLONCHAKS (Z), subtypes are differentiated according to the diagram below
other soils showing a "very weak ochric A horizon" and one of the following diagnostic horizon: Cambic, argillic B, calcic or gypsic, and takyric or lithic properties	YERMOSOLS (Y)
If other horizons than an ochric A are absent and the soil develops on unconsolidated older fluvial or aeolic deposits a Regit subtype was classified	differentiated according to the diagram below
other soils showing a "weak ochric A horizon", further properties correlate to those of the Yermosols	XEROSOLS (X)
other areas without significant soil development	MISCELLANEOUS LAND-UNITS: SAND DUNES, ROCK DEBRIS

Remarks to the "guide": theoretically also Gleysols (hydromorphic properties, but lacking of high salinity) and SOLONETZ (matric B-horizon is developed) may occur; under present arid conditions these soil units should not be expected. ARENOSOLS are classified in the "FAO-soil map of the world" according to their sedimentological properties (texture, colour) as a great soil unit; these soils are defined as Sandy REGIT YERMOSOLS on the soil type category since the texture should not be regarded as a diagnostic property on the soil type level.

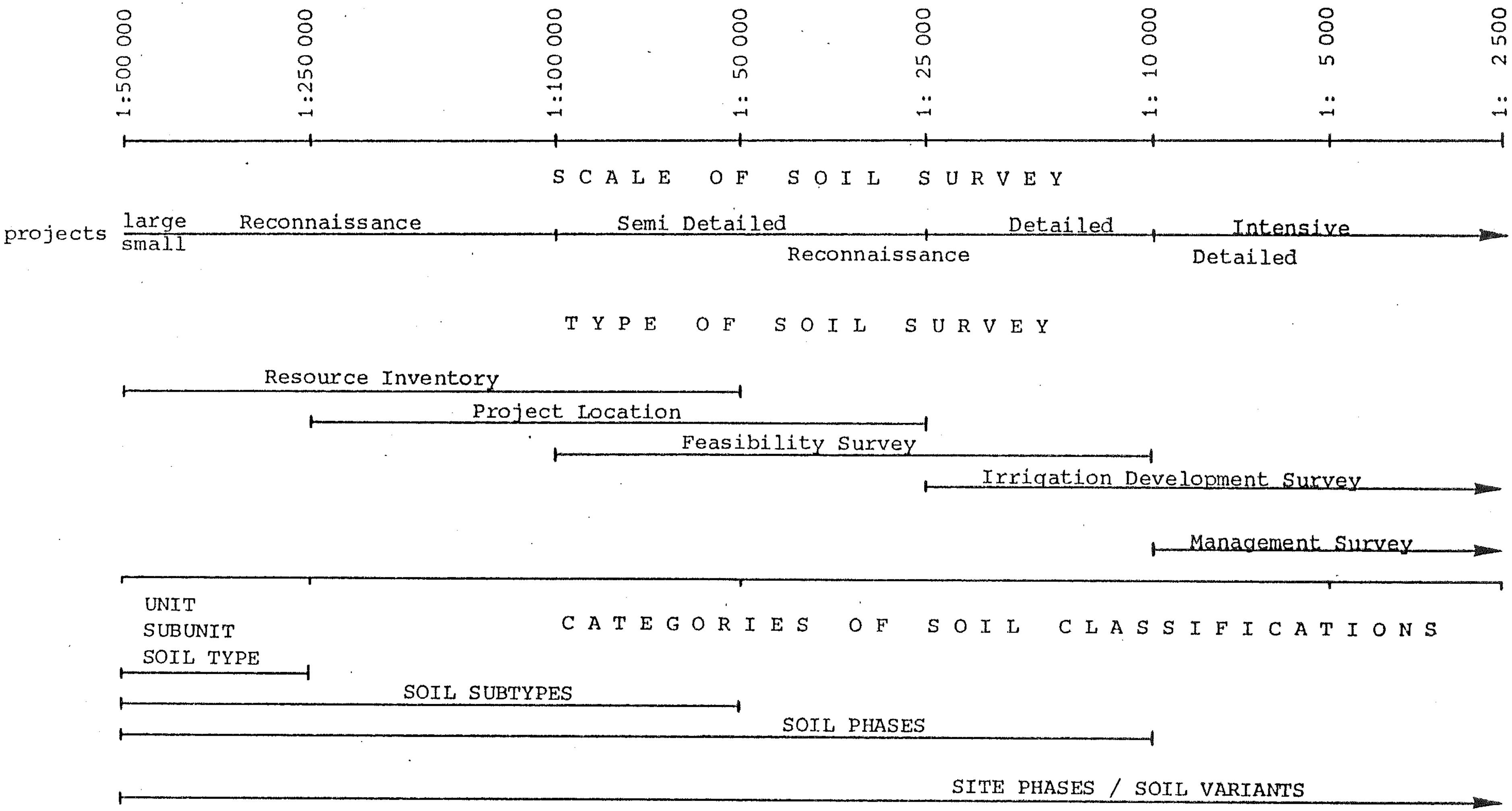
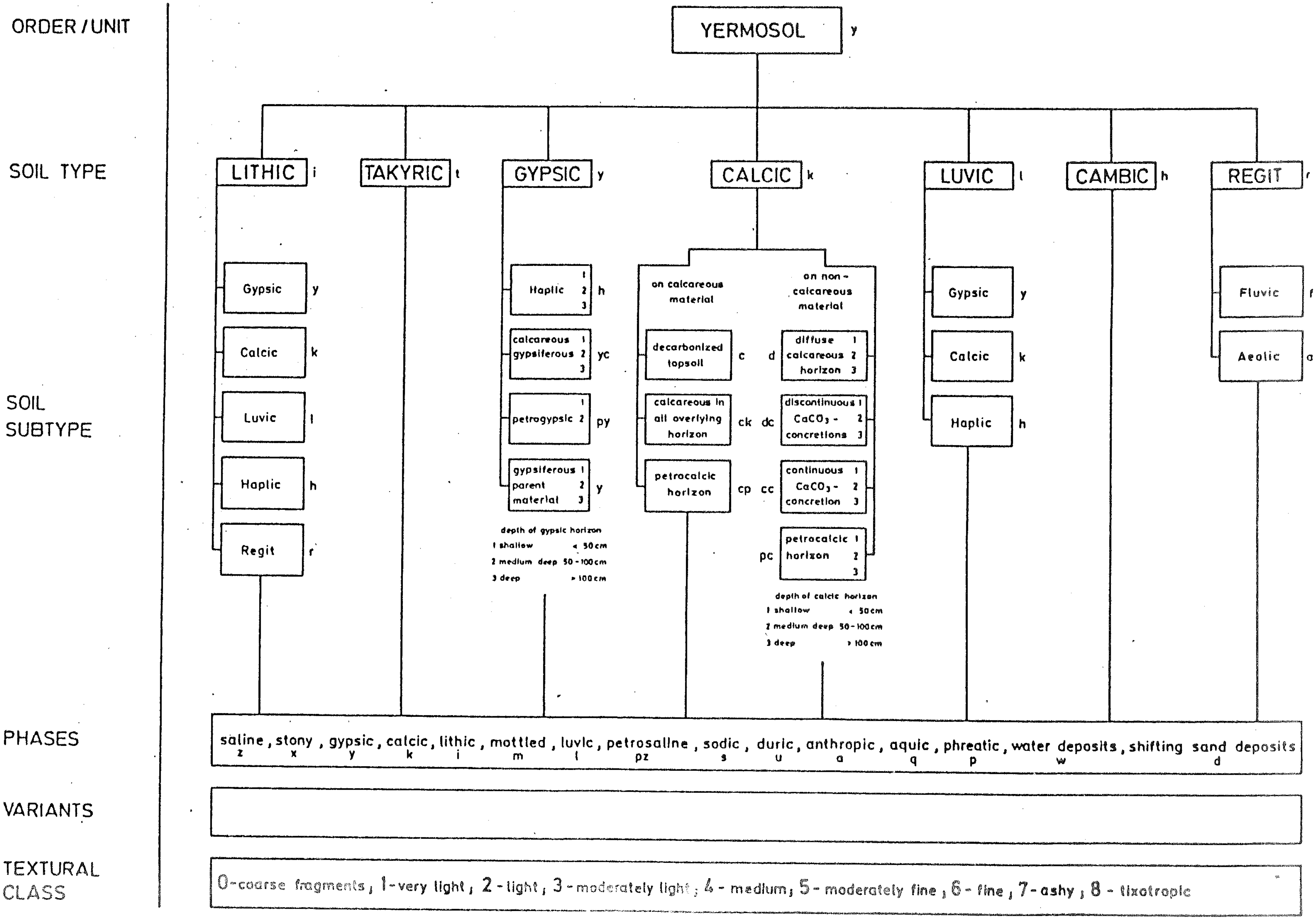


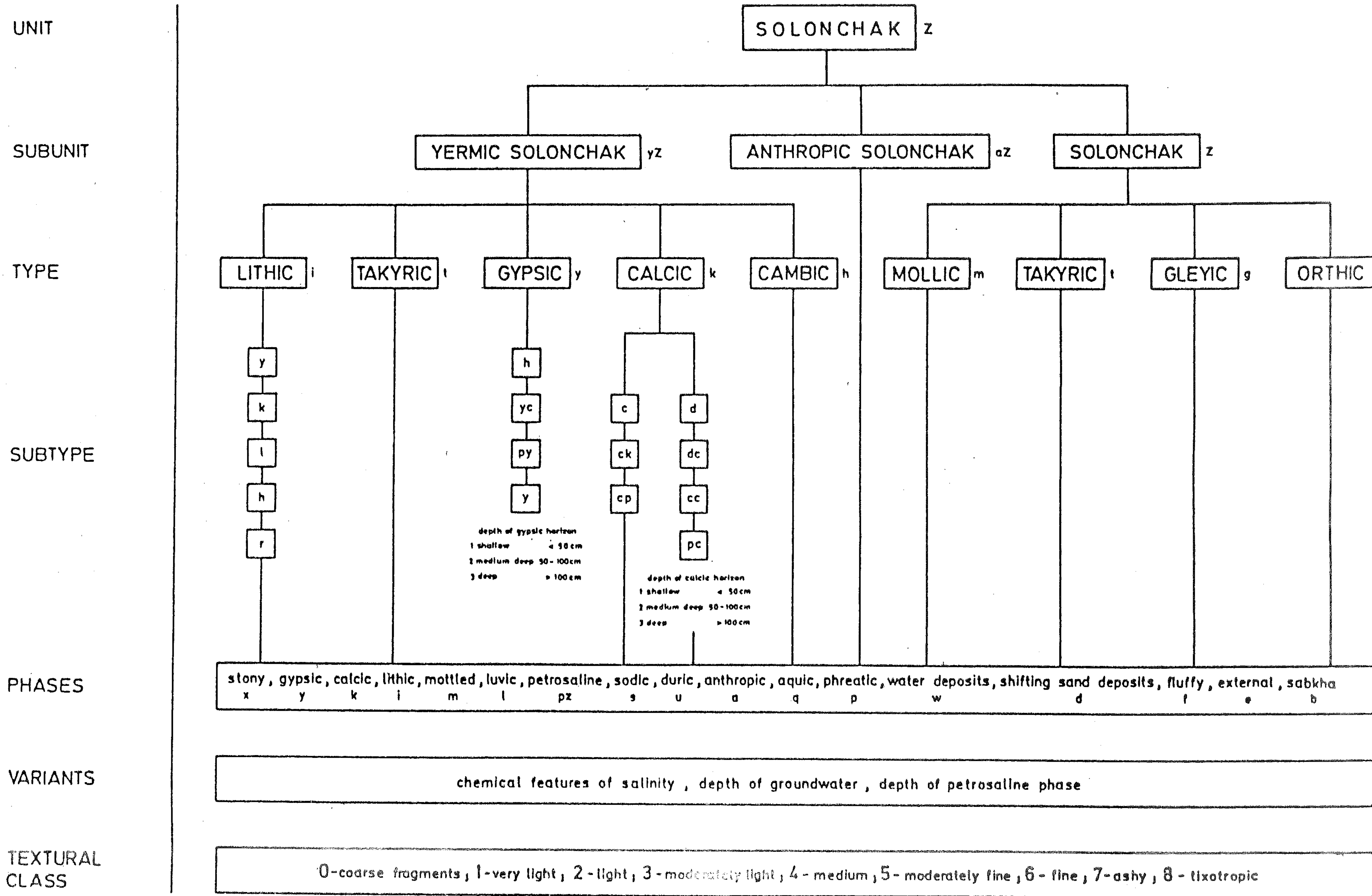
Figure 10: Level of Soil Classification and Scale / Type of Soil Survey


ORDER / UNIT
SOIL TYPE
SOIL SUBTYPE
PHASES
VARIANTS
TEXTURAL CLASS
YERMOSOL y
LITHIC i
TAKYRIC t
GYPSIC y
CALCIC k
LUVIC l
CAMBIC h
REGIT r
Gypsic y
Calcic k
Luvic l
Haplic h
Regit r
Haplic 1 2 3 h
calcareous gypsiferous 1 2 3 yc
petrogypsic 1 2 3 py
gypsiferous parent material 1 2 3 y
depth of gypsic horizon
1 shallow < 50cm
2 medium deep 50-100cm
3 deep > 100cm
on calcareous material
on non-calcareous material
decarbonized topsoil c
calcareous in all overlying horizon ck
petrocalcic horizon cp
d diffuse calcareous horizon 1 2 3
dc discontinuous $CaCO_3$ - concretions 1 2 3
cc continuous $CaCO_3$ - concretion 1 2 3
pc petrocalcic horizon 1 2 3
depth of calcic horizon
1 shallow < 50cm
2 medium deep 50-100cm
3 deep > 100cm
Gypsic y
Calcic k
Haplic h
Fluvic f
Aeolic a
saline z, stony x, gypsic y, calcic k, lithic i, mottled m, luvic l, petrosaline pz, sodic s, duric u, anthropic a, aquic q, phreatic p, water deposits w, shifting sand deposits d
0 - coarse fragments, 1 - very light, 2 - light, 3 - moderately light, 4 - medium, 5 - moderately fine, 6 - fine, 7 - ashy, 8 - tixotropic

YERMOSOLS	Y	Soils having an aridic moisture regime and a very weak ochric A horizon or an anthropic epipedon and one or more of the following diagnostic horizons or properties: lithic, takyric, gypsic, calcic, luvic, cambic. If there is developed only an ochric A horizon in unconsolidated sediments a REGIT subtype is classified. Generally the diagnostic properties are absent for high salinity, Vertisols, Lithosols, Permafrost and other diagnostic horizons. Often the soils occuring under present arid climatic conditions should be identified as Palaëosoils, whose development may have started since Tertiary geological times. The differentiation in soil types, according to diagnostic properties must be performed in following sequence, where the subsequently properties exclude the afore mentioned ones.
LITHIC YERMOSOLS	Yi	Yermosol having a lithic contact within 10 - 50 cm profile depth; diagnostic horizons in the solum will differentiate into the following subtypes:
	Yi(y)	Gypsic Lithic Yermosol having a main gypsic diagnostic horizon; in the presence of $CaCO_3$, the $CaSO_4$ content must be $\geq$ 35 % of the total sum of $CaSO_4 + CaCO_3$.
	Yi(k)	Calcic Lithic Yermosol having a diagnostic calcic horizon
	Yi(l)	Luvic Lithic Yermosol having a diagnostic luvic (argillic) horizon.
	Yi(h)	Haplic Lithic Yermosol having a cambic B horizon.
	Yi(r)	Regit Lithic Yermosol, showing no diagnostic horizon than an ochric A horizon.
TAKYRIC YERMOSOL	Yt	Yermosol having takyric features: heavy textured soil with polygonal structure of the dry topsoil and a platy and massive surface crust; further subdivisions should be waited for more detailed informations and data on Takyric Yermosols.
GYPSIC YERMOSOL	Yy	Yermosols having a diagnostic gypsic horizon, whose $CaSO_4$ content exceeds 5 % compared to the adjacent horizons and whose thickness is 15 cm or more and the product of thickness (cm) and $CaSO_4$ content (%) exceeds 150. The upper horizon boundary must be within 1.5 m solum. A cambic B, luvic or calcic horizons may be present. If diagnostic calcic and gypsic horizon occur within one profile, the gypsic horizon is presumed as main horizon when the $CaSO_4$ content (%) exceeds 35 % of the total sum of $CaSO_4$ and $CaCO_3$. The subdivision of Gypsic Yermosols is performed according to the genetic-morphological stages of the gypsic horizon:
	Yy(h)	Haplic Gypsic Yermosol, where the gypsum is segregated within the horizon in the form of soft or isolated crystals or crystal nests;
	Yy(c)	Calcareous-Gypsiferous Yermosol, where both a calcic and gypsic diagnostic horizon are developed, however, the gypsic horizon is classified as the main diagnostic one.
	Ypy	Petrogypsic Yermosol, where the gypsic horizon is developed as an indurated layer which is stable against water and where the root penetration is hampered. Massive or platy structure; the $CaSO_4$ content exceeds 60 % normally.
	Yyy	Gypsic Yermosol, developed on gypsiferous parent material; a subdivision should be waited for more detailed informations.
	1 - 3	The gypsiferous Yermosols are subdivided on the subtype categoric level accordingly the depth of the diagnostic horizon in: (1) shallow 0 - 50 cm, (2) moderately deep 50 - 100 cm and (3) deep 100 - 150 cm profile depth. The percentage of gypsum is classified as Soil Variant in (1) < 25 % $CaSO_4$; (2) 25 - 40 %; (3) 40 - 60 % and (4) > 60 %. Also the thickness of the diagnostic gypsic horizon is given as Soil Variant in (1) < 25 cm, (2) 25 - 50 cm, (3) 50 - 100 cm and (4) > 100 cm thickness. The thickness is classified as second Variant number as follows: 3/2 means a $CaSO_4$ content of 40 - 60 % and a thickness of 25 - 50 cm. Further ecological and genetical soil properties are given as Soil Phases according to Table .

CALCIC YERMOSOLS	Yk	Yermosols having a diagnostic calcic A, B or C horizon within 1.5 m profile depth, where the secondary enrichment of $CaCO_3$ exceeds 15 %, whose thickness is ≥ 15 cm and the content of $CaCO_3$ is ≥ 5 % more than in the subsoil. If the soil developed on calcareous parent material (> 40 % $CaSO_4$ equivalent) the percentage must not decrease with depth. A gypsic horizon may be present, but does not meet the requirements of a main diagnostic horizon. An argillic B_t horizon is absent or developed as weakly as a luvic phase. Soils having a duripan horizon are classified as Petrocalcic Yermosols, since the cementation is caused by a combination of silicates, $CaCO_3$ and Fe_2O_3 mostly.
	Yk (c) (ck) (cp)	Calcic Yermosols, developed on calcareous parent material. The subtypes are divided accordingly the degree of decarbonatization of the upper profile in: (c) complete decarbonatization of the topsoil, (ck) uncomplete decarbonatization of the epipedon and the secondary enrichment of the B horizon by $CaCO_3$ nodules and concrets; (cp) uncomplete decarbonatization of the epipedon and the development of petrocalcic layers (hardpan calcrete) in the A, B or C horizon).
	Yk d dc cc	Calcic Yermosols with a diagnostic secondary calcic A, B or C horizon within 1.5 m profile, developed on non-calcareous material. The subtypes are classified on the base of progressive development and physical and chemical features (genetic factors and soil fabric changes) of carbonate accumulations; (d) diffuse distribution of $CaCO_3$ within the horizon, typically for a weakly differentiated calcareous profile; (dc) discontinuous concretions or nodules are segregated within the horizon; between the hard or friable accumulations the distribution of $CaCO_3$ is diffuse; typically for moderately well differentiated calcareous profiles; (cc) continuous concretions or calcareous encrustation of a massive structure, non-laminated and non-platy fabric; below the encrustation there are always horizons of friable accumulations; typically for well differentiated calcareous profiles; (pc) petrocalcic horizon or layer of a laminated, massive encrustation, often with sheets of indurated layers; typically for very well differentiated calcaroeus profiles due to crusting; $CaCO_3$ content exceeds 40 % if the material is quartzitic sand, otherwise > 70 %; the encrustation may occur in variable depth, due to the pedogenetic processes: a duric phase designates those calcareous crusts, whose second important constituent is silica (silica-calcrete). The calcareous Yermosols are subdivided on the subtype category according to the depth of the diagnostic horizon in: (1.) shallow 0 - 50 cm; (2.) mod.deep 50 - 100 cm; (3.) deep 100 - 150 cm; petrocalcic layers are subdivided according to the thickness of the horizon in: (1.) > 25 cm, (2.) 25 - 50 cm, (3.) 50 - 100 cm, (4.) > 100 cm thickness. The content of $CaCO_3$ may be submitted as Soil Variant in: (1.) < 25 %, (2.) 25 - 40 %, (3.) 40 - 60 %, (4.) < 60 % $CaCO_3$. Further subdivisions according to Soil Phases and Soil Variants for project or site specific aspects.
LUVIC YERMOSOLS	Yl	Yermosols having a strong argillic B_t horizon of clay illuviation. A calcareous or gypsiferous horizon may occur beneath the B_t. A bleached clay eluviation horizon, E, is developed above the B_t. The increase of clay must exceed 3 % if the eluvial horizon has less than 15 % total clay, resp. the ratio of the clay in the B_t and E horizons must be 1.2 or more if the eluvial horizon has a clay content of 15 - 40 %; in a clayey soil (> 40 % clay) the argillic B_t horizon must contain at least 8 % more clay. The argillic B_t should be at least 15 cm thick (7.5 cm in loamy or clayey soils). In soils with massive or single grained structure the B_t has oriented clay bridging the sand grains and some peds (cutans). Luvic Yermosols should be classified as Paläeosoils, since humid moisture conditions are necessary for clay translocation and carbonates and sulphates are leached out of the topsoil. A matric B horizon and high ESP are leaking. A differentiation of Luvic Yermosols should be considered as provisional, since more data are required for a classification.
	Yl(k)	Calcic Luvic Yermosol, a diagnostic calcareous horizon is developed beneath the B_t horizon.
	Yl(y)	Gypsic Luvic Yermosol, a diagnostic gypsiferous horizon is developed beneath the B_t horizon.
	Yl(h)	Haplic Luvic Yermosol, no further diagnostic horizons or properties were identified.

CAMBIC YERMOSOL	Yh*	Yermosols, which show no further diagnostic horizons than an ochric A and a cambic B. A cambic B horizon developed by physical and chemical weathering or alteration of the parent material. Carbonates are leached frequently or accumulated in the subsoil. Often the structure of the cambic B horizon is coarse-prismatic; the tops of the prisms commonly lie only a few centimeters below a platy surface horizon (Aa). The color may be slightly darker compared to the underlying horizons. There is no division in subtypes. Often gypsic and calcic phases were designated. * h derived from haplic
REGIT YERMOSOLS	Yr	Soils on unconsolidated sediments with a weak soil formation development. The properties are largely derived from their manner of deposition. Beneath a weak ochric A horizon several sequences are developed of C, 2C, 3C horizons/Layers, which reflect lithological discontinuities. Efflorescences of salts, gypsum etc. indicate episodically soil solutions, which may percolate or ascend. Regit Yermosols are divided into subtypes on the basis of mode of deposition and types of sediments.
	Yrf	Fluvic Regit Yermosols are characteristically for fluvial rediments, which were deposited in small dried-up wadis or channels; a discordant stratification is typical; hydromorphic features within 0.5 m are leaching.
	Yra	Aeolian Regit Yermosols are characteristically for areas which consists of shifting sand (dune), where a weak profile development started. Often shifting sands are overlying older land surfaces or may accumulate in lee side areas. Active dunes are designated as Miscellaneous Land Units.


UNIT
SUBUNIT
TYPE
SUBTYPE
PHASES
VARIANTS
TEXTURAL CLASS
SOLONCHAK z
YERMIC SOLONCHAK yz
ANTHROPIC SOLONCHAK az
SOLONCHAK z
LITHIC i
TAKYRIC t
GYPSIC y
CALCIC k
CAMBIC h
MOLLIC m
TAKYRIC t
GLEYIC g
ORTHIC
y
k
l
h
r
h
yc
py
y
c
ck
cp
d
dc
cc
pc
depth of gypsic horizon
1 shallow < 50 cm
2 medium deep 50 - 100 cm
3 deep > 100 cm
depth of calcic horizon
1 shallow < 50 cm
2 medium deep 50 - 100 cm
3 deep > 100 cm
stony, gypsic, calcic, lithic, mottled, luvic, petrosaline, sodic, duric, anthropic, aquic, phreatic, water deposits, shifting sand deposits, fluffy, external, sabkha
x y k i m l pz s u a q p w d f e b
chemical features of salinity, depth of groundwater, depth of petrosaline phase
0 - coarse fragments; 1 - very light; 2 - light; 3 - moderately light; 4 - medium; 5 - moderately fine; 6 - fine; 7 - ashy; 8 - tixotropic

A N N E X 4

Soil Profile Description Cards

Eshkeda Project Area

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 1

Topography:	slightly undulating Serir south of Wadi Shatti depression
Microrelief:	
Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture
Vegetation:	cereal alfalfa

Depth cm	0-35	35-60	60-100	100-180			
Horizon	Ap	B	Go	Gr			
Color	7.5YR5/6	7.5YR6/6	10YR4/2 +7.5YR6/6				
Structure	sin oo	sin oo	sin oo	sin oo			
Consistence	1	1	1	1			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	Fe	-			
Gypsum	-	-	-	-			
Carbonates	Ia1	Ia1	Ia1	Ia1			
Texture	t'S	l'S	S	S			
Wetness	3	2	4	4			
Roots	4	2	1	0			

Samples cm	0-35	35-60	60-100	100-130			
Gravel %	0	0	0	0			
EC_e mS/cm	3.95	1.19	1.70	1.86			
Salt %	0.04	0.01	0.02	0.02			
pH paste)	7.8	8.0	7.8	7.8			
$CaCO_3$ %	< 1	<1	<1	<1			
Moist.Cap. %	16	17.15	17.3	17.5			
HC cm/d	28 Inf.	140	1200 ±	> 300			
Texture cS/mS/fS	20 / 44 / 23	20 / 54 / 16	33 / 52 / 9	10 / 48 / 7			
Texture silt/clay	7 / 6	6 / 4	4 / 2	3 / 2			

Parent mat.	aeolian sand, quaternary	Groundwater	below 1 m g.l.
Remarks:		Soil type	irrigated Yh1-pa
		Land Class	S4 m g

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 2

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal alfalfa

Depth cm	0-25	25-95	95-180				
Horizon	Ap	B	G				
Color	7.5YR5/6	7.5YR7/8	7.5YR7/8				
Structure	sin oo	sin oo	sin oo				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	–	–	–				
Cutans	–	–	–				
Fe/Mn	–	–	–				
Gypsum	–	–	–				
Carbonates							
Texture	x' l' S	S	S				
Wetness	3	2	4				
Roots	3	1	0				

Samples cm	0-25	25-50	50-95	95-120			
Gravel %	10	0	0	0			
EC_e mS/cm	0.94	5.06	0.60	0.52			
Salt %	0.01	0.06	0.01	0.01			
pH	7.7	8.0	7.7	8.2			
$CaCO_3$ %	<1	<1	<1	<1			
Moist.Cap. %	14	17	16.5	17.5			
HC cm/d	65 Inf.	60±	>300	>300			
Texture cS/mS/fS	38 / 42 / 9	28 / 61 / 4	27 / 63 / 5	21 / 70 / 5			
Texture silt/clay	6 / 5	5 / 2	4 / 1	3 / 1			

Parent mat.	aeolian sand, quaternary	Groundwater	below .95 m g.l.
Remarks:		Soil type	irrigated Yh1 -qa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 3

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-50	50-60	60-200		
Horizon	Ap	B	2 C	3C		
Color	7.5YR5/6	7.5YR6/8	7.5YR7/8	7.5YR7/8		
Structure	pl1	sin oo	sin oo	sin oo		
Consistence	1	1	0	0		
Plasticity	0	0	0	0		
Cementation	-	-	-	-		
Cutans	-	-	-	-		
Fe/Mn	-	-	-	-		
Gypsum	-	-	-	-		
Carbonates	-	-	-	-		
Texture	l'S	l'S	g'S	S		
Wetness	1	1	1	1 → 2		
Roots	4	1	0	0		

Samples cm	0-20	20-50	50-60	60-90	90-130	130-200
Gravel %	0	1	15	0	0	0
EC_e mS/cm	1.34	0.52	0.43	0.28	0.30	0.34
Salt %	0.02	0.01	<0.01	<0.01	< 0.01	<0.01
pH	7.7	8.3	8.4	8.5	8.6	8.3
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	18	19	19	21	21	21
HC cm/d	860	>300	>300	>440	>300	>300
Texture cS/mS/fS	21/55/15	32/56/4	34/55/5	19/71/5	21/72/2	10/81/6
Texture silt/clay	5/4	6/2	4/2	4/1	4/1	2/1

Parent mat.	aeolian sand, quaternary	Groundwater	below >2 m g.l.
Remarks:		Soil type	irrig. Yh1-pa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 4

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-30	30-100	100-170				
Horizon	Ap	B	G				
Color	7.5YR	7.5YR	10YR4/2				
Structure	sin	sin oo	sin oo				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	Ia1	Ia1	Ia1				
Texture	1' S	1' S	S				
Wetness	3	2	4				
Roots	3	1	0				

Samples cm	0-30	30-60	60-100	100-140			
Gravel %	5	0	0	0			
EC_e mS/cm	0.83	3.75	1.01	5.03			
Salt %	> 0.01	0.04	0.01	0.07			
pH	7.1	7.6	7.7	7.8			
$CaCO_3$ %	<1	<1	<1	< 1			
Moist.Cap. %	1 5	17.5	20	21			
HC cm/d	230	>300	210	>300			
Texture cS/mS/fS	33 / 41 / 18	5 / 12 / 65	21 / 53 / 20	3 / 56 / 32			
Texture silt/clay	4 / 4	12 / 6	3 / 3	6 / 3			

Parent mat.	aeolian sand, quaternary	Groundwater	below 1 m g.l.
Remarks:		Soil type	irrigated Yh 2/1 -aq
		Land Class	S 3 m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 5

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-75	75-200				
Horizon	Ap	B	C				
Color	7.5YR6/6	7/8YR	7.5YR7/8				
Structure	pl 0	sin oo	sin 00				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	Ia1	Ia1	Ia1				
Texture	l' S	l' S	S				
Wetness	3	3	3	3	3	2	
Roots	3	2	1	0	0	0	

Samples cm	0-20	20-50	50-75	75-100	100-150	150-200	
Gravel %	5	0	0	0	0	0	
EC_e mS/cm	0.94	0.55	0.52	2.20	1.90	2.09	
Salt %	0.01	0.01	0.01	0.02	0.02	0.02	
pH	7.7	8.1	8.2	7.7	7.8	7.6	
$CaCO_3$ %	<1	< 1	<1	< 1	<1	<1	
Moist.Cap. %	16.5	16	16	16	17.5	18	
HC cm/d	156Inf.	340±	> 300	650±	> 300	>300	
Texture cS/mS/fS	28 / 45 / 4	40 / 48 / 6	28 / 58 / 8	30 / 58 / 7	30 / 57 / 7	25 / 67 / 3	
Texture silt/clay	8 / 5	3 / 3	4 / 2	3 / 2	4 / 1	4 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh1- pa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 6

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-25	25-60	60-90	90-200			
Horizon	Ap	By	Bzt s	2 C			
Color	7.5YR5/6	5/6	7.5YR6/8	7.5YR8/6			
Structure	pl o	sbl 0	sbl 1	sin 00			
Consistence	1	1	1	0			
Plasticity	0	(1)	1	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	1/2	1/1	-			
Carbonates	-	-	-	-			
Texture	l'S	lS	sL	S			
Wetness	3	3	3	3 → 2			
Roots	4	2	1	0	0	0	

Samples cm	0-25	25-60	60-90	90-120	120-150	150-200	
Gravel %	0	20	0	0	10x	0	
EC_e mS/cm	2.63	2.72	14.20	9.06	1.94	2.90	
Salt %	0.03	0.03	0.18	0.11	0.02	0.03	
pH	7.5	7.6	7.6	7.7	7.6	7.5	
$CaCO_3$ %	1	1	< 1	< 1	< 1	< 1	
Moist.Cap. %	19	18	20	18	17	16	
HC cm/d	81	>300	130	570	>300	>300	
Texture cS/mS/fS	9 / 39 / 40	21 / 40 / 15	5 / 24 / 18	6 / 76 / 13	10 / 56 / 16	13 / 70 / 10	
Texture silt/clay	7 / 5	14 / 10	36 / 17	4 / 0	9 / 9	6 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:	small gravel layer in 60cm	Soil type	irrigated Yh 3/1-ply
		Land Class	S 2

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 7

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-100	100-160	160-200			
Horizon	Ap	By	C	2C			
Color	10YR6/6	10YR6/6	10YR7/8	10YR7/4			
Structure	pl 0	sin 01	sin 00	ma			
Consistence	1	0	0	1			
Plasticity	0-1	0	0	1			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	1/2	-	-			
Carbonates	-	-	-	-			
Texture	lS	g l S(t)	Sl	lS			
Wetness	3	3	2	4			
Roots	3	2	0	0			

Samples cm	0-20	20-50	50-80	80-115	115-160	160-200	
Gravel %	30	40	20	0	5	5	
EC_e mS/cm	3.44	2.44	4.12	2.40	3.66	3.58	
Salt %	0.04	0.02	0.04	0.03	0.04	0.05	
pH	7.6	7.7	7.6	7.7	7.7	7.8	
$CaCO_3$ %	< 1	1	1	<1	<1	<1	
Moist.Cap. %	18.5	14.5	15	20	17.5	20	
HC cm/d -class	63 Inf.	4	5	3	3	3	
Texture cS/mS/fS	27 / 27 / 23	59 / 19 / 6	48 / 30 / 5	8 / 63 / 19	10 / 34 / 33		
Texture silt/clay	15 / 8	7 / 9	7 / 10	5 / 5	13 / 10		

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.9 m g.l.
Remarks:	astropodes in By horizon	Soil type	irrigated Yh2 - ypa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 8

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-50	50-140	140-200		
Horizon	Ap	Byz	C	2C		
Color	10YR6/8	10YR6/8	7.5YR7/8	10YR/6/6+10YR7/1		
Structure	pl 0	sin oo	sin 00	sin + bl		
Consistence	1	0	0	1+2		
Plasticity	0	0	0	0+2		
Cementation	-	-	-	-		
Cutans	-	-	-	-		
Fe/Mn	-	-	-	-		
Gypsum	-	1/2	-	-		
Carbonates	-	-	-	-		
Texture	l' S	g l' S	g l' S	sT+l'S layers		
Wetness	1	1	3	2		
Roots	3	2	1	0		

Samples cm	0-20	20-50	50-80	80-100	100-140	140-200	
Gravel %	5	5	0	0	0	10x	
EC_e mS/cm	2.56	7.49	2.14	2.22	2.20	2.22	
Salt %	0.03	0.08	0.02	0.02	0.03	0.03	
pH	7.6	7.7	7.8	7.8	7.8	7.7	
$CaCO_3$ %	<1	<1	<1	<1	<1	<1	
Moist.Cap. %	16	16	17	17	18.5	21	
HC cm/d -class	325 Inf.	5	6	6	6	4	
Texture cS/mS/fS	28/35/24	46/35/7	50/35/3	43/44/2	49/42/2	59/33/1	
Texture silt/clay	7/6	5/7	6/6	6/5	4/3	4/3	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh 2/5+1-ypa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 9

Topography:	slightly undulating Serir south of Wadi Shatti depression	
Microrelief:		Surface Deposits: sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation: cereal

Depth cm	0-25	25-80	80-150	150-180			
Horizon	Ap	B	B	G			
Color	10YR5/6	10YR5/8	10YR8/8	10YR8/8			
Structure	platy 0	sin 00	sin 00	sin 00			
Consistence	1	0	0	0			
Plasticity	–	–	–	–			
Cementation	–	–	–	–			
Cutans	–	–	–	–			
Fe/Mn	–	–	–	–			
Gypsum	–	–	–	–			
Carbonates	–	–	–	–			
Texture	l'S	g'l'S	S	S			
Wetness	1	3	2	4			
Roots	3	2	0	0			

Samples cm	0-25	25-50	50-80	80-110	110-150	150-175	
Gravel %	10	20	10	1	10	0	
EC_e mS/cm	1.58	.59	3.6	.81	.69	.81	
Salt %	0.02	<0.01	0.04	< 0.01	< 0.01	< 0.01	
pH	7.8	8.4	8.2	8.0	8.3	8.3	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	18.5	19.5	19	18	20	18	
HC cm/d	38 Inf	>300	1600±	>300	>300	>300	
Texture cS/mS/fS	50 / 33 / 5	52 / 40 / 1	51 / 42 / 2	40 / 53 / 3	54 / 40 / 1	29 / 59 / 7	
Texture silt/clay	5 / 7	3 / 4	3 / 2	1 / 3	4 / 1	4 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.5 m g.l.
Remarks:		Soil type	irrigated Yh1-pa
		Land Class	S 3 m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 10

Topography:	slightly undulating Serir south of Wadi Shatti depression	
Microrelief:		Surface Deposits: sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation: cereal

Depth cm	0-25	25-60	60-200				
Horizon	Ap	B	C				
Color	10YR5/8	10YR7/8	10YR8/6				
Structure	pl.1	sin 00	sin oo				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l' s	g' x l' s	s				
Wetness	1	3	2				
Roots	3	2	0				

Samples cm	0-25	25-60	60-90	90-120	120-150	150-200	
Gravel %	10	20	5	0	0	0	
EC_e mS/cm	0.92	0.59	0.51	0.59	1.04	1.34	
Salt %	0.01	< 0.01	< 0.01	< 0.01	0.01	0.02	
pH	8.0	8.3	8.3	8.2	8.1	8.0	
$CaCO_3$ %	<1	< 1	<1	< 1	< 1	< 1	
Moist.Cap. %	18	18.5	19.5	18	19.5	18.5	
HC cm/d	63 Inf.	880	> 300	2000	> 300	> 300	
Texture cS/mS/fS	41/35/11	51/38/3	34/54/3	36/5/6	29/55/12	26/57/12	
Texture silt/clay	6/7	3/5	7/2	7/2	2/2	3/2	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh 1-pa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 11

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-100	100-160	160-200			
Horizon	Ap	B	C	G			
Color	7.5YR5/6	10YR8/8	10YR8/8	10YR8/8			
Structure	platy 1	sin oo	sin oo	sin oo			
Consistence	1-0	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l'S	l'S	S	S			
Wetness	1	3	2	4			
Roots	3	2	0	0			

Samples cm	0-20	20-60	60-100	100-140	140-160	160-180	
Gravel %	0	0	0	0	0	0	
EC_e mS/cm	0.63	0.43	0.50	0.48	0.72	0.73	
Salt %	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
pH	8.2	8.5	8.4	8.4	8.3	8.2	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	17.5	18.5	19	21	20	17.5	
HC cm/d	90	300	320	> 600	> 600	> 600	
Texture cS/mS/fS	27 / 51 / 12	30 / 60 / 4	22 / 68 / 6	29 / 63 / 5	19 / 70 / 6	25 / 61 / 10	
Texture silt/clay	5 / 5	4 / 2	2 / 2	2 / 1	4 / 1	3 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.6 m g.l.
Remarks:		Soil type	irrigated Yh 1-pa
		Land Class	S 3 m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 12

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-70	70-95	> 95			
Horizon	Ap	B	Bz	G			
Color	10YR7/8	10YR7/8	10YR6/2+ 6/8				
Structure	pla 1	sin 00	bl1	bl 1			
Consistence	1	0	1	-			
Plasticity	0	0	2	2			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l'S	l'S	sL	sL-stL			
Wetness	3	3	2	4			
Roots	3	2	1	5			

Samples cm	0-20	20-50	50-70	70-95			
Gravel %		0	0	0			
EC_e mS/cm	2.87	1.84	1.97	0.77			
Salt %	0.04	0.02					
pH	7.6	8.0	7.5	(7.3)			
$CaCO_3$ %	<1	< 1	< 1	<1			
Moist.Cap. %	20	19.5					
HC cm/d	277	>300	> 300	6-22			
Texture cS/mS/fS	21 / 41 / 23	18 / 36 / 27	24 / 38 / 22	10 / 19 / 27			
Texture silt/clay	8 / 7	10 / 9	8 / 8	26 / 18			

Parent mat.	aeolian sand, quaternary	Groundwater	below 0.95m g.l.
Remarks:		Soil type	irrigated Yh 2/3-qa
		Land Class	S 3

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 13

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-90	90-130				
Horizon	Ap	B	G				
Color	7.5YR 5/6	10YR 8/8	10YR				
Structure	platy 1	sin 00	sin 00				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l S	S	S				
Wetness	3	2	4				
Roots	3	2	0				

Samples cm	0-20	20-50	50-90	90-130			
Gravel %	0	0	0	0			
EC_e mS/cm	1.38	1.04	1.00	0.94			
Salt %	0.02	0.01	0.01	0.01			
pH	7.6	8.1	8.1	8.2			
$CaCO_3$ %	< 1	< 1	< 1	< 1			
Moist.Cap. %	17	17.5	18	18.5			
HC cm/d	112	> 300	1020	> 300			
Texture cS/mS/fS	26 / 57 / 9	32 / 55 / 7	36 / 57 / 5	34 / 58 / 4			
Texture silt/clay	5 / 3	4 / 2	1 / 1	3 / 1			

Parent mat.	aeolian sand, quaternary	Groundwater	below 0.7 m g.l.
Remarks:		Soil type	irrigated Yh1-qa
		Land Class	

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 14

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-25	25-90	90-200				
Horizon	Ap	Bw	C				
Color	10YR5/8	10YR5/8	10YR8/8				
Structure	platy 1	sin 00	sin 00				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l's	s	s				
Wetness	3	3	2				
Roots	3	2	0				

Samples cm	0-25	25-50	50-90	90-120	120-160	160-200	
Gravel %	0	0	0	0	0	0	
EC_e mS/cm	1.37	0.54	0.52	0.48	0.67	0.63	
Salt %	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
pH	7.8	8.2	8.1	8.1	8.1	8.1	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	19.5	19	17.5	17.5	17.5	18	
HC cm/d	200 Inf.	> 300	680	> 300	> 300	> 300	
Texture cS/mS/fS	11 51 31	10 57 28	16 63 16	21 55 20	32 46 16	40 43 11	
Texture silt/clay	4 3	3 2	3 2	3 1	4 2	4 2	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh 1-pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 15

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-60	60-230				
Horizon	Ap	B	C				
Color	10YR5/8	10YR8/6	10 YR 8/6				
Structure	pl 0	0	0				
Consistence	0	0	0				
Plasticity	-	-	-				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l S	S	S				
Wetness	1	1	1-3				
Roots	3	2	0				

Samples cm	0-20	20-60	60-85	85-105	105-150	150-200	
Gravel %	5	0	0	0	0	0	
EC_e mS/cm	1.10	0.52	0.63	0.93	1.75	2.04	
Salt %	0.01	< 0.01	< 0.01	0.01	0.02	0.02	
pH	7.7	8.1	8.2	7.9	7.7	7.6	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	16	15.5	17.5	17	17.5	17	
HC cm/d	186	300	> 300	> 300	1020	> 300	
Texture cS/mS/fS	19 / 54 / 16	38 / 53 / 4	17 / 70 / 8	16 / 73 / 6	11 / 78 / 8	17 / 68 / 10	
Texture silt/clay	6 / 5	3 / 2	3 / 2	4 / 1	2 / 1	4 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh 1 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 16

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-70	70-200				
Horizon	Ap	B	C				
Color	10 YR5/8	10 YR8/6	10YR8/6				
Structure	sin 00	sin 00	sin 00				
Consistence	0-1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l S	S	S				
Wetness	3	3	2				
Roots	3	2	0				

Samples cm	0-20	20-40	40-70	70-100	100-150	150-200	
Gravel %	0	0	0	0	0	0	
EC_e mS/cm	1.00	0.54	0.55	0.53	0.62	0.67	
Salt %	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
pH	8.0	8.1	8.3	8.5	8.6	8.3	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	17	16	17.5	19	20.5	18.5	
HC cm/d	186 Inf.	> 300	> 300	1100	> 300	> 300	
Texture cS/mS/fS	18 / 61 / 13	21 / 69 / 4	23 / 68 / 4	9 / 80 / 7	8 / 82 / 6	26 / 66 / 5	
Texture silt/clay	5 / 3	4 / 2	4 / 1	3 / 1	3 / 1	0 / 3	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh1-pa
		Land Class	S 3m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 17

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-60	60-100	100-200			
Horizon	Ap	B	B/C	C			
Color	10 YR5/8	5/8	8/8	8/8			
Structure	platy 0	sin 00	sin 00	sin 00			
Consistence	0-1	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	g l's	l's	s	s			
Wetness	1	1	3	3			
Roots	3	2	0	0			

Samples cm		0-20			20-40			40-60			60-100			100-150			150-200			
Gravel %		15			5			0			0			0			0			
EC_e mS/cm		0.84			0.53			0.41			0.48			0.44			0.75			
Salt %		< 0.01			< 0.01			< 0.01			< 0.01			< 0.01			< 0.01			
pH		8.0			8.1			8.2			8.3			8.2			8.0			
$CaCO_3$ %		< 1			< 1			< 1			< 1			< 1			< 1			
Moist.Cap. %		16.5			17.5			16.5			16			16.5			17			
HC cm/d		160			> 300			> 300			780			>300			> 300			
Texture	cS/mS/fS	30	43	15	41	47	4	31	57	5	22	61	10	33	59	5	39	53	4	
	silt/clay	6	6		4	4		4	3		3	2		2	1		3	1		

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh 1-pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 18

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-30	30-75	75-200
Horizon	Ap	B	C
Color	10YR5/8	8/6	8/6
Structure	pl 1	sin 00	sin 00
Consistence	1	0	0
Plasticity	0	0	0
Cementation	-	-	-
Cutans	-	-	-
Fe/Mn	-	-	-
Gypsum	-	-	-
Carbonates	-	-	-
Texture	l' S	l' S	S
Wetness	1	3	2-3
Roots	3	2	0

Samples cm	0-30	30-50	50-75	75-100	100-150	150-200
Gravel %	10	15	10	0	0	0
EC_e mS/cm	3.04	1.59	0.63	0.62	0.90	0.55
Salt %	0.03	0.02	< 0.01	< 0.01	0.01	< 0.01
pH	7.7	7.8	8.0	8.1	8.1	8.3
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	17	18	19	17	17	19.5
HC cm/d	150 Inf.	> 300	> 300	2400	> 300	> 300
Texture cS/mS/fS	41 / 35 / 11	48 / 40 / 5	40 / 49 / 4	25 / 66 / 4	24 / 67 / 3	33 / 61 / 2
Texture silt/clay	4 / 9	3 / 4	4 / 3	2 / 3	4 / 2	2 / 2

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	irrigated Yh1 - pa
		Land Class	S 3m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 19

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-30	30-100	100-135	135-160			
Horizon	Ap	B	B	G			
Color	10YR5/6	5/8	8/8	8/8			
Structure	platy 1	sin 00	sin 00	sin 00			
Consistence	0	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l'S	l'S	S	S			
Wetness	1	3	2	4			
Roots	4	2	0	0			

Samples cm	0-30	30-60	60-100	100-135			
Gravel %	5	0	0	0			
EC_e mS/cm	1.64	2.73	2.97	3.15			
Salt %	0.02	0.03	0.04	0.04			
pH	7.7	7.7	7.6	7.4			
$CaCO_3$ %	< 1	< 1	< 1	< 1			
Moist.Cap. %	17	17	19	20			
HC cm/d	102 Inf.	130	100	250			
Texture cS/mS/fS	13 / 44 / 18	26 / 45 / 19	6 / 20 / 59	15 / 44 / 33			
Texture silt/clay	19 / 6	6 / 4	7 / 8	4 / 4			

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.35m g.l.
Remarks:		Soil type	irrigated Yh 2/1 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 20

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-30	30-60	60-200				
Horizon	Ap	B	C				
Color	10 YR6/6	10YR6/6	10YR7/8				
Structure	pla 0	sin 00	sin 00				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l' S	l' S	S				
Wetness	1	2	2				
Roots	5	2	0				

Samples cm	0-30	30-60	60-90	90-120	120-150	150-200	
Gravel %	10	15	5	5	0	0	
EC_e mS/cm	1.9	0.36	0.34	0.27	0.27	0.27	
Salt %	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
pH	8.5	8.4	8.2	8.7	8.6	8.8	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	18.5	19	20	20.5	21.5	21.5	
HC cm/d	25 Inf.	350	1100	1600	1700	1700	
Texture cS/mS/fS	22 / 41 / 21	28 / 58 / 3	44 / 48 / 2	43 / 52 / 2	39 / 55 / 1	38 / 57 / 1	
Texture silt/clay	8 / 8	4 / 7	3 / 3	9 / 2	3 / 2	2 / 2	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 2/1 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 21

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-60	60-200			
Horizon	Ap	B	C			
Color	7.5YR5/6	7.5YR7/8	7.5YR7/8			
Structure	pl 1	sin 00	sin 00			
Consistence	0-1	0	0			
Plasticity	0	0	0			
Cementation	-	-	-			
Cutans	-	-	-			
Fe/Mn	-	-	-			
Gypsum-	-	-	-			
Carbonates	-	-	-			
Texture	1'S	S	S			
Wetness	1	1	2			
Roots	5	1	0			

Samples cm		0-20	20-60	60-90	90-120	120-150	150-200	
Gravel %		20	5	0	0	0	0	
EC_e mS/cm		1.76	0.80	0.47	0.42	0.44	0.81	
Salt %		0.02	0.01	< 0.01	< 0.01	< 0.01	0.01	
pH		7.7	8.0	8.1	8.4	8.5	8.1	
$CaCO_3$ %		< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %		16	20	20.5	22	22	22	
HC cm/d		51 Inf.	500	1600	2400	2400	> 2000	
Texture	cS/mS/fS	29 / 46 / 11	41 / 50 / 3	31 / 61 / 2	22 / 72 / 2	21 / 72 / 1	25 / 68 / 2	
	silt/clay	7 / 7	3 / 3	4 / 2	3 / 1	5 / 1	3 / 2	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 1 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 22

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal alfalfa

Depth cm	0-20	20-100	100-190	190-200		
Horizon	Ap	B	C	G		
Color	7.5YR5/5	7/8	7/8	7/8		
Structure	sin 00	sin 00	sin 00	sin 00		
Consistence	0	0	0	0		
Plasticity	0	0	0	0		
Cementation	-	-	-	-		
Cutans	-	-	-	-		
Fe/Mn	-	-	-	-		
Gypsum	-	-	-	-		
Carbonates	-	-	-	-		
Texture	l'S	l'S	S(S)	S		
Wetness	2	2	3	4		
Roots	3	3	1	0		

Samples cm	0-20	20-50	50-75	75-100	100-150	150-190
Gravel %	0	0	0	0	0	0
EC_e mS/cm	0.86	0.73	1.42	0.40	0.80	1.10
Salt %	0.01	0.01	0.01	< 0.01	0.01	0.01
pH	7.7	7.7	7.6	8.5	8.4	8.1
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	17.5	16.5	15.5	19	19.5	19.5
HC cm/d		> 600	1260	1300	1260	1260
Texture cS/mS/fS	22 50 18	24 54 12	28 51 14	34 50 11	14 69 13	13 68 15
Texture silt/clay	6 4	7 3	4 3	3 2	2 2	3 1

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.9 m g.l.
Remarks:		Soil type	Yh 2/1-pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement projec
Profile No: E 23

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-25	25-60	60-100	100-200		
Horizon	Ap	B	C	C		
Color	10YR5/8	10YR8/8	10YR8/8	10YR8/8		
Structure	pl 0	sin 00	sin 00	sin 00		
Consistence	0	0	0	0		
Plasticity	0	0	0	0		
Cementation	-	-	-	-		
Cutans	-	-	-	-		
Fe/Mn	-	-	-	-		
Gypsum	-	-	-	-		
Carbonates	-	-	-	-		
Texture	l's	l's	s	s		
Wetness	2	2	2	2-3		
Roots	2	1	0	0		

Samples cm	0-25	25-60	60-100	100-130	130-160	160-250
Gravel %	5	5	0	0	0	0
EC_e mS/cm	0.61	0.75	0.91	1.23	0.81	1.38
Salt %	< 0.01	< 0.01	0.01	0.02	0.01	0.02
pH	8.1	8.2	8.1	8.0	8.2	8.1
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	17.5	16	19.5	19	19.5	19
HC cm/d	295 Inf	> 300	> 1000	1400	1800	> 1500
Texture cS/mS/fS	28 / 47 / 18	33 / 47 / 11	36 / 55 / 5	37 / 52 / 4	37 / 53 / 5	21 / 66 / 8
Texture silt/clay	4 / 3	6 / 3	3 / 1	5 / 2	4 / 1	3 / 2

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 1 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 24

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-30	30-90	90-200				
Horizon	Ap	B/C	C				
Color	7.5YR5/6	6/6	7.5YR7/8				
Structure	sin+pl1	sin 00	sin 00				
Consistence	1	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	l'S	S	S				
Wetness	1-2	2	2-3				
Roots	3	0	0				

Samples cm	0-30	30-60	60-90	90-120	120-150	150-200	
Gravel %	5	0	0	0	0	0	
EC_e mS/cm	0.78	0.50	0.25	0.31	0.43	0.22	
Salt %	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
pH	7.8	8.4	8.8	8.7	8.6	8.8	
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1	
Moist.Cap. %	19	21	20.5	21.5	20.5	21	
HC cm/d	264	Inf. 500	1400	2040	2400	> 2000	
Texture cS/mS/fS	22/56/15	24/65/7	22/45/21	21/57/16	37/49/13	42/52/3	
Texture silt/clay	4/3	3/1	10/2	4/2	0/1	2/1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 2 -pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 25

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-25	25-85	85-120	120-160			
Horizon	Ap	B/C	C	G			
Color	7.5YR6/6	7.5YR6/6	7.5YR7/8	10YR7/4			
Structure	sin+pla1	sin 00	sin 00	sin 00			
Consistence	1	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l S	l' S	S	S			
Wetness	1	2	3	4			
Roots	3	2	2	0			

Samples cm	0-25	25-50	50-85	85-120			
Gravel %	0	0	0	0			
EC_e mS/cm	0.63	0.61	0.61	0.91			
Salt %	< 0.01	< 0.01	< 0.01	< 0.01			
pH	8.3	8.4	8.6	8.6			
$CaCO_3$ %	< 1	< 1	< 1	< 1			
Moist.Cap. %	19	20.5	19.5	20.5			
HC cm/d		720	780	950			
Texture cS/mS/fS	15 / 55 / 21	12 / 54 / 20	17 / 60 / 18	9 / 65 / 19			
Texture silt/clay	6 / 3	11 / 3	3 / 2	5 / 2			

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.5 m g.l.
Remarks:		Soil type	Yh1 - pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 26

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal, windbreak

Depth cm	0-20	20-60	60-170	170-(220)		
Horizon	Ap	B	C	G		
Color	7.5YR6/6	7.5YR6/6	7.5YR7/8	10YR7/4		
Structure	pl 1	sin 00	sin 00	sin 00		
Consistence	1	0	0	0		
Plasticity	0	0	0	0		
Cementation	-	-	-	-		
Cutans	-	-	-	-		
Fe/Mn	-	-	-	-		
Gypsum	-	-	-	-		
Carbonates	-	-	-	-		
Texture	l S	l S	S	S		
Wetness	1	2	4	5		
Roots	3	1	1	0		

Samples cm	0-20	20-60	60-90	90-120	120-150	150-200
Gravel %	5	0	0	0	0	0
EC_e mS/cm	0.83	0.36	0.46	0.60	0.44	1.11
Salt %	0.01	< 0,01	< 0.01	< 0.01	< 0.01	0.01
pH	7.9	8.4	8.5	8.6	8.4	8.1
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	20	17.5	18	20	21.5	20
HC cm/d	176 Inf.	1020	1200	1200	> 1000	> 1000
Texture cS/mS/fS	13 / 60 / 19	16 / 59 / 17		15 / 68 / 14	14 / 69 / 13	13 / 68 / 15
Texture silt/clay	5 / 3	4 / 4		1 / 2	2 / 2	3 / 1

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.7 m g.l.
Remarks:		Soil type	Yh 1 - pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 27

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-70	70-100	100			
Horizon	Ap	B	Gr	G			
Color	7.5YR5/6	6/8	7/8+black	7.5YR6/6			
Structure	pl 0	sin 00	sin 00	sin 00			
Consistence	0	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l S	S (l)	S (l)	S (l)			
Wetness	1	2	3	4			
Roots	3	2	0	0			

Samples cm	0-20	20-70	70-100				
Gravel %	10	0	0				
EC_e mS/cm	3.63	0.66	1.30				
Salt %	0.03	< 0.01	0.02				
pH	7.3	8.5	8.0				
$CaCO_3$ %	< 1	< 1	< 1				
Moist.Cap. %	16	17.5	19				
HC cm/d	288 Inf.	550	700				
Texture cS/mS/fS	19 / 51 / 19	28 / 59 / 9	20 / 52 / 21				
Texture silt/clay	7 / 4	3 / 1	5 / 2				

Parent mat.	aeolian sand, quaternary	Groundwater	below 1.0 m g.l.
Remarks:		Soil type	Yh1 - pa
		Land Class	S 3m

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 28

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	irrigated agriculture	Vegetation:	cereal

Depth cm	0-20	20-60	60-130			
Horizon	Ap	B	C			
Color	10 YR 7/8	10YR7/8	10YR8/8			
Structure	pl. 0	sin 00	sin 00			
Consistence	0	0	0			
Plasticity	0	0	0			
Cementation	-	-	-			
Cutans	-	-	-			
Fe/Mn	-	-	-			
Gypsum	-	-	-			
Carbonates	-	-	-			
Texture	l'S	S	S			
Wetness	1-2	2	2			
Roots	3	3	3			

Samples cm	0-20	20-60	60-90	90-120	120-150	150-200
Gravel %	10	5	0	0	0	0
EC_e mS/cm	1.77	2.30	3.42	3.53	4.24	3.90
Salt %	0.02	0.03	0.04	0.05	0.06	0.05
pH	7.8	8.3	8.0	8.0	8.1	8.1
$CaCO_3$ %	< 1	< 1	< 1	< 1	< 1	< 1
Moist.Cap. %	16	17.5	18	21.5	22	21
HC cm/d	81 Inf.	370	385	420	> 500	> 500
Texture cS/mS/fS	16 / 43 / 26	21 / 51 / 18	7 / 50 / 38	3 / 49 / 43	2 / 52 / 42	
Texture silt/clay	9 / 6	4 / 6	2 / 3	3 / 2	3 / 1	

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 1-pa
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 29

Topography:	slightly undulating Serir south of Wadi Shatti depression
Microrelief:	almost flat, upper plain
Surface Deposits:	sand, slightly gravelly
Land use:	desert
Vegetation:	none

Depth cm	0-20	20-70	70-180				
Horizon	Aa	By	C				
Color	7.5 YR	7.5YR	7.5YR				
Structure	col+pl1	sin 00	sin 00				
Consistence	1	1	0-1				
Plasticity	0	0	0				
Cementation	0	0	0				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	1/2	-				
Carbonates	-	-	-				
Texture	g l'S	l'S	g Sl				
Wetness	1	1	1				
Roots	0	0	0				

Samples cm	0-20	20-70	70-110	110-180			
Gravel %	0	0	0	0			
EC_e mS/cm	3.75	20.29	14.15	9.62			
Salt %	0.05	0.28	0.17	0.13			
pH	7.9	8.1	7.6	8.1			
$CaCO_3$ %	1	< 1	< 1	< 1			
Moist.Cap. %	20	21	19	21			
HC cm/d-class	5	5	5	6			
Texture cS/mS/fS	14 / 53 / 22	14 / 62 / 10	16 / 69 / 7	16 / 69 / 8			
Texture silt/clay	6 / 5	6 / 8	3 / 5	5 / 2			

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 2/1-py
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 30

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:	undulating, upper plain	Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-30	30-130	130-200
Horizon	Aay	C	2 C
Color	7.5YR	7.5YR	7.5YR
Structure	col+pl 0	sin 00	sin 00
Consistence	1	0	0
Plasticity	0	0	0
Cementation	0	0	0
Cutans	-	-	-
Fe/Mn	-	-	-
Gypsum	1/1	-	-
Carbonates	-	-	-
Texture	l'S	g'S	S
Wetness	1	1	2
Roots	0	0	0

Samples cm	0-30	30-80	80-130	130-200
Gravel %	10	10	5	0
EC_e mS/cm	11.7	5.04	6.36	6.38
Salt %	0.13	0.07	0.08	0.09
pH	7.8	8.0	8.2	8.1
$CaCO_3$ %	1	< 1	< 1	< 1
Moist.Cap. %	17.5	20	18.5	20.5
HC cm/d-class	5	5	6	6
Texture cS/mS/fS	20 / 62 / 9	26 / 57 / 8	28 / 41 / 17	42 / 48 / 2
Texture silt/clay	4 / 5	6 / 3	13 / 1	7 / 1

Parent mat.	aeolian sand, quaternary	Groundwater	below m g.l.
Remarks:		Soil type	Yh 1 -py
		Land Class	

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 31

Topography:	slightly undulating Serir of Wadi Shatti depression		
Microrelief:	undulating, medium slope	Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-5	5-25					
Horizon	N	Amz					
Color	gray	gray					
Structure	sin+col	ma+pl 2					
Consistence	-	3-4					
Plasticity	-	-					
Cementation	-	- w					
Cutans	-	-					
Fe/Mn	-	-					
Gypsum	-	2/2					
Carbonates	-	-					
Texture							
Wetness	1	1					
Roots	-	-					

Samples cm							
Gravel %							
EC_e mS/cm							
Salt %							
pH							
$CaCO_3$ %							
Moist.Cap. %							
HC cm/d							
Texture cS/mS/fS							
Texture silt/clay							

Parent mat.	aeolian sand, quaternary	Groundwater	below ? m g.l.
Remarks:	petrosaline phase	Soil type	yZ_t 6 - pz
		Land Class	N 2 zw

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 32

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-15	15-45	45-100	105-140			
Horizon	Aay	B	C	2 C			
Color	7.5YR	7.5YR	7.5YR	5 YR			
Structure	col+pl 1	sin 00	sin 01	ma			
Consistence	1	0	2	2			
Plasticity	0	0	0	2-3			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	1/2	1+2/2	-	-			
Carbonates	-	-	-	-			
Texture	l S	S	$\bar{g}$ S	T			
Wetness	1	1	1-2	2			
Roots	0	0	0	0			

Samples cm	0-15	15-45	45-100	105-140			
Gravel %	10	10	20	0			
EC_e mS/cm	11.66	19.38	16.93	93.35			
Salt %	0.14	0.25	0.26	3.03			
pH	7.8	8.0	8.2	7.7			
$CaCO_3$ %	< 1	< 1	< 1	0			
Moist.Cap. %	1.8	20	23.5	50			
HC cm/d	5	6	6	1			
Texture cS/mS/fS	41 / 31 / 8	46 / 37 / 4	31 / 57 / 3	1 / 3 / 1			
Texture silt/clay	11 / 9	8 / 5	5 / 4	95			

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	yZh 1/6 -py
		Land Class	S 4 zw

Wadi Shatti Drainage Project Cornelius - Brochier - Aqua Project ACI Date: June 1981	Surveyor: Petermann Area: Eshkeda settlement project Profile No: E 33

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:		Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-15	15-80	80-200				
Horizon	Aa	B	C				
Color	red-yell	red.yell	yell				
Structure	col 1	sin 00	sin 00				
Consistence	0	0	0				
Plasticity	0	0	0				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	-	-	-				
Carbonates	-	-	-				
Texture	S	S	S				
Wetness	1	1	1				
Roots	1	3	0				

Samples cm	0-15	15-80	80-150				
Gravel %	0	0	0				
EC_e mS/cm	1.02	3.92	3.11				
Salt %	0.01	0.05	0.04				
pH	8.2	7.8	8.0				
$CaCO_3$ %	< 1	< 1	< 1				
Moist.Cap. %	19	19.5	19				
HC cm/d -class	5	6	6				
Texture cS/mS/fS	22 / 57 / 14	20 / 57 / 14	28 / 43 / 19				
Texture silt/clay	4 / 3	5 / 4	8 / 2				

Parent mat.	aeolian sand, quaternary	Groundwater	below ? m g.l.
Remarks:		Soil type	Yh 1
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 34

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:	almost flat upper plain	Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-25	25-90	90-130	130-200			
Horizon	Aa	B	C	2 C			
Color	7.5YR	7.5YR	10YR	10YR			
Structure	pla 1	sin 00	ain 00	sin 00			
Consistence	0	0	0	0			
Plasticity	0	0	0	0			
Cementation	-	-	-	-			
Cutans	-	-	-	-			
Fe/Mn	-	-	-	-			
Gypsum	-	-	-	-			
Carbonates	-	-	-	-			
Texture	l'S	l'S	S	S			
Wetness	1	1	1-2	2-3			
Roots	0	0	0	0			
Samples cm	0-25	25-90	90-130	130-200			
Gravel %	10	0	0	0			
EC_e mS/cm	5.41	3.59	0.66	0.24			
Salt %	0.06	0.05	< 0.01	< 0.01			
pH	8.4	8.2	8.6	8.6			
$CaCO_3$ %	< 1	< 1	< 1	< 1			
Moist.Cap. %	17.5	19.5	20.5	20			
HC cm/d -class	5	5	6	6			
Texture cS/mS/fS	31 / 47 / 10	29 / 60 / 6	27 / 62 / 6	44 / 48 / 3			
Texture silt/clay	6 / 6	2 / 3	4 / 1	4 / 1			

Parent mat.	aeolian sand, quaternary	Groundwater	below 2 m g.l.
Remarks:		Soil type	Yh 1 -p
		Land Class	S 3m

Wadi Shatti Drainage Project
Cornelius - Brochier - Aqua Project ACI
Date: June 1981

Surveyor: Petermann
Area: Eshkeda settlement project
Profile No: E 35

Topography:	slightly undulating Serir south of Wadi Shatti depression		
Microrelief:	undulating	Surface Deposits:	sand, slightly gravelly
Land use:	desert	Vegetation:	none

Depth cm	0-10	10-35	35-80				
Horizon	Aay	C	C				
Color	7.5YR	7.5YR	5YR				
Structure	pla 0	sin	bl				
Consistence		1	2				
Plasticity	0	0	3				
Cementation	-	-	-				
Cutans	-	-	-				
Fe/Mn	-	-	-				
Gypsum	2/2	1/1	-				
Carbonates	-	-	-				
Texture	l' S	l' S	(s) T				
Wetness	1	1	1				
Roots	0	0	0				

Samples cm	0-35		35-80				
Gravel %	0		0				
EC_e mS/cm	6.0		59.3				
Salt %	0.08		1.73				
pH	7.9		7.7				
$CaCO_3$ %	< 1		0				
Moist.Cap. %	19.5		45				
HC cm/d -class	5		1				
Texture cS/mS/fS			6 / 11 / 4				
Texture silt/clay			79				

Parent mat.	aeolian sand, quaternary	Groundwater	below ? m g.l.
Remarks:		Soil type	Yh 1/6
		Land Class	N1 zw

A N N E X 5

Hydraulic Conductivity of Soil and Salinity Status of Groundwater

Annex 5: Hydraulic Conductivity of Soil and Salinity Status of Groundwater

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
1	1	96	1.86	1.19	3.2
	2	97	8.45	6.05	0.6
	3	98	-	-	0.7
	4	99	1.33	0.95	4.2
	5	100	1.86	1.19	1.1
	6	101	-	-	0.7
	7	102	1.61	1.03	0.4
	8	103	4.80	3.01	0.8
	9	104	2.06	1.32	4.3
	10	105	3.16	2.02	10.7
	11	106	2.99	1.91	3.2
	12	107	2.21	1.40	2.8
2	1	108	3.77	2.42	1.1
	2	109	4.08	2.61	1.6
	3	110	1.59	1.02	3.4
	4	111	-	-	1.5
	5	112	-	-	1.1
	6	113	2.42	1.55	1.3
	7	114	2.32	1.48	1.7
	8	115	1.36	0.86	1.3
	9	116	1.84	1.18	5.2
	10	117	1.23	0.78	12.1
	11	118	1.27	0.81	3.5
	12	119	3.12	2.00	1.0
3	1	120	5.52	3.54	8.7
	2	121	3.40	2.18	8.6
	3	122	4.31	2.89	2.1
	4	123	-	-	0.8
	5	124	1.25	0.81	4.2
	6	125	2.11	1.34	6.2
	7	126	1.98	1.27	11.6
	8	127	1.90	1.22	12.3
	9	128	16.62	0.64	0.7
	10	129	2.27	1.46	1.7
	11	130	3.88	2.48	9.0
	12	131	5.04	3.15	9.2
4	1	132	1.23	0.78	10.5
	2	133	2.77	1.77	3.6
	3	134	1.80	1.15	8.2
	4	135	2.14	1.37	7.6
	5	136	2.55	1.64	7.2
	6	137	2.26	1.44	6.1
	7	138	3.47	2.22	0.9
	8	139	5.94	3.80	1.4
	9	140	8.01	5.13	0.9
	10	141	1.32	0.85	0.5
	11	142	1.80	1.15	0.6
	12	143	4.93	3.35	0.9

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
5	1	147	-	-	-
	2	144	1.76	1.12	-
	3	145	3.08	1.97	5.7
	4	146	4.36	2.79	2.4
	5	148	-	-	3.2
	6	149	30.63	19.60	4.2
	7	160	35.95	23.01	1.34
	8	151	12.97	18.30	10.3
	9	152	12.39	7.93	-
	10	153	26.26	16.81	1.4
	11	154	8.8	5.63	5.8
	12	155	4.28	2.74	4.4
6	1	156	1.84	1.18	7.6
	2	157	10.72	6.86	8.2
	3	158	3.60	2.31	2.7
	4	159	2.81	1.80	2.6
	5	160	2.70	1.73	10.4
	6	161	14.48	9.27	1.7
	7	162	1.76	1.13	2.4
	8	163	3.44	2.20	1.0
	9	164	18.51	11.85	1.2
	10	165	7.56	4.84	0.4
	11	166	21.75	13.92	3.5
	12	167	30.74	19.67	0.5
7	1	168	6.20	3.97	11.1
	2	169	19.33	12.37	10.4
	3	170	3.10	1.98	6.8
	4	171	3.42	2.19	14.2
	5	172	4.88	3.12	8.9
	6	173	-	-	-
	7	174	-	-	-
	8	175	5.08	3.25	10.5
	9	176	2.09	1.34	10.0
	10	177	-	-	-
	11	178	-	-	-
	12	179	-	-	-
8	1	180	-	-	-
	2	181	-	-	-
	3	182	14.53	9.30	7.9
	4	183	13.4	8.58	5.7
	5	184	-	-	-
	6	185	3.27	2.09	12.3
	7	186	-	-	-
	8	187	-	-	-
	9	188	-	-	-
	10	189	-	-	-
	11	190	-	-	-
	12	191	-	-	-

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
9	1	192	-	-	-
	2	193	-	-	-
	3	194	3.21	2.05	11.4
	4	195	-	-	-
	5	196	12.99	8.31	6.0
	6	197	13.98	8.95	3.4
	7	198	12.97	8.17	11.2
	8	199	-	-	14.7
	9	200	4.35	2.78	19.0
	10	201	3.33	2.13	7.9
	11	202	25.42	16.27	5.7
	12	203	10.2	6.53	5.4
10	1	204	12.1	7.74	3.7
	2	205	3.27	1.87	1.6
	3	206	2.83	1.81	8.4
	4	207	2.87	1.84	5.2
	5	208	2.42	1.38	3.9
	6	209	9.26	5.93	11.7
	7	210	-	-	-
	8	211	-	-	-
	9	212	-	-	-
	10	213	3.36	2.15	2.0
	11	214	23.69	15.16	5.0
	12	215	-	-	-
11	1	228	1.78	1.14	3.5
	2	229	-	-	-
	3	230	2.12	1.36	-
	4	230	-	-	-
	5	232	-	-	-
	6	233	-	-	-
	7	234	-	-	-
	8	235	-	-	-
	9	236	-	-	-
	10	237	-	-	-
	11	238	-	-	-
	12	239	-	-	-
12	1	252	12.75	8.16	5.7
	2	253	18.69	11.96	6.9
	3	254	11.52	7.37	6.0
	4	255	13.40	8.58	6.0
	5	256	-	-	-
	6	257	-	-	-
	7	258	-	-	-
	8	259	-	-	-
	9	260	-	-	-
	10	261	-	-	-
	11	262	-	-	-
	12	263	-	-	-

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
13	1	286	-	-	-
	2	283	18.42	11.79	3.1
	3	284	-	-	-
	4	285	-	-	-
	5	282	19.76	12.65	4.9
	6	279	-	-	-
	7	280	-	-	-
	8	281	-	-	-
	9	278	-	-	-
	10	275	-	-	-
	11	276	-	-	-
	12	277	-	-	-
14	1	216	2.27	1.47	2.5
	2	217	8.95	5.73	2.6
	3	218	3.68	2.36	3.5
	4	219	1.57	1.00	3.7
	5	220	10.27	6.57	1.7
	6	221	16.92	10.83	1.7
	7	222	8.05	5.15	4.7
	8	223	47.94	30.68	3.8
	9	224	12.28	7.86	3.4
	10	225	6.84	4.38	4.3
	11	226	-	-	-
	12	227	5.61	3.59	4.4
15	1	240	3.53	2.26	1.7
	2	241	8.93	5.72	8.3
	3	242	3.38	2.16	1.3
	4	243	5.53	3.54	4.1
	5	244	3.86	2.47	1.6
	6	245	-	-	-
	7	246	-	-	-
	8	247	-	-	-
	9	248	-	-	-
	10	249	37.35	23.90	2.3
	11	250	34.61	22.15	-
	12	251	-	-	-
16	1	264	13.25	8.48	-
	2	265	-	-	-
	3	266	11.16	7.14	7.1
	4	267	10.16	6.50	3.2
	5	267	10.16	6.50	3.2
	6	269	-	-	-
	7	270	16.23	10.39	6.2
	8	271	-	-	7.0
	9	272	-	-	-
	10	273	12.2	7.81	7.8
	11	274	16.97	10.86	1.5

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
17	1	287	2.32	1.48	2.2
	2	288	3.06	2.02	4.2
	3	289	3.43	2.20	16.8
	4	290	-	-	-
	5	291	16.67	10.67	2.9
	6	292	12.90	8.26	0.5
	7	293	10.68	6.84	6.7
	8	294	5.95	3.81	1.8
	9	295	3.93	2.52	1.9
	10	296	-	-	-
	11	297	20.65	13.22	1.0
	12	298	3.26	2.09	2.1
18	1	1	8.33	5.33	5.2
	2	2	-	-	1.4
	3	3	14.95	9.57	-
	4	4	6.09	3.90	4.8
	5	5	3.07	1.92	-
	6	6	-	-	2.5
	7	7	3.06	1.96	6.2
	8	8	-	-	2.6
	9	9	-	-	-
	10	10	2.84	1.82	7.7
	11	11	4.56	2.92	13.6
19	1	12	17.0	10.88	-
	2	13	-	-	6.1
	3	14	2.0	1.28	12.5
	4	15	2.45	1.57	10.1
	5	16	2.93	1.88	17.8
	6	17	12.0	7.68	6.1
	7	18	2.72	1.74	11.1
	8	19	2.45	1.57	15.7
	9	20	17.05	10.91	3.2
	10	21	20.53	13.14	8.5
	11	22	3.58	2.29	18.3
	12	23	1.96	1.25	5.0
20	1	24	10.7	6.85	2.8
	2	25	2.61	1.67	4.5
	3	26	4.72	3.02	2.5
	4	27	2.40	1.54	3.0
	5	28	-	-	7.5
	6	29	2.81	1.80	2.3
	7	30	2.08	1.33	3.8
	8	31	1.89	1.21	4.8
	9	32	-	-	-
	10	33	-	-	-
	11	34	-	-	-
	12	35	2.26	1.43	8.5

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
21	1	36	4.59	2.94	4.1
	2	37	4.58	2.93	5.6
	3	38	4.14	2.65	3.6
	4	39	3.89	2.49	9.3
	5	40	1.64	1.05	-
	6	41	2.87	1.84	3.4
	7	42	1.37	0.88	8.4
	8	43	2.32	1.48	21.9
	9	44	2.89	1.85	5.4
	10	45	1.89	1.21	12.9
	11	46	3.18	2.04	10.8
	12	47	1.77	1.13	-
22	1	48	3.07	1.96	6.4
	2	49	4.94	3.16	6.0
	3	50	4.66	2.98	4.2
	4	51	3.30	2.11	8.8
	5	52	2.79	1.79	8.4
	6	53	4.86	3.11	4.7
	7	54	2.34	1.50	5.4
	8	55	1.99	1.27	5.5
	9	56	2.39	1.53	7.3
	10	57	3.90	2.50	4.4
	11	58	4.10	2.62	4.7
	12	59	2.67	1.71	12.2
23	1	60	36.01	23.10	1.7
	2	61	17.28	11.06	4.6
	3	62	39.09	25.02	6.7
	4	63	6.41	4.10	5.8
	5	64	2.07	1.32	11.5
	6	65	31.25	20.00	6.0
	7	66	-	-	-
	8	67	35.90	22.98	2.0
	9	68	34.83	22.29	4.9
	10	69	14.41	9.22	-
	11	70	45.47	29.10	3.1
	12	71	47.77	30.57	0.7
24	1	72	-	-	-
	2	73	-	-	-
	3	74	13.33	8.53	4.7
	4	75	4.09	2.62	3.8
	5	76	-	-	-
	6	77	38.36	24.55	1.9
	7	78	46.98	30.07	3.7
	8	79	53.87	34.48	4.9
	9	80	3.23	2.07	-
	10	81	-	-	-
	11	82	-	-	-
	12	83	7.06	4.52	-

District No.	Farm No.	Sample No.	EC mS/cm	Salt g/l	Kf m/d
25	1	84	-	-	-
	2	85	-	-	-
	3	86	-	-	-
	4	87	-	-	-
	5	88	-	-	-
	6	89	-	-	-
	7	90	-	-	-
	8	91	-	-	-
	9	92	-	-	-
	10	93	-	-	-
	11	94	-	-	-
	12	95	-	-	-