B. 3. 7 Proposed Subsurface Drainage

1. Proposed Subsurface Drainage Rate

(1) Concepts and Drainage Rate of Subsurface Drainage

1) Tolerance of berseem in high groundwater : 5 days

2) Rainfall for planning (1/10 year)

October : 189 mm for 5 days
November : 212 mm for 5 days (as critical month)

3) Evapotranspiration (ET) for 5 days

October : 12.5 mm (2.5 mm/day)
November : 7.0 mm (1.4 mm/day)

4) Soil class : D for both cases

5) Category of land use : pasture or range

6) Hydraulic condition : (see Table B. 3. 6 -1)

Good (Without farming drainage, hereafter w/o F. D)
Fair (with farming drainage, hereafter w/ F. D)

7) Runoff curve number : CN (see Table B. 3. 6 - 1)

CN = 80 (w/o F. D)
CN = 84 (w/o F. D)

8) Antecedent moisture condition (AMC)

October : AMC-II (antecedent 5 days rainfall 35 mm)
November : AMC-II (antecedent 5 days rainfall 50 mm)

AMC by Antecedent Rainfall

AMC	Antecedent 5 day Rainfall (mm)	
	Fallow Season	Growing Season
I	0 < < 12.7	0 < <35.5
II	12.7 < < 28	35.5< <53.3
III	28 <	53.3<

Source : HWDP-1 report, B-3

9) Adjustment of CN by AMC (see Table B. 3. 6 - 2)

October : CN = 80 (w/o F. D)
: CN = 84 (w/ F. D)
November : CN = 91 (w/o F. D)
: CN = 93 (w/ F. D)

10) Potential maximum retention (S)

$S = (25,400/CN) - 254$ (mm)

therefore;

October : S = 63.5 mm (w/o F. D, CN = 80)
: S = 48.4 mm (w/ F. D, CN = 84)
November : S = 25.1 mm (w/o F. D, CN = 91)
: S = 19.1 mm (w/o F. D, CN = 93)

11) Surface runoff rainfall (Re) is drained by drainage ditch

$Re = (P - 0.2*S)^2/(P + 0.8*S)$

therefore;

October : Re = 130 mm (w/o F. D)
: Re = 141 mm (w/ F. D)
November : Re = 184 mm (w/o F. D)
: Re = 191 mm (w/o F. D)

12) Infiltration (I) to soil in 5 days

$I = P - (Re + ET)$

therefore;

October : I = 189 - (130 + 12.5) = 46.5 mm (or 9.3 mm/day) (w/o F. D)
I = 189 - (141 + 12.5) = 35.5 mm (or 7.1 mm/day) (w/o F. D)
November :I = 212 - (184 + 7) = 21 mm (or 4.2 mm/day) (w/o F. D)
I = 212 - (191 + 7) = 14 mm (or 2.8 mm/day) (w/ F. D)

13) Drainage rate (R) considered deep percolation (Dp)

R = I - Dp (where; Dp = 2 mm/day by observation by M/P study)

October	: R = 7.3 mm/day	(w/o F. D)
	: R = 5.1 mm/day	(w/ F. D)
November	: R = 2.2 mm/day	(w/o F. D)
	: R = 0.8 mm/day	(w/o F. D)

In above study, I and R of October are too high because of following reasons;

- Rate of October is estimated under AMC-II, therefore, some of infiltration is retained as moisture in the soil.
- If this high drainage rate is applied, most of rainfall will be drained through subsurface drainage, and recharge of deep groundwater will be significantly decreased.

Therefore, subsurface drainage rate should be decided at 2.2 mm/day in case without farming drainage, and at 0.8 mm/day in case with farming drainage.

2. Design of Subsurface Drainage

(1) Zones of Subsurface Drainage

Depending on the 16 zones defined in Table B. 3. 1-4, subsurface drainage is studied and designed.

(2) Equation for Subsurface Drainage

The ellipse equation and the modified ellipse equation have applied for analysis. The ellipse equation is applied when the impermeable layer locates shallow from the tile drains, and the modified ellipse equation is applied when deep. The modified ellipse equation is solved with monographs, which are presented in Figure B. 3. 7 - 2 (1/3) to (3/3). The ellipse equation is expressed as below;

$$s = ((4K(m^2 + 2am)/q)^{1/2}$$

where;

s = drain spacing (m)

K = average hydraulic conductivity (m/day)

m = vertical distance, after drawdown, of water table above drain at midpoint between drains (m)

a = depth of barrier below drain (m)

q = drainage rate (m/day)

d = depth of drain (m)

c = depth to water table desired (m)

Figure B. 3. 7 - 1 shows the above factors.

(Note)

Where soil and subsoil materials are underlain by a barrier at relatively shallow depths (twice the depth of the drain or less) which restricts vertical flow and forces the groundwater to flow horizontally toward the drain.

TABLE B.3.7-1 COMPUTATION SHEET OF DRAINAGE SPACING

Class No	Area (ha)	Region No.	Average depth to impervious layer HP (m)	Hydraulic conductivity K (m/day)	Applied HP (m)	Applied K (m/day)	Ellipse Equation d	a	m	a/m	q (mm/day)	m/a	S/a	q/K	q (mm/day)	Deficiency of extract from 2.2 mm/day 2.2-q (mm/day)	Area Satisfied by Open Drainage (ha)	Deficiency of farming Drainage 0.8 mm/day 0.8-q (mm/day)	Area Satisfied by Farming Drainage (ha)	Sub-Total of Open & Farming Drainage (ha)	Ave. Depth of Drain d (m)	a (m)	m (m)	S (m)	m/a	S/a
1	6,096.0	1 4 12	4.0	> 4.65 V.R	4.0	4.650	1.00	3.00	0.80	3.75		0.27	67	0.00050	2.33	0.00	6,096.0	0.00	0.0	6,096.0						
2	21,134.0	2 7 11 21 29	4.0	3.05 - 4.65 R	4.0	3.850	1.00	3.00	0.80	3.75		0.27	67	0.00050	1.93	0.28	0.0	0.00	21,134.0	21,134.0						
3	8,996.0	3 5 13 15 32	4.0	1.52 - 3.05 S.R	4.0	2.285	1.00	3.00	0.80	3.75		0.27	67	0.00050	1.14	1.06	0.0	0.00	8,996.0	8,996.0						
4	7,641.0	6 22 35	4.0	0.49 - 1.52 M	4.0	1.005	1.00	3.00	0.80	3.75		0.27	67	0.00050	0.50	1.70	0.0	0.30	0.0	0.0	0.90	3.1	0.7	70	0.23	23
5	2,467.0	8	> 6.0	1.52 - 3.05 S.R	6.0	2.285	1.00	5.00	0.80	6.25		0.16	40	0.00074	1.69	0.51	0.0	0.00	2,467.0	2,467.0						
6	12,875.0	9 14 17 36	2.0	1.52 - 3.05 S.R	2.0	2.285	1.00	1.00	0.80	1.25	0.51	0.80	200	0.00023	0.53	1.67	0.0	0.27	0.0	0.0	0.90	1.1	0.7	70	0.64	64
7	4,352.0	10 19 30	2.0	3.05 - 4.65 R	2.0	3.850	1.00	1.00	0.80	1.25	0.86	0.80	200	0.00023	0.89	1.31	0.0	0.00	4,352.0	4,352.0						
8	3,601.0	16 26 37	0.8	1.52 - 3.05 S.R	0.8	2.285	1.00	-0.20	0.80	0					0.00	2.20	0.0	0.80	0.0	0.0	0.90	-0.1	0.7	70		
9	5,557.0	18 25 28	1.5 - 2.0	> 4.65 V.R	2.0	4.650	1.00	1.00	0.80	1.25	1.04	0.80	200	0.00023	1.07	1.13	0.0	0.00	5,557.0	5,557.0						
10	4,839.0	20 24	0.8 - 1.0	3.05 - 4.65 R	1.0	3.850	1.00	0.00	0.80	0					0.00	2.20	0.0	0.80	0.0	0.0	0.90	0.1	0.7	70	7.00	700
11	2,666.0	23		2.3 0.49 - 1.52 M	2.3	1.005	1.00	1.30	0.80	1.63	0.27	0.62	154	0.00028	0.28	1.92	0.0	0.52	0.0	0.0	0.90	1.4	0.7	70	0.50	50
12	261.0	33	1.7 - 2.0	< 0.49 S	2.0	0.490	1.00	1.00	0.80	1.25	0.11	0.80	200	0.00023	0.11	2.09	0.0	0.69	0.0	0.0	0.90	1.1	0.7	70	0.64	64
13	1,425.0	27		5.6 0.49 - 1.52 H	5.6	1.005	1.00	4.60	0.80	5.75		0.17	43	0.00070	0.70	1.50	0.0	0.10	0.0	0.0	0.90	4.7	0.7	70	0.15	15
14	0.0	31		0.2 3.05 - 4.65 R	0.2	3.850	1.00	-0.80	0.80	0					0.00	2.20	0.0	0.80	0.0	0.0	0.90	-0.7	0.7	70		
15	170.0	34		4.0 < 0.49 S	4.0	0.490	1.00	3.00	0.80	3.75		0.27	67	0.00050	0.25	1.96	0.0	0.56	0.0	0.0	0.90	3.1	0.7	70	0.23	23
16	0.0	38		1.5 0.49 - 1.52 M	1.5	1.005	1.00	0.50	0.80	0.63	0.14	1.60	400	0.00015	0.15	2.05	0.0	0.65	0.0	0.0	0.90	0.6	0.7	70	1.17	117
Total	82,080.0																6,096.0		42,506.0	48,602.0						

q/K	q (mm/day)	Deficiency of extract from 2.2 mm/day 2.2-q (mm/day)	Area Satisfied with Drain (ha)	Deficiency of Farming Drainage 0.8 mm/day 0.8-q (mm/day)	Area Satisfied with Farming Drainage (ha)	Area with Drain/ or Drain + Farm Drang (ha)	Total Area (ha)	Sartisfied Percentage (%)	Remaining Area (ha)	Ave. Depth of Drain d (m)	a (m)	m (m)	S (m)	m/a	S/a	q/K	q (mm/day	Deficiency of extract from 2.2 mm/day 2.2-q (mm/day)	Area Satisfied with Drain (ha)	Deficiency of Farming Drainage 0.8 mm/day 0.8-q (mm/day)	Area Satisfied with Farming Drainage (ha)	Area with Drain/ or Drain + Farm Drang (ha)	Total Area (ha)
			0.0		0.0	0.0	6,096.0	100	0.0										0.0		0.0	0.0	6,096.0
			0.0		0.0	0.0	21,134.0	100	0.0										0.0		0.0	0.0	21,134.0
			0.0		0.0	0.0	8,996.0	100	0.0										0.0		0.0	0.0	8,996.0
0.0033	3.32	0.00	7,641.0	0.00	0.0	7,641.0	7,641.0	100	0.0										0.0		0.0	0.0	7,641.0
			0.0		0.0	0.0	2,467.0	100	0.0										0.0		0.0	0.0	2,467.0
0.0014	3.20	0.00	12,875.0	0.00	0.0	12,875.0	12,875.0	100	0.0										0.0		0.0	0.0	12,875.0
			0.0		0.0	0.0	4,352.0	100	0.0										0.0		0.0	0.0	4,352.0
	0.67	1.53	0.0	0.13	0.0	0.0	0.0	0	3,601.0	0.80	0	0.6	30			0.00145	3.66	0.00	3,601.0	0.00	0.0	3,601.0	3,601.0
			0.0		0.0	0.0	5,557.0	100	0.0										0.0		0.0	0.0	5,557.0
0.00045	1.73	0.47	0.0	0.00	4,839.0	4,839.0	4,839.0	100	0.0										0.0		0.0	0.0	4,839.0
0.002	2.01	0.19	0.0	0.00	2,666.0	2,666.0	2,666.0	100	0.0										0.0		0.0	0.0	2,666.0
0.0014	0.69	1.51	0.0	0.11	0.0	0.0	0.0	0	261.0	0.80	1.2	0.6	30	0.50	25	0.0055	2.70	0.00	261.0	0.00	0.0	261.0	261.0
0.0042	4.22	0.00	1,425.0	0.00	0.0	1,425.0	1,425.0	100	0.0										0.0		0.0	0.0	1,425.0
	0.00	2.20	0.0	0.80	0.0	0.0	0.0	#DIV/0!	0.0										0.0		0.0	0.0	0.0
0.0033	1.62	0.58	0.0	0.00	170.0	170.0	170.0	100	0.0										0.0		0.0	0.0	170.0
0.00115	1.16	1.04	0.0	0.00	0.0	0.0	0.0	#DIV/0!	0.0										0.0		0.0	0.0	0.0
			21,941.0		7,675.0	29,616.0	78,218.0	95	3,862.0										3,862.0		0.0	3,862.0	82,080.0

FIGURE B. 3. 7 - 1 CROSS-SECTION SHOWING SYMBOLS USED IN ELLIPSE EQUATION

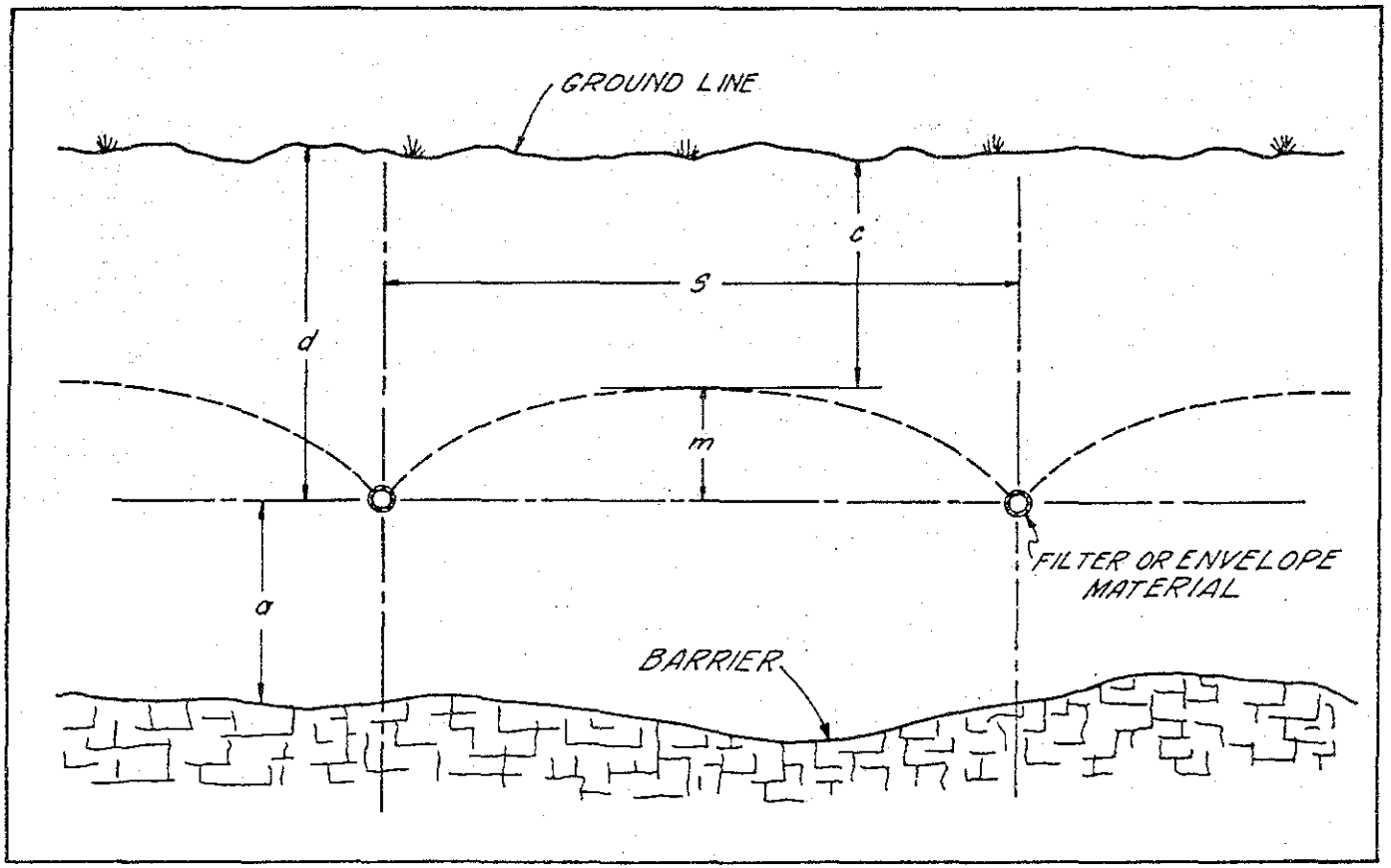


FIGURE B. 3. 7 - 2 GRAPHICAL SOLUTION OF MODIFIED ELLIPSE EQUATION (1/3)

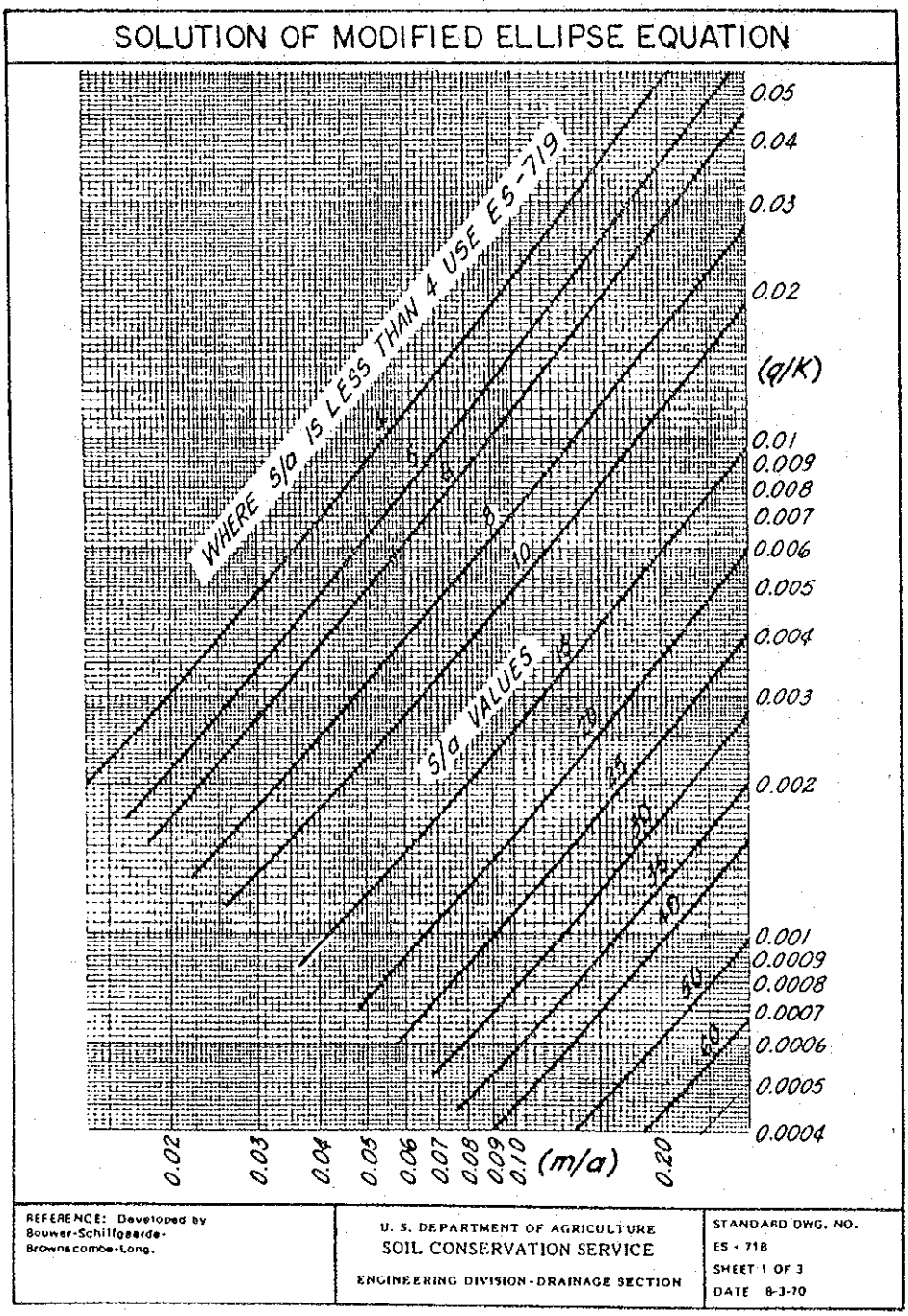


FIGURE B.3.7-2 GRAPHICAL SOLUTION OF MODIFIED ELLIPSE EQUATION (2/3)

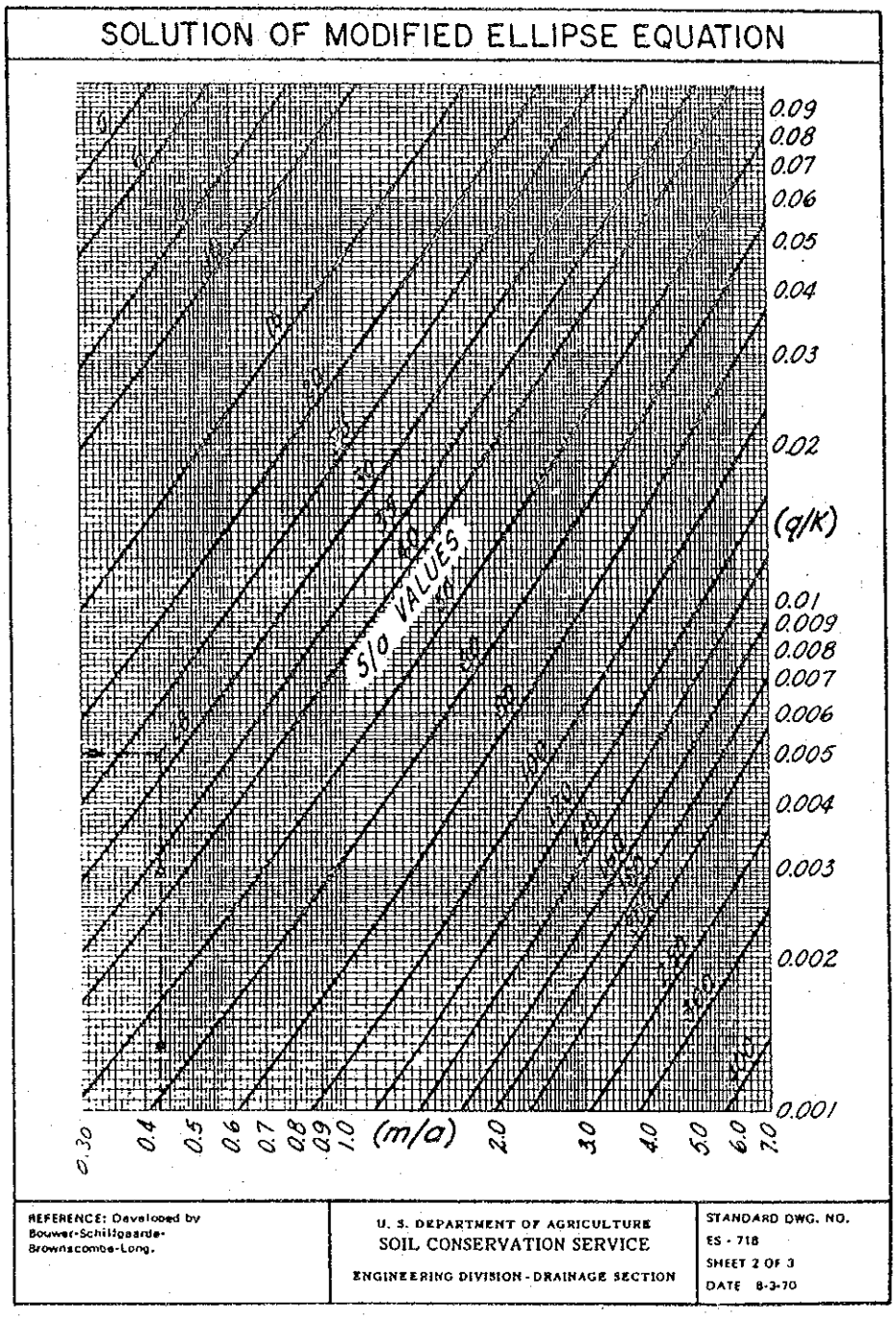
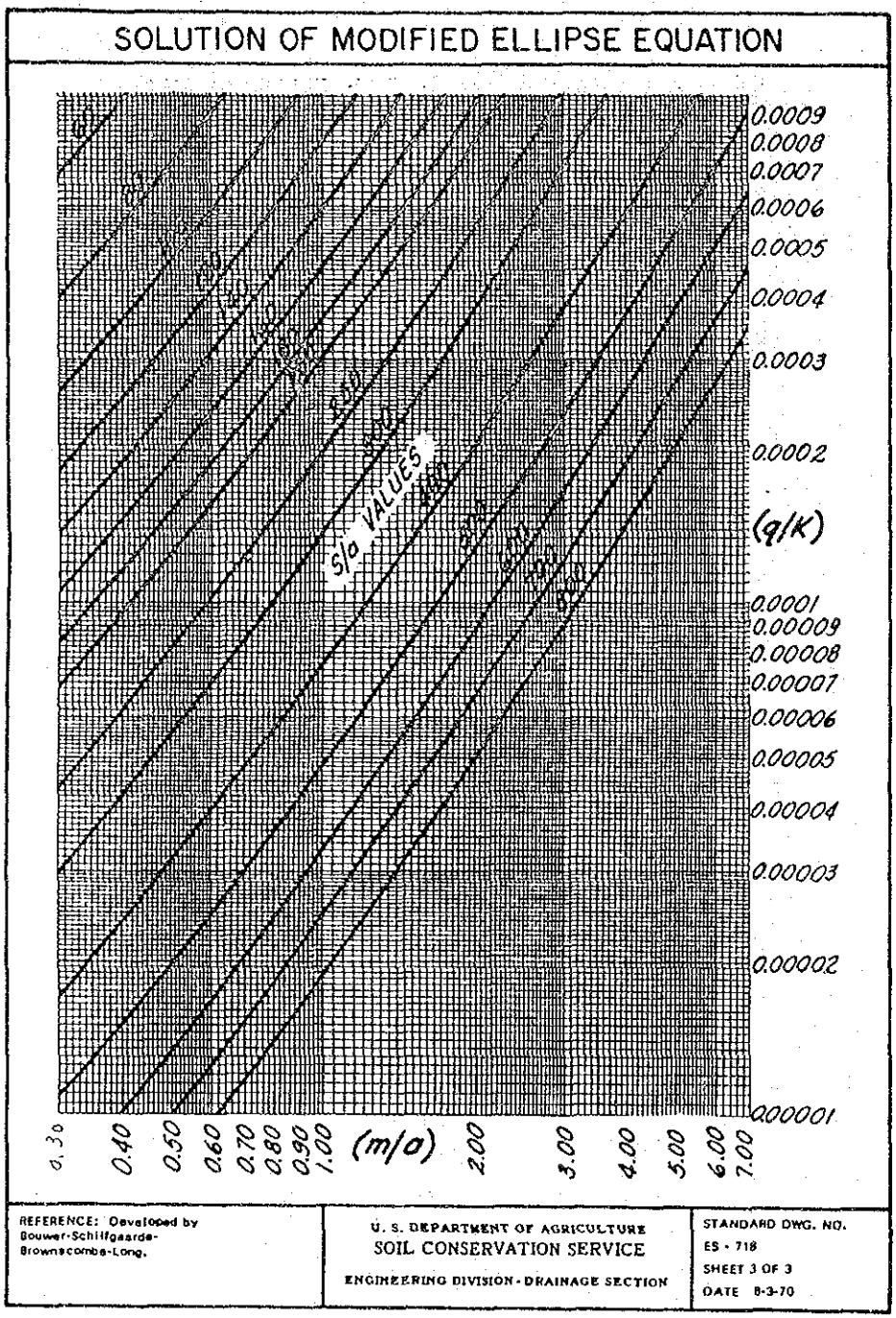


FIGURE B. 3. 7 - 2 GRAPHICAL SOLUTION OF MODIFIED ELLIPSE EQUATION (3/3)



APPENDIX B. 4 ON-FARM FACILITIES

CONTENTS

LIST OF TABLES

LIST OF FIGURE

B. 4. 1 Soil Bearing Test

1. Workability of Agricultural Machinery

The tests were conducted in late August at the four sites located in the poor ground areas (less than 2kg/cm^2 soil bearing force) which were identified in the M/P (refer to Figure B.4.1-1). In the survey, the penetration resistances were measured under two conditions: on the dry paddy fields just after harvesting and on the wet paddy fields at 24 hours after supplying water (3 cm depth). And the measurement depth was from 0 cm to 20 cm below the field surfaces.

As the results of the survey under the wet conditions, the bearing capacity at No.33 site did not fulfill the required level for plowing, harvesting and puddling (average 4 kg/cm^2, minimum 2 kg/cm^2) (refer to Table B.4.1-1).

2. Workability of Construction Machinery

At the mentioned four sites, the penetration resistances were measured until 50 cm depth from the field surfaces. The survey was carried out on the after harvesting paddy.

From the results at No.17 site, it becomes clear that even swampy type bulldozers are critically applicable after heavy rainfall in the poor ground areas, as this type is workable on the ground having more than 3 kg/cm^2 cone index (average within 50 cm depth) (refer to Table B.4.1-1).

(Data) Required minimum cone indexes of standard type bulldozers
(average within 50 cm depth):
15-ton class; 5 kg/cm^2, 21-ton class; 7 kg/cm^2.

B. 4. 2 Present Conditions of Sample Areas

The following six sample areas were chosen from the Project Area in order to perform the preliminary designs of land consolidation. The locations were selected considering the irrigation and drainage conditions and land holding conditions, and so on.

After deciding the sample areas, the topographic mapping (1:1,000 scale) and the cadastral survey of these areas were undertaken by the local contractor. The present conditions of these sample areas, on-farm facilities and land use, etc., are summarized based on the cadastral survey results (refer to Tables B.4.2-1 and B.4.2-2).

Sample Areas

Sample Area	Location	Total Area(ha)	Remarks
Katiposht	High Land	85.0	
Ejibar Kola	High Land	100.1	CAPIC Pilot Farm
Eslamabad	Middle Land	63.0	CAPIC Pilot Farm
Darzi Kola	Middle Land	97.0	
Moallem Kola	Low Land	125.7	
Suteh	Low Land	124.4	CAPIC Pilot Farm

Note) Total Area (ha): Paddy and on-farm facilities areas.

B. 4. 3 Sample Designs

Before the commencement of the sample designs, the improvement levels (type-A&B improvement) and the basic design criteria were studied. Then, the preliminary designs of land consolidation were carried out for the afore-mentioned six sample areas.

1. Design Criteria

The design criteria of the on-farm ditches are as follows:

(1) Terminal Irrigation Ditches

1) Typical Cross-section

The shape and size of the lateral irrigation ditches and the irrigation ditches are as follows:

Ditch type	:	Earth ditch,
Side slope	:	1:1 (trapezoid shape),
Berm width	:	30 cm,
Minimum bottom width	:	30 cm,
Minimum ditch depth	:	30 cm.

2) Hydraulic Study

(a) Applied Equation

The Manning equation is applied in calculation using the roughness coefficient of 0.03.

(b) Maximum Velocity

Maximum velocities are same as canal designs.

(c) Minimum Velocity

In flat areas, it is difficult to employ the standard minimum velocities (0.45-0.9 m/s for non sedimentation and 0.7 m/s for non-grass growing). Consequently, some degree of sedimentation and grass growing are not avoidable, and maintenance works, such as removing sediments and grasses are required.

On the other hand, in sloped areas, the minimum velocity is set at 0.3 m/s quoted from the CAPIC detailed designs.

(d) Freeboard

Freeboard is set at from 5 to 10 cm.

(2) Terminal Drainage Ditches

1) Typical Cross-section

The shape and size of the lateral drainage ditches and the drainage ditches are designed as follows:

Ditch type	:	Earth ditch,
Side slope	:	1:1 (trapezoid shape),
Berm width	:	30 cm,
Minimum bottom width:		30 cm,
Minimum ditch depth	:	0.6 m (Shallow type),
		1.0 m (Deep type),

1.5 m(Deeper type lateral drainage ditch in the tile drainage areas).

2) Hydraulic Study

(a) Applied Equation

The Manning equation is applied in calculation using the roughness coefficient of 0.035.

(b) Maximum and Minimum Velocities and Freeboard

Same as the irrigation ditches.

2. Outline of Designed On-farm Facilities

The type-A improvement sample designs were carried out for the all six sample areas. On the other hand, those of the type-B were performed for the two sample areas, Ejibar Kola and Suteh areas. The salient features of the designed on-farm facilities are tabulated in the following Tables (for general plans, refer to Drawings):

Type-A Improvement : Tables B.4.3-1 and B.4.3-2,
Type-B Improvement : Tables B.4.3-3 and B.4.3-4.

B. 4. 4 Earth Works Volume of Sample Designs

1. Calculation Method and Conditions

In the study, the calculation was carried out under the following method and conditions:

1) The calculation was carried out for the type-A improvement only.
2) Mesh method was adopted in the calculation of cutting/filling volumes and moving distances. Each field-lot was partitioned into 15 parts: 5-division for long side and 3-division for short side.
3) The calculation was carried out for alternate field-lots, viz. about 50% area calculation.

4) The elevation of existing plots was referred to the 1:1,000 scale topographic maps.

5) The embankment volumes for farm roads, ditches and boundary ridges are counted using their standard sections.

2. Results of Calculation

The results of the calculation are, as follows:

Earth Works Volumes

Sample Area	Short Side Length (m)	Cutting/Filling* Volume (m^3/ha)	Moving** Distance (m)	Remarks
Katiposht	30	2,470	43	
Ejibar Kola	30	1,680	43	
Eslamabad	30	1,260	45	
Darzi Kola-1	30	1,240	45	Sloped area
Darzi Kola-2	40	650	39	Gentle area
Moallem Kola	50	750	43	
Suteh	60	630	38	

Note) *: Including 10% increase to the calculated values. This is considered for calculation tolerance and the earth moving among the field-lots.
**: These figures are area-wise weighted averages.

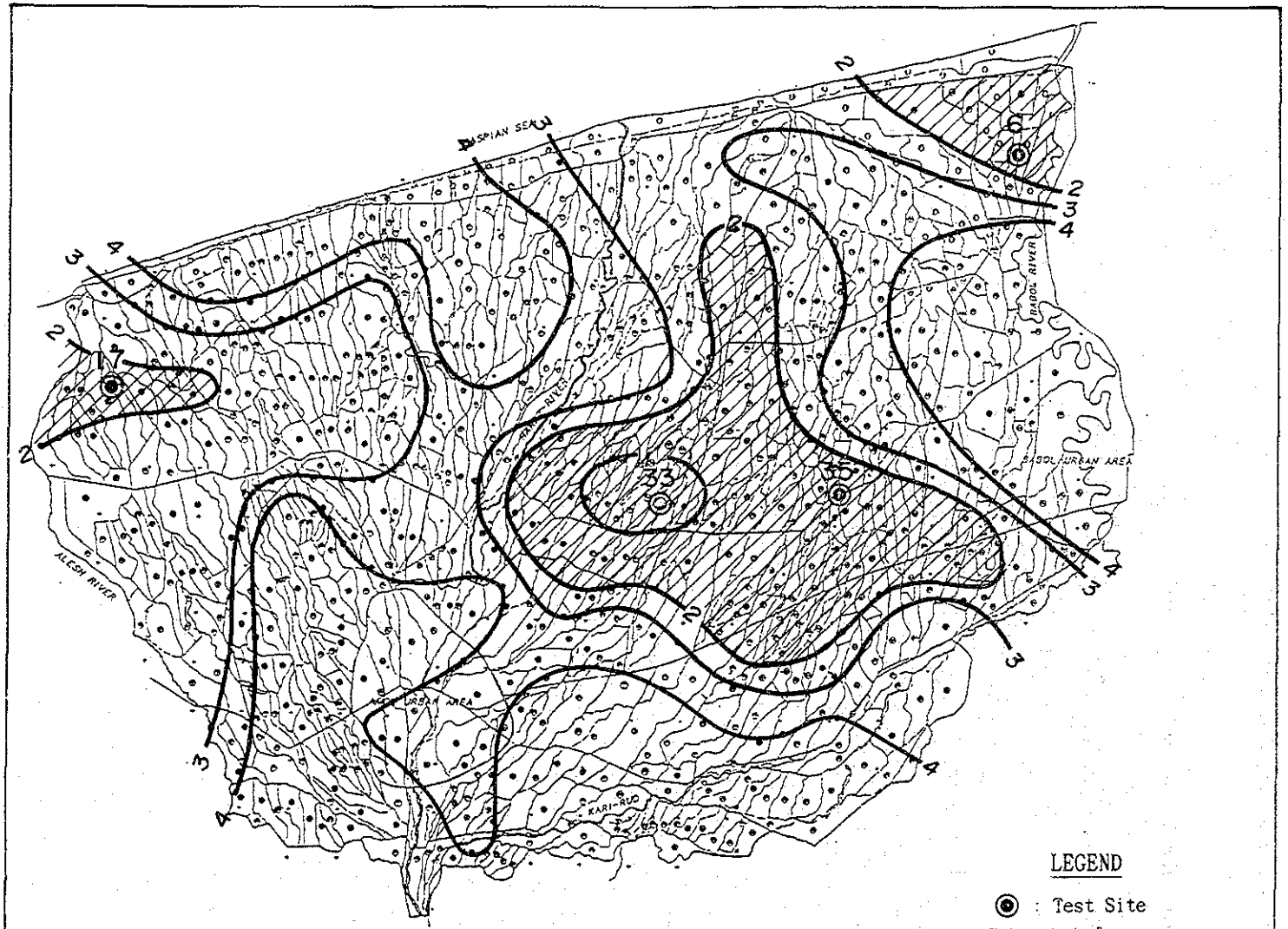


FIGURE B.4.1-1 LOCATION OF SOIL BEARING TEST

TABLE B.4.1-1 RESULTS OF SOIL BEARING TEST (Unit: kg/cm2)

Depth(cm)	5	10	15	20	25	30	35	40	45	50	Ave.	Min.
1. Test of Workability of Agricultural Machinery												
--Just after harvest--												
No. 6	4.9	6.6	10.3	15.0							9.2	4.9
No.17	5.7	5.7	6.1	6.3							6.0	5.7
No.33	2.5	2.8	4.9	7.0							4.3	2.5
No.35	3.3	3.9	5.7	11.6							8.1	3.3
--24 hours after water supplying--												
No.33	1.6	1.6	3.8	8.0							3.8	1.6
No.35	2.6	3.4	5.2	14.4							6.4	2.6
2. Test of Workability of Construction Machinery												
No. 6 (*)	5.0	5.4	8.3	8.5	11.6	15.3	13.7	17.0	14.5	14.5	11.4	5.0
No.17 (**)	0.8	1.6	2.4	2.5	3.4	4.2	4.5	3.5	3.7	3.8	3.0	0.8
No.33 (*)	4.3	6.8	10.8	8.8	6.9	7.2	7.2	6.9	7.0	6.2	7.2	4.3
No.35 (*)	2.8	4.9	9.0	8.5	8.8	9.2	8.8	7.1	5.3	7.1	7.2	2.8

Note) 1. Each figure is an average of twice measurements. If one of a pair fails due to hard soil, the other result is employed.
2. (*): No rainfall in 3 days before measurements, (**): Plenty rainfall in the previous day.

TABLE B.4.2-1 PRESENT ON-FARM FACILITIES AND LAND USE OF SAMPLE AREAS

Item	Ejbarkola	Cateposht	Eslamabad	Darzikola	Suteh	Moallemkola
1. Land Use						
Paddy (ha)	96.4	81.5	60.8	96.3	121.8	122.6
No. of Lots	340	264	559	284	365	246
Ave. Acreage of Lot (m2)	2,835	3,087	1,087	3,390	3,337	4,982
On-farm Facilities						
Ditch (ha)	1.8	1.8	1.3	0.3	1.2	2.2
Farm Road (ha)	1.9	1.8	1.0	0.4	1.4	0.9
Sub-total (ha)	3.7	3.6	2.2	0.7	2.6	3.1
Garden (ha)	0.0	1.3	2.3	1.0	6.5	4.4
Rest (ha)	0.6	5.6	0.0	2.0	3.1	20.7
Grand Total (ha)	100.7	91.9	65.2	100.1	133.9	150.8
Paddy & Facility Area (ha)	100.1	85.0	63.0	97.0	124.4	125.7
2. Major On-farm Facilities						
Ditch (m)	10,260	9,340	5,985	2,082	6,515	5,605
Farm Road (m)	4,770	5,200	2,737	1,460	3,920	1,935
3. Facility Density						
Ditch (m/ha)	102.5	109.8	95.0	21.5	52.4	44.6
Farm Road (m/ha)	47.6	61.1	43.5	15.1	31.5	15.4
4. Facility Area Ratio						
Ditch (%)	1.8	2.1	2.0	0.3	1.0	1.7
Farm Road (%)	1.9	2.1	1.5	0.5	1.1	0.7
Total (%)	3.7	4.2	3.5	0.8	2.1	2.5

Note) Facility densities and area ratios are culculated using paddy & facility areas.

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Ejbarkola)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private & Public	Area (m2)	964,000	0	Area (m2)	17,755	19,370	37,125	6,150	1,001,125	6,150	1,007,275
	No. of Owners	87		No. of Routes	32	16					
	No. of Owners Lots	115		Total Length (m)	10,260	4,770					
	No. of Lots	348									
Total (m2)		964,000	0		17,755	19,370	37,125	6,150	1,001,125	6,150	1,007,275
Total (m)					10,260	4,770					

Note) Above figures are measured using the 1:1,000 scale maps.

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Cateposht)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private	Area (m2)	814,910	7,030	Area (m2)	3,011	2,825	5,836	1,697	820,746	8,727	829,473
	No. of Owners	85		No. of Routes	12	9					
	No. of Owners Lots	111		Total Length (m)	2,135	875					
	No. of Lots	264									
Public	Area (m2)	0	5,500	Area (m2)	14,754	14,969	29,723	54,360	29,723	59,860	89,583
				No. of Routes	24	15					
				Total Length (m)	7,205	4,325					
Total (m2)		814,910	12,530		17,765	17,794	35,559	56,057	850,469	68,587	919,056
Total (m)					9,340	5,200					

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Eslamabad)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private	Area (m2)	607,555	22,578	Area (m2)	2,367	1,645	4,012	0	611,567	22,578	634,145
	No. of Owners	54		No. of Routes	10	5					
	No. of Owners Lots	76		Total Length (m)	1,175	773					
	No. of Lots	559									
Public	Area (m2)	0	0	Area (m2)	10,191	8,047	18,238	0	18,238	0	18,238
				No. of Routes	15	11					
				Total Length (m)	4,810	1,964					
Total (m2)		607,555	22,578		12,558	9,692	22,250	0	629,805	22,578	652,383
Total (m)					5,985	2,737					

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Darzikola)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private	Area (m2)	962,700	5,630	Area (m2)	1,245	319	1,564	750	964,264	6,380	970,644
	No. of Owners	85		No. of Routes	10	2					
	No. of Owners Lots	100		Total Length (m)	512	130					
	No. of Lots	284									
Public	Area (m2)	0	4,450	Area (m2)	1,675	4,144	5,819	19,600	5,819	24,050	29,869
				No. of Routes	4	8					
				Total Length (m)	1,579	1,330					
Total (m2)		962,700	10,080		2,920	4,463	7,383	20,350	970,083	30,430	1,000,513
Total (m)					2,082	1,460					

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Suteh)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private	Area (m2)	1,218,100	16,010	Area (m2)	1,631	0	1,631	160	1,219,731	16,170	1,235,901
	No. of Owners	121		No. of Routes	14	0					
	No. of Owners Lots	200		Total Length (m)	1,375	0					
	No. of Lots	365									
Public	Area (m2)	0	48,500	Area (m2)	10,356	13,522	23,878	30,749	23,878	79,249	103,127
				No. of Routes	9	7					
				Total Length (m)	5,140	3,920					
Total (m2)		1,218,100	64,510		11,987	13,522	25,509	30,909	1,243,609	95,419	1,339,028
Total (m)					6,515	3,920					

TABLE B.4.2-2 RESULTS OF CADASTRAL SURVEY (Present: Moalleakola)

Identification	Paddy (1) Item		Garden (2) (m2)	On-farm Facilities (3) Item	Ditch	Road	Sub-total	Rest(4) (m2)	Total Area (m2) (1)+(3)	(2)+(4)	Total
Private	Area (m2)	1,225,530	32,660	Area (m2)	1,783	202	1,985	0	1,227,515	32,660	1,260,175
	No. of Owners	122		No. of Routes	28	1					
	No. of Owners Lots	144		Total Length (m)	1,375	45					
	No. of Lots	246									
Public	Area (m2)	0	11,500	Area (m2)	19,984	9,113	29,097	207,200	29,097	218,700	247,797
				No. of Routes	7	5					
				Total Length (m)	4,230	1,890					
Total (m2)		1,225,530	44,160		21,767	9,315	31,082	207,200	1,256,612	251,360	1,507,972
Total (m)					5,605	1,935					

Note) 1. Private Rest: House, hut, grass, etc.
2. Public Rest: Cemetery, abbandang, the open along roads and canals, etc.

TABLE B.4.3-1 SAMPLE AREA ON-FARM FACILITIES (Type-A Improvement)

Item	Ejbarkola	Catepostht	Eslamabad	Darzikola	Suteh	Moallemkola
1. Major On-farm Facilities						
Main Farm Road (m)	1,610	1,420	1,370	330	1,140	760
Lateral Farm Road (m)	7,190	5,670	4,390	6,150	6,900	8,600
Total (m)	8,800	7,090	5,760	6,480	8,040	9,360
Lateral Irri. Ditch						
Type I (m)	2,000	570	0	2,720	1,180	720
Type II (m)	650	1,480	530	630	1,030	730
Type III (m)	320	0	110	0	620	570
Type IV (m)	0	350	0	0	120	0
Sub-total (m)	2,970	2,400	640	3,350	2,950	2,020
Irri. Ditch (m)	10,380	8,640	6,510	8,290	11,660	11,760
Total (m)	13,350	11,040	7,150	11,640	14,610	13,780
Lateral Drai. Ditch						
Shallow Type I (m)	2,790	330	0	0	0	0
Shallow Type II (m)	0	0	0	0	0	0
Deep Type (m)	0	0	100	1,660	2,970	3,830
Sub-total (m)	2,790	330	100	1,660	2,970	3,830
Drai. Ditch						
Shallow Type (m)	5,560	5,190	0	0	0	0
Deep Type (m)	0	0	4,850	5,700	6,080	5,220
Sub-total (m)	5,560	5,190	4,850	5,700	6,080	5,220
Total (m)	8,350	5,520	4,950	7,360	9,050	9,050
2. Appurtenant Structures						
Access Road						
Type I (Nos.)	0	0	110	80	110	130
Type II (Nos.)	340	290	0	110	0	0
Terminal Irri. Drop (Nos.)	170	180	80	100	0	0
Turnout (Nos.)	3	2	1	0	2	1
Terminal Drai. Drop (Nos.)	90	100	60	70	0	0
Lateral Irri. Ditch Road Crossing (Nos.)	15	13	3	20	14	14
Lateral Drai. Ditch Road Crossing (Nos.)	9	6	12	8	11	15

TABLE B.4.3-2 SAMPLE AREA ON-FARM FACILITY DENSITIES (Type-A Improvement) (Unit:m/ha)

Item	Ejbarkola	Catepostht	Eslamabad	Darzikola	Suteh	Moallemkola
Major On-farm Facilities						
Main Farm Road	16.1	16.7	21.8	3.4	9.2	6.0
Lateral Farm Road	71.8	66.7	69.7	63.4	55.5	68.4
Total	87.9	83.4	91.5	66.8	64.7	74.5
Lateral Irri. Ditch						
Type I	20.0	6.7	0.0	28.0	9.5	5.7
Type II	6.5	17.4	8.4	6.5	8.3	5.8
Type III	3.2	0.0	1.7	0.0	5.0	4.5
Type IV	0.0	4.1	0.0	0.0	1.0	0.0
Sub-total	29.7	28.2	10.2	34.5	23.7	16.1
Irri. Ditch	103.7	101.6	103.4	85.5	93.8	93.6
Total	133.3	129.8	113.5	120.0	117.5	109.7
Lateral Drai. Ditch						
Shallow Type I	27.9	3.9	0.0	0.0	0.0	0.0
Shallow Type II	0.0	0.0	0.0	0.0	0.0	0.0
Deep Type	0.0	0.0	1.6	17.1	23.9	30.5
Sub-total	27.9	3.9	1.6	17.1	23.9	30.5
Drai. Ditch						
Shallow Type	55.5	61.0	0.0	0.0	0.0	0.0
Deep Type	0.0	0.0	77.0	58.8	48.9	41.5
Sub-total	55.5	61.0	77.0	58.8	48.9	41.5
Total	83.4	64.9	78.6	75.9	72.8	72.0

TABLE B.4.3-3
SAMPLE AREA ON-FARM FACILITIES (Type-B Improvement)

Item	Ejbarkola	Suteh
1. Major On-farm Facilities		
Main Farm Road (m)	3,460	1,200
Lateral Farm Road (m)	8,570	10,960
Total (m)	12,030	12,160
Lateral Irri. Ditch		
Type I (m)	3,090	1,110
Type II (m)	1,060	1,270
Type III (m)	380	690
Type IV (m)	0	110
Sub-total (m)	4,530	3,180
Irri. Ditch (m)	8,760	11,680
Total (m)	13,290	14,860
Lateral Drai. Ditch		
Shallow Type I (m)	1,630	0
Shallow Type II (m)	0	0
Deep Type (m)	0	2,850
Sub-total (m)	1,630	2,850
Drai. Ditch		
Shallow Type (m)	9,420	0
Deep Type (m)	0	9,240
Sub-total (m)	9,420	9,240
Total (m)	11,050	12,090
2. Appurtenant Structures		
Access Road		
Type I (Nos.)	0	180
Type II (Nos.)	340	8
Terminal Irri. Drop (Nos.)	140	0
Turnout (Nos.)	5	2
Terminal Drai. Drop (Nos.)	120	0
Lateral Irri. Ditch		
Road Crossing (Nos.) *)	30	30
Lateral Drai. Ditch		
Road Crossing (Nos.) *)	16	9

Note: *) Including irrigation and drainage ditch road crossings.

TABLE B.4.3-4
SAMPLE AREA ON-FARM FACILITY DENSITIES
(Type-B Improvement) (Unit:m/ha)

Item	Ejbarkola	Suteh
Major On-farm Facilities		
Main Farm Road	34.6	9.6
Lateral Farm Road	85.6	88.1
Total	120.2	97.8
Lateral Irri. Ditch		
Type I	30.9	8.9
Type II	10.6	10.2
Type III	3.8	5.5
Type IV	0.0	0.9
Sub-total	45.2	25.6
Irri. Ditch	87.5	93.9
Total	132.8	119.5
Lateral Drai. Ditch		
Shallow Type I	16.3	0.0
Shallow Type II	0.0	0.0
Deep Type	0.0	22.9
Sub-total	16.3	22.9
Drai. Ditch		
Shallow Type	94.1	0.0
Deep Type	0.0	74.3
Sub-total	94.1	74.3
Total	110.4	97.2

B. 4. 5 Application Method of Sample Designs to the Entire Project Area

1. On-farm Improvement Types

As noted before, two types of on-farm improvement were proposed in the study, viz. type-A & B improvement.

The type-A improvement is of the plan of changing size and shape of lots, and fulfills the basic planning and design criteria of land consolidation. Improved farm by type-A will realize fully the expected effects, e.g. increase of agricultural productivity and preserving a favorable rural environment.

On the other hand, the type-B improvement is of the plan of not changing size and shape of lots. In other words, only terminal irrigation and drainage ditches and farm roads are to be constructed along the present lot boundaries, and no land grading is planned. In principle, each improved lot is planned to be bordered terminal irrigation and drainage ditches and farm roads, which are to be designed based on the afore-mentioned basic design criteria of land consolidation.

2. Application Criteria of Improvement Types to the Entire Project Area

The improvement costs of type-B must be smaller than those of type-A because of not including land grading works. However, generally speaking, the benefits accrued from the type-B improvement will also be smaller than those of type-A because the present size and shape of lots do not assure the high efficiencies of farm machinery. In balance, on the application criteria of improvement types, it can be said that;

a) The on-farm development levcl should satisfy the acceptable economic indicator, e.g. EIRR (economic internal rate of return), etc. and also should be appropriate technically,

b) The type-B improvement may be advantageous in the areas where the present size and shape of lots fulfill the favorite field conditions concerning to the farm machinery workability and the on-farm water management.

Keeping these basic ideas, the application criteria of the improvement types to the entire Project Area were studied and prepared as follows:

(1) Optimum Investment Condition

The on-farm development is planned within the optimum investment level studied in "E.1.2 Suitable Investment Level on Facilities Improvement". This aimed to evaluate the on-farm development level from the economical point of view.

In the study of optimum investment, four alternatives were established on the facilities improvement level, and EIRR's were computed. As the results, the optimum investment level of the on-farm development was estimated to be 191 billion rials in total (financial direct cost in Case-4).

In consequence of the cost estimates, the total on-farm development cost of the proposed improvement level was estimated to be 144 billion rials (financial direct cost), and this figure is below the afore-mentioned optimum investment level. Therefore, the on-farm development plan of the project is judged to be economically feasible.

(2) Application Limit of Type-A Improvement

The type-A improvement is applicable for the areas of which slopes are less than 1/50. This is because, in the areas more than 1/50 land slope, the short side length is limited to about 20 m from the viewpoint of desired field elevation differences between neighboring fields, and this length does not satisfy the required minimum length of 30 m which is necessary for the high working efficiency for combines. Therefore, the type-B improvement is applied for the high lands whose slopes are more than 1/50.

(3) Selection of Type-B Improvement

Present plots are to be used in the type-B improvement, thus the shapes and sizes of present plots are required to fulfill the conditions which enable farm machinery to work efficiently and farmers to manage irrigation and drainage water properly. Conclusively, a plot size needs to be more than 30 a. and shapes may as well be rectangular having the large long side to short

side ratio (the maximum long side length is 100 m). Considering these conditions, the selection of type-B improvement was studied as follows:

- Size of plot

There exist large ranges in present plot-size-distributions area by area. At present, the average plot size is about 30 a. in the Project Area, and that of low land is bigger than the other areas in tendency. Consequently the type-B improvement was judged to be applicable in the low land areas.

- Shape of plots

There is a great variety of plot shapes, and the dominant shape is similar to a rectangular in the Project Area. The following shape conditions are recognized from the sample areas (Moallem Kola and Suteh) located in the low land areas where the type-B is to be applicable from the size aspect. Although there exists the limitation of information/data, the basic approach to the planning is described:

a) In the Moallem Kola area (average land slope 1/400), there are many plots of which long side lengths are more than 100 m, and in this case, proposed ditches and farm roads are to be constructed by 100 intervals. And an arrangement of plot size enlargement by neighboring fields is necessary for some plots to obtain the area of 30 a. In consequence, the type-B improvement is not applicable in the higher portions of the low lands generally.

b) In the Suteh area (average land slope 1/760), which is more smaller in slope and more lower in elevation than the Moallem Kola area, the type-B is applicable generally. Therefore, in this study, the type-B improvement is to be applied in the low land areas whose land slope is less than about 1/800.

3. Application Method of Sample Designs

This application method of sample designs is prepared aiming at cost estimates.

With regard to the type-A, after unit costs and land slopes were compared, it was decided that the application of sample designs should be based on the land slope factor. And the application area was divided into three parts in order to improve the precision of cost estimates.

Concerning to the type-B, the sample designs of Ejibar Kola and Suteh are to be applied to the high land and the low land respectively.

Based on the prepared application criteria of improvement types and the above basic ideas, the application method of sample designs was determined as follows:

On-farm Improvement Types and Sample Design Application

Type	Description	Land Slope	Sample Design Application
Type-A1	Much Sloped Land	1/50 - 1/100	Ave. of Katiposht & Ejibar Kola
Type-A2	Middle Sloped Land	1/100 - 1/200	Ave. of Eslamabad & Darzi Kola
Type-A3	Less Sloped Land	1/200 - 1/800	Ave. of Moallem Kola & Suteh
Type-B1	High Land	more than 1/50	Ejibar Kola
Type-B2	Low Land	less than 1/800	Suteh

4. Cost Estimates Method

The unit cost per hectare of each type was calculated based on the above application method of sample designs. Then, the construction costs of the on-farm development of the project were estimated by multiplying these unit costs and relevant type areas.