THE HASHEMITE KINGDOM OF JORDAN

YARMOUK - JORDAN VALLEY PROJECT

MASTER PLAN REPORT

VOLUMES

III - LAND RESOURCES

IV - IRRIGATION AND DRAINAGE

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VOLUME III - LAND RESOURCES
YARMOUK-JORDAN VALLEY PROJECT
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LENGTH

1 - Millimeter (mm)	0.039 Inches
1 - Centimeter (cm)	0.394 Inches
1 - Meter (M)	39.37 Inches
1 - Meter	3.281 Feet
1 - Kilometer (Km)	0.621 Miles

AREA

1 - Square meter (M^2)	1.196 Square yards
1 - Donum	1,000. Square meters
1 - Donum	0.247 Acres
1 - Square kilometer (Km^2)	0.386 Square miles

VOLUME

1 - Cubic meter (M^3)	35.31 Cubic feet
1 - Cubic meter	1.308 Cubic yards
1 - Million cubic meters (MCM)	810.7 Acre feet

WEIGHT

1 - Kilogram (Kg)	2.205 Pounds
1 - Metric ton (MT)	1,000. Kilograms
1 - Metric ton	2,205. Pounds
1 - Metric ton	1.102 Tons (short)

FLOW

1 - Liter/second	15.85 U.S. gallons/minute
1 - Cubic meter/second (M^3/Sec.)	35.31 Cubic feet/second
1 - Cubic meter/second	86,400. Cubic meters/day
1 - Cubic meter/second	2,592,000. Cubic meters/month (30 days)
1 - Cubic meter/second	31,536,000. Cubic meters/year (365 days)
1 - Cubic meter/second	70.0 Acre feet/day
1 - Cubic meter/second	15,850. U.S. gallons/minute
1 - Cubic meter/hour (M^3/Hr.)	4.4 U.S. gallons/minute

ENERGY

1 - Kilowatt (kw)	1.341 Horse power (HP)
1 - Kilowatt-hour (kwh)	1.341 Horse power hours
1 - Kilowatt-hour	367,100. Kilogram meters

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PART 1. LAND CLASSIFICATION

Purpose and Scope

The purpose of the investigation was to make a systematic appraisal of the soil, topographic, irrigation, and drainage characteristics of the land in order to determine its degree of suitability for sustained irrigation agriculture. A detailed classification survey was carried out in accordance with Bureau of Reclamation standards, modified to meet local conditions.

This program was carried out in conjunction with F.O.A. technicians, through Cooperative Department for Water Resources Development, Ministry of Finance, Government of the Hashemite Kingdom of Jordan, and field investigations were completed in December of 1954. A total of 942,843 donums (1 donum = .247 acres) of land was classified, as shown in Table 3.1-1. Of this amount, 519,846 donums are classed as arable. Drawing JR-21 shows the general classification for the project.

Table 3.1-1

Summary of Land Classification

Land Class	Area in Donums	Percent of Total
1	143,090	15.2
2	138,474	14.7
3	65,972	7.0
4	172,310	18.3
6	422,997	44.8
Total	942,843	100.0

Topography

The floor of the valley consists of east and west terraces separated by the Jordan River and its flood plain. These terraces and the flood plain are referred to as the ghors and zor, respectively. The ghors slope toward the river at a rate of 15 to 25 meters per kilometer, and in many areas are highly eroded and of "badland" appearance, (the Katar), where it breaks into the zor. The zor, today, is a minor valley 1 to 2 kilometers wide and subject to a degree of annual flooding.

The sides of the Jordan Valley are well defined in that they are high and steep. In general, the area classified is bounded on the upper edge of the East and West Ghors by the escarpment.

Sheet erosion, encouraged by predominantly winter rains and sparse vegetation, has produced minor surface modifications. Cobbles and boulders scattered over certain areas indicate that sheet erosion and wind action have removed finer materials. Similarly, other localities appear to have recent deposits of wind and water borne materials.

Soils

Ancient faulting, accompanied by sinking and rising of large land masses, is responsible for the Jordan Valley as it exists today. At one time the area was covered by an arm of the Red Sea and during this period a thick blanket of calcareous silts and clays (marl) was deposited. Valley fill and land upheavals eventually raised these silty materials above the surface. Before it was covered by other materials from adjacent uplands, stream action accomplished a degree of surface sculpturing.

The Jordan River cut deeply through this material in a meandering course and today flows through its recent flood plain, the zor.

Materials deposited in the zor include coarse as well as fine separates, but calcareous silts and clays predominate since upland parent materials are of such nature.

Saline sedimentary deposits remain as terraces or benches on each side of the zor. These benches, ghors, were in turn covered by alluvial and colluvial material transported by tributary streams from adjacent uplands. Alluvial fans of varying size were thus laid down, some nearly coalescing while others do not. As stream sorting took place a few areas were covered by medium textured material particularly toward the southern part of the area. Predominantly, however, parent materials brought into the valley are calcareous silts and clays.

The depth of the alluvial deposit above the marl decreases from the foothills toward the center of the valley with some minor local variations. During the course of deposition of this transported material the coarser particles have naturally tended to separate out first, next to the hills, and the fines have been carried further out onto the ghor area.

Soils within the area classified were divided into four major recognized groups as follows: Reddish-Brown, Grayish-Brown, Whitish-Gray, and Azonal soils.

The Reddish-Brown soils are formed from alluvium laid down on top of marls and are generally located on the alluvial fans north of the River Zarqa. Higher rainfall in this area together with irrigation over a long period of years has increased water percolation through the soil profile and accounts for the two dominant characteristics which distinguish this soil from others in the project area. These characteristics are the bright reddish-brown color which result from oxidation of the iron in the soil, and a more highly developed subsurface horizon which, in places, approaches a weak clay pan. Depth of soil varies and is considerably thinner near the breaks which are called the "Katar". Clay loams are predominant and prismatic structure is often found between 30 and 45 centimeters. Because greater quantities of water have passed through this soil, it is generally permeable and free of serious saline and alkali problems. The major exception to good permeability occurs north of Wadi Arab as a result of the extremely high clay content of the soil.

The Grayish-Brown soils are also formed from alluvium laid down on top of marls and are generally located on the alluvial fans south of the River Zarqa. Precipitation is rather low in this area and it is reflected in the small amount of iron oxidation in the soil profile, the absence of prismatic structure, and the predominance of single grain lighter structures. Depths of these soils also vary, and like the Reddish-Brown soils become thinner near the "Katar". Texture varies from clay loams in the north to sandy loams in the extreme south. Scattered areas, of small extent, of saline soils with weakly cemented gravelly lime zones are found in this group. Permeability is generally good and the soils are well suited to sustained irrigation.

The Whitish-Gray soils are residual soils formed from saline water deposits and marl type parent material. These soils occur between the lower edge of the alluvial fans and the "Katar" with the largest areas being found in the southern parts of both the East and West Ghors. Depth of soil over modified or residual marly type parent material is usually sufficient for most truck and cereal crops. Loams and clay loams are the predominant textures. The surface soil is, usually, spongy and fluffy. Generally, the structure of the subsoil is either massive or laminated. Heavy salt deposits, gypsum predominating, are common throughout the entire profile and are heaviest at the lower limit of the zone of evaporation. Frequent, deep, vertical crevices and cracks are filled with top soil and cut through the marly deposits to form natural outlets for drainage. Inherently, these soils have a high fertility and productive capacity and will be well suited to sustained irrigation after reclamation.

The Azonal soils of recent flood plain deposition are found in the zor. Clay and sand are deposited in layers and the soil is, usually, sufficiently deep to afford a good root zone for most plants. Soil forming factors have not had sufficient time to produce an aggregate soil structure. Lands free of high water tables are also free of salts. Permeability of isolated pockets of clay is often low, but such pockets are usually dissected by stringers and lenses of subsurface sand and gravel assuring adequate drainage. These soils are well adapted to production of diversified truck and field crops.

The outstanding characteristics of these four soils types are summarized in Table 3.1-2, Evaluation of Soils Characteristics by Types which follows.

Table 3.1-2

Evaluation of Soils Characteristics
By Types

TYPE	PRESENCE OF MARLS		CHARACTERISTICS			DEGREE OF		PERMEABILITY	SPECIAL PROBLEMS	VEGETATIVE COVER	SUITABILITY	
	Modified	Residual	Parent Material	Texture	Structure	Salinity	Alkalinity				For Crops	For sustained Irrigation
Reddish-Brown	Seldom in 5-foot zone	Seldom in 5-foot zone	Alluvial fan deposits	Clay loam to Clay	Prismatic over Blocky or single grain - stable	None to very slight	NONE	Fair to Good	Clearing. Occasional Pockets of heavy surface cobble.	Native grass. Irrigated small grain	Orchards and other deep-rooted crops	Excellent
Grayish-Brown	Occasionally in 5-foot zone	Seldom in 5-foot zone	Alluvial fan deposits	Clay loam to clay (North) Loam to Sandy loam (South)	Single grain - stable	None to slight	NONE	Good	Clearing. Occasional Pockets of heavy surface cobble.	Native grass. Irrigated small grain and Truck Crops	Orchards and other deep-rooted crops	Excellent
Whitish-Gray	Frequently in 5-foot zone	Occasionally in 5-foot zone	Marl	Loam to Clay Loam	Sponge - (Surface) Massive or Laminated (Beneath) - unstable.	Heavy Salts Present	Slight	Fair to Good	Reclamation. Leaching may cause moderate settling of soils.	Salt grass, low brush, bananas, truck crops	Truck Crops and Cereals	Good (After reclamation)
Azonal (Zor)	Seldom in 5-foot zone	Seldom in 5-foot zone	Flood Plain Out-Wash	Complex, clay dominant	No aggregate structural development. Parent material in layers.	None to slight	NONE	Good	Leveling. To correct drainage problems in small areas for irrigation.	Salt grass, low brush, irrigated truck crops	Truck Crops and Cereals and Sugar Beets	Good

Methods

The features of soil, topography and drainage were examined and the effects they would have on crop adaptabilities, crop yields, and costs of production were evaluated in order to segregate the land into classes. Field mapping was done on aerial photographic mosaics that have a scale of approximately 1:2,500. Topographic sheets with 1 meter contour intervals were used in conjunction with the photographs. Drawing JR-20 provides an index of the aerial mosaics. Additional controls were maintained by use of a Brunton Compass and Abney Level. The areas covered by the photographs were traversed systematically with such deviations as necessary to determine the boundaries of the different land classes. On the more uniform areas 8 to 10 holes per square kilometer were dug with a soil auger to a depth of one and a half meters, recorded, and located on the photographs. On the more complex areas the investigation was much more intensive. The soil borings were spaced at sufficient intervals to determine as accurately as possible the delineations between land classes and subclasses. Numerous holes were also examined to evaluate the deeper subsoil and drainage conditions.

Individual classifiers in the field normally mapped a "tier" or "string" of photo maps extending from the River Jordan to the upper reaches of the ghor. These maps were in turn "matched" to the surrounding areas mapped by other classifiers in order to insure coordination of effort and continuity in delineating over-lapping classes of land. In this manner field consultations, coupled with additional soil analyses where the need was indicated, more readily resolved existing or potential problems.

After field and laboratory information were correlated, definition lines for land class and subclass areas were placed on the photo maps. These maps were individually inked, measured and tabulated in accordance with accepted practices. All measurements were adjusted to conform to the Palestine Grid system which had been reproduced on the controlled aerial mosaic photo maps. In this manner the total area of the project was summarized by individual land classes grouped as arable and non-arable lands. Subclasses within each major land class were grouped into categories of similar characteristics.

The laboratory furnished analytical data necessary for a scientific classification of the Jordan Valley soils. Disturbed soil samples from about 50 percent of the meter and one-half borings made by the field classifiers were submitted to the soils laboratory in Amman. Samples were of a composite nature and were taken according to textural zones or zones of other visible soil characteristics such as color change. Very rarely did a soil sample represent a depth greater than 60 centimeters. All samples were analyzed for total soluble salt content and soil alkalinity or degree of sodium saturation. Further analyses were made as requested by the field classifiers and additional tests performed when the need was indicated. The field infiltration sites selected throughout the valley were also used as representative areas for physical and chemical analyses of the soils.

In general, the methods of analysis used were essentially as outlined in Agriculture Handbook No. 60, United States Department of Agriculture issued in February of 1954, exceptions being mechanical analysis, dispersion percentage, hydraulic conductivity, organic matter, available phosphorus, and available potassium. The major analyses performed include the following:

1. Salinity (as indicated by measuring the electrical resistance of saturated soil paste or measuring the electrical conductivity of saturation extracts)
2. Soil reaction or pH (1:5 soil-water suspension)
3. pH (saturated soil paste)
4. Saturation moisture percentage
5. Air-dry moisture percentage
6. Exchangeable sodium
7. Cation exchange capacity
8. Mechanical analysis
9. Dispersion percentage
10. Hydraulic conductivity of disturbed soil samples
11. Organic matter
12. Total dissolved solids
13. Gypsum
14. Calcium, magnesium, sodium, potassium, carbonate, phosphorus, bicarbonate, chloride and sulfate

Mechanical analyses were made by shaking a weighed sample of soil, overnight, with 5 ml. of Calgon solution (304 gms/liter) and 5 ml. of sodium silicate solution in 4 oz. of demineralized water. The following morning the suspensions were diluted to 1 liter in a soil testing cylinder. They were again shaken, specific gravity read using a long hydrometer at 70 seconds settling time, and again at 6 hours and 40 minutes settling time using a big bulb hydrometer. The distance from the center of volume of the hydrometer bulb to an average reading (1.0150 on the long hydrometer and 1.0050 on the big bulb hydrometer) was taken as the distance of fall for calculating reading time by Stokes Law.

Dispersion percentages of silt and clay were determined by dividing the corrected 70 second reading obtained in shaking by that obtained in mechanical analysis and multiplying by 100. In shaking, a sample of soil of the same weight as that used in mechanical analysis was evacuated in 200 ml. of water and then diluted to one liter in a cylinder. The mixture was then inverted 30 times in one minute to thoroughly mix before allowing it to settle.

Hydraulic conductivity of disturbed soil samples was determined by U. S. Bureau of Reclamation procedure. A brass cylinder two inches in diameter and length was covered on one end with a circular piece of rayon cloth held in place by a rubber band. Soil passing a 2 mm. mesh sieve was placed in the cylinder and compacted by dropping the cylinder ten times from a height of one inch. A circular piece of filter paper was placed on the soil surface to prevent surface disturbance. The unit was then placed on a glass funnel and subjected to a 1:1 head of water. The percolate was measured hourly until a constant rate was obtained, and "Darcy's" formula used to calculate hydraulic conductivity. All tests were run in duplicate and Yarmouk River water was used in all tests.

Organic matter was determined by wet oxidation with chromic sulfuric acid using the "Walkley-Black" technique of adding the concentrated sulfuric acid to 10 ml. of dichromate solution containing the sample. The resulting hot solution was swirled and allowed to stand 10 minutes, after which 150 ml. of water was added. An excess of ferrous iron solution was added and the solution back titrated with standard potassium permanganate solution.

Available phosphorus was measured using 0.5 N-$NaHCO_3$ solution as an extracting reagent, as proposed by Sterling Olsen et al. Potassium was determined on the same extract with the flame photometer.

Soil Permeability Studies

Field investigations were conducted to obtain the permeability and internal water movement of various soils under undisturbed field conditions. These infiltration studies were conducted in accordance with the method given in Salinity Laboratory Handbook No. 60. An additional guard ring, composed of earth, surrounded each infiltration cylinder to compensate for lateral water movement. A 15 centimeter depth of water was maintained in the cylinder and earthen ring, and the rate of subsidence of the water surface inside the cylinder was measured hourly or more frequently if fast subsidence occurred. Triplicate infiltrometers were continuously maintained until a uniform infiltration rate was established. These tests were conducted with Yarmouk River water in order to simulate reaction under project water supply as closely as possible.

Thirty-eight sites were selected to represent typical areas. Results of these tests are presented in Table 3.1-8, Chemical and Physical Analyses of Infiltration Sites. Three of these sites were excavated to the assumed restricting zone depth (primarily marl) and the rates determined. In every instance these rates were higher than the surface rates indicating that flow divergence was negligible. A compact carbonate gypsiferous layer varying from 2.5 to 7.5 cm. and existing below the surface from 20 to 45 cm. is characteristic of some of the soils placed in Class 4 principally in the southern part of the valley. Although a slow infiltration rate was evidenced at first, mechanical probing of this compacted gypsiferous zone greatly increased the permeability. The site at Grid 139 North, 206 East, hole 10 illustrates this finding. Indications are that deep chiseling practices on these soils would aid materially in reclamation of these soils.

As indicated in Table 3.1-8, the soils north of the River Zarqa are relatively free of soluble salts, exchangeable sodium and gypsum. The soils of this area range from medium to heavy texture, being heavier toward the north end of the valley. Also illustrated is the fact that the soils south of the River Zarqa are generally higher in soluble salts and exchangeable sodium. Soil textures tend to be medium in nature, and the soluble salt concentrations are composed principally of divalent cations which reduces the seriousness of the exchangeable sodium indication. These soils appear high in exchangeable sodium, due to the low cation exchange capacities reflected as a result of interference by the divalent cations in the exchangeable cation analysis. In addition gypsum is present in sufficient concentration to prevent development of sodium alkalinity during reclamation.

Data revealing the effect of leaching on the soluble salt concentrations within the infiltration sites south of the River Zarqa are presented in Table 3.1-6, Soluble Salt Displacement Resulting from Infiltration Studies. In every instance appreciable salt displacement occurred during the infiltration test. It is remarkable that soils containing approximately 5.0% salt dropped to 0.1% salt during infiltration measurements. The magnitude of leaching in these soils was noticeable down to the 60 cm. depth, and in some sites extended as far down as the 120 cm. depth before slight salt differentials were noted.

In general, investigations indicate that the soils comprise two broad groups, non-saline in the area north of the Zarqa River, and saline in the area to the south. Infiltration rates for the non-saline soils were generally very satisfactory, with the exception of a few observed in the extreme northern sector, where drainage could be a problem. The saline soils, Class 4 land, will require reclamation in order to reach a productive state. Adequate drainage will be required to maintain productivity once the soils have been reclaimed.

Land Classes

A land class is a category of lands having similar physical and economic characteristics which affect the suitability of land for irrigation. It has been called an expression of relative level of payment capacity. Five major classes of land are recognized in this study.

A fraction-type symbol is used to designate the different land classes. The number in the numerator designates the class of land. The letters following the land class are the subclasses and show the nature of the deficiencies. The subclasses are "s", "t", and "d" and represent deficiencies in soils, topography or drainage respectively. They may be used singly or in combinations. The letters in the denominator indicate the nature and extent of the deficiencies. The example in the lower left corner of Drawing JR-22, Land Classification Symbols, indicates the position of the various deficiencies in a land class symbol.

After correlating field examinations and laboratory information, the lands were segregated according to their degree of suitability for irrigation agriculture. Boundary lines between basic land classes are shown on the aerial mosaics as solid lines. Subclasses are delineated by dashed lines. Each arable class delineation has at least one recorded soil profile and is labeled with a land classification symbol.

Area and soil profile description for each recorded profile includes the following: 1) types of existing vegetation; 2) topography information with regard to gradient, position and unevenness of surface; 3) drainage conditions; 4) soil information with respect to structure, cementation, color, and depth to residual marl; and 5) laboratory information. Mapping symbols and abbreviations used in the land classification survey are shown on Drawing JR-22.

The features of soil, topography and drainage of Class 1 lands are favorable for the production of high yields of climatically adapted crops at relatively low production costs. The characteristics of Class 2 lands may cause the following: slightly reduced yields, increased production costs, slightly restricted crop adaptabilities or a combination of these factors. Class 3 lands are restricted in suitability for irrigation agriculture because of features that materially reduce crop yields, restrict crop adaptabilities, increase production costs, or produce a combination of these results. Class 4 lands are temporarily unsuited for irrigation agriculture due to saline content of the soil; however, they are considered to be reclaimable to at least the productive level of Class 3 lands. Lands unsuited for irrigation agriculture are designated as Class 6. Estimates of the degree of suitability for irrigation agriculture were made by comparing the characteristics of the lands with the minimum land class specifications presented in Table 3.1-3, Specifications for Land Classification.

The Class 1 lands are located primarily on the recent flood plains of the perennial streams on the ghor terraces with small scattered areas occuring on the zor. They have deep permeable soils with no, or slight, evidence of alkali or saline conditions. Most of the Class 2 lands occur on the outer fringes of the recent flood plains, as deep soils with moderately heavy profiles. Also included in Class 2 are lands with coarse textured soils on the recent flood plains, areas relatively shallow in depth to marl, those primarily located along the edge of the

Table 3.1-3

Specifications of Land Classification
For The
Yarmouk-Jordan Valley Project

Factors Evaluated	Arable			Potential Arable*	Non-Arable
	Class 1	Class 2	Class 3	Class 4	Class 6
SOILS					
Texture	Sandy loam to very permeable clay.	Loamy sand to permeable clay.	Fine sand to slowly permeable clay.	Fine sand to slowly permeable clay	
Depth to:					
Sand, gravel or cobble	36" of fine sandy loam or heavier. 42" of sandy loam.	24" of fine sandy loam or heavier. 30"-36" of loamy sand.	18" of sandy loam or heavier. Fine sand permitted if underlain by heavier material.	18" of sandy loam or heavier. Fine sand permitted if underlain by heavier material.	
Bedrock, shale, or similar material	60"	36" depending on position and slope.	24" depending on position and slope.	24" depending on position and slope.	
Residual marl	36"	24"	18"	18"	
Modified marl	30"	18"	12"	12"	
Alkalinity	Surface pH 9.0 Subsoil pH 9.2	pH 9.2 pH 9.4	pH 9.4 pH 9.6	pH 9.4 pH 9.6	
Salinity	Surface .2% (may be higher in permeable soils) Subsoil .2% (soils with good drainage).	.5% (may be slightly higher in permeable soils). .5% (permeable soils with good drainage).	.5% (may be slightly higher in permeable soils). .75% (higher in open permeable soils with good drainage).	In excess of Class 3 limits but susceptible of leaching to at least Class 3 percentages.	This includes all lands which do not meet the minimum requirements for arable land. This may include small bodies of arable land lying within larger areas of non-arable land.
TOPOGRAPHY					
Slopes	Up to 4% in same plane. Less if complex slopes.	Smooth slopes up to 8% or complex slopes up to 4%.	Smooth slopes up to 12% or complex slopes less than 8%.	Smooth slopes up to 12% or complex slopes less than 8%.	
Surface	Regular enough to require only small amounts of levelling.	Moderate levelling and grading required. Estimated earth movement 200-500 M3/Donum.	Heavy levelling and grading required. Estimated earth movement 500-800 M3/Donum.	May exceed Class 2 levelling but should not be the maximum allowable for Class 3.	
Cover (loose rock and vegetation)	Cost of clearing small or insufficient to modify cultural practices or reduce productivity.	Clearing required. May be equivalent in cost to Class 2 levelling.	Heavy clearing necessary. May be equivalent in cost to Class 3 levelling.	May exceed Class 2 clearing but should not be the maximum allowable for Class 3.	
DRAINAGE					
Soil and Topography	Requires only normal drainage with maximum permissible drain spacing as established from infiltration tests.	Additional drainage required. Conditions indicate slightly closer drain spacing than that established for Class 1.	Additional drainage required. Conditions indicate closer drain spacing than that required for Class 2.	Project drainage required as indicated for the potential arable class.	

* Class 4 - Areas having soluble salts in excess of limits for Class 3 land, and with soils and topography such that reclamation is highly feasible. Land Class potential after leaching indicated by parenthetical symbols.

Note 1 - The pH limits as set forth in the standards are based on one to five dilutions with limits slightly higher than Bureau of Reclamation standards. This applies to soils which are calcareous and gypsiferous in character.

Note 2 - In the overall use of the standards the various limits set up for each item in each class are used as guides and may be deviated from depending upon circumstances. A combination of factors is used to determine the land class both present and ultimate.

upper scarp having moderate rock cover and areas with soils of slight alkali or saline conditions. The principal Class 3 lands are characterized by soils of very coarse texture, undulating topography, surface rock, or major degrees of slope. These areas are predominantly found adjacent to the upper reaches of the ghor and the immediate fan areas of stream channels. The Class 4 lands possess a high percentage of soluble salts and must be leached before successful irrigation agriculture can be initiated. The majority of this land is located south of River Zarqa on the East Ghor and on the West Ghor, which are areas of low rainfall. Localized areas occur intermittently throughout the project area. Lands designated as Class 6 are principally the rough "breaks" between the ghor and zor, stream channels, shallow soils with strong alkali and high salt content, and undulating areas of very heavy textured soil with high salt content.

Relation of Land Classes to Crop Production, Crop Adaptabilities and Management (Table 3.1-4)

Class 1

There are 143,090 donums of Class 1 land in the project area. The soils include deep, permeable clay loams and significant areas of sandy loams, and loams. The heavier textured profiles are primarily located north of the River Zarqa on the East Ghor and in the vicinity of Wadi Fari'a on the West Ghor. The fans of Wadi Hisban and Wadi Kafrein, located at the southern part of the East Ghor, comprise a large area of the lighter textured soils in this class. The water holding capacity is good and the inherent fertility of these soils is relatively high. These features provide an excellent environment for the growth of climatically adapted crops and do not present any major problems to the operator. A

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 1 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
1	1/ll,1/lm,1/ml,1/mm,1/mh,1/mhz,1/hh	Smooth lands, deep permeable sandy loams and loams, minor areas of clay.	143,090	15.2	Climatically adapted crops.	No special problems.
	2s/hhz	Clays and clay loam over marls.	2,766	0.3	Crops having moderately deep rooting systems.	Tillage problems.
	2s/hh	Clay, minor areas of clay loam, deep soils.	16,627	1.8	Crops having moderately deep rooting systems.	Tillage problems.
	2s/hha	Clay loams, minor areas of clay, deep, slight alkali.	11,024	1.2	Alkali tolerant, moderately deep rooted crops as sugar beets.	Tillage problems--leach to correct alkali.
	2s/lma,2s/lha,2s/mma,2s/mha	Light to medium textures, deep soil, slight alkali.	12,937	1.4	Alkali tolerant, deep rooted field and truck crops.	Leach to correct alkali.
	2s/ll	Smooth deep alluvium, low available water.	6,854	0.7	Deep rooted crops--early vegetables, potatoes.	Irrigate to avoid excessive deep percolation and fertilizer losses.
	2t/hhg	Clay loams, minor areas of clay, gradient 4-8%.	10,718	1.1		
2	2t/hhc,2t/hhu,2t/hhcg	Clay loams, moderate leveling or clearing required.	12,526	1.3	Climatically adapted crops.	Care in application of irrigation water on lands with gradient.
	2t/mhu,2t/mhcu,2t/lhu,2t/mmu,2t/mmcu, 2t/lmu,2t/llc,2t/llu,2t/llcg	Light to medium textures. Moderate leveling or clearing required.	12,549	1.3		
	2st/mhcu	Moderately undulating lands with soil and alkali variations similar to the 2s lands as indicated by denominator symbol.	9,727	1.0	Similar to 2s lands as indicated by denominator symbols.	Problems similar to 2s lands as indicated by subclass symbols. Care in application of irrigation water on lands with gradient. Leveling and clearing costs as indicated for 2t lands.
	2st/hhc hhac, hhcg	Same as above	14,034	1.5		
	2st/llc,2st/llu,2st/llacu,2st/lmc	Same as above	10,506	1.1		
	2st/hhg	Clay and clay loam texture, gradient.	7,193	0.8		
	2d/hh,2sd/hh,2td/hhu,2std/hhcg,2sd/hha, 2sd/hhz	Clay loams to clays. Water table present.	11,013	1.2	Crops having moderately deep or shallow rooting systems.	Drainage, other problems similar to 2st lands as indicated by subclass - symbols.
	3s/hha	Smooth, clay loams and clay, moderate alkali.	924	0.1	Moderately deep rooting system, moderately alkali tolerant crops.	Tillage
3	3s/hhaz,3s/mmaz	Medium and heavy textures, over marl. Moderate alkali.	3,933	0.4	Shallow rooted, moderately alkali tolerant crops	Subsoil to open up marl and increase effective root zone. Leach to correct alkali.
	3s/hma mma	Smooth, medium texture, moderate alkali.	782	0.1	Deep rooted, moderately alkali tolerant crops.	

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 2 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
3	3t/nng	Clay loams, minor areas of clay, soil deep, gradient 8-12%.	5,074	0.5	Climatically adapted crops.	Irrigate such that erosion is controlled.
	$3t/mmc_2u_2$, 3t/mlu	Medium textures, moderate to heavy leveling and clearing required.	4,460	0.5	Same as above.	Moderate clearing and leveling.
	3st/hhazu	Generally severe topographic limitations. Soil and alkali conditions similar to the 3s lands as indicated by denominator symbols	4,989	0.5	Similar to 3s lands as indicated by subclass symbols.	Similar to 3s lands as indicated by subclass symbols.
	$3st/hhc_2g_2$		11,517	1.2		
	$3st/mmau_2$, $3st/mmc_2g_2u_2$, 3st/lhc, $3st/lhc_3g_2$		15,718	1.7		
	$3st/llc_2u_2$, $3st/llac_2u_3$, $3st/llc\text{-}llu_2\text{-}llu_3$		14,902	1.6		
	3d/hh, 3sd/hh, 3td/hhu, $3std/llc_2u_2$	Water table present.	3,672	0.4	Similar to other 3s land as indicated by subclass symbols.	Drainage--other problems similar to those of 3s lands as indicated by subclass symbols.
4(1)	1/hh, 1/mh, 1/hl, 1/lh, 1/mm, 1/lmz, 1/ll	Smooth lands, deep, permeable sandy loams, loams and clay loams.	66,632	7.0	Climatically adapted crops. (After reclamation)	Leach to correct alkali.
4(2)	2s/hhz	Clay loams, clays over marls.	8,032	0.9	Crops having moderately deep rooting systems.	Leach to correct alkali.
	2s/hh, 2s/hl	Clay surface texture: smooth, deep soil.	8,906	1.0	Deep rooted crops.	Tillage problems--leach to correct alkali.
	2s/mm, 2s/ll	Medium and light textures. Low available water.	5,052	0.5	Very early truck crops.	Washing out of plants by wind or water. Excessive deep percolation
	2t/hhu, 2t/hhzu	Clay loams, minor areas of clay: soil deep; undulations	8,857	0.9		Leveling--leach to correct alkali.
	2t/mmg	Smooth, deep, medium texture. Gradient 4-8%.	1,969	0.2	Climatically adapted crops. (after reclamation)	Leach to correct alkali
	2t/hmu, 2t/mmu, 2t/mlu, 2t/mlcu, 2t/lmu, 2t/llgu	Medium and light textures, moderate undulations	11,894	1.3		Leveling--leach to correct alkali.
	2st/hhu, 2st/llcu	Moderately undulating lands with soil variations similar to 4 (2s) lands as indicated by denominator symbols.	4,711	0.5	Similar to the 2s lands as indicated by subclass symbols.	Problems are similar to those of 4(2s) lands as indicated by subclass symbols. Leaching required to correct alkali.
	2st/hhzu, 2st/mhzu		10,216	1.1		
	2d/mh, 2sd/hm, 2td/hhu, 2std/mmgu, 2sd/hhm	Water table present.	5,125	0.5	Shallow rooted crops.	Drainage--leach to correct alkali.

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 3 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
	3s/hn	Heavy-slowly permeable clay; smooth, deep soil.	7,632	0.8	Shallow rooted crops	Tillage problems, leach to correct alkali.
	3t/mmu,3t/lmu,3t/hmzgu$_2$	Medium and light textures. Heavy undulations	5,255	0.6	Climatically adapted crops (after reclamation)	Leveling - leach to correct alkali.
	3t/hhg$_2$u$_2$	Clay loam, minor areas of clay, moderate undulation, Gradient 4-8.	2,132	0.2		
4(3)	3st/hhg$_3$ 3st/mhac$_2$u$_2$ 3st/hmzg$_2$u$_2$,3st/hmzu$_2$,3st/mmzu$_2$	Generally severe topographic limitations. Soil conditions similar to the 4 (3s) and 4 (2s) lands as indicated by denominator symbols.	5,206 2,329 16,152	0.6 0.3 1.7	Similar to the 3s lands as indicated by subclass symbols.	Problems are similar to those of 4 (3s) lands as indicated by subclass symbols. Leaching required to correct alkali.
	3sd/nhz 3d/hm-3td/lhu-3std/mhu	Clays over marl, water table present. Medium and heavy textures. Moderate undulation. Water table present.	2,208	0.2	Shallow rooted crops	Drainage - leach to correct alkali; leveling where indicated in subclass.
6	6h, 6i (class 1, 2, 3)	Lands which by location are either high or isolated with respect to the delivery of irrigation water.	8,624	0.9	Native Pasture	--
	6s, 6t, 6st, 6std	Lands unsuitable for the economic production of any irrigated crop.	414,175	43.9	Native Pasture	--
		Total	942,844	100.0		

wide range of crops is being grown on these lands with good production.

Class 2

The Class 2 lands comprise 138,473 donums within the project area. Class 2 lands are generally less favorable for the production of most irrigated crops than are the Class 1 lands and in addition some of the Class 2 lands have developmental problems. The characteristics which cause these less favorable conditions and the major problems which may be anticipated are as follows:

a. Heavy Texture

(1) Permeable profiles (principal subclasses, 2s/hhz, 2s/hh). Approximately 19,000 donums are included in this grouping. The principal location of these lands is in the northern part of the valley in the vicinity of Adasiye. Infiltration rates range from 0.5 mm./hr. to 68.0 mm./hr. A large portion of this area has been farmed for many years and produces good crops. A minor portion of these soils are subject to vertical cracking and sealing necessitating care in water application. Tillage practices in these areas will be governed by the moisture content of the soil.

b. Saline-Alkali Lands

(1) Permeable profiles (principal subclass, 2s/hha). There are approximately 11,000 donums of land in this category. They occur generally on the upper fringe of lower lying areas. The problem is somewhat difficult to remedy with correctives due to heavy textured soils subject to vertical cracking; however, addition of gypsum and adequate subsurface drainage will help materially. Cultivation practices will be similar to the 2s/hh lands in regard to timeliness of operation. Crops such as sugar beets should do well on these areas.

(2) Very permeable profiles (principal subgroups, 2s/lma, 2s/lha, 2s/mma). These lands number approximately 13,000 donums.

The major portion is gently sloping and has soils that are deep, permeable and capable of holding a moderate amount of water for plant use. There is a slight alkali problem indicated by high exchangeable sodium, in most cases gypsum content is correspondingly high. Moderately alkali-tolerant, deep rooted crops should do well on these areas. When occurring as narrow tracts surrounded by soils of more favorable texture, appropriate soil-plant-water relations may be difficult to maintain and crop growth may be restricted. Irrigation practices producing moderate leaching are recommended.

c. Topographic Deficiencies

(1) Lands characterized by unevenness or cover, (principal subclasses, 2t/hhu, 2st/mhcu, 2st/llc). There are approximately 18,900 donums of Class 2 land that will require moderate leveling before they will be suitable for irrigation without special irrigation systems. Of this total approximately 4,000 donums have slight factors of both unevenness and rock or vegetative cover, the combination of which warrants placing them in a topographic deficiency category. Approximately 22,300 donums will require removal of rock or vegetative cover. These deficiency factors are expected to be corrected at a cost of between $14 and $19 per donum. After leveling and clearing has been accomplished, there are approximately 16,700 donums that will be of Class 1 quality.

(2) Gradient or complex slope (principal subclasses, 2t/hhg, 25/hhcg, 2st/hhg). These are lands with gradients that make irrigation patterns difficult since these areas quite often lie adjacent to smoother slopes. There are approximately 36,000 donums in this category, of which 15,600 donums will require clearing of cover. The general extent of topographic deficiencies is shown in Table 3.1-5, Extent of Topographic Deficiencies.

(3) Drainage problem (principal subclasses, 2sd/hh, 2d/hh, 2td/hhg). The total of approximately 11,000 donums in this grouping is rendered less significant due to the fact that the individual areas are

Table 3.1-5

Extent of Topographic Deficiencies

	EAST GHOR NORTH			EAST GHOR SOUTH			WEST GHOR		
Deficiency	Above Canal	Below Canal		Above Canal	Below Canal		Above Canal	Below Canal	
		Ghor	Zor		Ghor	Zor		Ghor	Zor
Cover	About half of area affected. Particularly near the alluvial fans.	Minor importance. About 5%	Negligible	About half of area affected.	Locally important. About 7% of total area.	Local Pockets - Negligible	About 20% of area affected.	Negligible	Negligible
Leveling	Minor importance. About 5%.	Minor importance. Less than 5% of area.	Of major proportions. Nearly all lands need some.	About 15% needs leveling	About 12% of this area needs leveling.	Of major importance. Is principal deficiency.	25% of area is in need of leveling.	12-15% area is in need of leveling.	Principal deficiency in the Zor.
Gradient	About one-third of area is affected.	About 10% of area is affected.	Of minor importance.	About 10% of area is affected.	Of minor importance-about 5%	Negligible	About 20% of area affected.	Negligible	Negligible

Notes: Most cover deficiencies are of class 2 intensity.
Gradients (g), mostly of class 2. Smooth Slopes up to 8% or complex slopes up to 4%.
Leveling (u), mostly class 2 intensity. Movement of 200 to 500 M^3 per donum required.

relatively small. Primarily they consist of lands in shallow depressions and have been taken into account in designing the project drainage pattern.

Class 3

The Class 3 lands occupy 65,972 donums of the project area. The characteristics of Class 3 lands are fairly favorable to irrigation agriculture. Moderate alkali, very coarse textures, and fairly rough topography are the factors which primarily limit the suitability of these lands for irrigation agriculture.

a. Saline-Alkali Lands

(1) Lands with moderate alkali, relatively permeable soils (principal subclasses, 3s/hha, 3s/hhaz). The area in this category totals approximately 5,000 donums. They are smooth gently sloping lands in which moderate amounts of alkali and soluble salts have accumulated. A large portion of these lands are farmed to grain. Current irrigation practices with an inadequate water supply have permitted accumulation of salts from the subsoil, particularly in those areas underlain by marl at a relatively shallow depth. Infiltration tests indicate the profiles to be susceptible to leaching with an adequate water supply and drainage system.

b. Topographic Deficiencies

(1) Lands of uneven topography or relatively steep gradient, (representative subclasses, $3t/hhg_3$, $3t/mmc_2u_2$, $3t/mlu_3$). Approximately 9,500 donums of land are classed in this category. Of this total nearly 90 percent will require grading or clearing estimated to cost between $16 and $32 per donum. The remaining 10 percent possesses relatively smooth gradient of between 8 and 12 percent slope with medium heavy to heavy textured soils, which will necessitate careful application of water.

(2) Lands with combination topographic and soil deficiencies, (representative subclasses, $3st/hhc_2g_2$, $3st/mmc_2g_2u_2$, $3st/llac_2g_2u_2$). This group of land comprises 42,000 donums and will require grading and clearing as described in the foregoing paragraph. Of the total land in this category about one-half has a good water holding capacity; however, the range between wilting point and field capacity will be slightly reduced by the alkali condition of some 7,500 donums. The remainder is comprised of light textured soils of which about 5,700 donums are affected by alkali. These lands frequently occur as irregular shapes surrounded by lands of poorer quality. Care should be exercised in leveling in order not to deposit a layer of unproductive soil over these marginal soils, resulting in severely restricted crop growth. Frequent irrigation and fertilization will be required to maintain crop production due to low water holding capacity and low inherent fertility of the soil.

(3) Drainage problem (principal subclasses, 3d/hh, 3sd/hh). Lands of this category are relatively minor, totaling approximately 3,600 donums. They normally occur as very small depressions with evidence of a water table; however, they are of farmable size, and project drainage has been designed to provide subsurface outlets.

Class 4

The Class 4 lands comprise 172,310 donums of the area. Of this total about 14 percent are of Class 1 and 2 potential after leaching operations are completed. Primarily the soil textures, and topography of these lands are favorable and in most instances there is an appreciable amount of gypsum present which will materially aid in the leaching process. Total soluble salt content may range from 0.5 percent to greater than 3.0 percent in cases where soil, topography and drainage characteristics are favorable for leaching. The majority of this land occurs in large bodies primarily on the lower edge of alluvial fans, and are presently not irrigated.

The area of the East Ghor associated with the fans of the Wadis Shueib, Kafrein, and Hisban are representative of this category. Representative samples show total soluble salt content in one irrigated field as less than 0.2 percent, as compared to samples showing greater than 2.0 percent in an adjacent field which has had no irrigation water applied, but which is comparable in soil texture, topography, and drainage characteristics. Better than three-fourths of this area is characterized by soils with profiles ranging in texture from sandy loams to clay loams or permeable clays. Light to medium textured profiles are characteristic of about one-third of the area. The blocking of ancient underground water development systems (fuquarās) has given rise to saline conditions in some areas. It is contemplated this condition will be remedied by subsurface drainage.

The Class 4 lands on the West Ghor south of Jericho are similar in nature and position to those described in the foregoing paragraph; however, the presence of fuquarās has not been detected. These lands are predominantly characterized by clay loam and clay profiles. Large bodies of this category extend northward from the Jericho vicinity where again fuquarās have materially contributed to the saline content of these areas. Infiltration rates on these soils are generally good as indicated by a rate of 5.1 mm./hr. on a soil composed of 90 centimeters of clay over clay loam to a 1.5 meter depth.

After leveling and leaching operations the Class 4 lands are expected to assume the characteristics of those classes and subclasses indicated by the classification symbol following the 4 designation.

Class 6

Approximately 423,000 donums of Class 6 land are unsuited for irrigation agriculture, of which 8,800 donums are due to isolation from lands of an arable nature or excessive elevation. The remainder is the rough, shallow soil "break" between the ghor and zor areas, stream channels, and scattered rough and stony lands.

Leaching

Approximately 174,000 donums will require leaching of salts from the soil before a satisfactory degree of crop production can be expected. A specific leaching program is recommended for approximately 167,000 donums. The TSS percentage of these soils ranges upward from 0.2% with the average percentage somewhat greater than 3.0%. Two tenths of one percent soluble salt present within the upper meter of soil may be potentially damaging to crop yields.

Lands requiring leaching are designated as Class 4, of which the largest areas are in the southern part of the valley. To establish a basis for leaching recommendations two trial areas were selected and prepared under normal field conditions. Each area was divided into four plots of equal size and each plot within an area given a specified water treatment. The major difference in preparation for leaching was that Area 1 was provided with subsurface drainage facilities while Area 2 did not have such facilities. Table 3.1-6, Soluble Salt Displacement, shows the total soluble salt displacement, the amount of water applied and the infiltration rate during water application. Location and details of methods and procedures used in leaching trials are in Part 5 of Volume VII. Results of the trials indicate that salts can be leached from the soil. An application of 15 centimeters of water followed by subsequent

Table 3.1-6

Soluble Salt Displacement
Resulting From Infiltration Studies
of Jordan Valley Soils
(Sheet 1 of 2)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	Infiltra-tion Rate MM/Hr.	Water Applied M	Conductivity $ECx10^3$ Before Inf.	Conductivity $ECx10^3$ After Inf.
		East Ghor Area				
139N-206E	10	0- 15	1.0	2.47	117	3.8
139.670N-		15- 30			99	4.8
205.225E		30- 45			66	(
		45- 60			56	(3.2
		60- 75			51	(
		75- 90			53	(17
		90-120			55	18
		120-150			54	15
137.5N-204E	24	0- 15	124.5	7.68	161	7.6
		15- 30			117	11
		30- 45			70	6.1
		45- 60			46	5.9
		60- 90			19	6.6
		90-120			14	6.5
134.5N-208E	20	0- 15	25.4	1.01	188	6.6
135.760N-		15- 30			113	3.8
206.090E		30- 60			92	4.4
		60- 90			61	4.3
		90-120			49	4.6
		120-150			31	5.8
		150-180			38	6.6
140.5N-206E	22	0- 15	10.2	2.19	44	6.2
140.800N-		15- 30			50	4.1
205.820E		30- 60			52	3.7
		60- 90			61	4.4
		90-120			65	6.6
		120-150			83	25
		West Ghor Area				
172N-200E	9	0- 15	35.6	4.51	76	3.1
		15- 30			58	1.3
		30- 60			60	5.0
		60- 90			38	2.9
		90-120			29	3.1

Table 3.1-6

Soluble Salt Displacement
Resulting From Infiltration Studies
of Jordan Valley Soils
(Sheet 2 of 2)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	Infiltra-tion Rate MM/Hr.	Water Applied M	Conductivity $ECx10^3$ Before Inf.	After Inf.
(West Ghor Area Cont'd)						
145N-198E	1	0- 15	17.8	1.40	5.0	2.0
		15- 30			19	3.8
		30- 60			32	3.3
		60- 90			61	7.1
		90-120			58	41
		120-150			58	53
137.5N-198E	13	0- 15	99.1	5.88	183	4.8
		15- 30			110	3.5
		30- 45			117	13
		45- 60			106	24
		60- 90			78	35
		90-120			55	44
		120-150			32	29
133N-202E	13	0- 15	1.0	.15	67	5.3
		15- 30			65	4.4
		30- 45			45	41
		45- 60			46	46
		60- 90			49	48
		90-120			50	41
		120-150			65	59
133N-202E 133.575N-200.990E	12	0- 15	5.1	.30	160	3.9
		15- 30			156	5.0
		30- 45			144	32
		45- 60			137	48
		60- 90			134	53
		90-120			122	62
		120-150			141	118

applications of the same amount (each applied immediately after the previous one has been absorbed by the soil, until a total of 80 to 100 centimeters has been applied) will remove the salts to a safe level for shallow rooted crops and additional applications of water will maintain this level when adequate subsurface drainage has been provided.

Project Subdivisions

For purposes of this study the Jordan Valley has been divided into three subdivisions. These are the East Ghor North, the East Ghor South, and the West Ghor. Each of these was further divided into two primary sub-areas, above and below the main canal. The zor was segregated in tabulations to indicate its relative importance, although it will be an integral part of the area served by the main canals.

Land classes are summarized for each subdivision and sub-area in Table 3.1-7, Land Classification Summary. The distribution of these lands is shown on the land classification map, Drawing JR-21.

East Ghor North

Description. The East Ghor North subdivision comprises the lands lying between Yarmouk River in the extreme northern part of the valley and the River Zarqa, which forms an approximate mid-point dividing line of the lands east of the Jordan River. The lands extend from the Jordan River eastward to the steep slopes leading out of the valley. Nine sizeable wadis provide drainage, forming a series of small alluvial fans and interfan areas. The general gradient is in a westerly direction, and the elevation ranges from approximately minus 212 meters along the Main Canal location in the Adasiye vicinity to about minus 226 meters near the Zarqa River. Annual precipitation in this subdivision is of greater magnitude than any other portion of the valley and ranges from

Table 3.1-7

Land Classification Summary
Yarmouk-Jordan Valley Project

Area	Arable Class 1	Arable Class 2	Arable Class 3	Total Class 1,2,3	Class 4: 1	Class 4: 2	Class 4: 3	Total Class 4	Non-Arable Class 6	Total All Classes
	donums	donums	donums	donums	donums	donums	donums	donums	donums	donums
East Ghor North										
Ghor Above Canal	9,867	18,759	13,077	41,703	--	--	--	--	44,159	85,862
Ghor Below Canal	59,071	43,605	9,019	111,695	1,060	2,063	315	3,438	46,706	161,839
Zor Below Canal	4,677	8,689	3,774	17,140	200	314	254	768	6,267	24,175
Total Ghor and Zor Below Canal	63,748	52,294	12,793	128,835	1,260	2,377	569	4,206	52,973	186,014
Grand Total East Ghor North	73,615	71,053	25,870	170,538	1,260	2,377	569	4,206	97,132	271,876
East Ghor South										
Ghor Above Canal	12,055	11,705	8,368	32,128	298	317	470	1,085	45,985	79,198
Ghor Below Canal	29,721	23,498	11,608	64,827	33,808	27,554	13,677	75,039	93,297	233,163
Zor Below Canal	985	8,343	2,789	12,117	1,732	2,212	200	4,144	5,342	21,603
Total Ghor and Zor Below Canal	30,706	31,841	14,397	76,944	35,540	29,766	13,877	79,183	98,639	254,766
Grand Total East Ghor South	42,761	43,546	22,765	109,072	35,838	30,083	14,347	80,268	114,624	333,964
West Ghor										
Ghor Above Canal	18,400	14,591	11,184	44,175	8,748	6,491	5,815	21,054	55,525	120,754
Ghor Below Canal	7,395	4,584	2,275	14,254	19,595	23,373	18,863	61,831	123,940	200,025
Zor Below Canal	919	4,700	3,878	9,497	1,190	2,440	1,321	4,951	1,776	16,224
Total Ghor and Zor Below Canal	8,314	9,284	6,153	23,751	20,785	25,813	20,184	66,782	125,716	216,249
Grand Total West Ghor	26,714	23,875	17,337	67,926	29,533	32,304	25,999	87,836	181,241	337,003
Totals										
All Land Above Canal	40,322	45,055	32,629	118,006	9,046	6,808	6,285	22,139	145,669	285,814
All Ghor Land Below Canal	96,187	71,687	22,902	190,776	54,463	52,990	32,855	140,308	263,943	595,027
All Zor Land Below Canal	6,581	21,732	10,441	38,754	3,122	4,966	1,775	9,863	13,385	62,002
All Ghor and Zor Below Canal	102,768	93,419	33,343	229,530	57,585	57,956	34,630	150,171	277,328	657,029
Grand Total All Land	143,090	138,474	65,972	347,536	66,631	64,764	40,915	172,310	422,997	942,843

Note: Class 6H and 6I (not shown) amounts to 8,823 donums or 2% of the total class 6 area; most of which is found on the West Ghor.

about 400 mm. near Adasiye to about 200 mm. near the River Zarqa. Typical land classification photo maps of this area are shown as Drawings JR-23 and JR-24.

Soils. The soils of the ghor have been formed primarily from alluvial materials that were stream borne and by general outwash from the uplands. This mantle was laid down over fine textured lake deposits (marls) and thins out as it approaches the "break" between the ghor and zor. Textures on the fans vary, but are predominantly medium with rock and gravels in the profiles being a limiting factor, especially in those areas adjacent to the hills. On the edges of the fans, clay loams predominate with clays occupying the interfan regions. Organic matter, while still relatively low, is higher in this northern area than any other part of the valley. Rainfall, together with other weathering agents, has played a principal part in modification of the soils. The lake-laid materials have undergone changes to such an extent that it is difficult in most cases to identify the original laminations and in most instances the structure has become softly consolidated. Marls were found to be present in the one and a half meter zone of depth in only 5 percent of arable area.

Topography. The series of alluvial fans in this area give rise to slopes whose gradient is seldom greater than 4 percent. Complex slopes of short runs occur on the upper edges of the fans adjacent to the foothills. Gradient on the larger fans, such as those of the Wadi Arab and River Zarqa, is relatively smooth with long uniform slopes. The lands between the Wadi Rajeb and River Zarqa are indicative of the larger interfan areas which are of medium to heavy texture with long gentle slopes. Above the location of the Main Canal, cover is generally composed of rock, while some vegetation removal will be required below the canal.

The zor area is characterized by old stream channels which have been filled in by flood action. The resulting complex slopes will require a major degree of leveling in these instances.

Drainage. Conditions for adequate surface drainage are favorable. Except for localized areas there should be little difficulty in establishing drainage outlets through natural stream channels.

Approximately 7 percent of the arable area has characteristics which indicate present or potential subsurface drainage problems. These areas are primarily indicated by the presence of a water table within the meter and a half depth of soil profile. This condition has developed where there is a pronounced differential in hydraulic conductivity of the soils in connection with a slope differential and in areas where fuquarās have been neglected or abandoned. A shallow depression occurs between Grid North 223 and North 230 comprised of slowly permeable soils whose clay fraction frequently exceeds 50 percent. Field observation indicates the clay to be of the expanding lattice type. Under present limited irrigation, drainage problems are not acute; however, irrigation with a full water supply will tend to aggravate conditions in this area. Controlled application of water, development with shallow rooted crops, encouragement of water penetration through use of gypsum, and installation of closely spaced drains are recommended.

Problem areas on the zor occur as a result of the proximity of the Jordan River water table, and from seeps or springs from the rough area which separates the ghor and zor. Installation of an interceptor ditch will effectively aid the latter condition while arable areas affected by the river water table can be productively farmed to shallow rooted crops with controlled irrigation practices.

Salinity and Alkalinity. In the area north of the River Zarqa soils are generally low in soluble salts and in exchangeable sodium and gypsum. These relationships are indicated in Table 3.1-8. Samples shown in this table were taken in areas where problems were either in evidence or whose existence was suspected. It will be noted that in practically every case where clay content is below 60 percent, the total soluble salts are below 0.2 by percentage, and exchangeable sodium is well below the critical point of 15 percent. Field permeability tests also indicate an adequate infiltration rate for the majority of the areas represented by these samples.

In the few areas where an excessive degree of alkalinity was found, the subsoil was the zone primarily affected. This condition is generally restricted to small areas in the vicinity of Adasiye, and where found, the soils are producing shallow rooted crops successfully. These soils show a clay content in excess of 60 percent with correspondingly low permeability rates. Although the total area represented by these latter conditions is small, they should receive additional study as the project proceeds. Soils amendments such as gypsum, and crop rotation including deep rooted crops should aid water penetration. The beneficial effects of drying on clay soils, through summer fallow, are also of considerable importance.

Findings and Conclusions. The East Ghor North area is generally suited for the further development of irrigation agriculture. Where water is available at the present time a variety of crops is being successfully grown. Soils are predominantly medium to heavy in texture, of good water holding capacity and are surprisingly fertile in view of the small amount of fertilizer utilized. The heavier clay soils are found primarily in the north end of the area, in the vicinity of Adasiye. Slopes are somewhat more complex in this subdivision. Rock cover is primarily found adjacent to the hills and stream channels with a greater degree of vegetative cover present below the proposed canal.

Areas involving salinity and alkalinity problems are relatively small, about 5 percent of the arable acreage, and where they occur are generally associated with drainage deficiencies. Installation of adequate subsurface drainage facilities and the addition of soil amendments such as gypsum will materially aid these lands.

East Ghor South

Description. The East Ghor South subdivision extends from the River Zarqa south to the northern edge of the Dead Sea, and from the steep slopes of the eastern foothills westward to the Jordan River. Lands in this subdivision lying north of the general vicinity of the surfaced road leading westward across the valley to the Damiya Bridge and the West Ghor, are rough and broken in nature. Southward from this vicinity the lands become generally smooth and gently sloping. The wide alluvial fans of the Wadi Shueib, Wadi Kafrein, and Wadi Hisban are partially irrigated with a limited water supply. The general gradient is westward toward the Jordan River and the area slopes to the south from an elevation of about minus 226 meters at the River Zarqa to approximately minus 392 meters at the Dead Sea. Rainfall in the area decreases from about 250 mm. near its northern boundary to about 100 mm. in the southern section. The land classification photo map JR-25 is representative of the northern section of the area, while JR-27 is typical of the lands to the south. Photo map JR-26 illustrates a representative section of zor land.

Soils. The most favorable soils are located on the broad, smooth, gently sloping alluvial fans of the three major wadis previously mentioned. Textures on the Wadi Shueib fan are loams, clay loams, and light clays with considerable rock in the area adjacent to Shunat Nimrin. Southward the fans of Wadi Kafrein and Wadi Hisban are lighter in texture with clay loams and loams predominating and sandy loam near Suweima. Soils on these fans are deep, porous, and relatively free of soluble salts and alkali. Where irrigated these areas produce good crops. Marl is seldom found within the one-and-a half meter depth.

The soils illustrated by profiles on land classification photo map JR-27 are generally representative of the areas south of Karama lying between the lower edge of the alluvial fans and the Katar. Color ranges from grayish-brown to whitish-gray with marl occurring under most of the area. North of Karama the lands become broken and soils are predominantly whitish-gray in color, with a smooth-lying area of these soils occurring in the vicinity of Grid North 164. Photo map JR-25 shows typical profiles of this latter area. Textures are predominantly clay loams, and soluble salt content is relatively high.

Topography. The majority of the East Ghor South area is characterized by long, gently sloping gradients well adapted to irrigation agriculture. Major exceptions to this condition are found immediately south of the River Zarqa and north of Karama where numerous small wadis cross the area, and in the zor. Leveling on the areas first mentioned above will be limited by shallowness to marl and rock in the profile. Less apparent, but of significance, are the small ridges formed on the ghor by wave action as the old inland lake receded, primarily found near the Katar south of the Ghor Nimrin area. Steeper gradients and rock cover are generally found above the Main Canal location as the result of stream outwash from the hills. A relatively insignificant area of vegetative cover, principally small Christ-thorn trees, is located in the vicinity of Wadi Hisban.

As in the other subdivisions, the zor requires a significant degree of leveling and clearing. This is particularly true south of Grid North 139 where flooding action of the Jordan River and outwash from the ghor and Katar have left partially filled channels, and thick growths of cane and salt cedar are prevalent.

Drainage. About 1 percent of the arable land area has evidence of a water table within the one-and-a half meter zone. The majority of this land is located along the lower edge of the ghor where water has been trapped by low alluvial ridges. Numerous channels pierce these "barriers" and removal of surface waters should be readily accomplished. The soils of these areas adjoining the Katar are generally heavy in texture and act as a vertical barrier for subsurface water. Fuquarās in the vicinity of Karama and Ghor Nimrin and artesian aquifers in the Ghor Nimrin and Ghor Kafrein areas create a drainage problem. Much of this land is within the area to be reclaimed by leaching practices. Infiltration tests have revealed the soils to be permeable. The 10 to 15 centimeter thick salt layer (formed at the evaporation zone of water under static head) occurring 40 to 60 centimeters below the ground surface can be broken mechanically with subsequent normal water movement. (See Table 3.1-8, Chemical and Physical Analyses of Infiltration Site, Hole 10). This problem is fully discussed in the Drainage section, Volume VII, of this report.

Drainage problems on the zor are primarily limited to small springs and waste irrigation water emerging from the Katar. An interceptor ditch at the "toe" of the slope is recommended for control in these localities. Minor areas, particularly south of Grid North 139, present problems in the form of depressions resulting from partially filled stream channels. Leveling will materially aid this present condition.

Salinity and Alkalinity. As can be seen on the land classification map of the Jordan Valley, the Class 4 land occupies a large part of the area in the East Ghor South. Of the 109,000 donums of land classified as Class 1, 2 or 3, approximately 27,000 donums are affected to a slight degree of salinity.

Land classification photo map JR-27 is typical of the Class 4 land on the East Ghor South. The complete analysis of Hole 22 shows high exchangeable sodium percentage, high gypsum content, and high total percent of soluble salts. Table 3.1-6 shows the conductivity of saturation extract of the soil strata before and after infiltration tests. With the application of 2.2 meters of water in this case, conductivities were reduced considerably in the top 1.2 meters of soil. Similar results are noted with varying amounts of water used in other tests both on the East Ghor and West Ghor.

Table 3.1-9 shows the composition of soluble salts in the 1:5 extracts, where five parts of water were used to one part of soil. Comparison with Table 3.1-8 indicates that in the areas south of River Zarqa leaching during infiltration tests considerably reduced the sulphate and chloride content and in all cases except one, sodium percentage decreased.

In the vicinity of Karama, the caving of a number of fuquarās has created a salinity problem, by forcing water with a rather high soluble salt content to the surface.

Near the Dead Sea, receding waters left heavy salt deposits. Soils towards the Dead Sea tend to light textures and should be readily reclaimable.

Much of the zor land lying adjacent to the Katar has a rather high salt content and is placed in Class 4. This can be noted on land classification photo map JR-26 showing the zor on both sides of the River Jordan and the adjacent breaks leading up to the ghor.

Findings and Conclusions. The East Ghor South is topographically well suited to irrigation agriculture. Where irrigated, soils on the major fan areas are presently producing good crops with a limited supply of water. In much of the area the line between irrigated and non-irrigated land is also indicative of salt-free and saline soils. Textures are variable, becoming lighter approaching the Dead Sea; however, clay loams predominate. Approximately 80,000 donums possess a high degree of salinity and will require leaching. Permeability, gypsum content and position of these lands are favorable for reclamation. Drainage studies indicate the presence of artesian aquifers which will be controlled as part of the land development program.

West Ghor Area

Description. This area occupies that portion of the Jordan Valley extending from the convergence of the Samarian Hills and the Jordan River at approximately Grid North 180, to the Dead Sea on the south and lying between the Jordan River on the east and the upward scarp of the hills on the west. The lands slope generally in an easterly direction toward the river. A number of stream channels cross the area including three perennial wadis of major importance, Wadi Fari'a on the north, whose fan is presently irrigated, Wadi Auja smaller in size but also presently developed and Wadi Qilt, whose alluvium forms the plains of Jericho, an area irrigated for many years. Small individual farms partially irrigated from springs or wells are scattered between these main areas.

Rainfall is generally the same as that of the East Ghor South, ranging from approximately 340 mm. near Wadi Fari'a to about 100 mm. in the vicinity of Jericho. Land classification photo map JR-28 shows an area in the vicinity of Wadi Fari'a, and photo map JR-29 shows an area in the vicinity of Jericho.

Soils. The soils on the West Ghor are predominantly formed from alluvial and colluvial deposits outwashing from the hills to the west. Soil depth varies, generally decreasing in thickness over the marly materials as the ghor and zor "break" is approached. The fans are somewhat cut-up by small channels angling in a south-easterly direction.

Soil texture varies considerably. The steep alluvial slopes, where wadis emerge from the hills, are quite gravelly with light and medium textures predominating. Southeast, toward the Dead Sea, and East of the Jerusalem road, soils are overwashed to a depth of 90 cm. over the marl, thinning out on the numerous ridges toward the lower edge of the fan. Most of the area which is not presently irrigated is high in lime and gypsum content and ranges from light brown to light reddish-brown in color.

Clay loams and clays predominate approaching the river. Total soluble salts are present in moderate to high concentrations. Where these soils have been adequately irrigated salts have been satisfactorily removed. The profiles and area shown on land classification photo map JR-29 are typical of this condition. Heavier textures predominate north of Jericho except where small alluvial fans possess light-colored soils of medium texture. Reddish-brown clays predominate in the vicinity of Grid North 158, East 194. Profiles are deep but salty probably due to the influence of fuquarās.

The Wadi Fari'a area, composed of dark colored soils, predominantly clay loams and clays, is extensively cultivated. Adequately irrigated areas are free from saline-alkali conditions and crop production is excellent. Steep alluvial slopes adjacent to the hills are lighter in color and high in clay and salt content. The area between Wadi Fari'a and Grid North 180 is predominantly composed of light colored soils derived from lake-laid deposits. Total salts and exchangeable sodium are relatively high. An infiltration rate of 35 mm. per hour was attained on a heavy clay loam, and the average conductivity of the saturation extract from samples throughout the 1.5 meter profile was reduced 84 percent by leaching which occurred during the infiltration test.

Soils on the zor are of recent alluvium, intermixed and reworked with river sediments. Much of the area is heavy textured and contains appreciable amounts of salt. (See land classification photo map JR-29, Hole 6) Productive fields of vegetable crops exist where lands are irrigated from the river. Clay content increases materially toward the south end of the valley, where a delta-like area is formed.

Topography. Gently sloping topography characterizes much of the large alluvial fan areas. Gradient is from the hills to the river, with a general slope of 1 to 2½ percent. The area south and east of Jericho approaching the Dead Sea is crossed by numerous small stream beds and swales fingering between marl ridges, which will necessitate a moderate degree of leveling. The nature of this area will tend to irregularly shaped, relatively small tracts of arable land. Much of the area on the lower part of the Jericho plain would benefit materially from releveling of irrigated fields. Uneven distribution of water, resulting from inadequate leveling, has produced varying degrees of leaching. Hole 22 on Drawing JR-29 has only slight evidence of salinity while adjacent areas which have received less water possess a greater degree. Areas in the vicinity of Grids North 140, 160 and 165, next to the steep alluvial slopes, will require a moderate to heavy amount of rock removal in addition to leveling. In general, however, the percentage of rock clearance required on the West Ghor is much less than that needed on the East Ghor.

Although the arable lands of the zor comprise only about 10 percent of the arable area of the western side of the valley, about half of this requires a moderate amount of leveling and brush removal. The zor area south of Grid North 137 is comparatively smooth as it has had less cutting action from flood waters than the northern sections.

Drainage. The general slope and numerous drainage-ways provide adequate surface drainage on the West Ghor except in very small isolated areas. Subsurface drainage is a factor of major importance in the vicinity of Grid North 146, low lying areas near Grid North 153 and Grid North 158, and shallow depressions around Grid North 167 and Grid North 172. These areas are apparently affected by the ancient fuquarās located in most instances in the proximity of the main West Ghor road leading northward from Jericho. Heavy textures and saline soils are found in these areas although hydraulic conductivity rates are generally favorable.

Alkalinity and Salinity. Alkalinity and salinity problems in the Jericho vicinity are very similar to those found in the southern part of the East Ghor South. Medium and light textures predominate and part of the area is irrigated. Comparison of an irrigated and non-irrigated field adjacent to one another frequently indicates high salinity and an appreciable amount of exchangeable sodium in the non-irrigated area while the area receiving an adequate supply of water is relatively free of these conditions. (Land classification photo map JR-29 illustrates this pattern.) In the areas tested, and illustrated in Table 3.1-8 Chemical and Physical Analyses of Infiltration Sites, there was sufficient gypsum in the soil to overcome sodium accumulation and permit leaching. These samples were all taken in areas placed in Class 4 with the exception of Holes 12 and 13 at Grid North 133, East 202, which are located on the northwestern shore of the Dead Sea.

The area north of Jericho contains two large blocks of land of saline nature. One extends from the vicinity of Grid North 150 to about Grid North 167 and the other northward from Wadi Fari'a to Grid North 180. Areas of land relatively free from salinity are scattered throughout and in most instances are characterized by varying degrees of present irrigation development. The area north of Wadi Fari'a is somewhat lower in gypsum content than corresponding areas to the south and will materially benefit from its addition to the soil.

Conclusions. The major portion of the West Ghor area is adapted to irrigation agriculture. Presently irrigated areas show the relatively high water holding capacity of the soils and indicate their susceptibility to removal of saline and alkaline characteristics in the majority of cases. Where these adverse conditions are present, an appreciable amount of gypsum is generally present, particularly in the Jericho vicinity. Infiltration rates are generally satisfactory, even where soil textures are high in clay content. Approximately 45 percent of the area above the proposed canal is characterized by topographic deficiencies, leveling or gradient. Leveling requirements below the canal are considerably less. Drainage conditions are generally good. Subsurface problems are confined mainly to areas influenced by fuquarās.

Summary and Conclusions

The arid climate of the Jordan Valley makes irrigation necessary for successful production of most crops. This is particularly true in the southern part of the area where rainfall contributes very little toward plant growth. All lands within the natural east-west topographic boundaries of the valley from the Yarmouk River to the Dead Sea within the Hashemite Kingdom of Jordan were classified as to their suitability for sustained irrigation agriculture. The gross land area within the project is approximately 942,800 donums. Of this total, about 347,500 donums are currently suitable for crop production, and about 172,300 donums are capable of varying degrees of crop productivity after reclamation.

Soils of the project area are generally immature (highest development occurring in the extreme northern end), relatively low in organic matter, and of a calcareous and gypsiferous nature. The basic fertility of the soils is relatively high with the exception of nitrogen and phosphorous. Textures range from light to heavy, with clay loams and clays predominant. Waterholding capacity of the soils is good and penetration rates are satisfactory with the exception of a few scattered areas in the northern part of the East Ghor.

Topography of the project area is favorable for irrigation development with minor modifications. Light to moderate leveling will be required on the ghor areas, primarily on the edges of alluvial fans and in areas adjacent to the Katar. Areas deficient topographically, primarily due to gradient, occur at the foot of the steep side slopes of the valley and to a lesser degree adjacent to small stream channels. Zor areas in general will require moderate to heavy leveling. Cover in the form of rock or cobble is most prevalent on the upper reaches of the ghors and in the vicinity of stream channels. Vegetative cover exists as relatively small brush with heaviest concentrations found on the zor in the form of cane, salt cedar and tamarisk. A minor area in the vicinity of Wadi Hisban is covered with scrub trees.

Surface drainage is favored by the natural slope from the side hills to the Jordan River and from north to south, with the exception of localized areas where shallow depressions occur in the ghors. Numerous stream channels provide natural outlets for surface water. Subsurface drainage appears to be of a more complicated nature due to the absence of significant layers of sand or gravel throughout the project, and due to relatively low permeability of some clays in the Adasiye vicinity, and along the "break" between the ghor and zor areas. However, field and disturbed permeability tests show that the majority of the soils are permeable. Soils high in soluble salt content and relatively shallow in depth to marl show appreciable quantities of gypsum in the profile and adequate infiltration rates. The largest group of soils with these characteristics occurs in the southern part of the valley. Leaching trials indicate that the major portion of these areas are susceptible to reclamation and they have been included in the arable area. When the project area is fully developed to irrigation agriculture, an adequate and active drainage program is mandatory.

Alkalinity is not a serious problem in the Jordan Valley, except for a relatively few very small areas.

In the marl zones, heavy calcium carbonate and gypsum were laid down in stratified layers when the valley was under water. Outwash soils from the adjoining hills are relatively high in calcium, and where they are quite thin over the marls, high soluble salt content is to be found.

Throughout the valley most of the overlayed soils are blocky to prismatic in structure, sound and not likely to puddle, swell, and seal during a leaching period. Almost all saline lands can be reclaimed, as indicated by trials at the Ghor Nimrin leaching plots and permeability tests made through the valley.

Because of the high gypsum content of a large part of the soils in the southern portion of the valley, some settling of the lands may follow leaching. This may necessitate some releveling of these areas.

Class 4 lands, all saline in character, constitute about 33 percent of the 519,800 donums classified as arable. Lands placed in Class 2 and Class 3 primarily because of a very slight degree of salinity total about 9 percent of the arable area. Of the Class 4 lands, about 2.4 percent are located in the East Ghor North; the remainder is almost equally divided between the East Ghor South and the West Ghor. The lower soluble salt and gypsum contents (the more modified profiles) can be attributed to heavier rainfall and present irrigation.

A majority of the arable lands within the Yarmouk-Jordan Valley Project are capable of supporting a program of sustained irrigation agriculture. Portions of the area have a long history of limited irrigation, indicating that considerable benefit can be derived from an adequate, better distributed water supply.

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 1 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH		Total Soluble Salts		Ex-change-able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses			Texture
			Paste	1-5	%	ECx10³									Sand %	Silt %	Clay %	
									EAST GHOR AREA									
227.5N-208E	7	0- 30	-	9.0	0.05	-	0.83	46	1.8	-	-	-	.5	-	-	-	-	C.
228.195N-		30- 90	-	9.3	0.09	-	3.4	46	7.5	-	-	-		-	-	-	-	C.
207.565E		90-150	-	9.1	0.20	-	5.5	46	12	-	-	-		-	-	-	-	C.
226N-208E	13	0- 30	-	8.8	0.05	-	0.60	-	-	-	-	-	.5	-	-	-	-	C.
227.400N-		30- 60	-	9.1	0.04	-	1.4	40	3.6	-	-	-		-	-	-	-	C.
207.930E		60-105	-	9.4	0.10	-	3.8	39	9.8	-	-	-		-	-	-	-	C.
		105-150	-	9.2	0.17	-	5.6	38	15	-	-	-		-	-	-	-	C.
226N-208E	1[1]												.5					
226.300N-																		
206.850E																		
224.5N-206E	6	0- 15	7.8	8.7	1.0	1.9	0.18	37	0.5	54	*1	6.6	5.1	70	8	56	36	Si.C.L.
224.820N-		15- 30	7.9	8.8	1.1	0.58	0.35	38	0.9	57	*1	16.5		56	11	49	40	Si.C.
205.500E		30- 45	7.9	8.8	1.2	0.66	0.32	37	0.9	56	*1	27.9		48	9	46	45	Si.C.
		45- 60	8.0	8.8	0.09	0.40	0.42	39	1.1	59	*1	20.8		42	12	47	41	Si.C.
		60- 75	7.7	8.6	0.18	1.5	0.66	35	1.9	63	*1	13.6		44	10	50	40	Si.C.
		75- 90	8.0	8.5	0.08	0.45	0.55	34	1.6	66	*1	16.3		45	10	46	44	Si.C.
		90-105	8.0	9.1	0.07	0.46	0.65	31	2.1	63	*1	18.0		54	11	50	39	Si.C.L.
		105-120	8.1	8.9	0.08	0.53	0.91	30	3.0	65	*1	21.8		43	12	49	39	Si.C.L.
		120-150	7.9	8.8	0.13	1.0	1.3	32	4.9	70	*1	14.0		57	8	53	39	Si.C.L.
224.5N-208E	7[1]												1.0					
224.800N-																		
206.385E																		
223N-208E	3[1]												1.0					
223.600N-																		
206.050E																		
220N-208E	1	0- 15	7.7	8.5	0.08	0.53	0.21	30	0.7	46	*1	22.6	68.6	56	24	47	29	C.L.
220.800N-		15- 30	7.8	8.7	0.08	0.64	0.58	29	2.0	47	*1	11.2		68	23	47	30	C.L.
206.730E		30- 45	7.8	8.8	0.08	0.64	0.53	28	1.9	48	*1	9.9		56	27	39	34	C.L.
		45- 60	8.0	8.9	0.07	0.60	0.39	28	1.4	53	*1	30.5		46	29	37	34	C.L.
		60- 90	7.9	9.0	0.07	0.62	0.31	25	1.2	54	*1	30.5		54	28	40	32	C.L.
		90-120	8.0	9.0	0.06	0.51	0.13	26	0.5	58	*1	-		77	24	41	35	C.L.
		120-150	8.0	8.8	0.07	0.53	0.34	27	1.3	58	*1	-		68	19	46	35	Si.C.L.

*Indicates the sign < (Less than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 2 of 6)

Sheet No. and Coordinate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10^3	Exchangeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchangeable Sodium %	Saturation %	Gypsum Me/100g	Hydraulic Conductivity MM/Hr.	Infiltration Rate MM/Hr.	Dispersion %	Mechanical Analyses Sand %	Mechanical Analyses Silt %	Mechanical Analyses Clay %	Texture
220N-206E	2	0- 30	7.9	8.5	0.11	1.1	0.67	34	2.0	59	*1	6.1	15.2	39	10	51	39	Si.C.L.
221.290N-		30- 60	7.9	8.6	0.11	1.2	0.85	29	3.0	57	*1	9.4		43	12	43	45	Si.C.
205.365E.		60- 90	7.9	8.5	0.28	4.0	2.8	26	11	59	*1	43.2		41	14	42	44	Si.C.
		90-105	8.1	8.8	0.15	2.3	1.1	24	4.4	61	*1	16.8		48	19	44	37	Si.C.L.
		105-120	8.1	8.7	0.12	2.5	0.82	21	4.0	52	*1	50.8		62	23	44	33	C.L.
		120-150	8.2	8.9	0.16	2.4	0.42	17	2.5	66	*1	33.0		73	27	43	30	C.L.
217N-208E	6	0- 15	7.9	9.0	0.07	0.51	0.20	26	0.8	49	*1	21.3	5.1	62	9	61	30	Si.C.L.
218.355N-		15- 30	7.8	8.8	0.06	0.51	0.21	25	0.8	51	*1	53.3		59	7	56	37	Si.C.L.
206.235E		30- 60	7.8	8.8	0.07	0.47	0.20	25	0.8	54	*1	78.7		59	9	52	39	Si.C.L.
		60- 90	8.0	8.9	0.06	0.52	0.40	22	1.8	58	*1	71.1		46	8	52	40	Si.C.
		90-120	8.1	9.0	0.08	0.57	0.73	22	3.3	60	*1	121.9		38	10	44	46	Si.C.
		120-150	8.1	8.8	0.12	1.3	1.4	25	5.7	58	*1	61.0		43	9	50	41	Si.C.
215.5N-208E	8 1/												35.6					
215.940N-																		
206.530E																		
214N-206E	4	0- 15	8.1	8.4	0.05	0.63	0.12	27	0.5	53	*1	4.8	5.1	65	16	54	30	Si.C.L.
215.500N-		15- 30	8.0	8.4	0.06	0.50	0.32	26	1.2	50	*1	17.3		62	17	47	36	Si.C.L.
205.100E		30- 60	8.1	8.5	0.07	-	-	-	-	-	-	24.9		55	17	47	36	Si.C.L.
		60- 90	8.1	8.7	0.11	1.8	1.2	22	5.5	57	*1	58.4		57	16	45	39	Si.C.L.
		90-120	8.4	9.2	0.09	1.7	1.3	20	7.6	57	*1	18.3		70	17	44	37	Si.C.L.
		120-150	8.4	9.2	0.08	-	-	-	-	-	-	18.8		72	17	47	36	Si.C.L.
211N-206E	6	0- 15	7.7	8.1	0.10	1.6	0.24	27	0.9	58	*1	5.6	10.2	52	15	56	29	Si.C.L.
212.000N-		15- 30	7.9	8.3	0.06	0.61	0.29	26	1.1	51	*1	22.6		52	16	50	34	Si.C.L.
205.325E		30- 45	8.1	8.4	0.06	0.65	0.22	28	0.8	28	*1	116.8		57	18	47	35	Si.C.L.
		45- 60	7.9	8.5	0.06	0.60	0.24	22	1.1	13	*1	157.5		60	19	52	29	Si.C.L.
		60- 90	7.9	8.6	0.06	0.71	0.16	19	0.8	55	*1	149.9		60	20	45	35	C.L.
		90-120	7.9	8.6	0.07	0.71	0.15	17	0.9	47	*1	132.1		62	24	41	35	C.L.
		120-150	7.9	8.8	0.06	0.71	0.35	14	2.4	50	*1	66.0		69	18	49	33	Si.C.L.
208N-206E	13	0- 15	8.0	8.9	0.04	0.72	0.27	21	1.3	51	*1	23.6	40.6	52	20	53	27	Si.L.
208.435N-		15- 30	8.1	8.5	0.04	0.63	0.11	18	0.7	46	*1	23.4		67	19	50	31	Si.C.L.
205.065E		30- 60	7.9	8.5	0.04	-	-	-	-	-	-	30.5		76	26	44	30	C.L.
		60- 90	8.0	8.6	0.05	0.63	0.21	15	1.4	49	*1	45.7		74	24	45	31	C.L.
		90-120	8.0	8.6	0.04	-	-	-	-	-	-	48.3		77	24	44	32	C.L.
		120-150	8.0	8.6	0.06	-	-	-	-	-	-	55.9		78	21	45	34	C.L.
205N-206E	5	0- 15	7.8	8.1	0.04	1.6	0.19	24	0.8	46	*1	14.7	61.0	60	35	47	18	L.
205.505N-		15- 30	7.9	8.2	0.04	-	-	-	-	-	-	20.3		49	36	45	19	L.
205.140E		30- 60	8.0	8.4	0.04	0.76	0.29	21	1.4	49	*1	12.7		61	30	49	21	L.
		60- 90	7.8	8.5	0.03	-	-	-	-	-	-	27.9		68	33	45	23	L.
		90-120	7.9	8.5	0.04	0.60	0.32	14	2.3	45	*1	40.6		66	32	42	26	L.
		120-150	7.8	8.5	0.05	-	-	-	-	-	-	33.0		69	29	43	28	L.

*Indicates the sign < (Less than).

Table 3.1-8

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 3 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10³	Ex-change able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
202N-206E	6 1/												.0					
202.350N-																		
204.995E																		
200.5N-206E	9	0- 15	7.7	8.4	0.08	1.1	0.30	25	1.2	49	*1	8.9	17.8	69	17	57	26	Si.L.
201.615N-		15- 30	7.9	8.5	0.06	-	-	-	-	-	-	10.2		69	16	55	29	Si.C.L.
205.195E		30- 60	7.8	8.4	0.07	0.76	0.31	25	1.2	50	*1	33.0		61	16	50	34	Si.C.L.
		60- 90	8.0	8.6	0.08	-	-	-	-	-	-	45.7		56	19	50	31	Si.C.L.
		90-120	8.1	8.7	0.07	0.82	0.46	22	2.0	48	*1	40.6		58	20	47	33	Si.C.L.
		120-150	8.1	8.7	0.07	-	-	-	-	-	-	30.5		63	18	48	34	Si.C.L.
197.5N-206E	6	0- 15	7.8	8.5	0.07	0.60	0.26	37	0.71	44	*1	5.8	10.2	71	10	70	20	Si.L.
198.460N-		15- 30	7.9	8.5	0.08	-	-	-	-	-	-	8.4		59	10	53	37	Si.C.L.
204.630E		30- 60	7.9	8.8	0.08	0.62	1.0	35	2.9	57	*1	11.4		58	10	51	39	Si.C.L.
		60- 90	8.1	9.1	0.07	-	-	-	-	-	-	16.3		60	10	50	40	Si.C.L.
		90-120	8.2	9.2	0.07	0.63	2.1	25	8.4	60	*1	11.4		76	10	54	36	Si.C.L.
		120-150	8.2	9.2	0.08	-	-	-	-	-	-	5.8		88	7	58	35	Si.C.L.
196N-206E	8	0- 15	7.7	8.5	0.05	0.74	3.2	21	1.6	39	*1	7.4	25.4	72	20	61	19	Si.L.
196.030N-		15- 30	7.4	8.6	0.05	-	-	-	-	-	-	21.3		64	20	57	23	Si.L.
204.200E		30- 60	7.9	8.6	0.04	0.47	0.82	19	4.3	46	*1	8.9		61	17	58	25	Si.L.
		60- 90	7.8	8.4	0.18	-	-	-	-	-	-	9.9		69	12	60	28	Si.L.
		90-120	7.6	8.7	0.60	9.3	4.2	23	18	62	*1	5.3		84	8	62	30	Si.C.L.
		120-150	7.7	8.7	0.65	-	-	-	-	-	-	6.1		86	18	57	25	Si.L.
190N-206E	29	0- 15	7.8	8.1	0.05	0.88	0.41	19	2.1	36	*1	5.6	20.3	70	30	49	21	L.
190.760N-		15- 30	7.8	8.2	0.04	-	-	-	-	-	-	7.9		65	29	46	25	L.
204.650E		30- 60	7.9	8.5	0.07	-	-	-	-	-	-	7.6		53	26	49	25	Si.L.
		60- 90	7.9	8.3	0.15	2.6	0.55	19	3.0	54	*1	15.5		67	16	55	29	Si.C.L.
		90-120	7.9	8.3	0.14	-	-	-	-	-	-	11.9		78	17	56	27	Si.L.
		120-150	7.8	8.4	0.16	-	-	-	-	-	-	8.4		89	11	62	27	Si.L.
184N-206E	30	0- 15	7.8	8.4	0.08	0.99	0.18	21	0.87	45	*1	10.7	10.2	60	21	58	21	Si.L.
185.330N-		15- 30	7.8	8.4	0.05	-	-	-	-	-	-	11.2		68	19	55	26	Si.L.
205.850E		30- 60	7.9	8.4	0.04	-	-	-	-	-	-	18.5		77	23	52	25	Si.L.
		60- 90	7.8	8.3	0.03	0.43	0.21	14	1.5	39	*1	19.0		78	23	56	21	Si.L.
		90-105	8.1	8.6	*0.03	-	-	-	-	-	-	33.0		83	44	40	16	L.
181N-208E	17	0- 15	7.5	8.3	0.04	0.78	0.34	22	1.5	42	*1	13.5	7.6	65	26	51	23	Si.L.
182.355N-		15- 30	8.1	8.4	0.06	-	-	-	-	-	-	19.0		57	16	50	34	Si.C.L.
207.110E		30- 60	7.9	8.5	0.06	-	-	-	-	-	-	53.3		55	16	49	35	Si.C.L.
		60- 90	8.1	8.3	0.06	0.70	0.74	25	3.0	38	*1	50.8		69	15	55	30	Si.C.L.
		90-120	8.3	8.8	0.07	-	-	-	-	-	-	45.7		72	8	58	34	Si.C.L.
		120-150	8.0	8.9	0.07	-	-	-	-	-	-	33.0		73	16	55	29	Si.C.L.

*Indicates the sign < (Less than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 4 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10³	Ex-change-able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
179.5N-210E	12	0- 15	7.7	8.2	0.11	1.9	0.65	21	3.1	45	*1	15.2	5.1	59	29	43	28	C.L.
150.780N-		15- 30	7.9	8.5	0.06	-	-	-	-	-	-	38.1		59	19	48	33	Si.C.L.
206.160E		30- 60	7.9	8.4	0.07	-	-	-	-	-	-	27.9		58	19	44	37	Si.C.L.
		60- 90	8.0	8.7	0.06	0.80	0.73	20	3.6	50	*1	45.7		65	21	45	36	Si.C.L.
		90- 120	8.1	8.7	0.06	-	-	-	-	-	-	66.0		66	22	45	33	C.L.
		120-150	8.1	8.9	0.06	-	-	-	-	-	-	61.0		56	21	45	34	C.L.
164.5N-206E	17	0- 15	7.6	8.7	0.04	0.92	0.13	10	1.3	31	*1	2.8	20.3	63	15	56	29	Si.C.L.
164.770N-		15- 30	7.9	8.8	0.03	-	-	-	-	-	-	3.0		68	46	35	19	Si.L.
204.730E		30- 60	7.6	8.7	*0.03	-	-	-	-	-	-	10.9		71	68	21	11	S.L.
		60- 90	8.1	9.0	*0.03	1.2	0.13	1.5	20	20	*1	30.5		64	81	11	8	Lmy.S.
		90-120	8.0	8.8	*0.03	-	-	-	-	-	-	101.6		58	91	5	4	S.
		120-150	8.1	9.0	0.03	-	-	-	-	-	-	18.3		68	63	27	10	S.L.
163N-204E	10	0- 15	7.5	8.4	**3.0	52	4.0	16	24	42	2	3.0	17.8	-				C.L.
163.700N-		15- 30	7.6	8.3	**3.0	36	5.1	18	26	47	1	2.5		-				S.C.L.
202.570E		30- 60	7.5	8.4	**3.0	37	5.0	19	26	53	6	7.6		-				C.L.
		60- 90	7.6	8.4	**3.0	40	7.3	21	36	57	7	10.7		-	FLOCCULATED[2/]			C.L.
		90-105	7.5	8.3	**3.0	39	5.2	19	28	54	-	9.7		-				C.L.
		105-150	7.7	8.7	2.5	29	11	23	48	71	4	* .3		-				Si.C.L.
161.5N-206E 162.430N- 204.065E	15[1/]												25.4					
161.5N-204E	12	0- 15	7.2	7.8	**2.5	59	5.1	25	21	40	3	6.4	1.0	-				C.L.
161.850N-		15- 30	7.6	8.0	**2.5	55	4.7	25	16	45	3	6.1		-				Si.C.
202.510E		30- 45	7.4	8.1	**2.5	47	6.2	26	24	49	8	30.5		-				Si.C.
		45- 60	7.8	8.1	**2.5	40	3.1	25	12	66	14	27.9		-				Si.C.
		60- 75	7.8	8.0	**2.5	29	4.7	27	17	71	8	27.9		-	FLOCCULATED			Si.C.
		75- 90	7.8	8.1	**2.5	43	7.9	27	26	72	4	12.7		-				Si.C.
		90-120	7.7	8.0	**2.5	48	9.0	30	30	79	2	6.9		-				Si.C.
		120-135	7.7	8.1	**2.5	40	6.5	22	20	82	2	10.2		-				Si.C.
		135-150	7.5	8.1	**2.5	46	9.5	30	32	83	2	5.1		-				Si.C.
145N-206E	26	0- 15	7.1	7.9	**3.0	102	6.0	14	43	40	6	11.9	27.9	-				C.L.
		15- 30	7.1	7.9	**3.0	85	6.0	18	33	47	32	13.7		-				C.L.
		30- 45	7.2	8.0	**3.0	93	5.0	12	42	48	46	13.7		-				Si.L.
		45- 60	7.0	7.8	**3.0	93	7.0	11	64	59	29	13.2		-				C.L.
		60- 75	7.0	7.5	**3.0	85	6.0	13	46	63	13	10.4		-	FLOCCULATED			C.L.
		75- 90	6.7	7.9	**3.0	73	9.0	13	69	68	8	9.1		-				C.L.
		90-120	6.8	7.8	**3.0	73	6.0	12	50	63	5	7.6		-				C.L.
		120-150	6.9	7.7	**3.0	73	8.0	10	80	59	4	4.8		-				C.L.

* Indicates the sign $<$ (Less than).

** Indicates the sign $>$ (Greater than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 5 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10³	Ex-changeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
145N-206E	27	0- 15	7.2	7.9	**3.0	114	4.0	-	-	47	38	7.6	12.7	-				C.L.
		15- 30	7.1	7.8	**3.0	79	4.0	10	40	56	38	6.6		-				L.
		30- 45	7.1	7.8	**3.0	102	2.0	9	22	62	30	4.3		-				C.L.
		45- 60	7.0	7.7	**3.0	85	6.0	12	50	69	20	5.3		-				C.L.
		60- 75	7.1	7.9	**3.0	57	2.0	11	18	65	12	6.6		-		FLOCCULATED		C.L.
		75- 90	7.1	7.8	**3.0	54	0.42	11	3.8	73	7	8.1		-				C.L.
		90-120	7.5	8.2	**3.0	56	12	15	81	65	10	15.0		-				C.L.
		120-150	7.3	8.3	**3.0	71	11	15	75	60	5	13.0		-				Si.C.L.
145N-206E	28	0- 15	7.3	8.1	**3.0	62	9.1	14	67	47	60	19.8	10.2	-				L.
		15- 30	7.2	8.2	**3.0	77	5.8	15	39	42	47	21.8		-				L.
		30- 45	7.4	8.2	**3.0	71	3.9	12	31	45	60	8.6		-				S.L.
		45- 60	7.4	8.1	**3.0	77	9.4	19	49	44	45	16.5		-				L.
		60- 75	7.5	8.2	**3.0	67	8.9	20	44	44	44	5.6		-		FLOCCULATED		L.
		75- 90	7.6	8.2	2.5	56	-	16	-	67	68	16.0		-				S.L.
		90-105	7.6	8.3	2.5	45	5.3	15	36	56	57	21.1		-				S.L.
		105-120	7.3	8.2	**3.0	62	12	15	80	70	12	11.2		-				C.L.
		120-150	7.6	8.4	**3.0	56	7.7	15	51	64	5	8.9		-				C.L.
139N-206E 139.670N-205.225E	10	0- 15	7.5	7.9	**2.8	117	3.2	11	29	37	43	11.7	1.0[3/]	-				S.C.L.
		15- 30	7.2	7.8	**2.8	99	4.1	15	27	43	-	24.9	81.3	-				C.L.
		30- 45	7.3	7.7	1.8	66	0.3	14	2.1	45	53	16.0		-				S.L.
		45- 60	7.3	7.7	1.8	56	1.0	15	6.7	45	-	15.0		-				S.C.L.
		60- 75	7.6	7.9	1.4	51	1.6	14	11	41	55	8.6		-		FLOCCULATED		S.L.
		75- 90	7.5	7.8	2.8	53	2.3	15	16	55	-	40.6		-				L.
		90-120	7.3	7.8	**3.0	55	0.7	17	4.1	80	7	27.9		-				C.L.
		120-150	7.6	8.1	**3.0	54	1.5	17	8.8	75	-	38.1		-				S.C.L.
137.5N-204E	24	0- 15	7.6	7.7	**3.0	161	2.0	13	22	40	-	16.0	124.5	-				S.L.
		15- 30	7.8	7.9	**2.8	117	1.7	15	11	41	27	19.6		-				S.L.
		30- 45	7.3	7.8	**2.8	70	4.6	14	32	40	-	2.8		-		FLOCCULATED		L.
		45- 60	7.9	8.3	1.4	46	1.2	8	14	34	20	17.3		-				S.L.
		60- 90	7.8	7.8	0.40	19	0.2	2	10	23	-	37.1		-				S.
		90-120	7.4	7.5	0.34	14	0.6	6	10	31	20	42.2		-				S.
134.5N-208E 135.760N-206.090E	20	0- 15	6.9	7.7	**3.0	188	2.4	10	24	32	8	16.8	75.4	-				C.L.
		15- 30	7.2	7.6	**2.8	113	2.2	13	17	36	-	11.4		-				Si.C.L.
		30- 60	7.3	7.9	**2.8	92	1.5	10	15	31	7	17.0		-				C.L.
		60- 90	7.4	8.0	2.0	61	2.7	10	27	31	-	14.7		-		FLOCCULATED		S.C.L.
		90-120	7.4	8.3	2.2	49	4.1	13	32	47	4	11.9		-				C.L.
		120-150	7.7	8.1	1.2	31	4.3	14	32	51	-	8.4		-				C.L.
		150-180	7.7	8.4	1.6	38	5.2	15	34	52	4	6.9		-				C.L.

* Indicates the sign < (Less than).

** Indicates the sign > (Greater than).

Table 3.1-8

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 6 of 6)

Sheet No. and Coordinate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10^3	Exchange-able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Saturation %	Gypsum Me/100g	Hydraulic Conductivity MM/Hr.	Infiltration Rate MM/Hr.	Dispersion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
140.5N-206E 140.800N-205.820E	22	0- 15	7.2	7.7	1.4	44	3.2	14	23	35	-	5.8	10.2	-				S.L.
		15- 30	7.3	7.9	2.2	50	3.9	16	25	36	6	8.4		-				L.
		30- 60	7.4	7.8	**3.0	52	2.4	18	14	44	-	15.2		-		FLOCCULATED		C.L.
		60- 90	7.5	8.0	**2.8	61	0.9	15	6.1	46	57	11.9		-				C.L.
		90-120	7.5	7.7	**2.2	65	7.5	11	68	28	-	23.9		-				L.
		120-150	7.7	8.2	**2.8	83	2.3	15	15	64	29	11.7		-				Si.C.L.
									WEST GHOR AREA									
172N-200E	9	0- 15	7.3	8.0	**2.8	76	5.4	27	20	51	-	8.9	35.6	-				C.L.
		15- 30	7.5	8.2	**2.8	58	4.5	25	18	61	6	7.4		-				C.L.
		30- 60	7.5	7.9	**2.8	60	5.3	23	23	58	2	16.5		-		FLOCCULATED		C.L.
		60- 90	7.3	7.9	2.0	38	5.8	24	25	57	-	30.5		-				C.L.
		90-120	7.5	7.9	1.4	29	4.4	26	17	57	2	17.8		-				C.L.
145N-198E	1	0- 15	7.2	7.7	0.19	5	3.1	15	20	39	7	3.6	17.8	-				L.
		15- 30	7.5	7.7	0.54	19	1.2	12	9.7	41	17	9.9		-				L.
		30- 60	7.1	7.6	1.4	32	2.9	10	28	49	-	13.2		-		FLOCCULATED		L.
		60- 90	7.2	8.0	**2.8	61	2.0	13	16	54	59	15.5		-				Si.L.
		90-120	7.5	7.7	**2.8	58	2.5	15	17	69	-	7.4		-				Si.C.L.
		120-150	6.9	7.6	**2.8	58	10	16	65	46	13	5.6		-				Si.C.
137.5N-198E	13	0- 15	7.6	9.0	**3.0	183	4.5	17	26	38	-	7.4	99.1	-				C.L.
		15- 30	8.1	8.8	**3.0	110	2.5	21	12	53	44	18.5		-				C.L.
		30- 45	7.7	8.2	**3.0	117	11	21	52	48	30	27.9		-				Si.L.
		45- 60	7.7	8.3	**3.0	106	6.4	24	27	60	44	24.1		-		FLOCCULATED		C.L.
		60- 90	8.1	8.4	**3.0	78	10	14	74	56	58	21.8		-				C.L.
		90-120	7.9	8.3	2.2	55	5.6	8.2	68	54	-	30.5		-				Si.L.
		120-150	8.0	8.4	1.0	32	-	7.6	-	53	59	35.6		-				L.
133N-202E	13	0- 15	7.3	7.8	**3.0	67	2.2	28	7.9	66	10	21.6	1.0	-				Si.C.
		15- 30	7.1	7.8	**3.0	65	3.1	28	11	57	-	17.8		-				C.
		30- 45	7.4	7.8	**3.0	45	4.9	31	16	75	8	7.4		-				C.
		45- 60	7.7	7.9	**3.0	46	12	34	36	86	-	3.6		-		FLOCCULATED		C.
		60- 90	7.4	8.4	**3.0	49	6.6	37	18	78	12	4.6		-				C.
		90-120	7.6	8.0	**3.0	50	5.8	37	16	82	-	6.1		-				C.
		120-150	7.2	7.6	**3.0	65	3.0	25	12	67	8	3.8		-				C.
133N-202E 133.575N-200.990E	12	0- 15	6.8	7.8	**3.0	160	7.8	26	30	51	31	30.5	5.1	-				Si.C.
		15- 30	6.8	7.6	**3.0	156	10	41	25	55	-	33.0		-				C.
		30- 45	7.1	7.5	**3.0	144	19	32	58	71	16	17.0		-				C.
		45- 60	7.2	7.8	**3.0	137	15	24	62	62	17	11.9		-		FLOCCULATED		C.
		60- 90	7.2	7.7	**3.0	134	6.4	27	24	75	14	45.7		-				C.
		90-120	7.2	7.5	**3.0	122	2.7	14	20	41	-	10.9		-				S.C.L.
		120-150	7.0	7.6	**3.0	141	6.6	17	40	43	-	13.5		-				S.C.L.

** Indicates the sign > (Greater than).

1/ Not sampled for analysis.
2/ Textures obtained by "hand-feel"; soil samples too salty for Mechanical Analyses.
3/ Numerator denotes rate prior to probing profile; denominator denotes rate resulting from the treatment.

Table 3.1-8

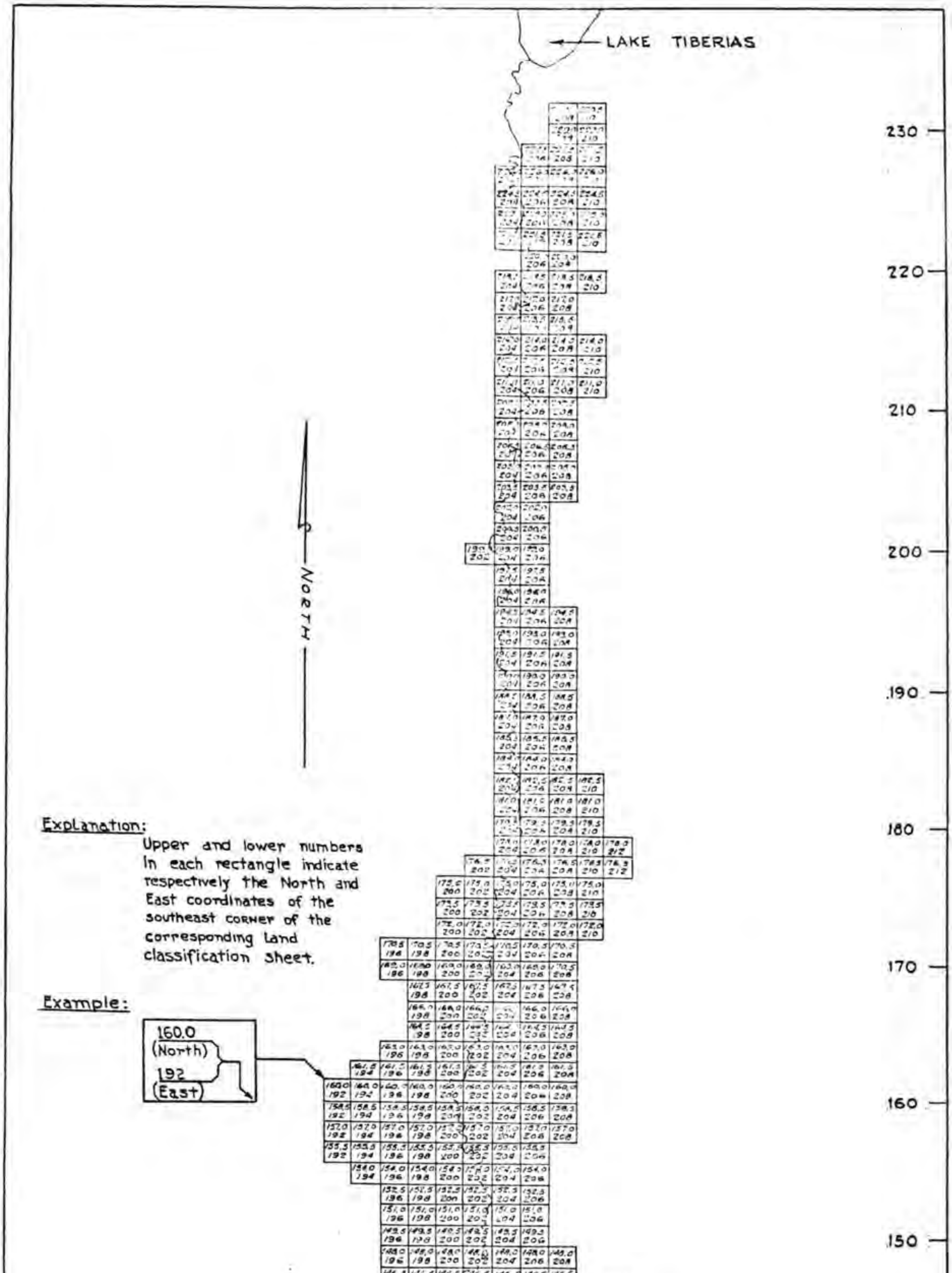
Table 3.1-9

COMPOSITION OF SOLUBLE SALTS IN 1-5 EXTRACTS (Sheet 1 of 1)

Sheet No.	Laboratory No.	Hole No.	Layer Depth Cm.	CATIONS Me/100g Ca	Mg	Na (By Difference)	ANIONS Me/100g CO_3	HCO_3	Cl	SO_4	Na %	SAR
				East Ghor Area								
224.5N-208E	3771	6	0-15	0.79	0.23	0.34	-	0.65	0.16	0.51	25.0	0.5
220N-206E	5160	2	0-15	0.64	0.36	0.41	-	0.83	0.25	0.33	29.1	0.5
220N-208E	5166	1	0-15	0.58	0.44	-	-	0.70	0.03	0.15	-	-
217N-208E	5425	6	0-15	0.86		-	-	0.75	0.03	0.17	-	-
211N-206E	5917	6	0-15	0.82	0.48	0.30	-	1.08	0.30	0.22	18.8	0.4
179.5N-210E	6966	12	0-15	0.66	0.40	0.73	-	0.78	0.53	0.48	40.8	0.5
163N-204E	7119	10	0-15	5.40	3.04	20.72	-	0.45	28.03	0.65	71.1	9.5
161.5N-204E	6957	12	0-15	6.81	4.04	17.72	-	0.35	27.65	0.54	62.0	7.5
145N-206E	3192	26	0-15	17.11	22.51	42.66	-	0.30	76.84	5.45	51.8	9.6
	3194		30-45	30.26	19.84	31.77	-	0.30	58.99	22.55	38.8	6.3
	3195		45-60	32.10	26.48	42.27	-	0.30	78.50	22.03	41.9	7.8
	*3746		30-60	14.72	3.74	1.39	-	0.28	0.66	18.91	7.0	0.5
145N-206E	3200	27	0-15	30.29	26.89	38.33	-	0.20	71.62	23.64	40.1	7.1
145N-206E	3208	28	0-15	25.48	13.81	21.23	-	0.30	37.93	22.25	35.1	4.8
140N-206E	8127	22	0-15	3.65	3.31	10.91	-	0.45	16.41	0.99	61.1	5.5
139N-206E	7877	10	0-15	20.91	15.88	37.76	Tr.	0.23	51.30	22.00	50.7	8.8
	*8139		0-15	13.80	1.60	0.74	-	0.35	0.30	15.47	2.8	0.2
137.5N-204E	7891	24	0-15	25.47	25.69	51.19	Tr.	0.18	72.20	29.96	50.0	10.1
	*8161		0-15	13.65	4.87	3.91	-	0.30	1.29	20.81	17.4	1.4
134.5N-208E	7884	20	0-15	20.02	29.34	56.36	-	0.28	93.61	11.82	53.3	11.1
	*8152		0-15	5.65	1.33	0.69	-	0.43	0.67	6.56	9.0	2.1
				West Ghor Area								
172N-200E	8704	9	0-15	6.59	10.43	29.82	-	0.38	43.24	3.19	63.7	10.2
	*8715		0-15	0.63	0.74	1.38	-	0.83	0.40	1.47	50.3	1.8
145N-198E	8698	1	0-15	6.35	1.65	2.16	-	0.53	0.34	9.27	21.3	1.0
	*8709		0-15	0.53	0.30	0.74	-	0.93	0.25	0.39	47.1	1.0
137.5N-198E	8372	13	0-15	15.35	1.40	151.29	-	0.38	132.65	34.98	90.0	52.4
	*8379		0-15	14.15	1.42	1.30	-	0.33	0.48	16.03	7.7	0.5
133N-202E	8120	13	0-15	20.36	14.12	22.50	-	0.53	46.73	9.68	39.5	5.4
	*8178		0-15	2.14	0.97	1.37	-	0.50	0.56	3.39	30.5	1.0
133N-202E	8113	12	0-15	50.94	36.40	76.07	-	0.20	143.17	20.02	46.6	11.5
	*8171		0-15	10.33	2.49	1.62	-	0.33	0.53	13.56	11.2	0.5
140N-206E	8188	-	0-.6	45.69	92.61	160.03	0.05	0.53	294.23	3.45	53.6	19.3
	8189	-	.6-8.0	38.50	70.41	111.22	-	0.45	215.35	4.29	50.5	15.1

*Sampled after infiltration test.

12/20/54


LAKE TIBERIAS
230
220
210
200
190
180
170
160
150
140
NORTH
Explanation:
Upper and lower numbers in each rectangle indicate respectively the North and East coordinates of the southeast corner of the corresponding Land classification sheet.
Example:
160.0 (North)
192 (East)
DEAD SEA
190
200
210
JORDAN VALLEY-MASTER PLAN
INDEX OF LAND CLASSIFICATION SHEETS
MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY
DATE 1-10-55
DWG. NO. JR-20

MAPPING SYMBOLS AND ABBREVIATIONS
JORDAN VALLEY LAND CLASSIFICATION SURVEY *

SOIL PROFILE SYMBOLS

SURFACE ROCK	
SANDS	S
LOAMY SANDS	LS
SANDY LOAMS	SL
LOAM	L
SILT LOAM	SiL
CLAY LOAMS	CL
VERY PERMEABLE & PERMEABLE CLAYS	PC
SLOWLY PERMEABLE CLAYS	SPC
GRAVEL & COBBLE	Gr Cb

INFORMATIVE SYMBOLS

SOILS

LIGHT	l
MEDIUM	m
HEAVY	h
SALINITY, ALKALINITY	a
PRESENCE OF MARL	z

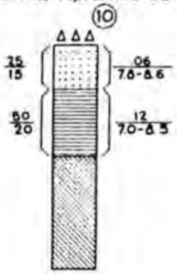
TOPOGRAPHY

COVER *(Rock or Brush)*	c
GRADIENT *(Slope)*	g
UNDULATION *(Surface Relief)*	u

DEGREE OF SEVERITY OF c, g or u MAY BE SUBSCRIPTED BY 2 or 3

SOIL PROFILE DATA & NOTES

Profile represents 1.5 M. of Depth



125 m N.W. of $182^{5}/206^{9}$ $\frac{2t}{lmzcu}$

SMALL GRAIN-GOOD. IRRIGATED LAND. AREA OF UNDULATING CROSS SLOPE TOPOGRAPHY. MODERATE TO HEAVY ROCK COVER. MODIFIED MARL 90-125 cm FRIABLE RED BROWN SiL 30-75 cm

Explanation:

25, 50 ARE PERCENTS OF SILT
15, 20 ARE PERCENTS OF CLAY
06, 12 ARE PERCENTS OF TOTAL SOLUBLE SALTS
7.8, 7.0 ARE pH VALUES OF SATURATED SOIL PASTE
8.6, 8.5 ARE pH VALUES OF 1 PART SOIL TO 5 PARTS WATER
(10) IS HOLE NUMBER FOR THE MAP

The notes show location of hole, crop or cover and condition, surface relief conditions bearing on topography classification, surface and sub-soil conditions bearing on drainability or basic soil deficiencies. Classification of $\frac{2t}{lmzcu}$ *is the appraisal for the area – not necessarily the exact data shown at the site of sampling*

BASIC LAND CLASSES & SUB-CLASSES

ARABLE

CLASS 1 - 1
CLASS 2 - 2s, 2t, 2d, 2st, 2sd, 2td, 2std
CLASS 3 - 3s, 3t, 3d, 3st, 3sd, 3td, 3std
CLASS 4 - 4(1), 4(2s), 4(2t), etc *Showing parenthetically ultimate land class after soluble salts have been removed by leaching*

NON-ARABLE

CLASS 6H - 6H(1), 6H(2s) etc *Elevated Areas*
6I - 6I(1), 6I(2s) etc *Isolated Areas*
CLASS 6 - 6s, 6t, 6d, 6st, 6sd, 6td, 6std

PROFILE NOTE ABBREVIATIONS

SOLUBLE SALTS

PERCENT BY WEIGHT	TSS
PARTS PER MILLION	PPM
ELECTRICAL CONDUCTIVITY OF SATURATION EXTRACT	ECe
GYPSUM MILLIEQUIVALENTS PER 100 GRAMS	Gyp
SODIUM	Na
EXCHANGEABLE SODIUM PERCENTAGE	ESP
SOLUBLE SODIUM PERCENTAGE	SSP
SODIUM ADSORPTION RATIO	SAR
CATION EXCHANGE CAPACITY m.e. PER 100 g SOIL	CEC

MOISTURE RELATIONS

SATURATION PERCENTAGE	SP
INFILTRATION RATE mm/hr	Inf
HYDRAULIC CONDUCTIVITY mm/hr	HC

$$\frac{3\,s\,t\,d}{m\,h\,a\,z\,c_2\,g_3\,u_2}$$

- SOILS DEFICIENCY
- LAND CLASS
- TOPOGRAPHY DEFICIENCY
- DRAINAGE DEFICIENCY
- TEXTURE OF SURFACE SOIL
- TEXTURE OF SUB SOIL
- PRESENCE OF SALINITY
- UNDULATION *(leveling required)*
- GRADIENT - 8-12 % SLOPE *(Class 3)*
- COVER, CLASS 2 SEVERITY
- PRESENCE OF MARL - MODIFIED or RESIDUAL

PRESENT CLASS — $4\left(\frac{2s}{hhz}\right)$ — ULTIMATE CLASSIFICATION AFTER RECLAMATION

* *Bureau of Reclamation, Dept. of Interior, U.S.A. Standard symbols modified where advisable to meet local conditions.*

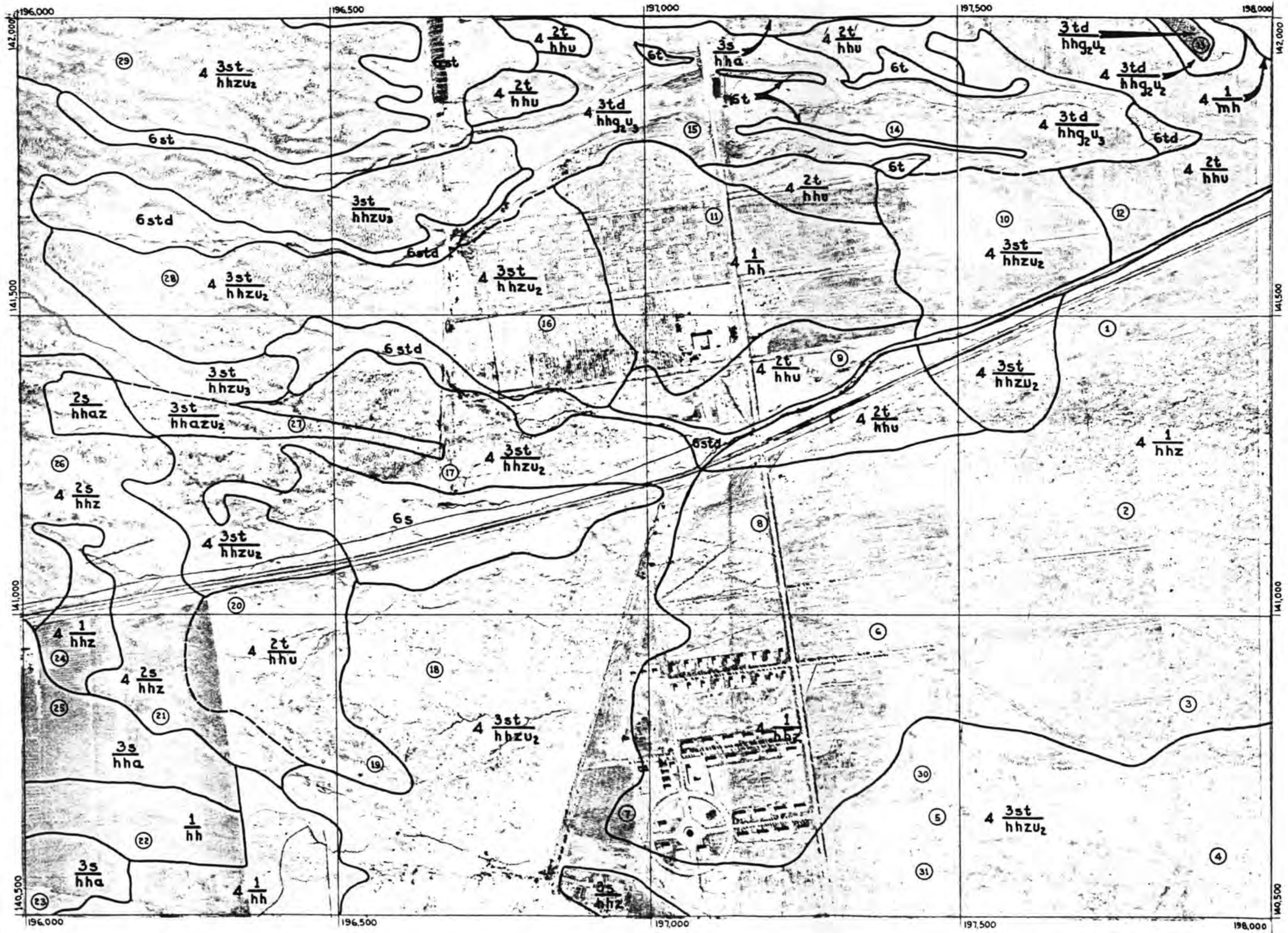
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT — MASTER PLAN

LAND CLASSIFICATION SYMBOLS

MICHAEL BAKER JR INC
HARZA ENGINEERING COMPANY

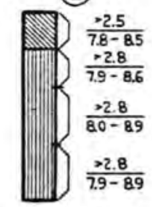
ROCHESTER PENNA. — DATE 3-55 — DWG No. JR-22



CONTROLLED MOSAIC BY AERO SERVICE CORPORATION, PHOTOGRAMMETRIC ENGINEERS, PHILADELPHIA 20, PA., U.S.A. DATE OF PHOTOGRAPHY NOVEMBER – DECEMBER 1952

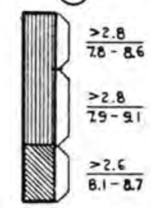
PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS



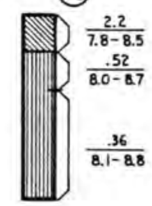
(2) 290m NW 141º/198º 4 1/hhz

PLOWED GROUND. 0-150cm MODERATE GYPSUM. 90-150cm WELL MODIFIED GRAY MARL. 60-90cm. HEAVY SILTY CLAY.



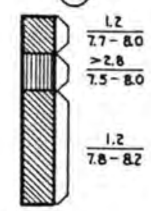
(10) 170m NE 141⁵/197⁵ 4 3st/hhzu₂

PLOWED UNEVEN SURFACE REQUIRING LIGHT TO MODERATE LEVELING. 45-105cm SLIGHTLY MOIST. MODIFIED MARL 105-150cm. DEPTH TO MARL IS VARIABLE AND OCCURS AT THE SURFACE IN SPOTS.



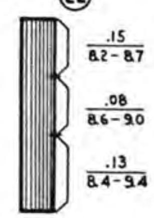
(11) 200m NE 141⁵/197º 4 1/hh

SCATTERED SALT TOLERANT WEEDS. UNIFORM TOPOGRAPHY. SURFACE SALT INDICATIONS.



(21) 270m SE 141º/196º 4 2s/hhz

PLOWED. 56-150cm SILTY CLAY LOAM DARK GRAY MODIFIED MARL WITH A FEW THIN LAYERS OF LIGHT GRAY MARL.

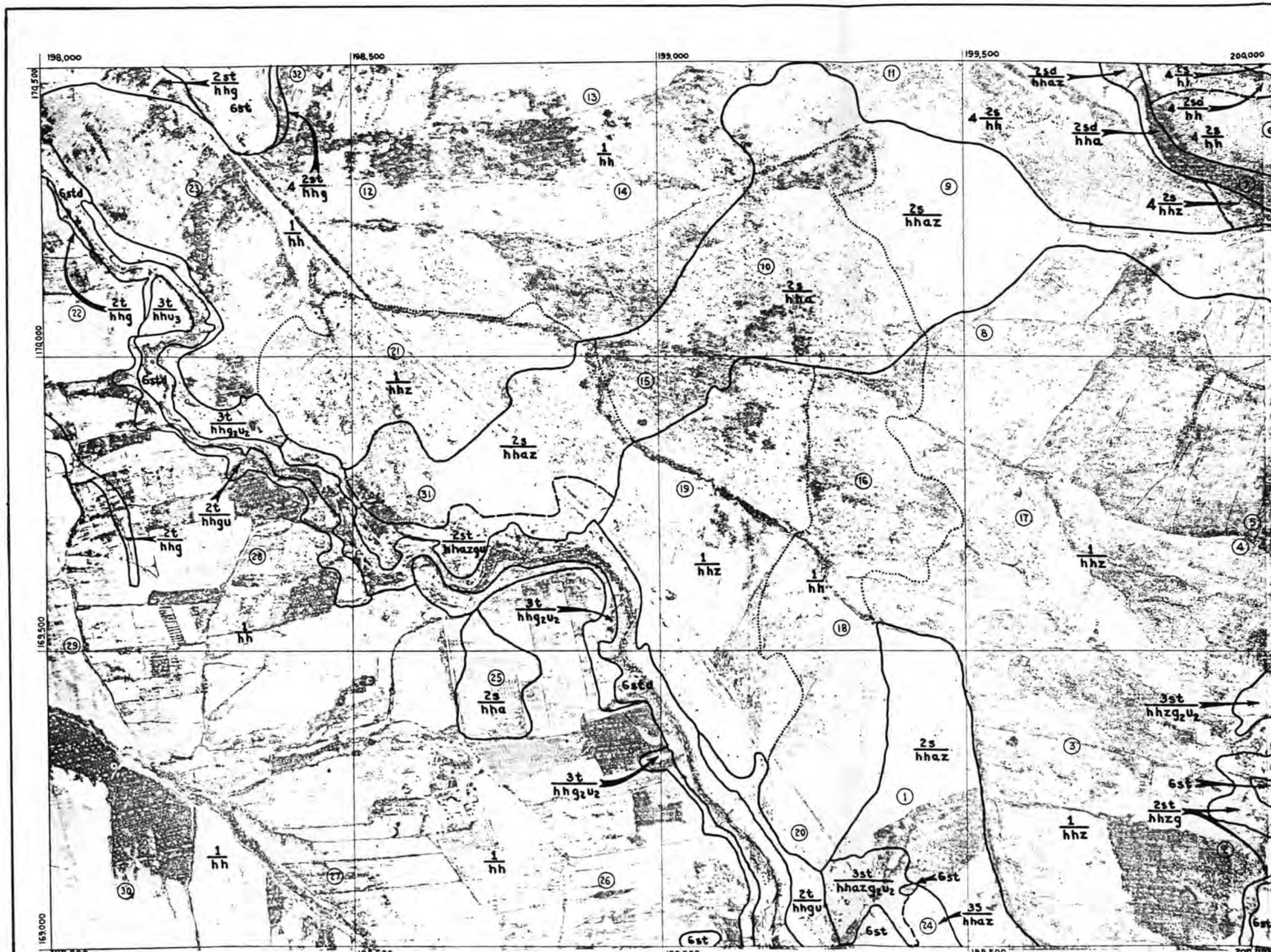


(22) 225m NE 140⁵/196º 1/hh

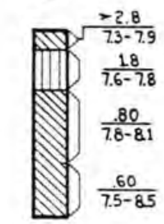
YOUNG ORANGES. SMALL AREA SOUTH HAS MODIFIED MARL AT 56cm—DOES NOT WARRANT SEGREGATION.

N

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN		
JORDAN VALLEY PROJECT	MASTER PLAN	
LAND CLASSIFICATION PHOTO MAP		
MICHAEL BAKER JR. INC. HARZA ENGINEERING COMPANY		
ROCHESTER, PENNA	DATE 2-55	DWG. NO. JR-29

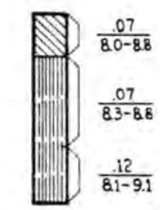


⑥ 128m S 170⁵/200⁰ 4 2s/hh



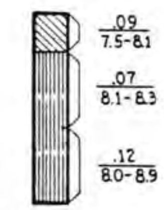
SALT BRUSH. BROWN 0-45cm GRAY WELL MODIFIED MARL 45-150cm SOME CONCRETIONS IN PROFILE.

⑲ 225m SE 170⁰/199⁰ 1/hhz



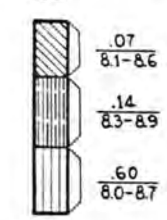
GRAIN STUBBLE. THOROUGHLY MODIFIED MARL. 105-150cm. HIGH IN LIME.

㉖ 145m NW 169⁰/199⁰ 1/hh



YOUNG ORANGES.

㉛ 290m NE 169⁵/198⁵ 2s/hhaz



MESQUITE. MODIFIED MARL WITH YELLOW MOTTLING 98-150cm

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PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

N

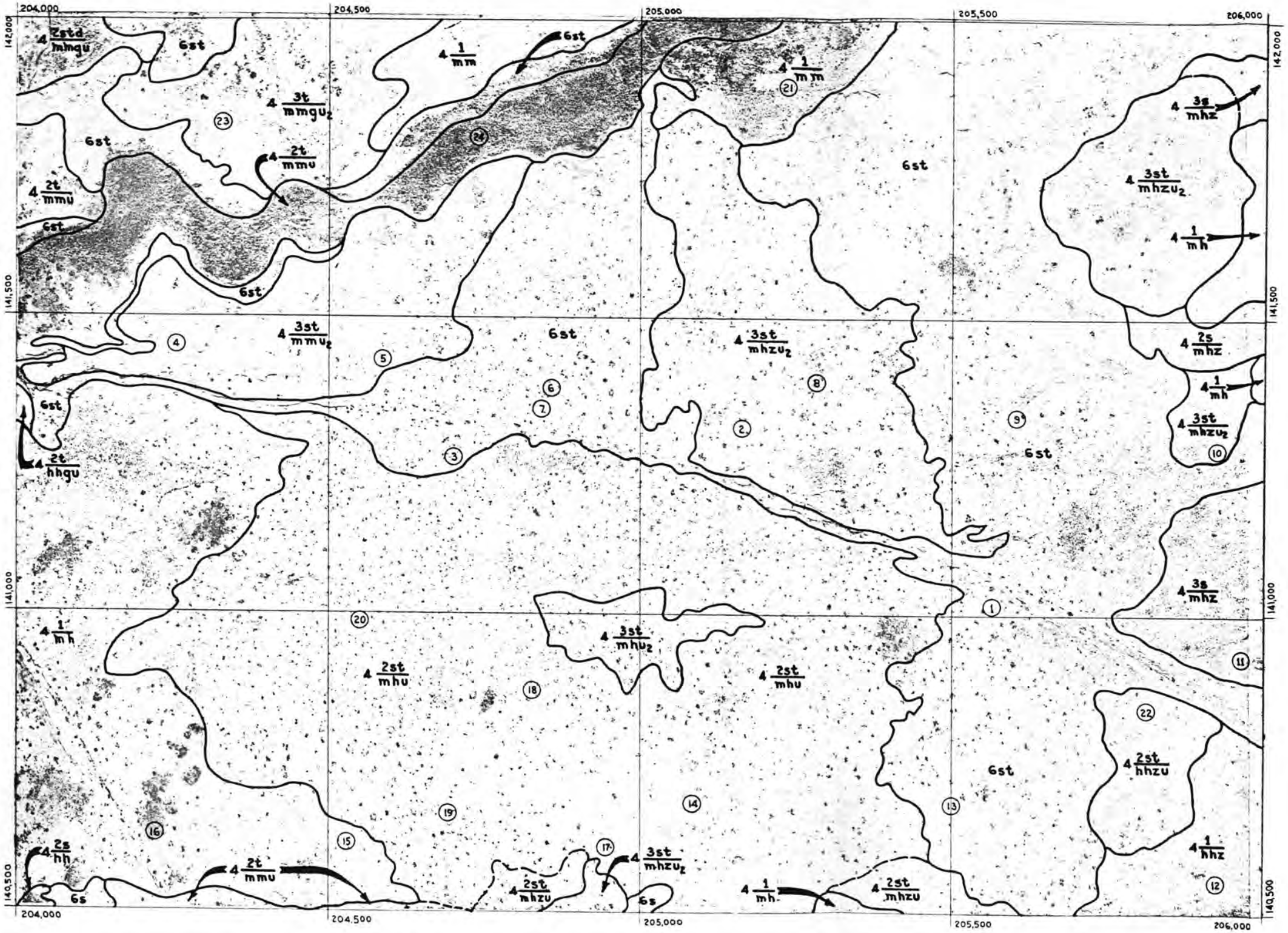
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

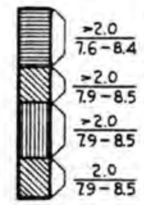
JORDAN VALLEY PROJECT | MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA. | DATE 2-55 | JR-28



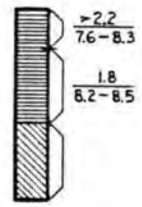


(2) 250m SE 141^{5} 205^{2} $4\frac{3st}{mhzu_2}$

NATIVE GRASSES. 0-45cm RED BROWN LOAM. 18-30" RED BROWN CLAY LOAM. 75-120cm. SLIGHTLY COMPACTED RED CLAY. 120-150cm. LIGHT CLAY LOAM.

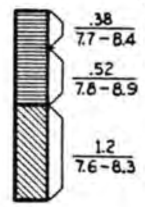
(9) 195m SE 141^{5} 205^{5} 6st

GYP HARD PAN ON SURFACE. 0-60 cm RED BROWN CLAY LOAM. 60-75cm GRAY CLAY LOAM. 75-150cm RESIDUAL MARL. LARGE AMOUNT OF GYPSUM IN PROFILE 0-75cm. MOISTURE 60cm PLUS.



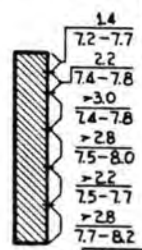
(18) 215m SW 141^{2} 205^{2} $4\frac{2st}{mhu}$

0-90cm RED BROWN LOAM. 90-135cm GRAY BROWN CLAY LOAM. 135-150cm RESIDUAL MARL. HEAVY GYPSUM 0-150cm



(21) 270m SE 142^{2} 205^{2} $4\frac{1}{mm}$

HOLE ON AN OUTWASHED BENCH — HAS BEEN FARMED. 0-75cm SILT LOAM. 75-150cm SILTY CLAY LOAM.



(22) 200m SW 141^{2} 206^{2} $4\frac{2st}{hhzu}$

NATIVE GRASS. SOME GYPSUM SALTS ON THE SURFACE. 0-150cm RED BROWN CLAY LOAM. 135-150cm RESIDUAL MARL — WET SOIL.

	E.Ce	C.E.C.	E.S.R	S.P.	H.C.(cm/hr)	GYP.
0 - 15cm	44	14	23	35	.58	—
15 - 30cm	50	16	25	36	.84	6
30 - 60cm	52	18	14	44	1.52	—
60 - 90cm	61	15	6.1	46	1.20	57
90 - 120cm	65	11	68	28	2.39	—
120 - 150cm	83	15	15	64	1.17	25

N

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PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

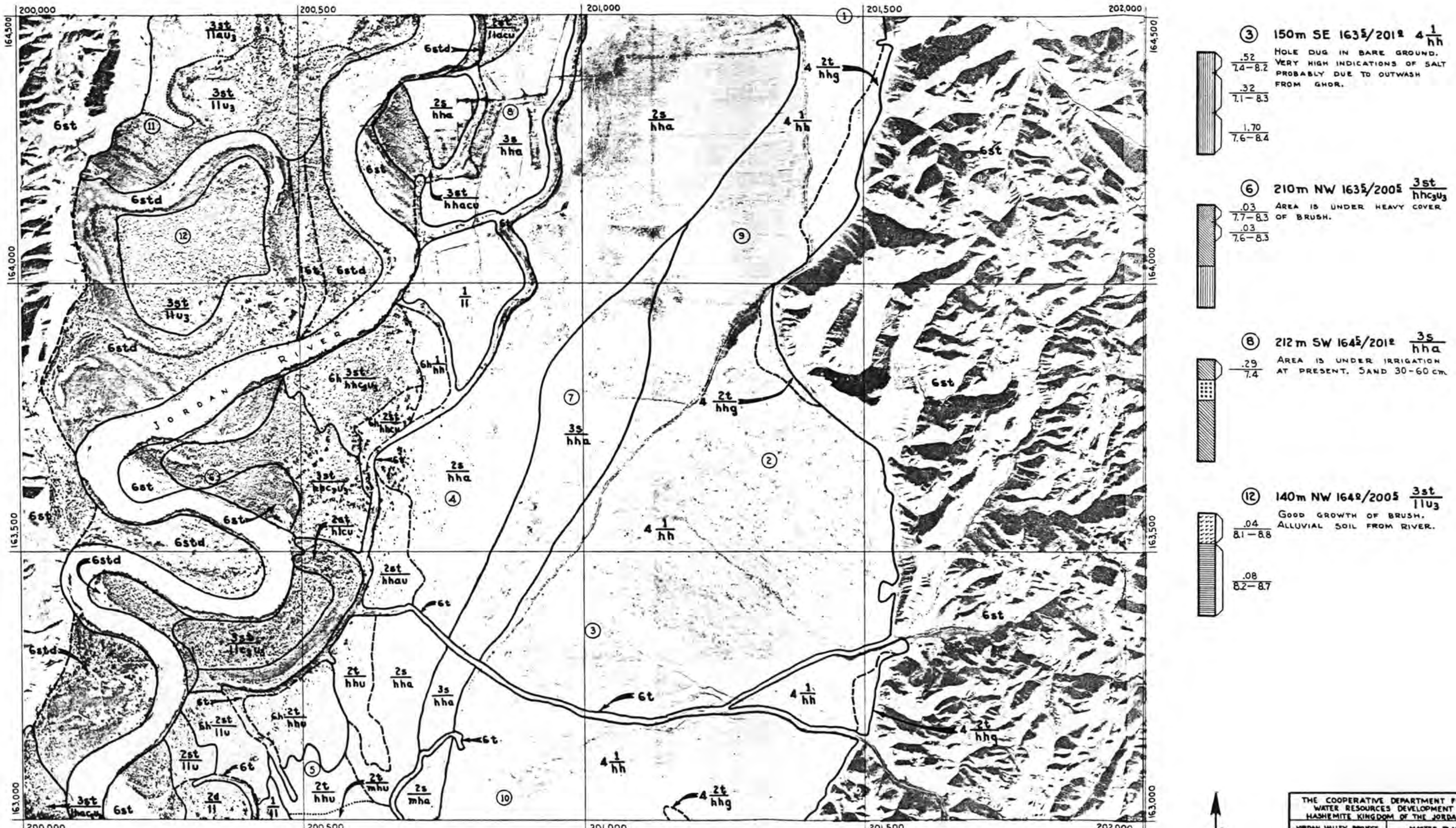
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA. | DATE 2-55 | DWG. NO. JR-27



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DATE OF PHOTOGRAPHY NOVEMBER – DECEMBER 1952

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

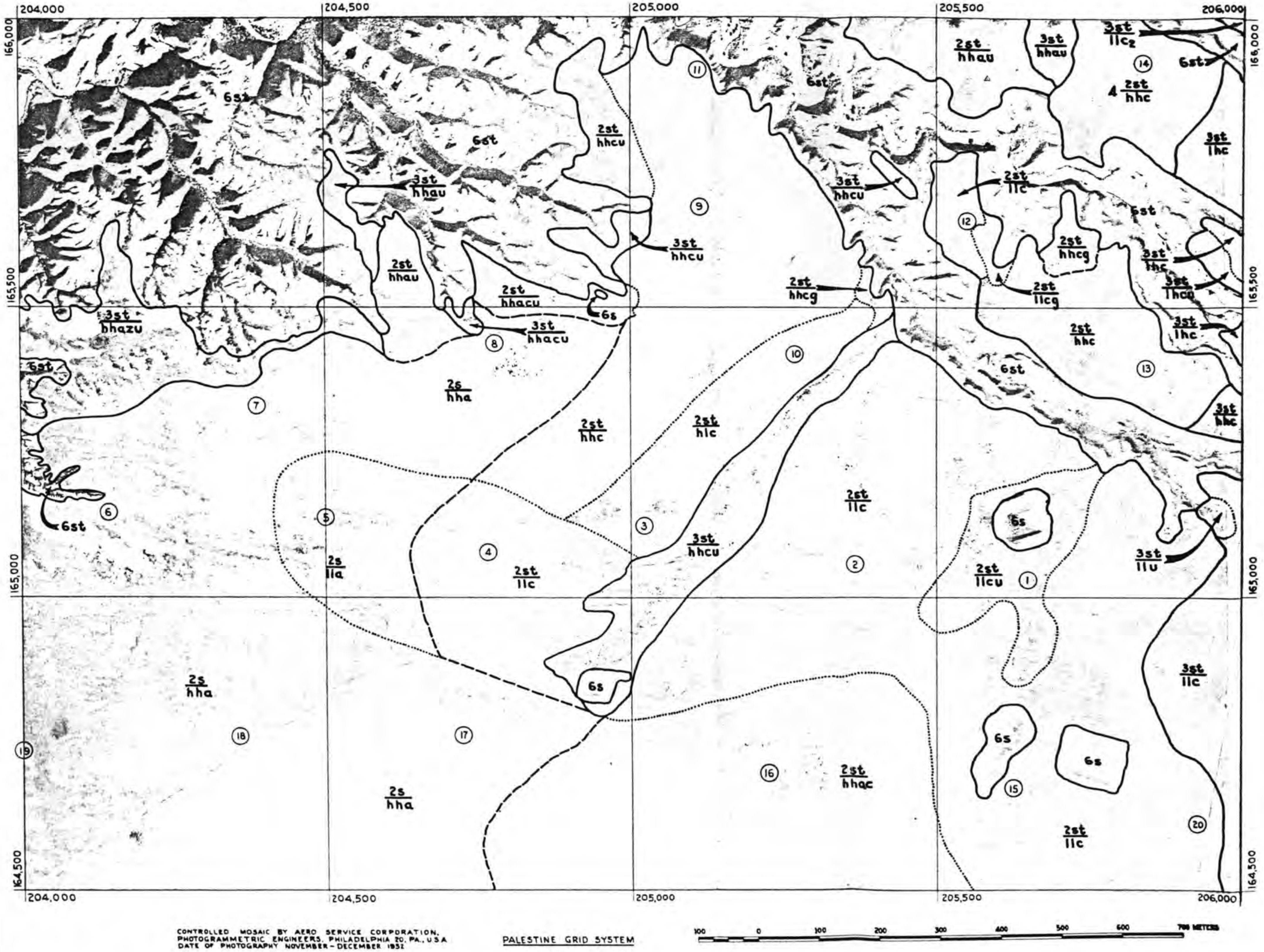
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT	MASTER PLAN

LAND CLASSIFICATION
PHOTO MAP

MICHAEL BAKER JR., INC
HARZA ENGINEERING COMPANY

ROCHESTER PENNA	DATE 2-55	JR-26



(5) 140m N 165²/204⁵ 2s/lld
SCATTERED ANNUAL GRASSES:

(12) 160m NE 205⁵/165⁵ 2st/llc
.04 / 8.4-9.0
.04 / 8.5-9.2
NATIVE GRASS:
SURFACE GRAVEL:

(13) 190m SW 165⁵/206² 2st/hhc
SCATTERED ANNUAL GRASSES:
CONSIDERABLE SURFACE ROCK:

(15) 210m NE 205⁵/164⁵ 2st/llc
GOOD GROWTH OF ANNUAL GRASSES: SOME SURFACE ROCK:

(17) 350m NE 164⁸/204⁸ 2s/hha
ANNUAL GRASSES: PROFILE LOCATED IN BARE SPOT:
20% EXCH. NA. 60-90cm:

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

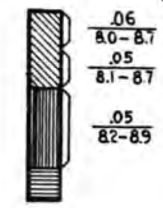
JORDAN VALLEY PROJECT — MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

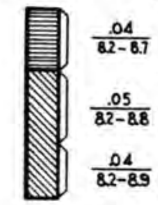
ROCHESTER, PENNA. DATE 2-55 DWG. NO. JR-25

(6) 40m W $184^{5}/205^{2}$ $\frac{1}{hh}$



SMALL GRAIN - GOOD. SMOOTH TOPOGRAPHY. MODIFIED MARL 127-150 cm. RED BROWN SOIL 45-127 cm.

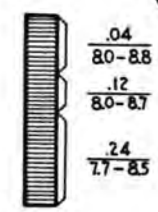
(16) 300 m SE $185^{5}/205^{2}$ $\frac{1}{mh}$



CULTIVATED GRAIN - GOOD STAND. IRRIGATED. GRAY BROWN LOAM 97-150 cm. COMPACTED PROFILE - FRIABLE.

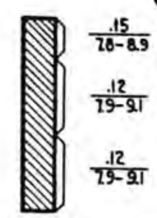
	ECe	S.P.	C.E.C.	E.S.P.	HC mm/hr
52-97cm	.43	60%	18	3.7	39.4

(20) 80 m SW $185^{5}/204^{8}$ $\frac{2t}{mmg}$



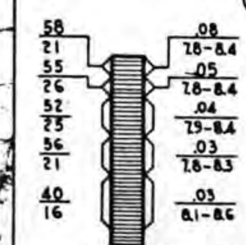
SMALL GRAIN GOOD. HOLE ON A 5% SLOPE. LIGHT RED BROWN PROFILE - FRIABLE. HEAVY SILT LOAM 45-150 cm.

(26) 240m SE $185^{2}/204^{2}$ $\frac{1}{hh}$



SMALL GRAIN - FAIR CROP. SMOOTH TOPOGRAPHY. MODIFIED MARL - MOIST PROFILE.

(30) 220m SW $185^{5}/206^{2}$ $\frac{1}{hh}$



CULTIVATED - IRRIGATED. RED BROWN FRIABLE MOIST PROFILE. TEXTURE BORDERS ON SILTY CLAY LOAM 0-80 cm. - HEAVIER IN MOST OF AREA.

	ECe	C.E.C.	E.S.P.	S.P.	GYPSUM	HC mm/hr	INFILTRATION mm/hr
0-15cm.	.99	21	0.87	45	<1	10.7	10.0
60-90cm.	.43	14	1.50	39	<1	19.1	—

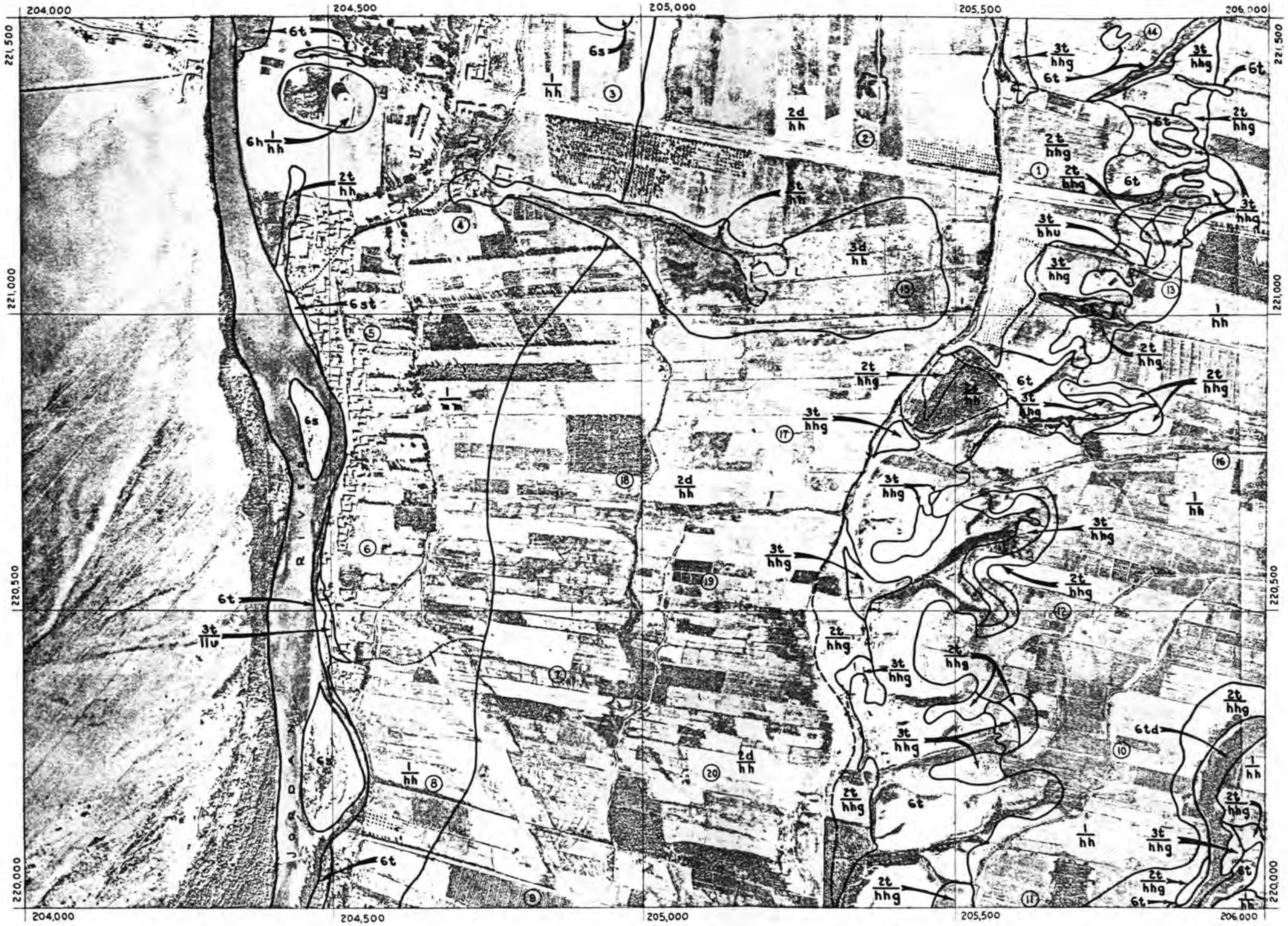
CONTROLLED MOSAIC BY AERO SERVICE CORPORATION, PHOTOGRAMMETRIC ENGINEERS, PHILADELPHIA 20, PA., U.S.A.
DATE OF PHOTOGRAPHY NOVEMBER - DECEMBER 1952

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

N

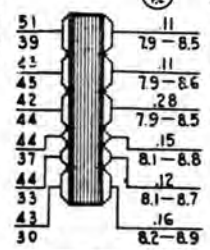
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN	
JORDAN VALLEY PROJECT	MASTER PLAN
LAND CLASSIFICATION PHOTO MAP	
MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY	
ROCHESTER, PENNA.	DATE 2-55
DRAWING JR-34	SHEET 3 OF 6



CONTROLLED MOSAIC BY AERO SERVICE CORPORATION, PHOTOGRAMMETRIC ENGINEERS, PHILADELPHIA 20, PA., U.S.A.
DATE OF PHOTOGRAPHY NOVEMBER - DECEMBER 1952

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS



(2) 250m SW $221^{5}/205^{5}$ $\frac{2d}{hh}$

LAND IS PRESENTLY IRRIGATED: CAULIFLOWER DOING POORLY: WATER TABLE AT 120 cm.:

DEPTH	EXCH. NA. m/100g	CEC	ESP	SP	GYP	H.C mm/hr	INFILTRATION mm/hr	DISPERSION
0-30cm	0.67	34	2.0	59	<1	6.1	15.0	39
30-60cm	0.85	25	3.0	57	<1	9.4		43
60-90cm	2.80	26	11.0	59	<1	41.5		41
90-105cm	1.10	24	4.4	61	<1	16.8		48
105-120cm	0.82	21	4.0	52	<1	51.0		62
120-150cm	0.42	17	2.5	66	<1	33.0		73

(4) 200m NE $221^{2}/204^{5}$ $\frac{1}{mm}$

IRRIGATED SMALL GRAIN: RED BROWN LOAM 0-60 cm.:

(12) 150m E $220^{5}/205^{5}$ $\frac{1}{hh}$

IRRIGATED SMALL GRAIN: RESIDUAL MARL BELOW 115 cm.

N

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT — MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER PENNA	DATE 2-55	JR 23

VOLUME III - LAND RESOURCES
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

PART 2. Agriculture

VOLUME III - LAND RESOURCES
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

PART 2. AGRICULTURE

Introduction

The objective of this report is to indicate agricultural capabilities of project lands determined suitable for irrigation, the lands being supplied with adequate quantities of irrigation water and taking into account specific characteristics of the local area and Middle East culture.

Information for this report was obtained from earlier studies, the land classification survey, field studies, consultations with Jordanian land operators and agricultural technicians of the Jordan Government and United States Foreign Operations Administration, reference to current United Nations surveys, and field observations made in neighboring Middle East countries where land conditions, climate and culture were generally similar.

Field studies included soil and topographic examinations, observation of existing crops and current methods of water application and land management. As was determined in Part 1 of this volume, the arable area within the project totals 519,800 donums. The soils, topography, and drainage characteristics of this land are favorable for irrigation farming and it lies in relatively large compact blocks. At the present time a minor area of the arable lands are occupied by permanent facilities such as roads, villages, etc. Under the anticipated land development program it is expected that wherever possible these permanent facilities will be confined to non-arable areas. However, a certain amount of arable land will be utilized in locating the main canals, and lateral distribution systems, farm roads, and other public facilities, for which a reduction of about 3 percent in arable area is made to determine the irrigable area. The irrigable area within the project has been calculated to be about 504,200 donums.

Agricultural History

The Jordan Valley has a long history of limited irrigation development. Biblical records show a variety of irrigated crops were grown on project lands, and indications point to even earlier irrigation within this and adjacent areas. Then, as now, the supply of water was insufficient to irrigate the entire area. Streams tributary to the Jordan River were diverted for crop irrigation and the water spread thinly over a maximum area. Lands far removed from these sources of supply normally received little or no irrigation and efforts were made to develop underground waters by construction of fuquarās, or water collection systems which utilized aquifers originating in the adjacent hills. Some of these ancient works have been rediscovered and restored to use. Other sources such as Elisha's Spring in Jericho have been intensively utilized and a variety of crops are still produced in this area.

Cereals, vegetables, and fruits such as citrus, olives, dates and bananas were produced in early history and are grown today where water supply permits.

Although actual records of lands irrigated are inadequate, it is certain that a significant portion of the area classed as irrigated both in the past and at present received water intermittently and in very limited amounts. This is indicated by the fact that certain tracts are irrigated one year and not the next. Annual variations in volume and duration of stream flow and fallow practices are primarily responsible for this condition. The relatively unleached condition of soils in many irrigated areas further emphasizes the fact that irrigation as practiced with a "full water supply" has been known on only a small part of the project area.

Present Agriculture

Under present conditions approximately 48 percent of the irrigable land within the project area is non-irrigated. Of this total only about 5 percent is cropped on a dry-farm basis. The major portion of this non-farmed area is covered with scattered patches of scrub-type brush and annual grasses, and is utilized for grazing purposes.

Of the lands termed as irrigated, it must be noted that the total includes all crops to which water was applied regardless of the adequacy of the amount. The distribution and amount of irrigated and non-irrigated lands for the year 1953 are presented as Table 3.2-1. The influence of the inadequate supply of irrigation water and the very small amount of fertilization normally utilized are reflected in the relatively low yields of crops now produced. Present production is illustrated in Table 3.2-2.

Principal Crops

Cereals constitute about 43 percent of the total crops grown on the irrigable area of the project. Wheat and barley comprise more than four-fifths of this category with more than three times as much wheat as barley. Other cereal grains include sorghum, corn (maize) and sesame with corn and sesame in the minor category. One reason for the large wheat planting is the country's heavy consumption of bread. The other principal reason is the relatively low irrigation requirement necessitated by traditional planting to take advantage of winter rains. The crop is always harvested, even if production is negligible, and yields are generally very low.

Vegetables occupy about 10 percent of the crop distribution. For the most part they are presently produced during the summer months with a few grown during the winter and early spring. Except for a very few areas the majority of these crops are inadequately irrigated. Principal vegetable crops include tomatoes, watermelons, eggplant, cucumber, marrow and beans. Of these, tomatoes, watermelons and eggplant comprise about 70 percent of the total vegetable area.

Orchard fruits are found in the amount of about 3 percent of the total irrigable project lands. Bananas are the principal orchard fruit and plantings are confined to areas where a reliable source of water is available. Citrus fruits (oranges, lemons, tangerines, etc.) are also produced in currently irrigated areas. Other fruits such as pomegranates, figs and grapes are found in small, scattered plantings. The main productive fruit areas are located in the vicinity of Adasiye and the Jericho vicinity.

Agricultural Practices

Seed stock quality is generally very low. Common practice is to utilize a portion of the field-run supply which has been passed down without material change for many generations. This is particularly true of cereal and vegetable crops. As a consequence there has been little semblance of purity of line in the seed stocks planted. A certain amount of resistance to adverse growing conditions such as salinity has been developed. For example, marrow was observed growing well in soil containing more than twice the amount of salinity usually termed as critical.

In most instances this has not been recognized and the seeds possessing this desirable characteristic have not been segregated.

New adapted varieties have been introduced to a very slight degree, and a limited amount of experimentation is being carried on within the valley. This work is being conducted at agricultural experiment stations, one located near Wadi Fari'a on the West Ghor and at Deir Alla and at Baqura on the East Ghor. A limited amount of nursery stock is produced in Jericho. These experimental areas have been established within the past five years and sufficient time has not elapsed to permit conclusive results.

Seed bed preparation is usually inadequate. Present methods of preparing the land for planting are essentially the same as those used in ancient times. Generally a single "nail-type" plow is used to open a furrow in the soil. Cereal and other field crop seed is usually broadcast by hand and then covered by plowing at right angles to the first operation. Upon occasion hand-hoes are used to break up clods between the first and second plowing but rarely is the use of a harrow or drag in evidence. This procedure obviously requires an abnormally high seeding rate to produce a satisfactory crop stand.

Vegetables are commonly transplanted from farm "nursery" plots. Transplants or seeds are planted in beds separated by deep wide irrigation channels. Plantings are placed midway between the crest and bottom of the ditch, which removes the seedling from the point of highest salinity. This practice is of distinct value where soils tend to be saline.

Crop rotation as a planned program is seldom followed. For the most part cereals, particularly wheat, are produced year after year on the same tracts of land. This practice is followed of necessity on some areas where shallow soils and lack of water limit the variety of crops that can be produced. However, it is also common practice on much of the land that is fully irrigated. In some cases on these latter areas land is left idle as fallow for one season, but in many cases it is again planted wholly or in part to the same crop.

Vegetable crops are rotated to a greater degree but this is primarily due to the practice of shifting tenant farmers annually from one tract of land to another. Again, planned rotation programs are generally lacking with market price and operator food needs the primary reasons for planting a specific crop.

Irrigation methods are influenced to a major degree by the source of the water supply. In many cases water is available in relatively large quantity for a short period of time. The tendency is to use a large head of water with no regard for water intake rate of the soil or topographic features of the land. In such instances, as most field head ditches are unlined, a degree of erosion takes place which eventually eliminates their usefulness and new ones must be constructed. Such practices also tend to spread a given amount of water over a large area with inadequate penetration at any one place. Cereals, which are generally irrigated with a semi-wild flooding technique, seldom receive full benefit from water applied in this manner.

Vegetables and fruits are usually irrigated by the basin methods. Good distribution of water is generally obtained with a minimum of waste.

Fertilizers and organic matter are generally of minor significance in current crop production. Animal manure is commonly gathered and dried for use as domestic fuel. The natural manures which are used for fertilizer are purchased in most cases and consist mainly of cattle and sheep dung. General practice is to pay for its collection and transportation to the farm where it is applied to vegetables and fruits. The majority of the better banana and citrus plantings utilize a type of compost incorporating these manures and some residue such as banana leaves. Mineral fertilizers are occasionally used by larger landowners but information regarding their value in the form of increased production is lacking. There are no regulations covering composition of commercial fertilizers, and consequently they are quite varied. Some unprocessed rock phosphate of local origin has been applied but value derived from application on the highly calcareous soils of the area is economically questionable. Cost is a prime deterrent to use of fertilizers as most operators feel they cannot afford to purchase them.

The addition of organic matter to the soil in the form of green manure or crop residue is virtually unknown. The lack of sufficient forage for roving herds of sheep and goats and shortage of water needed to produce crops for human consumption have taken precedence over growing of any crop for purposes of adding needed organic matter to the soil. Farm animals are allowed to eat crop residues to the ground or the plant stalks are completely removed by pulling them from the soil, roots and all, for feeding at a later time or for use as fuel. These practices precluded any appreciable use of organic matter for purposes of improving soil fertility or tilth.

Farm machinery within the area is generally light and simple. The single "nail-type" plow is the common ground-breaking implement and is drawn through the soil by animal power. Cultivation is practiced to a limited extent and is performed almost entirely by wide-bladed hand hoes. This long-handled, heavy implement is also used to a great degree for plowing, smoothing and irrigation ditching operations. Sowing of seed and other planting is done by hand. In Adasiye and Jericho and a few other localities modern machinery in the form of tractor-drawn disc plows, seed drills and harrows are utilized on a limited number of the larger holdings. This equipment has been introduced primarily within the past three years as has the F.O.A. demonstration program of techniques involved in its operation.

Harvesting of cereals is generally done by hand-sickle or by pulling the entire plant from the soil. Threshing is accomplished on "natural" threshing floors so placed as to take advantage of wind for winnowing purposes. Animals and flails are used to separate the grain and hand sieves for final separation. Vegetables and fruits are picked by hand.

In general the lack of adequate tools for cultural operations restricts timeliness of farm operations. This is reflected in the extensive time currently required for preparation of the land, harvesting periods and relatively low yields.

Farm animals are low in number. A few chickens together with a small number of sheep or goats are generally owned by individuals. Some families may have one or two horses or a similar number of oxen, donkeys or camels. The larger animals are primarily used for farm power and transportation. Forage crops for farm animals are practically non-existent and feed is obtained by herding on non-cropped land and use of a limited amount of crop residue.

Weed control practices are limited both in method and the extent to which they are employed. Weeds are recognized as pests that seriously reduce the productive capacity of agricultural lands and interfere with the farmer's effort to grow useful plants. The production of crops is largely in direct competition with weeds, whose control is a factor of major importance, especially in irrigation agriculture. Losses from weeds may be enumerated as follows:

(1) Weed competition with crops for water, light, and mineral nutrients.
(2) Additional labor required to combat weeds that could profitably be used to produce food.
(3) Weeds reduce the quality of farm products.
(4) Weeds harbor insects and fungus pests that attack crop plants.
(5) Weed infestation can become so rank that agricultural land is no longer productive.

It is reasonable to assume that these losses from weeds will be higher in an area of small farm units, (such as the development contemplated), than one of large units. From field observation it has been estimated that potential crop production in the Jordan Valley will be reduced by ten percent without an adequate weed control program.

The following weeds are some of those most commonly found in the Jordan Valley and will constitute an increasingly important problem as the area is developed for irrigation:

Bermuda grass	(Cynodon dactylon)
Chenopodiums	(Chenopodium spp)
Christ thorn	(Spini christi)
Tamarisk	(Tamarix pentandra)
Wild-onion	(Urginea maritima)
Yambut	(Prosopia stephanania)

There is ample evidence that the tendency to grow one crop on a given area of land for several seasons has allowed weeds to multiply. This is particularly true of those weeds which are compatible with the growth habits and management program of the crop.

As the new land is developed and brought under irrigation, the weed problems in these areas will become more numerous. For this reason it is desirable that weed control practices be established in the early stages of this development in order to hold weed infestations to a minimum. In addition, weed problems are more difficult on old irrigated lands, and the old established weeds more costly to control than those on new lands.

Many methods of weed control and eradication have been devised which may be grouped under the headings of:

(1) Mechanical methods (hand hoeing, tillage, burning, etc.)
(2) Cropping and competition methods
(3) Chemical methods

Present control measures consist almost entirely of the first category. They occur mainly as a by-product of normal seed-bed preparation and occasional cultivation. Some effort is made to periodically remove larger, woody-types of vegetation by hand "grubbing". Mechanical and cropping methods of control are recommended as being the most suitable for the Jordan Valley in the initial stages of development. Chemical weed-killers, which are more costly, can be used on the more persistent plant species to supplement these two methods. The agricultural experiment stations in the valley should include weed control in their annual program in order to develop the best techniques for the local conditions. A detailed weed survey of the valley should also be scheduled in the program of the contemplated farm extension service.

Insects and plant diseases receive little attention at the present time. Mild infestations of locusts from the desert areas have occurred from time to time. The coordinated effort of surrounding countries with the Jordan Government and United Nations representatives has succeeded in controlling the swarms to date. Poison baits and hand eradication seem most effective. A limited amount of chemical control for insects and plant diseases is employed primarily through hand dusting of crops. Pests of individual crops and recommended controls are given in Table 3.2-5, Data for Recommended Crops.

Anticipated Irrigation Agriculture

In an area, such as the Jordan Valley, which has a problem of over population, the production of food for human consumption is of primary importance. Therefore, an agricultural program must provide food for the family and a small cash crop to enable the purchase of necessities not produced on the farm. It should also provide feed for the livestock and enable fertility and tilth of the soil to be maintained.

Under the proposed plan of development it is expected that the people will continue to live in villages rather than on the farms. This custom is traditional in the area and will be advantageous in that every effort will be made to utilize all irrigable land for crop production by locating villages on non-arable lands.

Since it is beyond the scope of this report to identify agricultural programs for individual farm units, the subsequent discussion will be primarily concerned with establishment of a cropping pattern, or distribution of crops, over the project area which land classification has determined to be suitable for irrigation agriculture. The climate and soils are generally well suited to the growing of a wide variety of crops as has been pointed out in other sections of this report dealing specifically with these topics. It has also been noted that many types of crops have been and are now being grown within the area, and the lack of sufficient water has been one of the primary influencing factors determining the degree to which agriculture has been practiced.

Crops which are included in the patterns were selected as representative of those which are adapted to the area rather than trying to anticipate all crops which can be grown in the future.

Two specific cropping patterns are shown in Drawing DS-5-5, together with the irrigation and diversion requirements of each. Pattern "A" is designed to furnish a maximum of subsistence-type living with the primary emphasis on cereals and the productive periods reflecting the present irrigation influence. Provision has been made for production of some vegetables and fruits other than those required for the farmers themselves, and introduces sugar beets and peanuts to the area. These latter crops are both well adapted to the project soils and can be the basis for establishment of industrial plants producing sugar and edible oils. A part of the vegetable production may also lend itself readily to canning and preserving processes.

Cropping Pattern "B" was developed to introduçe rice, cotton and dates. There is a deficiency in these crops and an increase in production will alleviate the import situation. It is recognized that certain difficulties are inherent to the production of these crops, but their adaptation to soils and climate of the area warrant their consideration. The differences in time and length of growing season noted in the two patterns for a few crops are acceptable if compared with their production in irrigated areab of similar climate and soils. A summary of crops shown in both patterns "A" and "B" is given in Table 5.2-3, Estimated Distribution of Irrigation Crops with Project Development.

In addition, diversion requirements by months for the various crops are shown in Tables 3.2-6 and 3.2-7, "Diversion Requirements" for Northern and Southern Zones, respectively. The method of developing irrigation and diversion requirements are fully developed in Volume II, and further discussed in Volume VII.

Yields of crops have been estimated on the basis of a moderate improvement in management practices, availability of improved farm equipment, and use of adapted crop varieties. In addition, cognizance has been taken of the productive capacity of the project soils, and the influence of climatic factors as compared with similar areas. Average yields anticipated under project development are shown in Table 3.2-4. It is expected that generally, yields on Class 1 and Class 2 lands will exceed those obtained on Class 3 land by 20 to 30 percent.

Agricultural programs, as it has been previously noted, are carried out in most cases in accordance with traditional methods. Detailed recommendations for the growing of individual crops in local areas must necessarily come from experimental work such as is now being conducted at the Baqura, Deir Alla and Wadi Fari'a Experiment Stations. Special points of interest are discussed in the following paragraphs, and additional information for selected crops is given in Table 3.2-5

Cereals are well adapted to the soils of the area, and produce very well on the clay loams and lighter clays. Preparation of seed-beds should tend to establish a slightly better condition than is presently obtained. Better stands from less seed should result. Planting in rows will be advantageous for such crops as corn and sorghum, particularly from the standpoint of better penetration of irrigation water.

Rice is well adapted to the heavier clay soils. Such soils will require less water than finer textured soils to produce a crop. They will crust quickly after draining in the fall allowing earlier harvest. Rice will require more water to produce an equivalent amount of calories than do potatoes. However, it will prove advantageous to grow on alkali soils and can be followed by crops less tolerant in nature.

Crop residues of cereals should be mixed with the soil by working the straw into the surface soil to increase moisture penetration and reduce runoff. Wherever possible leguminous crops such as alfalfa and beans should be utilized in rotation with cereal crops. In particular it is not well for sorghum to be followed by wheat in rotation as the former crop will cause a temporary reduction in nitrogen content of the soil.

Sugar beets are a promising potential crop from the standpoint of adaptability to project soils, salinity tolerance, and their prospects of reducing sugar imports. Sugar beet tops and by-products of processing also would contribute materially to feed requirements of livestock. Beets require a significant amount of hand-labor and should be planted as a row crop. Both of these factors lend themselves well to farming in the area, and this crop fits well into rotation with other field crops and vegetables.

Cotton is well adapted to the lighter soils in the southern part of the valley. It can be grown during the hot summer months and will enter well into a rotation with vegetables such as potatoes or with a forage crop such as alfalfa. Only a few very small areas have been grown to date and while plant growth was excellent, considerable difficulty was encountered with boll-weevil. Further information is needed before control measures in the local area can be recommended.

Forage crops in the form of legumes such as alfalfa or berseem will be beneficial not only for production of animal forage but also will be helpful in soil improvement. These crops, plus by-products of sugar beet production and other crop residue such as peanut hay, should better condition work animals on the farms and encourage fattening of meat animals such as lambs. Rather than establish an enterprise within the project, it is expected that lambs would primarily be for family use and would come from adjacent upland areas. Of primary importance in rotation with vegetable and field crops, legumes will add to the nitrogen content of the soil and aid in improving soil condition by addition of organic matter.

Vegetable crops will assume significant degree of importance under project development. The major portion of the soils in the area, particularly those on alluvial fans and much of the zor, are well adapted to production of a wide variety of vegetables. Fertilizer and a full water supply will greatly increase present production. The use of more water must be coordinated with better methods of application.

Fruits will continue to be grown to great advantage in the project area. Bananas in particular are in a superior position for competition with surrounding Middle East areas. The soils which are shallow in depth to marl seem to produce excellent crops. Water and fertilizer are presently used to advantage on bananas and on citrus fruits. However, increased amounts of available nitrogen and phosphorous would materially help production and quality. Dates are well adapted to production and particularly on saline soil areas. The existing amount of parent stock is not well suited to propagation purposes. Since neighboring countries prohibit exportation of seedlings they must be secured from other areas.

Although grapes are grown to a major extent in the adjacent uplands, it is felt the valley offers some advantages. A variety such as Thompson Seedless, extensively grown in a similar area of the United States, could be used as fresh fruit and under valley conditions could also be dried for raisins. Both grapes and citrus fruits should do well on soils which contain appreciable amounts of rock in the profile. The majority of these soils are of clay and clay loam textures and occur on the upper slopes of the ghor. Vines and trees require less tillage, and while slopes may not require terracing, plantings should be established on the contour.

Summary and Conclusions

The Valley has a long history of limited irrigation. Production now is predominantly in the form of cereals, principally wheat. A variety of vegetables are produced on a small area and as with cereals, yields are relatively low. Fruits, especially bananas, are well adapted to the area and quality and flavor are good. Few farm animals are maintained by individuals and cropped area is seldom used specifically for animal feed. Animals secure most of their feed by foraging. Shortage of forage and fuel discourages addition of organic matter to the soil. Farm practices are generally inadequate to secure the production and quality possible even under existing conditions of limited water supply.

An extension type of educational program is mandatory to successfully establish and maintain the subsistence-type of farming recommended. The introduction of more advanced animal powered equipment such as small mold-board and disc plows, one-horse shovel cultivators and seed drills, and small section spike tooth harrows is strongly recommended. Small tools such as scythes and hand dusters will also increase efficiency and make for more timely farm operations.

Experimental programs with new varieties as well as improvement in purity and quality of existing crops are now being conducted at agricultural experiment stations within the valley. Additional fertilizer tests are needed, but it is apparent that present practices are entirely inadequate. Indications are that application of available nitrogen and phosphorous would benefit most crops significantly.

Anticipated development is based on a full water supply. However, practices which will produce maximum benefit with a minimum of waste should be utilized. This will also materially reduce future drainage problems. Field crops in particular will benefit by a more controlled type of distribution such as basin-flooding or combination of basin-flooding with furrows where slope is a definite factor. More significance should be placed on the relationship between the volume of water delivered and the length of time it is available, as concerned with the size of field, soil characteristics and crop water requirement.

Weeds will become a problem of increasing importance as irrigation development takes place. Mechanical and cropping methods of control are recommended in the initial stages of the project. Chemical weed-killers can be used on more persistent plant species to supplement these methods. A detailed weed survey program should be initiated to keep pace with agricultural development.

Crops which have been recommended under anticipated development include those which meet domestic needs and tastes and have market outlets, as well as being adapted to project soils and climate.

Table 3.2-1

Distribution of Crops,
Jordan Valley-1953[1]
(Sheet 1 of 2)

Irrigated Land	East Ghor North (donums)	East Ghor South (donums)	West Ghor (donums)	Total Project (donums)	Total Project (percent)
Wheat	63,000	30,600	32,600	126,200	25.0
Barley	19,200	4,700	9,100	33,000	6.6
Corn	2,500	540	100	3,140	0.6
Sesame	6,100	3,900	3,450	13,450	2.7
Sorghum	16,200	410	5,100	21,710	4.3
Sub-Total, Cereals	107,000	40,150	50,350	197,500	39.2
Eggplant	2,500	3,500	1,600	7,600	1.5
Tomatoes	2,700	6,500	6,400	15,600	3.1
Watermelons	9,600	1,100	1,200	11,900	2.3
Cucumber	800	420	2,280	3,500	0.7
Marrow	800	950	750	2,500	0.5
Cabbage	550	250	250	1,050	0.2
Cauliflower	330	90	460	880	0.2
Broadbeans	400	470	1,550	2,420	0.5
Onions	580	270	350	1,200	0.2
Potatoes	870	300	930	2,100	0.2
Sub-Total, Vegetables	19,130	13,850	15,770	48,750	9.7
Bananas	2,800	1,400	2,200	6,400	1.3
Citrus	840	240	620	1,700	0.3
Otherfruits	3,860	750	2,780	6,590	1.3
Sub-Total, Fruits	7,500	2,400	5,600	15,500	2.9
Total Irrigated Crops[2]	133,630	56,400	71,720	261,750	

Table 3.2-1

Distribution of Crops
Jordan Valley-1953[1]
(Sheet 2 of 2)

	East Ghor North (donums)	East Ghor South (donums)	West Ghor (donums)	Total Project (donums)	Total Project (percent)
Non-Irrigated Land					
Wheat	15,500	-	1,800	17,300	3.4
Barley	4,000	-	1,100	5,100	1.0
Sesame	220	-	-	220	- 3/
Watermelons	250	500	500	1,250	0.2
Sorghum	3,600	-	600	4,200	0.8
Sub-Total, Cropland	23,570	500	4,000	28,070	5.4
Fallow, Idle	11,600	48,400	57,240	117,240	23.5
Grazing, Waste, Etc.	700	78,300	18,140	97,140	19.3
Total, All Land	169,500	183,600	151,100	504,200	100.0

1/ Based on "Agricultural Economic Survey, Jordan Valley", United Nations Organization, 1953; adjusted to irrigable area of project.
2/ Includes all land reported as irrigated, at anytime during 1953, regardless of adequacy of irrigation.
3/ Less than 0.1 percent.

Table 3.2-2

Crop Yields, Jordan Valley-1953[1]
(Sheet 1 of 2)

	East Ghor North (Yield/Donum) Kilograms	East Ghor South (Yield/Donum) Kilograms	West Ghor (Yield/Donum) Kilograms	Total Project (Yield/Donum) Kilograms
Irrigated Land				
Cereals				
Wheat	90	90	85	90
Barley	100	90	70	90
Corn	200	120	120	190
Sesame	60	55	60	60
Sorghum	-	-	-	100
Vegetables				
Eggplant	1000	870	910	930
Tomatoes	620	430	520	500
Watermelon	470	430	470	490
Cucumbers	400	320	450	420
Marrow	640	350	500	490
Cabbage	690	770	840	900
Cauliflower	720	430	620	640
Broadbeans	330	350	300	320
Onions	770	520	900	750
Potatoes	1520	840	820	1100
Fruits[2]				
Bananas	1300	1250	1310	1295
Citrus	1300	1040	870	1098
Other Fruits	1100	1150	1430	1221

Table 3.2-2

Crop Yields, Jordan Valley-1953 1/
(Sheet 2 of 2)

Non-Irrigated Land	East Ghor North (Yield/Donum) Kilograms	East Ghor South (Yield/Donum) Kilograms	West Ghor (Yield/Donum) Kilograms	Total Project (Yield/Donum) Kilograms
Wheat	80	80	20	70
Barley	90	70	30	75
Sesame	30	40	40	30
Watermelons	90	-	65	200
Sorghum	280	-	430	60

1/ Based on "Agricultural Economic Survey, Jordan Valley", United Nations Organization, 1953.

2/ Fruit yields and production are based on trees or vines of bearing age.

Table 3.2-3

Estimated Distribution of Irrigated Crops With Project Development (Sheet 1 of 2)

Crops	Pattern "A" Donums	Pattern "A" Percent	Pattern "B" Donums	Pattern "B" Percent
CEREALS				
Wheat	121,000	24	70,600	14
Barley	55,500	11	-	-
Corn	17,600	3½	20,200	4
Rice	-	-	30,300	6
Sorghum	37,800	7½	20,200	4
Sub-total	231,900	46	141,300	28
VEGETABLES				
Tomatoes	22,700	4½	30,300	6
Potatoes	30,300	6	30,300	6
Cucumbers	11,300	2¼	15,150	3
Marrow	11,300	2¼	15,150	3
Cabbage	7,575	1½	7,575	1½
Cauliflower	7,575	1½	7,575	1½
Beans	22,600	4½	25,200	5
Eggplant	11,300	2¼	10,100	2
Watermelon	11,300	2¼	10,100	2
Peas	11,300	2¼	10,100	2
Onions	10,000	2	10,100	2
Sub-total	157,250	31¼	171,650	34
INDUSTRIAL CROPS				
Cotton	-	-	30,300	6
Peanuts	32,800	6½	20,200	4
Sesame	25,200	5	10,100	2
Sugar Beets	63,000	12½	60,600	12
Sub-total	121,000	24	121,200	24
FRUITS				
Bananas	31,500	6¼	30,300	6
Citrus	31,500	6¼	35,300	7
Dates	-	-	10,100	2
Others	12,600	2½	15,150	3
Sub-total	75,600	15	90,850	18

Table 3.2-3

Estimated Distribution of Irrigated
Crops With Project Development
(Sheet 2 of 2)

Crops	Pattern "A" Donums	Pattern "A" Percent	Pattern "B" Donums	Pattern "B" Percent
FORAGE				
Alfalfa	Hay and		80,800	16
Mangels	Fodder Crops		10,100	2
Cowpeas			10,100	2
Sub-total	88,200	17½	101,000	20
TOTAL GROSS CROP AREA	673,950	134	626,000	124
TOTAL NET CROP AREA	504,200	100	504,200	100
DOUBLE CROP AREA	169,750	34	121,800	24

Table 3.2-4

Estimated Crop Production
With Project Development

Crop	Yield/Donum (Kilograms)
CEREALS	
Wheat	190
Barley	210
Corn	340
Rice	380
Sorghum	320
VEGETABLES	
Tomatoes	1,680
Potatoes	1,550
Cucumbers	1,460
Marrow	1,750
Cabbage	2,120
Cauliflower	1,650
Beans	1,460
Eggplant	1,660
Watermelon	1,970
Peas	1,500
Onions	2,050
INDUSTRIAL CROPS	
Cotton	90
Peanuts	300
Sesame	65
Sugar Beets	3,100
FRUITS	
Bananas	2,600
Citrus	1,700
Dates	1,200
Others	1,000
FORAGE CROPS	
Alfalfa	1,300
Mangels	2,000
Cowpeas	1,500

Table 3.2-5

Data for Recommended Crops
(Sheet 1 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
CEREAL CROPS							
Corn (Maize)	Medium	March 1 May 15	August 1 October 1	5.0 4.5	0.91	340	Earworms (Heliothis sp.). Treat with DDT in oil, or apply as spray.
Rice	Medium	May 1	October 1	5.0	10.00	380	Weeds. Adequate submergence.
Sorghum	Medium	May 1 May 15	August 15 September 1	3.5 3.5	3.41	320	(If followed by other cereals, land should be heavily fertilized with nitrogen)
Barley	High	November 15	April 15	5.0	11.34	210	Powdery Mildew, Wheat Leaf Miner (Syringopias temperati[illegible]), Short-winged Wheat Leaf Beetle (Marseulia sp.). Seed selection and crop rotation.
Wheat	Medium	November 15 November 15	May 15 April 15	6.0 5.0	10.21	190 165	Same as Barley.
INDUSTRIAL CROPS							
Cotton	High	March 15	November 1	7.5	2.27	90	Boll Weevil (Anthonomus grandis). Dusting with nicotine.
Peanuts	Medium	May 1	September 15	4.5	3.40	300	None noted to date.
Sesame	Medium	May 1	July 15	2.5	1.00	65	Seed pods split and scatter. Seed selection.
Sugar Beets	High	October 1	April 1	6.0	0.56	3,100	New crop to area. Maybe attacked by locust.
TRUCK CROPS							
General Vegetables							
Cabbage	Medium	*September 1	January 15	4.5	**1,800	2,120	Aphids - dusting with "Derrimac". Cabbage Caterpillers - dusting with DDT or "Agricide".
Cauliflower	Medium	*September 1	January 15	4.5	**1,350	1,650	Same as Cabbage.
Cucumbers	Medium	February 1	June 1	4.0	0.22	1,460	Cutworms - DDT dust. Powdery Mildew - crop rotation.
Eggplant	Low to Medium	*March 15 *May 1	June 15 August 1	3.0 3.0	**1,350	1,660	Root rot. Selection of resistant varieties.
Marrows (Squash)	Medium	February 1	June 1	4.0	0.32	1,750	Same as Cucumbers.

Table 3.2-5

Data for Recommended Crops
(Sheet 2 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
TRUCK CROPS General Vegetables (Cont'd) Onions	Medium	September 1 *December 1	May 1 May 1	8.0 5.0	0.23 **25,000	2,050 2,050	Thrips are trouble some. Contolled by DDT
Peas (Garden)	Medium	January 1	April 1	3.0	8.50	1,500	Not serious.
OTHER CROPS Broadbeans (Horsebeans)	Medium	September 1	January 1	4.0	14.06	1,460	Not a problem at present.
Green Beans	Low	September 1	January 1	4.0	6.82	1,460	Not a problem at present.
Melons (Watermelons)	Low	February 1 February 1	July 1 June 15	5.0 4.5	0.45 0.45	1,970 1,800	Cutworms - DDT dust. Powdery Mildew - crop rotation.
Potatoes	Low to Medium	October 1 September 15	February 15 January 15	4.5 4.0	113.40 113.40	1,550 1,250	Aphid - dust with nicotine sulfate. Cutworms - dust with DDT. Curlytop, a virus disease-seed selection. Late Blight, a fungus disease - treat with "Paranox" or "Cupravit". Crop rotations are helpful in disease control.
Tomatoes	Medium	*August 15 May 15	December 15 September 15	4.0 4.0	**1,350 **1,350	1,680 1,680	Late Blight, a fungus disease - treat with "Paranox" or "Cupravit". Insect damage not serious.
FRUITS Bananas	Medium to High	Any Month	Year round - heaviest in August	72 (6 Years)	**110	2,600	Not a problem at present.
Date Palms	High	May 1 to July 1	September 1 to December 1	144 (12 Years)	** 16	1,200	Not a problem at present.
Grapes	Medium	January 1 to March 1	June 1 to July 1	36 (3 Years)	**110	1,000	Grape Bud Moth - controlled by "Ostico" or "Folidol". Powdery Mildew - treat with "Paranox" or "Cupravit". (Young plants sensitive to salinity)
Grapefruit, Oranges and Tangerines	Low to Medium	December 1 to February 1	November 1 to March 1	240 (20 Years)	** 50	1,700	Mediterranean Fruit Fly-trap in jars baited with "Clensel". Black scale - treat in dormant stage with "Ovicide" or spray in summer with "Folidol", "Arboleum", "Triond" or "Volk".

Table 3.2-5

Data for Recommended Crops
(Sheet 3 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
FRUITS (Cont'd) Lemons	Low	December 1 to February 1	Main Crop: August 1 to March 1 Secondary Crop: Balance of year	(Indefinite)	** 50	1,700	Same as Grapefruit.
Pomegranates	Low	December 1 to February	August 1 to November 1	(Indefinite)	**110	1,000	Mediterranean Fruit Fly-trap in jars baited with "Clensel". Control must be on a community basis.
FORAGE CROPS Alfalfa	Medium	October 1 to November 15	(6 Months after planting and every 45-60 days thereafter)	36 (3 Years)	3.18	1,300	New crop to area. May need control for locust. (After 3 years turn under as a green manure.)
Clover	Medium	October 1 to November 1	(6 Months after planting and every 45-60 days thereafter)	36 (3 Years)	3.18	1,300	Same as Alfalfa.
Mangels	High	October 1	February 15	4.5	1.36	2,000	Not a problem at present.
Cow Peas	Medium	February 1	June 1	4.0	2.27	1,500	Not a problem at present.

* Transplanting date.
** Plants per donum.

Table 3.2-5

Table 3.2-6

Diversion Requirements for Northern Zone (in mm)

Crop	K	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cereal Crops													
Corn	.85	33	55	116	199	242	273	281	272	235	200	119	52
Rice	1.20	46	78	164	282	342	387	398	386	333	284	168	74
Sorghum	.80	31	52	109	188	228	258	265	257	222	189	112	49
Wheat	.85	33	55	116	199	242	273	281	272	235	200	119	52
Industrial Crops													
Cotton	.65	25	42	89	153	185	209	215	209	180	153	91	40
Peanuts	.65	25	42	89	153	185	209	215	209	180	153	91	40
Sesame	.80	31	52	109	188	228	258	265	257	222	189	112	49
Sugar Beets	.80	31	52	109	188	228	258	265	257	222	189	112	49
Sugar Cane	.90	35	58	123	212	256	290	298	289	250	213	126	55
Truck Crops													
General Vegetables	.80	31	52	109	188	228	258	265	257	222	189	112	49
Beans	.75	29	49	102	176	214	242	249	241	208	177	105	46
Potatoes	.75	29	49	102	176	214	242	249	241	208	177	105	46
Tomatoes	.70	27	46	95	164	200	226	232	225	194	165	98	43
Fruits													
Bananas	1.30	50	84	177	306	370	419	431	418	361	307	182	80
Citrus	.65	25	42	89	153	185	209	215	209	180	153	91	40
Dates	1.20	46	78	164	282	342	387	398	386	333	284	168	74
Deciduous	.65	25	42	89	153	185	209	215	209	180	153	91	40
Grapes	.65	25	42	89	153	185	209	215	209	180	153	91	40
Forage Crops													
Alfalfa	.85	33	55	116	199	242	273	281	272	235	200	119	52
Clover	.85	33	55	116	199	242	273	281	272	235	200	119	52
Mangels	.80	31	52	109	188	228	258	265	257	222	189	112	49
Peas	.80	31	52	109	188	228	258	265	257	222	189	112	49

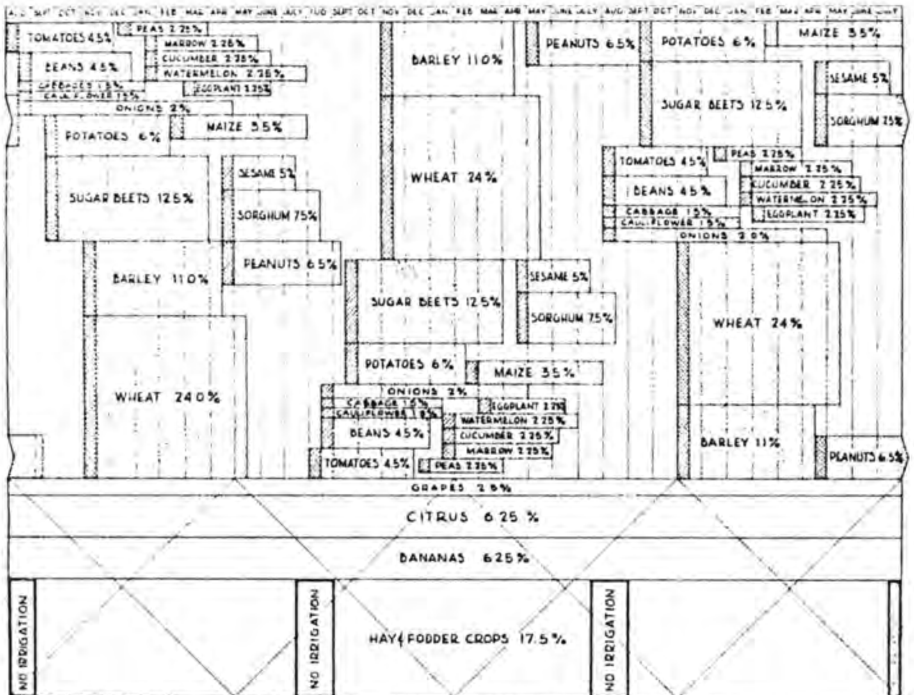
Table 3.2-6

Table 3.2-7

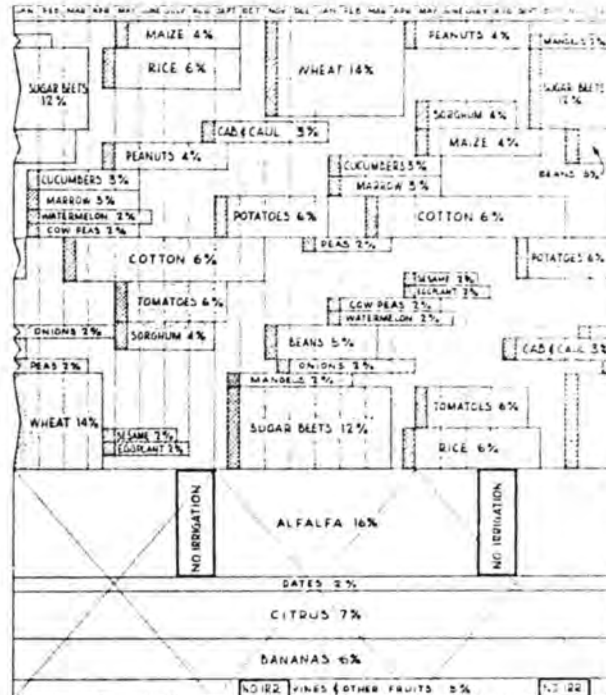
Diversion Requirements
for
Southern Zone
(in mm)

Crop	K	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cereal Crop													
Corn	.85	109	134	178	200	249	285	290	275	233	202	166	137
Rice	1.20	154	189	252	284	352	404	411	388	330	286	236	194
Sorghum	.80	103	126	168	189	235	269	274	259	220	191	157	129
Wheat	.85	109	134	178	200	249	285	290	275	233	202	166	137
Industrial Crops													
Cotton	.65	84	102	136	153	191	218	222	210	179	155	127	105
Peanuts	.65	84	102	136	153	191	218	222	210	179	155	127	105
Sesame	.80	103	126	168	189	235	269	274	259	220	191	157	129
Sugar Beets	.80	103	126	168	189	235	269	274	259	220	191	157	129
Sugar Cane	.90	116	142	189	213	264	303	308	291	248	215	177	145
Truck Crops													
General Vegetables	.80	103	126	168	189	235	269	274	259	220	191	157	129
Beans	.75	97	118	158	177	220	252	257	243	206	179	147	121
Potatoes	.75	97	118	158	177	220	252	257	243	206	179	147	121
Tomatoes	.70	90	110	147	165	206	235	240	227	192	167	137	113
Fruits													
Bananas	1.30	167	205	273	307	382	437	445	421	358	310	255	210
Citrus	.65	84	102	136	153	191	218	222	210	179	155	127	105
Dates	1.20	154	189	252	284	352	404	411	388	330	286	236	194
Deciduous	.65	84	102	136	153	191	218	222	210	179	155	127	105
Grapes	.65	84	102	136	153	191	218	222	210	179	155	127	105
Forage Crops													
Alfalfa	.85	109	134	178	200	249	285	290	275	233	202	166	137
Clover	.85	109	134	178	200	249	285	290	275	233	202	166	137
Mangels	.80	103	126	168	189	235	269	274	259	220	191	157	129
Peas	.80	103	126	168	189	235	269	274	259	220	191	157	129

Table 3.2-7



CROPPING PATTERN A *Based on 3 year rotation Developed by UNRWA Agricultural Economist*



CROPPING PATTERN B *Based on 2 year rotation developed by Baker-Harza incorporating tentative data from representatives of the Jordan Govt*

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		ANNUAL
NORTHERN	IRRIGATION REQ	M³/DONUM	19	33	70	99	119	103	81	49	71	81	62	52		819
ZONE	DIVERSION REQ	M³/DONUM	30	51	107	152	185	158	126	75	109	125	95	49		1260
SOUTHERN	IRRIGATION REQ	M³/DONUM	64	81	107	100	125	107	84	50	70	82	80	84		1032
ZONE	DIVERSION REQ	M³/DONUM	99	124	165	153	189	165	150	77	108	126	123	129		1588

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		ANNUAL
NORTHERN	IRRIGATION REQ	M³/DONUM	16	29	59	76	112	123	108	86	95	77	49	26		856
ZONE	DIVERSION REQ	M³/DONUM	25	45	91	117	172	189	166	132	146	118	75	40		1316
SOUTHERN	IRRIGATION REQ	M³/DONUM	53	69	91	76	116	129	112	86	94	78	69	69		1042
ZONE	DIVERSION REQ	M³/DONUM	82	106	140	117	178	198	172	132	145	120	106	106		1602

LEGEND

- AREA UNDER IRRIGATION
- AREA UNDER PREPARATORY TILLAGE
- FALLOW LAND
- CONTINUATION OF CROP
- PERMANENT CROP

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

DIVERSION REQUIREMENTS
FOR
SPECIFIC CROPPING PATTERNS

MICHAEL BAKER JR INC
HARZA ENGINEERING COMPANY

ROCHESTER PENNA | 3-55 | DS 5-5

DS-5-5

VOLUME IV
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

IRRIGATION AND DRAINAGE

VOLUME IV - IRRIGATION AND DRAINAGE
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

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VOLUME IV - IRRIGATION AND DRAINAGE
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

PART 1. Present Water Use
Irrigation
Other Uses

Water Utilization

One of the purposes of this investigation was to determine in what manner and to what degree water resources could best be developed, with particular emphasis on the expansion and intensification of irrigation agriculture. Present methods of irrigation and drainage were appraised, and information was assembled regarding the suitability of available water for use in sustained irrigation of the soils in the Jordan Valley. Studies were made to determine water requirements and to develop an irrigation regimen and drainage system for the project.

PART 1. PRESENT WATER USE

Irrigation

Irrigation has been a feature in the development of agriculture in the Jordan Valley since the earliest times of which there is any record. Evidence of old works indicates that at one time this area was much more highly developed and more intensively cultivated than today, supporting a population considerably larger than the present, and permitting export of agricultural products to surrounding areas. Some of these early developments, principally among those constructed during the time of the Roman occupation, continue in use even now. Earlier prosperity, resulting chiefly from the nearby overland trade routes, created a demand for the produce of the Valley. However, because of changes in the trade routes and movement of population centers, this demand diminished and irrigation works were neglected to the point where most of them become inoperative.

At the present time, to varying degrees of intensity, water for irrigation is supplied by gravity flow from the Yarmouk and Zarqa Rivers, by pumping from the Jordan River, by gravity flow from perennial wadis, by springs, by wells, and by ancient fuquarās constructed for development of ground water. There have been only minor attempts to coordinate these sources of water, and no plan integrating all water supplies into one system providing optimum development of the Jordan Valley has ever been put into effect.

Irrigation from Wadis

The largest areas of irrigated land in the valley of the Jordan derive their water from the flows of tributary wadis. Because of the similarity in problems and development the River Zarqa will be discussed in this group.

Of the cultivated area east of the Jordan River, 184,293 donums lying on the ghor have been registered as irrigated from ten wadis. Exact registration figures for the West Ghor are not available, but it is estimated that on this side of the river approximately 31,000 donums are irrigated from the flows of Wadi Fari'a and Wadi Auja. Almost all of the normal flows from these wadis is used for irrigation, but the areas served have been over-extended, distribution systems have not been efficiently designed or constructed, and shortages have inevitably resulted. Current rotation practices vary widely from two to as much as six years. Furthermore, in the absence of a coordinated over-all system, it has not been possible to conserve and utilize flood waters to any extensive degree.

Surface run-off at the present time is utilized only during the period of the rainy season and only then on lands not otherwise under irrigation or lands where irrigation waters must be supplemented. The general method of utilization of surface run-off is to divert the water with dikes and small channels so a spreading effect is achieved. Retention of this additional water is often needed to assure sufficient moisture for winter crops, especially small grains.

With the establishment of the Irrigation Department of Jordan in 1948, steps were initiated to facilitate control of these registered irrigated areas in a more progressive and efficient manner. Diversion structures with appurtenant control works and sluice gates have been constructed in eight wadis, and the related supply and distribution systems are partially completed. Most of the lined canals which have been constructed lie above the locations of the proposed East Ghor and West Ghor Main Canals, and can be integrated into the over-all development by extensions roughly parallel to the Main Canals, and appropriate exchange of water use. The portions of the existing systems which lie below the proposed Main Canal, consisting principally of inefficient, unlined supply and distribution channels, have not been considered in the integrated plan.

Wadi Arab - The diversion dam in Wadi Arab was constructed in 1948. Two supply canals were constructed, one on the north side of the wadi and one on the south. About one Kilometer of North Canal was constructed with reinforced concrete lining, while the remainder of the supply canals and distribution laterals totalling approximately 45 Kilometers are in unlined earth channels.

The gross area registered as irrigated from the wadi below the headworks is 14,323 donums. In 1950 the mean annual percentage of cropping recorded by the Irrigation Department was 44.7%.

Wadi Ziglab - The diversion dam in Wadi Ziglab was constructed in 1949. Two main supply canals, the North Branch and the South Branch, were lined with rubble masonry for a total distance of 3,625 meters. The remainder of the supply canals and distribution laterals in this system are in unlined earth channels.

The gross area registered as irrigated in Wadi Ziglab is 13,629 donums, while the mean annual percentage of cropping recorded in 1949 was 55%.

Wadi Jurum - The gross area commanded by the diversion dam in Wadi Jurum and registered as irrigated is 12,376 donums. Rubble masonry lining has been installed in 510 meters of canal and concrete lining in 3,725 meters of canal. The remainder of the supply canals and distribution laterals in this area are in unlined earth channels.

Wadi Yabes - There is a gross total of 8,140 donums registered as irrigated from Wadi Yabes. However, no modern irrigation works have been constructed in this area.

Wadi Kufrinja - In the area commanded by the diversion dam in Wadi Kufrinja, 11,432 donums have been registered as irrigated. Two supply canals have been constructed, the North Branch, known as the Hamra Canal, and the South Branch, known as the Fagaris Canal. The Fagaris Canal passes through the village of Kreimeh, where it branches to the east and to the west. The Hamra Canal has been lined with concrete for a distance of 1,802 meters, and the Fagaris Canal has been lined for a distance of 2,672 meters. Other reaches of supply canal or distribution lateral in this area are in unlined earth channels.

Wadi Rajeb - No modern works have been constructed to serve lands irrigated by diversions from Wadi Rajeb, although 9,085 donums are registered as irrigated in that area.

River Zarqa - A reinforced concrete diversion structure has been constructed across the River Zarqa. Six Kilometers of Main Canal with reinforced concrete lining have been constructed, including an aqueduct over the river. Approximately 115 Kilometers of unlined earth channels complete the supply and distribution system in this area. The gross area registered as irrigated from the River Zarqa amounts to 50,000 donums located in Ghors Deir Alla, Tiwal, Damiye, Abu Obeydeh and Shiqaq.

Wadi Shueib - A gross area of 22,709 donums located in Ghors Nimrin and Adwan, is registered as irrigated. Diversions from Wadi Shueib constitute the principal source of water for this area, although some lands are irrigated from wells. A concrete diversion structure has been constructed across Wadi Shueib, as well as a concrete lined supply canal which starts on the north side and then branches to the north and to the south. The south branch crosses the wadi on an aqueduct and continues down the left bank through Shunat Nimrin Village.

Wadi Kafrein - A total of 21,303 donums has been registered as irrigated by diversion of the flows of Wadi Kafrein. No modern irrigation works have been constructed in this area.

Wadi Hisban - A total of 21,296 donums has been registered as irrigated by diversion of the flows of Wadi Hisban. No modern irrigation works have been constructed in this area.

Wadi Fari'a - Existing developments in the Wadi Fari'a area are the largest and most important of those along the West Ghor. It is estimated that 16,000 donums are irrigated in the wadi proper and on Ghor Fari'a. This system includes a modern diversion structure, about ten Kilometers of concrete lined main canal, and a system of concrete lined distribution laterals. Appurtenant conveyance, measuring, control and protective structures have been built, together with drinking places and bridges.

Wadi Auja - A total area of 15,000 donums is estimated to be irrigated by diversion of the flows of Wadi Auja. This area is located in Ghors Arab el Abid and Arab el Ka'abina, in the vicinity of Auja Tahta Village. A diversion dam has been constructed, together with a lined supply canal and a system of lined distribution laterals.

Irrigation from the Yarmouk River

In the area between the Baha'i Village of Adasiye and Baqura Village, a gross total of 5,000 donums has been registered as irrigated by gravity flows diverted from the Yarmouk River. A crude dumped rock diversion dam, requiring constant maintenance, has been constructed across the river. Supply canals and distribution laterals are not lined, although some rubble masonry division boxes and turnouts have been built. Through applications of manure and commercial fertilizer, it has been customary to produce two or three crops annually in this area.

Irrigation from the Jordan River

Significant amounts of land lying on the zor, or flood plain of the Jordan River, are presently irrigated with water pumped directly from that river. Observations indicate that 12,095 donums are irrigated in this manner. In general the pumping plants are comparatively small, and limited areas are served by each plant. Distribution systems are of relatively inefficient design and because of the general characteristics of the soils encountered, disproportionately large percentages of the water pumped have been lost or wasted. These lands have in the past been subject to recurrent flooding by overflows from the Jordan River during periods of high run-off, a hazard which will be eliminated by construction of control structures on the Yarmouk and Jordan Rivers. However, upstream diversions and regulated flows in these rivers will contribute to an increase in the salinity of the waters of the lower Jordan and probably this source of irrigation water must of necessity be abandoned in the foreseeable future.

Irrigation from Springs and Wells

On the East Ghor 1,960 donums lying in the Wadi Arab area are registered as irrigated from Duga Spring, located about 4 Kilometers above the mouth of the wadi. In the Wadi Jurum area 2,660 donums are registered as irrigated from 5 small springs located within the irrigated area about 2 Kilometers west of the diversion dam. Certain minor areas, particularly in the vicinity of Wadi Shueib, Wadi Kafrein and Wadi Hisban, receive either a full or supplemental supply of irrigation water from wells.

On the West Ghor in what is known as the Jericho area, lying between Wadi Auja and the Dead Sea, it is estimated that some 8,000 donums are irrigated partly from springs and partly from wells. The irrigated areas are scattered here and there near the wells, or near springs such as Ain Nu'iema, Ain Duyuk and Ain Sultan. Other areas below the Jericho-Jerusalem road are irrigated from Qilt and Fawwar springs through a canal running from Wadi Qilt.

Few of the wells used for irrigation have been in useful intensive production long enough to establish the recharge rate. Furthermore, in many of the wells the quality of the water is questionable except for the production of highly salt tolerant crops. Particularly in shallow wells the quality may be expected to deteriorate as intensive irrigated agriculture is developed in surrounding areas.

Irrigation from Historical Works

Evidence of 22 fuquarās, constructed during the Roman occupation for development of ground water, has been discovered in the Jordan Valley. Two minor areas continue to receive irrigation water from these ancient sources. The flow from one fuquarā is used to irrigate an area on the East Ghor north of Wadi Shueib, and the flows from three fuquarās have been combined to irrigate an area on the West Ghor north of Wadi Fari'a. It is also probable that many of the springs within the Jordan Valley are the only remaining outward manifestations of other historical developments which have become blocked and lost through lack of maintenance.

Subsurface Drainage

Presently very little use is made of subsurface drainage waters. There are some instances where shallow open ditches have been constructed for draining high water table areas and such water has sometimes been used for irrigation purposes, but as a whole facilities for subsurface drainage of such areas are inadequate. There are certain locations in the northern part of the East Ghor where subsurface waters find their way to the zor below and these waters are reused for irrigation and for livestock and domestic water. In some instances drainage water has percolated through soils of a saline nature and the use of such water has done much to lower production on the zor lands.

Other Uses

Domestic and Livestock

There has been practically no development of water in the Jordan Valley solely for domestic use or for use by livestock. The supply for

Jericho, which is at present being modernized to a certain degree, comes from Elisha's Spring. Other villages in the valley have in general been established near perennial wadis, or more recently near canals constructed primarily for irrigation, and these open channels have provided a source of water for both humans and livestock, in spite of extreme hazard of pollution. Spring water and well water is also used to a minor extent. A large proportion of the population is nomadic, moving to the uplands in summer and back to the valley in winter, and the needs of these people for water for all purposes are satisfied simply by settling near an existing supply.

Salt Works

Within the project area is an ancient development for securing salt. These salt works are located on the East Ghor immediately north of the River Zarqa. The area from which salt is produced covers some 4,000 donums and is bounded by arable lands on all sides. Even though salt is still being produced by essentially the same inefficient method employed in olden time, the lands of this area are probably worth more as a source for salt than for agricultural purposes, if the cost of reclaiming such lands is considered. Because of high water the process for securing salt can only be carried on 3 or 4 months out of the year. Too, water from this area has infiltered adjacent areas and caused agricultural lands to go out of production. By controlling the water table of these salt beds, production could possibly be carried on 9 months out of the year, and adjacent lands could be protected from salt water encroachment. No drainage waters from this area could be used for any purpose other than a source of salt. Even though this area has produced salt for centuries full utilization of the resources has never been attained.

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PART 2. Quality of Water
- Scope of Investigations
- Methods and Analyses
- Computations and Interpretations
- Example

PART 2. QUALITY OF WATER

Scope of Investigations

Quality of water is an important consideration in any appraisal of conditions in an area to be irrigated.

Many incomplete investigations have been conducted in the past in connection with the quality of water from the various sources proposed for irrigation of the Jordan Valley. In many cases these investigations covered only restricted fields, such as determination of total dissolved solids, chlorinity or salinity, which, while valuable as background material and for correlation of the relative adaptability of various sources, permit only a limited interpretation of the suitability of the waters for use in irrigation agriculture. In addition to the concentration of dissolved constituents, as determined by analysis or from electrical conductivity, the composition of these constituents is of major importance in determining the quality of water in relation to its use in irrigating a specific area. In the limited time available for the present investigation it was not possible to complete an adequate study of all factors affecting the quality of water. The purpose of this investigation was, therefore, to supplement previous findings, and either to confirm or refute earlier interpretations.

In this discussion consideration is given only to the quality of water from major sources, the Yarmouk River, the Jordan River, the River Zarqa and certain perennial wadis tributary to the Jordan River since these represent the sources recommended for use on the project.

Additional information regarding the quality of water from other sources is discussed elsewhere in this report.

Methods and Analyses

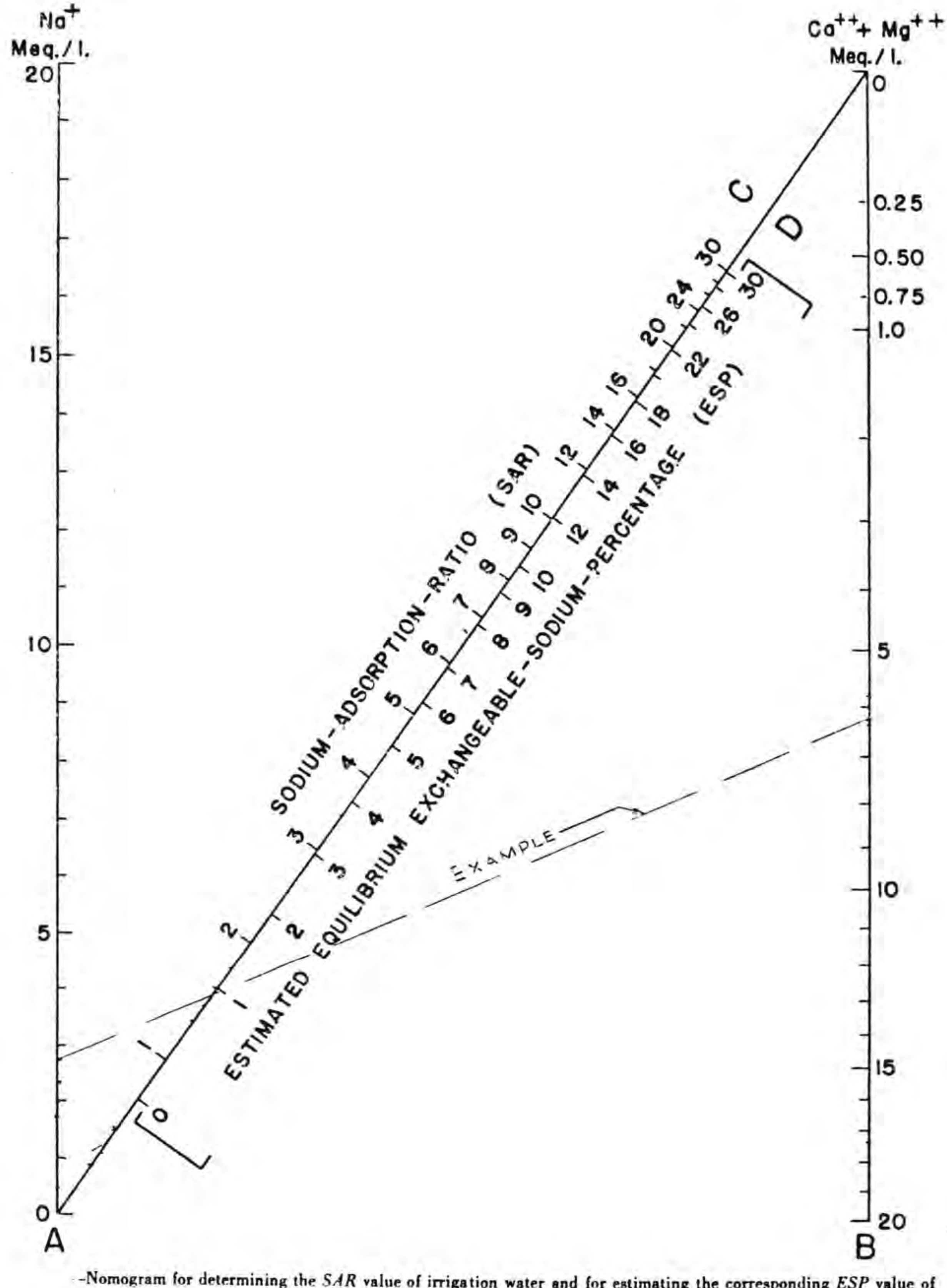
For convenient interpretation of data, waters have been classified in accordance with the system based on electrical conductivity and the sodium-adsorption-ratio. A nomogram for determining the sodium-adsorption-ratio is presented on page 12, the diagram for the classification of irrigation waters by the method mentioned is on page 13, and an example of the use of the two is on page 20. The drawings and the general methods of analysis used are from Agriculture Handbook No. 60, United States Department of Agriculture. The following laboratory tests were made on water samples analyzed:

Electrical Conductivity	- EC
Total Dissolved Solids	- TDS
Calcium	- Ca
Magnesium	- Mg
Sodium	- Na
Potassium	- K
Chloride	- Cl
Sulfate	- SO_4
Carbonate	- CO_3
Bicarbonate	- HCO_3

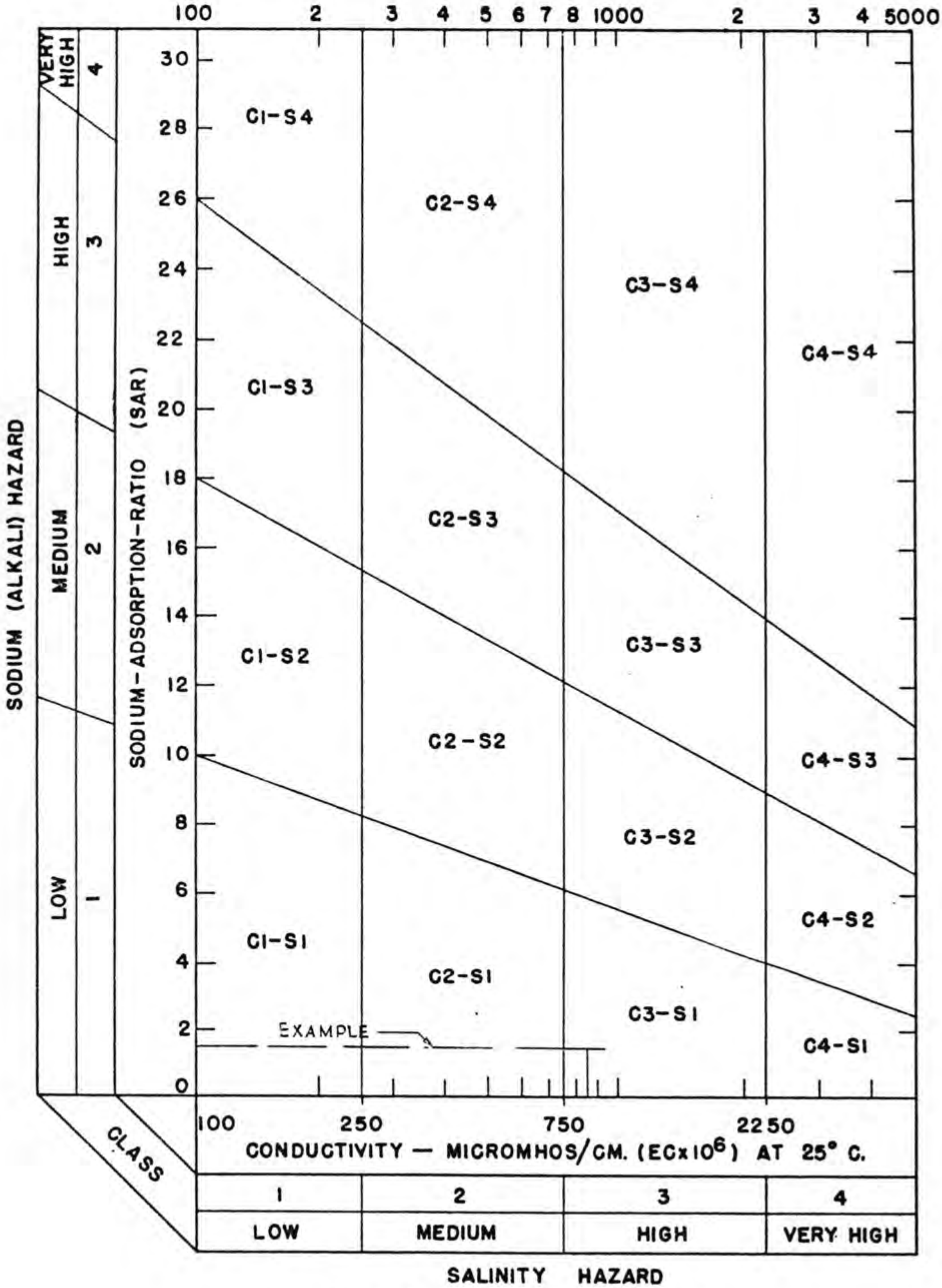
In addition, occasional tests were made for the presence of boron (B), but none of the samples so analyzed contained boron in anything approaching a toxic concentration. Other symbols used are:

Hydrogen ion concentration	- pH
Soluble-sodium percentage	- SSP
Sodium-adsorption-ratio	- SAR

In these investigations, the Jordan River was sampled at two locations, one immediately below the confluence of Wadi Malih and the river, and the other at Allenby Bridge. The Yarmouk River was sampled near Adasiye. The Zarqa River and the perennial wadis were sampled in



-Nomogram for determining the *SAR* value of irrigation water and for estimating the corresponding *ESP* value of a soil that is at equilibrium with the water.



–Diagram for the classification of irrigation waters.

each case near the point where the stream leaves the gorge cutting through the escarpment and enters upon the ghor.

Computations and Interpretations

Average or representative analyses of water samples from the various locations cited, together with the classification of each of these waters is given in Table 4.2-1 which follows. The significance and interpretation of the quality-class ratings, as established in Agriculture Handbook No. 60, are summarized below:

Conductivity

"LOW-SALINITY WATER (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

"MEDIUM-SALINITY WATER (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

"HIGH-SALINITY WATER (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

"VERY HIGH SALINITY WATER (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Sodium

"The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

"LOW-SODIUM WATER (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

"MEDIUM-SODIUM WATER (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

"HIGH-SODIUM WATER (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

"VERY HIGH SODIUM WATER (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

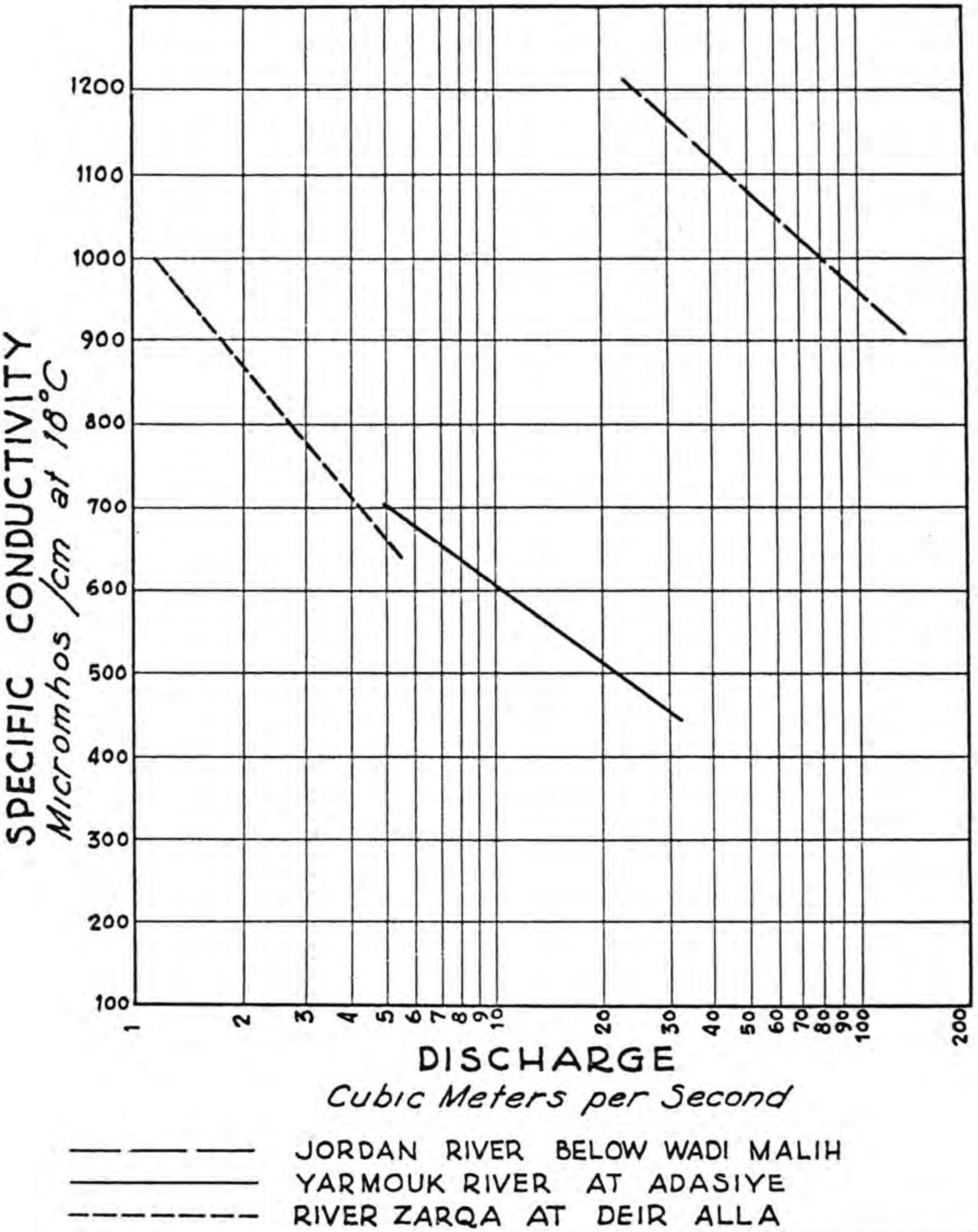
"Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of C1-S3 and C1-S4 waters. For calcareous soils with high pH values or for non-calcareous soils, the sodium status of waters in classes C1-S3, C1-S4, and C2-S4 may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2-S3 and C3-S2 waters are used".

The quality of the water in all the streams investigated deteriorates with diminished flows. Approximations of the discharge-quality relations for the Jordan River below Wadi Malih, the Yarmouk River near Adasiye and the River Zarqa at Deir Alla are shown on Drawing No. JR-50. Any major and permanent change in the regimen of these rivers will

Table 4.2-1

Average Water Analyses

Location	Temp. °F	pH	$ECx10^6$	TDS	Na	Ca	Mg	Cl	CO_3	HCO_3	SO_4	NO_3	B	SSP	SAR	Class
					Milliequivalents per Liter											
Jordan River at Wadi Malih	68	7.4	992	706	5.76	2.85	2.35	6.54	-	3.11	1.18	0.21	-	52.6	3.6	C3-S1
Jordan River at Allenby Bridge	68	7.9	2,402	1,681	15.74	5.11	7.86	21.66	.09	3.58	3.35	-	-	54.8	6.2	C4-S2
Yarmouk River near Adasiye	63	7.5	681	485	2.24	1.90	1.71	1.72	.03	3.21	0.83	0.16	-	38.3	1.7	C2-S1
River Zarqa near Deir Alla	60	7.4	849	621	2.80	3.49	2.68	3.18	.08	3.59	1.41	0.54	-	31.2	1.6	C3-S1
Wadi Arab	65	7.4	680	550	1.26	3.30	3.10	1.43	.08	4.88	1.14	0.46	-	16.4	0.8	C2-S1
Wadi Ziglab	69	8.2	781	547	0.65	3.75	3.60	1.69	.87	5.11	0.31	-	-	8.1	0.4	C3-S1
Wadi Yabes	64	7.5	400	369	0.78	2.55	1.64	0.84	-	3.67	0.12	0.32	-	15.7	0.5	C2-S1
Wadi Kufrinja	62	7.5	458	321	0.48	2.40	1.48	0.73	-	3.20	0.17	0.24	-	11.0	0.3	C2-S1
Wadi Rajeb	62	7.4	487	341	0.43	2.55	1.56	0.68	-	3.44	0.25	0.24	-	9.5	0.3	C2-S1
Wadi Shueib	70	8.3	478	335	0.48	2.65	1.80	0.79	0.40	2.84	0.33	-	-	9.7	0.3	C2-S1
Wadi Auja	64	8.1	464	325	0.43	2.35	1.88	0.79	0.57	3.20	0.10	-	-	9.2	0.3	C2-S1



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invalidate the determined relationship. Thus, the relationship for the Jordan cannot be used to estimate the water quality when significant portions of the flows of the Yarmouk River are diverted. The curves will, however, be useful in estimating the quality of stored or diverted water, and in appraising the anticipated quality of blended flows.

Conclusions

Waters of the Yarmouk River, or of Wadis Arab, Yabes, Kufrinja, Rajeb, Shueib or Auja, can be used for irrigation agriculture with little probability that soil salinity will develop, providing a moderate amount of leaching occurs during normal irrigation operations. Waters of the River Zarqa or of Wadi Ziglab should not be used alone on soils with restricted drainage, and even with adequate drainage it is probable that some method of salinity control would be required. However, water from these latter two sources would require only slight dilution with water of better quality to remove any significant hazard of saline contamination through their use. Therefore, under the normal recommended operation of the project, no special restrictions need be placed on use of water from the River Zarqa or Wadi Ziglab. Water from any of these tributaries of the Jordan can be used with little probability of the development of harmful concentrations of exchangeable sodium.

Waters of the reaches of the Jordan River between the Yarmouk River and Wadi Malih could at present be used for irrigation of soils with adequate drainage, although special management for salinity control might be required. However, the quality of water in the Jordan River deteriorates as it flows toward the south, until in the reach below the Allenby Bridge, it is at best of border line quality for any use in irrigation agriculture.

With diversion of the flows of the Yarmouk River and the possibility of diminution of the flows of the Jordan River below Lake Tiberias, it is probable that the quality of the water in the Jordan will drop below the permissible limits of use in irrigation agriculture. Therefore, the use of water diverted directly from the Jordan River is not recommended.

Use of Sodium-Adsorption-Ratio Nomogram (Page 12) and Classification Diagram (Page 13)

EXAMPLE

Classification of irrigation waters from data in laboratory analyses is illustrated by the following:

1) Take the analyses for the River Zarqa near Deir Alla which appears as line 4 in Table 4.2-1 on page 16.

2) From this table read the following values:

Electrical Conductivity	-	849
Milliequivalents per liter, sodium(Na)	-	2.80
Milliequivalents per liter, calcium(Ca)	-	3.49
Milliequivalents per liter, magnesium(Mg)	-	2.68

3) Plot milliequivalents per liter of sodium on Scale A on the nomogram on page 12.

4) Add the milliequivalents per liter of calcium and magnesium and plot the result, 6.17, on Scale B of the same nomogram.

5) Connect the two points and read the sodium-adsorption-ratio (SAR) as 1.5 on Scale C.

6) Plot sodium-adsorption-ratio (SAR) of 1.5 on the vertical scale on the left of the diagram on page 13 and project a horizontal line from this point.

7) Plot the conductivity of 849 on the horizontal scale at the bottom of the same diagram and project a line vertically upward to intersect the sodium-adsorption-ratio (SAR) line.

8) Note the group in which the point of intersection falls, in this case, group C3-S1. From definitions on pages 14 and 15 it is found that this is a high salinity, low sodium water which can be used only when there is adequate drainage, and even then special management practices are necessary for the control of salinity. Ordinarily, only those crops with high salt tolerance should be irrigated with this water.

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PART 3. WATER REQUIREMENTS

Introduction

Irrigation requirements, the results of integration and correlation of physical data and climatic phenomena, are the bases for adequate design and efficient operation of any irrigation project. The physical characteristics of the crop, which determine its consumptive use coefficient, together with variations in rainfall, temperature, relative humidity, and location, which determines duration of daytime hours, all enter into the final irrigation requirement for each individual crop. When these data have been combined for all the different crops, the overall irrigation requirement for the project may be determined.

Several different methods of integration and correlation have been studied, and from these there have emerged two which have gained wide acceptance. Both combine climatological and irrigation data. The Lowry-Johnson method makes use of the effective heat and requires a long period of temperature records for acceptable results. The second, the Blaney-Criddle method, correlates latitude, temperature, crop and consumptive use. Its application in widely separated parts of the world has resulted in comparable results for the same crop even though the period of record of climatic data has been relatively short. Because of this feature, it has been selected as the method for use in determining irrigation requirements for this project. In its simplest form the

Blaney-Criddle formula is:

$$f = t \times p \quad (1),$$

from which the following relations can be derived:

$$u = f \times k \quad (2), \text{ and}$$

$$IR = u - r \quad (3).$$

The more frequently used terms, symbols and notations used in computing irrigation and water requirements are presented and defined in the following section:

Terms, Symbols and Notations

Definition of Terms

The more important terms as defined and used by the leading professional and technical societies and organizations dealing with irrigation follow:

1) Consumptive Use (Evapo-Transpiration). The sum of the volumes of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from adjacent soil, snow, or intercepted precipitation on the area in any specified time, divided by the given area. If the unit of time is small, such as day or week, the consumptive use is expressed in acre-inches per acre or depth in inches; whereas, if the unit of time is large, such as crop-growing season or 12-month period, the consumptive use is expressed as acre-feet per acre or depth in feet. (American Society of Agricultural Engineers and Soil Conservation Service)

2) Irrigation Requirement. The quantity of water, exclusive of precipitation, that is required for crop production. It includes surface evaporation and other economically unavoidable wastes. Usually expressed in depth (volume per unit area) for a given time. (American

Society of Agricultural Engineers.) (American Society of Civil Engineers.)

3) Field Irrigation Efficiency. The percentage of irrigation water delivered to the field that is available for consumptive use by crops. (Soil Conservation Service.)

4) Diversion Requirement. To the irrigation requirement is added an allowance for estimated deep percolation losses and waste in application on the farm and a further addition for estimated conveyance loss and waste between source of supply and the farm to give the diversion requirement. (Bureau of Reclamation.)

5) Effective Rainfall. That part of the total rainfall which is available for plant use. Usually, effective rains are those which exceed one half inch and occur within a few consecutive hours. It has been assumed, for the purposes of this report, that 80% of all rainfall is effective when the total exceeds 25 mm per month, and that none is effective when the total is less than 25 mm per month.

<u>Symbols and Notations</u>

Symbols and notations to express the conditions as presented above follow:

- IR Irrigation Requirement as defined in preceding section
- U Consumptive Use, total for any period as defined in preceding section
- F Sum of monthly consumptive use factors for any period
- K Crop coefficient for any period
- t Mean monthly temperature (Fahrenheit)

p Monthly percent of daytime hours of the year

f $\frac{t \times p}{100}$ = monthly consumptive use factor

k Monthly crop consumptive use coefficient (see K above)

u k x f, monthly consumptive use in inches

r Effective rainfall

Coefficients and Constants

Coefficients and constants which enter into the determination of irrigation requirements are discussed in considerable detail below:

Consumptive Use Coefficient

Each crop, and sometimes even different varieties of the same crop, has individual characteristics of which the most important is the monthly consumptive use coefficient (k), which varies but little from one location to another. Analyses of experimental work show that this factor does vary somewhat in monthly values but such variations are, as a rule, relatively small. For all practical purposes the monthly consumptive use coefficient (k) is numerically equal to the seasonal coefficient (K). Values and ranges of the consumptive use coefficient (K) as determined by workers in irrigation requirements in widely separated areas are presented in Table 4.3-1.

Table 4.3-1

Numerical Values of "K"
Consumptive Use Coefficient

CROP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	RANGE
	Source of Information										
Alfalfa	.85	.80- .85	.70-.85	.70-.85	.85	.85	.85	.85	.85	.85	.70- .85
Beans	.65	.60- .70	.60	.60	.65	.65	.65	.75	.70	.75	.60- .75
Beets, Sugar	.70	.65- .75	—	.70	.70	.70	—	.80	—	—	.65- .80
Cane, Sugar	—	.80	—	—	—	—	.90	—	—	—	.80- .90
Citrus	.55	.50- .65	.65	.65	.55	—	.65	—	—	—	.50- .65
Corn	.75	.75- .85	.75	.75	.75	.80	.80	.75	.75	.75	.75- .85
Cotton	.62	.60- .65	.62	.62	.62	—	—	—	.62	—	.60- .65
Flax	—	.80	—	.80	—	.80	—	—	—	—	.80
Grains, Small	.75	.75- .85	.60-.70	.70	.75	.75	.75	.75	.75	.75	.60- .85
Orchard (deciduous)	—	—	.65	.65	.65	—	—	—	—	—	.65
Pasture	.75	.75	.60-.75	.80	.75	.75	.75	.75	.75	.75	.60- .80
Peas	—	.80	—	—	—	—	—	—	—	—	.80
Potatoes	.70	.65- .75	—	.70	.70	.70	.70	—	.70	—	.65- .75
Rice	1.00	.85-1.20	—	—	1.00	—	1.00	—	—	—	.85-1.20
Sorghum	.70	.70	.70	.70	.70	—	.70- .80	.70	.70	—	.70- .80
Tomatoes	—	.70	—	—	—	—	—	—	—	—	.70
Truck	—	.80	.70	.55-.70	—	—	—	—	.75	—	.55- .80

(1) Blaney, Harry F. "Consumptive Use of Water", Transactions ASCE, Vol. 117, P. 964, 1952.

(2) Blaney, Harry F., and Criddle, Wayne D. "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data". SCS-TP-96, Washington, D.C., February, 1952.

(3) Blaney, Harry F., Hanson, Eldon, G., and Lits, G. Marvin "Consumptive Use and Irrigation Water Requirements of Crops in New Mexico", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., December, 1950. (Provisional)

(4) Blaney, Harry F., and Harris, Karl "Consumptive Use and Irrigation Water Requirements of Crops in Arizona", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., December, 1951.

(5) Criddle, Wayne D. "Consumptive Use of Water and Irrigation Requirements", JOURNAL OF SOIL AND WATER CONSERVATION, September, 1953.

(6) Erie, Leonard J. "Consumptive Use and Irrigation Water Requirements of Crops in South Dakota", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., March, 1952. (Provisional)

(7) Flanagan, Jeff E., and Cabezas R. "Requisitos de Riego para el Salvador", Boletin Tecnico No. 11, Centro Nacional de Agronomia, May, 1952.

(8) Hanson, Richard E., and Meyer, Walter R. "Irrigation Requirements, Estimates for Kansas", Kansas State College, Bulletin No. 69, June, 1953.

(9) Houston, Clyde E. "Consumptive Use of Irrigation Water by Crops in Nevada", the University of Nevada, Bulletin No. 185, July, 1950.

(10) Tomlinson, Byron R. "Estimate of Water Requirements of Crops", Wyoming Agricultural Experiment Station, University of Wyoming, Bulletin No. 303, February, 1951.

Duration of Daytime Hours

The monthly percentage of daytime hours in the year is a function of location, specifically latitude, and is a constant for a given latitude. Latitudes within the project area vary from 31°49' at the Dead Sea to 32°41' near Lake Tiberias. For purposes of this report the latitude of 32°0' has been used throughout. A check was made to determine to what extent this would affect the calculations and it was found that the greatest possible error that could be introduced by use of a single latitude would be less than one fourth of one percent. Monthly values of the constant (p) are shown below:

Table 4.3-2

Monthly Percent of Daytime Hours
(p)
For Latitude 32°0' North

Month	(p)	Month	(p)
January	7.04	July	9.62
February	7.57	August	9.13
March	8.18	September	8.47
April	8.87	October	7.82
May	9.44	November	7.22
June	9.75	December	6.89

Temperature

Temperature, while neither a coefficient nor a constant, is the most important single factor in the application of the consumptive use formula. It is an inherent characteristic of an area and data must be available before any of the methods can be applied. Such temperature data as are available are collected, compiled and mean monthly values determined before they enter into the calculations.

Data Available

There are no long term climatic data available within the project area; but there are seven locations as shown on the Base Map, JR-8, at which records of from 3 to 17 years are to be had. In addition, there are three reference stations adjacent to the project area (Jenin, Jerusalem, and Amman) that have complete records of 12 to 16 years duration. Temperature and rainfall data for these ten stations are portrayed in Drawing DS-5-3. In this drawing it will be noted that all stations have a similar temperature curve which reaches its peak in July or August. The rainfall pattern is not as clear cut as the temperature curve, and there is a marked decrease from north to south. Further, the records for all stations show several months of no effective rainfall. Detailed records of all these stations along with others both within and outside the project area are presented in Tables 4.3-6 to 4.3-23; while an index of data available at the stations used in computing irrigation requirements are presented in Table 4.3-3 which follows:

Table 4.3-3

Index of Climatic Data Available
For Computing Irrigation Requirements

Name	Latitude	Longitude	Elevation	Years of Record Temperature	Years of Record Rainfall
		Jordan Valley			
Degania	32°41'N	35°34'E	- 198 M	7	17
Wadi el Arab	32°36'N	35°37'E	- 197 M	4	4
Beisan	32°30'N	35°30'E	- 118 M	10	10
Wadi el Jurum	32°26'N	35°36'E	- 180 M	3	4
Tirath-Zvi	32°23'N	35°32'E	- 245 M	5	5
Jericho	31°51'N	35°27'E	- 250 M	13	22
Dead Sea (N)	31°49'N	35°34'E	- 392 M	15	17
		Adjacent Area			
Jenin	32°28'N	35°18'E	160 M	12	12
Amman	31°58'N	35°56'E	790 M	16	15
Jerusalem	31°47'N	35°14'E	827 M	13	16

Establishment of Zones of Consumptive Use and Irrigation Requirements

Many of the published reports dealing with irrigation in the Jordan Valley show three zones of irrigation requirements with widely divergent numerical values both by zones and months. Since the project area, which embraces the Yarmouk-Jordan Valleys between Adasiye Diversion Dam and the Dead Sea, is only slightly more than 100 Kilometers in length, it seemed highly unlikely that three zones would be encountered. A detailed examination was, therefore, made of all factors affecting Consumptive Use and Irrigation Requirements.

Consumptive Use

Temperature records throughout the project area and adjacent areas were examined in detail and plotted on Drawing DS-5-3. These curves show a remarkable uniformity of temperature throughout the entire project area. It had already been established that the use of one single latitude, 32° North, would introduce a maximum error of less than one fourth of one percent. Since temperature (t) and the monthly percent of daytime hours (p), which is a function of latitude, show little or no variation throughout the project area, the inevitable conclusion is that there is but one zone of Consumptive Use.

Irrigation Requirements

Rainfall varies considerably from one end of the project area to the other as is shown by Tables 4.3-6 to 4.3-23 inclusive and graphically demonstrated on Drawing DS-5-3. When these variations in rainfall are correlated to consumptive use it is found that there is sufficient variation to justify the establishment of two zones of Irrigation Requirements. While no hard and fast line can be drawn between these zones, the River Zarqa represents an approximate boundary between the northern zone of relatively high rainfall and the more arid southern zone.

Application of the Formula

The Blaney-Criddle method of determining consumptive use and irrigation requirements is dependent on the three factors just discussed as well as on effective rainfall. The percentage of daylight hours in the month (p) is taken from Table 4.3-2 and multiplied by the value of the temperature factor (t), taken from Table 4.3-24, "Mean Monthly Temperatures". The resultant is the monthly consumptive use factor (f) as shown in equation (1) on page 22. This is then multiplied by a monthly crop consumptive use coefficient (k) (Table 4.3-1) to determine the monthly consumptive use (u) as in equation (2) on page 22. The formula and its application is rather simple when expressed in English units of measurements, but becomes cumbersome when metric units are used. To obviate the tedious and cumbersome calculations involved in converting between English and metric units, the nomograph, Drawing DS-5-2, was developed to give a simultaneous solution in both systems using either system as the base. The same procedure as outlined above is used in the graphic solution which is illustrated by an example on the nomograph. After the monthly consumptive use (u) has been found, either by direct calculation or from the nomograph, the effective rainfall (r), is subtracted to determine the monthly irrigation requirement in accordance with equation (3) on page 22. Effective rainfall which was defined on page 23 can be computed for each station from data on Drawing DS-5-3. An examination of this drawing shows little or no effective rainfall at any time for the two stations in the southern zone. The same is true for stations in the northern zone during the summer months, but there is some effective rainfall at all stations during the winter. Effective rainfall computed from data on Drawing DS-5-3 was weighted according to years of record and distance from project area. These data which are the "r" used in computing irrigation requirements are in Table 4.3-4 below.

Table 4.3-4

Effective Rainfall (r)
(mm)

Month	Northern Zone	Southern Zone
January	61	15
February	56	11
March	31	0
April	0	0
May	0	0
June	0	0
July	0	0
August	0	0
September	0	0
October	0	0
November	27	0
December	51	1
Annual	226	27

After monthly irrigation requirements have been determined, the overall efficiency of 65%, which is used throughout this report, is applied to establish the monthly diversion requirement.

Water Requirements

Irrigation requirements and corresponding diversion requirements for each of the two established zones were determined primarily from the basis of a cropping pattern developed jointly with U.N.R.W.A. personnel. This pattern was later modified in accordance with the expressed wish of the Jordan Government to include certain crops which at present constitute major factors in the unfavorable trade balance of the country. These cropping patterns, together with the unit irrigation requirements and diversion requirements for each are presented on Drawing DS-5-5.

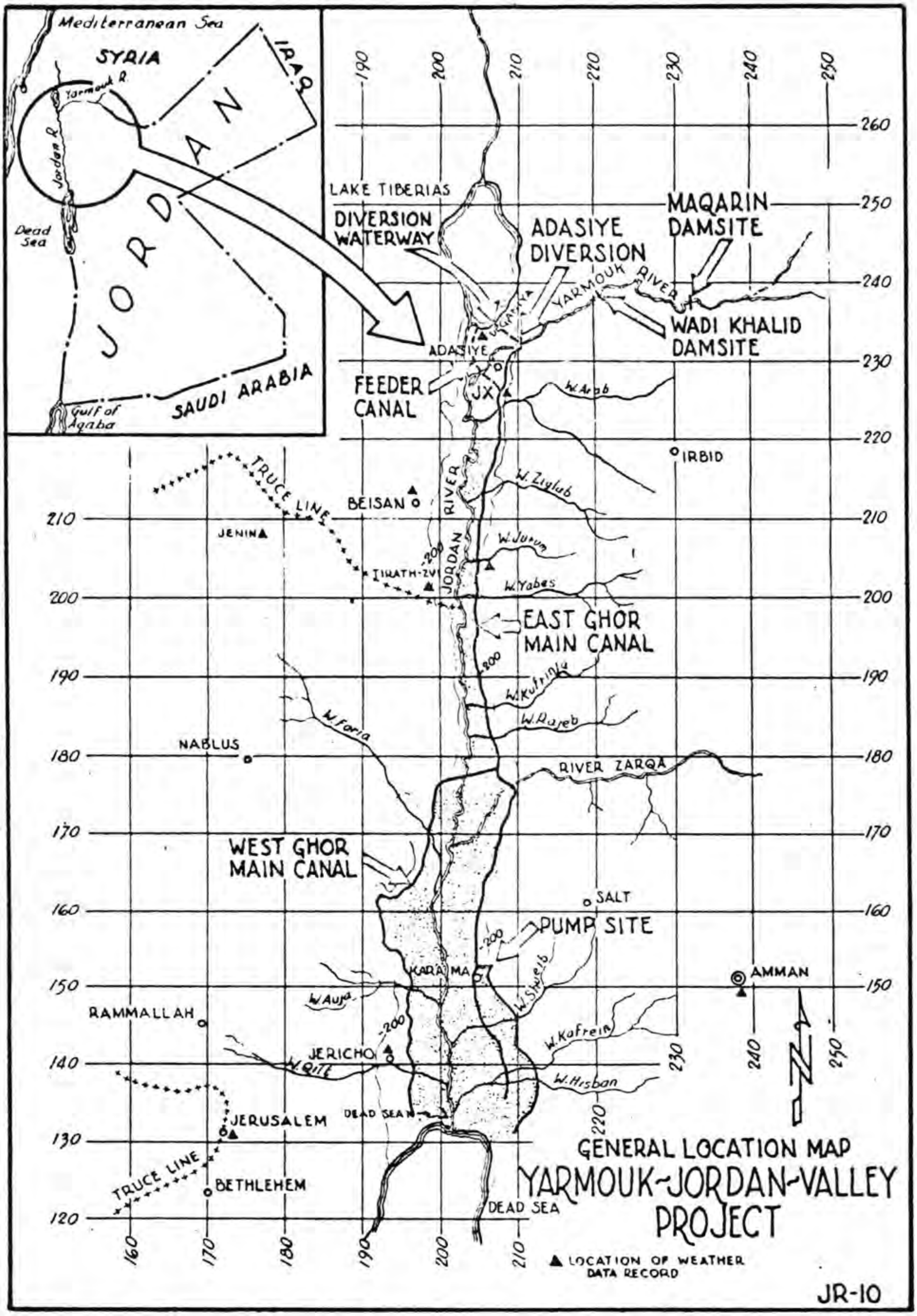
Annual diversion requirements as developed from the two patterns are presented in the table which follows:

Table 4.3-5

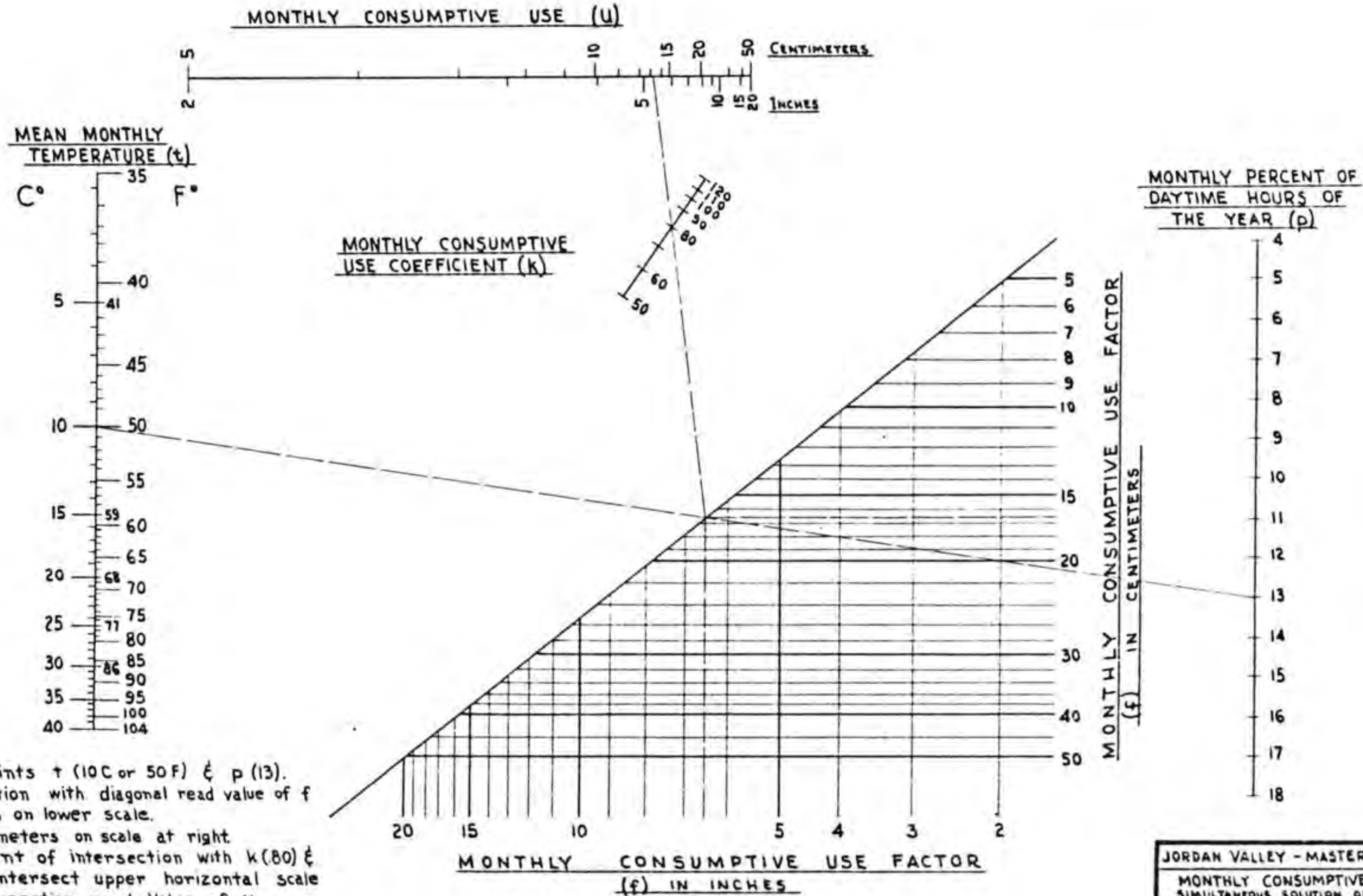
Summary of Water Requirements

Area and Sub-Area	Net Irrigable Area in 1000 Donums	Diversion Requirements Annual - MCM Pattern A	Diversion Requirements Annual - MCM Pattern B
East Ghor (North)			
Below Canal	129.0	162.5	169.8
Above Canal	40.5	51.0	53.3
Sub-Total	169.5	213.5	223.1
East Ghor (South)			
Below Canal	151.4	240.4	242.5
Above Canal	32.2	51.1	51.6
Sub-Total	183.6	291.5	294.1
Total East Ghor	353.1	505.0	517.2
West Ghor			
Below Canal	87.8	139.4	140.7
Above Canal	63.3	100.5	101.4
Total West Ghor	151.1	239.9	242.1
GRAND TOTAL FOR PROJECT	504.2	744.9	759.3
Wadi Fari'a	9.5	15.1	15.2
TOTAL	513.7	760.0	774.5

These quantities were computed by multiplying the area in each geographic sub-division by the unit requirement for the corresponding zone. In addition to lands within the project area, total diversion requirements cover 9,500 donums in Wadi Fari'a.

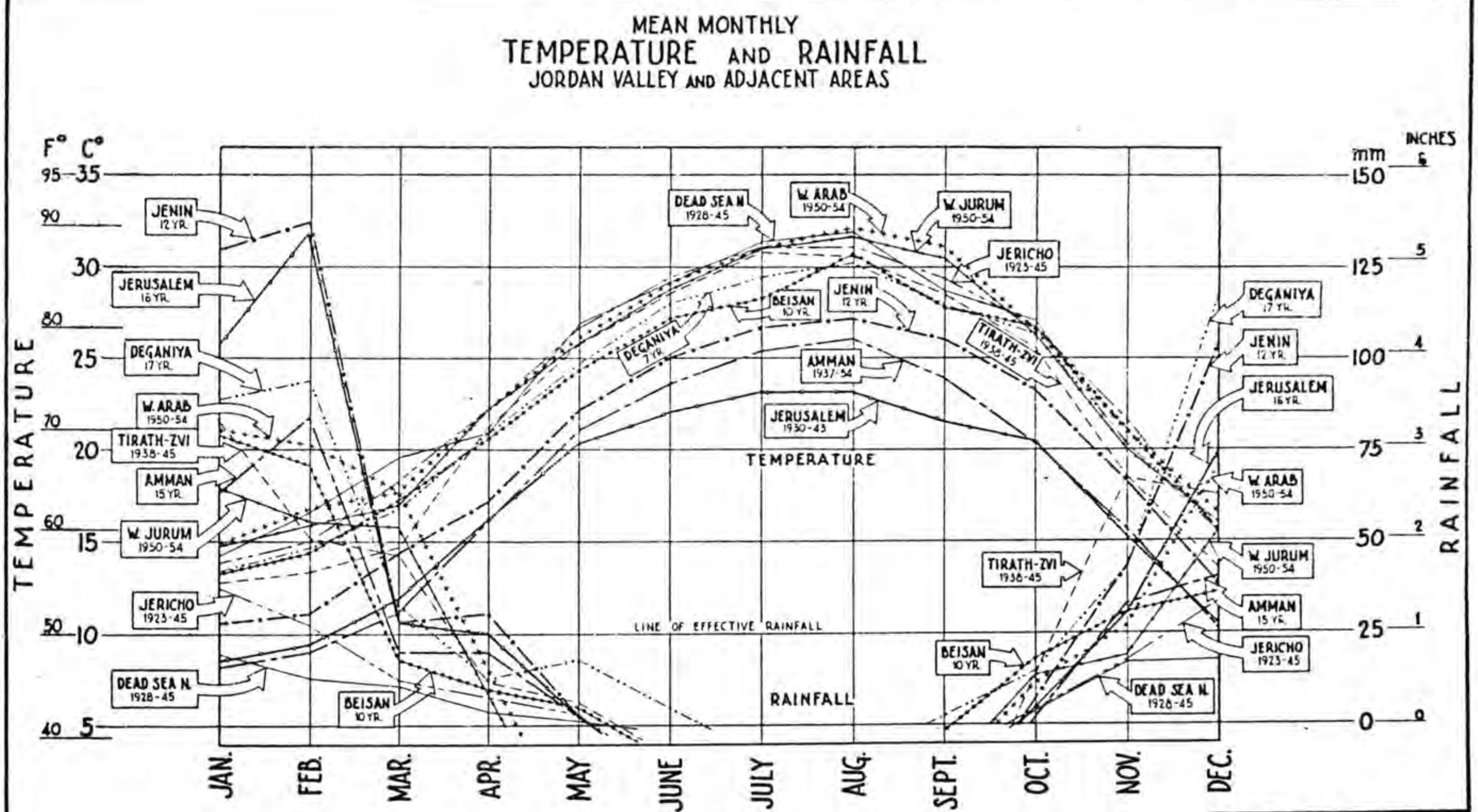


Mediterranean Sea
SYRIA
IRAQ
JORDAN
Yarmouk R.
Jordan R.
Dead Sea
SAUDI ARABIA
Gulf of Aqaba
LAKE TIBERIAS
DIVERSION WATERWAY
ADASIYE DIVERSION
MAQARIN DAMSITE
YARMOUK RIVER
WADI KHALID DAMSITE
ADASIYE
FEEDER CANAL
JX
W. Arab
IRBID
TRUCE LINE
BEISAN
JORDAN RIVER
W. Ziglab
JENIN
W. Jurum
TIRATH-ZVI
W. Yabes
EAST GHOR MAIN CANAL
W. Kufrinja
W. Rajeb
W. Faria
NABLUS
RIVER ZARQA
WEST GHOR MAIN CANAL
SALT
PUMP SITE
KARAMA
W. Shueib
AMMAN
W. Auja
RAMMALLAH
JERICHO
W. Qilt
W. Kafrein
W. Hisban
DEAD SEA
JERUSALEM
TRUCE LINE
BETHLEHEM
DEAD SEA
GENERAL LOCATION MAP
YARMOUK-JORDAN-VALLEY PROJECT
▲ LOCATION OF WEATHER DATA RECORD
JR-10



Example:
Connect points t (10 C or 50 F) & p (13).
At intersection with diagonal read value of f
6.5 inches on lower scale.
16.5 centimeters on scale at right.
Connect point of intersection with k (80) & extend to intersect upper horizontal scale at this intersection read value of u
5.2 inches on bottom of scale.
13.2 centimeters on top of scale.

JORDAN VALLEY - MASTER PLAN
MONTHLY CONSUMPTIVE USE SIMULTANEOUS SOLUTION OF THE BLANEY-CRIDDLE FORMULA IN METRIC AND ENGLISH UNITS
MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY
DATE 1950 DEVELOPED BY J.E.F. — DWG. NO. DS-5-2



SOURCE
CLIMATIC ANALOGUES OF PALESTINE AND TRANS-JORDAN
M. Y. NUTTONSON, 1946

HUNDRED YEARS OF RAINFALL OBSERVATIONS
1844/45 – 1944/45
DR. D. ASHBEL

CURRENT RECORDS

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

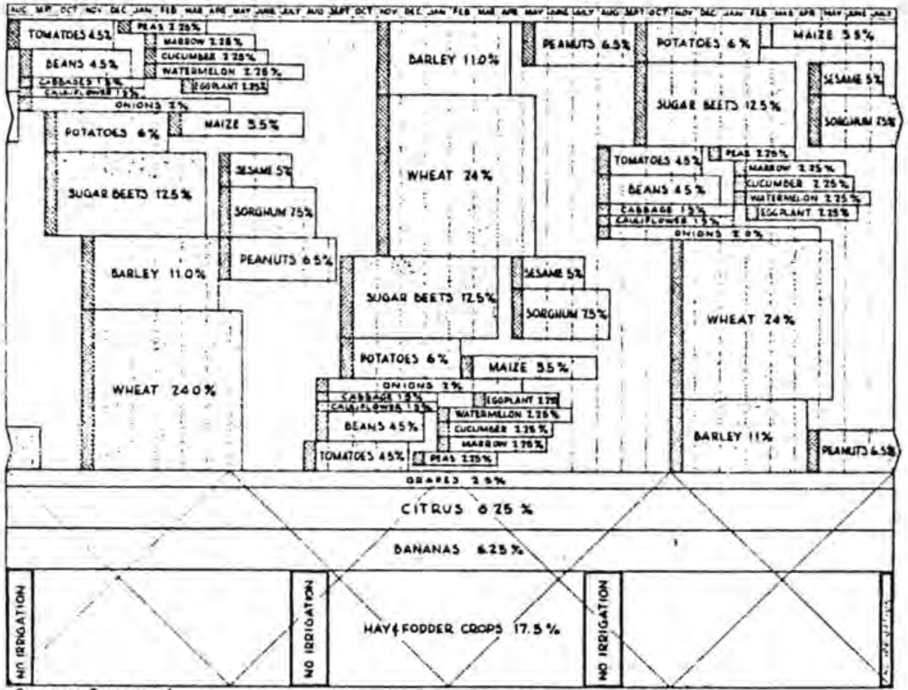
CLIMATIC DATA FOR IRRIGATION REQUIREMENTS

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

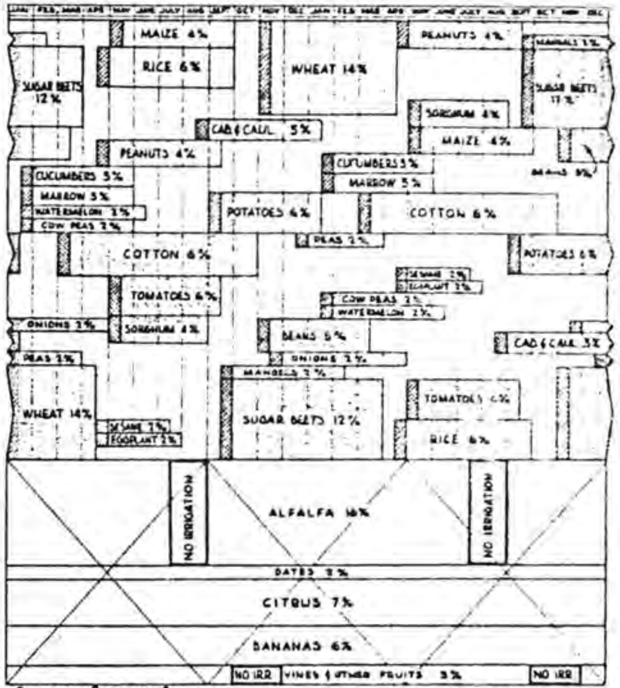
ROCHESTER, PENNA. | DATE 6-54 | DWG. NO. DS-5-3

DS-5-3

DS-5-5



CROPPING PATTERN A *Based on 3 year rotation Developed by UNRWA Agricultural Economist*



CROPPING PATTERN B *Based on 2 year rotation Developed by Baker-Harza incorporating tentative data from representatives of the Jordan Gov't*

IRRIGATION AND DIVERSION REQUIREMENTS (Cropping Pattern A)

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NORTHERN	IRRIGATION REQ.	M³/DONUM	19	55	70	99	119	105	81	49	71	81	62	52	819
ZONE	DIVERSION REQ.	M³/DONUM	30	51	107	152	185	156	126	75	109	125	95	49	1260
SOUTHERN	IRRIGATION REQ.	M³/DONUM	64	81	107	100	125	107	84	50	70	82	80	84	1037
ZONE	DIVERSION REQ.	M³/DONUM	99	124	165	153	189	165	150	77	108	126	125	129	1588

IRRIGATION AND DIVERSION REQUIREMENTS (Cropping Pattern B)

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NORTHERN	IRRIGATION REQ.	M³/DONUM	16	29	59	76	112	125	108	86	95	77	49	26	856
ZONE	DIVERSION REQ.	M³/DONUM	25	45	91	117	172	189	166	132	146	118	75	40	1516
SOUTHERN	IRRIGATION REQ.	M³/DONUM	55	69	91	76	116	129	112	86	94	78	69	69	1042
ZONE	DIVERSION REQ.	M³/DONUM	82	106	140	117	178	196	172	152	145	120	106	106	1602

LEGEND

- AREA UNDER IRRIGATION
- AREA UNDER PREPARATORY TILLAGE
- FALLOW LAND
- CONTINUATION OF CROP
- PERMANENT CROP

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

DIVERSION REQUIREMENTS FOR

SPECIFIC CROPPING PATTERNS

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

ROCHESTER PENNA. | 3-55 | DS 5-5

Table 4.3-6

Rainfall at Degania "A"
235,300 N. - 204,000 E.
Elevation -200 M.
(in mm)

Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1917	-	-	-	-	-	-	-	-	0.0	17.8	60.0	227.9	
1918	105.6	125.6	114.5	14.8	0.0	0.0	0.0	0.0	0.0	0.0	36.0	135.5	532.0
1919	105.0	91.0	49.0	32.0	0.0	0.0	0.0	0.0	-	-	-	-	
1920	-	-	-	-	-	-	-	-	0.0	0.0	72.6	0.0	
1921	77.8	137.6	60.4	0.0	4.7	0.0	0.0	0.0	0.0	5.5	41.9	164.9	492.8
1922	169.2	53.3	47.6	3.2	0.0	0.0	0.0	0.0	0.0	0.0	57.0	128.0	458.3
1923	57.0	123.5	40.0	0.0	28.0	0.0	0.0	0.0	0.0	18.0	7.0	89.5	363.0
1924	116.5	107.5	37.5	0.0	24.0	2.5	0.0	0.0	0.0	21.5	9.7	66.0	385.2
1925	60.5	33.0	3.0	27.5	0.0	0.0	0.0	0.0	-	-	-	-	
1926	-	-	-	-	-	-	-	-	0.0	0.0	0.0	250.5	
1927	72.0	147.2	46.0	42.0	0.0	0.0	0.0	0.0	0.0	7.0	8.0	18.0	340.2
1928	57.5	115.0	2.0	2.0	0.0	0.0	0.0	0.0	-	-	-	-	
1929	-	-	-	-	-	-	-	-	0.0	0.0	108.0	62.5	
1930	89.0	59.0	8.5	28.0	0.0	0.0	0.0	0.0	0.0	0.0	34.0	92.0	310.5
1931	75.0	119.0	22.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	9.0	80.0	309.5
1932	28.0	132.0	8.0	5.0	0.0	0.0	0.0	0.0	-	-	-	-	
1933	-	-	-	-	-	-	-	-	-	-	-	-	
1934	-	-	-	-	-	-	-	-	0.0	4.5	6.5	206.0	
1935	76.0	-	-	-	-	-	-	-	2.3	33.6	65.8	25.8	
1936	52.5	29.7	16.7	8.8	8.8	0.0	0.0	0.0	0.0	0.0	113.0	92.1	321.6
1937	123.6	34.8	4.8	18.0	0.0	0.0	0.0	0.0	0.0	18.0	37.5	17.5	245.2
1938	174.0	87.4	56.2	0.0	29.0	0.0	0.0	0.0	0.0	1.0	121.3	70.4	539.3
1939	63.2	122.4	85.9	18.4	0.0	0.0	0.0	0.0	0.0	1.0	57.9	52.3	401.1
1940	136.7	45.4	23.4	8.1	0.0	0.0	0.0	0.0	0.0	21.4	43.3	62.0	340.3
1941	57.1	64.9	73.0	6.0	0.0	0.0	0.0	0.0	2.0	2.0	4.9	138.4	348.3
1942	39.6	44.5	50.5	0.0	0.0	0.0	0.0	0.0	0.0	59.6	80.9	12.4	287.5
1943	171.0	41.6	51.9	77.0	2.8	0.0	0.0	0.0	0.0	1.6	4.3	44.9	395.1
1944	231.7	34.9	48.9	11.4	4.4	0.0	0.0	0.0	0.0	0.0	172.6	207.5	711.4
1945	101.9	64.0	25.1	49.1	3.4	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	23	22	22	23	22	22	22	22	23	23	23	23	17
Mean for Years of Record	97.4	82.4	39.8	15.3	4.8	0.3	0.0	0.0	0.18	9.2	50.1	97.7	399.4

Source: Hundred Years of Rainfall Observation - Dr. Ashbel - Jerusalem, 1945.

Table 4.3-7

Rainfall at Adasiye
230,000 N. - 208,000 E.
Elevation -200 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	30.0	12.5	
1948	54.0	107.0	147.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	36.5	110.1	484.6
1949	93.1	95.6	91.7	103.8	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	3.7	42.6	145.4	
1952	60.1	98.0	59.3	0.0	0.0	0.0	0.0	0.0	0.0	6.4	19.0	49.4	292.2
1953	154.9	90.0	128.0	7.0	0.0	0.0	0.0	0.0	0.0	15.6	135.8	91.2	622.5
1954	115.8	132.6	15.8	11.6	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	3
Mean for Years of Record	95.6	104.6	88.6	30.5	0.0	0.0	0.0	0.0	0.0	5.1	52.8	81.7	466.4

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Surveys, Jordan.

Table 4.3-7

Table 4.3-8

Rainfall at Baqura
227,800 N. - 205,800 E.
Elevation -200M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	41.0	30.8	
1948	62.5	88.0	144.5	21.0	0.0	0.0	0.0	0.0	0.0	0.0	39.5	110.5	466.0
1949	81.0	73.5	83.5	88.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	4.5	44.5	150.2	
1952	59.3	90.4	52.8	0.0	0.0	0.0	0.0	0.0	0.0	10.7	22.4	55.5	291.1
1953	161.5	78.4	104.1	15.2	0.0	0.0	0.0	0.0	0.0	6.7	157.4	80.5	603.8
1954	89.9	132.6	15.0	15.0	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	
Mean for Years of Record	90.8	92.6	80.0	27.8	0.0	0.0	0.0	0.0	0.0	4.4	61.0	85.5	

Source: Technical Papers No. 16, 17, 20, and 21. Department of Lands and Surveys, Jordan.

Table 4.3-9

Rainfall at Wadi Arab
224,000 N. - 207,800 E.
Elevation -197 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	10.2	40.7	143.2	
1952	56.7	85.5	45.8	0.0	0.0	0.0	0.0	0.0	0.0	12.5	20.5	54.2	275.2
1953	147.5	78.4	114.4	16.7	0.0	0.0	0.0	0.0	0.0	7.7	151.0	79.8	595.5
1954	89.5	128.8	13.3	-	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	2	2	2	2	2	2	3	3	3	2
Mean for Years of Record	97.9	97.6	57.8	8.4	0.0	0.0	0.0	0.0	0.0	10.1	70.7	92.4	435.4

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan

Table 4.3-10

Rainfall at Wadi Ziglab
214,000 N. - 206,000 E.
Elevation -190 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	28.0	30.2	133.0	
1952	55.8	62.9	64.9	2.5	0.0	0.0	0.0	0.0	0.0	17.3	7.6	40.4	251.4
1953	149.1	78.6	86.4	12.0	0.0	0.0	0.0	0.0	0.0	0.0	186.7	83.2	596.0
1954	80.2	116.0	4.1	22.0	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	95.0	85.8	51.8	12.2	0.0	0.0	0.0	0.0	0.0	15.1	74.8	85.5	423.7

Source: Technical Papers No. 20 and 21. Department of Irrigation and Water Power, Jordan

Table 4.3-11

Rainfall at Beisan
211,500 N. - 197,500 E.
Elevation -118M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
Average Rainfall 10 Year Record	78.7	71.1	17.8	10.2	5.1	0.0	0.0	0.0	0.0	17.8	30.5	35.6	266.7

Source: Climatic Analogues of Palestine and Trans-Jordan - M. Y. Nuttonson - 1946.

No other data available.

Table 4.3-12

Table 4.3-12

Rainfall at Wadi Jurum
204,000 N. - 206,000 E.
Elevation -180 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total annual
1951	-	-	-	-	-	-	-	-	-	18.7	29.4	130.1	
1952	50.4	43.3	62.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	21.3	18.6	202.8
1953	107.3	74.2	89.5	9.4	0.0	0.0	0.0	0.0	0.0	0.0	126.8	77.2	484.4
1954	57.6	85.6	4.9	11.1	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	71.8	67.7	52.1	6.8	0.0	0.0	0.0	0.0	0.0	8.6	59.2	75.3	343.6

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan.

Table 4.3-13

Rainfall at Tirath-Zvi
203,200 N. - 199,900 E.
Elevation -220 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1938	-	-	-	-	-	-	-	-	0.0	0.0	131.1	29.9	
1939	28.6	83.5	68.4	10.2	0.0	0.0	0.0	0.0	0.0	1.9	49.1	31.5	273.2
1940	115.0	3.5	22.5	3.0	0.0	0.0	0.0	0.0	0.0	25.0	56.8	66.8	292.6
1941	35.1	29.4	43.9	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.6	127.8	243.8
1942	22.8	37.2	47.0	0.0	0.0	0.0	0.0	0.0	0.0	66.9	58.3	22.8	255.0
1943	173.1	75.2	80.8	39.3	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	393.4
1944	131.5	54.5	34.5	4.0	47.0	0.0	0.0	0.0	0.0	0.0	144.5	160.5	376.5
1945	74.0	72.5	30.0	29.0	0.0	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	7	7	7	7	7	7	7	7	7	7	7	7	6
Mean for Years of Record	82.9	50.8	46.7	12.2	6.7	0.0	0.0	0.0	0.0	13.7	67.2	62.7	305.8

Source: Hundred Years of Rainfall Observations, (1844/45 - 1944/45) - Dr. Ashbel, Jerusalem, 1945.

Table 4.3-14

Rainfall at El-Qarn
194,100 N. - 204,300 E.
Elevation -178M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	18.0	11.0	
1948	47.0	47.0	82.5	17.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	70.2	274.7
1949	105.2	159.7	232.7	287.7	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	6.0	17.0	230.00	
1952	102.5	99.0	109.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	2.0	7.0	326.7
1953	113.0	84.0	110.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	88.5	67.5	471.6
1954	62.4	90.0	4.0	16.0	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	3
Mean for Years of Record	86.0	95.9	107.8	65.7	0.0	0.0	0.0	0.0	0.0	2.6	27.3	77.1	357.7

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Survey and Department of Irrigation, Jordan

Table 4.3-15

Rainfall at Wadi Kufrinja
186,400 N. - 206,700 E.
Elevation -200 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	2.3	22.7	148.4	
1952	56.5	73.9	51.8	0.0	0.0	0.0	0.0	0.0	0.0	5.4	9.8	6.4	203.[illegible]
1953	79.2	76.9	89.7	1.5	0.0	0.0	0.0	0.0	0.0	0.6	95.2	71.7	414.8
1954	33.7	94.6	5.9	32.5	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	56.5	81.8	49.1	11.3	0.0	0.0	0.0	0.0	0.0	2.8	42.6	75.5	309.3

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan.

Table 4.3-16

Table 4.3-16

Rainfall at River Zarqa - Deir 'Alla
178.2 N. - 209,000 E.
Elevation -185 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	0.0	8.0	121.8	
1952	49.6	53.3	74.8	0.3	0.0	0.0	0.0	0.0	0.0	3.1	6.9	5.5	193.5
1953	59.4	93.3	95.9	6.1	0.0	0.0	0.0	0.0	0.0	0.0	97.2	83.2	435.1
1954	34.2	107.4	9.3	45.7	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	47.7	84.7	60	17.4	0.0	0.0	0.0	0.0	0.0	1.0	37.4	70.2	314.3

Source: Technical Papers No. 20 and 21, Irrigation Department, Jordan.

Table 4.3-17

Rainfall at Jericho
140,000 N. - 193,000 E.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1923	-	-	-	-	-	-	-	-	0.0	11.4	8.0	50.1	
1924	20.2	59.3	0.0	0.0	25.0	0.0	0.0	0.0	0.0	1.2	28.8	28.1	162.6
1925	12.0	23.6	11.0	18.0	0.0	0.0	0.0	0.0	0.0	6.3	19.9	8.0	96.0
1926	55.1	37.2	20.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	114.4
1927	17.0	48.8	8.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	5.0	103.8
1928	21.3	41.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	30.8	98.4
1929	29.6	25.0	2.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	32.5	10.3	117.9
1930	54.5	22.0	1.0	20.5	1.0	0.0	0.0	0.0	0.0	0.0	8.0	50.5	157.5
1931	37.5	20.0	1.5	4.5	0.0	0.0	0.0	0.0	0.0	4.0	3.5	8.0	79.0
1932	18.5	26.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	50.5
1933	22.5	19.0	10.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.5	66.5
1934	65.0	12.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	79.5	170.0
1935	26.5	43.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	17.0	15.0	4.5	106.5
1936	18.0	11.5	24.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	50.0	31.5	139.5
1937	39.0	2.5	0.0	16.5	0.0	0.0	0.0	0.0	0.0	8.0	47.0	1.5	114.5
1938	52.5	59.0	20.5	1.0	7.0	0.0	0.0	0.0	-	-	-	-	
1939	-	-	-	-	-	-	-	-	0.0	2.0	26.5	47.7	
1940	85.8	2.2	3.0	25.7	0.0	0.0	0.0	0.0	0.0	6.5	17.0	24.8	165.0
1941	20.0	7.4	37.5	3.7	0.0	0.0	0.0	0.0	0.0	3.2	4.1	76.3	152.2
1942	14.8	23.5	38.0	1.1	0.0	0.0	0.0	0.0	0.0	17.6	8.8	7.9	111.7
1943	57.2	31.7	42.2	16.2	1.1	0.0	0.0	0.0	0.0	8.4	0.0	14.4	171.2
1944	44.5	7.6	19.3	11.7	11.8	0.0	0.0	0.0	0.0	0.0	81.4	78.3	252.6
1945	75.6	50.6	22.8	4.8	19.8	0.0	0.0	0.0	-	-	-	-	
1952	-	-	-	-	-	-	-	-	-	0.0	1.8	4.2	
1953	25.3	52.4	43.5	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	22	22	22	22	22	22	22	22	22	22	22	22	19
Mean for Years of Record	36.9	28.4	14.2	7.7	3.0	0.0	0.0	0.0	0.0	4.1	17.2	27.1	129.7

Source: Hundred Years of Rainfall Observations (1844/45 - 1944/45) - Dr. D. Ashbel, 1945

Table 4.3-18

Rainfall at Kafrein
139,500 N. - 211,600 E.
Elevation -230 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	26.9	2.4	
1948	58.8	22.5	45.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	34.8	167.2
1949	18.3	31.5	51.7	50.8	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	2.0	7.0	117.1	
1952	31.0	33.7	52.3	3.4	0.0	0.0	0.0	0.0	0.0	4.0	1.1	10.0	135.5
1953	30.5	49.6	27.9	5.5	0.0	0.0	0.0	0.0	0.0	-	-	-	
1954	-	16.6	4.8	11.9	-	-	-	-	-	-	-	-	
Total Years of Record	4	5	5	5	4	4	4	4	4	4	4	4	2
Mean for Years of Record	34.6	30.8	36.4	14.3	0.0	0.0	0.0	0.0	0.0	1.5	10.2	41.1	151.4

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Surveys - Irrigation Section, Jordan.

Table 4.3-19

Rainfall at Dead Sea (North)
137,000 N. - 201,000 E.
Elevation -390M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1929	9.0	22.9	8.3	12.6	0.0	0.0	0.0	0.0	0.0	0.0	11.0	4.5	68.3
1930	13.6	17.7	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5	29.5	84.1
1931	22.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	8.5	39.4
1932	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	2.0	0.0	15.5
1933	8.5	11.5	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.0	29.0
1934	25.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	36.5	64.2
1935	13.5	12.4	0.5	0.0	1.0	0.0	0.0	0.0	0.0	26.8	14.0	2.0	70.2
1936	9.3	6.3	10.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	29.0	23.5	84.6
1937	36.2	10.3	0.0	3.0	0.0	0.0	0.0	0.0	0.0	2.5	22.2	0.0	74.2
1938	26.3	20.6	15.8	0.0	4.0	0.0	0.0	0.0	0.0	0.0	35.7	16.0	118.6
1939	5.5	42.7	39.6	0.0	0.0	0.0	0.0	0.0	0.0	1.5	30.5	25.5	145.3
1940	58.0	2.0	6.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	12.5	111.2
1941	9.0	12.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	40.0	77.0
1942	4.0	14.0	35.5	0.0	0.0	0.0	0.0	0.0	0.0	9.0	2.5	0.0	65.0
1943	19.8	7.4	33.8	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	75.3
1944	25.1	4.8	8.8	20.7	2.4	0.0	0.0	0.0	0.0	0.0	109.5	64.3	235.6
1945	36.0	20.0	11.0	2.0	16.0	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	17	17	17	17	17	17	17	17	16	16	16	16	16
Mean for Years of Record	19.5	12.4	11.0	4.2	1.4	0.0	0.0	0.0	0.0	2.7	18.7	17.2	84.8

Source: Hundred Years of Rainfall Observation (1844/45 - 1944/45) - Dr. D. Ashbel - Jerusalem, 1945.

Table 4.3-19

Table 4.3-20

Rainfall at Ghor Fari'a P. Post (Ex-Jiftlik)
172,000 N. - 196,000 E.
Elevation -240 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1952	-	-	-	-	-	-	-	-	-	0.0	6.0	8.5	
1953	48.5	55.5	76.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	90.0	67.5	339.5
1954	-	53.0	5.0	15.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	1	2	2	2	2	2	2	2	2	2	2	2	1
Mean for Years of Record	48.5	54.2	40.8	8.2	0.0	0.0	0.0	0.0	0.0	0.0	48.0	38.0	339.5

Source: Technical Paper No. 21, Irrigation Department, Jordan.

Table 4.3-20

Table 4.3-21

Rainfall at Amman - R.A.F.
153,000 N. - 242,500 E.
Elevation 780 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1927	47.0	190.8	5.4	36.9	2.1	0.0	0.0	0.0	0.0	8.1	22.2	109.0	421.5
1928	46.4	109.3	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.8	48.8	237.3
1929	70.3	84.7	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.3	41.4	259.4
1930	86.9	47.6	6.4	26.5	1.0	0.0	0.0	0.0	0.0	0.0	17.7	50.6	236.7
1931	97.4	50.3	24.9	8.4	0.0	0.0	0.0	0.0	0.0	1.9	14.2	91.7	288.8
1932	45.4	58.5	7.0	10.4	0.0	0.0	0.0	0.0	0.0	9.7	4.5	0.6	136.1
1933	53.3	25.2	31.4	13.4	0.0	0.0	0.0	0.0	0.2	0.1	7.2	5.1	135.9
1934	94.3	45.3	-	7.4	0.0	0.0	0.0	0.0	0.0	1.7	0.0	67.0	
1935	76.9	142.3	17.3	14.8	4.5	0.0	0.0	0.0	0.0	14.9	14.0	4.9	289.6
1936	13.4	103.1	24.8	11.2	0.0	0.0	0.0	0.0	0.0	0.1	66.5	87.3	306.4
1937	117.0	16.1	0.0	54.8	3.8	0.0	0.0	0.0	0.0	4.6	14.0	1.1	211.4
1938	97.0	132.8	66.4	1.3	24.1	0.0	0.0	0.0	0.0	0.2	126.5	28.2	476.5
1939	24.8	79.4	84.8	4.3	0.0	0.0	0.0	0.0	0.0	3.3	71.8	20.4	288.8
1940	124.1	5.2	30.0	31.4	0.0	0.0	0.0	0.0	0.0	8.4	32.8	59.0	290.9
1941	61.6	22.4	24.0	6.2	0.0	0.0	0.0	0.0	0.0	2.2	3.5	155.1	275.0
1942	56.9	86.6	96.9	0.3	0.0	0.0	0.0	0.0	0.0	54.6	27.8	18.6	341.7
1943	105.4	50.5	86.7	34.4	2.3	0.0	0.0	0.0	0.0	4.5	0.6	18.2	302.6
1944	141.7	12.6	20.2	11.7	13.0	0.0	0.0	0.0	0.0	0.0	136.8	94.0	430.0
1945	1[illegible].2	106.0	19.3	4.6	19.6	0.0	0.0	0.0	-	-	-	-	
1946	-	-	-	-	-	-	-	-	-	-	-	-	
1947	-	-	-	-	-	-	-	-	-	0.0	22.2	21.0	
1948	92.8	69.1	76.1	12.0	1.3	0.0	0.0	0.0	0.0	2.1	12.4	44.3	310.1
1949	74.9	123.9	116.0	52.5	2.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	0.9	19.9	179.8	
1952	35.6	79.7	46.9	0.4	0.0	0.0	0.0	0.0	0.0	8.5	3.9	12.3	187.3
1953	29.3	81.3	168.7	1.8	0.0	0.0	0.0	0.0	0.0	1.5	91.3	60.5	434.4
1954	17.7	90.3	12.8	16.2	-	-	-	-	-	-	-	-	
Total Years of Record	24	24	23	24	23	23	23	23	22	23	23	23	20
Mean for Years of Record	71.3	75.5	43.0	15.0	3.2	0.0	0.0	0.0	0.09	5.5	34.2	53.9	293.1

Source: Hundred Years of Rainfall Observation (1844/45 - 1944/45) - Dr. D. Ashbel - Jerusalem, 1945; and Technical Papers No. 16, 17, 20 and 21, Department of Lands and Surveys, Jordan.

Table 4.3-21

Table 4.3-22

Rainfall at Jenin
207,600 N. - 178,500 E.
Elevation 138 M
(In mm)

Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1952	-	-	-	-	-	-	-	-	-	21.5	18.6	29.6	
1953	151.4	97.9	125.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	167.8	109.4	654.7
1954	-	109.6	16.2	19.2	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	1	2	2	2	2	2	2	2	2	2	2	2	1
Mean for Years of Record1/	151.4	103.8	70.6	11.2	0.0	0.0	0.0	0.0	0.0	10.2	93.2	69.5	654.7
Average Rainfall for 17 Years2/	129.5	137.2	27.9	30.5	2.5	0.0	0.0	0.0	0.0	7.6	43.2	104.1	482.6

Source: 1/ Technical Paper No. 21, Department of Irrigation, Jordan.
2/ Climatic Analogues of Palestine and Trans-Jorden - M.Y. Nuttonson - 1946.

Table 4.3-23

Rainfall at Jerusalem
132,000 N. - 171,000 E.
Elevation 827 M.
(In mm)
Sheet 1 of 2

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1846	59.4	73.5	53.6	-	0.0	0.0	0.0	0.0	0.0	39.9	63.7	0.0	
1847	97.4	326.0	59.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	158.5	671.3
1848	244.0	57.5	0.0	1.9	14.0	0.0	0.0	0.0	0.0	0.0	1.9	156.5	457.5
1849	192.5	130.5	117.2	0.0	0.0	0.0	0.0	0.0	-	-	-	-	
1850	-	-	-	-	-	-	-	-	0.0	0.0	63.7	335.0	
1851	145.0	238.0	39.9	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	151.0	595.7
1852	134.5	245.0	87.5	0.0	23.8	0.0	0.0	0.0	0.0	0.0	17.9	93.0	604.7
1853	41.3	39.9	212.0	11.7	19.9	0.0	0.0	0.0	0.0	0.0	59.4	123.0	507.4
1854	130.5	198.0	240.0	107.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	63.0	772.3
1855	323.0	125.7	87.5	23.8	0.0	0.0	0.0	0.0	0.0	0.0	9.5	31.6	604.4
1856	175.0	225.0	101.0	246.0	0.6	0.0	0.0	0.0	0.0	0.0	147.0	41.5	936.4
1857	129.0	559.0	39.3	9.8	0.0	0.0	0.0	0.0	0.0	14.0	65.8	159.0	997.4
1858	225.5	234.0	16.0	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	216.0	747.1
1859	110.0	31.3	162.0	61.4	0.0	3.9	0.0	0.0	0.0	43.7	27.7	7.5	397.8
"Missing"													
1898	-	-	-	-	-	-	-	-	0.0	0.0	55.2	143.5	
1899	139.5	51.2	60.0	29.1	0.0	0.0	0.0	0.0	0.0	4.0	32.1	153.7	519.5
1900	59.7	222.3	46.6	4.1	6.6	0.0	0.0	0.0	0.0	2.7	13.0	119.9	479.4
1901	174.1	3.3	26.5	12.4	23.7	0.0	0.0	0.0	0.0	4.0	42.9	149.2	436.0
1902	301.0	42.6	40.8	21.5	1.1	0.0	0.0	0.0	0.0	16.0	189.8	176.1	790.9
1903	174.3	79.5	93.4	9.4	0.0	3.0	0.0	0.0	0.0	3.3	35.0	70.7	468.6
1904	241.1	31.1	139.1	30.4	0.2	0.0	0.0	0.0	0.0	5.3	88.6	346.3	882.1
1905	90.3	174.1	127.4	4.0	0.0	0.0	0.0	0.0	0.0	15.9	0.0	272.1	726.7
1906	152.2	174.0	50.7	117.5	23.1	0.0	0.0	0.0	0.0	18.2	17.1	43.5	596.3
1907	145.1	65.5	110.2	29.4	9.3	0.0	0.0	0.0	-	-	-	-	
"Missing"													
1932 (St. Anne)	-	-	-	-	-	-	-	-	10.0	28.5	10.2	4.8	
1933	92.0	65.5	35.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	9.6	22.6	228.7
1934	244.0	96.4	6.2	35.6	0.0	0.0	0.0	0.0	0.0	3.9	9.9	142.5	538.5
1935	79.1	275.3	28.0	2.4	0.0	0.0	0.0	0.0	0.0	9.1	46.3	27.8	468.0
1936	30.8	182.1	44.3	17.2	0.0	0.0	0.0	0.0	0.0	0.0	150.2	160.5	585.1
1937	278.0	43.9	11.6	38.5	2.5	0.0	0.0	0.0	0.0	25.4	36.6	11.6	448.1
1938	221.2	248.5	96.8	-	-	-	-	-	-	-	-	-	
1939	-	-	-	-	-	-	-	-	0.0	4.4	114.7	72.6	
1940	261.1	11.7	58.1	27.7	0.0	0.0	0.0	0.0	0.0	13.0	15.7	138.9	532.2

Table 4.3-23

Table 4.3-23

Rainfall at Jerusalem
132,000 N. - 171,000 E.
Elevation 627 M.
(In mm)
Sheet 2 of 2

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1941	109.0	15.1	152.0	4.0	0.0	0.0	0.0	0.0	0.0	10.0	8.0	345.3	544.4
1942	130.4	89.5	215.0	1.1	0.0	0.0	0.0	0.0	0.0	66.0	68.0	12.2	582.2
1943	275.9	121.1	152.3	49.3	2.0	0.0	0.0	0.0	0.0	26.6	2.3	34.3	693.5
1944	297.5	32.6	49.4	44.3	21.9	0.0	0.0	0.0	0.0	0.0	299.5	164.4	909.9
1945	152.7	214.2	35.2	-	-	-	-	-	-	-	-	-	
"Missing"													
1952	-	-	-	-	-	-	-	-	-	0.0	19.4	25.2	
1953	85.7	125.7	216.5	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
1954	-	152.1	21.0	16.0	-	-	-	-	-	-	-	-	
Total Years of Record	35	35	36	33	33	33	33	33	35	35	35	35	29
Mean of Years of Record	135.6	143.0	85.6	31.3	4.4	0.1	0.0	0.0	0.3	11.5	50.2	120.5	616.5

Source: Hundred Years of Rainfall Observations (1844/45 - 1944/45) - Dr. D. Ashbel, 1945; and
Technical Paper No. 21 - Department of Irrigation - Jordan

Table 4.3-24

Mean Monthly Temperatures
Jordan Valley and Adjacent Areas
(Degrees Centigrade)

Sheet 1 of 1

Station	Elevation	Years of Record	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Degania1/	-200 M	7	13.4	14.7	16.7	20.9	24.7	28.0	29.6	30.2	27.9	26.3	20.4	15.6	22.4
Beisan1/	-118 M	10	13.3	14.4	17.2	20.5	24.4	27.2	28.3	30.6	27.7	26.1	21.1	15.0	22.1
Jericho1/	-260 M	13	13.9	15.0	18.3	22.2	26.6	29.4	31.1	31.1	29.4	26.6	21.7	15.5	23.4
Jenin1/	138 M	12	10.6	11.1	14.4	17.2	22.2	25.0	26.6	27.2	26.1	23.3	18.3	12.8	19.5
Jerusalem2/	827 M	1930-1943	8.6	9.5	12.0	16.2	20.4	22.1	23.2	23.2	21.6	20.5	15.3	10.5	16.9
Tirath-Zvi2/	-220 M	1935-1943	12.8	13.4	14.7	21.3	25.8	28.6	30.8	30.6	28.5	25.6	18.6	13.6	22.0
Dead Sea (N)2/	-390 M	1920-1943	14.3	16.6	19.6	20.8	26.9	29.1	31.3	31.9	25.7	27.1	20.4	15.5	23.5
Amman R.A.F.3/	750 M	1923-1954	[illegible]	9.1	12.0	16.2	19.8	23.6	25.1	25.5	23.7	20.7	15.7	10.1	17.5
Wadi El Arab4/	-197 M	1950-1954	14.9	16.8	18.2	21.7	26.1	29.0	30.9	32.1	30.8	27.0	21.5	16.6	23.8
Wadi Jurum4/	-180 M	1950-1954	14.8	15.8	17.6	23.7	25.8	29.6	31.0	31.6	30.1	26.2	20.2	17.3	23.6
Adasiye4/	-200 M	1949-1951	15.6	17.0	21.9	25.2	26.9	30.6	32.3	31.8	30.7	25.1	25.0	19.4	25.2
Wadi Ziglab4/	-190 M	1950-1954	13.7	15.8	19.8	21.4	26.1	29.1	31.0	32.1	31.4	27.0	21.4	15.4	23.7
Wadi Kufrinja4/	-200 M	1951-1954	16.0	15.9	19.3	22.2	27.8	30.1	-	34.2	31.2	28.4	23.9	-	24.9
River Zarqa - Deir Alla4/	-155 M	1951-1954	16.8	15.9	18.2	22.2	27.8	29.9	32.4	32.7	31.1	28.1	22.0	17.3	24.5

Source: 1/ Climatic Analogues of Palestine and Trans-Jordan - M. Y. Nuttonson - 1946.

2/ Temperatures and Humidity of Palestine and Adjacent Countries - Dr. D. Ashbel - 1945.

3/ Current Daily Records - R.A.F. Camp, Amman, Jordan.

4/ Current Records by Irrigation Department.

VOLUME IV - IRRIGATION AND DRAINAGE
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PART 4. Drainage
- Introduction
- Basic Information
- Water Source - Quality and Quantity
- Special Problems
- Investigations
- Leaching
- Types of Drains

PART 4. DRAINAGE

Introduction

Good drainage practice, both surface and subsurface, is essential to the successful operation of any irrigation system. Drainage in agriculture is a method of improving the soil by withdrawing excess water from it. The objective of this drainage investigation was to design a system whereby a 1.4 meter depth root zone could be maintained free of excess water within all irrigable lands throughout the project, permitting the growth of almost any of the plants adaptable to the area.

Drainage investigation of the project deals primarily with the following four elements: Topography, soils, water tables, and water source, including both quality and quantity. Methods of investigation were essentially those recommended by the United States Bureau of Reclamation, Soil Conservation Service and Salinity Laboratory, modified to meet local conditions.

Basic Information

The topography of the project is characterized by two main features: high benches known as ghors, and the flood plain called the zor. The zor, or recent flood plain, occupies the center of the Jordan Valley. The ghors lie on either side of the zor and rise with an abrupt elevation change, ranging from 30 to 60 meters. Tributary streams or wadis on both sides of the valley cross the ghors to merge with the Jordan River. These streams have become deeply but narrowly entrenched and separate the ghors into distinct segments. Except where the surface is modified by alluvial fans and colluvial slopes, the overall gradient of the ghors is moderate, ranging between one and three percent. There are several places where shallow undrained depressions occur in the ghors but, as a whole, good surface drainage is provided by the natural slopes from north to south and from the side hills to the Jordan River.

Soil textures of the ghors range from light loams to clay loams and clays, with clay loam predominating. These textures continue to considerable depth and significant layers of incoherent sand or gravel are uncommon. Soil textures and salinity vary throughout the Jordan Valley, but generally are heavier near the zor and lighter towards the hills. The highest salt concentrationsare found towards the southern end of the valley.

No subsurface barriers were located within 4.0 meters of the surface, where such barriers could be considered as controlling the drainage of a defined area; however, local barriers were found covering limited areas, generally small. Field studies reveal that the heavier soils, as found where the ghor breaks into the zor, form a vertical barrier in that the permeability of such soils, in general, are much lower than the soils toward the hillsides. This fact may account for the flow of subsurface waters of the ghor in a general direction more or less angular rather than perpendicular to the Jordan River.

Meteorological data show no great amount of rainfall during 7 months of the year; however, January, February and March are peak months. Long range rainfall records for the project area are not available, but such records as have been compiled indicate there has not been sufficient precipitation to have produced surface run-off of an extent great enough to have created high water tables from that cause alone. However, high water tables do exist in places throughout the project area, and while many of these problems can be attributed to improper irrigation practices, in other high water table areas there has been no irrigation for hundreds of years. It has definitely been established that many of the high water tables found in the southern part of the valley and on the West Ghor have not been caused by ponding of local surface run-off water.

Water Source - Quality and Quantity

Water source studies reveal that the cause of high water table areas in the project can be attributed to the following:

1. Inefficient use of irrigation waters.
2. Uncontrolled springs.
3. Artesian seepage (static water).
4. Free flow seepage.
5. Special problems arising from ancient water works, generally of Roman origin.

The normal quantity of water to be dealt with in maintaining a well-drained root zone where intensive irrigation is carried on is in this report, assumed to be 10% of the total irrigation water applied. Additional water may be contributed from other sources such as those mentioned above. It is difficult to compute the definite quantity of water emitted from such sources as springs, artesian seepage and the ancient fuquarās unless a complete study is made to determine such factors as recharge, static head, water bearing aquifers, and soil permeabilities.

Springs in the project area are not numerous and generally the flow is quite small. No serious problems are expected from this source of underground water.

Artesian waters, however, present quite a serious drainage problem, especially in the southern part of the East Ghor area. Topographical conditions are quite favorable for adequate surface drainage, and removal of excess surface water presents no problem. However, climatic conditions are such that, over extensive areas of land, water which has been forced into the root zone from below by hydrostatic pressure has evaporated before reaching the surface of the ground. A high concentration of salt has thus been left near the lower limit of the evaporation zone, because of the high salt content of the artesian waters. It is very important to maintain the subsurface waters in this area at least 1.4 meters below the ground surface for two reasons: 1) most lands will require leaching before crop production can be obtained and 2) the subsurface evaporation zone is approximately one-half (0.5) meter from the surface. The high salinity of the artesian waters would greatly reduce production or even inhibit growth of many crops if permitted to encroach on this horizon. The permeability of the subsurface soils in this area is favorable to adequate drainage, but to secure further insurance against recontamination of the root zone a plan to reduce the static head of artesian water is highly recommended. To lower the static head on the artesian waters in question would require the drilling of a number of wells in the area and installing pumps to keep the static head well below the drainage system. To off-set a portion of the cost of such an installation, the artesian waters could be blended with normal irrigation waters to supplement present water supply, but due to the high salinity of the artesian waters at the present time, its use for irrigation without blending with a water of higher quality is not recommended.

Free flow water found in the project area is quite localized and can usually be traced to excess irrigation waters that have found their way to the surface. Such water can easily be controlled by adequate surface drainage without undue expense.

Special Problems

Most of the ancient water works found in the project area were constructed by the Romans some 2000 years ago. Many irrigation systems were built throughout the Jordan Valley during Roman rule. Recorded in "The Legacy of Rome" (published in Latin) is the identification of some 22 individual systems in the project area where subsurface water has been developed and used for irrigation. Almost all work was done with slave labor and it is reported that during the peak of construction some 30,000 slaves were employed. The irrigation systems referred to are known as "fuquarās" and "kanāts".

The fuquarās are underground canals which were used to develop and carry the water to gravity canals called kanāts. It is the fuquarā part of the system that has created the drainage problems. Topography played an important part in locating the fuquarās in order for them to function as an integral part of an irrigation plan. For this reason they start near the foothills and extend toward the valley. Two methods of construction were used; namely, the dry system and the wet system, the only difference between the two being the source of water. Both systems were quite effective in meeting their purpose, however, it is the dry system that is creating the most serious drainage problems.

To construct the wet type fuquarā, vertical shafts were dug to a water bearing aquifer. Normally these shafts were dug 25 to 30 meters apart, then a connecting tunnel was dug joining all the shafts. The tunnel slope was generally maintained between 2 and 15 meters in 1000 meters depending on topography where the tunnel daylighted to connect with the kanāt part of the system. Once this type of system becomes inoperative the water only rises in the tunnel to a point equal to the elevation of the water bearing aquifer. A normal drainage system will remove these subsurface waters quite adequately and since no great hydrostatic head is present to force the water upward, it is felt that further high water tables will be eliminated. In general the amount of water developed by this type fuquarā is very limited and the quality very poor as far as irrigation is concerned.

In constructing the dry type fuquarā the vertical shafts and connecting tunnel were dug, extending the tunnel to join the kanāt system. One of the shafts, usually near the outlet, was extended downward to an artesian aquifer thus bringing water to the tunnel from below. Each shaft could be extended to the artesian aquifer to produce additional water if required. The static head created by waters from the artesian aquifer has proved to be the source of water causing high water tables in many areas where fuquarās of this type have been blocked, particularly in the southern part of the East Ghor Area.

The average length of the wet type fuquaras is much greater than the dry type, which usually is between 300 and 500 meters, while the former range from 500 meters to 1.5 Kilometers. The tunnel dimensions, however, are essentially the same, 0.7 meters wide and 2.0 meters in height. A typical cross section of a fuquara is shown on Drawing JR-6, which follows, and the approximate locations of known fuquaras within the project area are shown on Drawing JR-8, Base Map.

Fortunately the dry type fuquaras occur in the same area as that affected by artesian seepage and the recommendation to lower the water table by pumping would reclaim this area also. The quality of the water from the dry type fuquaras is essentially the same as that found coming from the artesian aquifer.

Investigations

Some 38 undisturbed soil permeability tests were conducted throughout the project area, following the methods as set forth by the U. S. Salinity Laboratory Handbook No. 60 issued in February, 1954. Water from the Yarmouk River was used throughout the tests and rate of infiltration, depth, lateral movement and salt dispersion carefully noted. The results of the field permeability tests supported by soils investigation are used as bases for determining drain spacing requirements. The basic formula used to determine spacing is a modified adaptation of Darcy's Law as shown on Drawing JR-7, which follows.

Leaching

Lands within the project area requiring some degree of leaching before becoming productive amount to approximately 174,000 donums. A specific leaching program will be required for approximately 167,000 donums located generally on the East Ghor south of the River Zarqa, and on the West Ghor. Lands near the Dead Sea have the highest percentage of total soluble salts.

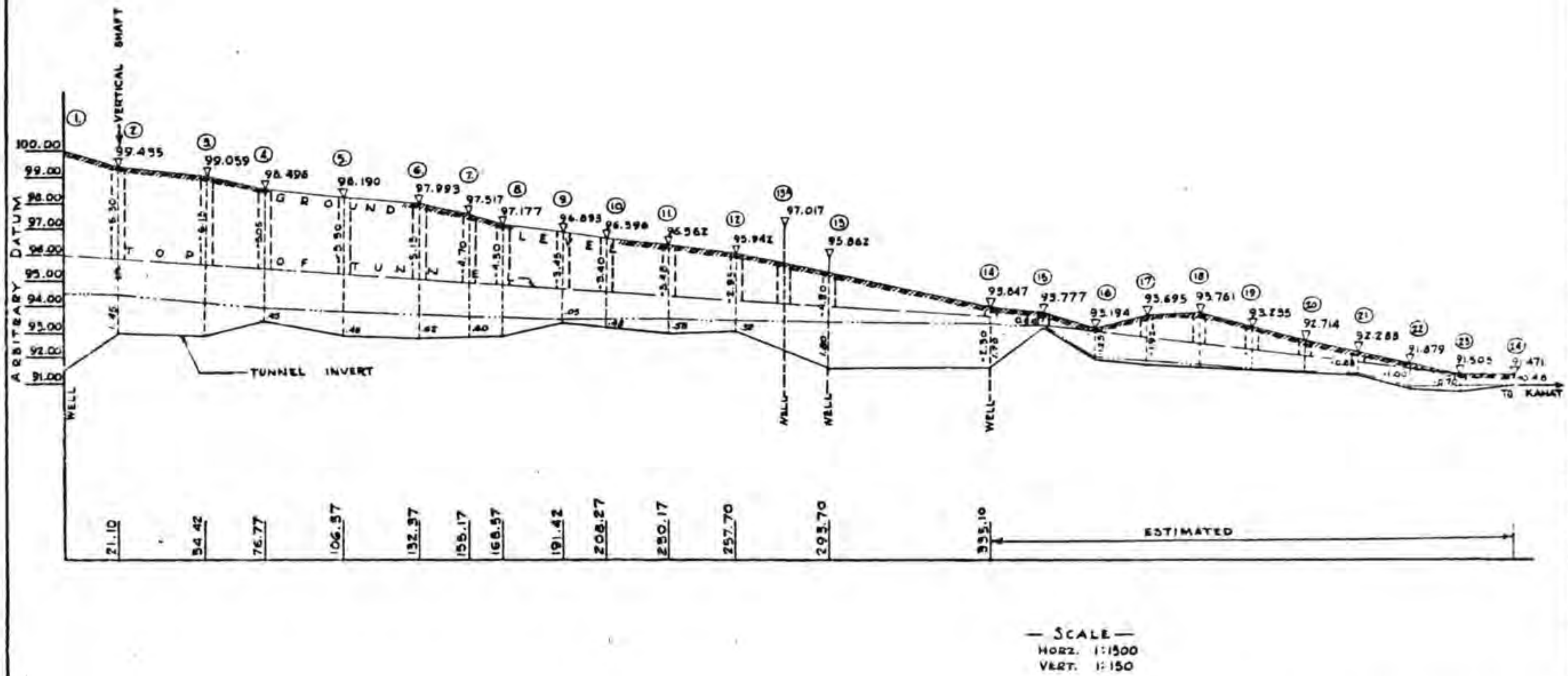
In order to establish procedure for leaching such lands, two test areas were selected, located approximately by coordinates as 142.0N. - 204.4E. Approximately 150 meters separated the two areas. The physical difference between the areas was the installation of drainage facilities in area 1 while area 2 did not have such facilities. Soil samples were taken on a definite pattern from the areas before any water was applied and the same pattern followed in taking subsequent samples after water applications.

The quality of water available for use as a leaching medium was not desirable, however, the final results show that such lands can be leached and perhaps more successfully with a better quality water as shown by the infiltration studies. The final results of the trials show conclusively that definite patterns should be followed as to quantity of water applied and method of application. Another interesting fact observed during the trials, relative to drainage, is that subsurface drainage installation must wait until after a degree of leaching has been done, due to the poor stability of the soils until a large percentage of the salts have been removed. The salts can be forced downward more evenly without a drainage system, but a reverse movement can be expected unless a drainage system can be installed after salts have been removed to approximately 90 centimeters. The quantity of water applied for normal irrigation of shallow rooted plants would not be sufficient to keep the salts at this level without the aid of subsurface drainage.

Types of Drain

Topography, size of farm unit, the need for fullest land utilization, and weed control have definitely favored the selection of covered drains rather than open drains, with the exception of a few shallow open drains to remove excess surface waters. Normally the closed type drains include a manufactured conduit such as concrete tile, clay tile or fiber pipe, with a gravel and sand blanket, placed in a trench which is completely backfilled, so that normal farming operations can be done directly over the drainage system.

The high salinity of drainage waters, excepting in the northern portion of the East Ghor Area limits the utility of concrete tile. Clay tile and fiber pipe which would be acceptable are not manufactured in the Kingdom in quantities sufficient to satisfy the needs of the project, and import cost of such materials would make this type of drain prohibitively expensive. For these reasons alone the rock or stone type drain is recommended. All materials and labor required to construct this type of drain are available within the boundaries of the Kingdom and can be utilized fully. Properly constructed rock drains need not present any greater maintenance problem than tile drains.



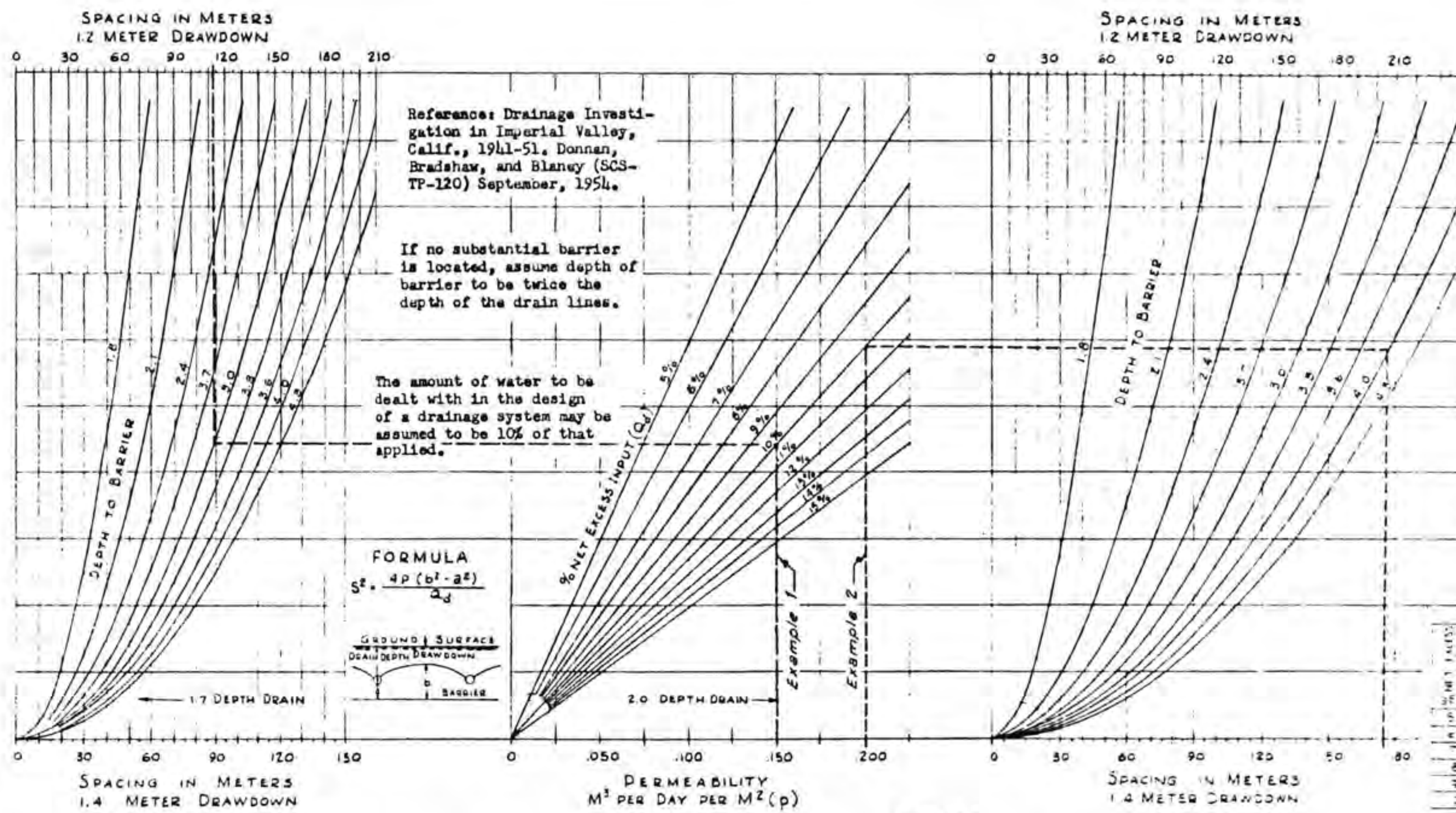
JORDAN VALLEY - MASTER PLAN

TYPICAL FUQURA

LONGITUDINAL SECTION OF A DRY TYPE FUQURA NEAR WADI ARROUB

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

DATE 12-7-54 | DWG. Nº JR-6



% NET EXCESS INPUT	q_d
5	[illegible]
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8	[illegible]
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10	[illegible]
11	[illegible]
12	[illegible]
13	[illegible]
14	[illegible]
15	[illegible]

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DRAIN SPACING CURVES

REFERENCE - SCS-TP-120 SEPT. 1954

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

DATE 12-15-54 DWG NO JR-7

EXAMPLE 1

Determine drain spacing for a depth to water table of 1.2 meters at midpoint between drains, under the following conditions: an overall coefficient of permeability (p) of .15 M^3/M^2 per day, and an average drain depth of 1.7 meters. Assume 10% excess water (Q_d), and 3 meters to depth barrier.

Enter chart at .15 (p), go vertically to intersect 10% excess line; thence horizontally to left to intersect the 3 meter barrier curve; thence vertically, upward, and read drain spacing of 112 meters on scale at top of chart.

EXAMPLE 2

Determine drain spacing for a depth to water table of 1.4 meters at midpoint between drains, under the following conditions: an overall coefficient of permeability (p) of .20 M^3/M^2 per day, average drain depth of 2.0 meters, and depth barrier unknown. Assume 10% excess water (Q_d).

Enter chart at .20 (p), go vertically to intersect 10% excess line; thence horizontally to right to intersect 4 meter barrier curve (When barrier depth is unknown, assume to be 2 times drain depth), thence vertically downward and read spacing of 175 meters on scale at bottom of chart.

When permeability (p) is beyond the range of the chart use maximum established drain spacing according to depth of drain.

THE HASHEMITE KINGDOM OF JORDAN

YARMOUK - JORDAN VALLEY PROJECT

MASTER PLAN REPORT

VOLUMES

III - LAND RESOURCES

IV - IRRIGATION AND DRAINAGE

1955

MICHAEL BAKER, JR., INC.
ROCHESTER, PENNSYLVANIA

HARZA ENGINEERING COMPANY
CHICAGO, ILLINOIS

CONSULTING ENGINEERS

VOLUME III - LAND RESOURCES
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Contents

List of Tables

List of Drawings

TABLE OF EQUIVALENTS

LENGTH

1 - Millimeter (mm)	0.039 Inches
1 - Centimeter (cm)	0.394 Inches
1 - Meter (M)	39.37 Inches
1 - Meter	3.281 Feet
1 - Kilometer (Km)	0.621 Miles

AREA

1 - Square meter (M^2)	1.196 Square yards
1 - Donum	1,000. Square meters
1 - Donum	0.247 Acres
1 - Square kilometer (Km^2)	0.386 Square miles

VOLUME

1 - Cubic meter (M^3)	35.31 Cubic feet
1 - Cubic meter	1.308 Cubic yards
1 - Million cubic meters (MCM)	810.7 Acre feet

WEIGHT

1 - Kilogram (Kg)	2.205 Pounds
1 - Metric ton (MT)	1,000. Kilograms
1 - Metric ton	2,205. Pounds
1 - Metric ton	1.102 Tons (short)

FLOW

1 - Liter/second	15.85 U.S. gallons/minute
1 - Cubic meter/second (M^3/Sec.)	35.31 Cubic feet/second
1 - Cubic meter/second	86,400. Cubic meters/day
1 - Cubic meter/second	2,592,000. Cubic meters/month (30 days)
1 - Cubic meter/second	31,536,000. Cubic meters/year (365 days)
1 - Cubic meter/second	70.0 Acre feet/day
1 - Cubic meter/second	15,850. U.S. gallons/minute
1 - Cubic meter/hour (M^3/Hr.)	4.4 U.S. gallons/minute

ENERGY

1 - Kilowatt (kw)	1.341 Horse power (HP)
1 - Kilowatt-hour (kwh)	1.341 Horse power hours
1 - Kilowatt-hour	367,100. Kilogram meters

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PART 1. LAND CLASSIFICATION

Purpose and Scope

The purpose of the investigation was to make a systematic appraisal of the soil, topographic, irrigation, and drainage characteristics of the land in order to determine its degree of suitability for sustained irrigation agriculture. A detailed classification survey was carried out in accordance with Bureau of Reclamation standards, modified to meet local conditions.

This program was carried out in conjunction with F.O.A. technicians, through Cooperative Department for Water Resources Development, Ministry of Finance, Government of the Hashemite Kingdom of Jordan, and field investigations were completed in December of 1954. A total of 942,843 donums (1 donum = .247 acres) of land was classified, as shown in Table 3.1-1. Of this amount, 519,846 donums are classed as arable. Drawing JR-21 shows the general classification for the project.

Table 3.1-1

Summary of Land Classification

Land Class	Area in Donums	Percent of Total
1	143,090	15.2
2	138,474	14.7
3	65,972	7.0
4	172,310	18.3
6	422,997	44.8
Total	942,843	100.0

Topography

The floor of the valley consists of east and west terraces separated by the Jordan River and its flood plain. These terraces and the flood plain are referred to as the ghors and zor, respectively. The ghors slope toward the river at a rate of 15 to 25 meters per kilometer, and in many areas are highly eroded and of "badland" appearance, (the Katar), where it breaks into the zor. The zor, today, is a minor valley 1 to 2 kilometers wide and subject to a degree of annual flooding.

The sides of the Jordan Valley are well defined in that they are high and steep. In general, the area classified is bounded on the upper edge of the East and West Ghors by the escarpment.

Sheet erosion, encouraged by predominantly winter rains and sparse vegetation, has produced minor surface modifications. Cobbles and boulders scattered over certain areas indicate that sheet erosion and wind action have removed finer materials. Similarly, other localities appear to have recent deposits of wind and water borne materials.

Soils

Ancient faulting, accompanied by sinking and rising of large land masses, is responsible for the Jordan Valley as it exists today. At one time the area was covered by an arm of the Red Sea and during this period a thick blanket of calcareous silts and clays (marl) was deposited. Valley fill and land upheavals eventually raised these silty materials above the surface. Before it was covered by other materials from adjacent uplands, stream action accomplished a degree of surface sculpturing.

The Jordan River cut deeply through this material in a meandering course and today flows through its recent flood plain, the zor.

Materials deposited in the zor include coarse as well as fine separates, but calcareous silts and clays predominate since upland parent materials are of such nature.

Saline sedimentary deposits remain as terraces or benches on each side of the zor. These benches, ghors, were in turn covered by alluvial and colluvial material transported by tributary streams from adjacent uplands. Alluvial fans of varying size were thus laid down, some nearly coalescing while others do not. As stream sorting took place a few areas were covered by medium textured material particularly toward the southern part of the area. Predominantly, however, parent materials brought into the valley are calcareous silts and clays.

The depth of the alluvial deposit above the marl decreases from the foothills toward the center of the valley with some minor local variations. During the course of deposition of this transported material the coarser particles have naturally tended to separate out first, next to the hills, and the fines have been carried further out onto the ghor area.

Soils within the area classified were divided into four major recognized groups as follows: Reddish-Brown, Grayish-Brown, Whitish-Gray, and Azonal soils.

The Reddish-Brown soils are formed from alluvium laid down on top of marls and are generally located on the alluvial fans north of the River Zarqa. Higher rainfall in this area together with irrigation over a long period of years has increased water percolation through the soil profile and accounts for the two dominant characteristics which distinguish this soil from others in the project area. These characteristics are the bright reddish-brown color which result from oxidation of the iron in the soil, and a more highly developed subsurface horizon which, in places, approaches a weak clay pan. Depth of soil varies and is considerably thinner near the breaks which are called the "Katar". Clay loams are predominant and prismatic structure is often found between 30 and 45 centimeters. Because greater quantities of water have passed through this soil, it is generally permeable and free of serious saline and alkali problems. The major exception to good permeability occurs north of Wadi Arab as a result of the extremely high clay content of the soil.

The Grayish-Brown soils are also formed from alluvium laid down on top of marls and are generally located on the alluvial fans south of the River Zarqa. Precipitation is rather low in this area and it is reflected in the small amount of iron oxidation in the soil profile, the absence of prismatic structure, and the predominance of single grain lighter structures. Depths of these soils also vary, and like the Reddish-Brown soils become thinner near the "Katar". Texture varies from clay loams in the north to sandy loams in the extreme south. Scattered areas, of small extent, of saline soils with weakly cemented gravelly lime zones are found in this group. Permeability is generally good and the soils are well suited to sustained irrigation.

The Whitish-Gray soils are residual soils formed from saline water deposits and marl type parent material. These soils occur between the lower edge of the alluvial fans and the "Katar" with the largest areas being found in the southern parts of both the East and West Ghors. Depth of soil over modified or residual marly type parent material is usually sufficient for most truck and cereal crops. Loams and clay loams are the predominant textures. The surface soil is, usually, spongy and fluffy. Generally, the structure of the subsoil is either massive or laminated. Heavy salt deposits, gypsum predominating, are common throughout the entire profile and are heaviest at the lower limit of the zone of evaporation. Frequent, deep, vertical crevices and cracks are filled with top soil and cut through the marly deposits to form natural outlets for drainage. Inherently, these soils have a high fertility and productive capacity and will be well suited to sustained irrigation after reclamation.

The Azonal soils of recent flood plain deposition are found in the zor. Clay and sand are deposited in layers and the soil is, usually, sufficiently deep to afford a good root zone for most plants. Soil forming factors have not had sufficient time to produce an aggregate soil structure. Lands free of high water tables are also free of salts. Permeability of isolated pockets of clay is often low, but such pockets are usually dissected by stringers and lenses of subsurface sand and gravel assuring adequate drainage. These soils are well adapted to production of diversified truck and field crops.

The outstanding characteristics of these four soils types are summarized in Table 3.1-2, Evaluation of Soils Characteristics by Types which follows.

Table 3.1-2

Evaluation of Soils Characteristics
By Types

TYPE	PRESENCE OF MARLS		CHARACTERISTICS			DEGREE OF		PERMEABILITY	SPECIAL PROBLEMS	VEGETATIVE COVER	SUITABILITY	
	Modified	Residual	Parent Material	Texture	Structure	Salinity	Alkalinity				For Crops	For sustained Irrigation
Reddish-Brown	Seldom in 5-foot zone	Seldom in 5-foot zone	Alluvial fan deposits	Clay loam to Clay	Prismatic over Blocky or single grain - stable	None to very slight	NONE	Fair to Good	Clearing. Occasional Pockets of heavy surface cobble.	Native grass. Irrigated small grain	Orchards and other deep-rooted crops	Excellent
Grayish-Brown	Occasionally in 5-foot zone	Seldom in 5-foot zone	Alluvial fan deposits	Clay loam to clay (North) Loam to Sandy loam (South)	Single grain - stable	None to slight	NONE	Good	Clearing. Occasional Pockets of heavy surface cobble.	Native grass. Irrigated small grain and Truck Crops	Orchards and other deep-rooted crops	Excellent
Whitish-Gray	Frequently in 5-foot zone	Occasionally in 5-foot zone	Marl	Loam to Clay Loam	Sponge - (Surface) Massive or Laminated (Beneath) - unstable.	Heavy Salts Present	Slight	Fair to Good	Reclamation. Leaching may cause moderate settling of soils.	Salt grass, low brush, bananas, truck crops	Truck Crops and Cereals	Good (After reclamation)
Azonal (Zor)	Seldom in 5-foot zone	Seldom in 5-foot zone	Flood Plain Out-Wash	Complex, clay dominant	No aggregate structural development. Parent material in layers.	None to slight	NONE	Good	Leveling. To correct drainage problems in small areas for irrigation.	Salt grass, low brush, irrigated truck crops	Truck Crops and Cereals and Sugar Beets	Good

Methods

The features of soil, topography and drainage were examined and the effects they would have on crop adaptabilities, crop yields, and costs of production were evaluated in order to segregate the land into classes. Field mapping was done on aerial photographic mosaics that have a scale of approximately 1:2,500. Topographic sheets with 1 meter contour intervals were used in conjunction with the photographs. Drawing JR-20 provides an index of the aerial mosaics. Additional controls were maintained by use of a Brunton Compass and Abney Level. The areas covered by the photographs were traversed systematically with such deviations as necessary to determine the boundaries of the different land classes. On the more uniform areas 8 to 10 holes per square kilometer were dug with a soil auger to a depth of one and a half meters, recorded, and located on the photographs. On the more complex areas the investigation was much more intensive. The soil borings were spaced at sufficient intervals to determine as accurately as possible the delineations between land classes and subclasses. Numerous holes were also examined to evaluate the deeper subsoil and drainage conditions.

Individual classifiers in the field normally mapped a "tier" or "string" of photo maps extending from the River Jordan to the upper reaches of the ghor. These maps were in turn "matched" to the surrounding areas mapped by other classifiers in order to insure coordination of effort and continuity in delineating over-lapping classes of land. In this manner field consultations, coupled with additional soil analyses where the need was indicated, more readily resolved existing or potential problems.

After field and laboratory information were correlated, definition lines for land class and subclass areas were placed on the photo maps. These maps were individually inked, measured and tabulated in accordance with accepted practices. All measurements were adjusted to conform to the Palestine Grid system which had been reproduced on the controlled aerial mosaic photo maps. In this manner the total area of the project was summarized by individual land classes grouped as arable and non-arable lands. Subclasses within each major land class were grouped into categories of similar characteristics.

The laboratory furnished analytical data necessary for a scientific classification of the Jordan Valley soils. Disturbed soil samples from about 50 percent of the meter and one-half borings made by the field classifiers were submitted to the soils laboratory in Amman. Samples were of a composite nature and were taken according to textural zones or zones of other visible soil characteristics such as color change. Very rarely did a soil sample represent a depth greater than 60 centimeters. All samples were analyzed for total soluble salt content and soil alkalinity or degree of sodium saturation. Further analyses were made as requested by the field classifiers and additional tests performed when the need was indicated. The field infiltration sites selected throughout the valley were also used as representative areas for physical and chemical analyses of the soils.

In general, the methods of analysis used were essentially as outlined in Agriculture Handbook No. 60, United States Department of Agriculture issued in February of 1954, exceptions being mechanical analysis, dispersion percentage, hydraulic conductivity, organic matter, available phosphorus, and available potassium. The major analyses performed include the following:

1. Salinity (as indicated by measuring the electrical resistance of saturated soil paste or measuring the electrical conductivity of saturation extracts)
2. Soil reaction or pH (1:5 soil-water suspension)
3. pH (saturated soil paste)
4. Saturation moisture percentage
5. Air-dry moisture percentage
6. Exchangeable sodium
7. Cation exchange capacity
8. Mechanical analysis
9. Dispersion percentage
10. Hydraulic conductivity of disturbed soil samples
11. Organic matter
12. Total dissolved solids
13. Gypsum
14. Calcium, magnesium, sodium, potassium, carbonate, phosphorus, bicarbonate, chloride and sulfate

Mechanical analyses were made by shaking a weighed sample of soil, overnight, with 5 ml. of Calgon solution (304 gms/liter) and 5 ml. of sodium silicate solution in 4 oz. of demineralized water. The following morning the suspensions were diluted to 1 liter in a soil testing cylinder. They were again shaken, specific gravity read using a long hydrometer at 70 seconds settling time, and again at 6 hours and 40 minutes settling time using a big bulb hydrometer. The distance from the center of volume of the hydrometer bulb to an average reading (1.0150 on the long hydrometer and 1.0050 on the big bulb hydrometer) was taken as the distance of fall for calculating reading time by Stokes Law.

Dispersion percentages of silt and clay were determined by dividing the corrected 70 second reading obtained in shaking by that obtained in mechanical analysis and multiplying by 100. In shaking, a sample of soil of the same weight as that used in mechanical analysis was evacuated in 200 ml. of water and then diluted to one liter in a cylinder. The mixture was then inverted 30 times in one minute to thoroughly mix before allowing it to settle.

Hydraulic conductivity of disturbed soil samples was determined by U. S. Bureau of Reclamation procedure. A brass cylinder two inches in diameter and length was covered on one end with a circular piece of rayon cloth held in place by a rubber band. Soil passing a 2 mm. mesh sieve was placed in the cylinder and compacted by dropping the cylinder ten times from a height of one inch. A circular piece of filter paper was placed on the soil surface to prevent surface disturbance. The unit was then placed on a glass funnel and subjected to a 1:1 head of water. The percolate was measured hourly until a constant rate was obtained, and "Darcy's" formula used to calculate hydraulic conductivity. All tests were run in duplicate and Yarmouk River water was used in all tests.

Organic matter was determined by wet oxidation with chromic sulfuric acid using the "Walkley-Black" technique of adding the concentrated sulfuric acid to 10 ml. of dichromate solution containing the sample. The resulting hot solution was swirled and allowed to stand 10 minutes, after which 150 ml. of water was added. An excess of ferrous iron solution was added and the solution back titrated with standard potassium permanganate solution.

Available phosphorus was measured using 0.5 N-$NaHCO_3$ solution as an extracting reagent, as proposed by Sterling Olsen et al. Potassium was determined on the same extract with the flame photometer.

Soil Permeability Studies

Field investigations were conducted to obtain the permeability and internal water movement of various soils under undisturbed field conditions. These infiltration studies were conducted in accordance with the method given in Salinity Laboratory Handbook No. 60. An additional guard ring, composed of earth, surrounded each infiltration cylinder to compensate for lateral water movement. A 15 centimeter depth of water was maintained in the cylinder and earthen ring, and the rate of subsidence of the water surface inside the cylinder was measured hourly or more frequently if fast subsidence occurred. Triplicate infiltrometers were continuously maintained until a uniform infiltration rate was established. These tests were conducted with Yarmouk River water in order to simulate reaction under project water supply as closely as possible.

Thirty-eight sites were selected to represent typical areas. Results of these tests are presented in Table 3.1-8, Chemical and Physical Analyses of Infiltration Sites. Three of these sites were excavated to the assumed restricting zone depth (primarily marl) and the rates determined. In every instance these rates were higher than the surface rates indicating that flow divergence was negligible. A compact carbonate gypsiferous layer varying from 2.5 to 7.5 cm. and existing below the surface from 20 to 45 cm. is characteristic of some of the soils placed in Class 4 principally in the southern part of the valley. Although a slow infiltration rate was evidenced at first, mechanical probing of this compacted gypsiferous zone greatly increased the permeability. The site at Grid 139 North, 206 East, hole 10 illustrates this finding. Indications are that deep chiseling practices on these soils would aid materially in reclamation of these soils.

As indicated in Table 3.1-8, the soils north of the River Zarqa are relatively free of soluble salts, exchangeable sodium and gypsum. The soils of this area range from medium to heavy texture, being heavier toward the north end of the valley. Also illustrated is the fact that the soils south of the River Zarqa are generally higher in soluble salts and exchangeable sodium. Soil textures tend to be medium in nature, and the soluble salt concentrations are composed principally of divalent cations which reduces the seriousness of the exchangeable sodium indication. These soils appear high in exchangeable sodium, due to the low cation exchange capacities reflected as a result of interference by the divalent cations in the exchangeable cation analysis. In addition gypsum is present in sufficient concentration to prevent development of sodium alkalinity during reclamation.

Data revealing the effect of leaching on the soluble salt concentrations within the infiltration sites south of the River Zarqa are presented in Table 3.1-6, Soluble Salt Displacement Resulting from Infiltration Studies. In every instance appreciable salt displacement occurred during the infiltration test. It is remarkable that soils containing approximately 5.0% salt dropped to 0.1% salt during infiltration measurements. The magnitude of leaching in these soils was noticeable down to the 60 cm. depth, and in some sites extended as far down as the 120 cm. depth before slight salt differentials were noted.

In general, investigations indicate that the soils comprise two broad groups, non-saline in the area north of the Zarqa River, and saline in the area to the south. Infiltration rates for the non-saline soils were generally very satisfactory, with the exception of a few observed in the extreme northern sector, where drainage could be a problem. The saline soils, Class 4 land, will require reclamation in order to reach a productive state. Adequate drainage will be required to maintain productivity once the soils have been reclaimed.

Land Classes

A land class is a category of lands having similar physical and economic characteristics which affect the suitability of land for irrigation. It has been called an expression of relative level of payment capacity. Five major classes of land are recognized in this study.

A fraction-type symbol is used to designate the different land classes. The number in the numerator designates the class of land. The letters following the land class are the subclasses and show the nature of the deficiencies. The subclasses are "s", "t", and "d" and represent deficiencies in soils, topography or drainage respectively. They may be used singly or in combinations. The letters in the denominator indicate the nature and extent of the deficiencies. The example in the lower left corner of Drawing JR-22, Land Classification Symbols, indicates the position of the various deficiencies in a land class symbol.

After correlating field examinations and laboratory information, the lands were segregated according to their degree of suitability for irrigation agriculture. Boundary lines between basic land classes are shown on the aerial mosaics as solid lines. Subclasses are delineated by dashed lines. Each arable class delineation has at least one recorded soil profile and is labeled with a land classification symbol.

Area and soil profile description for each recorded profile includes the following: 1) types of existing vegetation; 2) topography information with regard to gradient, position and unevenness of surface; 3) drainage conditions; 4) soil information with respect to structure, cementation, color, and depth to residual marl; and 5) laboratory information. Mapping symbols and abbreviations used in the land classification survey are shown on Drawing JR-22.

The features of soil, topography and drainage of Class 1 lands are favorable for the production of high yields of climatically adapted crops at relatively low production costs. The characteristics of Class 2 lands may cause the following: slightly reduced yields, increased production costs, slightly restricted crop adaptabilities or a combination of these factors. Class 3 lands are restricted in suitability for irrigation agriculture because of features that materially reduce crop yields, restrict crop adaptabilities, increase production costs, or produce a combination of these results. Class 4 lands are temporarily unsuited for irrigation agriculture due to saline content of the soil; however, they are considered to be reclaimable to at least the productive level of Class 3 lands. Lands unsuited for irrigation agriculture are designated as Class 6. Estimates of the degree of suitability for irrigation agriculture were made by comparing the characteristics of the lands with the minimum land class specifications presented in Table 3.1-3, Specifications for Land Classification.

The Class 1 lands are located primarily on the recent flood plains of the perennial streams on the ghor terraces with small scattered areas occuring on the zor. They have deep permeable soils with no, or slight, evidence of alkali or saline conditions. Most of the Class 2 lands occur on the outer fringes of the recent flood plains, as deep soils with moderately heavy profiles. Also included in Class 2 are lands with coarse textured soils on the recent flood plains, areas relatively shallow in depth to marl, those primarily located along the edge of the

Table 3.1-3

Specifications of Land Classification
For The
Yarmouk-Jordan Valley Project

Factors Evaluated	Arable			Potential Arable*	Non-Arable
	Class 1	Class 2	Class 3	Class 4	Class 6
S O I L S					
Texture	Sandy loam to very permeable clay.	Loamy sand to permeable clay.	Fine sand to slowly permeable clay.	Fine sand to slowly permeable clay	
Depth to:					
Sand, gravel or cobble	36" of fine sandy loam or heavier. 42" of sandy loam.	24" of fine sandy loam or heavier. 30"-36" of loamy sand.	18" of sandy loam or heavier. Fine sand permitted if underlain by heavier material.	18" of sandy loam or heavier. Fine sand permitted if underlain by heavier material.	
Bedrock, shale, or similar material	60"	36" depending on position and slope.	24" depending on position and slope.	24" depending on position and slope.	
Residual marl	36"	24"	18"	18"	
Modified marl	30"	18"	12"	12"	
Alkalinity	Surface pH 9.0 Subsoil pH 9.2	pH 9.2 pH 9.4	pH 9.4 pH 9.6	pH 9.4 pH 9.6	
Salinity	Surface .2% (may be higher in permeable soils) Subsoil .2% (soils with good drainage).	.5% (may be slightly higher in permeable soils). .5% (permeable soils with good drainage).	.5% (may be slightly higher in permeable soils). .75% (Higher in open permeable soils with good drainage).	In excess of Class 3 limits but susceptible of leaching to at least Class 3 percentages.	This includes all lands which do not meet the minimum requirements for arable land. This may include small bodies of arable land lying within larger areas of non-arable land.
T O P O G R A P H Y					
Slopes	Up to 4% in same plane. Less if complex slopes.	Smooth slopes up to 8% or complex slopes up to 4%.	Smooth slopes up to 12% or complex slopes less than 8%.	Smooth slopes up to 12% or complex slopes less than 8%.	
Surface	Regular enough to require only small amounts of levelling.	Moderate levelling and grading required. Estimated earth movement 200-500 M^3/Donum.	Heavy levelling and grading required. Estimated earth movement 500-800 M^3/Donum.	May exceed Class 2 levelling but should not be the maximum allowable for Class 3.	
Cover (loose rock and vegetation)	Cost of clearing small or insufficient to modify cultural practices or reduce productivity.	Clearing required. May be equivalent in cost to Class 2 levelling.	Heavy clearing necessary. May be equivalent in cost to Class 3 levelling.	May exceed Class 2 clearing but should not be the maximum allowable for Class 3.	
D R A I N A G E					
Soil and Topography	Requires only normal drainage with maximum permissible drain spacing as established from infiltration tests.	Additional drainage required. Conditions indicate slightly closer drain spacing than that established for Class 1.	Additional drainage required. Conditions indicate closer drain spacing than that required for Class 2.	Project drainage required as indicated for the potential arable class.	

* Class 4 - Areas having soluble salts in excess of limits for Class 3 land, and with soils and topography such that reclamation is highly feasible. Land Class potential after leaching indicated by parenthetical symbols.

Note 1 - The pH limits as set forth in the standards are based on one to five dilutions with limits slightly higher than Bureau of Reclamation standards. This applies to soils which are calcareous and gypsiferous in character.

Note 2 - In the overall use of the standards the various limits set up for each item in each class are used as guides and may be deviated from depending upon circumstances. A combination of factors is used to determine the land class both present and ultimate.

upper scarp having moderate rock cover and areas with soils of slight alkali or saline conditions. The principal Class 3 lands are characterized by soils of very coarse texture, undulating topography, surface rock, or major degrees of slope. These areas are predominantly found adjacent to the upper reaches of the ghor and the immediate fan areas of stream channels. The Class 4 lands possess a high percentage of soluble salts and must be leached before successful irrigation agriculture can be initiated. The majority of this land is located south of River Zarqa on the East Ghor and on the West Ghor, which are areas of low rainfall. Localized areas occur intermittently throughout the project area. Lands designated as Class 6 are principally the rough "breaks" between the ghor and zor, stream channels, shallow soils with strong alkali and high salt content, and undulating areas of very heavy textured soil with high salt content.

Relation of Land Classes to Crop Production, Crop Adaptabilities and Management (Table 3.1-4)

Class 1

There are 143,090 donums of Class 1 land in the project area. The soils include deep, permeable clay loams and significant areas of sandy loams, and loams. The heavier textured profiles are primarily located north of the River Zarqa on the East Ghor and in the vicinity of Wadi Fari'a on the West Ghor. The fans of Wadi Hisban and Wadi Kafrein, located at the southern part of the East Ghor, comprise a large area of the lighter textured soils in this class. The water holding capacity is good and the inherent fertility of these soils is relatively high. These features provide an excellent environment for the growth of climatically adapted crops and do not present any major problems to the operator. A

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 1 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
1	1/ll,1/lm,1/ml,1/mm,1/mh,1/mhz,1/hh	Smooth lands, deep permeable sandy loams and loams, minor areas of clay.	143,090	15.2	Climatically adapted crops.	No special problems.
2	2s/hhz	Clays and clay loam over marls.	2,766	0.3	Crops having moderately deep rooting systems.	Tillage problems.
	2s/hh	Clay, minor areas of clay loam, deep soils.	16,627	1.8	Crops having moderately deep rooting systems.	Tillage problems.
	2s/hha	Clay loams, minor areas of clay, deep, slight alkali.	11,024	1.2	Alkali tolerant, moderately deep rooted crops as sugar beets.	Tillage problems--leach to correct alkali.
	2s/lma,2s/lha,2s/mma,2s/mha	Light to medium textures, deep soil, slight alkali.	12,937	1.4	Alkali tolerant, deep rooted field and truck crops.	Leach to correct alkali.
	2s/ll	Smooth deep alluvium, low available water.	6,854	0.7	Deep rooted crops--early vegetables, potatoes.	Irrigate to avoid excessive deep percolation and fertilizer losses.
	2t/hhg	Clay loams, minor areas of clay, gradient 4-8%.	10,718	1.1	Climatically adapted crops.	Care in application of irrigation water on lands with gradient.
	2t/hhc,2t/hhu,2t/hhcg	Clay loams, moderate leveling or clearing required.	12,526	1.3		
	2t/mhu,2t/mhcu,2t/lhu,2t/mmu,2t/mmcu, 2t/lmu,2t/llc,2t/llu,2t/llcg	Light to medium textures. Moderate leveling or clearing required.	12,549	1.3		
	2st/mhcu	Moderately undulating lands with soil and alkali variations similar to the 2s lands as indicated by denominator symbol.	9,727	1.0	Similar to 2s lands as indicated by denominator symbols.	Problems similar to 2s lands as indicated by subclass symbols. Care in application of irrigation water on lands with gradient. Leveling and clearing costs as indicated for 2t lands.
	2st/hhc hhac, hhcg	Same as above	14,034	1.5		
	2st/llc,2st/llu,2st/llscu,2st/lmc	Same as above	10,506	1.1		
	2st/hhg	Clay and clay loam texture, gradient.	7,193	0.8		
	2d/hh,2sd/hh,2td/hhu,2std/hhcg,2sd/hha, 2sd/hhz	Clay loams to clays. Water table present.	11,013	1.2	Crops having moderately deep or shallow rooting systems.	Drainage, other problems similar to 2st lands as indicated by subclass - symbols.
3	3s/hha	Smooth, clay loams and clay, moderate alkali.	924	0.1	Moderately deep rooting system, moderately alkali tolerant crops.	Tillage
	3s/hmaz,3s/mmaz	Medium and heavy textures, over marl. Moderate alkali.	3,933	0.4	Shallow rooted, moderately alkali tolerant crops	Subsoil to open up marl and increase effective root zone. Leach to correct alkali.
	3s/hma mma	Smooth, medium texture, moderate alkali.	782	0.1	Deep rooted, moderately alkali tolerant crops.	

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 2 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
3	3t/hmg	Clay loams, minor areas of clay, soil deep, gradient 8-12%.	5,074	0.5	Climatically adapted crops.	Irrigate such that erosion is controlled.
	3t/mmc$_2$u$_2$,3t/mlu	Medium textures, moderate to heavy leveling and clearing required.	4,460	0.5	Same as above.	Moderate clearing and leveling.
	3st/hhazu 3st/hhc$_2$g$_2$ 3st/mmau$_2$, 3st/mmc$_2$g$_2$u$_2$, 3st/lhc, 3st/lhc$_3$g$_2$ 3st/llc$_2$u$_2$, 3st/llac$_2$u$_3$, 3st/llc-llu$_2$-llu$_3$	Generally severe topographic limitations. Soil and alkali conditions similar to the 3s lands as indicated by denominator symbols	4,989 11,517 15,718 14,902	0.5 1.2 1.7 1.6	Similar to 3s lands as indicated by subclass symbols.	Similar to 3s lands as indicated by subclass symbols.
	3d/hh,3sd/hh,3td/hhu,3std/llc$_2$u$_2$	Water table present.	3,672	0.4	Similar to other 3s land as indicated by subclass symbols.	Drainage--other problems similar to those of 3s lands as indicated by subclass symbols.
4(1)	1/hh,1/mh,1/hl,1/lh,1/mm,1/lm,1/ll	Smooth lands, deep, permeable sandy loams, loams and clay loams.	66,632	7.0	Climatically adapted crops. (After reclamation)	Leach to correct alkali.
4(2)	2s/hhz	Clay loams, clays over marls.	8,032	0.9	Crops having moderately deep rooting systems.	Leach to correct alkali.
	2s/hh,2s/hl	Clay surface texture: smooth, deep soil.	8,906	1.0	Deep rooted crops.	Tillage problems--leach to correct alkali.
	2s/mm,2s/ll	Medium and light textures. Low available water.	5,052	0.5	Very early truck crops.	Washing out of plants by wind or water. Excessive deep percolation.
	2t/hhu,2t/hhzu	Clay loams, minor areas of clay: soil deep; undulations	8,857	0.9		Leveling--leach to correct alkali.
	2t/mmg	Smooth, deep, medium texture. Gradient 4-8%.	1,969	0.2	Climatically adapted crops. (after reclamation)	Leach to correct alkali
	2t/hmu,2t/mmu,2t/mlu,2t/mlcu,2t/lmu,2t/llgu	Medium and light textures, moderate undulations	11,894	1.3		Leveling--leach to correct alkali.
	2st/hhu,2st/llcu	Moderately undulating lands with soil variations similar to 4 (2s) lands as indicated by denominator symbols.	4,711	0.5	Similar to the 2s lands as indicated by subclass symbols.	Problems are similar to those of 4(2s) lands as indicated by subclass symbols. Leaching required to correct alkali.
	2st/hhzu,2st/mhzu		10,216	1.1		
	2d/mh,2sd/hm,2td/hhu,2std/mmgu,2sd/hhz	Water table present.	5,125	0.5	Shallow rooted crops.	Drainage--leach to correct alkali.

Table 3.1-4

Relation of Land Classes and Principal Subclasses to Crop Adaptability and Management
Sheet 3 of 3

Land Class	Principal Subclasses	Salient Features	Gross Area	Percent of Total	Crop Adaptability	Management Problems
	3s/hn	Heavy-slowly permeable clay; smooth, deep soil.	7,632	0.8	Shallow rooted crops	Tillage problems, leach to correct alkali.
	3t/mmu, 3t/lmu, 3t/nmzg$_2$u$_2$	Medium and light textures. Heavy undulations	5,255	0.6	Climatically adapted crops (after reclamation)	Leveling - leach to correct alkali.
	3t/hhg$_2$u$_2$	Clay loam, minor areas of clay, moderate undulation, Gradient 4-8.	2,132	0.2		
4(3)	3st/hhg$_3$ 3st/mhac$_2$u$_2$ 3st/nmzg$_2$u$_2$, 3st/nmzu$_2$, 3st/mmzu$_2$	Generally severe topographic limitations. Soil conditions similar to the 4 (3s) and 4 (2s) lands as indicated by denominator symbols.	5,206 2,329 16,152	0.6 0.3 1.7	Similar to the 3s lands as indicated by subclass symbols.	Problems are similar to those of 4 (3s) lands as indicated by subclass symbols. Leaching required to correct alkali.
	3sd/nhz 3d/nm-3td/lhu-3std/mhu	Clays over marl, water table present. Medium and heavy textures. Moderate undulation. Water table present.	2,208	0.2	Shallow rooted crops	Drainage - leach to correct alkali; leveling where indicated in subclass.
6	6h, 6i (class 1, 2, 3)	Lands which by location are either high or isolated with respect to the delivery of irrigation water.	8,824	0.9	Native Pasture	—
	6s, 6t, 6st, 6std	Lands unsuitable for the economic production of any irrigated crop.	444,175	43.9	Native Pasture	—
		Total	942,844	100.0		

wide range of crops is being grown on these lands with good production.

Class 2

The Class 2 lands comprise 138,473 donums within the project area. Class 2 lands are generally less favorable for the production of most irrigated crops than are the Class 1 lands and in addition some of the Class 2 lands have developmental problems. The characteristics which cause these less favorable conditions and the major problems which may be anticipated are as follows:

a. Heavy Texture

(1) Permeable profiles (principal subclasses, 2s/hhz, 2s/hh). Approximately 19,000 donums are included in this grouping. The principal location of these lands is in the northern part of the valley in the vicinity of Adasiye. Infiltration rates range from 0.5 mm./hr. to 68.0 mm./hr. A large portion of this area has been farmed for many years and produces good crops. A minor portion of these soils are subject to vertical cracking and sealing necessitating care in water application. Tillage practices in these areas will be governed by the moisture content of the soil.

b. Saline-Alkali Lands

(1) Permeable profiles (principal subclass, 2s/hha). There are approximately 11,000 donums of land in this category. They occur generally on the upper fringe of lower lying areas. The problem is somewhat difficult to remedy with correctives due to heavy textured soils subject to vertical cracking; however, addition of gypsum and adequate subsurface drainage will help materially. Cultivation practices will be similar to the 2s/hh lands in regard to timeliness of operation. Crops such as sugar beets should do well on these areas.

(2) Very permeable profiles (principal subgroups, 2s/lma, 2s/lha, 2s/mma). These lands number approximately 13,000 donums.

The major portion is gently sloping and has soils that are deep, permeable and capable of holding a moderate amount of water for plant use. There is a slight alkali problem indicated by high exchangeable sodium, in most cases gypsum content is correspondingly high. Moderately alkali-tolerant, deep rooted crops should do well on these areas. When occurring as narrow tracts surrounded by soils of more favorable texture, appropriate soil-plant-water relations may be difficult to maintain and crop growth may be restricted. Irrigation practices producing moderate leaching are recommended.

c. Topographic Deficiencies

(1) Lands characterized by unevenness or cover, (principal subclasses, 2t/hhu, 2st/mhcu, 2st/llc). There are approximately 18,900 donums of Class 2 land that will require moderate leveling before they will be suitable for irrigation without special irrigation systems. Of this total approximately 4,000 donums have slight factors of both unevenness and rock or vegetative cover, the combination of which warrants placing them in a topographic deficiency category. Approximately 22,300 donums will require removal of rock or vegetative cover. These deficiency factors are expected to be corrected at a cost of between $14 and $19 per donum. After leveling and clearing has been accomplished, there are approximately 16,700 donums that will be of Class 1 quality.

(2) Gradient or complex slope (principal subclasses, 2t/hhg, 25/hhcg, 2st/hhg). These are lands with gradients that make irrigation patterns difficult since these areas quite often lie adjacent to smoother slopes. There are approximately 36,000 donums in this category, of which 15,600 donums will require clearing of cover. The general extent of topographic deficiencies is shown in Table 3.1-5, Extent of Topographic Deficiencies.

(3) Drainage problem (principal subclasses, 2sd/hh, 2d/hh, 2td/hhg). The total of approximately 11,000 donums in this grouping is rendered less significant due to the fact that the individual areas are

Table 3.1-5

Extent of Topographic Deficiencies

	EAST GHOR NORTH			EAST GHOR SOUTH			WEST GHOR		
	Above	Below Canal		Above	Below Canal		Above	Below Canal	
Deficiency	Canal	Ghor	Zor	Canal	Ghor	Zor	Canal	Ghor	Zor
Cover	About half of area affected. Particularly near the alluvial fans.	Minor importance. About 5%	Negligible	About half of area affected.	Locally important. About 7% of total area.	Local Pockets - Negligible	About 20% of area affected.	Negligible	Negligible
Leveling	Minor importance. About 5%.	Minor importance. Less than 5% of area.	Of major proportions. Nearly all lands need some.	About 15% needs leveling	About 12% of this area needs leveling.	Of major importance. Is principal deficiency.	25% of area is in need of leveling.	12-15% area is in need of leveling.	Principal deficiency in the Zor.
Gradient	About one-third of area is affected.	About 10% of area is affected.	Of minor importance.	About 10% of area is affected.	Of minor importance-about 5%	Negligible	About 20% of area affected.	Negligible	Negligible

Notes: Most cover deficiencies are of class 2 intensity.
Gradients (g), mostly of class 2. Smooth Slopes up to 8% or complex slopes up to 4%.
Leveling (u), mostly class 2 intensity. Movement of 200 to 500 M^3 per donum required.

relatively small. Primarily they consist of lands in shallow depressions and have been taken into account in designing the project drainage pattern.

Class 3

The Class 3 lands occupy 65,972 donums of the project area. The characteristics of Class 3 lands are fairly favorable to irrigation agriculture. Moderate alkali, very coarse textures, and fairly rough topography are the factors which primarily limit the suitability of these lands for irrigation agriculture.

a. Saline-Alkali Lands

(1) Lands with moderate alkali, relatively permeable soils (principal subclasses, 3s/hha, 3s/hhaz). The area in this category totals approximately 5,000 donums. They are smooth gently sloping lands in which moderate amounts of alkali and soluble salts have accumulated. A large portion of these lands are farmed to grain. Current irrigation practices with an inadequate water supply have permitted accumulation of salts from the subsoil, particularly in those areas underlain by marl at a relatively shallow depth. Infiltration tests indicate the profiles to be susceptible to leaching with an adequate water supply and drainage system.

b. Topographic Deficiencies

(1) Lands of uneven topography or relatively steep gradient, (representative subclasses, $3t/hhg_3$, $3t/mmc_2u_2$, $3t/mlu_3$). Approximately 9,500 donums of land are classed in this category. Of this total nearly 90 percent will require grading or clearing estimated to cost between $16 and $32 per donum. The remaining 10 percent possesses relatively smooth gradient of between 8 and 12 percent slope with medium heavy to heavy textured soils, which will necessitate careful application of water.

(2) Lands with combination topographic and soil deficiencies, (representative subclasses, $3st/hhc_2g_2$, $3st/mmc_2g_2u_2$, $3st/llac_2g_2u_2$). This group of land comprises 42,000 donums and will require grading and clearing as described in the foregoing paragraph. Of the total land in this category about one-half has a good water holding capacity; however, the range between wilting point and field capacity will be slightly reduced by the alkali condition of some 7,500 donums. The remainder is comprised of light textured soils of which about 5,700 donums are affected by alkali. These lands frequently occur as irregular shapes surrounded by lands of poorer quality. Care should be exercised in leveling in order not to deposit a layer of unproductive soil over these marginal soils, resulting in severely restricted crop growth. Frequent irrigation and fertilization will be required to maintain crop production due to low water holding capacity and low inherent fertility of the soil.

(3) Drainage problem (principal subclasses, 3d/hh, 3sd/hh). Lands of this category are relatively minor, totaling approximately 3,600 donums. They normally occur as very small depressions with evidence of a water table; however, they are of farmable size, and project drainage has been designed to provide subsurface outlets.

Class 4

The Class 4 lands comprise 172,310 donums of the area. Of this total about 14 percent are of Class 1 and 2 potential after leaching operations are completed. Primarily the soil textures, and topography of these lands are favorable and in most instances there is an appreciable amount of gypsum present which will materially aid in the leaching process. Total soluble salt content may range from 0.5 percent to greater than 3.0 percent in cases where soil, topography and drainage characteristics are favorable for leaching. The majority of this land occurs in large bodies primarily on the lower edge of alluvial fans, and are presently not irrigated.

The area of the East Ghor associated with the fans of the Wadis Shueib, Kafrein, and Hisban are representative of this category. Representative samples show total soluble salt content in one irrigated field as less than 0.2 percent, as compared to samples showing greater than 2.0 percent in an adjacent field which has had no irrigation water applied, but which is comparable in soil texture, topography, and drainage characteristics. Better than three-fourths of this area is characterized by soils with profiles ranging in texture from sandy loams to clay loams or permeable clays. Light to medium textured profiles are characteristic of about one-third of the area. The blocking of ancient underground water development systems (fuquarās) has given rise to saline conditions in some areas. It is contemplated this condition will be remedied by subsurface drainage.

The Class 4 lands on the West Ghor south of Jericho are similar in nature and position to those described in the foregoing paragraph; however, the presence of fuquarās has not been detected. These lands are predominantly characterized by clay loam and clay profiles. Large bodies of this category extend northward from the Jericho vicinity where again fuquarās have materially contributed to the saline content of these areas. Infiltration rates on these soils are generally good as indicated by a rate of 5.1 mm./hr. on a soil composed of 90 centimeters of clay over clay loam to a 1.5 meter depth.

After leveling and leaching operations the Class 4 lands are expected to assume the characteristics of those classes and subclasses indicated by the classification symbol following the 4 designation.

Class 6

Approximately 423,000 donums of Class 6 land are unsuited for irrigation agriculture, of which 8,800 donums are due to isolation from lands of an arable nature or excessive elevation. The remainder is the rough, shallow soil "break" between the ghor and zor areas, stream channels, and scattered rough and stony lands.

Leaching

Approximately 174,000 donums will require leaching of salts from the soil before a satisfactory degree of crop production can be expected. A specific leaching program is recommended for approximately 167,000 donums. The TSS percentage of these soils ranges upward from 0.2% with the average percentage somewhat greater than 3.0%. Two tenths of one percent soluble salt present within the upper meter of soil may be potentially damaging to crop yields.

Lands requiring leaching are designated as Class 4, of which the largest areas are in the southern part of the valley. To establish a basis for leaching recommendations two trial areas were selected and prepared under normal field conditions. Each area was divided into four plots of equal size and each plot within an area given a specified water treatment. The major difference in preparation for leaching was that Area 1 was provided with subsurface drainage facilities while Area 2 did not have such facilities. Table 3.1-6, Soluble Salt Displacement, shows the total soluble salt displacement, the amount of water applied and the infiltration rate during water application. Location and details of methods and procedures used in leaching trials are in Part 5 of Volume VII. Results of the trials indicate that salts can be leached from the soil. An application of 15 centimeters of water followed by subsequent

Table 3.1-6

Soluble Salt Displacement
Resulting From Infiltration Studies
of Jordan Valley Soils
(Sheet 1 of 2)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	Infiltra-tion Rate MM/Hr.	Water Applied M	Conductivity $ECx10^3$ Before Inf.	Conductivity $ECx10^3$ After Inf.
		East Ghor Area				
139N-206E	10	0- 15	1.0	2.47	117	3.8
139.670N-		15- 30			99	4.8
205.225E		30- 45			66	(3.2
		45- 60			56	(
		60- 75			51	(17
		75- 90			53	(
		90-120			55	18
		120-150			54	15
137.5N-204E	24	0- 15	124.5	7.68	161	7.6
		15- 30			117	11
		30- 45			70	6.1
		45- 60			46	5.9
		60- 90			19	6.6
		90-120			14	6.5
134.5N-208E	20	0- 15	25.4	1.01	188	6.6
135.760N-		15- 30			113	3.8
206.090E		30- 60			92	4.4
		60- 90			61	4.3
		90-120			49	4.6
		120-150			31	5.8
		150-180			38	6.6
140.5N-206E	22	0- 15	10.2	2.19	44	6.2
140.800N-		15- 30			50	4.1
205.820E		30- 60			52	3.7
		60- 90			61	4.4
		90-120			65	6.6
		120-150			83	25
		West Ghor Area				
172N-200E	9	0- 15	35.6	4.51	76	3.1
		15- 30			58	1.3
		30- 60			60	5.0
		60- 90			38	2.9
		90-120			29	3.1

Table 3.1-6

Soluble Salt Displacement
Resulting From Infiltration Studies
of Jordan Valley Soils
(Sheet 2 of 2)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	Infiltra-tion Rate MM/Hr.	Water Applied M	Conductivity $ECx10^3$	
					Before Inf.	After Inf.
(West Ghor Area Cont'd)						
145N-198E	1	0- 15	17.8	1.40	5.0	2.0
		15- 30			19	3.8
		30- 60			32	3.3
		60- 90			61	7.1
		90-120			58	41
		120-150			58	53
137.5N-198E	13	0- 15	99.1	5.88	183	4.8
		15- 30			110	3.5
		30- 45			117	13
		45- 60			106	24
		60- 90			78	35
		90-120			55	44
		120-150			32	29
133N-202E	13	0- 15	1.0	.15	67	5.3
		15- 30			65	4.4
		30- 45			45	41
		45- 60			46	46
		60- 90			49	48
		90-120			50	41
		120-150			65	59
133N-202E 133.575N-200.990E	12	0- 15	5.1	.30	160	3.9
		15- 30			156	5.0
		30- 45			144	32
		45- 60			137	48
		60- 90			134	53
		90-120			122	62
		120-150			141	118

applications of the same amount (each applied immediately after the previous one has been absorbed by the soil, until a total of 80 to 100 centimeters has been applied) will remove the salts to a safe level for shallow rooted crops and additional applications of water will maintain this level when adequate subsurface drainage has been provided.

Project Subdivisions

For purposes of this study the Jordan Valley has been divided into three subdivisions. These are the East Ghor North, the East Ghor South, and the West Ghor. Each of these was further divided into two primary sub-areas, above and below the main canal. The zor was segregated in tabulations to indicate its relative importance, although it will be an integral part of the area served by the main canals.

Land classes are summarized for each subdivision and sub-area in Table 3.1-7, Land Classification Summary. The distribution of these lands is shown on the land classification map, Drawing JR-21.

East Ghor North

Description. The East Ghor North subdivision comprises the lands lying between Yarmouk River in the extreme northern part of the valley and the River Zarqa, which forms an approximate mid-point dividing line of the lands east of the Jordan River. The lands extend from the Jordan River eastward to the steep slopes leading out of the valley. Nine sizeable wadis provide drainage, forming a series of small alluvial fans and interfan areas. The general gradient is in a westerly direction, and the elevation ranges from approximately minus 212 meters along the Main Canal location in the Adasiye vicinity to about minus 226 meters near the Zarqa River. Annual precipitation in this subdivision is of greater magnitude than any other portion of the valley and ranges from

Table 3.1-7

Land Classification Summary
Yarmouk-Jordan Valley Project

Area	Arable Class 1	Arable Class 2	Arable Class 3	Total Class 1,2,3	Class 4: 1	Class 4: 2	Class 4: 3	Total Class 4	Non-Arable Class 6	Total All Classes
	donums	donums	donums	donums	donums	donums	donums	donums	donums	donums
East Ghor North										
Ghor Above Canal	9,867	18,759	13,077	41,703	--	--	--	--	44,159	85,862
Ghor Below Canal	59,071	43,605	9,019	111,695	1,060	2,063	315	3,438	46,706	161,839
Zor Below Canal	4,677	8,689	3,774	17,140	200	314	254	768	6,267	24,175
Total Ghor and Zor Below Canal	63,748	52,294	12,793	128,835	1,260	2,377	569	4,206	52,973	186,014
Grand Total East Ghor North	73,615	71,053	25,870	170,538	1,260	2,377	569	4,206	97,132	271,876
East Ghor South										
Ghor Above Canal	12,055	11,705	8,368	32,128	298	317	470	1,085	45,985	79,198
Ghor Below Canal	29,721	23,498	11,608	64,827	33,808	27,554	13,677	75,039	93,297	233,163
Zor Below Canal	985	8,343	2,789	12,117	1,732	2,212	200	4,144	5,342	21,603
Total Ghor and Zor Below Canal	30,706	31,841	14,397	76,944	35,540	29,766	13,877	79,183	98,639	254,766
Grand Total East Ghor South	42,761	43,546	22,765	109,072	35,838	30,083	14,347	80,268	144,624	333,964
West Ghor										
Ghor Above Canal	18,400	14,591	11,184	44,175	8,748	6,491	5,815	21,054	55,525	120,754
Ghor Below Canal	7,395	4,584	2,275	14,254	19,595	23,373	18,863	61,831	123,940	200,025
Zor Below Canal	919	4,700	3,878	9,497	1,190	2,440	1,321	4,951	1,776	16,224
Total Ghor and Zor Below Canal	8,314	9,284	6,153	23,751	20,785	25,813	20,184	66,782	125,716	216,249
Grand Total West Ghor	26,714	23,875	17,337	67,926	29,533	32,304	25,999	87,836	181,241	337,003
Totals										
All Land Above Canal	40,322	45,055	32,629	118,006	9,046	6,808	6,285	22,139	145,669	285,814
All Ghor Land Below Canal	96,187	71,687	22,902	190,776	54,463	52,990	32,855	140,308	263,943	595,027
All Zor Land Below Canal	6,581	21,732	10,441	38,754	3,122	4,966	1,775	9,863	13,385	62,002
All Ghor and Zor Below Canal	102,768	93,419	33,343	229,530	57,585	57,956	34,630	150,171	277,328	657,029
Grand Total All Land	143,090	138,474	65,972	347,536	66,631	64,764	40,915	172,310	422,997	942,843

Note: Class 6H and 6I (not shown) amounts to 8,823 donums or 2% of the total class 6 area; most of which is found on the West Ghor.

about 400 mm. near Adasiye to about 200 mm. near the River Zarqa. Typical land classification photo maps of this area are shown as Drawings JR-23 and JR-24.

Soils. The soils of the ghor have been formed primarily from alluvial materials that were stream borne and by general outwash from the uplands. This mantle was laid down over fine textured lake deposits (marls) and thins out as it approaches the "break" between the ghor and zor. Textures on the fans vary, but are predominantly medium with rock and gravels in the profiles being a limiting factor, especially in those areas adjacent to the hills. On the edges of the fans, clay loams predominate with clays occupying the interfan regions. Organic matter, while still relatively low, is higher in this northern area than any other part of the valley. Rainfall, together with other weathering agents, has played a principal part in modification of the soils. The lake-laid materials have undergone changes to such an extent that it is difficult in most cases to identify the original laminations and in most instances the structure has become softly consolidated. Marls were found to be present in the one and a half meter zone of depth in only 5 percent of arable area.

Topography. The series of alluvial fans in this area give rise to slopes whose gradient is seldom greater than 4 percent. Complex slopes of short runs occur on the upper edges of the fans adjacent to the foothills. Gradient on the larger fans, such as those of the Wadi Arab and River Zarqa, is relatively smooth with long uniform slopes. The lands between the Wadi Rajeb and River Zarqa are indicative of the larger interfan areas which are of medium to heavy texture with long gentle slopes. Above the location of the Main Canal, cover is generally composed of rock, while some vegetation removal will be required below the canal.

The zor area is characterized by old stream channels which have been filled in by flood action. The resulting complex slopes will require a major degree of leveling in these instances.

Drainage. Conditions for adequate surface drainage are favorable. Except for localized areas there should be little difficulty in establishing drainage outlets through natural stream channels.

Approximately 7 percent of the arable area has characteristics which indicate present or potential subsurface drainage problems. These areas are primarily indicated by the presence of a water table within the meter and a half depth of soil profile. This condition has developed where there is a pronounced differential in hydraulic conductivity of the soils in connection with a slope differential and in areas where fuquarās have been neglected or abandoned. A shallow depression occurs between Grid North 223 and North 230 comprised of slowly permeable soils whose clay fraction frequently exceeds 50 percent. Field observation indicates the clay to be of the expanding lattice type. Under present limited irrigation, drainage problems are not acute; however, irrigation with a full water supply will tend to aggravate conditions in this area. Controlled application of water, development with shallow rooted crops, encouragement of water penetration through use of gypsum, and installation of closely spaced drains are recommended.

Problem areas on the zor occur as a result of the proximity of the Jordan River water table, and from seeps or springs from the rough area which separates the ghor and zor. Installation of an interceptor ditch will effectively aid the latter condition while arable areas affected by the river water table can be productively farmed to shallow rooted crops with controlled irrigation practices.

Salinity and Alkalinity. In the area north of the River Zarqa soils are generally low in soluble salts and in exchangeable sodium and gypsum. These relationships are indicated in Table 3.1-8. Samples shown in this table were taken in areas where problems were either in evidence or whose existence was suspected. It will be noted that in practically every case where clay content is below 60 percent, the total soluble salts are below 0.2 by percentage, and exchangeable sodium is well below the critical point of 15 percent. Field permeability tests also indicate an adequate infiltration rate for the majority of the areas represented by these samples.

In the few areas where an excessive degree of alkalinity was found, the subsoil was the zone primarily affected. This condition is generally restricted to small areas in the vicinity of Adasiye, and where found, the soils are producing shallow rooted crops successfully. These soils show a clay content in excess of 60 percent with correspondingly low permeability rates. Although the total area represented by these latter conditions is small, they should receive additional study as the project proceeds. Soils amendments such as gypsum, and crop rotation including deep rooted crops should aid water penetration. The beneficial effects of drying on clay soils, through summer fallow, are also of considerable importance.

Findings and Conclusions. The East Ghor North area is generally suited for the further development of irrigation agriculture. Where water is available at the present time a variety of crops is being successfully grown. Soils are predominantly medium to heavy in texture, of good water holding capacity and are surprisingly fertile in view of the small amount of fertilizer utilized. The heavier clay soils are found primarily in the north end of the area, in the vicinity of Adasiye. Slopes are somewhat more complex in this subdivision. Rock cover is primarily found adjacent to the hills and stream channels with a greater degree of vegetative cover present below the proposed canal.

Areas involving salinity and alkalinity problems are relatively small, about 5 percent of the arable acreage, and where they occur are generally associated with drainage deficiencies. Installation of adequate subsurface drainage facilities and the addition of soil amendments such as gypsum will materially aid these lands.

East Ghor South

Description. The East Ghor South subdivision extends from the River Zarqa south to the northern edge of the Dead Sea, and from the steep slopes of the eastern foothills westward to the Jordan River. Lands in this subdivision lying north of the general vicinity of the surfaced road leading westward across the valley to the Damiya Bridge and the West Ghor, are rough and broken in nature. Southward from this vicinity the lands become generally smooth and gently sloping. The wide alluvial fans of the Wadi Shueib, Wadi Kafrein, and Wadi Hisban are partially irrigated with a limited water supply. The general gradient is westward toward the Jordan River and the area slopes to the south from an elevation of about minus 226 meters at the River Zarqa to approximately minus 392 meters at the Dead Sea. Rainfall in the area decreases from about 250 mm. near its northern boundary to about 100 mm. in the southern section. The land classification photo map JR-25 is representative of the northern section of the area, while JR-27 is typical of the lands to the south. Photo map JR-26 illustrates a representative section of zor land.

Soils. The most favorable soils are located on the broad, smooth, gently sloping alluvial fans of the three major wadis previously mentioned. Textures on the Wadi Shueib fan are loams, clay loams, and light clays with considerable rock in the area adjacent to Shunat Nimrin. Southward the fans of Wadi Kafrein and Wadi Hisban are lighter in texture with clay loams and loams predominating and sandy loam near Suweima. Soils on these fans are deep, porous, and relatively free of soluble salts and alkali. Where irrigated these areas produce good crops. Marl is seldom found within the one-and-a half meter depth.

The soils illustrated by profiles on land classification photo map JR-27 are generally representative of the areas south of Karama lying between the lower edge of the alluvial fans and the Katar. Color ranges from grayish-brown to whitish-gray with marl occurring under most of the area. North of Karama the lands become broken and soils are predominantly whitish-gray in color, with a smooth-lying area of these soils occurring in the vicinity of Grid North 164. Photo map JR-25 shows typical profiles of this latter area. Textures are predominantly clay loams, and soluble salt content is relatively high.

Topography. The majority of the East Ghor South area is characterized by long, gently sloping gradients well adapted to irrigation agriculture. Major exceptions to this condition are found immediately south of the River Zarqa and north of Karama where numerous small wadis cross the area, and in the zor. Leveling on the areas first mentioned above will be limited by shallowness to marl and rock in the profile. Less apparent, but of significance, are the small ridges formed on the ghor by wave action as the old inland lake receded, primarily found near the Katar south of the Ghor Nimrin area. Steeper gradients and rock cover are generally found above the Main Canal location as the result of stream outwash from the hills. A relatively insignificant area of vegetative cover, principally small Christ-thorn trees, is located in the vicinity of Wadi Hisban.

As in the other subdivisions, the zor requires a significant degree of leveling and clearing. This is particularly true south of Grid North 139 where flooding action of the Jordan River and outwash from the ghor and Katar have left partially filled channels, and thick growths of cane and salt cedar are prevalent.

Drainage. About 1 percent of the arable land area has evidence of a water table within the one-and-a half meter zone. The majority of this land is located along the lower edge of the ghor where water has been trapped by low alluvial ridges. Numerous channels pierce these "barriers" and removal of surface waters should be readily accomplished. The soils of these areas adjoining the Katar are generally heavy in texture and act as a vertical barrier for subsurface water. Fuquarās in the vicinity of Karama and Ghor Nimrin and artesian aquifers in the Ghor Nimrin and Ghor Kafrein areas create a drainage problem. Much of this land is within the area to be reclaimed by leaching practices. Infiltration tests have revealed the soils to be permeable. The 10 to 15 centimeter thick salt layer (formed at the evaporation zone of water under static head) occurring 40 to 60 centimeters below the ground surface can be broken mechanically with subsequent normal water movement. (See Table 3.1-8, Chemical and Physical Analyses of Infiltration Site, Hole 10). This problem is fully discussed in the Drainage section, Volume VII, of this report.

Drainage problems on the zor are primarily limited to small springs and waste irrigation water emerging from the Katar. An interceptor ditch at the "toe" of the slope is recommended for control in these localities. Minor areas, particularly south of Grid North 139, present problems in the form of depressions resulting from partially filled stream channels. Leveling will materially aid this present condition.

Salinity and Alkalinity. As can be seen on the land classification map of the Jordan Valley, the Class 4 land occupies a large part of the area in the East Ghor South. Of the 109,000 donums of land classified as Class 1, 2 or 3, approximately 27,000 donums are affected to a slight degree of salinity.

Land classification photo map JR-27 is typical of the Class 4 land on the East Ghor South. The complete analysis of Hole 22 shows high exchangeable sodium percentage, high gypsum content, and high total percent of soluble salts. Table 3.1-6 shows the conductivity of saturation extract of the soil strata before and after infiltration tests. With the application of 2.2 meters of water in this case, conductivities were reduced considerably in the top 1.2 meters of soil. Similar results are noted with varying amounts of water used in other tests both on the East Ghor and West Ghor.

Table 3.1-9 shows the composition of soluble salts in the 1:5 extracts, where five parts of water were used to one part of soil. Comparison with Table 3.1-8 indicates that in the areas south of River Zarqa leaching during infiltration tests considerably reduced the sulphate and chloride content and in all cases except one, sodium percentage decreased.

In the vicinity of Karama, the caving of a number of fuquarās has created a salinity problem, by forcing water with a rather high soluble salt content to the surface.

Near the Dead Sea, receding waters left heavy salt deposits. Soils towards the Dead Sea tend to light textures and should be readily reclaimable.

Much of the zor land lying adjacent to the Katar has a rather high salt content and is placed in Class 4. This can be noted on land classification photo map JR-26 showing the zor on both sides of the River Jordan and the adjacent breaks leading up to the ghor.

Findings and Conclusions. The East Ghor South is topographically well suited to irrigation agriculture. Where irrigated, soils on the major fan areas are presently producing good crops with a limited supply of water. In much of the area the line between irrigated and non-irrigated land is also indicative of salt-free and saline soils. Textures are variable, becoming lighter approaching the Dead Sea; however, clay loams predominate. Approximately 80,000 donums possess a high degree of salinity and will require leaching. Permeability, gypsum content and position of these lands are favorable for reclamation. Drainage studies indicate the presence of artesian aquifers which will be controlled as part of the land development program.

West Ghor Area

Description. This area occupies that portion of the Jordan Valley extending from the convergence of the Samarian Hills and the Jordan River at approximately Grid North 180, to the Dead Sea on the south and lying between the Jordan River on the east and the upward scarp of the hills on the west. The lands slope generally in an easterly direction toward the river. A number of stream channels cross the area including three perennial wadis of major importance, Wadi Fari'a on the north, whose fan is presently irrigated, Wadi Auja smaller in size but also presently developed and Wadi Qilt, whose alluvium forms the plains of Jericho, an area irrigated for many years. Small individual farms partially irrigated from springs or wells are scattered between these main areas.

Rainfall is generally the same as that of the East Ghor South, ranging from approximately 340 mm. near Wadi Fari'a to about 100 mm. in the vicinity of Jericho. Land classification photo map JR-28 shows an area in the vicinity of Wadi Fari'a, and photo map JR-29 shows an area in the vicinity of Jericho.

Soils. The soils on the West Ghor are predominantly formed from alluvial and colluvial deposits outwashing from the hills to the west. Soil depth varies, generally decreasing in thickness over the marly materials as the ghor and zor "break" is approached. The fans are somewhat cut-up by small channels angling in a south-easterly direction.

Soil texture varies considerably. The steep alluvial slopes, where wadis emerge from the hills, are quite gravelly with light and medium textures predominating. Southeast, toward the Dead Sea, and East of the Jerusalem road, soils are overwashed to a depth of 90 cm. over the marl, thinning out on the numerous ridges toward the lower edge of the fan. Most of the area which is not presently irrigated is high in lime and gypsum content and ranges from light brown to light reddish-brown in color.

Clay loams and clays predominate approaching the river. Total soluble salts are present in moderate to high concentrations. Where these soils have been adequately irrigated salts have been satisfactorily removed. The profiles and area shown on land classification photo map JR-29 are typical of this condition. Heavier textures predominate north of Jericho except where small alluvial fans possess light-colored soils of medium texture. Reddish-brown clays predominate in the vicinity of Grid North 158, East 194. Profiles are deep but salty probably due to the influence of fuquarās.

The Wadi Fari'a area, composed of dark colored soils, predominantly clay loams and clays, is extensively cultivated. Adequately irrigated areas are free from saline-alkali conditions and crop production is excellent. Steep alluvial slopes adjacent to the hills are lighter in color and high in clay and salt content. The area between Wadi Fari'a and Grid North 180 is predominantly composed of light colored soils derived from lake-laid deposits. Total salts and exchangeable sodium are relatively high. An infiltration rate of 35 mm. per hour was attained on a heavy clay loam, and the average conductivity of the saturation extract from samples throughout the 1.5 meter profile was reduced 84 percent by leaching which occurred during the infiltration test.

Soils on the zor are of recent alluvium, intermixed and reworked with river sediments. Much of the area is heavy textured and contains appreciable amounts of salt. (See land classification photo map JR-29, Hole 6) Productive fields of vegetable crops exist where lands are irrigated from the river. Clay content increases materially toward the south end of the valley, where a delta-like area is formed.

Topography. Gently sloping topography characterizes much of the large alluvial fan areas. Gradient is from the hills to the river, with a general slope of 1 to 2½ percent. The area south and east of Jericho approaching the Dead Sea is crossed by numerous small stream beds and swales fingering between marl ridges, which will necessitate a moderate degree of leveling. The nature of this area will tend to irregularly shaped, relatively small tracts of arable land. Much of the area on the lower part of the Jericho plain would benefit materially from releveling of irrigated fields. Uneven distribution of water, resulting from inadequate leveling, has produced varying degrees of leaching. Hole 22 on Drawing JR-29 has only slight evidence of salinity while adjacent areas which have received less water possess a greater degree. Areas in the vicinity of Grids North 140, 160 and 165, next to the steep alluvial slopes, will require a moderate to heavy amount of rock removal in addition to leveling. In general, however, the percentage of rock clearance required on the West Ghor is much less than that needed on the East Ghor.

Although the arable lands of the zor comprise only about 10 percent of the arable area of the western side of the valley, about half of this requires a moderate amount of leveling and brush removal. The zor area south of Grid North 137 is comparatively smooth as it has had less cutting action from flood waters than the northern sections.

Drainage. The general slope and numerous drainage-ways provide adequate surface drainage on the West Ghor except in very small isolated areas. Subsurface drainage is a factor of major importance in the vicinity of Grid North 146, low lying areas near Grid North 153 and Grid North 158, and shallow depressions around Grid North 167 and Grid North 172. These areas are apparently affected by the ancient fuquarās located in most instances in the proximity of the main West Ghor road leading northward from Jericho. Heavy textures and saline soils are found in these areas although hydraulic conductivity rates are generally favorable.

Alkalinity and Salinity. Alkalinity and salinity problems in the Jericho vicinity are very similar to those found in the southern part of the East Ghor South. Medium and light textures predominate and part of the area is irrigated. Comparison of an irrigated and non-irrigated field adjacent to one another frequently indicates high salinity and an appreciable amount of exchangeable sodium in the non-irrigated area while the area receiving an adequate supply of water is relatively free of these conditions. (Land classification photo map JR-29 illustrates this pattern.) In the areas tested, and illustrated in Table 3.1-8 Chemical and Physical Analyses of Infiltration Sites, there was sufficient gypsum in the soil to overcome sodium accumulation and permit leaching. These samples were all taken in areas placed in Class 4 with the exception of Holes 12 and 13 at Grid North 133, East 202, which are located on the northwestern shore of the Dead Sea.

The area north of Jericho contains two large blocks of land of saline nature. One extends from the vicinity of Grid North 150 to about Grid North 167 and the other northward from Wadi Fari'a to Grid North 180. Areas of land relatively free from salinity are scattered throughout and in most instances are characterized by varying degrees of present irrigation development. The area north of Wadi Fari'a is somewhat lower in gypsum content than corresponding areas to the south and will materially benefit from its addition to the soil.

Conclusions. The major portion of the West Ghor area is adapted to irrigation agriculture. Presently irrigated areas show the relatively high water holding capacity of the soils and indicate their susceptibility to removal of saline and alkaline characteristics in the majority of cases. Where these adverse conditions are present, an appreciable amount of gypsum is generally present, particularly in the Jericho vicinity. Infiltration rates are generally satisfactory, even where soil textures are high in clay content. Approximately 45 percent of the area above the proposed canal is characterized by topographic deficiencies, leveling or gradient. Leveling requirements below the canal are considerably less. Drainage conditions are generally good. Subsurface problems are confined mainly to areas influenced by fuquarās.

Summary and Conclusions

The arid climate of the Jordan Valley makes irrigation necessary for successful production of most crops. This is particularly true in the southern part of the area where rainfall contributes very little toward plant growth. All lands within the natural east-west topographic boundaries of the valley from the Yarmouk River to the Dead Sea within the Hashemite Kingdom of Jordan were classified as to their suitability for sustained irrigation agriculture. The gross land area within the project is approximately 942,800 donums. Of this total, about 347,500 donums are currently suitable for crop production, and about 172,300 donums are capable of varying degrees of crop productivity after reclamation.

Soils of the project area are generally immature (highest development occurring in the extreme northern end), relatively low in organic matter, and of a calcareous and gypsiferous nature. The basic fertility of the soils is relatively high with the exception of nitrogen and phosphorous. Textures range from light to heavy, with clay loams and clays predominant. Waterholding capacity of the soils is good and penetration rates are satisfactory with the exception of a few scattered areas in the northern part of the East Ghor.

Topography of the project area is favorable for irrigation development with minor modifications. Light to moderate leveling will be required on the ghor areas, primarily on the edges of alluvial fans and in areas adjacent to the Katar. Areas deficient topographically, primarily due to gradient, occur at the foot of the steep side slopes of the valley and to a lesser degree adjacent to small stream channels. Zor areas in general will require moderate to heavy leveling. Cover in the form of rock or cobble is most prevalent on the upper reaches of the ghors and in the vicinity of stream channels. Vegetative cover exists as relatively small brush with heaviest concentrations found on the zor in the form of cane, salt cedar and tamarisk. A minor area in the vicinity of Wadi Hisban is covered with scrub trees.

Surface drainage is favored by the natural slope from the side hills to the Jordan River and from north to south, with the exception of localized areas where shallow depressions occur in the ghors. Numerous stream channels provide natural outlets for surface water. Subsurface drainage appears to be of a more complicated nature due to the absence of significant layers of sand or gravel throughout the project, and due to relatively low permeability of some clays in the Adasiye vicinity, and along the "break" between the ghor and zor areas. However, field and disturbed permeability tests show that the majority of the soils are permeable. Soils high in soluble salt content and relatively shallow in depth to marl show appreciable quantities of gypsum in the profile and adequate infiltration rates. The largest group of soils with these characteristics occurs in the southern part of the valley. Leaching trials indicate that the major portion of these areas are susceptible to reclamation and they have been included in the arable area. When the project area is fully developed to irrigation agriculture, an adequate and active drainage program is mandatory.

Alkalinity is not a serious problem in the Jordan Valley, except for a relatively few very small areas.

In the marl zones, heavy calcium carbonate and gypsum were laid down in stratified layers when the valley was under water. Outwash soils from the adjoining hills are relatively high in calcium, and where they are quite thin over the marls, high soluble salt content is to be found.

Throughout the valley most of the overlayed soils are blocky to prismatic in structure, sound and not likely to puddle, swell, and seal during a leaching period. Almost all saline lands can be reclaimed, as indicated by trials at the Ghor Nimrin leaching plots and permeability tests made through the valley.

Because of the high gypsum content of a large part of the soils in the southern portion of the valley, some settling of the lands may follow leaching. This may necessitate some releveling of these areas.

Class 4 lands, all saline in character, constitute about 33 percent of the 519,800 donums classified as arable. Lands placed in Class 2 and Class 3 primarily because of a very slight degree of salinity total about 9 percent of the arable area. Of the Class 4 lands, about 2.4 percent are located in the East Ghor North; the remainder is almost equally divided between the East Ghor South and the West Ghor. The lower soluble salt and gypsum contents (the more modified profiles) can be attributed to heavier rainfall and present irrigation.

A majority of the arable lands within the Yarmouk-Jordan Valley Project are capable of supporting a program of sustained irrigation agriculture. Portions of the area have a long history of limited irrigation, indicating that considerable benefit can be derived from an adequate, better distributed water supply.

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 1 of 6)

EAST GHOR AREA

Sheet No. and Coordinate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10³	Exchangeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchangeable Sodium %	Saturation %	Gypsum Me/100g	Hydraulic Conductivity MM/Hr.	Infiltration Rate MM/Hr.	Dispersion %	Mechanical Analyses Sand %	Mechanical Analyses Silt %	Mechanical Analyses Clay %	Texture
227.5N-208E	7	0- 30	-	9.0	0.05	-	0.83	46	1.8	-	-	-	.5	-	-	-	-	C.
228.195N-		30- 90	-	9.3	0.09	-	3.4	46	7.5	-	-	-		-	-	-	-	C.
207.565E		90-150	-	9.1	0.20	-	5.5	46	12	-	-	-		-	-	-	-	C.
226N-208E	13	0- 30	-	8.8	0.05	-	0.60	-	-	-	-	-	.5	-	-	-	-	C.
227.400N-		30- 60	-	9.1	0.04	-	1.4	40	3.6	-	-	-		-	-	-	-	C.
207.930E		60-105	-	9.4	0.10	-	3.8	39	9.8	-	-	-		-	-	-	-	C.
		105-150	-	9.2	0.17	-	5.6	38	15	-	-	-		-	-	-	-	C.
226N-208E 226.300N- 206.850E	4 1/												.5					
224.5N-206E	6	0- 15	7.8	8.7	1.0	1.9	0.18	37	0.5	54	*1	6.6	5.1	70	8	56	36	Si.C.L.
224.820N-		15- 30	7.9	8.8	1.1	0.58	0.35	38	0.9	57	*1	16.5		56	11	49	40	Si.C.
205.500E		30- 45	7.9	8.8	1.2	0.66	0.32	37	0.9	56	*1	27.9		48	9	46	45	Si.C.
		45- 60	8.0	8.8	0.09	0.40	0.42	39	1.1	59	*1	20.8		42	12	47	41	Si.C.
		60- 75	7.7	8.6	0.18	1.5	0.66	35	1.9	63	*1	13.6		44	10	50	40	Si.C.
		75- 90	8.0	8.5	0.08	0.45	0.55	34	1.6	66	*1	16.3		45	10	46	44	Si.C.
		90-105	8.0	9.1	0.07	0.46	0.65	31	2.1	63	*1	18.0		54	11	50	39	Si.C.L.
		105-120	8.1	8.9	0.08	0.53	0.91	30	3.0	65	*1	21.8		43	12	49	39	Si.C.L.
		120-150	7.9	8.8	0.13	1.0	1.3	32	4.9	70	*1	14.0		57	8	53	39	Si.C.L.
224.5N-208E 224.800N- 206.385E	7 1/												1.0					
223N-208E 223.600N- 206.050E	3 1/												1.0					
220N-208E	1	0- 15	7.7	8.5	0.08	0.53	0.21	30	0.7	46	*1	22.6	68.6	56	24	47	29	C.L.
220.800N-		15- 30	7.8	8.7	0.08	0.64	0.58	29	2.0	47	*1	11.2		68	23	47	30	C.L.
206.730E		30- 45	7.8	8.8	0.08	0.64	0.53	28	1.9	48	*1	9.9		56	27	39	34	C.L.
		45- 60	8.0	8.9	0.07	0.60	0.39	28	1.4	53	*1	30.5		46	29	37	34	C.L.
		60- 90	7.9	9.0	0.07	0.62	0.31	25	1.2	54	*1	30.5		54	28	40	32	C.L.
		90-120	8.0	9.0	0.06	0.51	0.13	26	0.5	58	*1	-		77	24	41	35	C.L.
		120-150	8.0	8.8	0.07	0.53	0.34	27	1.3	58	*1	-		68	19	46	35	Si.C.L.

*Indicates the sign < (Less than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 2 of 6)

Sheet No. and Coordinate	Hole No.	Layer Depth Cm.	pH		Total Soluble Salts		Exchangeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchangeable Sodium %	Saturation %	Gypsum Me/100g	Hydraulic Conductivity MM/Hr.	Infiltration Rate MM/Hr.	Dispersion %	Mechanical Analyses			Texture
			Paste	1-5	%	$ECx10^3$									Sand %	Silt %	Clay %	
220N-206E	2	0- 30	7.9	8.5	0.11	1.1	0.67	34	2.0	59	*1	6.1	15.2	39	10	51	39	Si.C.L.
221.290N-		30- 60	7.9	8.6	0.11	1.2	0.85	29	3.0	57	*1	9.4		43	12	43	45	Si.C.
205.365E.		60- 90	7.9	8.5	0.28	4.0	2.8	26	11	59	*1	43.2		41	14	42	44	Si.C.
		90-105	8.1	8.8	0.15	2.3	1.1	24	4.4	61	*1	16.8		48	19	44	37	Si.C.L.
		105-120	8.1	8.7	0.12	2.5	0.82	21	4.0	52	*1	50.8		62	23	44	33	C.L.
		120-150	8.2	8.9	0.16	2.4	0.42	17	2.5	66	*1	33.0		73	27	43	30	C.L.
217N-208E	6	0- 15	7.9	9.0	0.07	0.51	0.20	26	0.8	49	*1	21.3	5.1	62	9	61	30	Si.C.L.
218.355N-		15- 30	7.8	8.8	0.06	0.51	0.21	25	0.8	51	*1	53.3		59	7	56	37	Si.C.L.
206.235E		30- 60	7.8	8.8	0.07	0.47	0.20	25	0.8	54	*1	78.7		59	9	52	39	Si.C.L.
		60- 90	8.0	8.9	0.06	0.52	0.40	22	1.8	58	*1	71.1		46	8	52	40	Si.C.
		90-120	8.1	9.0	0.08	0.57	0.73	22	3.3	60	*1	121.9		38	10	44	46	Si.C.
		120-150	8.1	8.8	0.12	1.3	1.4	25	5.7	58	*1	61.0		43	9	50	41	Si.C.
215.5N-208E	8 1/												35.6					
215.940N-																		
206.530E																		
214N-206E	4	0- 15	8.1	8.4	0.05	0.63	0.12	27	0.5	53	*1	4.8	5.1	65	16	54	30	Si.C.L.
215.500N-		15- 30	8.0	8.4	0.06	0.50	0.32	26	1.2	50	*1	17.3		62	17	47	36	Si.C.L.
205.100E		30- 60	8.1	8.5	0.07	-	-	-	-	-	-	24.9		55	17	47	36	Si.C.L.
		60- 90	8.1	8.7	0.11	1.8	1.2	22	5.5	57	*1	58.4		57	16	45	39	Si.C.L.
		90-120	8.4	9.2	0.09	1.7	1.3	20	7.6	57	*1	18.3		70	17	44	37	Si.C.L.
		120-150	8.4	9.2	0.08	-	-	-	-	-	-	18.8		72	17	47	36	Si.C.L.
211N-206E	6	0- 15	7.7	8.1	0.10	1.6	0.24	27	0.9	58	*1	5.6	10.2	52	15	56	29	Si.C.L.
212.000N-		15- 30	7.9	8.3	0.06	0.61	0.29	26	1.1	51	*1	22.6		52	16	50	34	Si.C.L.
205.325E		30- 45	8.1	8.4	0.06	0.65	0.22	28	0.8	28	*1	116.8		57	18	47	35	Si.C.L.
		45- 60	7.9	8.5	0.06	0.60	0.24	22	1.1	13	*1	157.5		60	19	52	29	Si.C.L.
		60- 90	7.9	8.6	0.06	0.71	0.16	19	0.8	55	*1	149.9		60	20	45	35	C.L.
		90-120	7.9	8.6	0.07	0.71	0.15	17	0.9	47	*1	132.1		62	24	41	35	C.L.
		120-150	7.9	8.8	0.06	0.71	0.35	14	2.4	50	*1	66.0		69	18	49	33	Si.C.L.
208N-206E	13	0- 15	8.0	8.9	0.04	0.72	0.27	21	1.3	51	*1	23.6	40.6	52	20	53	27	Si.L.
208.435N-		15- 30	8.1	8.5	0.04	0.63	0.11	18	0.7	46	*1	23.4		67	19	50	31	Si.C.L.
205.065E		30- 60	7.9	8.5	0.04	-	-	-	-	-	-	30.5		76	26	44	30	C.L.
		60- 90	8.0	8.6	0.05	0.63	0.21	15	1.4	49	*1	45.7		74	24	45	31	C.L.
		90-120	8.0	8.6	0.04	-	-	-	-	-	-	48.3-		77	24	44	32	C.L.
		120-150	8.0	8.6	0.06	-	-	-	-	-	-	55.9		78	21	45	34	C.L.
205N-206E	5	0- 15	7.8	8.1	0.04	1.6	0.19	24	0.8	46	*1	14.7	61.0	60	35	47	18	L.
205.505N-		15- 30	7.9	8.2	0.04	-	-	-	-	-	-	20.3		49	36	45	19	L.
205.140E		30- 60	8.0	8.4	0.04	0.76	0.29	21	1.4	49	*1	12.7		61	30	49	21	L.
		60- 90	7.8	8.5	0.03	-	-	-	-	-	-	27.9		68	33	45	23	L.
		90-120	7.9	8.5	0.04	0.60	0.32	14	2.3	45	*1	40.6		66	32	42	26	L.
		120-150	7.8	8.5	0.05	-	-	-	-	-	-	33.0		69	29	43	28	L.

*Indicates the sign < (Less than).

Table 3.1-8

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 3 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10³	Ex-change-able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
202N-206E	6 1/												.0					
202.350N-																		
204.995E																		
200.5N-206E	9	0- 15	7.7	8.4	0.08	1.1	0.30	25	1.2	49	*1	8.9	17.8	69	17	57	26	Si.L.
201.615N-		15- 30	7.9	8.5	0.06	-	-	-	-	-	-	10.2		69	16	55	29	Si.C.L.
205.195E		30- 60	7.8	8.4	0.07	0.76	0.31	25	1.2	50	*1	33.0		61	16	50	34	Si.C.L.
		60- 90	8.0	8.6	0.08	-	-	-	-	-	-	45.7		56	19	50	31	Si.C.L.
		90-120	8.1	8.7	0.07	0.82	0.46	22	2.0	48	*1	40.6		58	20	47	33	Si.C.L.
		120-150	8.1	8.7	0.07	-	-	-	-	-	-	30.5		63	18	48	34	Si.C.L.
197.5N-206E	6	0- 15	7.8	8.5	0.07	0.60	0.26	37	0.71	44	*1	5.8	10.2	71	10	70	20	Si.L.
198.460N-		15- 30	7.9	8.5	0.08	-	-	-	-	-	-	8.4		59	10	53	37	Si.C.L.
204.630E		30- 60	7.9	8.8	0.08	0.62	1.0	35	2.9	57	*1	11.4		58	10	51	39	Si.C.L.
		60- 90	8.1	9.1	0.07	-	-	-	-	-	-	16.3		60	10	50	40	Si.C.L.
		90-120	8.2	9.2	0.07	0.63	2.1	25	8.4	60	*1	11.4		76	10	54	36	Si.C.L.
		120-150	8.2	9.2	0.08	-	-	-	-	-	-	5.8		88	7	58	35	Si.C.L.
196N-206E	8	0- 15	7.7	8.5	0.05	0.74	3.2	21	1.6	39	*1	7.4	25.4	72	20	61	19	Si.L.
196.030N-		15- 30	7.4	8.6	0.05	-	-	-	-	-	-	21.3		64	20	57	23	Si.L.
204.200E		30- 60	7.9	8.6	0.04	0.47	0.82	19	4.3	46	*1	8.9		61	17	58	25	Si.L.
		60- 90	7.8	8.4	0.18	-	-	-	-	-	-	9.9		69	12	60	28	Si.L.
		90-120	7.6	8.7	0.60	9.3	4.2	23	18	62	*1	5.3		84	8	62	30	Si.C.L.
		120-150	7.7	8.7	0.65	-	-	-	-	-	-	6.1		86	18	57	25	Si.L.
190N-206E	29	0- 15	7.8	8.1	0.05	0.88	0.41	19	2.1	36	*1	5.6	20.3	70	30	49	21	L.
190.760N-		15- 30	7.8	8.2	0.04	-	-	-	-	-	-	7.9		65	29	46	25	L.
204.650E		30- 60	7.9	8.5	0.07	-	-	-	-	-	-	7.6		53	26	49	25	Si.L.
		60- 90	7.9	8.3	0.15	2.6	0.55	19	3.0	54	*1	15.5		67	16	55	29	Si.C.L.
		90-120	7.9	8.3	0.14	-	-	-	-	-	-	11.9		78	17	56	27	Si.L.
		120-150	7.8	8.4	0.16	-	-	-	-	-	-	8.4		89	11	62	27	Si.L.
184N-206E	30	0- 15	7.8	8.4	0.08	0.99	0.18	21	0.87	45	*1	10.7	10.2	60	21	58	21	Si.L.
185.330N-		15- 30	7.8	8.4	0.05	-	-	-	-	-	-	11.2		68	19	55	26	Si.L.
205.850E		30- 60	7.9	8.4	0.04	-	-	-	-	-	-	18.5		77	23	52	25	Si.L.
		60- 90	7.8	8.3	0.03	0.43	0.21	14	1.5	39	*1	19.0		78	23	56	21	Si.L.
		90-105	8.1	8.6	*0.03	-	-	-	-	-	-	33.0		83	44	40	16	L.
181N-208E	17	0- 15	7.5	8.3	0.04	0.78	0.34	22	1.5	42	*1	13.5	7.6	65	26	51	23	Si.L.
182.355N-		15- 30	8.1	8.4	0.06	-	-	-	-	-	-	19.0		57	16	50	34	Si.C.L.
207.110E		30- 60	7.9	8.5	0.06	-	-	-	-	-	-	53.3		55	16	49	35	Si.C.L.
		60- 90	8.1	8.3	0.06	0.70	0.74	25	3.0	38	*1	50.8		69	15	55	30	Si.C.L.
		90-120	8.3	8.8	0.07	-	-	-	-	-	-	45.7		72	8	58	34	Si.C.L.
		120-150	8.0	8.9	0.07	-	-	-	-	-	-	33.0		73	16	55	29	Si.C.L.

*Indicates the sign < (Less than).

Table 3.1-8

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 4 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10^3	Ex-changeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Mechanical Analyses Silt %	Mechanical Analyses Clay %	Texture
179.5N-210E	12	0- 15	7.7	8.2	0.11	1.9	0.65	21	3.1	45	*1	15.2	5.1	59	29	43	28	C.L.
150.780N-		15- 30	7.9	8.5	0.06	-	-	-	-	-	-	38.1		59	19	48	33	Si.C.L.
206.160E		30- 60	7.9	8.4	0.07	-	-	-	-	-	-	27.9		58	19	44	37	Si.C.L.
		60- 90	8.0	8.7	0.06	0.80	0.73	20	3.6	50	*1	45.7		65	21	45	36	Si.C.L.
		90- 120	8.1	8.7	0.06	-	-	-	-	-	-	66.0		66	22	45	33	C.L.
		120-150	8.1	8.9	0.06	-	-	-	-	-	-	61.0		56	21	45	34	C.L.
164.5N-206E	17	0- 15	7.6	8.7	0.04	0.92	0.13	10	1.3	31	*1	2.8	20.3	63	15	56	29	Si.C.L.
164.770N-		15- 30	7.9	8.8	0.03	-	-	-	-	-	-	3.0		68	46	35	19	Si.L.
204.730E		30- 60	7.6	8.7	*0.03	-	-	-	-	-	-	10.9		71	68	21	11	S.L.
		60- 90	8.1	9.0	*0.03	1.2	0.13	1.5	20	20	*1	30.5		64	81	11	8	Lmy.S.
		90-120	8.0	8.8	*0.03	-	-	-	-	-	-	101.6		58	91	5	4	S.
		120-150	8.1	9.0	0.03	-	-	-	-	-	-	18.3		68	63	27	10	S.L.
163N-204E	10	0- 15	7.5	8.4	**3.0	52	4.0	16	24	42	2	3.0	17.8	-				C.L.
163.700N-		15- 30	7.6	8.3	**3.0	36	5.1	18	26	47	1	2.5		-				S.C.L.
202.570E		30- 60	7.5	8.4	**3.0	37	5.0	19	26	53	6	7.6		-				C.L.
		60- 90	7.6	8.4	**3.0	40	7.3	21	36	57	7	10.7		-	FLOCCULATED[2]			C.L.
		90-105	7.5	8.3	**3.0	39	5.2	19	28	54	-	9.7		-				C.L.
		105-150	7.7	8.7	2.5	29	11	23	48	71	4	* .3		-				Si.C.L.
161.5N-206E	15[1]												25.4					
162.430N-																		
204.065E																		
161.5N-204E	12	0- 15	7.2	7.8	**2.5	59	5.1	25	21	40	3	6.4	1.0	-				C.L.
161.850N-		15- 30	7.6	8.0	**2.5	55	4.7	25	16	45	3	6.1		-				Si.C.
202.510E		30- 45	7.4	8.1	**2.5	47	6.2	26	24	49	8	30.5		-				Si.C.
		45- 60	7.8	8.1	**2.5	40	3.1	25	12	66	14	27.9		-				Si.C.
		60- 75	7.8	8.0	**2.5	29	4.7	27	17	71	8	27.9		-	FLOCCULATED			Si.C.
		75- 90	7.8	8.1	**2.5	43	7.9	27	26	72	4	12.7		-				Si.C.
		90-120	7.7	8.0	**2.5	48	9.0	30	30	79	2	6.9		-				Si.C.
		120-135	7.7	8.1	**2.5	40	6.5	22	20	82	2	10.2		-				Si.C.
		135-150	7.5	8.1	**2.5	46	9.5	30	32	83	2	5.1		-				Si.C.
145N-206E	26	0- 15	7.1	7.9	**3.0	102	6.0	14	43	40	6	11.9	27.9	-				C.L.
		15- 30	7.1	7.9	**3.0	85	6.0	18	33	47	32	13.7		-				C.L.
		30- 45	7.2	8.0	**3.0	93	5.0	12	42	48	46	13.7		-				Si.L.
		45- 60	7.0	7.8	**3.0	93	7.0	11	64	59	29	13.2		-				C.L.
		60- 75	7.0	7.5	**3.0	85	6.0	13	46	63	13	10.4		-	FLOCCULATED			C.L.
		75- 90	6.7	7.9	**3.0	73	9.0	13	69	68	8	9.1		-				C.L.
		90-120	6.8	7.8	**3.0	73	6.0	12	50	63	5	7.6		-				C.L.
		120-150	6.9	7.7	**3.0	73	8.0	10	80	59	4	4.8		-				C.L.

* Indicates the sign < (Less than).
** Indicates the sign > (Greater than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 5 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH Paste	pH 1-5	Total Soluble Salts %	Total Soluble Salts ECx10^3	Ex-changeable Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses Sand %	Silt %	Clay %	Texture
145N-206E	27	0- 15	7.2	7.9	**3.0	114	4.0	-	-	47	38	7.6	12.7	-				C.L.
		15- 30	7.1	7.8	**3.0	79	4.0	10	40	56	38	6.6		-				L.
		30- 45	7.1	7.8	**3.0	102	2.0	9	22	62	30	4.3		-				C.L.
		45- 60	7.0	7.7	**3.0	85	6.0	12	50	69	20	5.3		-				C.L.
		60- 75	7.1	7.9	**3.0	57	2.0	11	18	65	12	6.6		-	FLOCCULATED			C.L.
		75- 90	7.1	7.8	**3.0	54	0.42	11	3.8	73	7	8.1		-				C.L.
		90-120	7.5	8.2	**3.0	56	12	15	81	65	10	16.0		-				C.L.
		120-150	7.3	8.3	**3.0	71	11	15	75	60	5	13.0		-				Si.C.L.
145N-206E	28	0- 15	7.3	8.1	**3.0	62	9.1	14	67	47	60	19.8	10.2	-				L.
		15- 30	7.2	8.2	**3.0	77	5.8	15	39	42	47	21.8		-				L.
		30- 45	7.4	8.2	**3.0	71	3.9	12	31	45	60	8.6		-				S.L.
		45- 60	7.4	8.1	**3.0	77	9.4	19	49	44	45	16.5		-				L.
		60- 75	7.5	8.2	**3.0	67	8.9	20	44	44	44	5.6		-	FLOCCULATED			L.
		75- 90	7.6	8.2	2.5	56	-	16	-	67	68	16.0		-				S.L.
		90-105	7.6	8.3	2.5	45	5.3	15	36	56	57	21.1		-				S.L.
		105-120	7.3	8.2	**3.0	62	12	15	80	70	12	11.2		-				C.L.
		120-150	7.6	8.4	**3.0	56	7.7	15	51	64	5	8.9		-				C.L.
139N-206E 139.670N-205.225E	10	0- 15	7.5	7.9	**2.8	117	3.2	11	29	37	43	11.7	1.0 3/	-				S.C.L.
		15- 30	7.2	7.8	**2.8	99	4.1	16	27	43	-	24.9		-				C.L.
		30- 45	7.3	7.7	1.8	66	0.3	14	2.1	45	53	16.0	81.3	-				S.L.
		45- 60	7.3	7.7	1.8	56	1.0	15	6.7	45	-	15.0		-	FLOCCULATED			S.C.L.
		60- 75	7.6	7.9	1.4	51	1.6	14	11	41	55	8.6		-				S.L.
		75- 90	7.5	7.8	2.8	53	2.3	15	16	55	-	40.6		-				L.
		90-120	7.3	7.8	**3.0	55	0.7	17	4.1	80	7	27.9		-				C.L.
		120-150	7.6	8.1	**3.0	54	1.5	17	8.8	75	-	38.1		-				S.C.L.
137.5N-204E	24	0- 15	7.6	7.7	**3.0	161	2.0	13	22	40	-	16.0	124.5	-				S.L.
		15- 30	7.8	7.9	**2.8	117	1.7	15	11	41	27	19.6		-				S.L.
		30- 45	7.3	7.6	**2.8	70	4.6	14	32	40	-	2.8		-	FLOCCULATED			L.
		45- 60	7.9	8.3	1.4	46	1.2	8	14	34	20	17.3		-				S.L.
		60- 90	7.8	7.8	0.40	19	0.2	2	10	23	-	37.1		-				S.
		90-120	7.4	7.5	0.34	14	0.6	6	10	31	20	42.2		-				S.
134.5N-208E 135.760N-206.090E	20	0- 15	6.9	7.7	**3.0	188	2.4	10	24	32	8	16.8	75.4	-				C.L.
		15- 30	7.2	7.6	**2.8	113	2.2	13	17	36	-	11.4		-				Si.C.L.
		30- 60	7.3	7.9	**2.8	92	1.5	10	15	31	7	17.0		-				C.L.
		60- 90	7.4	8.0	2.0	61	2.7	10	27	31	-	14.7		-	FLOCCULATED			S.C.L.
		90-120	7.4	8.3	2.2	49	4.1	13	32	47	4	11.9		-				C.L.
		120-150	7.7	8.1	1.2	31	4.3	14	32	51	-	8.4		-				C.L.
		150-180	7.7	8.4	1.6	38	5.2	15	34	52	4	6.9		-				C.L.

* Indicates the sign < (Less than).

** Indicates the sign > (Greater than).

Table 3.1-8

CHEMICAL AND PHYSICAL ANALYSES
OF THE JORDAN VALLEY
INFILTRATION SITES - SOILS
(Sheet 6 of 6)

Sheet No. and Coord-inate	Hole No.	Layer Depth Cm.	pH		Total Soluble Salts		Ex-change-able Sodium Me/100g	Cation Exchange Cap'y Me/100g	Exchange-able Sodium %	Satura-tion %	Gypsum Me/100g	Hydraulic Conduct-ivity MM/Hr.	Infiltra-tion Rate MM/Hr.	Disper-sion %	Mechanical Analyses			Texture
			Paste	1-5	%	$ECx10^3$									Sand %	Silt %	Clay %	
140.5N-206E 140.800N-205.820E	22	0- 15	7.2	7.7	1.4	44	3.2	14	23	35	-	5.8	10.2	-				S.L.
		15- 30	7.3	7.9	2.2	50	3.9	16	25	36	6	8.4		-				L.
		30- 60	7.4	7.8	**3.0	52	2.4	18	14	44	-	15.2		-	FLOCCULATED			C.L.
		60- 90	7.5	8.0	**2.8	61	0.9	15	6.1	46	57	11.9		-				C.L.
		90-120	7.5	7.7	**2.2	65	7.5	11	68	28	-	23.9		-				L.
		120-150	7.7	8.2	**2.8	83	2.3	15	15	64	29	11.7		-				Si.C.L.
									WEST GHOR AREA									
172N-200E	9	0- 15	7.3	8.0	**2.8	76	5.4	27	20	51	-	8.9	35.6	-				C.L.
		15- 30	7.5	8.2	**2.8	58	4.5	25	18	61	6	7.4		-				C.L.
		30- 60	7.5	7.9	**2.8	60	5.3	23	23	59	2	16.5		-	FLOCCULATED			C.L.
		60- 90	7.3	7.9	2.0	38	5.8	24	25	57	-	30.5		-				C.L.
		90-120	7.5	7.9	1.4	29	4.4	26	17	57	2	17.8		-				C.L.
145N-198E	1	0- 15	7.2	7.7	0.19	5	3.1	15	20	39	7	3.6	17.8	-				L.
		15- 30	7.5	7.7	0.54	19	1.2	12	9.7	41	17	9.9		-				L.
		30- 60	7.1	7.6	1.4	32	2.9	10	28	49	-	13.2		-	FLOCCULATED			L.
		60- 90	7.2	8.0	**2.8	61	2.0	13	16	54	59	15.5		-				Si.L.
		90-120	7.5	7.7	**2.8	58	2.5	15	17	69	-	7.4		-				Si.C.L.
		120-150	6.9	7.6	**2.8	58	10	16	65	46	13	5.6		-				Si.C.
137.5N-198E	13	0- 15	7.6	9.0	**3.0	183	4.5	17	26	38	-	7.4	99.1	-				C.L.
		15- 30	8.1	8.8	**3.0	110	2.5	21	12	53	44	18.5		-				C.L.
		30- 45	7.7	8.2	**3.0	117	11	21	52	48	30	27.9		-				Si.L.
		45- 60	7.7	8.3	**3.0	106	6.4	24	27	60	44	24.1		-	FLOCCULATED			C.L.
		60- 90	8.1	8.4	**3.0	78	10	14	74	56	58	21.8		-				C.L.
		90-120	7.9	8.3	2.2	55	5.6	8.2	68	54	-	30.5		-				Si.L.
		120-150	8.0	8.4	1.0	32	-	7.6	-	53	59	35.6		-				L.
133N-202E	13	0- 15	7.3	7.8	**3.0	67	2.2	28	7.9	66	10	21.6	1.0	-				Si.C.
		15- 30	7.1	7.8	**3.0	65	3.1	28	11	57	-	17.8		-				C.
		30- 45	7.4	7.8	**3.0	45	4.9	31	16	75	8	7.4		-				C.
		45- 60	7.7	7.9	**3.0	46	12	34	36	86	-	3.6		-	FLOCCULATED			C.
		60- 90	7.4	8.4	**3.0	49	6.6	37	18	78	12	4.6		-				C.
		90-120	7.6	8.0	**3.0	50	5.8	37	16	82	-	6.1		-				C.
		120-150	7.2	7.6	**3.0	65	3.0	25	12	67	8	3.8		-				C.
133N-202E 133.575N-200.990E	12	0- 15	6.8	7.8	**3.0	160	7.8	26	30	51	31	30.5	5.1	-				Si.C.
		15- 30	6.8	7.6	**3.0	156	10	41	25	55	-	33.0		-				C.
		30- 45	7.1	7.5	**3.0	144	19	32	58	71	16	17.0		-				C.
		45- 60	7.2	7.8	**3.0	137	15	24	62	62	17	11.9		-	FLOCCULATED			C.
		60- 90	7.2	7.7	**3.0	134	6.4	27	24	75	14	45.7		-				C.
		90-120	7.2	7.5	**3.0	122	2.7	14	20	41	-	10.9		-				S.C.L.
		120-150	7.0	7.6	**3.0	141	6.6	17	40	43	-	13.5		-				S.C.L.

** Indicates the sign > (Greater than).

1/ Not sampled for analysis.
2/ Textures obtained by "hand-feel"; soil samples too salty for Mechanical Analyses.
3/ Numerator denotes rate prior to probing profile; denominator denotes rate resulting from the treatment.

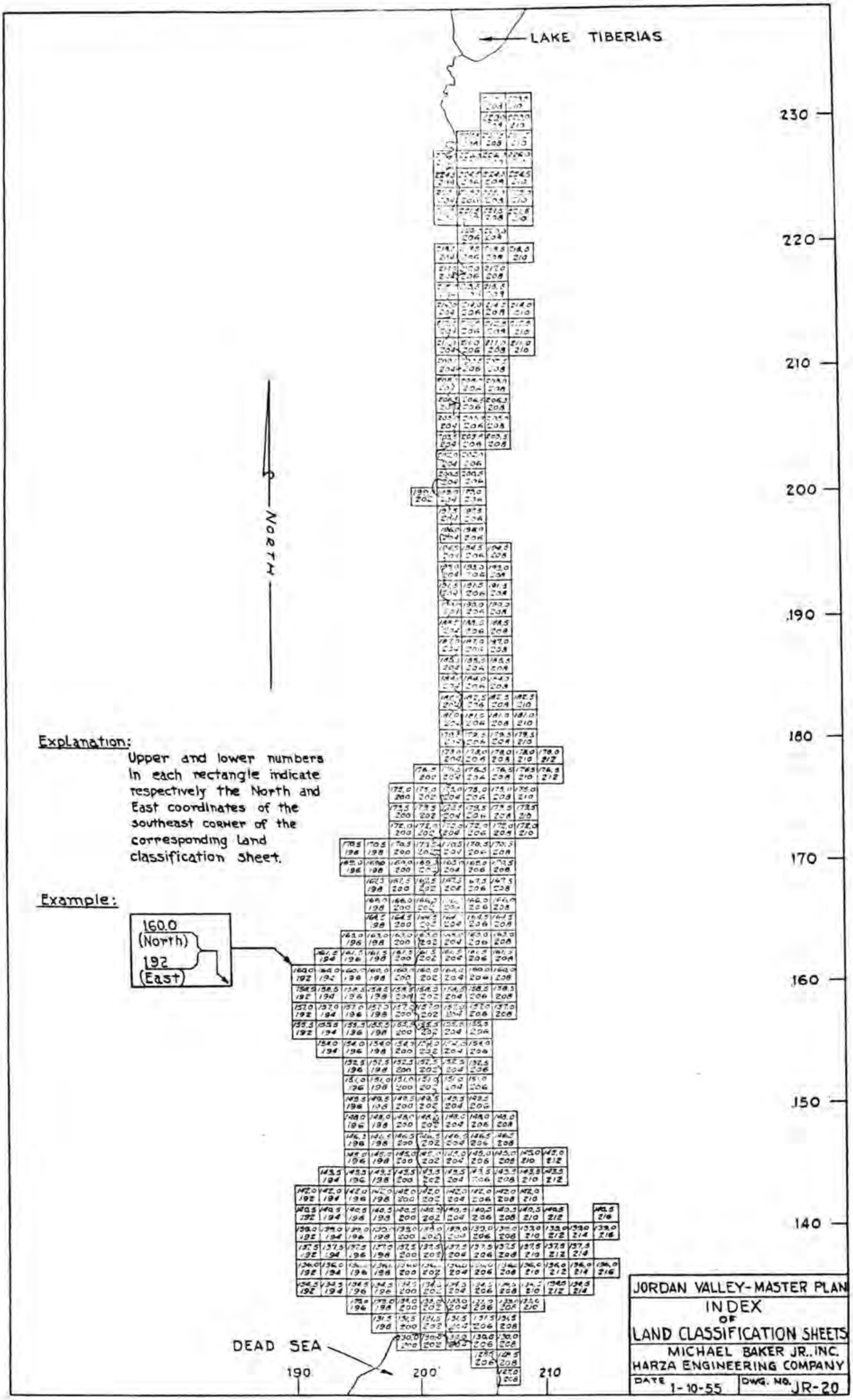
Table 3.1-8

Table 3.1-9

COMPOSITION OF SOLUBLE SALTS
IN 1-5 EXTRACTS
(Sheet 1 of 1)

Sheet No.	Laboratory No.	Hole No.	Layer Depth Cm.	CATIONS Me/100g Ca	Mg	Na (By Difference)	ANIONS Me/100g CO_3	HCO_3	Cl	SO_4	Na %	SAR
				East Ghor Area								
224.5N-208E	3771	6	0-15	0.79	0.23	0.34	-	0.65	0.16	0.51	25.0	0.5
220N-206E	5160	2	0-15	0.64	0.36	0.41	-	0.83	0.25	0.33	29.1	0.5
220N-208E	5166	1	0-15	0.58	0.44	-	-	0.70	0.03	0.15	-	-
217N-208E	5425	6	0-15	0.86		-	-	0.75	0.03	0.17	-	-
211N-206E	5917	6	0-15	0.82	0.48	0.30	-	1.08	0.30	0.22	18.8	0.4
179.5N-210E	6956	12	0-15	0.66	0.40	0.73	-	0.78	0.53	0.48	40.8	0.5
163N-204E	7119	10	0-15	5.40	3.04	20.72	-	0.45	28.03	0.65	71.1	9.5
161.5N-204E	6957	12	0-15	6.81	4.04	17.72	-	0.35	27.65	0.54	62.0	7.5
145N-206E	3192	26	0-15	17.11	22.51	42.66	-	0.30	76.84	5.45	51.8	9.6
	3194		30-45	30.25	19.84	31.77	-	0.30	58.99	22.55	38.8	6.3
	3195		45-60	32.10	26.48	42.27	-	0.30	78.50	22.03	41.9	7.8
	*3746		30-60	14.72	3.74	1.39	-	0.28	0.66	18.91	7.0	0.5
145N-206E	3200	27	0-15	30.29	26.89	38.33	-	0.20	71.62	23.64	40.1	7.1
145N-206E	3208	28	0-15	25.48	13.81	21.23	-	0.30	37.93	22.25	35.1	4.8
140N-206E	8127	22	0-15	3.65	3.31	10.91	-	0.45	16.41	0.99	61.1	5.5
139N-206E	7877	10	0-15	20.91	15.88	37.76	Tr.	0.23	51.30	22.00	50.7	8.6
	*8139		0-15	13.80	1.60	0.74	-	0.35	0.30	15.47	2.8	0.2
137.5N-204E	7891	24	0-15	25.47	25.69	51.19	Tr.	0.18	72.20	29.96	50.0	10.1
	*8161		0-15	13.65	4.87	3.91	-	0.30	1.29	20.81	17.4	1.4
134.5N-208E	7884	20	0-15	20.02	29.34	56.36	-	0.28	93.61	11.82	53.3	11.1
	*8152		0-15	5.65	1.33	0.69	-	0.43	0.67	6.56	9.0	2.1
				West Ghor Area								
172N-200E	8704	9	0-15	6.59	10.43	29.82	-	0.38	43.24	3.19	63.7	10.2
	*8715		0-15	0.63	0.74	1.38	-	0.83	0.40	1.47	50.3	1.8
145N-198E	8698	1	0-15	6.35	1.65	2.16	-	0.53	0.34	9.27	21.3	1.0
	*8709		0-15	0.53	0.30	0.74	-	0.93	0.25	0.39	47.1	1.0
137.5N-198E	8372	13	0-15	15.35	1.40	151.29	-	0.38	132.65	34.98	90.0	52.4
	*8379		0-15	14.15	1.42	1.30	-	0.33	0.48	16.03	7.7	0.5
133N-202E	8120	13	0-15	20.36	14.12	22.50	-	0.53	46.73	9.68	39.5	5.4
	*8178		0-15	2.14	0.97	1.37	-	0.50	0.56	3.39	30.5	1.0
133N-202E	8113	12	0-15	50.94	36.40	76.07	-	0.20	143.17	20.02	46.6	11.5
	*8171		0-15	10.33	2.49	1.62	-	0.33	0.53	13.56	11.2	0.5
140N-206E	8188	-	0- .6	45.69	92.61	160.03	0.05	0.53	294.23	3.45	53.6	19.3
	8189	-	.6-8.0	38.50	70.41	111.22	-	0.45	215.35	4.29	50.5	15.1

*Sampled after infiltration test.


LAKE TIBERIAS
NORTH
DEAD SEA
230
220
210
200
190
180
170
160
150
140
190
200
210
Explanation:
Upper and lower numbers in each rectangle indicate respectively the North and East coordinates of the southeast corner of the corresponding Land classification sheet.
Example:
160.0
(North)
192
(East)
JORDAN VALLEY-MASTER PLAN
INDEX
OF
LAND CLASSIFICATION SHEETS
MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY
DATE 1-10-55
DWG. NO. JR-20

MAPPING SYMBOLS AND ABBREVIATIONS
JORDAN VALLEY LAND CLASSIFICATION SURVEY *

SOIL PROFILE SYMBOLS

ΔΔΔ	SURFACE ROCK	
	SANDS	S
	LOAMY SANDS	LS
	SANDY LOAMS	SL
	LOAM	L
	SILT LOAM	SiL
	CLAY LOAMS	CL
	VERY PERMEABLE & PERMEABLE CLAYS	PC
	SLOWLY PERMEABLE CLAYS	SPC
ΔΔ ΔΔΔ	GRAVEL & COBBLE	Gr Cb

INFORMATIVE SYMBOLS

SOILS

LIGHT	l
MEDIUM	m
HEAVY	h
SALINITY, ALKALINITY	a
PRESENCE OF MARL	z

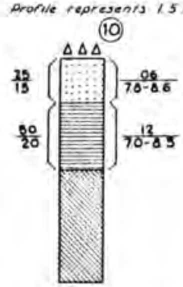
TOPOGRAPHY

COVER *(Rock or Brush)*	c
GRADIENT *(Slope)*	g
UNDULATION *(Surface Relief)*	u

DEGREE OF SEVERITY OF c, g or u MAY BE SUBSCRIPTED BY 2 or 3

SOIL PROFILE DATA & NOTES

Profile represents 1.5 M. of Depth



125 m N.W. of 182⁵/206⁹ $\frac{2t}{lmzcu}$

SMALL GRAIN-GOOD. IRRIGATED LAND.
AREA OF UNDULATING CROSS SLOPE
TOPOGRAPHY MODERATE TO HEAVY
ROCK COVER. MODIFIED MARL 90-125 cm
FRIABLE RED BROWN SiL 30-75 cm

Explanation:

25, 50 ARE PERCENTS OF SILT
15, 20 ARE PERCENTS OF CLAY
06, 12 ARE PERCENTS OF TOTAL SOLUBLE SALTS
78, 70 ARE pH VALUES OF SATURATED SOIL PASTE
86, 85 ARE pH VALUES OF 1 PART SOIL TO 5 PARTS WATER
(10) IS HOLE NUMBER FOR THE MAP

The notes show location of hole, crop or cover and condition, surface relief conditions bearing on topography classification, surface and sub-soil conditions bearing on drainability or basic soil deficiencies. Classification of $\frac{2t}{lmzcu}$ *is the appraisal for the area – not necessarily the exact data shown at the site of sampling*

BASIC LAND CLASSES & SUB-CLASSES

ARABLE

CLASS 1 - 1
CLASS 2 - 2s, 2t, 2d, 2st, 2sd, 2td, 2std
CLASS 3 - 3s, 3t, 3d, 3st, 3sd, 3td, 3std
CLASS 4 - 4(1), 4(2s), 4(2t), etc *Showing parenthetically ultimate land class after soluble salts have been removed by leaching*

NON-ARABLE

CLASS 6H - 6H(1), 6H(2s) etc *Elevated Areas*
6I - 6I(1), 6I(2s) etc *Isolated Areas*
CLASS 6 - 6s, 6t, 6d, 6st, 6sd, 6td, 6std

PROFILE NOTE ABBREVIATIONS

SOLUBLE SALTS

PERCENT BY WEIGHT	TSS
PARTS PER MILLION	PPM
ELECTRICAL CONDUCTIVITY OF SATURATION EXTRACT	ECe
GYPSUM MILLIEQUIVALENTS PER 100 GRAMS	Gyp
SODIUM	Na
EXCHANGEABLE SODIUM PERCENTAGE	ESP
SOLUBLE SODIUM PERCENTAGE	SSP
SODIUM ADSORPTION RATIO	SAR
CATION EXCHANGE CAPACITY m.e. PER 100 g. SOIL	CEC

MOISTURE RELATIONS

SATURATION PERCENTAGE	SP
INFILTRATION RATE mm/hr	Inf
HYDRAULIC CONDUCTIVITY mm/hr	HC

$$\frac{3std}{mhazc_2g_3u_1}$$

- SOILS DEFICIENCY — s
- LAND CLASS — 3
- TOPOGRAPHY DEFICIENCY — t
- DRAINAGE DEFICIENCY — d
- TEXTURE OF SURFACE SOIL — m
- TEXTURE OF SUB SOIL — h
- PRESENCE OF SALINITY — a
- PRESENCE OF MARL-MODIFIED or RESIDUAL — z
- COVER, CLASS 2 SEVERITY — c_2
- GRADIENT 8-12 % SLOPE *(Class 3)* — g_3
- UNDULATION *(leveling required)* — u_1

$$4\left(\frac{2s}{hhz}\right)$$

- PRESENT CLASS — 4
- ULTIMATE CLASSIFICATION AFTER RECLAMATION — 2s

* *Bureau of Reclamation, Dept. of Interior, U.S.A. Standard symbols modified where advisable to meet local conditions.*

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

LAND CLASSIFICATION SYMBOLS

MICHAEL BAKER JR INC.
HARZA ENGINEERING COMPANY

ROCHESTER PENNA. | DATE 3-55 | DWG NO. JR-22

JR-22

VOLUME III - LAND RESOURCES
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

PART 2. Agriculture

PART 2. AGRICULTURE

Introduction

The objective of this report is to indicate agricultural capabilities of project lands determined suitable for irrigation, the lands being supplied with adequate quantities of irrigation water and taking into account specific characteristics of the local area and Middle East culture.

Information for this report was obtained from earlier studies, the land classification survey, field studies, consultations with Jordanian land operators and agricultural technicians of the Jordan Government and United States Foreign Operations Administration, reference to current United Nations surveys, and field observations made in neighboring Middle East countries where land conditions, climate and culture were generally similar.

Field studies included soil and topographic examinations, observation of existing crops and current methods of water application and land management. As was determined in Part 1 of this volume, the arable area within the project totals 519,800 donums. The soils, topography, and drainage characteristics of this land are favorable for irrigation farming and it lies in relatively large compact blocks. At the present time a minor area of the arable lands are occupied by permanent facilities such as roads, villages, etc. Under the anticipated land development program it is expected that wherever possible these permanent facilities will be confined to non-arable areas. However, a certain amount of arable land will be utilized in locating the main canals, and lateral distribution systems, farm roads, and other public facilities, for which a reduction of about 3 percent in arable area is made to determine the irrigable area. The irrigable area within the project has been calculated to be about 504,200 donums.

Agricultural History

The Jordan Valley has a long history of limited irrigation development. Biblical records show a variety of irrigated crops were grown on project lands, and indications point to even earlier irrigation within this and adjacent areas. Then, as now, the supply of water was insufficient to irrigate the entire area. Streams tributary to the Jordan River were diverted for crop irrigation and the water spread thinly over a maximum area. Lands far removed from these sources of supply normally received little or no irrigation and efforts were made to develop underground waters by construction of fuquarās, or water collection systems which utilized aquifers originating in the adjacent hills. Some of these ancient works have been rediscovered and restored to use. Other sources such as Elisha's Spring in Jericho have been intensively utilized and a variety of crops are still produced in this area.

Cereals, vegetables, and fruits such as citrus, olives, dates and bananas were produced in early history and are grown today where water supply permits.

Although actual records of lands irrigated are inadequate, it is certain that a significant portion of the area classed as irrigated both in the past and at present received water intermittently and in very limited amounts. This is indicated by the fact that certain tracts are irrigated one year and not the next. Annual variations in volume and duration of stream flow and fallow practices are primarily responsible for this condition. The relatively unleached condition of soils in many irrigated areas further emphasizes the fact that irrigation as practiced with a "full water supply" has been known on only a small part of the project area.

Present Agriculture

Under present conditions approximately 48 percent of the irrigable land within the project area is non-irrigated. Of this total only about 5 percent is cropped on a dry-farm basis. The major portion of this non-farmed area is covered with scattered patches of scrub-type brush and annual grasses, and is utilized for grazing purposes.

Of the lands termed as irrigated, it must be noted that the total includes all crops to which water was applied regardless of the adequacy of the amount. The distribution and amount of irrigated and non-irrigated lands for the year 1953 are presented as Table 3.2-1. The influence of the inadequate supply of irrigation water and the very small amount of fertilization normally utilized are reflected in the relatively low yields of crops now produced. Present production is illustrated in Table 3.2-2.

Principal Crops

Cereals constitute about 43 percent of the total crops grown on the irrigable area of the project. Wheat and barley comprise more than four-fifths of this category with more than three times as much wheat as barley. Other cereal grains include sorghum, corn (maize) and sesame with corn and sesame in the minor category. One reason for the large wheat planting is the country's heavy consumption of bread. The other principal reason is the relatively low irrigation requirement necessitated by traditional planting to take advantage of winter rains. The crop is always harvested, even if production is negligible, and yields are generally very low.

Vegetables occupy about 10 percent of the crop distribution. For the most part they are presently produced during the summer months with a few grown during the winter and early spring. Except for a very few areas the majority of these crops are inadequately irrigated. Principal vegetable crops include tomatoes, watermelons, eggplant, cucumber, marrow and beans. Of these, tomatoes, watermelons and eggplant comprise about 70 percent of the total vegetable area.

Orchard fruits are found in the amount of about 3 percent of the total irrigable project lands. Bananas are the principal orchard fruit and plantings are confined to areas where a reliable source of water is available. Citrus fruits (oranges, lemons, tangerines, etc.) are also produced in currently irrigated areas. Other fruits such as pomegranates, figs and grapes are found in small, scattered plantings. The main productive fruit areas are located in the vicinity of Adasiye and the Jericho vicinity.

Agricultural Practices

Seed stock quality is generally very low. Common practice is to utilize a portion of the field-run supply which has been passed down without material change for many generations. This is particularly true of cereal and vegetable crops. As a consequence there has been little semblance of purity of line in the seed stocks planted. A certain amount of resistance to adverse growing conditions such as salinity has been developed. For example, marrow was observed growing well in soil containing more than twice the amount of salinity usually termed as critical.

In most instances this has not been recognized and the seeds possessing this desirable characteristic have not been segregated.

New adapted varieties have been introduced to a very slight degree, and a limited amount of experimentation is being carried on within the valley. This work is being conducted at agricultural experiment stations, one located near Wadi Fari'a on the West Ghor and at Deir Alla and at Baqura on the East Ghor. A limited amount of nursery stock is produced in Jericho. These experimental areas have been established within the past five years and sufficient time has not elapsed to permit conclusive results.

Seed bed preparation is usually inadequate. Present methods of preparing the land for planting are essentially the same as those used in ancient times. Generally a single "nail-type" plow is used to open a furrow in the soil. Cereal and other field crop seed is usually broadcast by hand and then covered by plowing at right angles to the first operation. Upon occasion hand-hoes are used to break up clods between the first and second plowing but rarely is the use of a harrow or drag in evidence. This procedure obviously requires an abnormally high seeding rate to produce a satisfactory crop stand.

Vegetables are commonly transplanted from farm "nursery" plots. Transplants or seeds are planted in beds separated by deep wide irrigation channels. Plantings are placed midway between the crest and bottom of the ditch, which removes the seedling from the point of highest salinity. This practice is of distinct value where soils tend to be saline.

Crop rotation as a planned program is seldom followed. For the most part cereals, particularly wheat, are produced year after year on the same tracts of land. This practice is followed of necessity on some areas where shallow soils and lack of water limit the variety of crops that can be produced. However, it is also common practice on much of the land that is fully irrigated. In some cases on these latter areas land is left idle as fallow for one season, but in many cases it is again planted wholly or in part to the same crop.

Vegetable crops are rotated to a greater degree but this is primarily due to the practice of shifting tenant farmers annually from one tract of land to another. Again, planned rotation programs are generally lacking with market price and operator food needs the primary reasons for planting a specific crop.

Irrigation methods are influenced to a major degree by the source of the water supply. In many cases water is available in relatively large quantity for a short period of time. The tendency is to use a large head of water with no regard for water intake rate of the soil or topographic features of the land. In such instances, as most field head ditches are unlined, a degree of erosion takes place which eventually eliminates their usefulness and new ones must be constructed. Such practices also tend to spread a given amount of water over a large area with inadequate penetration at any one place. Cereals, which are generally irrigated with a semi-wild flooding technique, seldom receive full benefit from water applied in this manner.

Vegetables and fruits are usually irrigated by the basin methods. Good distribution of water is generally obtained with a minimum of waste.

Fertilizers and organic matter are generally of minor significance in current crop production. Animal manure is commonly gathered and dried for use as domestic fuel. The natural manures which are used for fertilizer are purchased in most cases and consist mainly of cattle and sheep dung. General practice is to pay for its collection and transportation to the farm where it is applied to vegetables and fruits. The majority of the better banana and citrus plantings utilize a type of compost incorporating these manures and some residue such as banana leaves. Mineral fertilizers are occasionally used by larger landowners but information regarding their value in the form of increased production is lacking. There are no regulations covering composition of commercial fertilizers, and consequently they are quite varied. Some unprocessed rock phosphate of local origin has been applied but value derived from application on the highly calcareous soils of the area is economically questionable. Cost is a prime deterrent to use of fertilizers as most operators feel they cannot afford to purchase them.

The addition of organic matter to the soil in the form of green manure or crop residue is virtually unknown. The lack of sufficient forage for roving herds of sheep and goats and shortage of water needed to produce crops for human consumption have taken precedence over growing of any crop for purposes of adding needed organic matter to the soil. Farm animals are allowed to eat crop residues to the ground or the plant stalks are completely removed by pulling them from the soil, roots and all, for feeding at a later time or for use as fuel. These practices precluded any appreciable use of organic matter for purposes of improving soil fertility or tilth.

Farm machinery within the area is generally light and simple. The single "nail-type" plow is the common ground-breaking implement and is drawn through the soil by animal power. Cultivation is practiced to a limited extent and is performed almost entirely by wide-bladed hand hoes. This long-handled, heavy implement is also used to a great degree for plowing, smoothing and irrigation ditching operations. Sowing of seed and other planting is done by hand. In Adasiye and Jericho and a few other localities modern machinery in the form of tractor-drawn disc plows, seed drills and harrows are utilized on a limited number of the larger holdings. This equipment has been introduced primarily within the past three years as has the F.O.A. demonstration program of techniques involved in its operation.

Harvesting of cereals is generally done by hand-sickle or by pulling the entire plant from the soil. Threshing is accomplished on "natural" threshing floors so placed as to take advantage of wind for winnowing purposes. Animals and flails are used to separate the grain and hand sieves for final separation. Vegetables and fruits are picked by hand.

In general the lack of adequate tools for cultural operations restricts timeliness of farm operations. This is reflected in the extensive time currently required for preparation of the land, harvesting periods and relatively low yields.

Farm animals are low in number. A few chickens together with a small number of sheep or goats are generally owned by individuals. Some families may have one or two horses or a similar number of oxen, donkeys or camels. The larger animals are primarily used for farm power and transportation. Forage crops for farm animals are practically non-existent and feed is obtained by herding on non-cropped land and use of a limited amount of crop residue.

Weed control practices are limited both in method and the extent to which they are employed. Weeds are recognized as pests that seriously reduce the productive capacity of agricultural lands and interfere with the farmer's effort to grow useful plants. The production of crops is largely in direct competition with weeds, whose control is a factor of major importance, especially in irrigation agriculture. Losses from weeds may be enumerated as follows:

(1) Weed competition with crops for water, light, and mineral nutrients.
(2) Additional labor required to combat weeds that could profitably be used to produce food.
(3) Weeds reduce the quality of farm products.
(4) Weeds harbor insects and fungus pests that attack crop plants.
(5) Weed infestation can become so rank that agricultural land is no longer productive.

It is reasonable to assume that these losses from weeds will be higher in an area of small farm units, (such as the development contemplated), than one of large units. From field observation it has been estimated that potential crop production in the Jordan Valley will be reduced by ten percent without an adequate weed control program.

The following weeds are some of those most commonly found in the Jordan Valley and will constitute an increasingly important problem as the area is developed for irrigation:

Bermuda grass	(Cynodon dactylon)
Chenopodiums	(Chenopodium spp)
Christ thorn	(Spini christi)
Tamarisk	(Tamarix pentandra)
Wild-onion	(Urginea maritima)
Yambut	(Prosopia stephanania)

There is ample evidence that the tendency to grow one crop on a given area of land for several seasons has allowed weeds to multiply. This is particularly true of those weeds which are compatible with the growth habits and management program of the crop.

As the new land is developed and brought under irrigation, the weed problems in these areas will become more numerous. For this reason it is desirable that weed control practices be established in the early stages of this development in order to hold weed infestations to a minimum. In addition, weed problems are more difficult on old irrigated lands, and the old established weeds more costly to control than those on new lands.

Many methods of weed control and eradication have been devised which may be grouped under the headings of:

(1) Mechanical methods (hand hoeing, tillage, burning, etc.)
(2) Cropping and competition methods
(3) Chemical methods

Present control measures consist almost entirely of the first category. They occur mainly as a by-product of normal seed-bed preparation and occasional cultivation. Some effort is made to periodically remove larger, woody-types of vegetation by hand "grubbing". Mechanical and cropping methods of control are recommended as being the most suitable for the Jordan Valley in the initial stages of development. Chemical weed-killers, which are more costly, can be used on the more persistent plant species to supplement these two methods. The agricultural experiment stations in the valley should include weed control in their annual program in order to develop the best techniques for the local conditions. A detailed weed survey of the valley should also be scheduled in the program of the contemplated farm extension service.

Insects and plant diseases receive little attention at the present time. Mild infestations of locusts from the desert areas have occurred from time to time. The coordinated effort of surrounding countries with the Jordan Government and United Nations representatives has succeeded in controlling the swarms to date. Poison baits and hand eradication seem most effective. A limited amount of chemical control for insects and plant diseases is employed primarily through hand dusting of crops. Pests of individual crops and recommended controls are given in Table 3.2-5, Data for Recommended Crops.

Anticipated Irrigation Agriculture

In an area, such as the Jordan Valley, which has a problem of over population, the production of food for human consumption is of primary importance. Therefore, an agricultural program must provide food for the family and a small cash crop to enable the purchase of necessities not produced on the farm. It should also provide feed for the livestock and enable fertility and tilth of the soil to be maintained.

Under the proposed plan of development it is expected that the people will continue to live in villages rather than on the farms. This custom is traditional in the area and will be advantageous in that every effort will be made to utilize all irrigable land for crop production by locating villages on non-arable lands.

Since it is beyond the scope of this report to identify agricultural programs for individual farm units, the subsequent discussion will be primarily concerned with establishment of a cropping pattern, or distribution of crops, over the project area which land classification has determined to be suitable for irrigation agriculture. The climate and soils are generally well suited to the growing of a wide variety of crops as has been pointed out in other sections of this report dealing specifically with these topics. It has also been noted that many types of crops have been and are now being grown within the area, and the lack of sufficient water has been one of the primary influencing factors determining the degree to which agriculture has been practiced.

Crops which are included in the patterns were selected as representative of those which are adapted to the area rather than trying to anticipate all crops which can be grown in the future.

Two specific cropping patterns are shown in Drawing DS-5-5, together with the irrigation and diversion requirements of each. Pattern "A" is designed to furnish a maximum of subsistence-type living with the primary emphasis on cereals and the productive periods reflecting the present irrigation influence. Provision has been made for production of some vegetables and fruits other than those required for the farmers themselves, and introduces sugar beets and peanuts to the area. These latter crops are both well adapted to the project soils and can be the basis for establishment of industrial plants producing sugar and edible oils. A part of the vegetable production may also lend itself readily to canning and preserving processes.

Cropping Pattern "B" was developed to introduce rice, cotton and dates. There is a deficiency in these crops and an increase in production will alleviate the import situation. It is recognized that certain difficulties are inherent to the production of these crops, but their adaptation to soils and climate of the area warrant their consideration. The differences in time and length of growing season noted in the two patterns for a few crops are acceptable if compared with their production in irrigated areas of similar climate and soils. A summary of crops shown in both patterns "A" and "B" is given in Table 3.2-3, Estimated Distribution of Irrigation Crops with Project Development.

In addition, diversion requirements by months for the various crops are shown in Tables 3.2-6 and 3.2-7, "Diversion Requirements" for Northern and Southern Zones, respectively. The method of developing irrigation and diversion requirements are fully developed in Volume II, and further discussed in Volume VII.

Yields of crops have been estimated on the basis of a moderate improvement in management practices, availability of improved farm equipment, and use of adapted crop varieties. In addition, cognizance has been taken of the productive capacity of the project soils, and the influence of climatic factors as compared with similar areas. Average yields anticipated under project development are shown in Table 3.2-4. It is expected that generally, yields on Class 1 and Class 2 lands will exceed those obtained on Class 3 land by 20 to 30 percent.

Agricultural programs, as it has been previously noted, are carried out in most cases in accordance with traditional methods. Detailed recommendations for the growing of individual crops in local areas must necessarily come from experimental work such as is now being conducted at the Baqura, Deir Alla and Wadi Fari'a Experiment Stations. Special points of interest are discussed in the following paragraphs, and additional information for selected crops is given in Table 3.2-5

Cereals are well adapted to the soils of the area, and produce very well on the clay loams and lighter clays. Preparation of seed-beds should tend to establish a slightly better condition than is presently obtained. Better stands from less seed should result. Planting in rows will be advantageous for such crops as corn and sorghum, particularly from the standpoint of better penetration of irrigation water.

Rice is well adapted to the heavier clay soils. Such soils will require less water than finer textured soils to produce a crop. They will crust quickly after draining in the fall allowing earlier harvest. Rice will require more water to produce an equivalent amount of calories than do potatoes. However, it will prove advantageous to grow on alkali soils and can be followed by crops less tolerant in nature.

Crop residues of cereals should be mixed with the soil by working the straw into the surface soil to increase moisture penetration and reduce runoff. Wherever possible leguminous crops such as alfalfa and beans should be utilized in rotation with cereal crops. In particular it is not well for sorghum to be followed by wheat in rotation as the former crop will cause a temporary reduction in nitrogen content of the soil.

Sugar beets are a promising potential crop from the standpoint of adaptability to project soils, salinity tolerance, and their prospects of reducing sugar imports. Sugar beet tops and by-products of processing also would contribute materially to feed requirements of livestock. Beets require a significant amount of hand-labor and should be planted as a row crop. Both of these factors lend themselves well to farming in the area, and this crop fits well into rotation with other field crops and vegetables.

Cotton is well adapted to the lighter soils in the southern part of the valley. It can be grown during the hot summer months and will enter well into a rotation with vegetables such as potatoes or with a forage crop such as alfalfa. Only a few very small areas have been grown to date and while plant growth was excellent, considerable difficulty was encountered with boll-weevil. Further information is needed before control measures in the local area can be recommended.

Forage crops in the form of legumes such as alfalfa or berseem will be beneficial not only for production of animal forage but also will be helpful in soil improvement. These crops, plus by-products of sugar beet production and other crop residue such as peanut hay, should better condition work animals on the farms and encourage fattening of meat animals such as lambs. Rather than establish an enterprise within the project, it is expected that lambs would primarily be for family use and would come from adjacent upland areas. Of primary importance in rotation with vegetable and field crops, legumes will add to the nitrogen content of the soil and aid in improving soil condition by addition of organic matter.

Vegetable crops will assume significant degree of importance under project development. The major portion of the soils in the area, particularly those on alluvial fans and much of the zor, are well adapted to production of a wide variety of vegetables. Fertilizer and a full water supply will greatly increase present production. The use of more water must be coordinated with better methods of application.

Fruits will continue to be grown to great advantage in the project area. Bananas in particular are in a superior position for competition with surrounding Middle East areas. The soils which are shallow in depth to marl seem to produce excellent crops. Water and fertilizer are presently used to advantage on bananas and on citrus fruits. However, increased amounts of available nitrogen and phosphorous would materially help production and quality. Dates are well adapted to production and particularly on saline soil areas. The existing amount of parent stock is not well suited to propagation purposes. Since neighboring countries prohibit exportation of seedlings they must be secured from other areas.

Although grapes are grown to a major extent in the adjacent uplands, it is felt the valley offers some advantages. A variety such as Thompson Seedless, extensively grown in a similar area of the United States, could be used as fresh fruit and under valley conditions could also be dried for raisins. Both grapes and citrus fruits should do well on soils which contain appreciable amounts of rock in the profile. The majority of these soils are of clay and clay loam textures and occur on the upper slopes of the ghor. Vines and trees require less tillage, and while slopes may not require terracing, plantings should be established on the contour.

Summary and Conclusions

The Valley has a long history of limited irrigation. Production now is predominantly in the form of cereals, principally wheat. A variety of vegetables are produced on a small area and as with cereals, yields are relatively low. Fruits, especially bananas, are well adapted to the area and quality and flavor are good. Few farm animals are maintained by individuals and cropped area is seldom used specifically for animal feed. Animals secure most of their feed by foraging. Shortage of forage and fuel discourages addition of organic matter to the soil. Farm practices are generally inadequate to secure the production and quality possible even under existing conditions of limited water supply.

An extension type of educational program is mandatory to successfully establish and maintain the subsistence-type of farming recommended. The introduction of more advanced animal powered equipment such as small mold-board and disc plows, one-horse shovel cultivators and seed drills, and small section spike tooth harrows is strongly recommended. Small tools such as scythes and hand dusters will also increase efficiency and make for more timely farm operations.

Experimental programs with new varieties as well as improvement in purity and quality of existing crops are now being conducted at agricultural experiment stations within the valley. Additional fertilizer tests are needed, but it is apparent that present practices are entirely inadequate. Indications are that application of available nitrogen and phosphorous would benefit most crops significantly.

Anticipated development is based on a full water supply. However, practices which will produce maximum benefit with a minimum of waste should be utilized. This will also materially reduce future drainage problems. Field crops in particular will benefit by a more controlled type of distribution such as basin-flooding or combination of basin-flooding with furrows where slope is a definite factor. More significance should be placed on the relationship between the volume of water delivered and the length of time it is available, as concerned with the size of field, soil characteristics and crop water requirement.

Weeds will become a problem of increasing importance as irrigation development takes place. Mechanical and cropping methods of control are recommended in the initial stages of the project. Chemical weed-killers can be used on more persistent plant species to supplement these methods. A detailed weed survey program should be initiated to keep pace with agricultural development.

Crops which have been recommended under anticipated development include those which meet domestic needs and tastes and have market outlets, as well as being adapted to project soils and climate.

Table 3.2-1

Distribution of Crops,
Jordan Valley-1953 1/
(Sheet 1 of 2)

Irrigated Land	East Ghor North (donums)	East Ghor South (donums)	West Ghor (donums)	Total Project (donums)	Total Project (percent)
Wheat	63,000	30,600	32,600	126,200	25.0
Barley	19,200	4,700	9,100	33,000	6.6
Corn	2,500	540	100	3,140	0.6
Sesame	6,100	3,900	3,450	13,450	2.7
Sorghum	16,200	410	5,100	21,710	4.3
Sub-Total, Cereals	107,000	40,150	50,350	197,500	39.2
Eggplant	2,500	3,500	1,600	7,600	1.5
Tomatoes	2,700	6,500	6,400	15,600	3.1
Watermelons	9,600	1,100	1,200	11,900	2.3
Cucumber	800	420	2,280	3,500	0.7
Marrow	800	950	750	2,500	0.5
Cabbage	550	250	250	1,050	0.2
Cauliflower	330	90	460	880	0.2
Broadbeans	400	470	1,550	2,420	0.5
Onions	580	270	350	1,200	0.2
Potatoes	870	300	930	2,100	0.2
Sub-Total, Vegetables	19,130	13,850	15,770	48,750	9.7
Bananas	2,800	1,400	2,200	6,400	1.3
Citrus	840	240	620	1,700	0.3
Otherfruits	3,860	750	2,780	6,590	1.3
Sub-Total, Fruits	7,500	2,400	5,600	15,500	2.9
Total Irrigated Crops 2/	133,630	56,400	71,720	261,750	

Table 3.2-1

Distribution of Crops
Jordan Valley-1953 1/
(Sheet 2 of 2)

	East Ghor North (donums)	East Ghor South (donums)	West Ghor (donums)	Total Project (donums)	Total Project (percent)
Non-Irrigated Land					
Wheat	15,500	-	1,800	17,300	3.4
Barley	4,000	-	1,100	5,100	1.0
Sesame	220	-	-	220	- 3/
Watermelons	250	500	500	1,250	0.2
Sorghum	3,600	-	600	4,200	0.8
Sub-Total, Cropland	23,570	500	4,000	28,070	5.4
Fallow, Idle	11,600	48,400	57,240	117,240	23.5
Grazing, Waste, Etc.	700	78,300	18,140	97,140	19.3
Total, All Land	169,500	183,600	151,100	504,200	100.0

1/ Based on "Agricultural Economic Survey, Jordan Valley", United Nations Organization, 1953; adjusted to irrigable area of project.
2/ Includes all land reported as irrigated, at anytime during 1953, regardless of adequacy of irrigation.
3/ Less than 0.1 percent.

Table 3.2-1

Table 3.2-2

Crop Yields, Jordan Valley-1953[1]
(Sheet 1 of 2)

	East Ghor North (Yield/Donum) Kilograms	East Ghor South (Yield/Donum) Kilograms	West Ghor (Yield/Donum) Kilograms	Total Project (Yield/Donum) Kilograms
Irrigated Land				
Cereals				
Wheat	90	90	85	90
Barley	100	90	70	90
Corn	200	120	120	190
Sesame	60	55	60	60
Sorghum	-	-	-	100
Vegetables				
Eggplant	1000	870	910	930
Tomatoes	620	430	520	500
Watermelon	470	430	470	490
Cucumbers	400	320	450	420
Marrow	640	350	500	490
Cabbage	690	770	840	900
Cauliflower	720	430	620	640
Broadbeans	330	350	300	320
Onions	770	520	900	750
Potatoes	1520	840	820	1100
Fruits[2]				
Bananas	1300	1250	1310	1295
Citrus	1300	1040	870	1098
Other Fruits	1100	1150	1430	1221

Table 3.2-2

Crop Yields, Jordan Valley-1953 1/
(Sheet 2 of 2)

Non-Irrigated Land	East Ghor North (Yield/Donum) Kilograms	East Ghor South (Yield/Donum) Kilograms	West Ghor (Yield/Donum) Kilograms	Total Project (Yield/Donum) Kilograms
Wheat	80	80	20	70
Barley	90	70	30	75
Sesame	30	40	40	30
Watermelons	90	-	65	200
Sorghum	280	-	430	60

1/ Based on "Agricultural Economic Survey, Jordan Valley", United Nations Organization, 1953.

2/ Fruit yields and production are based on trees or vines of bearing age.

Table 3.2-2

Table 3.2-3

Estimated Distribution of Irrigated Crops With Project Development (Sheet 1 of 2)

Crops	Pattern "A" Donums	Pattern "A" Percent	Pattern "B" Donums	Pattern "B" Percent
CEREALS				
Wheat	121,000	24	70,600	14
Barley	55,500	11	-	-
Corn	17,600	3½	20,200	4
Rice	-	-	30,300	6
Sorghum	37,800	7½	20,200	4
Sub-total	231,900	46	141,300	28
VEGETABLES				
Tomatoes	22,700	4½	30,300	6
Potatoes	30,300	6	30,300	6
Cucumbers	11,300	2¼	15,150	3
Marrow	11,300	2¼	15,150	3
Cabbage	7,575	1½	7,575	1½
Cauliflower	7,575	1½	7,575	1½
Beans	22,600	4½	25,200	5
Eggplant	11,300	2¼	10,100	2
Watermelon	11,300	2¼	10,100	2
Peas	11,300	2¼	10,100	2
Onions	10,000	2	10,100	2
Sub-total	157,250	31¼	171,650	34
INDUSTRIAL CROPS				
Cotton	-	-	30,300	6
Peanuts	32,800	6½	20,200	4
Sesame	25,200	5	10,100	2
Sugar Beets	63,000	12½	60,600	12
Sub-total	121,000	24	121,200	24
FRUITS				
Bananas	31,500	6¼	30,300	6
Citrus	31,500	6¼	35,300	7
Dates	-	-	10,100	2
Others	12,600	2½	15,150	3
Sub-total	75,600	15	90,850	18

Table 3.2-3

Estimated Distribution of Irrigated
Crops With Project Development
(Sheet 2 of 2)

Crops	Pattern "A" Donums	Pattern "A" Percent	Pattern "B" Donums	Pattern "B" Percent
FORAGE				
Alfalfa	Hay and		80,800	16
Mangels	Fodder Crops		10,100	2
Cowpeas			10,100	2
Sub-total	88,200	17½	101,000	20
TOTAL GROSS CROP AREA	673,950	134	626,000	124
TOTAL NET CROP AREA	504,200	100	504,200	100
DOUBLE CROP AREA	169,750	34	121,800	24

Table 3.2-4

Estimated Crop Production
With Project Development

Crop	Yield/Donum (Kilograms)
CEREALS	
Wheat	190
Barley	210
Corn	340
Rice	380
Sorghum	320
VEGETABLES	
Tomatoes	1,680
Potatoes	1,550
Cucumbers	1,460
Marrow	1,750
Cabbage	2,120
Cauliflower	1,650
Beans	1,460
Eggplant	1,660
Watermelon	1,970
Peas	1,500
Onions	2,050
INDUSTRIAL CROPS	
Cotton	90
Peanuts	300
Sesame	65
Sugar Beets	3,100
FRUITS	
Bananas	2,600
Citrus	1,700
Dates	1,200
Others	1,000
FORAGE CROPS	
Alfalfa	1,300
Mangels	2,000
Cowpeas	1,500

Table 3.2-5

Data for Recommended Crops
(Sheet 1 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
CEREAL CROPS Corn (Maize)	Medium	March 1 May 15	August 1 October 1	5.0 4.5	0.91	340	Earworms (Heliothis sp.). Treat with DDT in oil, or apply as spray.
Rice	Medium	May 1	October 1	5.0	10.00	380	Weeds. Adequate submergence.
Sorghum	Medium	May 1 May 15	August 15 September 1	3.5 3.5	3.41	320	(If followed by other cereals, land should be heavily fertilized with nitrogen)
Barley	High	November 15	April 15	5.0	11.34	210	Powdery Mildew, Wheat Leaf Miner (Syringopias temperatil...), Short-winged Wheat Leaf Beetle (Marseulia sp.). Seed selection and crop rotation.
Wheat	Medium	November 15 November 15	May 15 April 15	6.0 5.0	10.21	190 165	Same as Barley.
INDUSTRIAL CROPS Cotton	High	March 15	November 1	7.5	2.27	90	Boll Weevil (Anthonomus grandis). Dusting with nicotine.
Peanuts	Medium	May 1	September 15	4.5	3.40	300	None noted to date.
Sesame	Medium	May 1	July 15	2.5	1.00	65	Seed pods split and scatter. Seed selection.
Sugar Beets	High	October 1	April 1	6.0	0.56	3,100	New crop to area. Maybe attacked by locust.
TRUCK CROPS General Vegetables Cabbage	Medium	*September 1	January 15	4.5	**1,800	2,120	Aphids - dusting with "Derrimac". Cabbage Caterpillers - dusting with DDT or "Agricide".
Cauliflower	Medium	*September 1	January 15	4.5	**1,350	1,650	Same as Cabbage.
Cucumbers	Medium	February 1	June 1	4.0	0.22	1,460	Cutworms - DDT dust. Powdery Mildew - crop rotation.
Eggplant	Low to Medium	*March 15 *May 1	June 15 August 1	3.0 3.0	**1,350	1,660	Root rot. Selection of resistant varieties.
Marrows (Squash)	Medium	February 1	June 1	4.0	0.32	1,750	Same as Cucumbers.

Table 3.2-5

Table 3.2-5

Data for Recommended Crops
(Sheet 2 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
TRUCK CROPS General Vegetables (Cont'd) Onions	Medium	September 1 *December 1	May 1 May 1	8.0 5.0	0.23 **25,000	2,050 2,050	Thrips are trouble some. Contolled by DDT
Peas (Garden)	Medium	January 1	April 1	3.0	8.50	1,500	Not serious.
OTHER CROPS Broadbeans (Horsebeans)	Medium	September 1	January 1	4.0	14.06	1,460	Not a problem at present.
Green Beans	Low	September 1	January 1	4.0	6.82	1,460	Not a problem at present.
Melons (Watermelons)	Low	February 1 February 1	July 1 June 15	5.0 4.5	0.45 0.45	1,970 1,800	Cutworms - DDT dust. Powdery Mildew - crop rotation.
Potatoes	Low to Medium	October 1 September 15	February 15 January 15	4.5 4.0	113.40 113.40	1,550 1,250	Aphid - dust with nicotine sulfate. Cutworms - dust with DDT. Curlytop, a virus disease-seed selection. Late Blight, a fungus disease - treat with "Paranox" or "Cupravit". Crop rotations are helpful in disease control.
Tomatoes	Medium	*August 15 May 15	December 15 September 15	4.0 4.0	**1,350 **1,350	1,680 1,680	Late Blight, a fungus disease - treat with "Paranox" or "Cupravit". Insect damage not serious.
FRUITS Bananas	Medium to High	Any Month	Year round - heaviest in August	72 (6 Years)	**110	2,600	Not a problem at present.
Date Palms	High	May 1 to July 1	September 1 to December 1	144 (12 Years)	** 16	1,200	Not a problem at present.
Grapes	Medium	January 1 to March 1	June 1 to July 1	36 (3 Years)	**110	1,000	Grape Bud Moth - controlled by "Ostico" or "Folidol". Powdery Mildew - treat with "Paranox" or "Cupravit". (Young plants sensitive to salinity)
Grapefruit, Oranges and Tangerines	Low to Medium	December 1 to February 1	November 1 to March 1	240 (20 Years)	** 50	1,700	Mediterranean Fruit Fly-trap in jars baited with "Clensel". Black scale - treat in dormant stage with "Ovicide" or spray in summer with "Folidol", "Arboleum", "Triond" or "Volk".

Table 3.2-5

Data for Recommended Crops
(Sheet 3 of 3)

Crop	Relative Tolerance to salt	Dates of Planting	Dates of Harvesting	Months on Land	Seeding Rate Kg./Donum	Yield Kg./Donum	Common Pests and Diseases and Their Control
FRUITS (Cont'd)							
Lemons	Low	December 1 to February 1	Main Crop: August 1 to March 1 Secondary Crop: Balance of year	(Indefinite)	** 50	1,700	Same as Grapefruit.
Pomegranates	Low	December 1 to February	August 1 to November 1	(Indefinite)	**110	1,000	Mediterranean Fruit Fly-trap in jars baited with "Clensel". Control must be on a community basis.
FORAGE CROPS							
Alfalfa	Medium	October 1 to November 15	(6 Months after planting and every 45-60 days thereafter)	36 (3 Years)	3.18	1,300	New crop to area. May need control for locust. (After 3 years turn under as a green manure.)
Clover	Medium	October 1 to November 1	(6 Months after planting and every 45-60 days thereafter)	36 (3 Years)	3.18	1,300	Same as Alfalfa.
Mangels	High	October 1	February 15	4.5	1.36	2,000	Not a problem at present.
Cow Peas	Medium	February 1	June 1	4.0	2.27	1,500	Not a problem at present.

* Transplanting date.
** Plants per donum.

Table 3.2-6

Diversion Requirements for Northern Zone (in mm)

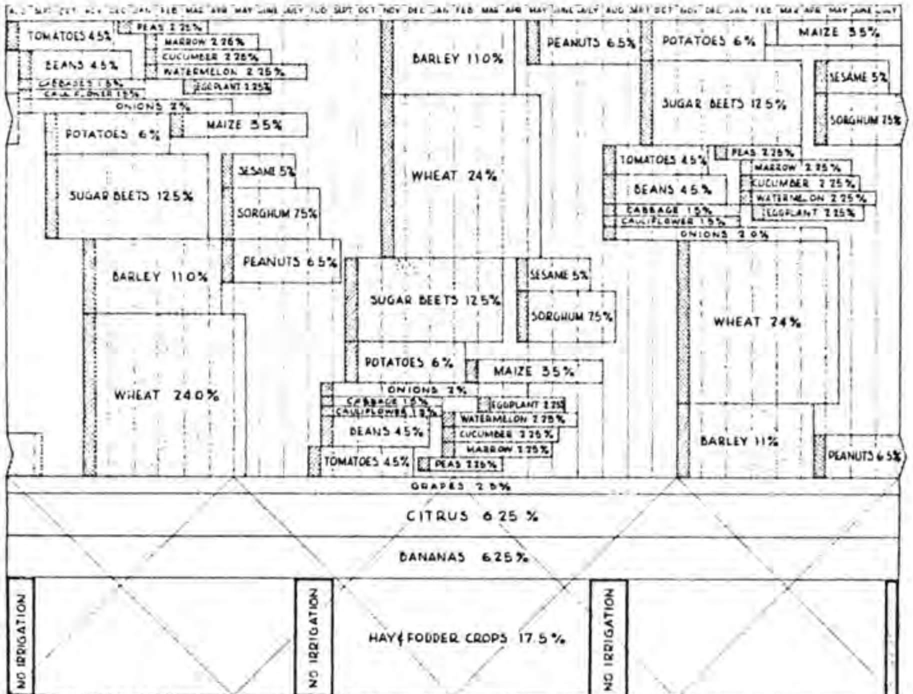
Crop	K	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cereal Crops													
Corn	.85	33	55	116	199	242	273	281	272	235	200	119	52
Rice	1.20	46	78	164	282	342	387	398	386	333	284	168	74
Sorghum	.80	31	52	109	168	228	258	265	257	222	189	112	49
Wheat	.85	33	55	116	199	242	273	281	272	235	200	119	52
Industrial Crops													
Cotton	.65	25	42	89	153	185	209	215	209	180	153	91	40
Peanuts	.65	25	42	89	153	185	209	215	209	180	153	91	40
Secame	.80	31	52	109	188	228	258	265	257	222	189	112	49
Sugar Beets	.80	31	52	109	188	228	258	265	257	222	189	112	49
Sugar Cane	.90	35	58	123	212	256	290	298	289	250	213	126	55
Truck Crops													
General Vegetables	.80	31	52	109	188	228	258	265	257	222	189	112	49
Beans	.75	29	49	102	176	214	242	249	241	208	177	105	46
Potatoes	.75	29	49	102	176	214	242	249	241	208	177	105	46
Tomatoes	.70	27	46	95	164	200	226	232	225	194	165	98	43
Fruits													
Bananas	1.30	50	84	177	306	370	419	431	418	361	307	182	60
Citrus	.65	25	42	89	153	185	209	215	209	180	153	91	40
Dates	1.20	46	78	164	282	342	357	398	386	333	284	168	74
Deciduous	.65	25	42	89	153	185	209	215	209	180	153	91	40
Grapes	.65	25	42	89	153	185	209	215	209	180	153	91	40
Forage Crops													
Alfalfa	.85	33	55	116	199	242	273	281	272	235	200	119	52
Clover	.85	33	55	116	199	242	273	281	272	235	200	119	52
Mangels	.80	31	52	109	188	228	258	265	257	222	189	112	49
Peas	.80	31	52	109	188	228	258	265	257	222	189	112	49

Table 3.2-6

Table 3.2-7

Diversion Requirements
for
Southern Zone
(in mm)

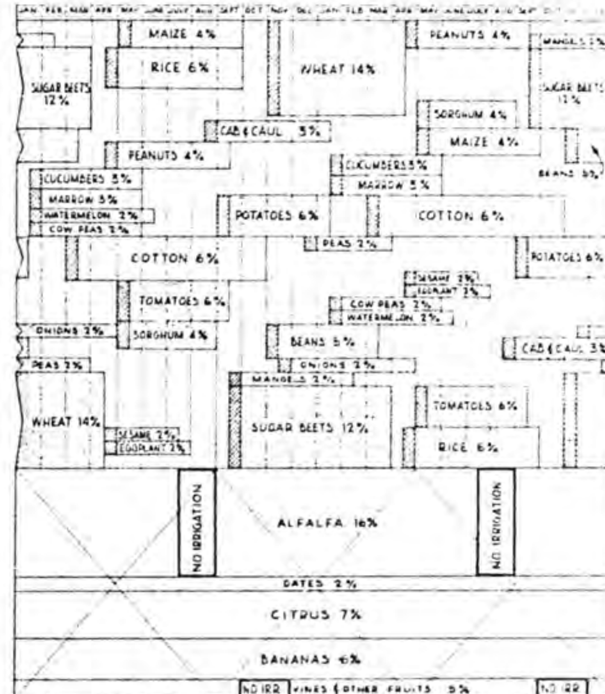
Crop	K	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cereal Crop													
Corn	.85	109	134	178	200	249	285	290	275	233	202	166	137
Rice	1.20	154	189	252	284	352	404	411	388	330	286	236	194
Sorghum	.80	103	126	168	189	235	269	274	259	220	191	157	129
Wheat	.85	109	134	178	200	249	285	290	275	233	202	166	137
Industrial Crops													
Cotton	.65	84	102	136	153	191	218	222	210	179	155	127	105
Peanuts	.65	84	102	136	153	191	218	222	210	179	155	127	105
Sesame	.80	103	126	168	189	235	269	274	259	220	191	157	129
Sugar Beets	.80	103	126	168	189	235	269	274	259	220	191	157	129
Sugar Cane	.90	116	142	189	213	264	303	308	291	248	215	177	145
Truck Crops													
General Vegetables	.80	103	126	168	189	235	269	274	259	220	191	157	129
Beans	.75	97	118	158	177	220	252	257	243	206	179	147	121
Potatoes	.75	97	118	158	177	220	252	257	243	206	179	147	121
Tomatoes	.70	90	110	147	165	206	235	240	227	192	167	137	113
Fruits													
Bananas	1.30	167	205	273	307	382	437	445	421	358	310	255	210
Citrus	.65	84	102	136	153	191	218	222	210	179	155	127	105
Dates	1.20	154	189	252	284	352	404	411	388	330	286	236	194
Deciduous	.65	84	102	136	153	191	218	222	210	179	155	127	105
Grapes	.65	84	102	136	153	191	218	222	210	179	155	127	105
Forage Crops													
Alfalfa	.85	109	134	178	200	249	285	290	275	233	202	166	137
Clover	.85	109	134	178	200	249	285	290	275	233	202	166	137
Mangels	.80	103	126	168	189	235	269	274	259	220	191	157	129
Peas	.80	103	126	168	189	235	269	274	259	220	191	157	129



CROPPING PATTERN A *Based on 3 year rotation. Developed by UNRWA Agricultural Economist*

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NORTHERN	IRRIGATION REQ	M³/DONUM	19	33	70	99	119	103	81	49	71	81	62	52	819
ZONE	DIVERSION REQ	M³/DONUM	30	51	107	152	185	158	126	75	109	125	95	49	1260
SOUTHERN	IRRIGATION REQ	M³/DONUM	64	81	107	100	123	107	84	50	70	82	80	84	1037
ZONE	DIVERSION REQ	M³/DONUM	99	124	165	153	189	165	130	77	108	126	123	129	1588



CROPPING PATTERN B *Based on 4 year rotation. Developed by Baker-Harza incorporating tentative data from representatives of the Jordan Govt*

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NORTHERN	IRRIGATION REQ	M³/DONUM	16	29	59	76	112	123	108	86	95	77	43	26	856
ZONE	DIVERSION REQ	M³/DONUM	25	45	91	117	172	189	166	132	146	118	75	40	1316
SOUTHERN	IRRIGATION REQ	M³/DONUM	53	69	91	76	116	129	112	86	94	78	69	69	1042
ZONE	DIVERSION REQ	M³/DONUM	82	106	140	117	178	198	172	132	145	120	106	106	1602

LEGEND

- AREA UNDER IRRIGATION
- AREA UNDER PREPARATORY TILLAGE
- FALLOW LAND
- CONTINUATION OF CROP
- PERMANENT CROP

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

DIVERSION REQUIREMENTS
FOR
SPECIFIC CROPPING PATTERNS

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VOLUME IV - IRRIGATION AND DRAINAGE
YARMOUK-JORDAN VALLEY PROJECT
MASTER PLAN REPORT

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PART 1. Present Water Use
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Water Utilization

One of the purposes of this investigation was to determine in what manner and to what degree water resources could best be developed, with particular emphasis on the expansion and intensification of irrigation agriculture. Present methods of irrigation and drainage were appraised, and information was assembled regarding the suitability of available water for use in sustained irrigation of the soils in the Jordan Valley. Studies were made to determine water requirements and to develop an irrigation regimen and drainage system for the project.

PART 1. PRESENT WATER USE

Irrigation

Irrigation has been a feature in the development of agriculture in the Jordan Valley since the earliest times of which there is any record. Evidence of old works indicates that at one time this area was much more highly developed and more intensively cultivated than today, supporting a population considerably larger than the present, and permitting export of agricultural products to surrounding areas. Some of these early developments, principally among those constructed during the time of the Roman occupation, continue in use even now. Earlier prosperity, resulting chiefly from the nearby overland trade routes, created a demand for the produce of the Valley. However, because of changes in the trade routes and movement of population centers, this demand diminished and irrigation works were neglected to the point where most of them become inoperative.

At the present time, to varying degrees of intensity, water for irrigation is supplied by gravity flow from the Yarmouk and Zarqa Rivers, by pumping from the Jordan River, by gravity flow from perennial wadis, by springs, by wells, and by ancient fuquarās constructed for development of ground water. There have been only minor attempts to coordinate these sources of water, and no plan integrating all water supplies into one system providing optimum development of the Jordan Valley has ever been put into effect.

Irrigation from Wadis

The largest areas of irrigated land in the valley of the Jordan derive their water from the flows of tributary wadis. Because of the similarity in problems and development the River Zarqa will be discussed in this group.

Of the cultivated area east of the Jordan River, 184,293 donums lying on the ghor have been registered as irrigated from ten wadis. Exact registration figures for the West Ghor are not available, but it is estimated that on this side of the river approximately 31,000 donums are irrigated from the flows of Wadi Fari'a and Wadi Auja. Almost all of the normal flows from these wadis is used for irrigation, but the areas served have been over-extended, distribution systems have not been efficiently designed or constructed, and shortages have inevitably resulted. Current rotation practices vary widely from two to as much as six years. Furthermore, in the absence of a coordinated over-all system, it has not been possible to conserve and utilize flood waters to any extensive degree.

Surface run-off at the present time is utilized only during the period of the rainy season and only then on lands not otherwise under irrigation or lands where irrigation waters must be supplemented. The general method of utilization of surface run-off is to divert the water with dikes and small channels so a spreading effect is achieved. Retention of this additional water is often needed to assure sufficient moisture for winter crops, especially small grains.

With the establishment of the Irrigation Department of Jordan in 1948, steps were initiated to facilitate control of these registered irrigated areas in a more progressive and efficient manner. Diversion structures with appurtenant control works and sluice gates have been constructed in eight wadis, and the related supply and distribution systems are partially completed. Most of the lined canals which have been constructed lie above the locations of the proposed East Ghor and West Ghor Main Canals, and can be integrated into the over-all development by extensions roughly parallel to the Main Canals, and appropriate exchange of water use. The portions of the existing systems which lie below the proposed Main Canal, consisting principally of inefficient, unlined supply and distribution channels, have not been considered in the integrated plan.

Wadi Arab - The diversion dam in Wadi Arab was constructed in 1948. Two supply canals were constructed, one on the north side of the wadi and one on the south. About one Kilometer of North Canal was constructed with reinforced concrete lining, while the remainder of the supply canals and distribution laterals totalling approximately 45 Kilometers are in unlined earth channels.

The gross area registered as irrigated from the wadi below the headworks is 14,323 donums. In 1950 the mean annual percentage of cropping recorded by the Irrigation Department was 44.7%.

Wadi Ziglab - The diversion dam in Wadi Ziglab was constructed in 1949. Two main supply canals, the North Branch and the South Branch, were lined with rubble masonry for a total distance of 3,625 meters. The remainder of the supply canals and distribution laterals in this system are in unlined earth channels.

The gross area registered as irrigated in Wadi Ziglab is 13,629 donums, while the mean annual percentage of cropping recorded in 1949 was 55%.

Wadi Jurum - The gross area commanded by the diversion dam in Wadi Jurum and registered as irrigated is 12,376 donums. Rubble masonry lining has been installed in 510 meters of canal and concrete lining in 3,725 meters of canal. The remainder of the supply canals and distribution laterals in this area are in unlined earth channels.

Wadi Yabes - There is a gross total of 8,140 donums registered as irrigated from Wadi Yabes. However, no modern irrigation works have been constructed in this area.

Wadi Kufrinja - In the area commanded by the diversion dam in Wadi Kufrinja, 11,432 donums have been registered as irrigated. Two supply canals have been constructed, the North Branch, known as the Hamra Canal, and the South Branch, known as the Fagaris Canal. The Fagaris Canal passes through the village of Kreimeh, where it branches to the east and to the west. The Hamra Canal has been lined with concrete for a distance of 1,802 meters, and the Fagaris Canal has been lined for a distance of 2,672 meters. Other reaches of supply canal or distribution lateral in this area are in unlined earth channels.

Wadi Rajeb - No modern works have been constructed to serve lands irrigated by diversions from Wadi Rajeb, although 9,085 donums are registered as irrigated in that area.

River Zarqa - A reinforced concrete diversion structure has been constructed across the River Zarqa. Six Kilometers of Main Canal with reinforced concrete lining have been constructed, including an aqueduct over the river. Approximately 115 Kilometers of unlined earth channels complete the supply and distribution system in this area. The gross area registered as irrigated from the River Zarqa amounts to 50,000 donums located in Ghors Deir Alla, Tiwal, Damiye, Abu Obeydeh and Shiqaq.

Wadi Shueib - A gross area of 22,709 donums located in Ghors Nimrin and Adwan, is registered as irrigated. Diversions from Wadi Shueib constitute the principal source of water for this area, although some lands are irrigated from wells. A concrete diversion structure has been constructed across Wadi Shueib, as well as a concrete lined supply canal which starts on the north side and then branches to the north and to the south. The south branch crosses the wadi on an aqueduct and continues down the left bank through Shunat Nimrin Village.

Wadi Kafrein - A total of 21,303 donums has been registered as irrigated by diversion of the flows of Wadi Kafrein. No modern irrigation works have been constructed in this area.

Wadi Hisban - A total of 21,296 donums has been registered as irrigated by diversion of the flows of Wadi Hisban. No modern irrigation works have been constructed in this area.

Wadi Fari'a - Existing developments in the Wadi Fari'a area are the largest and most important of those along the West Ghor. It is estimated that 16,000 donums are irrigated in the wadi proper and on Ghor Fari'a. This system includes a modern diversion structure, about ten Kilometers of concrete lined main canal, and a system of concrete lined distribution laterals. Appurtenant conveyance, measuring, control and protective structures have been built, together with drinking places and bridges.

Wadi Auja - A total area of 15,000 donums is estimated to be irrigated by diversion of the flows of Wadi Auja. This area is located in Ghors Arab el Abid and Arab el Ka'abina, in the vicinity of Auja Tahta Village. A diversion dam has been constructed, together with a lined supply canal and a system of lined distribution laterals.

Irrigation from the Yarmouk River

In the area between the Baha'i Village of Adasiye and Baqura Village, a gross total of 5,000 donums has been registered as irrigated by gravity flows diverted from the Yarmouk River. A crude dumped rock diversion dam, requiring constant maintenance, has been constructed across the river. Supply canals and distribution laterals are not lined, although some rubble masonry division boxes and turnouts have been built. Through applications of manure and commercial fertilizer, it has been customary to produce two or three crops annually in this area.

Irrigation from the Jordan River

Significant amounts of land lying on the zor, or flood plain of the Jordan River, are presently irrigated with water pumped directly from that river. Observations indicate that 12,095 donums are irrigated in this manner. In general the pumping plants are comparatively small, and limited areas are served by each plant. Distribution systems are of relatively inefficient design and because of the general characteristics of the soils encountered, disproportionately large percentages of the water pumped have been lost or wasted. These lands have in the past been subject to recurrent flooding by overflows from the Jordan River during periods of high run-off, a hazard which will be eliminated by construction of control structures on the Yarmouk and Jordan Rivers. However, upstream diversions and regulated flows in these rivers will contribute to an increase in the salinity of the waters of the lower Jordan and probably this source of irrigation water must of necessity be abandoned in the foreseeable future.

Irrigation from Springs and Wells

On the East Ghor 1,960 donums lying in the Wadi Arab area are registered as irrigated from Duga Spring, located about 4 Kilometers above the mouth of the wadi. In the Wadi Jurum area 2,660 donums are registered as irrigated from 5 small springs located within the irrigated area about 2 Kilometers west of the diversion dam. Certain minor areas, particularly in the vicinity of Wadi Shueib, Wadi Kafrein and Wadi Hisban, receive either a full or supplemental supply of irrigation water from wells.

On the West Ghor in what is known as the Jericho area, lying between Wadi Auja and the Dead Sea, it is estimated that some 8,000 donums are irrigated partly from springs and partly from wells. The irrigated areas are scattered here and there near the wells, or near springs such as Ain Nu'iema, Ain Duyuk and Ain Sultan. Other areas below the Jericho-Jerusalem road are irrigated from Qilt and Fawwar springs through a canal running from Wadi Qilt.

Few of the wells used for irrigation have been in useful intensive production long enough to establish the recharge rate. Furthermore, in many of the wells the quality of the water is questionable except for the production of highly salt tolerant crops. Particularly in shallow wells the quality may be expected to deteriorate as intensive irrigated agriculture is developed in surrounding areas.

Irrigation from Historical Works

Evidence of 22 fuquarās, constructed during the Roman occupation for development of ground water, has been discovered in the Jordan Valley. Two minor areas continue to receive irrigation water from these ancient sources. The flow from one fuquarā is used to irrigate an area on the East Ghor north of Wadi Shueib, and the flows from three fuquarās have been combined to irrigate an area on the West Ghor north of Wadi Fari'a. It is also probable that many of the springs within the Jordan Valley are the only remaining outward manifestations of other historical developments which have become blocked and lost through lack of maintenance.

Subsurface Drainage

Presently very little use is made of subsurface drainage waters. There are some instances where shallow open ditches have been constructed for draining high water table areas and such water has sometimes been used for irrigation purposes, but as a whole facilities for subsurface drainage of such areas are inadequate. There are certain locations in the northern part of the East Ghor where subsurface waters find their way to the zor below and these waters are reused for irrigation and for livestock and domestic water. In some instances drainage water has percolated through soils of a saline nature and the use of such water has done much to lower production on the zor lands.

Other Uses

Domestic and Livestock

There has been practically no development of water in the Jordan Valley solely for domestic use or for use by livestock. The supply for

Jericho, which is at present being modernized to a certain degree, comes from Elisha's Spring. Other villages in the valley have in general been established near perennial wadis, or more recently near canals constructed primarily for irrigation, and these open channels have provided a source of water for both humans and livestock, in spite of extreme hazard of pollution. Spring water and well water is also used to a minor extent. A large proportion of the population is nomadic, moving to the uplands in summer and back to the valley in winter, and the needs of these people for water for all purposes are satisfied simply by settling near an existing supply.

Salt Works

Within the project area is an ancient development for securing salt. These salt works are located on the East Ghor immediately north of the River Zarqa. The area from which salt is produced covers some 4,000 donums and is bounded by arable lands on all sides. Even though salt is still being produced by essentially the same inefficient method employed in olden time, the lands of this area are probably worth more as a source for salt than for agricultural purposes, if the cost of reclaiming such lands is considered. Because of high water the process for securing salt can only be carried on 3 or 4 months out of the year. Too, water from this area has infiltered adjacent areas and caused agricultural lands to go out of production. By controlling the water table of these salt beds, production could possibly be carried on 9 months out of the year, and adjacent lands could be protected from salt water encroachment. No drainage waters from this area could be used for any purpose other than a source of salt. Even though this area has produced salt for centuries full utilization of the resources has never been attained.

PART 2. QUALITY OF WATER

Scope of Investigations

Quality of water is an important consideration in any appraisal of conditions in an area to be irrigated.

Many incomplete investigations have been conducted in the past in connection with the quality of water from the various sources proposed for irrigation of the Jordan Valley. In many cases these investigations covered only restricted fields, such as determination of total dissolved solids, chlorinity or salinity, which, while valuable as background material and for correlation of the relative adaptability of various sources, permit only a limited interpretation of the suitability of the waters for use in irrigation agriculture. In addition to the concentration of dissolved constituents, as determined by analysis or from electrical conductivity, the composition of these constituents is of major importance in determining the quality of water in relation to its use in irrigating a specific area. In the limited time available for the present investigation it was not possible to complete an adequate study of all factors affecting the quality of water. The purpose of this investigation was, therefore, to supplement previous findings, and either to confirm or refute earlier interpretations.

In this discussion consideration is given only to the quality of water from major sources, the Yarmouk River, the Jordan River, the River Zarqa and certain perennial wadis tributary to the Jordan River since these represent the sources recommended for use on the project.

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PART 2. Quality of Water
Scope of Investigations
Methods and Analyses
Computations and
Interpretations
Example

Additional information regarding the quality of water from other sources is discussed elsewhere in this report.

Methods and Analyses

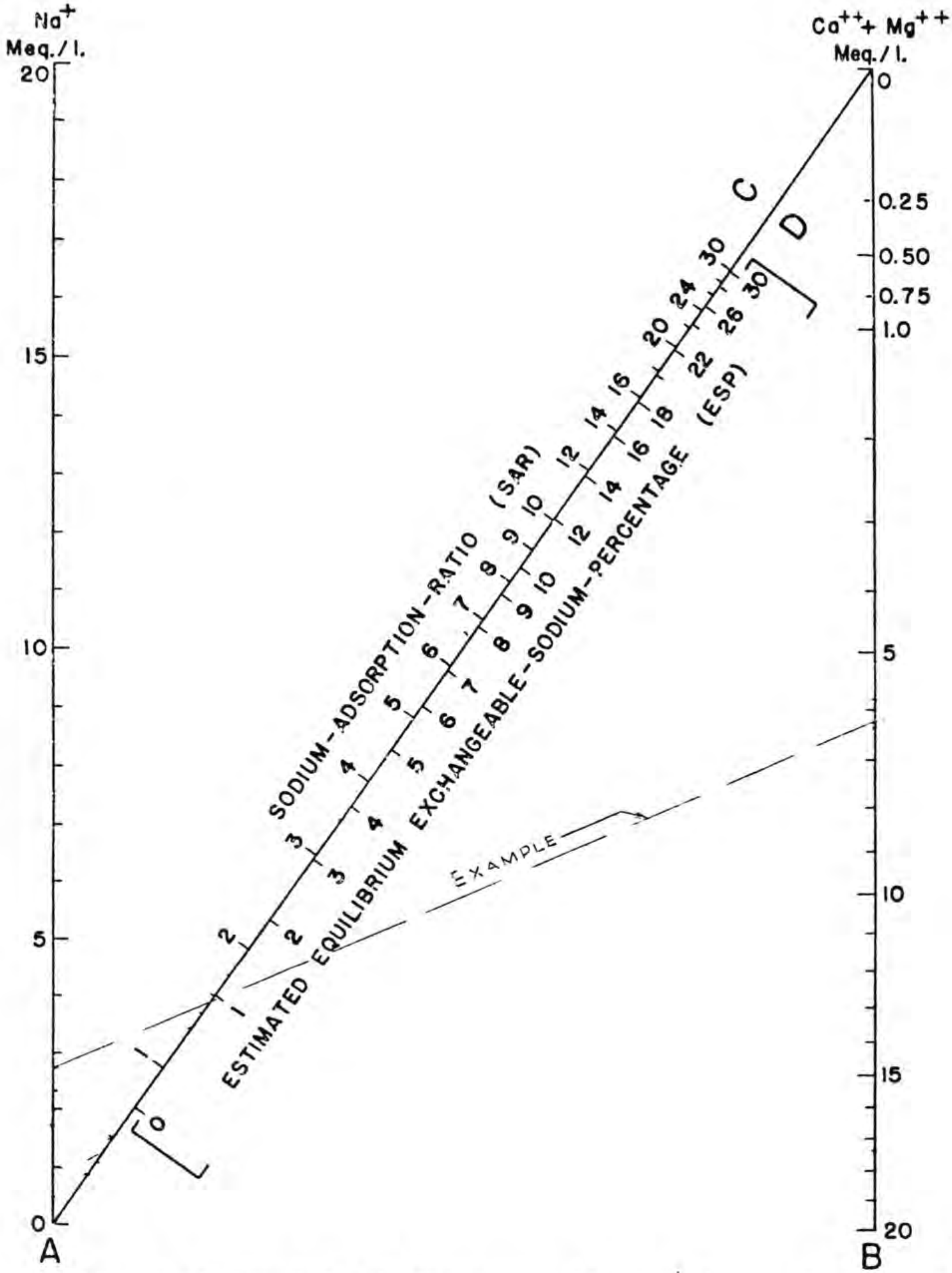
For convenient interpretation of data, waters have been classified in accordance with the system based on electrical conductivity and the sodium-adsorption-ratio. A nomogram for determining the sodium-adsorption-ratio is presented on page 12, the diagram for the classification of irrigation waters by the method mentioned is on page 13, and an example of the use of the two is on page 20. The drawings and the general methods of analysis used are from Agriculture Handbook No. 60, United States Department of Agriculture. The following laboratory tests were made on water samples analyzed:

Electrical Conductivity	- EC
Total Dissolved Solids	- TDS
Calcium	- Ca
Magnesium	- Mg
Sodium	- Na
Potassium	- K
Chloride	- Cl
Sulfate	- SO_4
Carbonate	- CO_3
Bicarbonate	- HCO_3

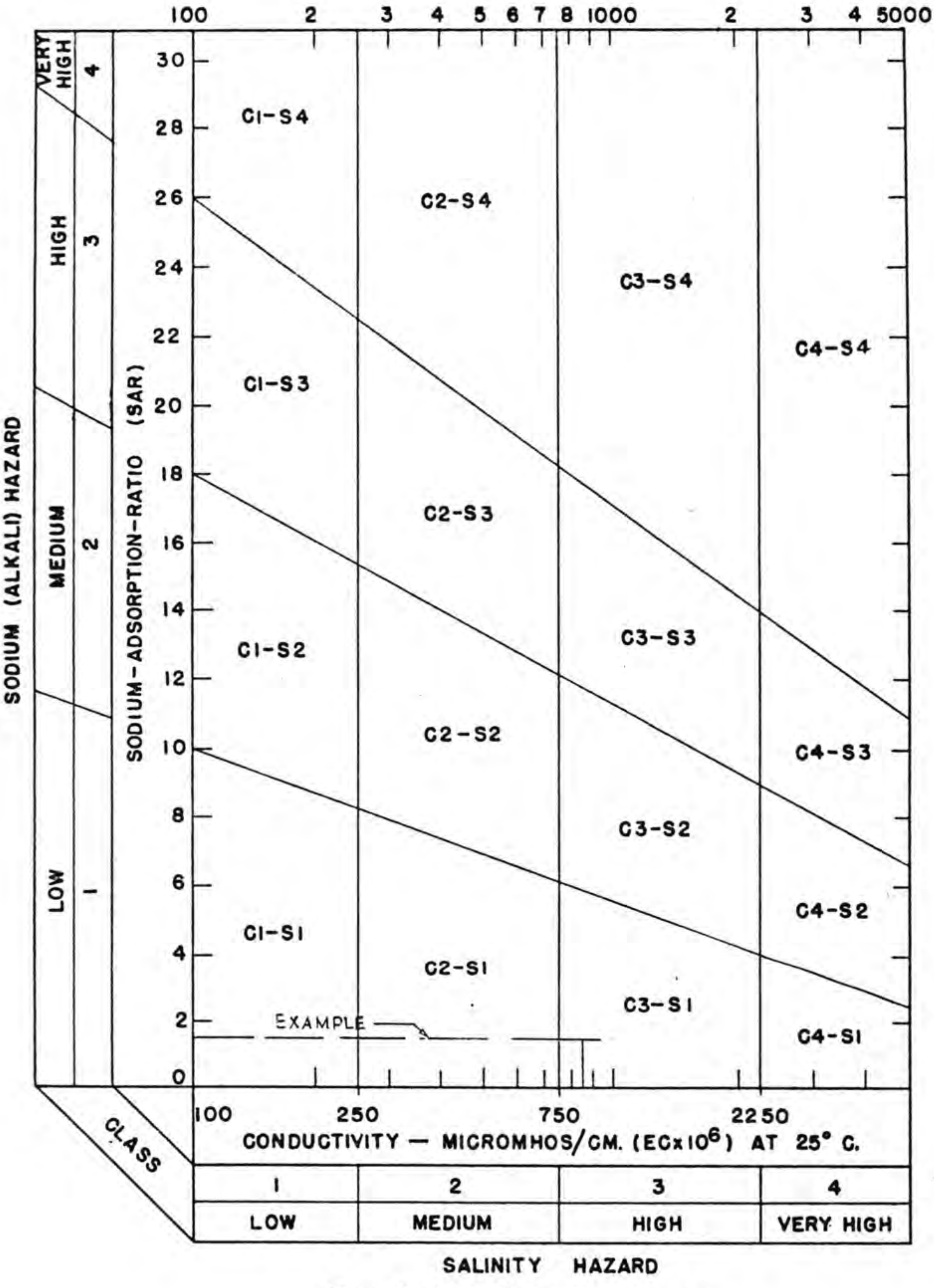
In addition, occasional tests were made for the presence of boron (B), but none of the samples so analyzed contained boron in anything approaching a toxic concentration. Other symbols used are:

Hydrogen ion concentration	- pH
Soluble-sodium percentage	- SSP
Sodium-adsorption-ratio	- SAR

In these investigations, the Jordan River was sampled at two locations, one immediately below the confluence of Wadi Malih and the river, and the other at Allenby Bridge. The Yarmouk River was sampled near Adasiye. The Zarqa River and the perennial wadis were sampled in



-Nomogram for determining the *SAR* value of irrigation water and for estimating the corresponding *ESP* value of a soil that is at equilibrium with the water.



–Diagram for the classification of irrigation waters.

each case near the point where the stream leaves the gorge cutting through the escarpment and enters upon the ghor.

Computations and Interpretations

Average or representative analyses of water samples from the various locations cited, together with the classification of each of these waters is given in Table 4.2-1 which follows. The significance and interpretation of the quality-class ratings, as established in Agriculture Handbook No. 60, are summarized below:

Conductivity

"LOW-SALINITY WATER (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

"MEDIUM-SALINITY WATER (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

"HIGH-SALINITY WATER (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

"VERY HIGH SALINITY WATER (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Sodium

"The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

"LOW-SODIUM WATER (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

"MEDIUM-SODIUM WATER (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

"HIGH-SODIUM WATER (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

"VERY HIGH SODIUM WATER (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

"Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of C1-S3 and C1-S4 waters. For calcareous soils with high pH values or for non-calcareous soils, the sodium status of waters in classes C1-S3, C1-S4, and C2-S4 may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2-S3 and C3-S2 waters are used".

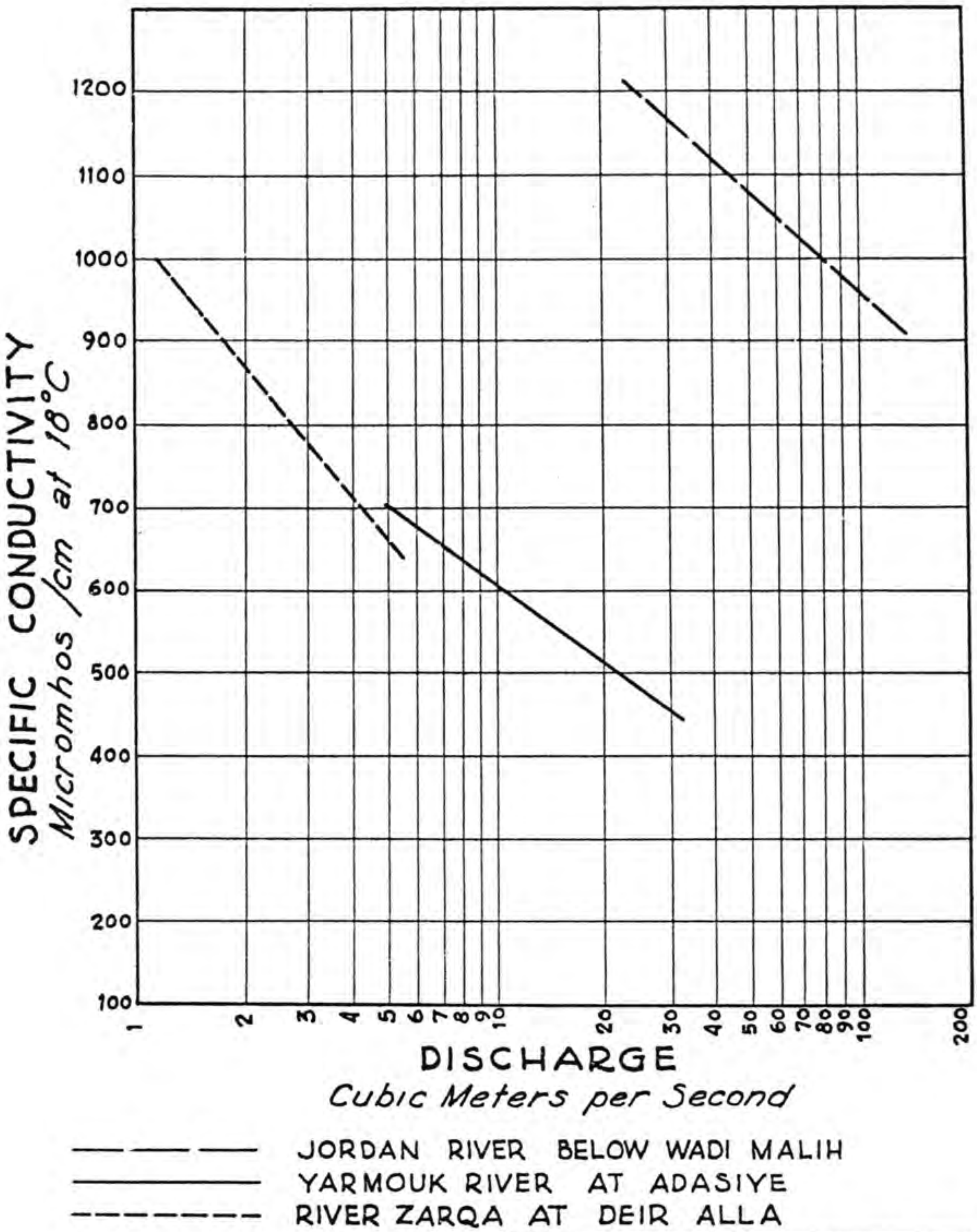
The quality of the water in all the streams investigated deteriorates with diminished flows. Approximations of the discharge-quality relations for the Jordan River below Wadi Malih, the Yarmouk River near Adasiye and the River Zarqa at Deir Alla are shown on Drawing No. JR-50. Any major and permanent change in the regimen of these rivers will

Table 4.2-1

Table 4.2-1

Average Water Analyses

Location	Temp. °F	pH	$ECx10^6$	TDS	Na	Ca	Mg	Cl	CO_3	HCO_3	SO_4	NO_3	B	SSP	SAR	Class
					Milliequivalents per Liter											
Jordan River at Wadi Malih	68	7.4	992	706	5.76	2.85	2.35	6.54	-	3.11	1.18	0.21	-	52.6	3.6	C3-S1
Jordan River at Allenby Bridge	68	7.9	2,402	1,681	15.74	5.11	7.86	21.66	.09	3.58	3.35	-	-	54.8	6.2	C4-S2
Yarmouk River near Adasiye	63	7.5	681	485	2.24	1.90	1.71	1.72	.03	3.21	0.83	0.16	-	38.3	1.7	C2-S1
River Zarqa near Deir Alla	60	7.4	849	621	2.80	3.49	2.68	3.18	.08	3.99	1.41	0.54	-	31.2	1.6	C3-S1
Wadi Arab	65	7.4	680	550	1.26	3.30	3.10	1.43	.08	4.88	1.14	0.46	-	16.4	0.8	C2-S1
Wadi Ziglab	69	8.2	781	547	0.65	3.75	3.60	1.69	.87	5.11	0.31	-	-	8.1	0.4	C3-S1
Wadi Yabes	64	7.5	400	369	0.78	2.55	1.64	0.84	-	3.67	0.12	0.32	-	15.7	0.5	C2-S1
Wadi Kufrinja	62	7.5	458	321	0.48	2.40	1.48	0.73	-	3.20	0.17	0.24	-	11.0	0.3	C2-S1
Wadi Rajeb	62	7.4	487	341	0.43	2.55	1.56	0.68	-	3.44	0.25	0.24	-	9.5	0.3	C2-S1
Wadi Shueib	70	8.3	478	335	0.48	2.65	1.80	0.79	0.40	2.84	0.33	-	-	9.7	0.3	C2-S1
Wadi Auja	64	8.1	464	325	0.43	2.35	1.88	0.79	0.57	3.20	0.10	-	-	9.2	0.3	C2-S1



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DISCHARGE-QUALITY RELATIONS

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invalidate the determined relationship. Thus, the relationship for the Jordan cannot be used to estimate the water quality when significant portions of the flows of the Yarmouk River are diverted. The curves will, however, be useful in estimating the quality of stored or diverted water, and in appraising the anticipated quality of blended flows.

Conclusions

Waters of the Yarmouk River, or of Wadis Arab, Yabes, Kufrinja, Rajeb, Shueib or Auja, can be used for irrigation agriculture with little probability that soil salinity will develop, providing a moderate amount of leaching occurs during normal irrigation operations. Waters of the River Zarqa or of Wadi Ziglab should not be used alone on soils with restricted drainage, and even with adequate drainage it is probable that some method of salinity control would be required. However, water from these latter two sources would require only slight dilution with water of better quality to remove any significant hazard of saline contamination through their use. Therefore, under the normal recommended operation of the project, no special restrictions need be placed on use of water from the River Zarqa or Wadi Ziglab. Water from any of these tributaries of the Jordan can be used with little probability of the development of harmful concentrations of exchangeable sodium.

Waters of the reaches of the Jordan River between the Yarmouk River and Wadi Malih could at present be used for irrigation of soils with adequate drainage, although special management for salinity control might be required. However, the quality of water in the Jordan River deteriorates as it flows toward the south, until in the reach below the Allenby Bridge, it is at best of border line quality for any use in irrigation agriculture.

With diversion of the flows of the Yarmouk River and the possibility of diminution of the flows of the Jordan River below Lake Tiberias, it is probable that the quality of the water in the Jordan will drop below the permissible limits of use in irrigation agriculture. Therefore, the use of water diverted directly from the Jordan River is not recommended.

Use of Sodium-Adsorption-Ratio Nomogram (Page 12) and Classification Diagram (Page 13)

EXAMPLE

Classification of irrigation waters from data in laboratory analyses is illustrated by the following:

1) Take the analyses for the River Zarqa near Deir Alla which appears as line 4 in Table 4.2-1 on page 16.

2) From this table read the following values:

Electrical Conductivity	- 849
Milliequivalents per liter, sodium(Na)	- 2.80
Milliequivalents per liter, calcium(Ca)	- 3.49
Milliequivalents per liter, magnesium(Mg)	- 2.68

3) Plot milliequivalents per liter of sodium on Scale A on the nomogram on page 12.

4) Add the milliequivalents per liter of calcium and magnesium and plot the result, 6.17, on Scale B of the same nomogram.

5) Connect the two points and read the sodium-adsorption-ratio (SAR) as 1.5 on Scale C.

6) Plot sodium-adsorption-ratio (SAR) of 1.5 on the vertical scale on the left of the diagram on page 13 and project a horizontal line from this point.

7) Plot the conductivity of 849 on the horizontal scale at the bottom of the same diagram and project a line vertically upward to intersect the sodium-adsorption-ratio (SAR) line.

8) Note the group in which the point of intersection falls, in this case, group C3-S1. From definitions on pages 14 and 15 it is found that this is a high salinity, low sodium water which can be used only when there is adequate drainage, and even then special management practices are necessary for the control of salinity. Ordinarily, only those crops with high salt tolerance should be irrigated with this water.

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PART 3. Water Requirements
Introduction
Terms, Symbols and Notations
Coefficients and Constants
Data Available
Zones of Consumptive Use
Application of the Formula
Water Requirements
Climatic Data

PART 3. WATER REQUIREMENTS

Introduction

Irrigation requirements, the results of integration and correlation of physical data and climatic phenomena, are the bases for adequate design and efficient operation of any irrigation project. The physical characteristics of the crop, which determine its consumptive use coefficient, together with variations in rainfall, temperature, relative humidity, and location, which determines duration of daytime hours, all enter into the final irrigation requirement for each individual crop. When these data have been combined for all the different crops, the overall irrigation requirement for the project may be determined.

Several different methods of integration and correlation have been studied, and from these there have emerged two which have gained wide acceptance. Both combine climatological and irrigation data. The Lowry-Johnson method makes use of the effective heat and requires a long period of temperature records for acceptable results. The second, the Blaney-Criddle method, correlates latitude, temperature, crop and consumptive use. Its application in widely separated parts of the world has resulted in comparable results for the same crop even though the period of record of climatic data has been relatively short. Because of this feature, it has been selected as the method for use in determining irrigation requirements for this project. In its simplest form the

Blaney-Criddle formula is:

$$f = t \times p \quad (1),$$

from which the following relations can be derived:

$$u = f \times k \quad (2), \text{ and}$$
$$IR = u - r \quad (3).$$

The more frequently used terms, symbols and notations used in computing irrigation and water requirements are presented and defined in the following section:

Terms, Symbols and Notations

Definition of Terms

The more important terms as defined and used by the leading professional and technical societies and organizations dealing with irrigation follow:

1) Consumptive Use (Evapo-Transpiration). The sum of the volumes of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from adjacent soil, snow, or intercepted precipitation on the area in any specified time, divided by the given area. If the unit of time is small, such as day or week, the consumptive use is expressed in acre-inches per acre or depth in inches; whereas, if the unit of time is large, such as crop-growing season or 12-month period, the consumptive use is expressed as acre-feet per acre or depth in feet. (American Society of Agricultural Engineers and Soil Conservation Service)

2) Irrigation Requirement. The quantity of water, exclusive of precipitation, that is required for crop production. It includes surface evaporation and other economically unavoidable wastes. Usually expressed in depth (volume per unit area) for a given time. (American

Society of Agricultural Engineers.) (American Society of Civil Engineers.)

3) Field Irrigation Efficiency. The percentage of irrigation water delivered to the field that is available for consumptive use by crops. (Soil Conservation Service.)

4) Diversion Requirement. To the irrigation requirement is added an allowance for estimated deep percolation losses and waste in application on the farm and a further addition for estimated conveyance loss and waste between source of supply and the farm to give the diversion requirement. (Bureau of Reclamation.)

5) Effective Rainfall. That part of the total rainfall which is available for plant use. Usually, effective rains are those which exceed one half inch and occur within a few consecutive hours. It has been assumed, for the purposes of this report, that 80% of all rainfall is effective when the total exceeds 25 mm per month, and that none is effective when the total is less than 25 mm per month.

Symbols and Notations

Symbols and notations to express the conditions as presented above follow:

- IR — Irrigation Requirement as defined in preceding section
- U — Consumptive Use, total for any period as defined in preceding section
- F — Sum of monthly consumptive use factors for any period
- K — Crop coefficient for any period
- t — Mean monthly temperature (Fahrenheit)

p Monthly percent of daytime hours of the year

f $\frac{t \times p}{100}$ = monthly consumptive use factor

k Monthly crop consumptive use coefficient (see K above)

u k x f, monthly consumptive use in inches

r Effective rainfall

Coefficients and Constants

Coefficients and constants which enter into the determination of irrigation requirements are discussed in considerable detail below:

Consumptive Use Coefficient

Each crop, and sometimes even different varieties of the same crop, has individual characteristics of which the most important is the monthly consumptive use coefficient (k), which varies but little from one location to another. Analyses of experimental work show that this factor does vary somewhat in monthly values but such variations are, as a rule, relatively small. For all practical purposes the monthly consumptive use coefficient (k) is numerically equal to the seasonal coefficient (K). Values and ranges of the consumptive use coefficient (K) as determined by workers in irrigation requirements in widely separated areas are presented in Table 4.3-1.

Table 4.3-1

Numerical Values of "K"
Consumptive Use Coefficient

CROP	Source of Information (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	RANGE
Alfalfa	.85	.80- .85	.70-.85	.70-.85	.85	.85	.85	.85	.85	.85	.70- .85
Beans	.65	.60- .70	.60	.60	.65	.65	.65	.75	.70	.75	.60- .75
Beets, Sugar	.70	.65- .75	—	.70	.70	.70	—	.80	—	—	.65- .80
Cane, Sugar	—	.80	—	—	—	—	.90	—	—	—	.80- .90
Citrus	.55	.50- .65	.65	.65	.55	—	.65	—	—	—	.50- .65
Corn	.75	.75- .85	.75	.75	.75	.80	.80	.75	.75	.75	.75- .85
Cotton	.62	.60- .65	.62	.62	.62	—	—	—	.62	—	.60- .65
Flax	—	.80	—	.80	—	.80	—	—	—	—	.80
Grains, Small	.75	.75- .85	.60-.70	.70	.75	.75	.75	.75	.75	.75	.60- .85
Orchard (deciduous)	—	—	.65	.65	.65	—	—	—	—	—	.65
Pasture	.75	.75	.60-.75	.80	.75	.75	.75	.75	.75	.75	.60- .80
Peas	—	.80	—	—	—	—	—	—	—	—	.80
Potatoes	.70	.65- .75	—	.70	.70	.70	.70	—	.70	—	.65- .75
Rice	1.00	.85-1.20	—	—	1.00	—	1.00	—	—	—	.85-1.20
Sorghum	.70	.70	.70	.70	.70	—	.70- .80	.70	.70	—	.70- .80
Tomatoes	—	.70	—	—	—	—	—	—	—	—	.70
Truck	—	.80	.70	.55-.70	—	—	—	—	.75	—	.55- .80

(1) Blaney, Harry F. — "Consumptive Use of Water", Transactions ASCE, Vol. 117, P. 964, 1952.

(2) Blaney, Harry F., and Criddle, Wayne D. — "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data". SCS-TP-96, Washington, D.C., February, 1952.

(3) Blaney, Harry F., Hanson, Eldon, G., and Litz, G. Marvin — "Consumptive Use and Irrigation Water Requirements of Crops in New Mexico", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., December, 1950. (Provisional)

(4) Blaney, Harry F., and Harris, Karl — "Consumptive Use and Irrigation Water Requirements of Crops in Arizona", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., December, 1951.

(5) Criddle, Wayne D. — "Consumptive Use of Water and Irrigation Requirements", JOURNAL OF SOIL AND WATER CONSERVATION, September, 1953.

(6) Erie, Leonard J. — "Consumptive Use and Irrigation Water Requirements of Crops in South Dakota", U.S. Dept. of Agri., Soil Conservation Service, Washington, D.C., March, 1952. (Provisional)

(7) Flanagan, Jeff E., and Cabezas R. — "Requisitos de Riego para el Salvador", Boletin Tecnico No. 11, Centro Nacional de Agronomia, May, 1952.

(8) Hanson, Richard E., and Meyer, Walter R. — "Irrigation Requirements, Estimates for Kansas", Kansas State College, Bulletin No. 69, June, 1953.

(9) Houston, Clyde E. — "Consumptive Use of Irrigation Water by Crops in Nevada", the University of Nevada, Bulletin No. 185, July, 1950.

(10) Tomlinson, Byron R. — "Estimate of Water Requirements of Crops", Wyoming Agricultural Experiment Station, University of Wyoming, Bulletin No. 303, February, 1951.

Duration of Daytime Hours

The monthly percentage of daytime hours in the year is a function of location, specifically latitude, and is a constant for a given latitude. Latitudes within the project area vary from 31°49' at the Dead Sea to 32°41' near Lake Tiberias. For purposes of this report the latitude of 32°0' has been used throughout. A check was made to determine to what extent this would affect the calculations and it was found that the greatest possible error that could be introduced by use of a single latitude would be less than one fourth of one percent. Monthly values of the constant (p) are shown below:

Table 4.3-2

Monthly Percent of Daytime Hours
(p)
For Latitude 32°0' North

Month	(p)	Month	(p)
January	7.04	July	9.62
February	7.57	August	9.13
March	8.18	September	8.47
April	8.87	October	7.82
May	9.44	November	7.22
June	9.75	December	6.89

Temperature

Temperature, while neither a coefficient nor a constant, is the most important single factor in the application of the consumptive use formula. It is an inherent characteristic of an area and data must be available before any of the methods can be applied. Such temperature data as are available are collected, compiled and mean monthly values determined before they enter into the calculations.

Data Available

There are no long term climatic data available within the project area; but there are seven locations as shown on the Base Map, JR-8, at which records of from 3 to 17 years are to be had. In addition, there are three reference stations adjacent to the project area (Jenin, Jerusalem, and Amman) that have complete records of 12 to 16 years duration. Temperature and rainfall data for these ten stations are portrayed in Drawing DS-5-3. In this drawing it will be noted that all stations have a similar temperature curve which reaches its peak in July or August. The rainfall pattern is not as clear cut as the temperature curve, and there is a marked decrease from north to south. Further, the records for all stations show several months of no effective rainfall. Detailed records of all these stations along with others both within and outside the project area are presented in Tables 4.3-6 to 4.3-23; while an index of data available at the stations used in computing irrigation requirements are presented in Table 4.3-3 which follows:

Table 4.3-3

Index of Climatic Data Available
For Computing Irrigation Requirements

Name	Latitude	Longitude	Elevation	Years of Record Temperature	Years of Record Rainfall
		Jordan Valley			
Degania	32°41'N	35°34'E	- 198 M	7	17
Wadi el Arab	32°36'N	35°37'E	- 197 M	4	4
Beisan	32°30'N	35°30'E	- 118 M	10	10
Wadi el Jurum	32°26'N	35°36'E	- 180 M	3	4
Tirath-Zvi	32°23'N	35°32'E	- 245 M	5	5
Jericho	31°51'N	35°27'E	- 250 M	13	22
Dead Sea (N)	31°49'N	35°34'E	- 392 M	15	17
		Adjacent Area			
Jenin	32°28'N	35°18'E	160 M	12	12
Amman	31°58'N	35°56'E	790 M	16	15
Jerusalem	31°47'N	35°14'E	827 M	13	16

Establishment of Zones of Consumptive Use and Irrigation Requirements

Many of the published reports dealing with irrigation in the Jordan Valley show three zones of irrigation requirements with widely divergent numerical values both by zones and months. Since the project area, which embraces the Yarmouk-Jordan Valleys between Adasiye Diversion Dam and the Dead Sea, is only slightly more than 100 Kilometers in length, it seemed highly unlikely that three zones would be encountered. A detailed examination was, therefore, made of all factors affecting Consumptive Use and Irrigation Requirements.

Consumptive Use

Temperature records throughout the project area and adjacent areas were examined in detail and plotted on Drawing DS-5-3. These curves show a remarkable uniformity of temperature throughout the entire project area. It had already been established that the use of one single latitude, 32° North, would introduce a maximum error of less than one fourth of one percent. Since temperature (t) and the monthly percent of daytime hours (p), which is a function of latitude, show little or no variation throughout the project area, the inevitable conclusion is that there is but one zone of Consumptive Use.

Irrigation Requirements

Rainfall varies considerably from one end of the project area to the other as is shown by Tables 4.3-6 to 4.3-23 inclusive and graphically demonstrated on Drawing DS-5-3. When these variations in rainfall are correlated to consumptive use it is found that there is sufficient variation to justify the establishment of two zones of Irrigation Requirements. While no hard and fast line can be drawn between these zones, the River Zarqa represents an approximate boundary between the northern zone of relatively high rainfall and the more arid southern zone.

Application of the Formula

The Blaney-Criddle method of determining consumptive use and irrigation requirements is dependent on the three factors just discussed as well as on effective rainfall. The percentage of daylight hours in the month (p) is taken from Table 4.3-2 and multiplied by the value of the temperature factor (t), taken from Table 4.3-24, "Mean Monthly Temperatures". The resultant is the monthly consumptive use factor (f) as shown in equation (1) on page 22. This is then multiplied by a monthly crop consumptive use coefficient (k) (Table 4.3-1) to determine the monthly consumptive use (u) as in equation (2) on page 22. The formula and its application is rather simple when expressed in English units of measurements, but becomes cumbersome when metric units are used. To obviate the tedious and cumbersome calculations involved in converting between English and metric units, the nomograph, Drawing DS-5-2, was developed to give a simultaneous solution in both systems using either system as the base. The same procedure as outlined above is used in the graphic solution which is illustrated by an example on the nomograph. After the monthly consumptive use (u) has been found, either by direct calculation or from the nomograph, the effective rainfall (r), is subtracted to determine the monthly irrigation requirement in accordance with equation (3) on page 22. Effective rainfall which was defined on page 23 can be computed for each station from data on Drawing DS-5-3. An examination of this drawing shows little or no effective rainfall at any time for the two stations in the southern zone. The same is true for stations in the northern zone during the summer months, but there is some effective rainfall at all stations during the winter. Effective rainfall computed from data on Drawing DS-5-3 was weighted according to years of record and distance from project area. These data which are the "r" used in computing irrigation requirements are in Table 4.3-4 below.

Table 4.3-4

Effective Rainfall (r)
(mm)

Month	Northern Zone	Southern Zone
January	61	15
February	56	11
March	31	0
April	0	0
May	0	0
June	0	0
July	0	0
August	0	0
September	0	0
October	0	0
November	27	0
December	51	1
Annual	226	27

After monthly irrigation requirements have been determined, the overall efficiency of 65%, which is used throughout this report, is applied to establish the monthly diversion requirement.

Water Requirements

Irrigation requirements and corresponding diversion requirements for each of the two established zones were determined primarily from the basis of a cropping pattern developed jointly with U.N.R.W.A. personnel. This pattern was later modified in accordance with the expressed wish of the Jordan Government to include certain crops which at present constitute major factors in the unfavorable trade balance of the country. These cropping patterns, together with the unit irrigation requirements and diversion requirements for each are presented on Drawing DS-5-5.

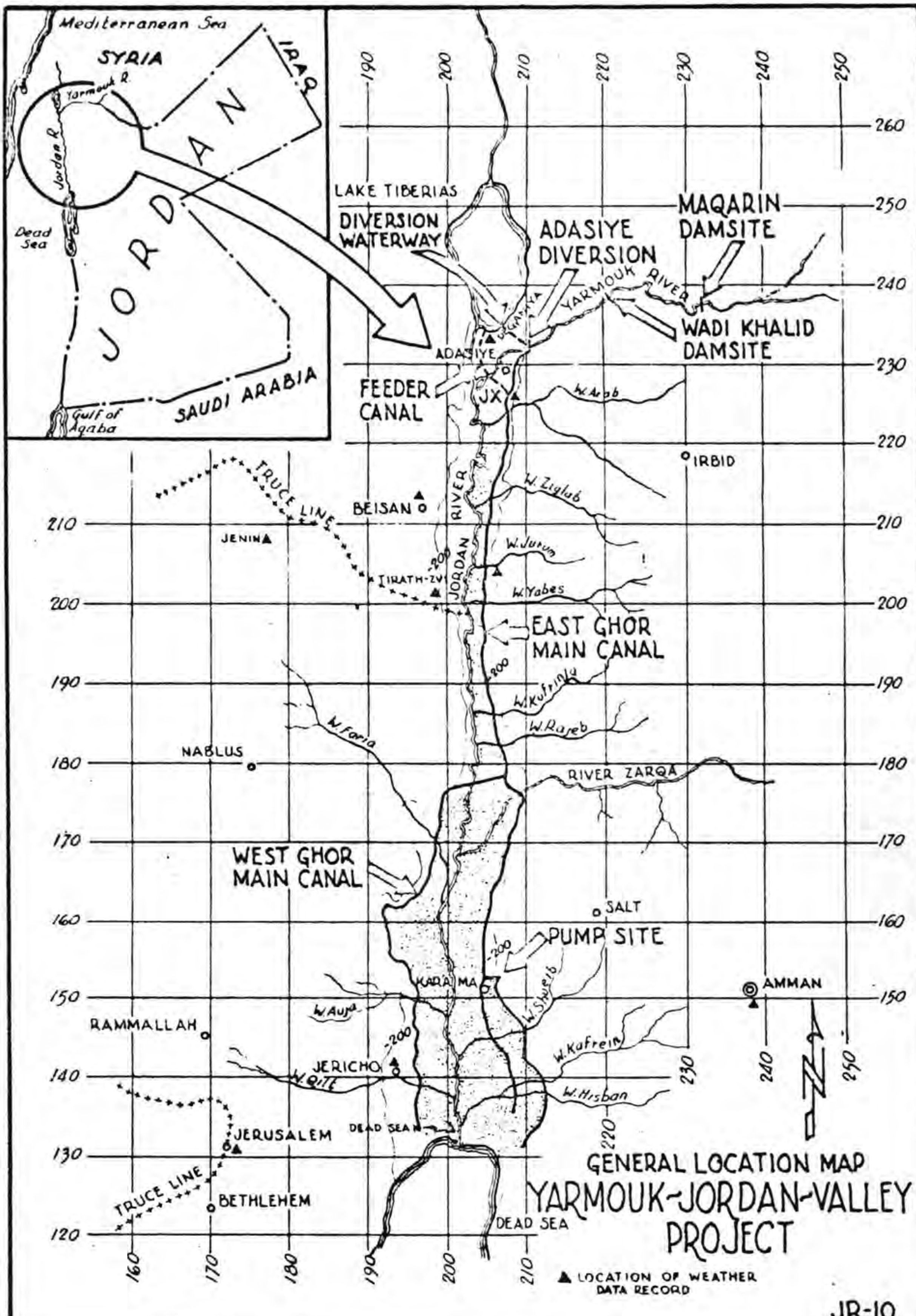
Annual diversion requirements as developed from the two patterns are presented in the table which follows:

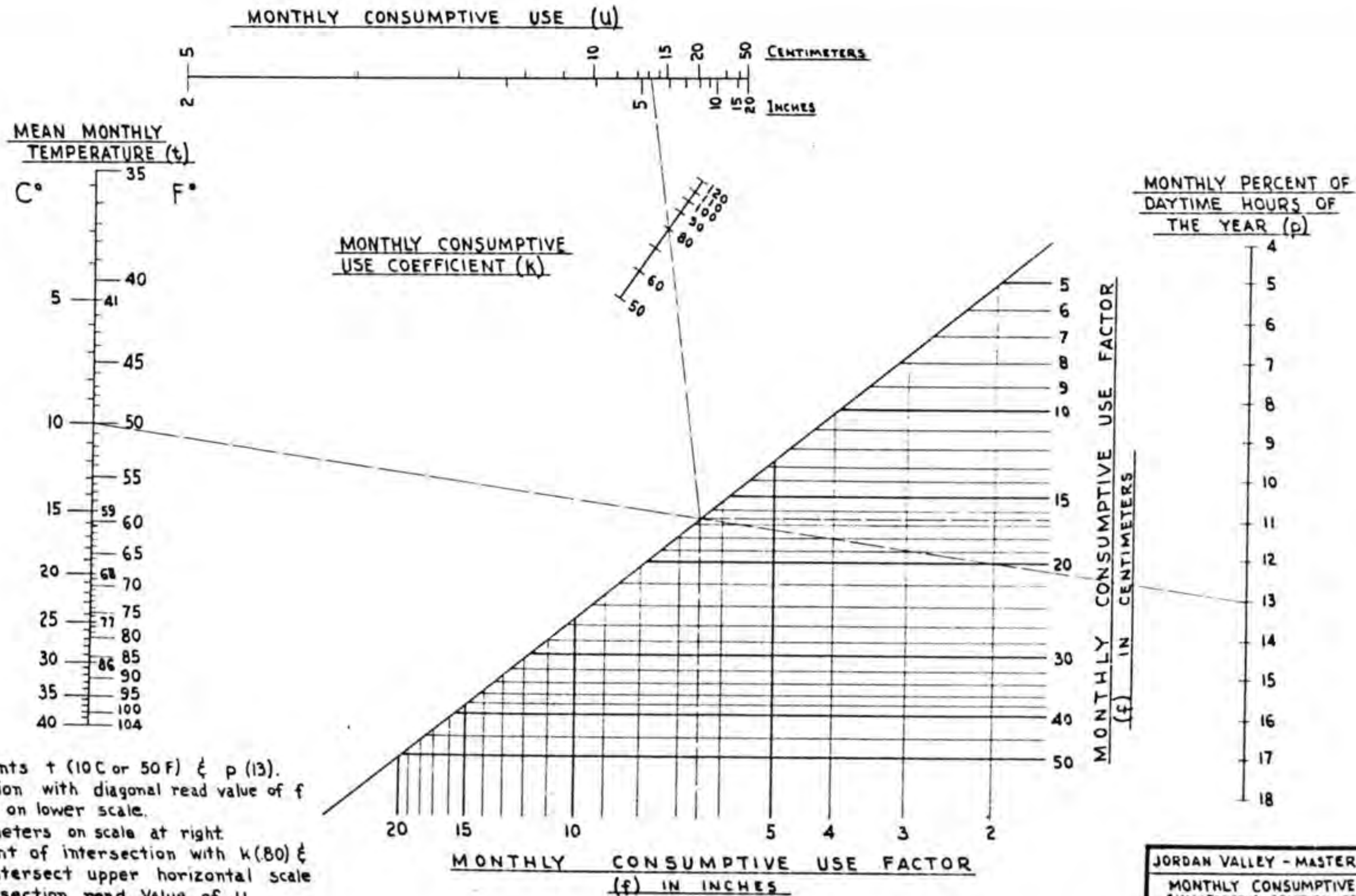
Table 4.3-5

Summary of Water Requirements

Area and Sub-Area	Net Irrigable Area in 1000 Donums	Diversion Requirements Annual - MCM Pattern A	Diversion Requirements Annual - MCM Pattern B
East Ghor (North)			
Below Canal	129.0	162.5	169.8
Above Canal	40.5	51.0	53.3
Sub-Total	169.5	213.5	223.1
East Ghor (South)			
Below Canal	151.4	240.4	242.5
Above Canal	32.2	51.1	51.6
Sub-Total	183.6	291.5	294.1
Total East Ghor	353.1	505.0	517.2
West Ghor			
Below Canal	87.8	139.4	140.7
Above Canal	63.3	100.5	101.4
Total West Ghor	151.1	239.9	242.1
GRAND TOTAL FOR PROJECT	504.2	744.9	759.3
Wadi Fari'a	9.5	15.1	15.2
TOTAL	513.7	760.0	774.5

These quantities were computed by multiplying the area in each geographic sub-division by the unit requirement for the corresponding zone. In addition to lands within the project area, total diversion requirements cover 9,500 donums in Wadi Fari'a.


Mediterranean Sea
SYRIA
IRAQ
JORDAN
Yarmouk R.
Jordan R.
Dead Sea
SAUDI ARABIA
Gulf of Aqaba
LAKE TIBERIAS
DIVERSION WATERWAY
ADASIYE DIVERSION
MAQARIN DAMSITE
YARMOUK RIVER
WADI KHALID DAMSITE
ADASIYE
FEEDER CANAL
JX
W. Arab
IRBID
W. Ziglab
BEISAN
JORDAN RIVER
TRUCE LINE
JENIN
W. Jurum
TIRATH-ZVI
W. Yabes
EAST GHOR MAIN CANAL
W. Kufrinja
W. Rajeb
W. Faria
NABLUS
RIVER ZARQA
WEST GHOR MAIN CANAL
SALT
PUMP SITE
KARAMA
AMMAN
W. Auja
W. Shueib
RAMMALLAH
JERICHO
W. Qilt
W. Kafrein
W. Hisban
DEAD SEA
JERUSALEM
BETHLEHEM
GENERAL LOCATION MAP
YARMOUK-JORDAN-VALLEY PROJECT
▲ LOCATION OF WEATHER DATA RECORD
JR-10

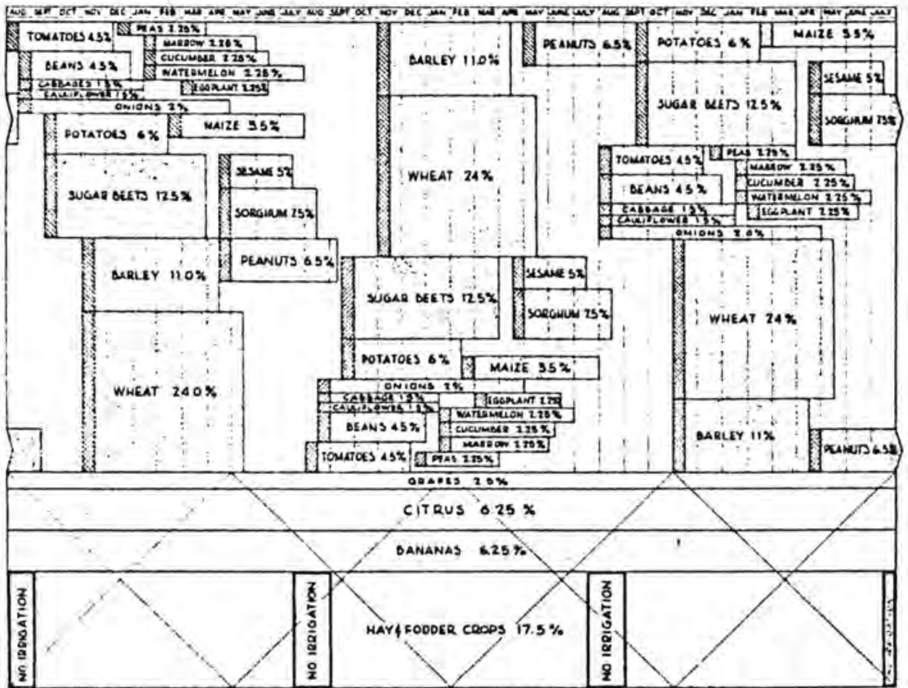


Example:

Connect points t (10 C or 50 F) & p (13).
At intersection with diagonal read value of f
6.5 inches on lower scale.
16.5 centimeters on scale at right.
Connect point of intersection with k (.80) & extend to intersect upper horizontal scale at this intersection read value of u
5.2 inches on bottom of scale.
13.2 centimeters on top of scale.

JORDAN VALLEY - MASTER PLAN	
MONTHLY CONSUMPTIVE USE SIMULTANEOUS SOLUTION OF THE BLANEY-CRIDDLE FORMULA IN METRIC AND ENGLISH UNITS	
MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY	
DATE 1950 DEVELOPED BY J.E.F.	DWG. NO. DS-5-2

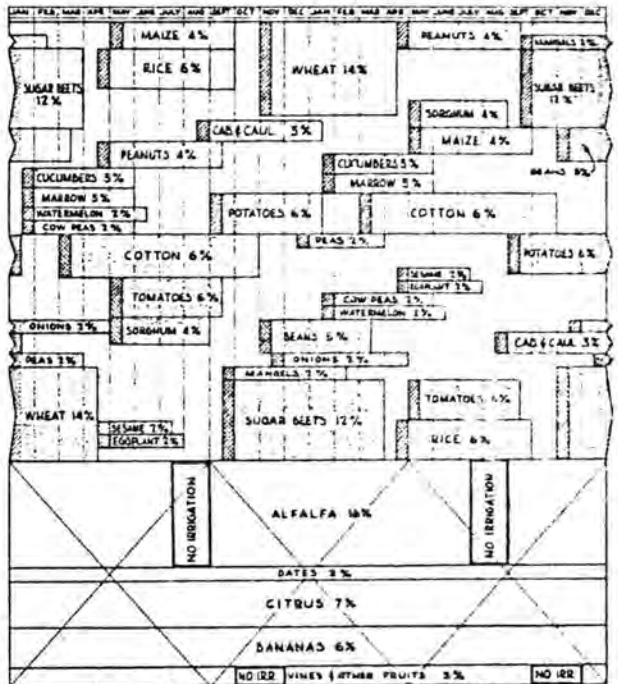
DS-5-2



CROPPING PATTERN A *Based on 3 year rotation Developed by UNRWA Agricultural Economist*

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		ANNUAL
NORTHERN	IRRIGATION REQ.	M³/DONUM	19	55	70	99	119	105	81	49	71	81	62	52		819
ZONE	DIVERSION REQ.	M³/DONUM	30	51	107	152	185	158	126	75	109	125	95	49		1260
SOUTHERN	IRRIGATION REQ.	M³/DONUM	64	81	107	100	125	107	84	50	70	82	80	84		1032
ZONE	DIVERSION REQ.	M³/DONUM	99	124	165	153	189	165	150	77	108	126	125	129		1588



CROPPING PATTERN B *Based on 2 year rotation Developed by Baker-Harza incorporating tentative data from representatives of the Jordan Gov't*

IRRIGATION AND DIVERSION REQUIREMENTS

		UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		ANNUAL
NORTHERN	IRRIGATION REQ.	M³/DONUM	16	29	59	76	112	125	108	84	95	77	49	26		856
ZONE	DIVERSION REQ.	M³/DONUM	25	45	91	117	172	189	166	132	146	118	75	40		1516
SOUTHERN	IRRIGATION REQ.	M³/DONUM	53	69	91	76	116	129	112	86	94	78	69	69		1042
ZONE	DIVERSION REQ.	M³/DONUM	82	106	140	117	178	198	172	132	145	120	106	106		1602

LEGEND

- AREA UNDER IRRIGATION
- AREA UNDER PREPARATORY TILLAGE
- FALLOW LAND
- CONTINUATION OF CROP
- PERMANENT CROP

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

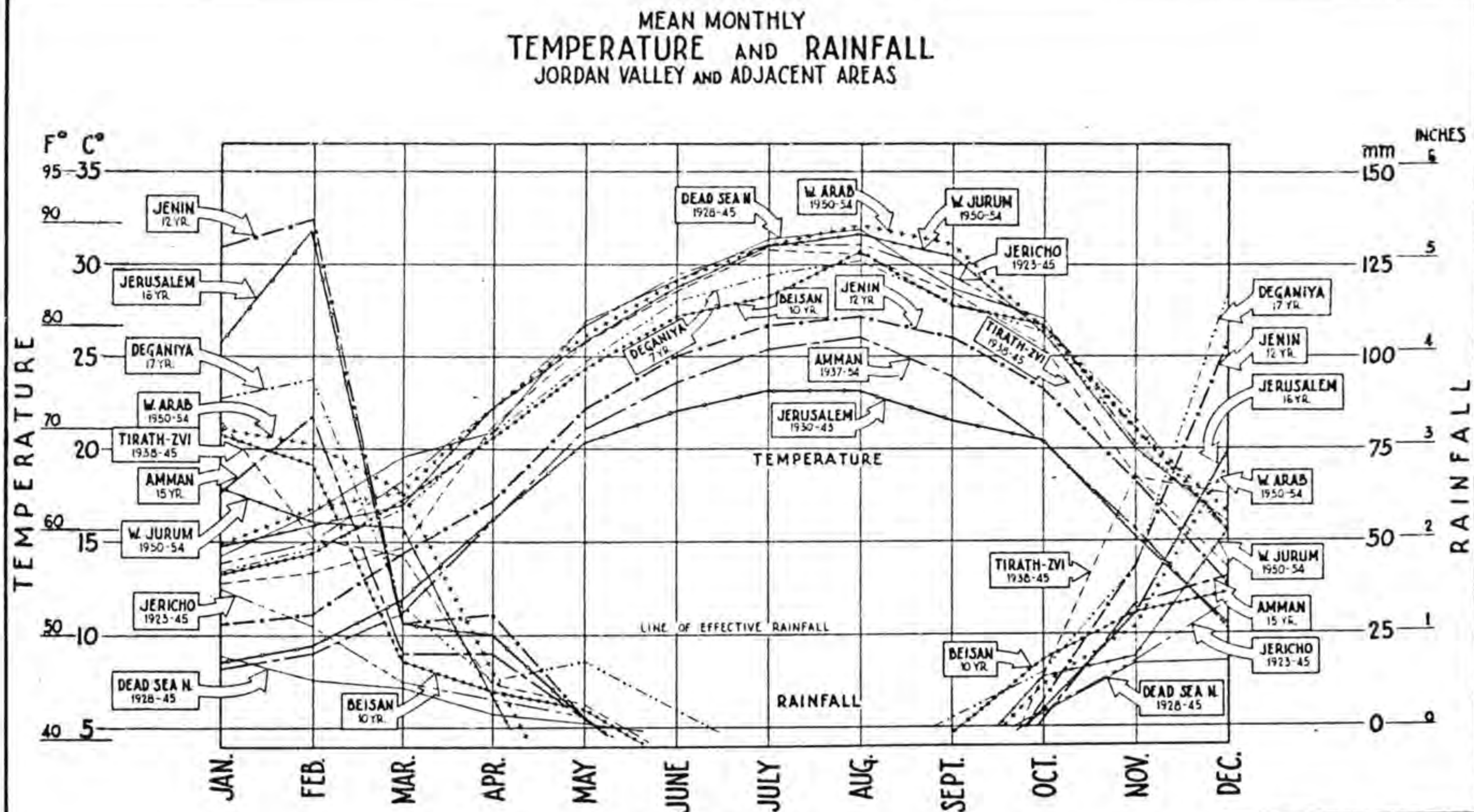
JORDAN VALLEY PROJECT | MASTER PLAN

DIVERSION REQUIREMENTS FOR
SPECIFIC CROPPING PATTERNS

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

ROCHESTER PENNA. | 3-55 | DS 5-5

DS-5-5



SOURCE
CLIMATIC ANALOGUES OF PALESTINE AND TRANS-JORDAN
M. Y. NUTTONSON, 1946

HUNDRED YEARS OF RAINFALL OBSERVATIONS
1844/45 – 1944/45
DR. D. ASHBEL

CURRENT RECORDS

THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT — MASTER PLAN

CLIMATIC DATA FOR IRRIGATION REQUIREMENTS

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA. — DATE 6-54 — DS-5-3

DS-5-3

Table 4.3-6

Rainfall at Degania "A"
235,300 N. - 204,000 E.
Elevation -200 M.
(in mm)

Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1917	-	-	-	-	-	-	-	-	0.0	17.8	60.0	227.9	
1918	105.6	125.6	114.5	14.8	0.0	0.0	0.0	0.0	0.0	0.0	36.0	135.5	532.0
1919	105.0	91.0	49.0	32.0	0.0	0.0	0.0	0.0	-	-	-	-	
1920	-	-	-	-	-	-	-	-	0.0	0.0	72.6	0.0	
1921	77.8	137.6	60.4	0.0	4.7	0.0	0.0	0.0	0.0	5.5	41.9	164.9	492.8
1922	169.2	53.3	47.6	3.2	0.0	0.0	0.0	0.0	0.0	0.0	57.0	128.0	458.3
1923	57.0	123.5	40.0	0.0	28.0	0.0	0.0	0.0	0.0	18.0	7.0	89.5	363.0
1924	116.5	107.5	37.5	0.0	24.0	2.5	0.0	0.0	0.0	21.5	9.7	66.0	385.2
1925	60.5	33.0	3.0	27.5	0.0	0.0	0.0	0.0	-	-	-	-	
1926	-	-	-	-	-	-	-	-	0.0	0.0	0.0	250.5	
1927	72.0	147.2	46.0	42.0	0.0	0.0	0.0	0.0	0.0	7.0	8.0	18.0	340.2
1928	57.5	115.0	2.0	2.0	0.0	0.0	0.0	0.0	-	-	-	-	
1929	-	-	-	-	-	-	-	-	0.0	0.0	108.0	62.5	
1930	89.0	59.0	8.5	28.0	0.0	0.0	0.0	0.0	0.0	0.0	34.0	92.0	310.5
1931	75.0	119.0	22.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	9.0	80.0	309.5
1932	28.0	132.0	8.0	5.0	0.0	0.0	0.0	0.0	-	-	-	-	
1933	-	-	-	-	-	-	-	-	-	-	-	-	
1934	-	-	-	-	-	-	-	-	0.0	4.5	6.5	206.0	
1935	76.0	-	-	-	-	-	-	-	2.3	33.6	65.8	28.8	
1936	52.5	29.7	16.7	8.8	8.8	0.0	0.0	0.0	0.0	0.0	113.0	92.1	321.6
1937	123.6	34.8	4.8	18.0	0.0	0.0	0.0	0.0	0.0	18.0	37.5	17.5	245.2
1938	174.0	87.4	56.2	0.0	29.0	0.0	0.0	0.0	0.0	1.0	121.3	70.4	539.3
1939	63.2	122.4	85.9	18.4	0.0	0.0	0.0	0.0	0.0	1.0	57.9	52.3	401.1
1940	136.7	45.4	23.4	8.1	0.0	0.0	0.0	0.0	0.0	21.4	43.3	62.0	340.3
1941	57.1	64.9	73.0	6.0	0.0	0.0	0.0	0.0	2.0	2.0	4.9	135.4	346.3
1942	39.6	44.5	50.5	0.0	0.0	0.0	0.0	0.0	0.0	59.6	80.9	12.4	287.5
1943	171.0	41.6	51.9	77.0	2.8	0.0	0.0	0.0	0.0	1.6	4.3	44.9	395.1
1944	231.7	34.9	48.9	11.4	4.4	0.0	0.0	0.0	0.0	0.0	172.6	207.5	711.4
1945	101.9	64.0	25.1	49.1	3.4	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	23	22	22	23	22	22	22	22	23	23	23	23	17
Mean for Years of Record	97.4	82.4	39.8	15.3	4.8	0.3	0.0	0.0	0.18	9.2	50.1	97.7	399.4

Source: Hundred Years of Rainfall Observation - Dr. Ashbel - Jerusalem, 1945.

Table 4.3-6

Table 4.3-7

Rainfall at Adasiye
230,000 N. - 208,000 E.
Elevation -200 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	30.0	12.5	
1948	54.0	107.0	147.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	36.5	110.1	484.6
1949	93.1	95.6	91.7	103.8	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	3.7	42.6	145.4	
1952	60.1	98.0	59.3	0.0	0.0	0.0	0.0	0.0	0.0	6.4	19.0	49.4	292.2
1953	154.9	90.0	128.0	7.0	0.0	0.0	0.0	0.0	0.0	15.6	135.8	91.2	622.5
1954	115.8	132.6	15.8	11.6	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	3
Mean for Years of Record	95.6	104.6	88.6	30.5	0.0	0.0	0.0	0.0	0.0	5.1	52.8	81.7	466.4

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Surveys, Jordan.

Table 4.3-8

Rainfall at Baqura
227,800 N. - 205,800 E.
Elevation -200M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	41.0	30.8	
1948	62.5	88.0	144.5	21.0	0.0	0.0	0.0	0.0	0.0	0.0	39.5	110.5	466.0
1949	81.0	73.5	83.5	88.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	4.5	44.5	150.2	
1952	59.3	90.4	52.8	0.0	0.0	0.0	0.0	0.0	0.0	10.7	22.4	55.5	291.1
1953	161.5	78.4	104.1	15.2	0.0	0.0	0.0	0.0	0.0	6.7	157.4	80.5	603.8
1954	89.9	132.6	15.0	15.0	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	
Mean for Years of Record	90.8	92.6	80.0	27.8	0.0	0.0	0.0	0.0	0.0	4.4	61.0	85.5	

Source: Technical Papers No. 16, 17, 20, and 21. Department of Lands and Surveys, Jordan.

Table 4.3-8

Table 4.3-9

Rainfall at Wadi Arab
224,000 N. - 207,800 E.
Elevation -197 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	10.2	40.7	143.2	
1952	56.7	85.5	45.8	0.0	0.0	0.0	0.0	0.0	0.0	12.5	20.5	54.2	275.2
1953	147.5	78.4	114.4	16.7	0.0	0.0	0.0	0.0	0.0	7.7	151.0	79.8	595.5
1954	89.5	128.8	13.3	-	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	2	2	2	2	2	2	3	3	3	2
Mean for Years of Record	97.9	97.6	57.8	8.4	0.0	0.0	0.0	0.0	0.0	10.1	70.7	92.4	435.4

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan

Table 4.3-10

Rainfall at Wadi Ziglab
214,000 N. - 206,000 E.
Elevation -190 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	28.0	30.2	133.0	
1952	55.8	62.9	64.9	2.5	0.0	0.0	0.0	0.0	0.0	17.3	7.6	40.4	251.4
1953	149.1	78.6	86.4	12.0	0.0	0.0	0.0	0.0	0.0	0.0	186.7	83.2	596.0
1954	80.2	116.0	4.1	22.0	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	95.0	85.8	51.8	12.2	0.0	0.0	0.0	0.0	0.0	15.1	74.8	85.5	423.7

Source: Technical Papers No. 20 and 21. Department of Irrigation and Water Power, Jordan

Table 4.3-11

Rainfall at Beisan
211,500 N. - 197,500 E.
Elevation -118M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
Average Rainfall 10 Year Record	78.7	71.1	17.8	10.2	5.1	0.0	0.0	0.0	0.0	17.8	30.5	35.6	266.7

Source: Climatic Analogues of Palestine and Trans-Jordan - M. Y. Nuttonson - 1946.

No other data available.

Table 4.3-11

Table 4.3-12

Rainfall at Wadi Jurum
204,000 N. - 206,000 E.
Elevation -180 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	18.7	29.4	130.1	
1952	50.4	43.3	62.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	21.3	18.6	202.8
1953	107.3	74.2	89.5	9.4	0.0	0.0	0.0	0.0	0.0	0.0	126.8	77.2	484.4
1954	57.6	85.6	4.9	11.1	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	71.8	67.7	52.1	6.8	0.0	0.0	0.0	0.0	0.0	8.6	59.2	75.3	343.6

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan.

Table 4.3-13

Rainfall at Tirath-Zvi
203,200 N. - 199,900 E.
Elevation -220 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1938	-	-	-	-	-	-	-	-	0.0	0.0	131.1	29.9	
1939	28.6	83.5	68.4	10.2	0.0	0.0	0.0	0.0	0.0	1.9	49.1	31.5	273.2
1940	115.0	3.5	22.5	3.0	0.0	0.0	0.0	0.0	0.0	25.0	56.8	66.8	292.6
1941	35.1	29.4	43.9	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.6	127.8	243.8
1942	22.8	37.2	47.0	0.0	0.0	0.0	0.0	0.0	0.0	66.9	58.3	22.8	255.0
1943	173.1	75.2	80.8	39.3	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	393.4
1944	131.5	54.5	34.5	4.0	47.0	0.0	0.0	0.0	0.0	0.0	144.5	160.5	376.5
1945	74.0	72.5	30.0	29.0	0.0	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	7	7	7	7	7	7	7	7	7	7	7	7	6
Mean for Years of Record	82.9	50.8	46.7	12.2	6.7	0.0	0.0	0.0	0.0	13.7	67.2	62.7	305.8

Source: Hundred Years of Rainfall Observations, (1844/45 - 1944/45) - Dr. Ashbel, Jerusalem, 1945.

Table 4.3-14

Rainfall at El-Qarn
194,100 N. - 204,300 E.
Elevation -178M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	18.0	11.0	
1948	47.0	47.0	82.5	17.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	70.2	274.7
1949	105.2	159.7	232.7	287.7	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	6.0	17.0	230.00	
1952	102.5	99.0	109.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	2.0	7.0	326.7
1953	113.0	84.0	110.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	88.5	67.5	471.6
1954	62.4	90.0	4.0	16.0	-	-	-	-	-	-	-	-	
Total Years of Record	5	5	5	5	4	4	4	4	4	5	5	5	3
Mean for Years of Record	86.0	95.9	107.8	65.7	0.0	0.0	0.0	0.0	0.0	2.6	27.3	77.1	357.7

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Survey and Department of Irrigation, Jordan

Table 4.3-15

Rainfall at Wadi Kufrinja
186,400 N. - 206,700 E.
Elevation -200 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	2.3	22.7	148.4	
1952	56.5	73.9	51.8	0.0	0.0	0.0	0.0	0.0	0.0	5.4	9.8	6.4	203.[illegible]
1953	79.2	76.9	89.7	1.5	0.0	0.0	0.0	0.0	0.0	0.6	95.2	71.7	414.8
1954	33.7	94.6	5.9	32.5	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	56.5	81.8	49.1	11.3	0.0	0.0	0.0	0.0	0.0	2.8	42.6	75.5	309.3

Source: Technical Papers No. 20 and 21, Department of Irrigation, Jordan.

Table 4.3-16

Rainfall at River Zarqa - Deir 'Alla
178.2 N. - 209,000 E.
Elevation -185 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1951	-	-	-	-	-	-	-	-	-	0.0	8.0	121.8	
1952	49.6	53.3	74.8	0.3	0.0	0.0	0.0	0.0	0.0	3.1	6.9	5.5	193.5
1953	59.4	93.3	95.9	6.1	0.0	0.0	0.0	0.0	0.0	0.0	97.2	83.2	435.1
1954	34.2	107.4	9.3	45.7	-	-	-	-	-	-	-	-	
Total Years of Record	3	3	3	3	2	2	2	2	2	3	3	3	2
Mean for Years of Record	47.7	84.7	60	17.4	0.0	0.0	0.0	0.0	0.0	1.0	37.4	70.2	314.3

Source: Technical Papers No. 20 and 21, Irrigation Department, Jordan.

Table 4.3-16

Table 4.3-17

Rainfall at Jericho
140,000 N. - 193,000 E.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1923	-	-	-	-	-	-	-	-	0.0	11.4	8.0	50.1	
1924	20.2	59.3	0.0	0.0	25.0	0.0	0.0	0.0	0.0	1.2	28.8	25.1	162.6
1925	12.0	23.6	11.0	18.0	0.0	0.0	0.0	0.0	0.0	6.3	19.9	8.0	98.0
1926	55.1	37.2	20.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	144.4
1927	17.0	48.8	8.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	5.0	103.8
1928	21.3	41.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	30.8	98.4
1929	29.6	25.0	2.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	32.5	10.3	117.9
1930	54.5	22.0	1.0	20.5	1.0	0.0	0.0	0.0	0.0	0.0	8.0	50.5	157.5
1931	37.5	20.0	1.5	4.5	0.0	0.0	0.0	0.0	0.0	4.0	3.5	8.0	79.0
1932	18.5	26.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	50.5
1933	22.5	19.0	10.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.5	66.5
1934	65.0	12.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	79.5	170.0
1935	26.5	43.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	17.0	15.0	4.5	106.5
1936	18.0	11.5	24.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	50.0	31.5	139.5
1937	39.0	2.5	0.0	16.5	0.0	0.0	0.0	0.0	0.0	8.0	47.0	1.5	114.5
1938	52.5	59.0	20.5	1.0	7.0	0.0	0.0	0.0	-	-	-	-	
1939	-	-	-	-	-	-	-	-	0.0	2.0	26.5	47.7	
1940	85.8	2.2	3.0	25.7	0.0	0.0	0.0	0.0	0.0	6.5	17.0	24.8	165.0
1941	20.0	7.4	37.5	3.7	0.0	0.0	0.0	0.0	0.0	3.2	4.1	76.3	152.2
1942	14.8	23.5	38.0	1.1	0.0	0.0	0.0	0.0	0.0	17.6	8.8	7.9	111.7
1943	57.2	31.7	42.2	16.2	1.1	0.0	0.0	0.0	0.0	8.4	0.0	14.4	171.2
1944	44.5	7.6	19.3	11.7	11.8	0.0	0.0	0.0	0.0	0.0	81.4	78.3	254.6
1945	75.6	50.6	22.8	4.8	19.8	0.0	0.0	0.0	-	-	-	-	
1952	-	-	-	-	-	-	-	-	-	0.0	1.8	4.2	
1953	25.3	52.4	43.5	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	22	22	22	22	22	22	22	22	22	22	22	22	19
Mean for Years of Record	36.9	28.4	14.2	7.7	3.0	0.0	0.0	0.0	0.0	4.1	17.2	27.1	129.7

Source: Hundred Years of Rainfall Observations (1844/45 - 1944/45) - Dr. D. Ashbel, 1945

Table 4.3-17

Table 4.3-18

Rainfall at Kafrein
139,500 N. - 211,600 E.
Elevation -230 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1947	-	-	-	-	-	-	-	-	-	0.0	26.9	2.4	
1948	58.8	22.5	45.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	34.8	167.2
1949	18.3	31.5	51.7	50.8	0.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	2.0	7.0	117.1	
1952	31.0	33.7	52.3	3.4	0.0	0.0	0.0	0.0	0.0	4.0	1.1	10.0	135.5
1953	30.5	49.6	27.9	5.5	0.0	0.0	0.0	0.0	0.0	-	-	-	
1954	-	16.6	4.8	11.9	-	-	-	-	-	-	-	-	
Total Years of Record	4	5	5	5	4	4	4	4	4	4	4	4	2
Mean for Years of Record	34.6	30.8	36.4	14.3	0.0	0.0	0.0	0.0	0.0	1.5	10.2	41.1	151.4

Source: Technical Papers No. 16, 17, 20, and 21, Department of Lands and Surveys - Irrigation Section, Jordan.

Table 4.3-19

Rainfall at Dead Sea (North)
137,000 N. - 201,000 E.
Elevation -390M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1929	9.0	22.9	8.3	12.6	0.0	0.0	0.0	0.0	0.0	0.0	11.0	4.5	68.3
1930	13.6	17.7	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5	29.5	84.1
1931	22.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	8.5	39.4
1932	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	2.0	0.0	15.5
1933	8.5	11.5	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.0	29.0
1934	25.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	36.5	64.2
1935	13.5	12.4	0.5	0.0	1.0	0.0	0.0	0.0	0.0	26.8	14.0	2.0	70.2
1936	9.3	6.3	10.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	29.0	23.5	84.6
1937	36.2	10.3	0.0	3.0	0.0	0.0	0.0	0.0	0.0	2.5	22.2	0.0	74.2
1938	26.3	20.6	15.8	0.0	4.0	0.0	0.0	0.0	0.0	0.0	35.7	16.0	118.6
1939	5.5	42.7	39.6	0.0	0.0	0.0	0.0	0.0	0.0	1.5	30.5	25.5	145.3
1940	58.0	2.0	6.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	12.5	111.2
1941	9.0	12.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	40.0	77.0
1942	4.0	14.0	35.5	0.0	0.0	0.0	0.0	0.0	0.0	9.0	2.5	0.0	65.0
1943	19.8	7.4	33.8	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	75.3
1944	25.1	4.8	8.8	20.7	2.4	0.0	0.0	0.0	0.0	0.0	109.5	64.3	235.6
1945	36.0	20.0	11.0	2.0	16.0	0.0	0.0	0.0	-	-	-	-	
Total Years of Record	17	17	17	17	17	17	17	17	16	16	16	16	16
Mean for Years of Record	19.5	12.4	11.0	4.2	1.4	0.0	0.0	0.0	0.0	2.7	18.7	17.2	84.8

Source: Hundred Years of Rainfall Observation (1844/45 - 1944/45) - Dr. D. Ashbel - Jerusalem, 1945.

Table 4.3-19

Table 4.3-20

Rainfall at Ghor Fari'a P. Post (Ex-Jiftlik)
172,000 N. - 196,000 E.
Elevation -240 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1952	-	-	-	-	-	-	-	-	-	0.0	6.0	8.5	
1953	48.5	55.5	76.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	90.0	67.5	339.5
1954	-	53.0	5.0	15.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	1	2	2	2	2	2	2	2	2	2	2	2	1
Mean for Years of Record	48.5	54.2	40.8	8.2	0.0	0.0	0.0	0.0	0.0	0.0	48.0	38.0	339.5

Source: Technical Paper No. 21, Irrigation Department, Jordan.

Table 4.3-20

Table 4.3-21

Rainfall at Amman - R.A.F.
153,000 N. - 242,500 E.
Elevation 780 M.
(In mm)
Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1927	47.0	190.8	5.4	36.9	2.1	0.0	0.0	0.0	0.0	8.1	22.2	109.0	421.5
1928	46.4	109.3	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.8	48.8	237.3
1929	70.3	84.7	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.3	41.4	259.4
1930	86.9	47.6	6.4	26.5	1.0	0.0	0.0	0.0	0.0	0.0	17.7	30.6	236.7
1931	97.4	50.3	24.9	8.4	0.0	0.0	0.0	0.0	0.0	1.9	14.2	91.7	288.8
1932	45.4	58.5	7.0	10.4	0.0	0.0	0.0	0.0	0.0	9.7	4.5	0.6	136.1
1933	53.3	25.2	31.4	13.4	0.0	0.0	0.0	0.0	0.2	0.1	7.2	5.1	135.9
1934	94.3	45.3	-	7.4	0.0	0.0	0.0	0.0	0.0	1.7	0.0	87.0	
1935	76.9	142.3	17.3	14.8	4.5	0.0	0.0	0.0	0.0	14.9	14.0	4.9	289.6
1936	13.4	103.1	24.8	11.2	0.0	0.0	0.0	0.0	0.0	0.1	68.5	67.3	305.4
1937	117.0	16.1	0.0	54.8	3.8	0.0	0.0	0.0	0.0	4.6	14.0	1.1	211.4
1938	97.0	132.8	66.4	1.3	24.1	0.0	0.0	0.0	0.0	0.2	126.5	28.2	476.5
1939	24.8	79.4	84.8	4.3	0.0	0.0	0.0	0.0	0.0	3.3	71.8	20.4	288.8
1940	124.1	5.2	30.0	31.4	0.0	0.0	0.0	0.0	0.0	8.4	32.8	59.0	290.9
1941	61.6	22.4	24.0	6.2	0.0	0.0	0.0	0.0	0.0	2.2	3.5	155.1	275.0
1942	56.9	86.6	96.9	0.3	0.0	0.0	0.0	0.0	0.0	54.6	27.8	18.6	341.7
1943	105.4	50.5	86.7	34.4	2.3	0.0	0.0	0.0	0.0	4.5	0.6	18.2	302.6
1944	141.7	12.6	20.2	11.7	13.0	0.0	0.0	0.0	0.0	0.0	136.8	94.0	430.0
1945	10[illegible].2	106.0	19.3	4.6	19.6	0.0	0.0	0.0	-	-	-	-	
1946	-	-	-	-	-	-	-	-	-	-	-	-	
1947	-	-	-	-	-	-	-	-	-	0.0	22.2	21.0	
1948	92.8	69.1	76.1	12.0	1.3	0.0	0.0	0.0	0.0	2.1	12.4	44.3	310.1
1949	74.9	123.9	116.0	52.5	2.0	0.0	0.0	0.0	0.0	-	-	-	
1950	-	-	-	-	-	-	-	-	-	-	-	-	
1951	-	-	-	-	-	-	-	-	-	0.9	19.9	179.8	
1952	35.6	79.7	46.9	0.4	0.0	0.0	0.0	0.0	0.0	8.5	3.9	12.3	187.3
1953	29.3	81.3	168.7	1.8	0.0	0.0	0.0	0.0	0.0	1.5	91.3	60.5	434.4
1954	17.7	90.3	12.8	16.2	-	-	-	-	-	-	-	-	
Total Years of Record	24	24	23	24	23	23	23	23	22	23	23	23	20
Mean for Years of Record	71.3	75.5	43.0	15.0	3.2	0.0	0.0	0.0	0.09	5.5	34.2	53.9	293.1

Source: Hundred Years of Rainfall Observation (1844/45 - 1944/45) - Dr. D. Ashbel - Jerusalem, 1945; and Technical Papers No. 16, 17, 20 and 21, Department of Lands and Surveys, Jordan.

Table 4.3-22

Rainfall at Jenin
207,600 N. - 178,500 E.
Elevation 138 M
(In mm)

Sheet 1 of 1

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1952	-	-	-	-	-	-	-	-	-	21.5	18.6	29.6	
1953	151.4	97.9	125.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	167.8	109.4	654.7
1954	-	109.6	16.2	19.2	0.0	0.0	0.0	0.0	0.0	-	-	-	
Total Years of Record	1	2	2	2	2	2	2	2	2	2	2	2	1
Mean for Years of Record1/	151.4	103.8	70.6	11.2	0.0	0.0	0.0	0.0	0.0	10.2	93.2	69.5	654.7
Average Rainfall for 17 Years2/	129.5	137.2	27.9	30.5	2.5	0.0	0.0	0.0	0.0	7.6	43.2	104.1	482.6

Source: 1/ Technical Paper No. 21, Department of Irrigation, Jordan.
2/ Climatic Analogues of Palestine and Trans-Jordan - M.Y. Nuttonson - 1946.

Table 4.3-22

Table 4.3-23

Rainfall at Jerusalem
132,000 N. - 171,000 E.
Elevation 827 M.
(In mm)
Sheet 1 of 2

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1846	59.4	73.5	53.6	-	0.0	0.0	0.0	0.0	0.0	39.9	63.7	0.0	
1847	97.4	326.0	59.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	158.5	671.3
1848	244.0	67.5	0.0	1.9	14.0	0.0	0.0	0.0	0.0	0.0	1.9	156.5	[illegible]
1849	192.5	130.5	117.2	0.0	0.0	0.0	0.0	0.0	-	-	-	-	
1850	-	-	-	-	-	-	-	-	0.0	0.0	63.7	335.0	
1851	145.0	238.0	39.9	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	151.0	595.7
1852	134.5	248.0	87.5	0.0	23.8	0.0	0.0	0.0	0.0	0.0	17.9	93.0	604.7
1853	44.7	39.9	212.0	11.7	19.9	0.0	0.0	0.0	0.0	0.0	59.4	123.0	507.4
1854	130.5	196.0	240.0	107.0	0.0	0.0	0.0	0.0	0.0	38.0	0.0	63.5	777.1
1855	325.0	125.7	87.5	23.8	0.0	0.0	0.0	0.0	0.0	0.0	9.8	31.6	604.4
1856	175.0	225.0	101.0	246.0	0.6	0.0	0.0	0.0	0.0	0.0	147.0	41.6	936.4
1857	229.0	559.0	39.8	9.8	0.0	0.0	0.0	0.0	0.0	14.0	65.8	169.0	995.4
1858	229.5	234.0	15.0	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	216.0	747.1
1859	[illegible]	31.3	162.0	61.4	0.0	3.9	0.0	0.0	0.0	43.7	27.7	7.8	497.3
"Missing"													
1898	-	-	-	-	-	-	-	-	0.0	0.0	66.2	143.5	
1899	139.5	51.2	60.0	29.1	0.0	0.0	0.0	0.0	0.0	4.0	32.1	153.7	519.9
1900	59.7	222.3	46.6	4.1	6.6	0.0	0.0	0.0	0.0	2.7	15.0	119.9	479.4
1901	174.0	3.3	25.5	12.4	23.7	0.0	0.0	0.0	0.0	4.0	42.9	149.2	436.0
1902	301.0	42.6	40.8	21.5	1.1	0.0	0.0	0.0	0.0	16.0	189.8	176.1	790.9
1903	174.3	79.5	93.4	9.4	0.0	3.0	0.0	0.0	0.0	3.3	35.0	70.7	468.6
1904	242.1	31.2	139.1	30.4	0.2	0.0	0.0	0.0	0.0	5.3	88.6	346.3	882.1
1905	90.3	144.1	127.4	4.0	0.0	0.0	0.0	0.0	0.0	15.3	0.0	272.1	703.7
1906	152.2	174.0	50.7	117.5	23.1	0.0	0.0	0.0	0.0	18.2	17.1	43.5	598.3
1907	145.1	65.5	110.2	29.4	9.3	0.0	0.0	0.0	-	-	-	-	
"Missing"													
1932 (St. Anne)	-	-	-	-	-	-	-	-	10.0	28.5	10.2	4.8	
1933	92.0	65.5	35.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	9.6	22.6	228.7
1934	244.0	96.4	6.2	35.6	0.0	0.0	0.0	0.0	0.0	3.9	9.9	142.5	538.5
1935	79.1	275.3	28.0	2.4	0.0	0.0	0.0	0.0	0.0	9.1	46.3	27.8	468.0
1936	30.8	182.1	44.3	17.2	0.0	0.0	0.0	0.0	0.0	0.0	150.2	160.5	585.1
1937	278.0	43.9	11.6	38.5	2.5	0.0	0.0	0.0	0.0	25.4	36.6	11.6	448.1
1938	221.2	248.5	96.8	-	-	-	-	-	-	-	-	-	
1939	-	-	-	-	-	-	-	-	0.0	4.4	114.7	72.5	
1940	261.1	11.7	58.1	27.7	0.0	0.0	0.0	0.0	0.0	18.0	16.7	138.9	532.2

Table 4.3-23

Rainfall at Jerusalem
132,000 N. - 171,000 E.
Elevation 827 M.
(In mm)
Sheet 2 of 2

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1941	109.0	15.1	152.0	4.0	0.0	0.0	0.0	0.0	0.0	10.0	8.0	346.3	644.4
1942	130.4	39.5	215.0	1.1	0.0	0.0	0.0	0.0	0.0	66.0	68.0	12.2	552.2
1943	275.9	121.1	1[illegible]2.3	49.3	2.0	0.0	0.0	0.0	0.0	26.6	2.3	34.3	593.5
1944	297.5	32.6	49.4	44.3	21.9	0.0	0.0	0.0	0.0	0.0	299.5	154.4	909.9
1945	152.7	214.2	35.2	-	-	-	-	-	-	-	-	-	
"Missing"													
1952	-	-	-	-	-	-	-	-	-	0.0	19.4	25.2	
1953	85.7	125.7	215.5	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	
1954	-	152.1	21.0	16.0	-	-	-	-	-	-	-	-	
Total Years of Record	35	36	36	33	33	33	33	33	35	35	35	35	29
Mean of Years of Record	135.6	143.0	85.6	31.3	4.4	0.1	0.0	0.0	0.3	11.5	50.2	120.5	515.5

Source: Hundred Years of Rainfall Observations (1844/45 - 1944/45) - Dr. D. Ashbel, 1945; and
Technical Paper No. 21 - Department of Irrigation - Jordan

Table 4.3-24

Mean Monthly Temperatures
Jordan Valley and Adjacent Areas
(Degrees Centigrade)

Sheet 1 of 1

Station	Elevation	Years of Record	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Degania 1/	-200 M	7	13.4	14.7	16.7	20.9	24.7	28.0	29.6	30.2	27.9	26.2	20.4	15.6	22.4
Beisan 1/	-118 M	10	13.3	14.4	17.2	20.5	24.4	27.2	28.3	30.6	27.7	26.1	21.1	15.0	22.1
Jericho 1/	-260 M	13	13.9	15.0	18.3	22.2	26.6	29.4	31.1	31.1	29.4	26.6	21.7	15.5	23.4
Jenin 1/	138 M	12	10.6	11.1	14.4	17.2	22.2	25.0	26.6	27.2	26.1	23.3	18.3	12.8	19.5
Jerusalem 2/	827 M	1930-1943	8.6	9.5	12.0	16.2	20.4	22.1	23.2	23.2	21.6	20.5	15.3	10.5	16.9
Tirath-Zvi 2/	-220 M	1935-1943	12.8	13.4	14.7	21.3	25.8	28.6	30.8	30.6	28.5	25.6	18.6	13.6	22.0
Dead Sea (N) 2/	-390 M	1926-1943	14.3	16.6	19.6	20.6	26.9	29.1	31.3	31.9	25.7	27.1	20.4	15.6	23.5
Amman R.A.F. 3/	750 M	1923-1954	[illegible]	9.1	12.0	16.2	19.8	23.6	25.1	25.5	23.7	20.7	15.7	10.1	17.5
Wadi El Arab 4/	-197 M	1950-1954	14.9	16.8	18.2	21.7	26.1	29.0	30.9	32.1	30.8	27.0	21.5	16.6	23.8
Wadi Jurum 4/	-180 M	1950-1954	14.8	15.8	17.6	23.7	25.8	29.6	31.0	31.6	30.1	26.2	20.2	17.3	23.6
Adasiye 4/	-200 M	1949-1951	15.6	17.0	21.9	25.2	26.9	30.6	32.3	31.8	30.7	26.1	25.0	19.4	25.2
Wadi Ziglab 4/	-190 M	1950-1954	13.7	15.8	19.8	21.4	26.1	29.1	31.0	32.1	31.4	27.0	21.4	15.4	23.7
Wadi Kufrinja 4/	-200 M	1951-1954	16.0	15.9	19.3	22.2	27.8	30.1	-	34.2	31.2	28.4	23.9	-	24.9
River Zarqa - Deir Alla 4/	-185 M	1951-1954	16.8	16.9	18.2	22.2	27.8	29.9	32.4	32.7	31.1	28.1	22.0	17.3	24.5

Source: 1/ Climatic Analogues of Palestine and Trans-Jordan - M. Y. Nuttonson - 1946.

2/ Temperatures and Humidity of Palestine and Adjacent Countries - Dr. D. Ashbel - 1945.

3/ Current Daily Records - R.A.F. Camp, Amman, Jordan.

4/ Current Records by Irrigation Department.

Table 4.3-24

PART 4. DRAINAGE

Introduction

Good drainage practice, both surface and subsurface, is essential to the successful operation of any irrigation system. Drainage in agriculture is a method of improving the soil by withdrawing excess water from it. The objective of this drainage investigation was to design a system whereby a 1.4 meter depth root zone could be maintained free of excess water within all irrigable lands throughout the project, permitting the growth of almost any of the plants adaptable to the area.

Drainage investigation of the project deals primarily with the following four elements: Topography, soils, water tables, and water source, including both quality and quantity. Methods of investigation were essentially those recommended by the United States Bureau of Reclamation, Soil Conservation Service and Salinity Laboratory, modified to meet local conditions.

Basic Information

The topography of the project is characterized by two main features: high benches known as ghors, and the flood plain called the zor. The zor, or recent flood plain, occupies the center of the Jordan Valley. The ghors lie on either side of the zor and rise with an abrupt elevation change, ranging from 30 to 60 meters. Tributary streams or wadis on both sides of the valley cross the ghors to merge with the Jordan River. These streams have become deeply but narrowly entrenched and separate the ghors into distinct segments. Except where the surface is modified by alluvial fans and colluvial slopes, the overall gradient of the ghors is moderate, ranging between one and three percent. There are several places where shallow undrained depressions occur in the ghors but, as a whole, good surface drainage is provided by the natural slopes from north to south and from the side hills to the Jordan River.

Soil textures of the ghors range from light loams to clay loams and clays, with clay loam predominating. These textures continue to considerable depth and significant layers of incoherent sand or gravel are uncommon. Soil textures and salinity vary throughout the Jordan Valley, but generally are heavier near the zor and lighter towards the hills. The highest salt concentrationsare found towards the southern end of the valley.

No subsurface barriers were located within 4.0 meters of the surface, where such barriers could be considered as controlling the drainage of a defined area; however, local barriers were found covering limited areas, generally small. Field studies reveal that the heavier soils, as found where the ghor breaks into the zor, form a vertical barrier in that the permeability of such soils, in general, are much lower than the soils toward the hillsides. This fact may account for the flow of subsurface waters of the ghor in a general direction more or less angular rather than perpendicular to the Jordan River.

Meteorological data show no great amount of rainfall during 7 months of the year; however, January, February and March are peak months. Long range rainfall records for the project area are not available, but such records as have been compiled indicate there has not been

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PART 4. Drainage

Introduction
Basic Information
Water Source - Quality and Quantity
Special Problems
Investigations
Leaching
Types of Drains

sufficient precipitation to have produced surface run-off of an extent great enough to have created high water tables from that cause alone. However, high water tables do exist in places throughout the project area, and while many of these problems can be attributed to improper irrigation practices, in other high water table areas there has been no irrigation for hundreds of years. It has definitely been established that many of the high water tables found in the southern part of the valley and on the West Ghor have not been caused by ponding of local surface run-off water.

Water Source - Quality and Quantity

Water source studies reveal that the cause of high water table areas in the project can be attributed to the following:

1. Inefficient use of irrigation waters.
2. Uncontrolled springs.
3. Artesian seepage (static water).
4. Free flow seepage.
5. Special problems arising from ancient water works, generally of Roman origin.

The normal quantity of water to be dealt with in maintaining a well-drained root zone where intensive irrigation is carried on is in this report, assumed to be 10% of the total irrigation water applied. Additional water may be contributed from other sources such as those mentioned above. It is difficult to compute the definite quantity of water emitted from such sources as springs, artesian seepage and the ancient fuquarās unless a complete study is made to determine such factors as recharge, static head, water bearing aquifers, and soil permeabilities.

Springs in the project area are not numerous and generally the flow is quite small. No serious problems are expected from this source of underground water.

Artesian waters, however, present quite a serious drainage problem, especially in the southern part of the East Ghor area. Topographical conditions are quite favorable for adequate surface drainage, and removal of excess surface water presents no problem. However, climatic conditions are such that, over extensive areas of land, water which has been forced into the root zone from below by hydrostatic pressure has evaporated before reaching the surface of the ground. A high concentration of salt has thus been left near the lower limit of the evaporation zone, because of the high salt content of the artesian waters. It is very important to maintain the subsurface waters in this area at least 1.4 meters below the ground surface for two reasons: 1) most lands will require leaching before crop production can be obtained and 2) the subsurface evaporation zone is approximately one-half (0.5) meter from the surface. The high salinity of the artesian waters would greatly reduce production or even inhibit growth of many crops if permitted to encroach on this horizon. The permeability of the subsurface soils in this area is favorable to adequate drainage, but to secure further insurance against recontamination of the root zone a plan to reduce the static head of artesian water is highly recommended. To lower the static head on the artesian waters in question would require the drilling of a number of wells in the area and installing pumps to keep the static head well below the drainage system. To off-set a portion of the cost of such an installation, the artesian waters could be blended with normal irrigation waters to supplement present water supply, but due to the high salinity of the artesian waters at the present time, its use for irrigation without blending with a water of higher quality is not recommended.

Free flow water found in the project area is quite localized and can usually be traced to excess irrigation waters that have found their way to the surface. Such water can easily be controlled by adequate surface drainage without undue expense.

Special Problems

Most of the ancient water works found in the project area were constructed by the Romans some 2000 years ago. Many irrigation systems were built throughout the Jordan Valley during Roman rule. Recorded in "The Legacy of Rome" (published in Latin) is the identification of some 22 individual systems in the project area where subsurface water has been developed and used for irrigation. Almost all work was done with slave labor and it is reported that during the peak of construction some 30,000 slaves were employed. The irrigation systems referred to are known as "fuquarās" and "kanāts".

The fuquarās are underground canals which were used to develop and carry the water to gravity canals called kanāts. It is the fuquarā part of the system that has created the drainage problems. Topography played an important part in locating the fuquarās in order for them to function as an integral part of an irrigation plan. For this reason they start near the foothills and extend toward the valley. Two methods of construction were used; namely, the dry system and the wet system, the only difference between the two being the source of water. Both systems were quite effective in meeting their purpose, however, it is the dry system that is creating the most serious drainage problems.

To construct the wet type fuquarā, vertical shafts were dug to a water bearing aquifer. Normally these shafts were dug 25 to 30 meters apart, then a connecting tunnel was dug joining all the shafts. The tunnel slope was generally maintained between 2 and 15 meters in 1000 meters depending on topography where the tunnel daylighted to connect with the kanāt part of the system. Once this type of system becomes inoperative the water only rises in the tunnel to a point equal to the elevation of the water bearing aquifer. A normal drainage system will remove these subsurface waters quite adequately and since no great hydrostatic head is present to force the water upward, it is felt that further high water tables will be eliminated. In general the amount of water developed by this type fuquarā is very limited and the quality very poor as far as irrigation is concerned.

In constructing the dry type fuquarā the vertical shafts and connecting tunnel were dug, extending the tunnel to join the kanāt system. One of the shafts, usually near the outlet, was extended downward to an artesian aquifer thus bringing water to the tunnel from below. Each shaft could be extended to the artesian aquifer to produce additional water if required. The static head created by waters from the artesian aquifer has proved to be the source of water causing high water tables in many areas where fuquarās of this type have been blocked, particularly in the southern part of the East Ghor Area.

The average length of the wet type fuquarās is much greater than the dry type, which usually is between 300 and 500 meters, while the former range from 500 meters to 1.5 Kilometers. The tunnel dimensions, however, are essentially the same, 0.7 meters wide and 2.0 meters in height. A typical cross section of a fuquarā is shown on Drawing JR-6, which follows, and the approximate locations of known fuquarās within the project area are shown on Drawing JR-8, Base Map.

Fortunately the dry type fuquarās occur in the same area as that affected by artesian seepage and the recommendation to lower the water table by pumping would reclaim this area also. The quality of the water from the dry type fuquarās is essentially the same as that found coming from the artesian aquifer.

Investigations

Some 38 undisturbed soil permeability tests were conducted throughout the project area, following the methods as set forth by the U. S. Salinity Laboratory Handbook No. 60 issued in February, 1954. Water from the Yarmouk River was used throughout the tests and rate of infiltration, depth, lateral movement and salt dispersion carefully noted. The results of the field permeability tests supported by soils investigation are used as bases for determining drain spacing requirements. The basic formula used to determine spacing is a modified adaptation of Darcy's Law as shown on Drawing JR-7, which follows.

Leaching

Lands within the project area requiring some degree of leaching before becoming productive amount to approximately 174,000 donums. A specific leaching program will be required for approximately 167,000 donums located generally on the East Ghor south of the River Zarqa, and on the West Ghor. Lands near the Dead Sea have the highest percentage of total soluble salts.

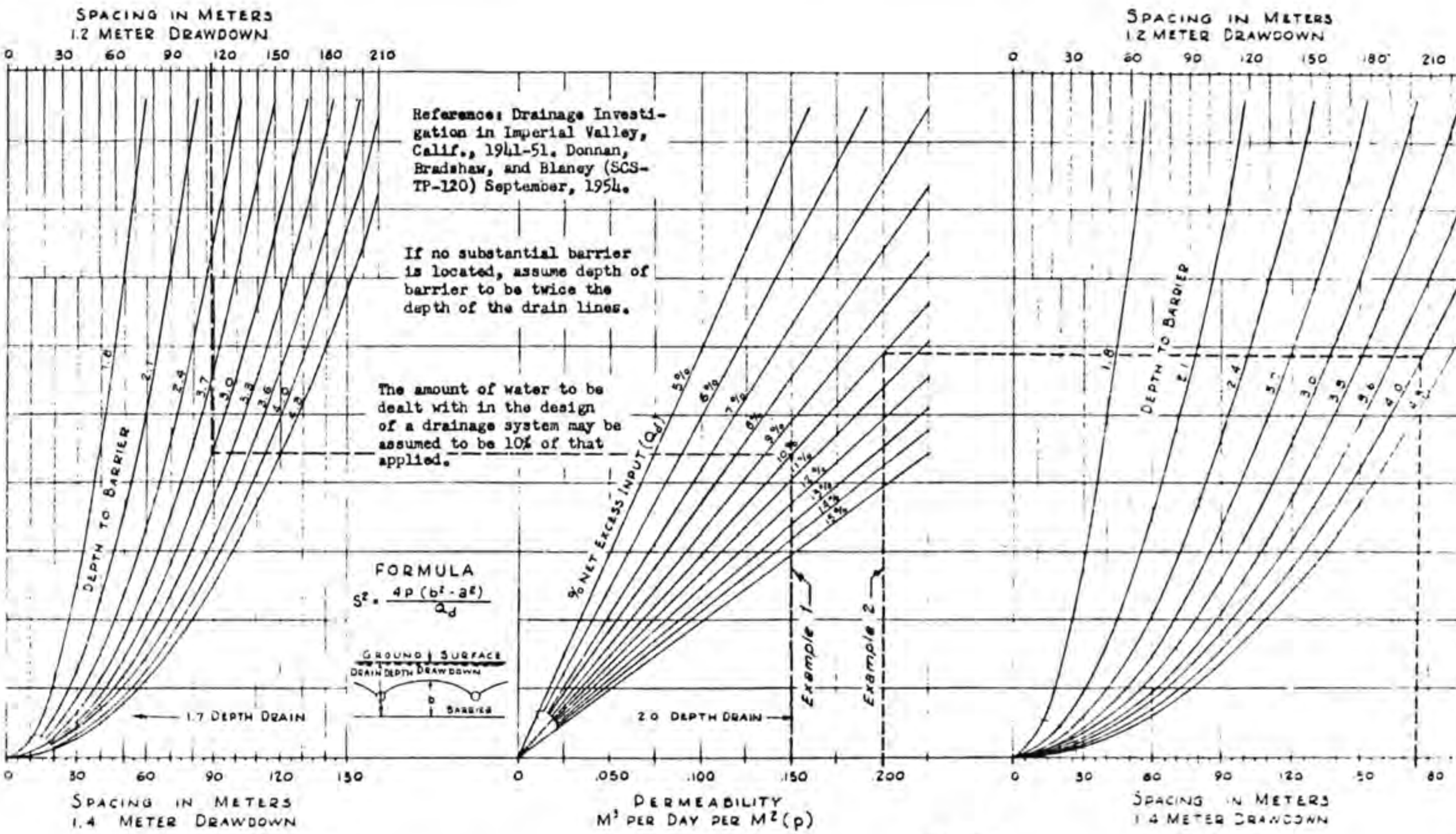
In order to establish procedure for leaching such lands, two test areas were selected, located approximately by coordinates as 142.0N. - 204.4E. Approximately 150 meters separated the two areas. The physical difference between the areas was the installation of drainage facilities in area 1 while area 2 did not have such facilities. Soil samples were taken on a definite pattern from the areas before any water was applied and the same pattern followed in taking subsequent samples after water applications.

The quality of water available for use as a leaching medium was not desirable, however, the final results show that such lands can be leached and perhaps more successfully with a better quality water as shown by the infiltration studies. The final results of the trials show conclusively that definite patterns should be followed as to quantity of water applied and method of application. Another interesting fact observed during the trials, relative to drainage, is that subsurface drainage installation must wait until after a degree of leaching has been done, due to the poor stability of the soils until a large percentage of the salts have been removed. The salts can be forced downward more evenly without a drainage system, but a reverse movement can be expected unless a drainage system can be installed after salts have been removed to approximately 90 centimeters. The quantity of water applied for normal irrigation of shallow rooted plants would not be sufficient to keep the salts at this level without the aid of subsurface drainage.

Types of Drain

Topography, size of farm unit, the need for fullest land utilization, and weed control have definitely favored the selection of covered drains rather than open drains, with the exception of a few shallow open drains to remove excess surface waters. Normally the closed type drains include a manufactured conduit such as concrete tile, clay tile or fiber pipe, with a gravel and sand blanket, placed in a trench which is completely backfilled, so that normal farming operations can be done directly over the drainage system.

The high salinity of drainage waters, excepting in the northern portion of the East Ghor Area limits the utility of concrete tile. Clay tile and fiber pipe which would be acceptable are not manufactured in the Kingdom in quantities sufficient to satisfy the needs of the project, and import cost of such materials would make this type of drain prohibitively expensive. For these reasons alone the rock or stone type drain is recommended. All materials and labor required to construct this type of drain are available within the boundaries of the Kingdom and can be utilized fully. Properly constructed rock drains need not present any greater maintenance problem than tile drains.



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EXAMPLE 1

Determine drain spacing for a depth to water table of 1.2 meters at midpoint between drains, under the following conditions: an overall coefficient of permeability (p) of .15 M³/M² per day, and an average drain depth of 1.7 meters. Assume 10% excess water (Qd), and 3 meters to depth barrier.

Enter chart at .15 (p), go vertically to intersect 10% excess line; thence horizontally to left to intersect the 3 meter barrier curve; thence vertically, upward, and read drain spacing of 112 meters on scale at top of chart.

EXAMPLE 2

Determine drain spacing for a depth to water table of 1.4 meters at midpoint between drains, under the following conditions: an overall coefficient of permeability (p) of .20 M³/M² per day, average drain depth of 2.0 meters, and depth barrier unknown. Assume 10% excess water (Qd).

Enter chart at .20 (p), go vertically to intersect 10% excess line; thence horizontally to right to intersect 4 meter barrier curve (When barrier depth is unknown, assume to be 2 times drain depth), thence vertically downward and read spacing of 175 meters on scale at bottom of chart.

When permeability (p) is beyond the range of the chart use maximum established drain spacing according to depth of drain.

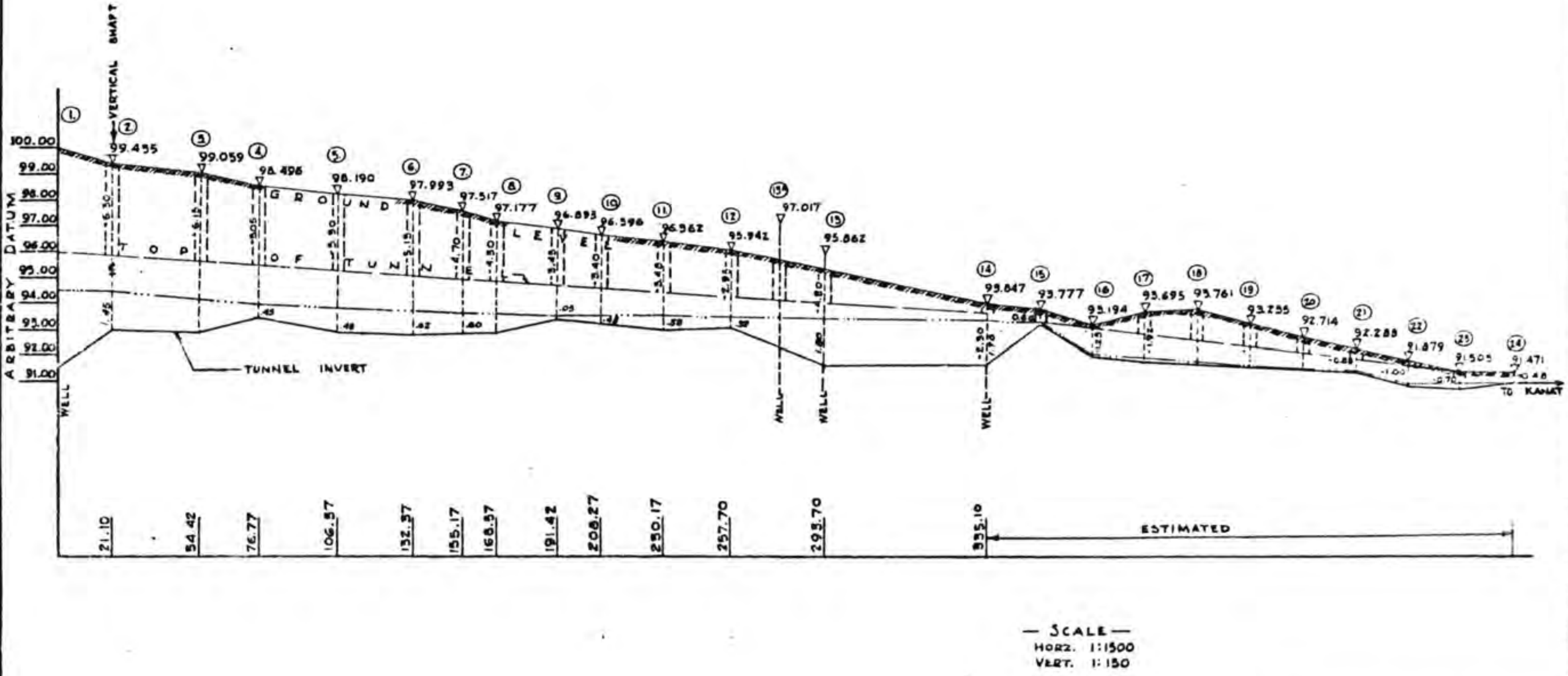
JORDAN VALLEY – MASTER PLAN

DRAIN SPACING CURVES

REFERENCE – SCS-TP-120 SEPT. 1954

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

DATE 12-15-54 DWG NO JR-7



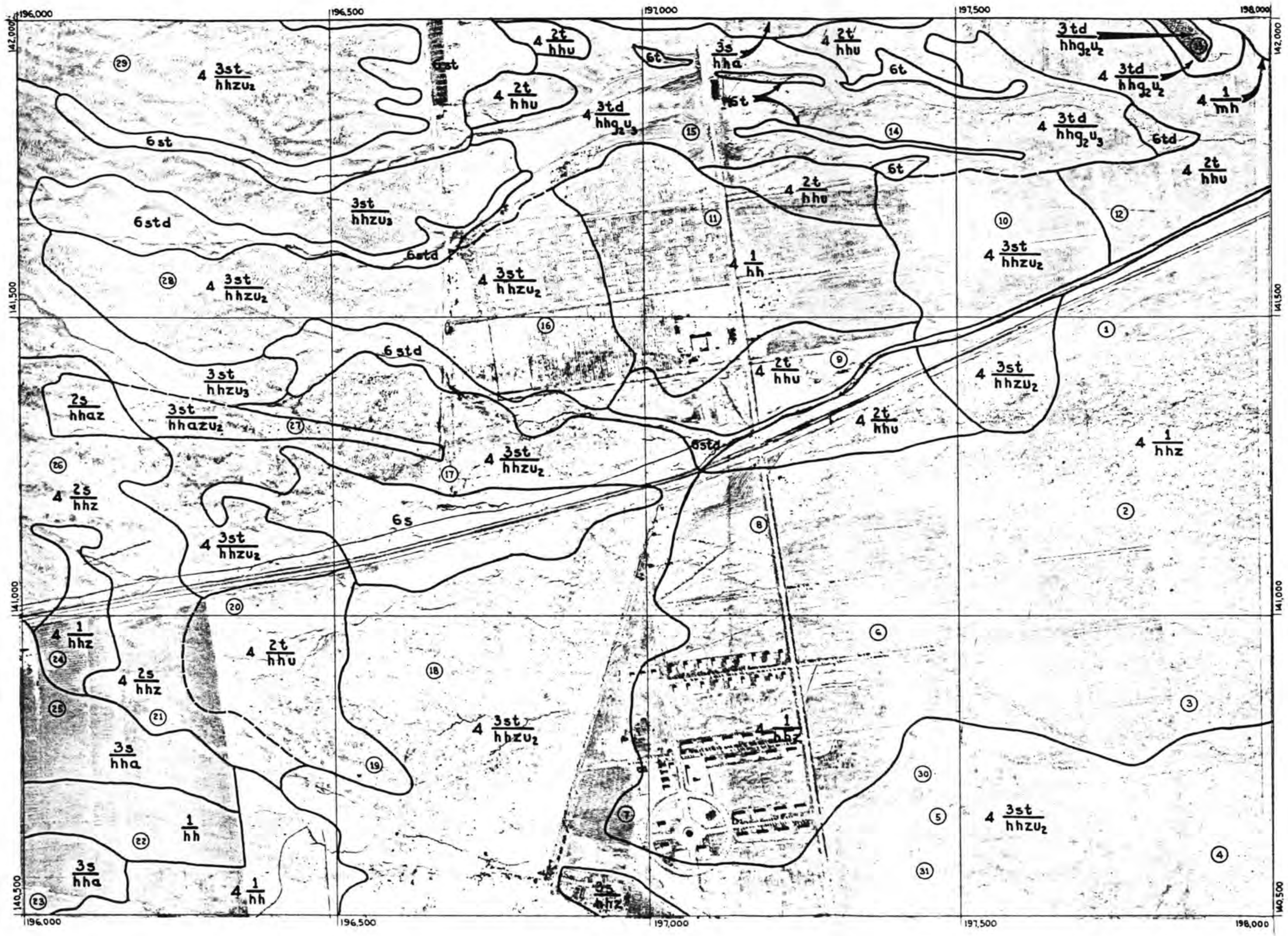
JORDAN VALLEY - MASTER PLAN

TYPICAL FUQURA
LONGITUDINAL SECTION OF A DRY TYPE FUQURA NEAR WADI ARROUB

MICHAEL BAKER JR. INC.
HARZA ENGINEERING COMPANY

DATE 12-7-54 | DWG. Nº JR-6

JR-6



② 290m NW $141^{o}/198^{o}$ 4 $\frac{1}{hhz}$

>2.5	7.8 - 8.5
>2.8	7.9 - 8.6
>2.8	8.0 - 8.9
>2.8	7.9 - 8.9

PLOWED GROUND. 0-150cm MODERATE GYPSUM. 90-150cm WELL MODIFIED GRAY MARL. 60-90cm HEAVY SILTY CLAY.

⑩ 170m NE $141^{5}/197^{5}$ 4 $\frac{3st}{hhzu_2}$

>2.8	7.8 - 8.6
>2.8	7.9 - 9.1
>2.6	8.1 - 8.7

PLOWED UNEVEN SURFACE REQUIRING LIGHT TO MODERATE LEVELING. 45-105cm SLIGHTLY MOIST. MODIFIED MARL 105-150cm DEPTH TO MARL IS VARIABLE AND OCCURS AT THE SURFACE IN SPOTS.

⑪ 200m NE $141^{5}/197^{o}$ 4 $\frac{1}{hh}$

2.2	7.8 - 8.5
.52	8.0 - 8.7
.36	8.1 - 8.8

SCATTERED SALT TOLERANT WEEDS. UNIFORM TOPOGRAPHY. SURFACE SALT INDICATIONS.

㉑ 270m SE $141^{o}/196^{o}$ 4 $\frac{2s}{hhz}$

1.2	7.7 - 8.0
>2.8	7.5 - 8.0
1.2	7.8 - 8.2

PLOWED. 56-150cm SILTY CLAY LOAM DARK GRAY MODIFIED MARL WITH A FEW THIN LAYERS OF LIGHT GRAY MARL.

㉒ 225m NE $140^{5}/196^{o}$ $\frac{1}{hh}$

.15	8.2 - 8.7
.08	8.6 - 9.0
.13	8.4 - 9.4

YOUNG ORANGES. SMALL AREA SOUTH HAS MODIFIED MARL AT 56cm—DOES NOT WARRANT SEGREGATION.

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PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

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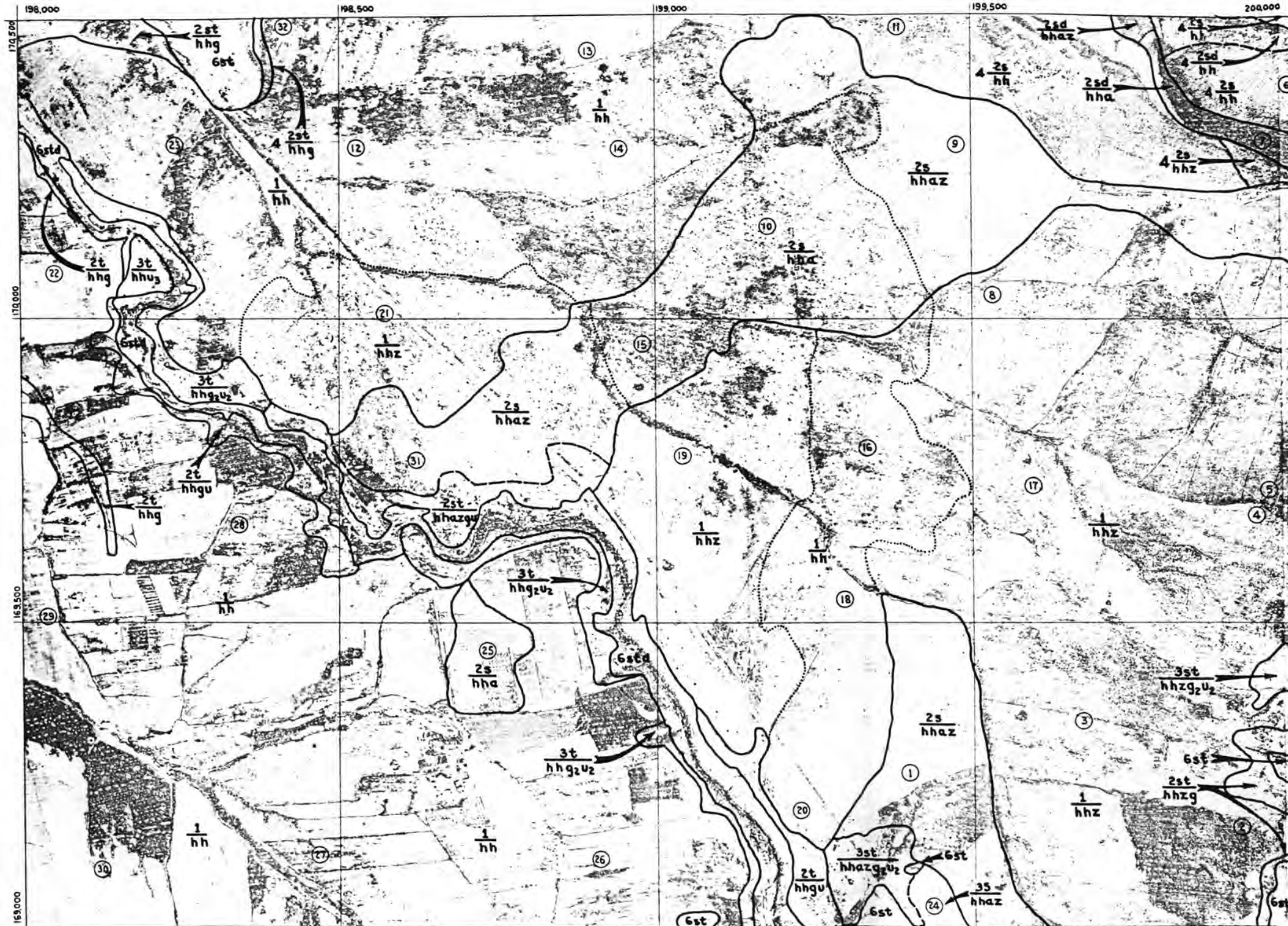
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

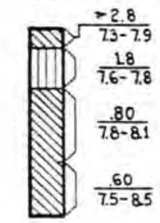
JORDAN VALLEY PROJECT | MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY

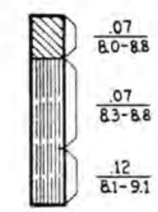
ROCHESTER, PENNA | DATE 2-55 | DWG. NO. JR-29





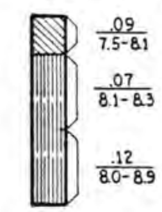
128m S 170⁵/200⁰ $4\frac{2s}{hh}$

SALT BRUSH. BROWN 0-45cm GRAY WELL MODIFIED MARL 45-150cm SOME CONCRETIONS IN PROFILE.



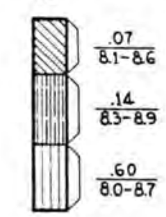
225m SE 170⁰/199⁰ $\frac{1}{hhz}$

GRAIN STUBBLE. THOROUGHLY MODIFIED MARL. 105-150cm. HIGH IN LIME.



145m NW 169⁰/199⁰ $\frac{1}{hh}$

YOUNG ORANGES.



290m NE 169⁵/198⁵ $\frac{2s}{hhaz}$

MESQUITE. MODIFIED MARL WITH YELLOW MOTTLING 98-150 cm

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DATE OF PHOTOGRAPHY NOVEMBER-DECEMBER 1952

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

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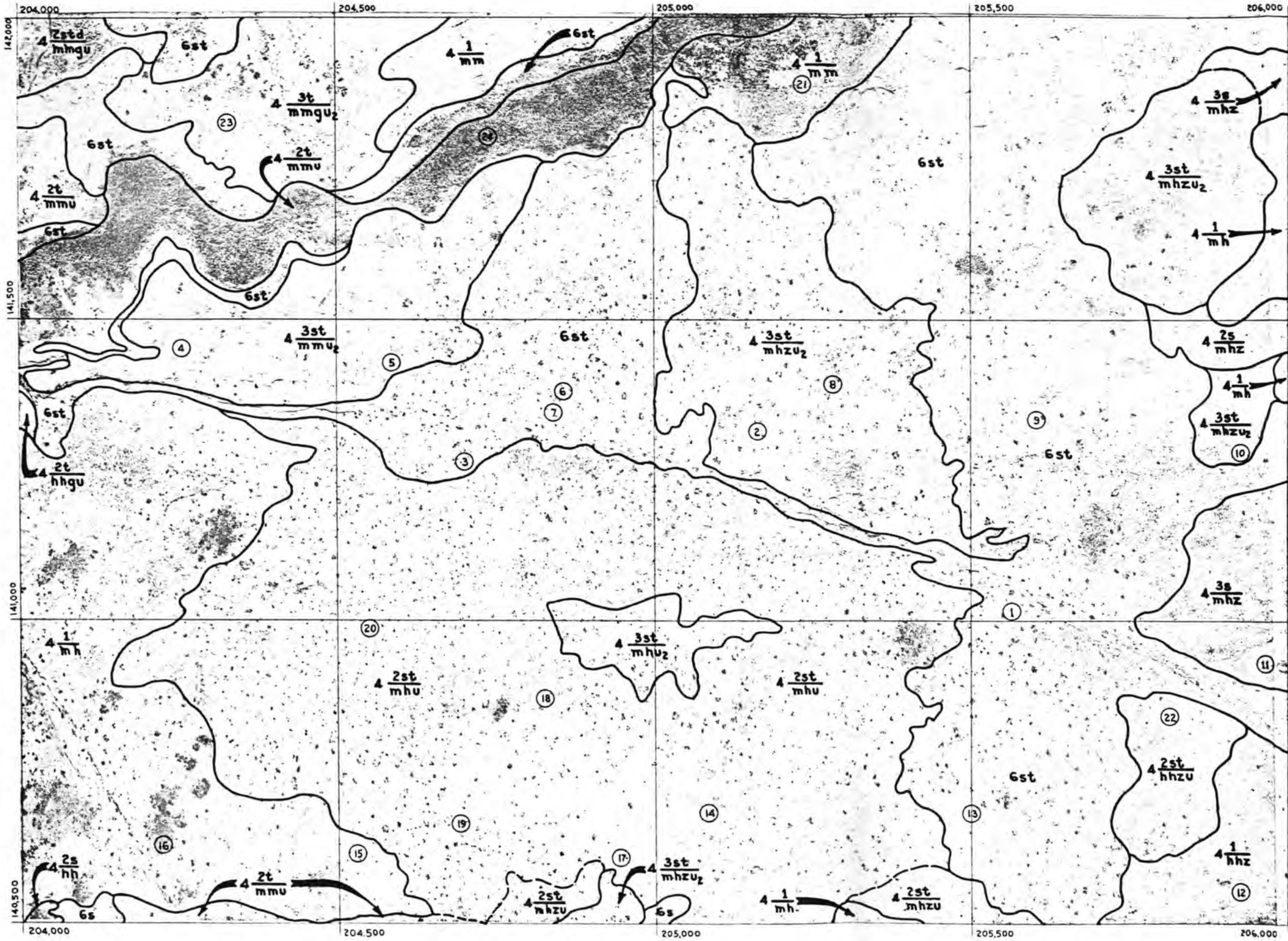
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN		
JORDAN VALLEY PROJECT	MASTER PLAN	
LAND CLASSIFICATION PHOTO MAP		
MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY		
ROCHESTER, PENNA.	DATE 2-55	JR-28



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PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

(2) 250m SE 141² 205² 4 3st/mhzu₂

>2.0 / 7.6 – 8.4; >2.0 / 7.9 – 8.5; >2.0 / 7.9 – 8.5; 2.0 / 7.9 – 8.5

NATIVE GRASSES. 0-45cm RED BROWN LOAM. 18-30" RED BROWN CLAY LOAM. 75-120cm. SLIGHTLY COMPACTED RED CLAY. 120-150cm. LIGHT CLAY LOAM.

(9) 195m SE 141² 205² 6st

GYP HARD PAN ON SURFACE. 0-60 cm RED BROWN CLAY LOAM. 60-75cm GRAY CLAY LOAM. 75-150cm RESIDUAL MARL. LARGE AMOUNT OF GYPSUM IN PROFILE 0-75cm. MOISTURE 60cm. PLUS.

(18) 215m SW 141² 205² 4 2st/mhu

>2.2 / 7.6 – 8.3; 1.8 / 8.2 – 8.5

0-90cm. RED BROWN LOAM. 90-135cm GRAY BROWN CLAY LOAM. 135-150cm RESIDUAL MARL. HEAVY GYPSUM 0-150cm

(21) 270m SE 142² 205² 4 1/mm

.38 / 7.7 – 8.4; .52 / 7.8 – 8.9; 1.2 / 7.6 – 8.3

HOLE ON AN OUTWASHED BENCH — HAS BEEN FARMED. 0-75cm SILT LOAM. 75-150cm SILTY CLAY LOAM.

(22) 200m SW 141² 206² 4 2st/hhzu

1.4 / 7.2 – 7.7; 2.2 / 7.4 – 7.8; >3.0 / 7.4 – 7.8; >2.8 / 7.5 – 8.0; >2.2 / 7.5 – 7.7; >2.8 / 7.7 – 8.2

NATIVE GRASS. SOME GYPSUM SALTS ON THE SURFACE. 0-150cm RED BROWN CLAY LOAM. 135-150cm RESIDUAL MARL - WET SOIL.

	E.Ce	C.E.C.	E.S.R	S.P.	H.C.(cm/hr)	GYP.
0 - 15cm	44	14	23	35	.58	—
15 - 30cm	50	16	25	36	.84	6
30 - 60cm	52	18	14	44	1.52	—
60 - 90cm	61	15	6.1	46	1.20	57
90 - 120cm	65	11	68	28	2.39	—
120 - 150cm	83	15	15	64	1.17	29

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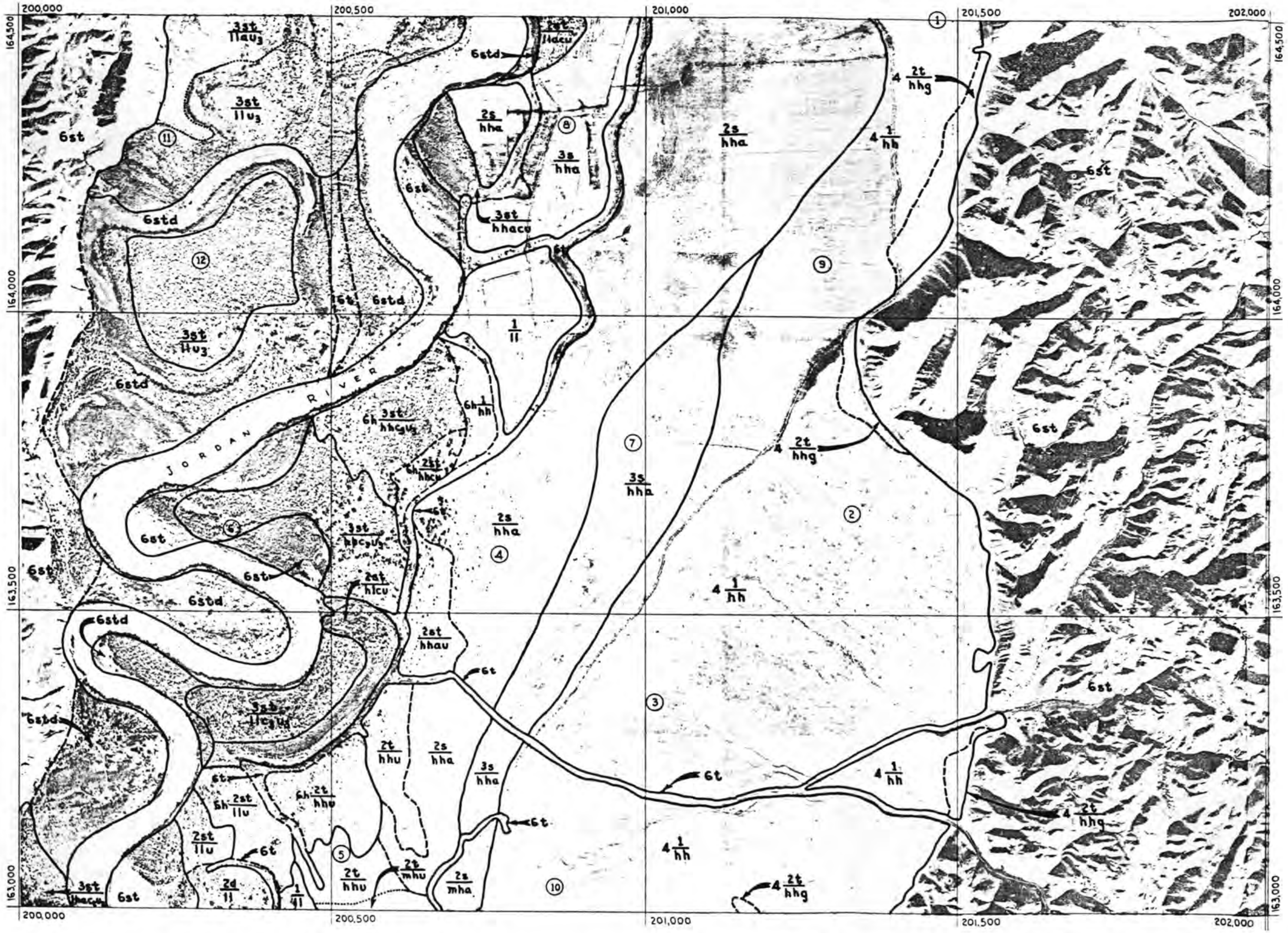
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN

JORDAN VALLEY PROJECT | MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA. DATE 2-55 DWG. NO. JR-27



③ 150m SE 163⁵/201² $4\frac{1}{hh}$

Hole dug in bare ground. Very high indications of salt probably due to outwash from Ghor.

⑥ 210m NW 163⁵/200⁵ $\frac{3st}{hhc_3u_3}$

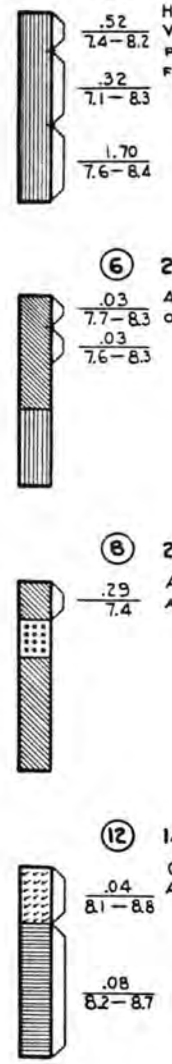
Area is under heavy cover of brush.

⑧ 212m SW 164⁵/201² $\frac{3s}{hha}$

Area is under irrigation at present. Sand 30-60 cm.

⑫ 140m NW 164⁰/200⁵ $\frac{3st}{llu_3}$

Good growth of brush. Alluvial soil from river.



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DATE OF PHOTOGRAPHY NOVEMBER-DECEMBER 1951

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

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THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT
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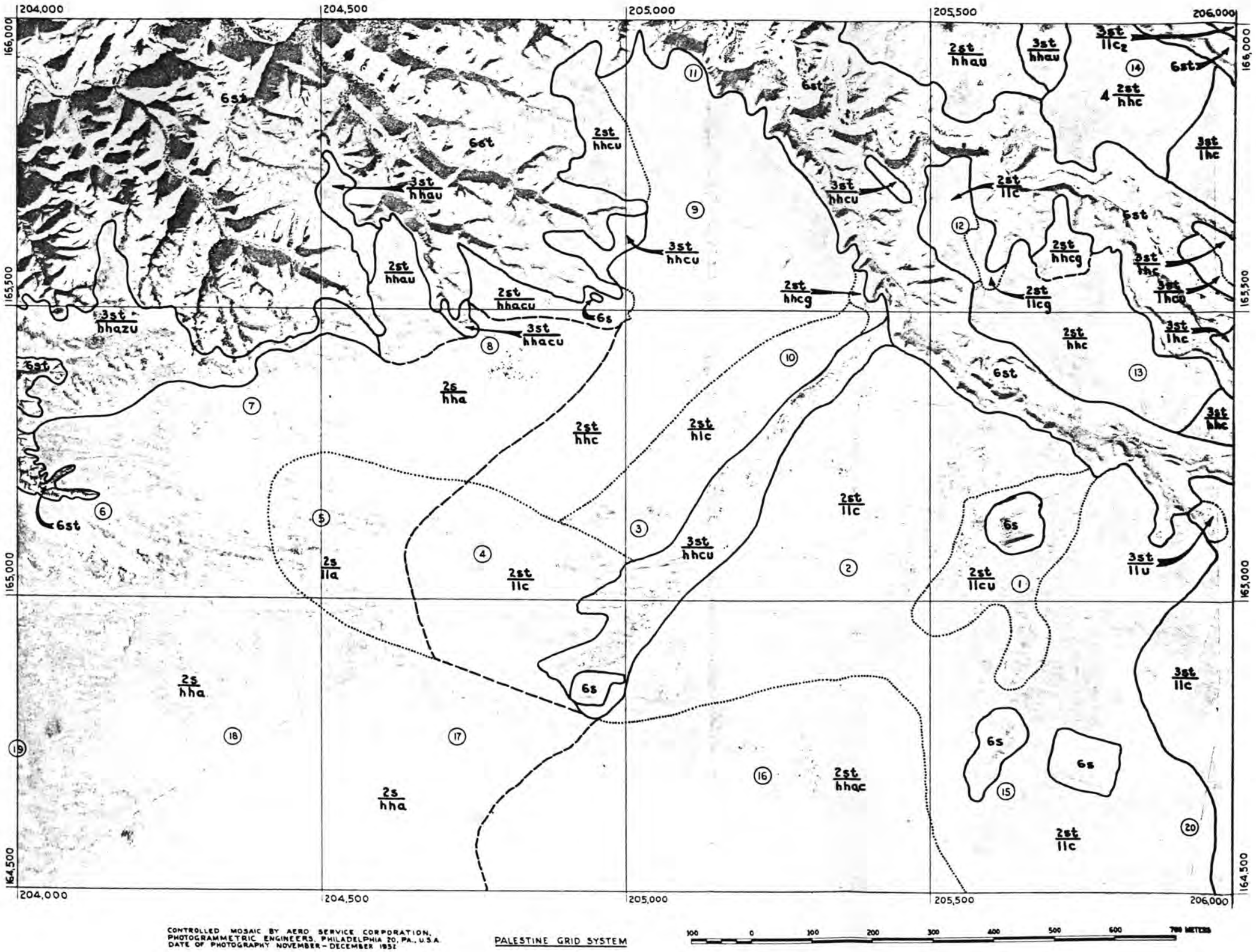
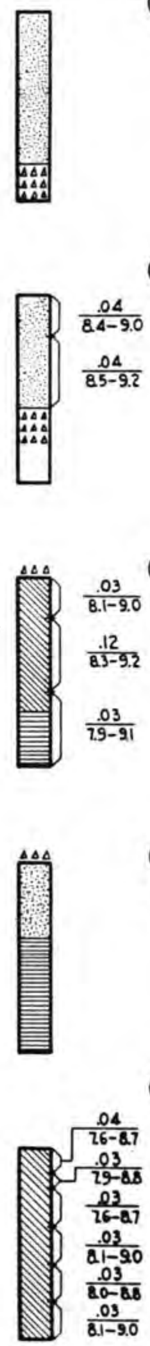
JORDAN VALLEY PROJECT	MASTER PLAN

LAND CLASSIFICATION
PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA.	DATE 2-55	JR-26





(5) 140m N $165^N/204^E$ $\frac{2S}{lld}$

SCATTERED ANNUAL GRASSES:

(12) 160m NE $205^E/165^N$ $\frac{2st}{llc}$

NATIVE GRASS:
SURFACE GRAVEL:

(13) 190m SW $165^N/206^W$ $\frac{2st}{hhc}$

SCATTERED ANNUAL GRASSES:
CONSIDERABLE SURFACE ROCK:

(15) 210m NE $205^E/164^N$ $\frac{2st}{llc}$

GOOD GROWTH OF ANNUAL GRASSES: SOME SURFACE ROCK:

(17) 350m NE $164^N/204^E$ $\frac{2S}{hha}$

ANNUAL GRASSES: PROFILE LOCATED IN BARE SPOT: 20% EXCH. NA. 60-90cm :

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LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR, INC
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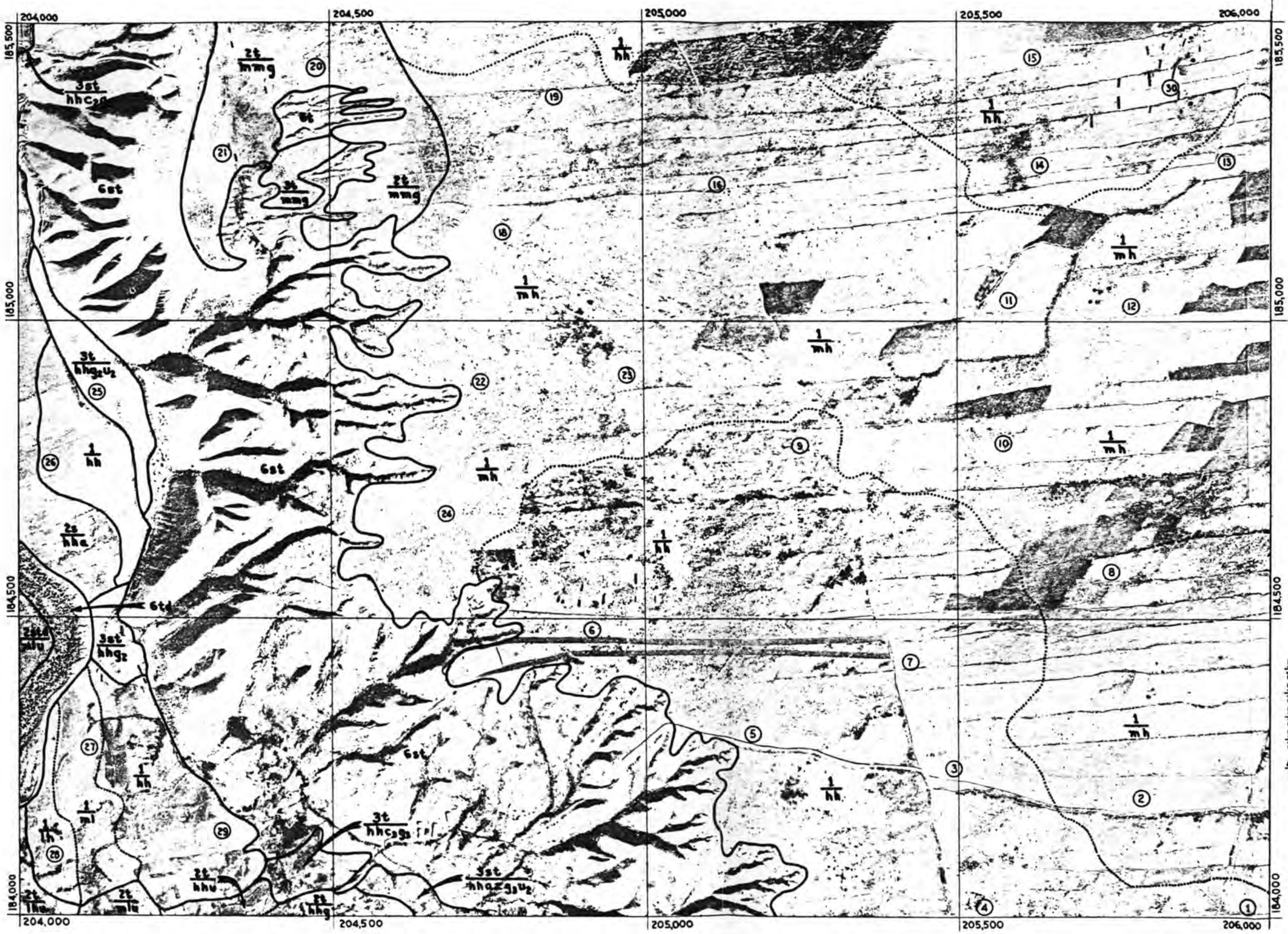
ROCHESTER PENNA | DATE 2-55 | DWG. NO. JR-25 | SHEET 8 OF 8



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PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS

(6) 40 m W 184⁵/205⁸ — 1/hh

.06 / 8.0–8.7
.05 / 8.1–8.7
.05 / 8.2–8.9

SMALL GRAIN – GOOD. SMOOTH TOPOGRAPHY. MODIFIED MARL 127–150 cm. RED BROWN SOIL 45–127 cm.

(16) 300 m SE 185⁵/205⁸ — 1/mh

.04 / 8.2–8.7
.05 / 8.2–8.8
.04 / 8.2–8.9

CULTIVATED GRAIN – GOOD STAND. IRRIGATED. GRAY BROWN LOAM 97–150 cm. COMPACTED PROFILE – FRIABLE.

	ECe	S.P.	C.E.C.	E.S.P.	HC mm/hr
52–97cm	.43	60%	18	3.7	39.4

(20) 80 m SW 185⁵/204⁸ — 2t/mmg

.04 / 8.0–8.8
.12 / 8.0–8.7
.24 / 7.7–8.5

SMALL GRAIN GOOD. HOLE ON A 5% SLOPE. LIGHT RED BROWN PROFILE – FRIABLE. HEAVY SILT LOAM 45–150 cm.

(26) 240 m SE 185²/204⁸ — 1/hh

.15 / 7.8–8.9
.12 / 7.9–9.1
.12 / 7.9–9.1

SMALL GRAIN – FAIR CROP. SMOOTH TOPOGRAPHY. MODIFIED MARL – MOIST PROFILE.

(30) 220 m SW 185⁵/206⁸ — 1/hh

58/21 — .08 / 7.8–8.4
55/26 — .05 / 7.8–8.4
52/25 — .04 / 7.9–8.4
56/21 — .03 / 7.8–8.3
40/16 — .03 / 8.1–8.6

CULTIVATED – IRRIGATED. RED BROWN FRIABLE MOIST PROFILE. TEXTURE BORDERS ON SILTY CLAY LOAM 0–90 cm. – HEAVIER IN MOST OF AREA.

	ECe	C.E.C.	E.S.P.	S.P.	GYPSUM	HC mm/hr	INFILTRATION mm/hr
0–15cm	.99	21	0.87	45	<1	10.7	10.0
60–90cm	.43	14	1.50	39	<1	19.1	—

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THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM O' THE JORDAN

JORDAN VALLEY PROJECT — MASTER PLAN

LAND CLASSIFICATION PHOTO MAP

MICHAEL BAKER JR., INC.
HARZA ENGINEERING COMPANY

ROCHESTER, PENNA. — DATE 2-55 — JR-34

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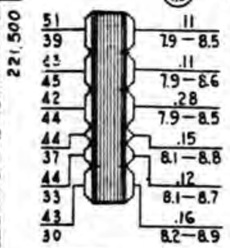
DATE OF PHOTOGRAPHY NOVEMBER - DECEMBER 1952

PALESTINE GRID SYSTEM

100 0 100 200 300 400 500 600 700 METERS



② 250m SW 221⁵/205⁵ 2d/hh

LAND IS PRESENTLY IRRIGATED:
CAULIFLOWER DOING POORLY:
WATER TABLE AT 120 cm.:

DEPTH	EXCH. NA. m/100g	CEC	ESP	SP	GYP	H.C. mm/hr	INFILTRATION mm/hr	DISPERSION
0-30cm	0.67	34	2.0	59	<1	6.1	15.0	39
30-60cm	0.85	25	3.0	57	<1	9.4		43
60-90cm	2.80	26	11.0	59	<1	41.5		41
90-105cm	1.10	24	4.4	61	<1	16.8		48
105-120cm	0.82	21	4.0	52	<1	51.0		62
120-150cm	0.42	17	2.5	66	<1	33.0		73

④ 200m NE 221⁰/204⁵ 1/mm

IRRIGATED SMALL GRAIN:
RED BROWN LOAM 0-60 cm.:

⑫ 150m E 220⁵/205⁵ 1/hh

IRRIGATED SMALL GRAIN:
RESIDUAL MARL BELOW 115 cm.

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THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF THE JORDAN		
JORDAN VALLEY PROJECT	MASTER PLAN	
LAND CLASSIF·CATION PHOTO MAP		
MICHAEL BAKER JR., INC. HARZA ENGINEERING COMPANY		
ROCHESTER PENNA.	DATE 2-55	DWG. NO. JR 23


LAKE TIBERIAS
DEAD SEA
BEISAN
JERICHO
TO JERUSALEM
Class 1 Suitable for sustained high production of any climatically adapted crop with minimum costs of management
Class 2 Slightly less productive, adapted to fewer crops, and more difficult and costly to manage because of slight to moderate limitations of soil, topography, or drainage.
Class 3 Restricted productivity because of moderate to severe limitations of soil, topography, or drainage.
Class 4 Lands presently saline in character above limits for class 1, 2, or 3 which upon leaching may become class 1, 2, or 3 in productive capacity.
Class 6 Unsuitable for irrigated cropping because of extreme limitations of soil, topography, drainage.
Boundary of area classified
Main Canal
SCALE IN KILOMETERS
PALESTINE GRID
N 238,000
E 202,000
THE COOPERATIVE DEPARTMENT FOR WATER RESOURCES DEVELOPMENT HASHEMITE KINGDOM OF JORDAN
JORDAN VALLEY PROJECT
MASTER PLAN
LAND CLASSIFICATION
MICHAEL BAKER JR INC
HARZA ENGINEERING COMPANY
ROCHESTER, PENNA
DATE 2-55
DWG NO. JR-21