D-2. Drainage

D-2-1. Existing Drainage Facilities

In the Project Area, 28 drainage canals, extending 247,207 m in total length, have been constructed as part of the Phetchaburi Stage II Development. These drainage canals, the earth canals with embankment slope by 1 : 1.5, convey the water in 1.0 to 2.0 m depth on an average, although fluctuating from 0.5 to 3.0 m in depth with various water amount to run through. Table D-13 shows the length, canal capacity and the numbers of the appurtenant structures provided for the existing drainage canals.

On the other hand, the seadikes, having a designed total length of 90,987 m, will be completed at the end of 1982. The designed crest elevation of the dikes is EL.2.3 m including 0.5 m freeboard against the tidal elevation of EL.1.80 m. The crest width is 4.0 m or 6.0 and paved with laterites.

Seadike	Length(m)	Nos. of Tide Gate	Sill Elevation (MSL)
No.1 Seadike			
0 + 000 - 14 + 159	14,159	17	- 0.10 ~ - 0.90
10 + 150 - 29 + 455	19,305	7	0.30 ~ - 0.70
25 + 250 - 59 + 133	33,883	23	0.10 ~ - 1.00
No.2 Seadike			
0 + 000 - 23 + 640	23,640	16	0.30 ~ - 1.00
Total	90,987	63	

D-2-2. Surface Drainage

The drainage systems in the surveyed area (74,000 ha in gross) can be roughly classified as follows:

Drainage System

Area with existing system	(sq.km)
- Right bank	433.3
- Left bank	45.1
Naturally drained area	
- Right bank	108.7
- Left bank	152.9
Total	740.0

The area of 478.4 sq.km covered by the existing drainage canal systems as composed of the 15 sub-system, 11 in the right bank and four in the left bank (See Figure D-6). The areas with existing drainage canals and the related canal capacity are shown in Table D-14. In the said table, however, the drainage area of the right bank drainage system are shown by those of the inflow points to the Extension Area. The drainage capacity for the both left and right bank is averaged at 27.2 mm/day, although varying from 24.3 to 37.4 mm/day. This average value is larger than the designed value of 22.5 mm/day for the Chaophya and the Maeklong Projects.

The construction of the drainage canals under the existing Project has greatly improved the drainage conditions of the Area, leaving no serious inundation problems but those in the scattered low-lying lands. The drainage conditions in those low-lying lands will be improved by construction of the drains to be connected with the existing drainage canals under the proposed on-farm development projects.

D-2-3. Subsurface Drainage

In the irrigation period, the water balance in the soils can be summarized as follows, as the water sources depend on the percolation of the irrigation water.

Percolation = Variations in the groundwater table + Horizontal movement of the groundwater

$$= Di\ (Pw - Pa)/100 + n \cdot Gl$$

where; Di = Variations of the groundwater table for n-days (mm)

Pw = Liquid phase under irrigation (%)

Pd = Liquid phase under non-irrigation (%)

Gl = Horizontal movement of groundwater

The liquid phase under irrigation was observed at five subsurface points by 39 percent, while that under non-irrigation was estimated at 20 percent (See Table D-15). The patterns of the groundwater table fluctuation in the Area can be specified into three, type I, II and III (See Appendix A). According to the groundwater table fluctuation records in 1976, which provide a comparatively high preciseness (Table D-16), the groundwater table analysis was made by applying the above equation for the respective patterns, excepting for the type I the groundwater table of which has been affected by tidal changes. The percolation in elevated areas was adopted by the actual results measured for type III (ave. EL.66 m MSL) and type II (ave. EL.3.8 m MSL) by 2.0 mm/day and 1.5 mm/day, respectively.

Type III:

Di = 1.06 m - 0.15 m : 910 mm

n = Mar. II - Aug. III : 160 days

$Vi = \frac{910\ (39 - 20)}{100}$: 173 mm

$$160 \times 2.0 \text{ mm/day} = 173 \text{ mm} + 160 \times G1$$

$$\therefore G1 = 0.92 \text{ mm/day}$$

Type II:

$Di = 0.62 \text{ m} - 0.15 \text{ m}$: 470 mm

$n = \text{Mar. III} - \text{Jul. III}$: 120 days

$Vi = \frac{470\ (39 - 20)}{100}$: 90 mm

$$120 \times 1.5 \text{ mm/day} = 89 \text{ mm} + 120 \times G1$$

$$\therefore G1 = 0.76 \text{ mm/day}$$

As learned from the above, the groundwater in the Project Area is assumed to move to the adjacent areas and the related drainage canals at the rate of 0.8 - 0.9 mm/day.

The control of the groundwater table below 0.5 m from the ground surface will require to eliminate the groundwater by about 1.3 mm/day or 0.15 ℓ/s/ha for both areas of type III and II in the same procedures mentioned above. Actually, however, this value could be regarded as the maximum in taking the deep percolation into consideration.

It is desirable for paddy cropping to lower the groundwater table below the bottom of the root zone by means of subsurface drainage so as to prevent salinization of the root zone. In the Project area, however, it is hardly possible for 65 percent of the Area to continue to drain the groundwater out of the Area, the gulf of thailand, unless a pump station(s) is constructed. The area for which drainage of groundwater by natural means is available amounts to 26,000 ha (or corresponding to 35 percent of the total area) and well agrees with area under the groundwater movement of Type III (refer to Appendix A). The estimation is made basing on the following assumption;

The elevation of a given paddy field has to satisfy the following equation;

$$0.15 + 0.2 + Lxi + 1.2 \leq G.L$$

where;

G.L = elevation of a given paddy field in m MSL
mean sea level = 0.15 m MSL
loss head at tide gate = 0.2 m
L = distance from seadike
i = drainage canal slope of 1/5,000
water surface in canal = 1.2 m below field surface

It is generally said that when applying the underdrain works to the grounds with average soil permeability coefficient more than 1.0×10^{-3} cm/sec at the point 1.0 m below the ground surface, the Darcy's Law-based subsurface drainage theory would not be applicable to the common soils of loamy soils and/or clayey soils due to remarkable change in locations and time factor for the permeability coefficient, excepting for the sandy soils which will not be affected in the soil features by implementing the underdrain construction works. Under the conditions, installation of the underdrain system should be carried out with elaborate study and tests to determine the installation depth and intervals. Commonly, the following empirical equation can be adopted to the determination of the intervals.

$$\frac{E}{2} = h\sqrt{\frac{k}{q}}$$

where;

E = intervals of underdrain (m)
h = depth of groundwater table above center line of underdrain (m)
k = coefficient of permeability (m/sec)
q = designed drainage (cu.m/s/sq.m)

Figure D - 6 Drainage System

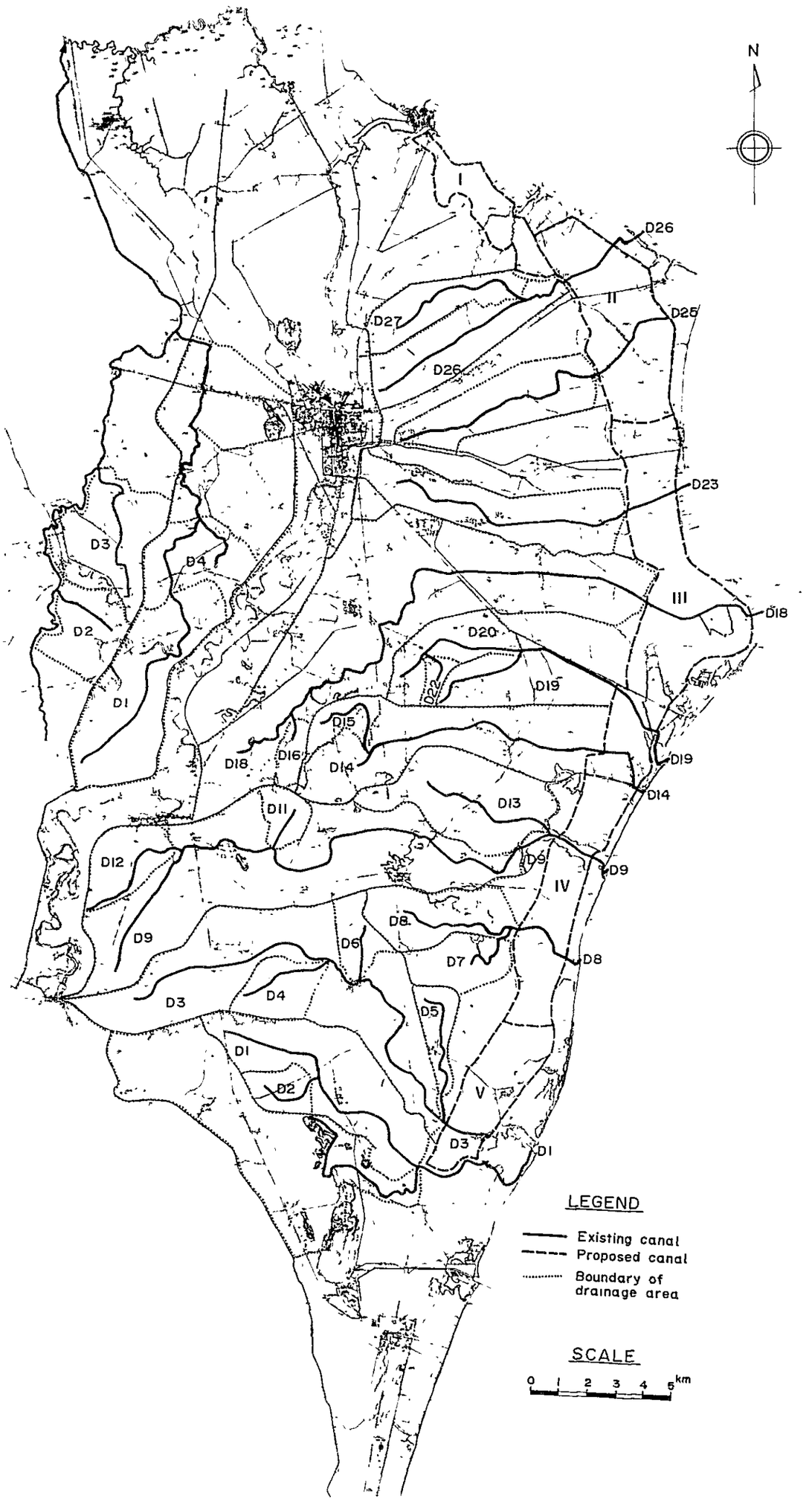

Table D-13 Existing Drainage Canals

Canal	Length (m)	Canal Capacity (cu.m/s)	Appurtenant Culvert	Appurtenant Bridge
(Right Bank)				
D-1	17,500	1.145 - 7.770	3	1
D-2	3,243	1.105	-	1
D-3	20,829	1.565 - 15.700	2	2
D-4	4,073	1.630 - 1.654	1	-
D-5	6,064	0.651 - 1.054	2	-
D-6	3,490	1.275	-	-
D-7	5,000	0.845 - 2.000	-	-
D-8	8,919	0.803 - 7.000	-	1
D-9	23,535	11.920 - 17.400	2	2
D-11	2,425	1.350 - 1.410	-	-
D-12	4,920	1.275 - 2.340	1	-
D-13	8,800	0.294 - 5.360	-	1
D-14	13,255	0.966 - 8.850	1	2
D-15	3,847	1.030	-	1
D-16	3,153	0.802 - 0.842	-	-
D-18	26,669	0.415 - 18.000	2	-
D-19	10,198	1.040 - 6.272	1	-
D-20	6,128	0.544 - 2.850	1	1
D-21	2,421	0.606	-	-
D-23	12,973	1.110 - 5.590	-	1
D-25	10,800	1.540 - 5.873	-	-
D-26	10,900	1.360 - 8.469	-	-
D-27	6,800	1.175 - 3.293	-	-
Interception	8,010	*	-	3
Sub-total	223,952		16	16
(Left Bank)				
D-1	8,644	2.340 - 6.040	-	1
D-2	3,148	2.340	-	-
D-3	6,623	1.065 - 4.250	1	1
D-4	4,840	1.460 - 1.550	1	-
Sub-total	23,255		2	2
Total	247,207		18	18

Data Source: design drawings, RID
*: not indicated

Table D-14 Capacity of Existing Drainage Canals

Canal	Drainage Area (sq.km) Direct	Accumulated	Canal Capacity (cu.m/s)	(mm/day)
(Right Bank)				
D-1	20.4	23.9	7.700	27.8
D-2	3.5		1.105	27.3
D-3	37.9	51.4	15.700	26.4
D-4	5.5		1.654	26.0
D-5	4.0		1.054	22.8
D-6	4.0		1.275	27.5
D-8	10.5	18.0	7.000	33.6
D-7	7.5		2.000	23.0
D-9	43.9	54.8	17.400	27.4
D-11	4.3		1.410	28.3
D-12	6.6		2.340	30.6
D-13	16.4	16.4	5.360	28.2
D-14	24.3	27.9	8.850	27.4
D-15	3.6		1.030	24.7
D-19	10.8	19.8	6.272	27.4
D-20	7.6		2.850	32.4
D-21	1.4		0.606	37.4
D-18	60.2	63.1	18.000	24.6
D-16	2.9		0.842	25.1
D-23	19.9	19.9	5.590	24.3
D-25	13.2	13.2	4.040	26.4
D-26	13.4	23.9	8.469	30.6
D-27	10.5		3.293	27.1
Sub-total/Average	332.2			27.2
(Left Bank)				
D-1	21.3	21.3	6.040	24.5
D-2	7.6	7.6	2.341	26.6
D-3	12.1	12.1	4.250	30.3
D-4	4.1	4.1	1.550	32.7
Sub-total/Average	45.1			27.2
Total/Average	377.4			27.2

Table D-15 Soil Characteristic

Sample Area	Depth (cm)	Apparent Specific Gravity	Real Specific Gravity	Three Phases (%)			Porosity (%)
				Solid	Vapor	Liquid	
No.1	0 - 85	1.49	2.68	55.5	5.9	38.6	44.5
No.2	0 - 100	1.25	2.72	46.1	4.3	49.6	53.9
No.3	0 - 100	1.45	2.73	53.0	8.1	38.9	47.0
No.4	0 - 80	1.58	2.69	58.6	6.5	34.9	41.4
No.5	0 - 100	1.40	2.69	52.1	14.4	33.5	47.9
Mean		1.43	2.70	53.1	7.8	39.0	46.9

Note: Sampled in Nov. - Dec. 1980.

Table D-16 Fluctuation of Groundwater Table in 1976

Month	Groundwater Table below Ground Surface (m)		
	Type I	Type II	Type III
Mar. I	0.25	0.54	1.06
II	0.26	0.58	1.06
III	0.25	0.62	1.01
Apr. I	0.25	0.61	1.03
II	0.18	0.56	0.93
III	0.16	0.51	0.90
May I	0.25	0.51	0.96
II	0.16	0.41	0.89
III	0.14	0.32	0.79
Jun. I	0.14	0.30	0.49
II	0.12	0.28	0.38
III	0.09	0.28	0.37
Jul. I	0.08	0.22	0.33
II	0.07	0.17	0.25
III	0.09	0.15	0.25
Aug. I	0.09	0.16	0.20
II	0.10	0.19	0.19
III	0.09	0.17	0.15

APPENDIX E ON-FARM DEVELOPMENT

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APPENDIX E. ON-FARM DEVELOPMENT

E-1. Dikes and Ditches Project

E-1-1. Accomplishments in Dikes & Ditches Project

Dikes and ditches projects as an on-farm development project for 52,640 ha area in the project area were initiated in 1964 and completed in 1968. Whole the project was implemented based on the Dikes and Ditches Act.

Project accomplishments in each year in terms of acreage covered and canal length constructed are as shown as follows:

Year	Acreage in ha	Length of Ditch in m
1964	1,600	46,448
1965	9,920	287,981
1966	21,920	636,345
1967	17,600	510,934
1968	1,600	46,451
Total	52,640	1,528,159

Gross construction cost covering 1964 - 1968 is estimated at ฿9,375,000 consisting of the following items:

Purchase of equipment	6,400,000 ฿
Construction cost	2,975,000 ฿
Total ------	9,375,000 ฿

The abovestated cost has been evaluated on the basis of 1981 price level, amounting to ฿31,370,000. The cost per m for ditches is computed at ฿20.50.

The structures related to the ditches are intake gates (ø 200 - 300 mm), division boxes and parshall flumes, and the list of ditches and its related structures are shown in Table E-1.

The map showing the annual construction progress during 1964 - 1968 is as shown in attached Figure E-1. As per the Figure E-1, the first year construction was started at sample areas, followed by those areas located along the main canals No.1 and No.2. After 1967, construction areas were moved to the expansion areas as benefited from the reservoir and completion was in the terminal part of the left main canal in 1968.

Land acquisition has been made through donation by the land owners under the provision in the Dikes and Ditches Act.

E-1-2. Physical Features of Dikes and Ditches Project in the Area

Dikes and ditches as constructed under the Project are as shown in the attached Figure E-2, and the list of ditches and its related structures by each irrigaiton canal are also show in Table E-1.

Cross sections of the ditch constructed in this area is fixed at the following dimension based on the Section 4 of the Dikes and Ditches Act.

Kind of canal	Earth canal
Section of canal	Trapezoid section
Invert width of canal	0.4 - 0.55 m
Side slope	1 to 1.0
Free board	0.10 m
Depth of discharge area	0.75 m
Depth of canal	0.85 m
Width of berm	0.30 m
Canal slope	1 : 4,000 - 1 : 3,000

Table E-1. List of Ditches

Description	Irrigable Area (ha)	Gross Area (ha)	Canal Length (m)	Ditch Length (m)	Density of Ditch (m/ha)	Pershall Flume (pc)	Division Box (pc)	Intake Number (pc)
(West Bank)								
* Main canal	6,186	16,002	36,330	179,970	29.0	0	12	50
1R	2,754	3,217	26,460	117,330	42.4	0	18	34
1L-1R	452	452	2,824	8,920	19.7	0	5	2
2R	862	862	8,087	28,909	33.5	0	0	10
3R	1,587	1,587	5,660	30,630	19.3	0	0	11
1L	940	940	5,300	22,500	23.9	0	0	7
2L	1,476	3,210	11,600	45,810	31.0	0	0	12
1R-2L	1,734	1,734	5,810	25,340	14.6	0	0	10
Sub-total	16,002			459,409	26.6	0	35	136
(East Bank)								
* Main canal No.1	3,622	6,403	16,660	109,742	30.3	2	16	38
1R-1	909	909	20,000	28,870	31.8	0	0	23
2R-1	1,066	1,587	8,850	34,650	32.5	0	9	21
1R-2R-1	185	185	2,526	5,430	29.4	0	2	5
1L-2R-1	336	336	2,550	6,260	18.6	0	4	4
1L-1	285	285	2,600	9,820	34.5	0	4	9
Sub-total	6,403			194,772	29.5	2	35	100
* Main canal No.2	3,733	5,796	19,556	111,987	30.0	4	37	54
1R-2	883	2,065	6,500	20,445	23.1	0	6	13
1R-1R-2	824	1,182	6,250	21,060	25.6	0	4	17
1R-1R-1R-2	358	358	3,775	12,380	34.6	0	2	11
Sub-total	5,798			165,872	28.3	4	49	95
* Main canal No.3	3,718	24,997	25,900	106,106	28.5	1	24	71
1R-3	349	349	4,000	9,500	27.2	0	2	7
2R-3	414	414	3,075	7,506	18.1	1	4	9
3R-3	974	974	8,000	22,360	23.0	0	0	24
1L-3	2,209	15,956	28,050	65,310	29.6	0	14	37
1R-1L-3	1,421	1,421	7,400	46,130	32.4	0	8	16
2R-1L-3	701	701	2,860	12,438	17.7	0	1	7
3R-1L-3	1,991	3,679	11,292	48,651	24.4	0	0	22
1R-3R-1L-3	1,688	1,688	8,664	40,440	24.0	0	9	15
4R-1L-3	1,155	1,155	8,650	42,520	36.8	0	25	14
5R-1L-3	611	2,803	8,924	26,530	43.4	0	2	9
1L-5R-1L-3	1,290	1,290	8,431	47,060	36.5	0	5	13
2L-5R-1L-3	902	902	5,940	23,580	26.1	0	0	10
6R-1L-3	932	932	8,150	24,360	26.1	0	7	10
7R-1L-3	632	632	3,990	17,590	27.8	1	4	6
8R-1L-3	900	900	5,665	31,150	34.6	0	0	10
9R-1L-3	673	1,022	3,800	18,700	27.8	0	0	7
1L-9R-1L-3	349	349	2,940	7,940	22.8	0	0	4
10R-1L-3	252	252	3,060	2,930	11.6	0	0	1
11R-1L-3	250	250	2,520	7,940	31.8	0	0	5
2L-3	2,368	3,586	14,000	68,405	28.9	0	11	46
1L-2L-3	689	689	4,675	18,670	27.1	0	7	15
2L-2L-3	529	529	2,875	12,290	23.2	0	0	13
Sub-total	24,997			708,106	27.4	3	123	371
Total	53,200			1,528,159	27.9	9	242	702

Ditches length in each main canal and its density are as follows:

Canal Name	Ditch Length in m	Irrigation Area in ha	Ditch Density, m/ha
Main canal No.1	194,722	6,403	29.5
Main canal No.2	165,872	5,798	28.3
Main canal No.3	708,106	24,997	27.4
Left main canal	459,409	16,002	26.6
Total	1,528,159	53,200	27.9

Details of ditch length and densities are as shown in the attached Table E-1. Comparing with the canal density in the other on-farm projects implemented to date, the density is too low.

Project Name	Ditch Density
Sapphaya	56.0 m/ha
Boromphart	37.5 m/ha

E-1-3. Sample Area

The five sample areas with different areal conditions have been selected in order to study the approach to the on-farm development in the Project Area. The general description of these sample area are shown below and their location map and topographical map are as shown in the attached Figures E-3 to E-8.

Sample Area No.	Site Condition	Area in ha
No.1	flat, good drainage	288 ha
No.2	low elevation, poor drainage	273 ha
No.3	undulating plain, paddy field	317 ha
No.4	paddy field, upland mixed	286 ha
No.5	paddy field, irregular shape	331 ha

Table E-2 Present Condition of Each Sample Area

Sampling Number	Site Condition	Area in ha	Elevation in m.	Irrigation & Drainage Condition		Density (on-farm)			Land Holding		Cropping Pattern	
				Canal Irrigation	Drainage Canal	Ditch (m/ha)	Drain (m/ha)	Road (m/ha)	Number (owners)	Size (Average)	Rainy Season	Dry Season
No. 1	Paddy field God drainage condition	288	14.5-11.0	Main canal No.1	Drainage canal D-3	34.7	12.7	14.5	15	2.5 (ha)	Paddy LV50% HYV50% 2.5-2.7 t/ha	Vegetable
No. 2	Paddy Field Bad drainage condition	273	3.0-1.5	Main canal No.1	Drainage canal D-18	12.3	4.1	0	131	2.1 (ha)	Paddy LV90% HYV10% 1.3-2.0 t/ha	fallow area
No.3	Undulating Plain Paddy field	317	2.8-1.5	1L-3, 6R-1L-3	D-26	19.8	13.0	6.2	284	1.3 (ha)	Paddy LV80% HYV20% 2.5-2.7 t/ha	Upland in partly
No.4	Paddy field and Upland	286	9.4-4.0	1L of left canal	D-3	9.0	9.4	14.0	277	1.47 (ha)	Paddy LV70% HYV30% 2.0-2.5 t/ha	Paddy HYV 50% 3.0-3.5 Vegetable 50%
No.5	Paddy field un-uniformed	331	7.4-3.8	1R-1L-3	D-18 (Tha Wai canal)	22.7	1.0	6.7	227	1.34 (ha)	Paddy LV90% HYV10% 2.2-2.5 t/ha	Fallow area

Remarks 1) The density of ditch and drain is excluded from irrigation and drainage canals

2) The density of road is excluded from village roads and operation and maintenance roads

* (Interior Ministry of Land Department - Phetchaburi) *

Acreages indicated above are as estimated on the 1 : 4,000 aerophoto map prepared by RID. The present condition of each sample area is illustrated in Table E-2.

The cadastral surveys have been conducted for the selected five sample areas so as to avail necessary data for land substitution program to be implemented under the Project. With having due co-operation extended by the provincial office of the Department concerned of the Ministry of Interior the surveys were made on the following items.

1. Land owners' name
2. Land registration number
3. Acreage registered
4. Land tenure
5. Acreage planted by owner farmers and/or by tenants
6. Name of tenant farmers

Questionnaire used for survey, results therefrom and cadastral map prepared are as attached as Figures E-9 to E-13.

E-1-4. Problems

Ditches as constructed in the Project Area under the Dikes and Ditches project involves the following problems:

(1) Alignment of ditches under the Dikes and Ditches project is in any case specified to have about 400 m interval and laid out in parallel with each other. Due to this uniformed alignment, ditches used to segment farm plot at many places. Based

on the study result on the selcted five (5) sample areas, 12 - 40 percent of farm plots is segmented by ditches constructed, and this causes damages on ditches and water supply function is considerable deteriorated due to frequent crossing over ditches for daily farming practices. And 13 - 45 percent (Average 27 percent) of farm plots is connected directly with ditches. While 55 - 67 percent (Average 63 percent) of farm plots is obliged to be supplied with the water by so-called plot-to-plot irrigation.

(2) Most of ditches constructed area of excavated earth ditch and in many areas gravity irrigation cannot afford to meet the requirement with the low full water supply level. Further, there had been no proper attention paid on canal slope and topographic condition in various localities, and there found many cases where gravity irrigation cannot be applied and on the contrary there are considerable inundation damages in the lowland areas.

(3) There exist 702 units of turnout, which is installated along the main and lateral canals. Among of them, there are 213 units of turnout, taking water directly from main canals. In view of water management, direct intake from main canal is not recommended. And no measurement facilities are provided for water management purpose.

(4) Ditch density reveals at about 27.9 m/ha on an average in the whole Project Area. This shows considerably lower rate as compared with 56 m/ha at Sapphaya and 38 m/ha at Boromphart where land consolidation works have been implemented already.

(5) Construction works covered only main drainage systems and no drain ditches at on-farm level are so far constructed in the area.

(6) Farm road density is lower than 20 m/ha in the sample areas. The construction of farm roads along the farm ditches is necessary to improve the accesibity for farming works.

E-2. On-farm Development

E-2-1. General

The irrigation project and the dikes and ditches project have been implemented, and the projected benefits have been attained to some extent in stabilization of wet season paddy cropping and in increase of dry season cropping acreage. To improve further the agricultural productivity in the Area, however, those found various on-farm facilities needed to be provided as the base for introducing of HYV, increase in dry season cropping acreage and introducing of diversification crops.

Engineering measures to be taken for improvement of physical infrastructures at on-farm level consists of the parts or all of the followings:

1. Provision of terminal irrigation/drainage system to avial full control of water.
2. Provision of road system for farming practice and O & M of facilities.
3. Replotting of farm plot and land levelling for more efficient farming practices and higher water management.

E-2-2. Options for On-farm Development

Technically, so called land consolidation is the most advanced measure in full improvement of on-farm facilities, where all the farm plots be reparcelled through replotting in rectangular shape with ditch and drain along the shorter side. For this, comparatively higher construction cost is required especially for levelling work for reparcelling and replotting. While for implementing such an intensive on-farm development, level of farming technique shall be high enough to accept higher standard of improved farming tech-

nique, and the farmers attitude towards such development be active enough as well. Otherwise, attaining of projected benefits to pay for the costs invested be substantially delayed.

Under the considerations as above, three (3) different types of on-farm development have been worked out as options for different standards for development.

Type A: At least the plots owned by 70 percent of all owners shall be directly connected with ditches/drains or provided with farm inlet/drain outlet. Farm ditches and drains be located along the existing property boundaries.

Type B: In principle, every farm plot be directly connected with ditches/drains or provided with farm inlet/drain outlet. Ditches and drains be in principle located along the existing property boundaries, and at the same time alignment be as straight as possible. As is the case there might be segmentation of farm plot and this might require land levelling to ease replotting. To avail higher efficiency in water management, the maximum length of farm ditch shall be limited to shorter than 1,000 m.

Type C: All the farm plots is to be reparcelled in rectangular with the longer side fixed at 160 m. The length of shorter side can be determined depending on the replotting scheme. For replotting, levelling work would be required, and a farm plot might be divided into 3 - 4 sub-plots to minimize the earth-moving quantity for levelling work. One of the shorter sides is directly connected with farm ditch and provided with a farm inlet and the other side is connected with farm drain. Each farm plot shall be connected with farm road or provided with access to farm road.

E-2-3. Criteria for Development Planning

On-farm development plans complying the above-mentioned three (3) types of improvement will be implemented in accordance with the following criteria.

Type A

(1) Plot arrangement:	° No replotting is carried out. ° Present plots be maintained as much as possible.
(2) Farm ditches	° Located along the existing boundary lines. ° At least the plots owned by 70 percent of all owners shall be provided with farm inlet at each plot owned. ° There are no limitations on the maximum length of ditches and check structures are provided as required.
(3) Farm drains	° Located along the existing boundary lines. ° At least the plots owned by 70 percent of all owners shall be adjoined with farm drain. ° The check structures are provided at the end point.
(4) Farm roads	° To be located along farm ditches with the width of 1.00 m (O & M road).
(5) Land levelling	° No levelling will be undertaken.
(6) Reduction rate of land	° Less than 6.5 percent.

Type B

(1)	Plot arrangement	° Replotting would be made only in case the plot be crossed by ditches and drains. ° Present plots be maintained as much as possible except minor re-arrangement required.
(2)	Farm ditches	° To be located, in principle, on the existing plot boundary lines. Partially adjustment is required, if necessary. ° The plots owned by all owners shall be provided with farm inlet at each plot owned. ° Maximum length is 1,000 m. Slope is 1:3,000.
(3)	Farm drains	° In principle, located on the existing plot boundary lines. Partially adjustment is required, if necessary. ° The plots owned by all owners shall be adjoined with farm drain.
(4)	Farm roads	° To be located along farm ditches with the width of 1.00 m (O & M road). ° To be located along main ditch. The width will be 3.0 m with the laterite pavement (Farm road)
(5)	Land leveling	° Leveling only for partially replotting area
(6)	Reduction rate of land	° Less than 6.5 percent.

Type C

(1)	Plot arrangement	° Replotting shall be necessary. Standard size is 160 m x 50 m (5 rai)
(2)	Farm ditches	° Farm inlet shall be provided for each plot. ° The maximum length is 500 m. The maximum slope is 1:1,500.
3)	Farm drains	° Located along the shorter size of plot. The maximum length is 500 m.
4)	Farm roads	° To be located along farm ditches with the width of 3.00 m. ° Main farm roads will be paved with laterite.
5)	Land leveling	° Leveling shall be undertaken for the whole area.
6)	Reduction rate of land	° Less than 7.0 percent.

E-2-4. Case Study of Sample Areas

To make a study of the technical methologies for land consolidation, five sample areas were selected in the Project Area with consideration given to the land form, land category, irrigation and drainage conditions and other factors.

The layout of on-farm facilities and estimation of construction cost have been done for each selected sample areas, based on the different consolidation types including Type A, B and C. The layout drawing concerned are attached in Figures E-19 to E-34 respectively.

The density of proposed on-farm facilities, estimated for the layout of each sample areas are summarized in Table E-3, and the work volume and construction cost were also estimated, based on the layout drawing for each sample area. The results are illustrated in Table E-4 and E-5 respectively.

Table E-3. Density of On-farm Facilities

Sample Area	Type	Density (m/ha)				
		Main Canals	Ditches	Drains	Farm Roads	O & M Roads
No.1	A	-	52.0	26.7	14.5	52.0
	B	11.2	35.9	41.7	25.7	35.9
No.2	A	-	20.9	18.3	-	20.9
	B	-	20.0	22.2	-	20.0
No.3	A	-	27.0	26.2	13.0	27.0
	B	5.3	36.6	31.3	18.3	36.6
No.4	A	4.3	33.8	17.7	18.3	33.8
	B	4.3	33.9	22.9	18.3	33.9
No.5	A	-	26.3	29.3	6.7	26.3
	B	5.5	28.0	34.6	12.2	28.0

Table L-4. Summary of Work Volume for Each Sample Area

Sample Area	Acreage (ha)	Type	Structures (Unit)					Quantity (m)				
			Turn-outs	End-checks	Division Box	Checks	Crossing	Main Canals	Ditches	Drains	Farm Roads	O & M Roads
No.1	217	A	3	11	1	13	13	-	11,280	5,800	-	11,280
		B	4	14	4	9	16	2,430	7,800	9,040	2,430	7,800
No.2	261	A	6	9	0	6	1	-	5,460	4,780	-	5,460
		B	7	13	1	7	2	-	5,210	5,800	-	5,210
No.3	248	A	4	9	1	8	5	-	6,690	6,490	-	6,690
		B	5	15	5	9	11	1,320	9,070	7,760	1,320	9,070
No.4	264	A	8	17	2	8	6	-	9,110	4,860	-	9,110
		B	9	18	2	8	8	1,140	9,000	6,040	1,140	9,000
No.5	268	A	5	12	1	9	7	-	7,060	7,860	-	7,060
		B	5	15	5	10	7	1,570	7,500	9,270	1,470	7,500

Table E-5. Summary of Construction Cost for Each Sample Area

Sample Areas	Gross Area (ha)	Irrigable Area (ha)	Type	Total Construction Cost ($)	Per ha Cost ($/ha)	
					Gross Area	Irrigable Area
No.1	288	260.1	A	200,900	698	772
			B	263,400	915	1,013
No.2	273	260.8	A	114,800	421	440
			B	121,500	445	466
No.3	317	255.0	A	144,300	455	566
			B	232,400	733	911
No.4	286	264.3	A	204,700	716	774
			B	214,400	750	811
No.5	331	308.8	A	161,900	489	524
			B	227,300	687	736
		Average:	Type A		554 $/ha	615 $/ha
			Type B		706	787

E-2-5. Application of Consolidation Types to the Project

From the results of case study of sample areas, the three (3) types employed in this land consolidation program are such that the consolidation level goes up in the order of A, B and C and the construction cost also rises accordingly. In land consolidation of Type C, each plot is shaped into a rectangle and irrigation and drainage may be optionally controlled for each farm plot under a certain water utilization program, though it, in turn, involves such difficulties as below;

- Higher investment cost per a unit area
- Farmers' will whether they may accept to pay for land leveling cost as regulated in the law, or not.
- Higher standard of farming technique by beneficiary farmers is a must to secure expected project benefit.
- Whether high cropping intensities could be expected or not, especially in the dry season.

With the above considerations, it shall be concluded that the application of Type C under the present project plan formulation is still too early for the Area. On the other hand, the Type A and B to be applied for the on-farm development plan under the present project, in principle, will not involve the land re-parcelling and leveling but implement construction and/or improvement of the farm ditches/drains, and provision of farm roads, when the necessity arises. It is natural that the on-farm facilities in Type A and B methods should well function to assure the year-round irrigation and drainage so as for direct irrigation from their ditches to benefit the farmers more than 70 percent in the respective development areas. And, as the cost for land consolidation for Type A and B is low, it will be possible to expand the area of land consolidation at a relatively early time. Therefore, the Type A and B are recommended to be implemented at this stage.

The more detailed application method to the Project Area are described as follows;

In order to apply an on-farm development program to the Project Area, the gross project area of 52,600 ha is divided into small blooks by using the grid system in accordance with the mesh data by elevation, gradient, salinity distribution and land use in the Project Area (See Figure E-14 to E-17), which are related to the determination of development priorities and level of on-farm development to be applied, taking the present irrigation canals and roads conditions into consideration.

The gross project area of 52,600 ha can be divided into the following five (5) zones according to the above said mesh data.

(1)	Higher part - paddy field zone:	El.14.5 - 11.0 m No drainage and salinity problems.
(2)	Lower part - paddy field zone:	EL. 3.0 - 1.5 m Poor drainage conditions, partially has a salinity problem.
(3)	Undulating plain - paddy field zone:	EL. 2.8 - 1.5 m No salinity problem upland in part.
(4)	Middle part - paddy/upland mixed zone:	EL. 9.4 - 4.0 m High gradient.
(5)	Middle part - paddy field zone:	EL. 7.4 - 3.8 m

For the above five (5) zones, development plan shall be finally worked out and based on the following basic concepts.

Zone 1) The area is located on the relatively high portion of south-western part of the Project Area, having an area of 6,240 ha. There are no drainage and salinity problems in this zone. The Type B will be applied to the whole area.

Zone 2) The area is located along the coast and northern part of the Project Area having an area of 19,580 ha of which 4,980 ha land has a relatively low salinity (6 - 8 EC x 10^{-3}). Type B will be applied and the 4,980 ha area. Type A will be applied to the remaining area of 14,600 ha where are suffering from salt problems.

Zone 3) The area is located at the eastern part of municipality of Muang Phetchaburi which are mainly in the semi-recent terraces formed on the alluvial soil, having an area of 4,280 ha. There is no salinity problem. The type B will be applied to this area.

Zone 4) The area is located at the central part of right bank of main canal where paddy and upland crops are cultivated with a relatively high gradient. The Type B will be applied to this area.

Zone 5) The area is located at the central part of Project Area extending to right bank of Phetchaburi river with considerable undufation/rolling slope. The Type B will be applied to this area.

The area each on-farm development type is summarized as follows:

Applied Sample No.	Area (ha) Type A	Type B	Total (ha)
No.1	-	6,240	6,240
2	14,600	4,980	19,580
3	-	4,280	4,280
4	-	7,490	7,490
5	-	11,110	11,110
Total	14,600	34,100	48,700

The classification of Type A and B in the Project Area is shown in the attached Figure E-18.

Figure E-1 Progress of Ditch and Dike Project

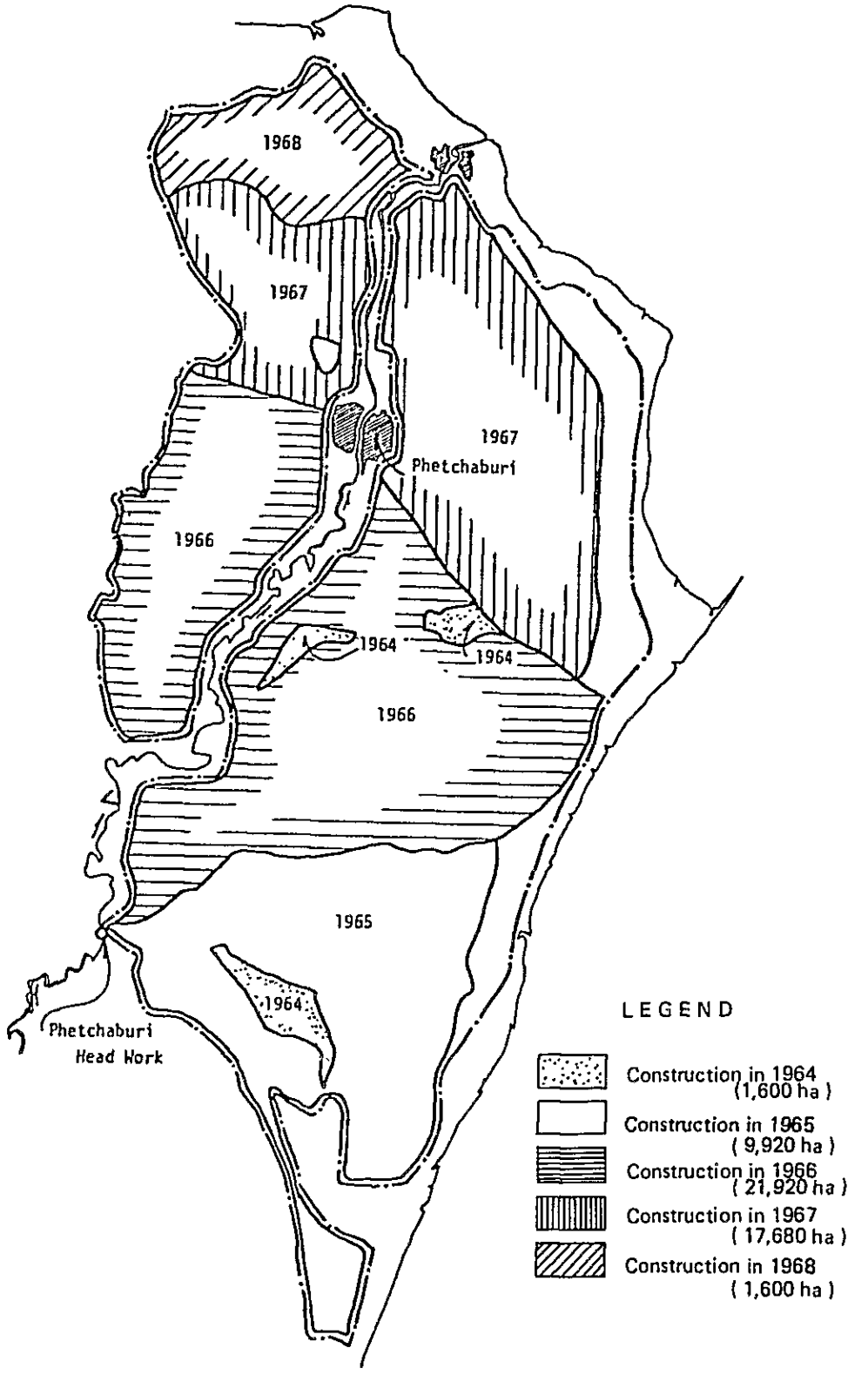


Figure E-2 Location of Ditches

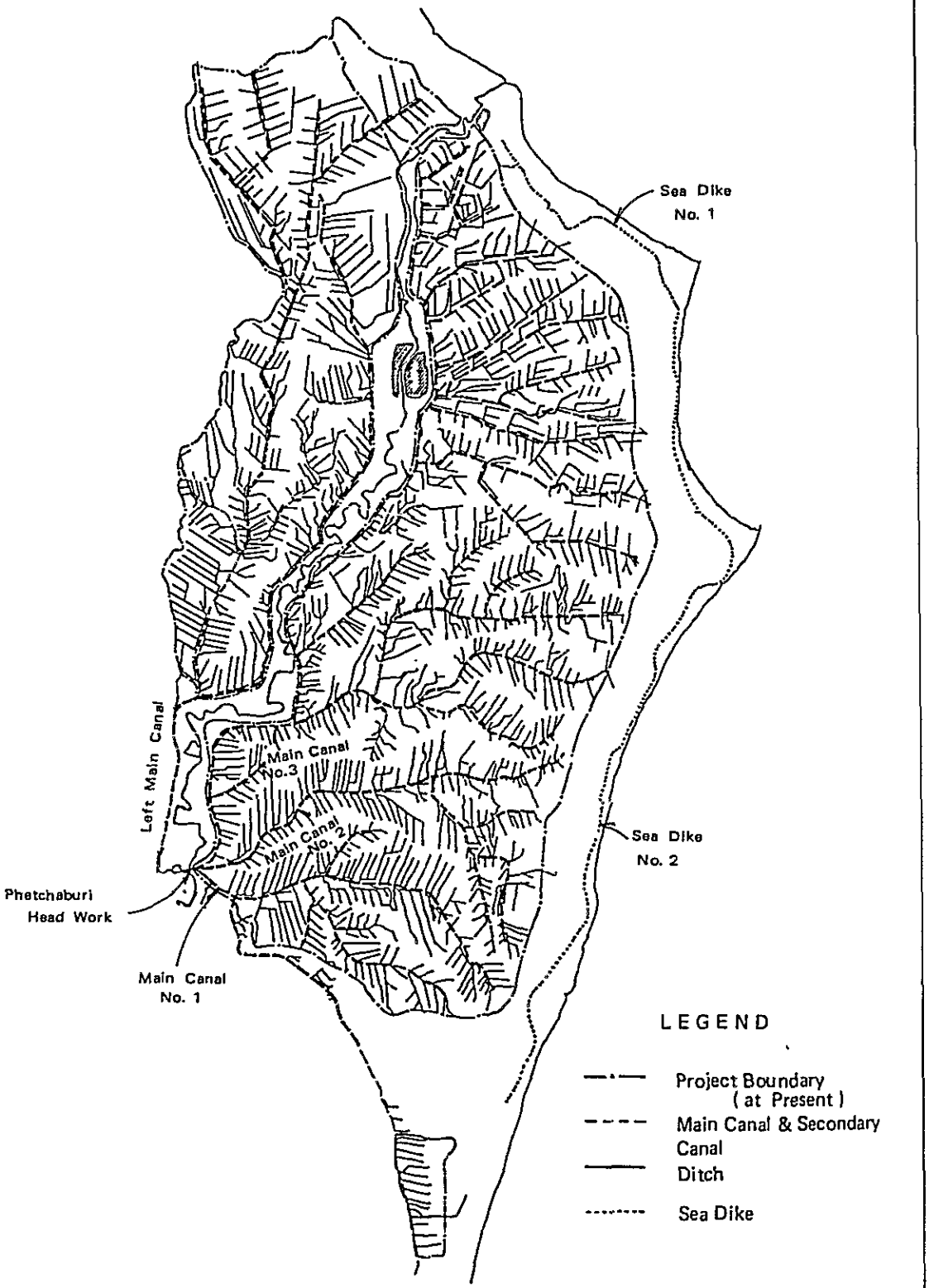


Figure E-3 Location of Sample Area

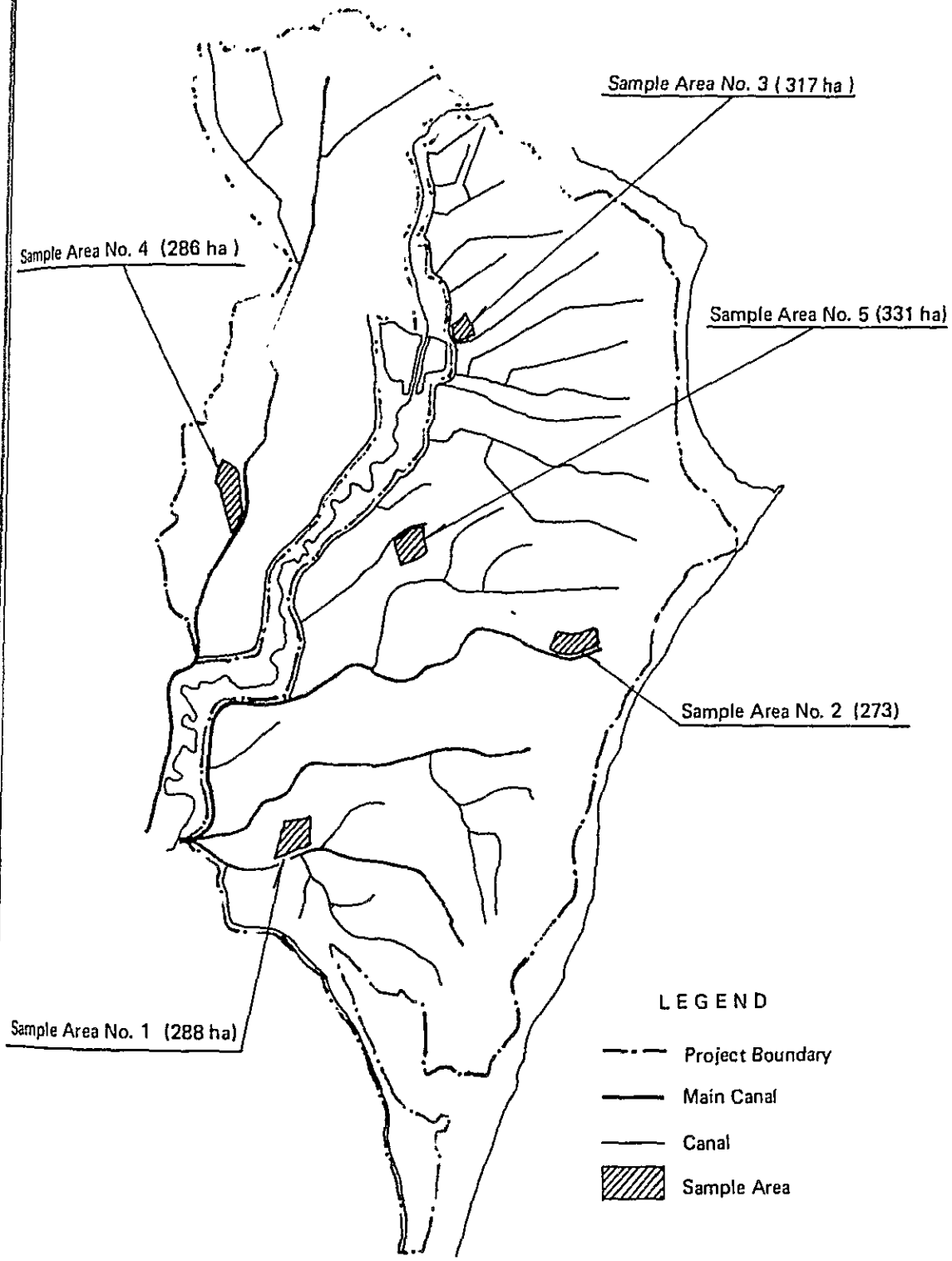


Figure E - 4 Topographical Map of Sample Area No.1

N

Scale

0 100 200 300 400 500

Figure E - 5 Topographical Map of Sample Area No.2

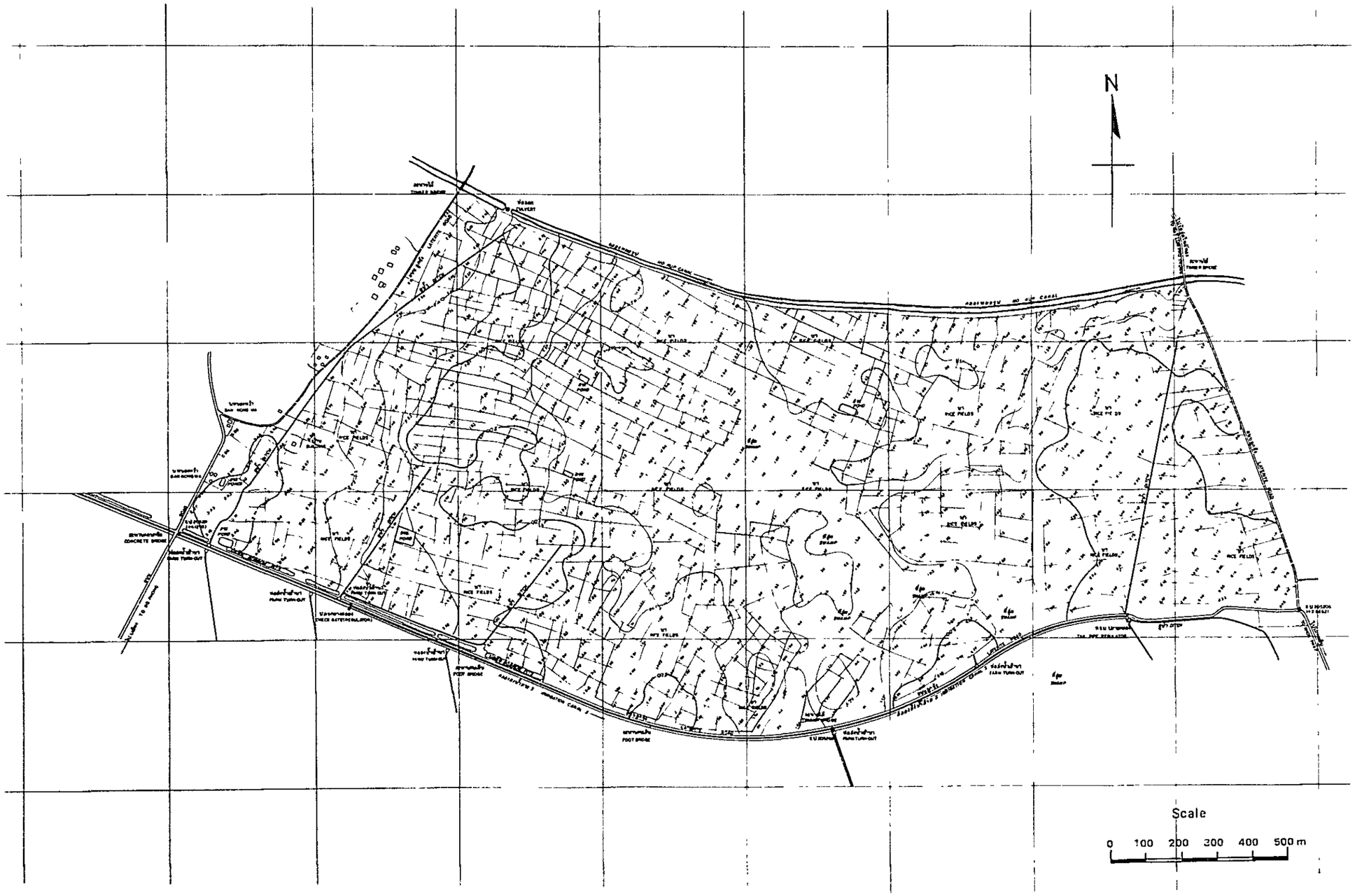


Figure E - 6 Topographical Map of Sample Area No.3

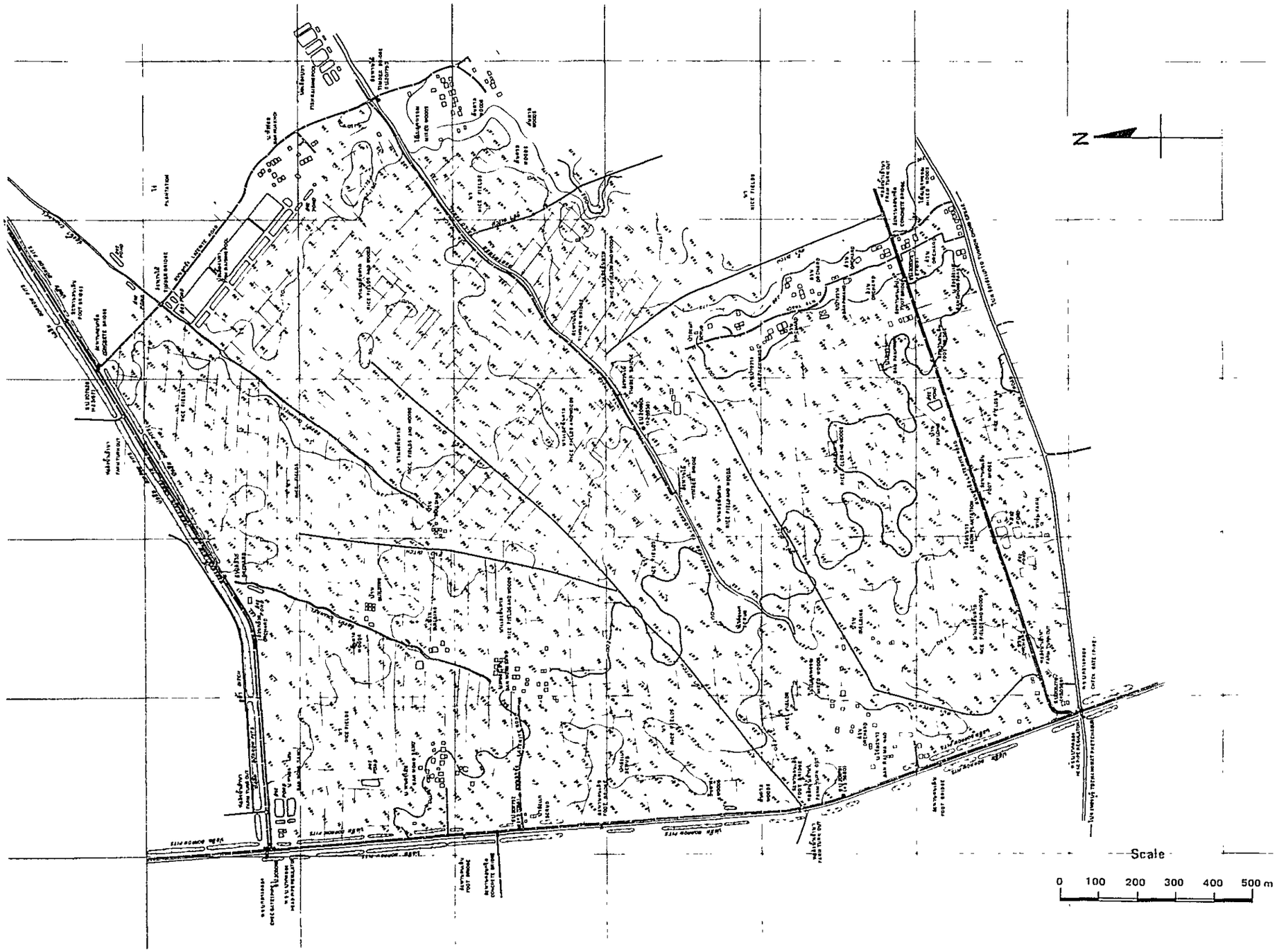


Figure E - 7 Topographical Map of Sample Area No.4

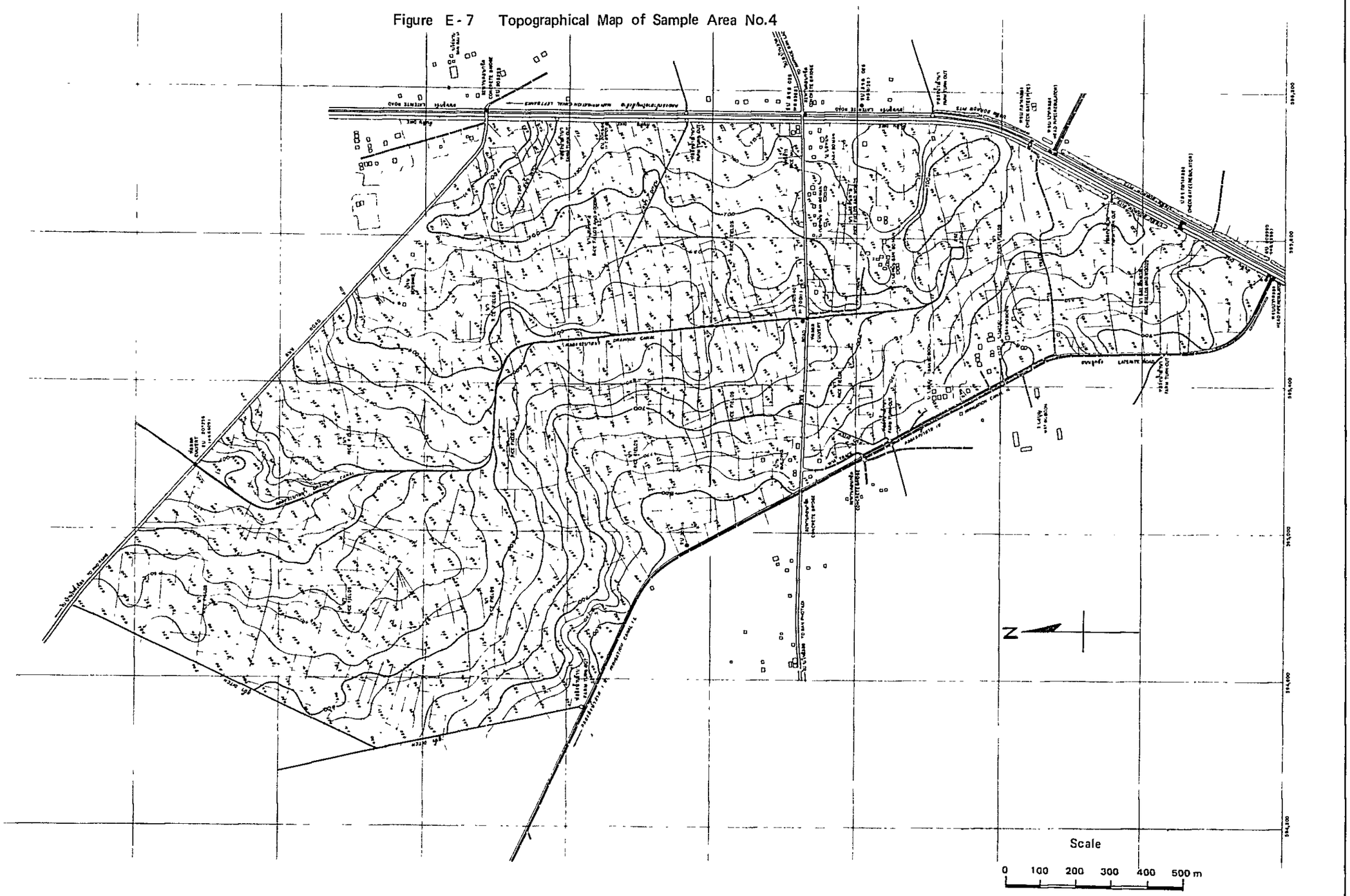


Figure E - 8 Topographical Map of Sample Area No.5

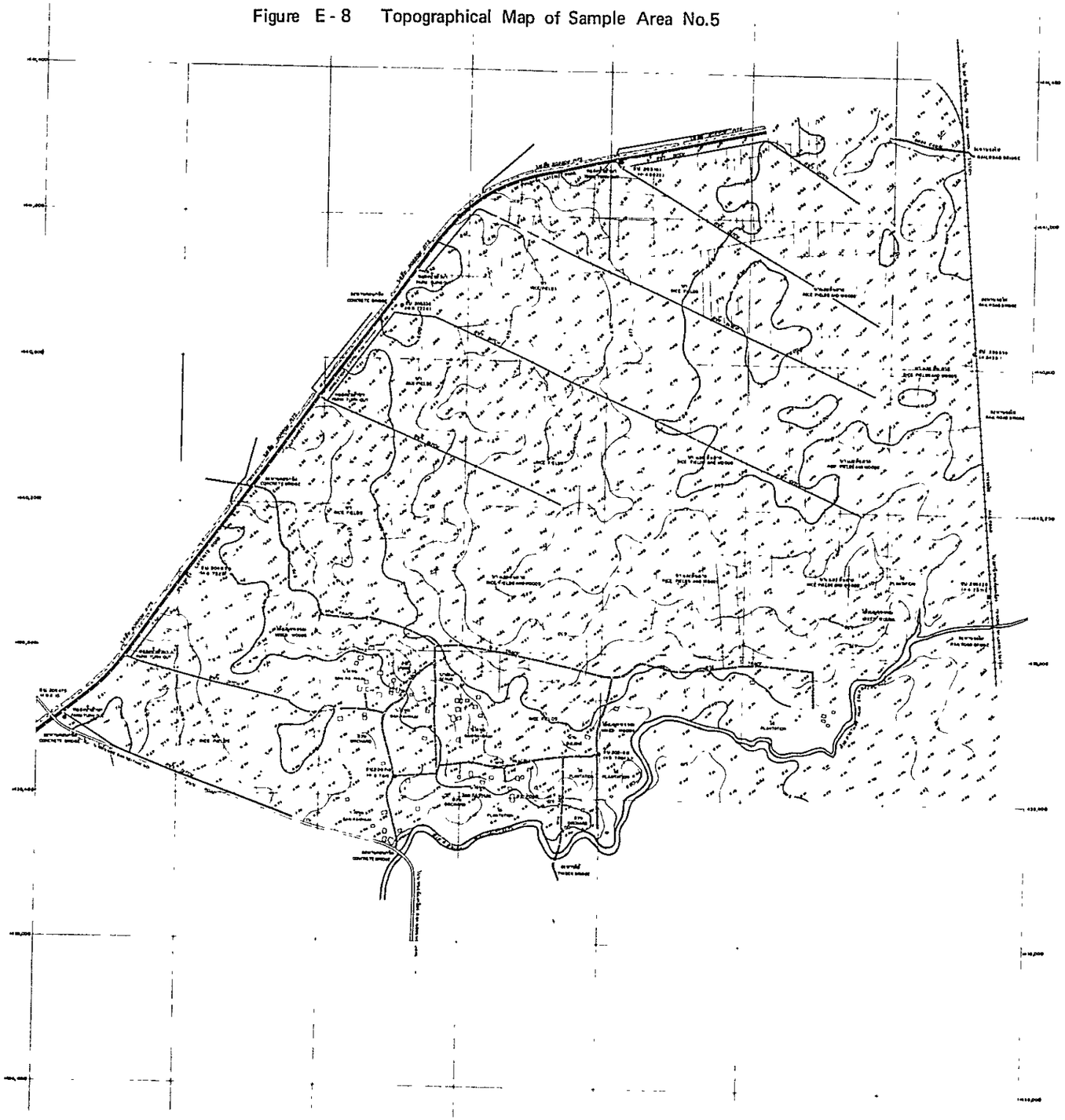


Figure E-9 Cadastral Map of Sample Area
— Sample Area No. 1 —

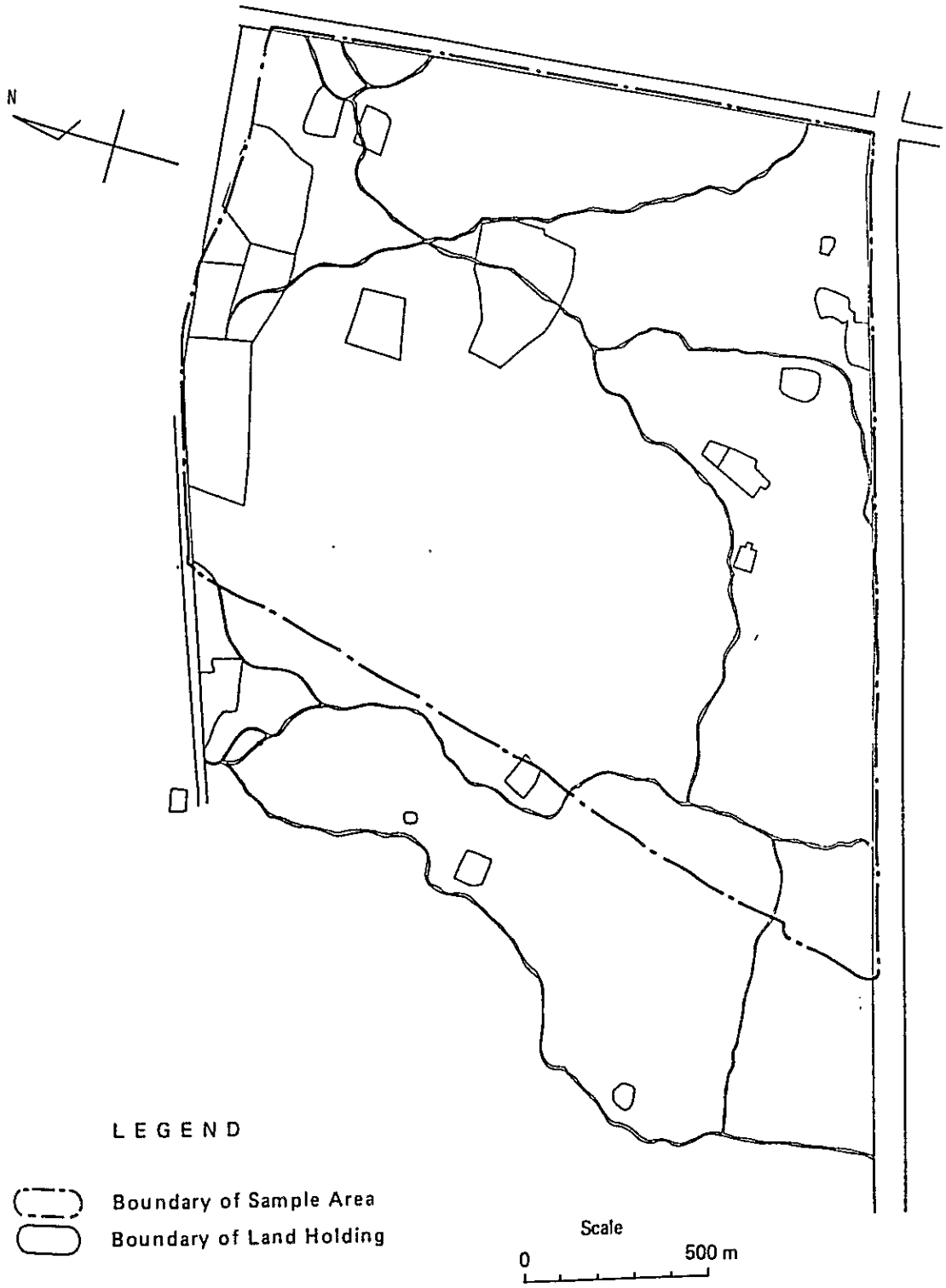


Figure E-10 Cadastral Map of Sample Area

— Sample Area No. 2 —

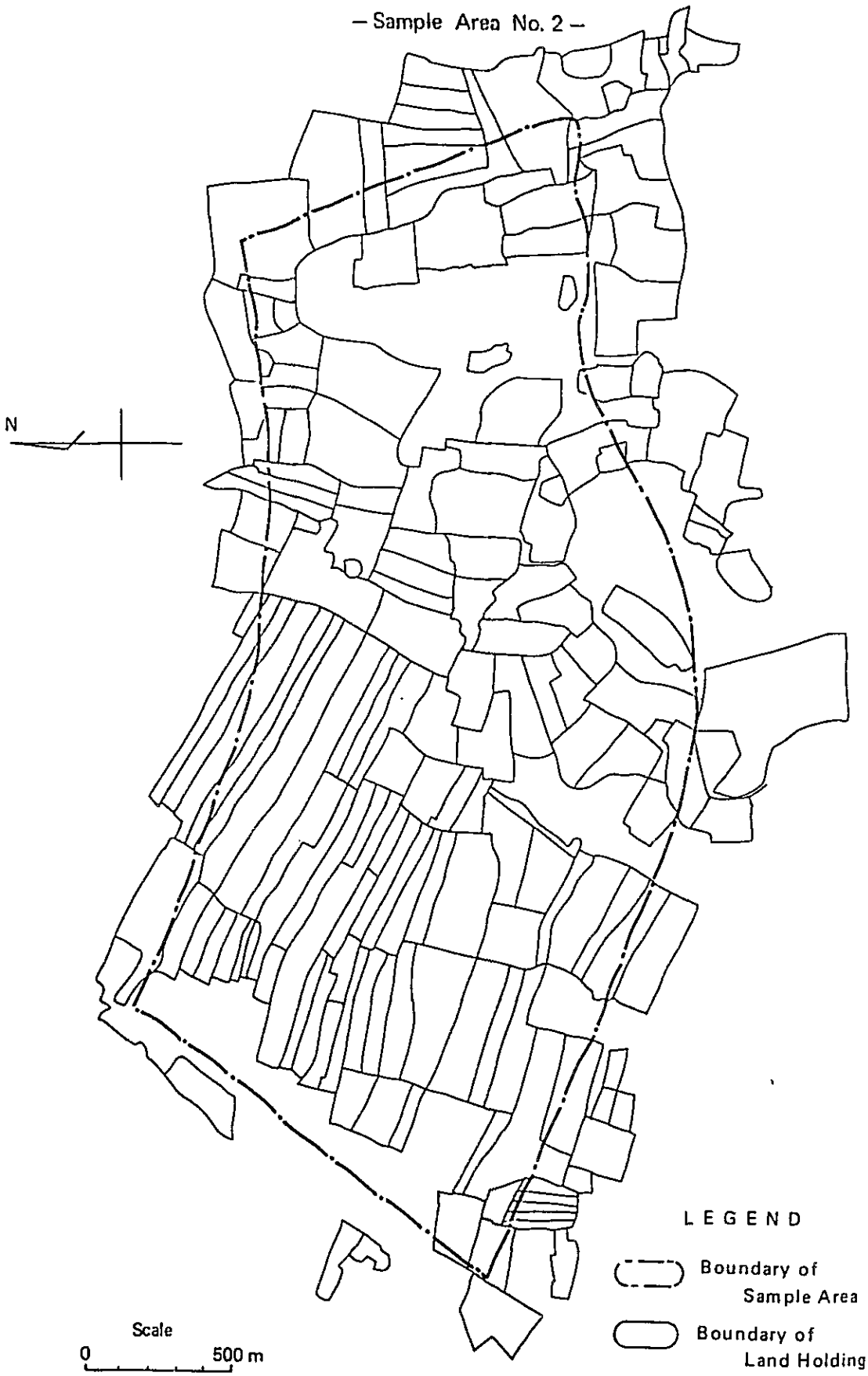


Figure E-11 Cadastral Map of Sample Area

— Sample Area No. 3 —

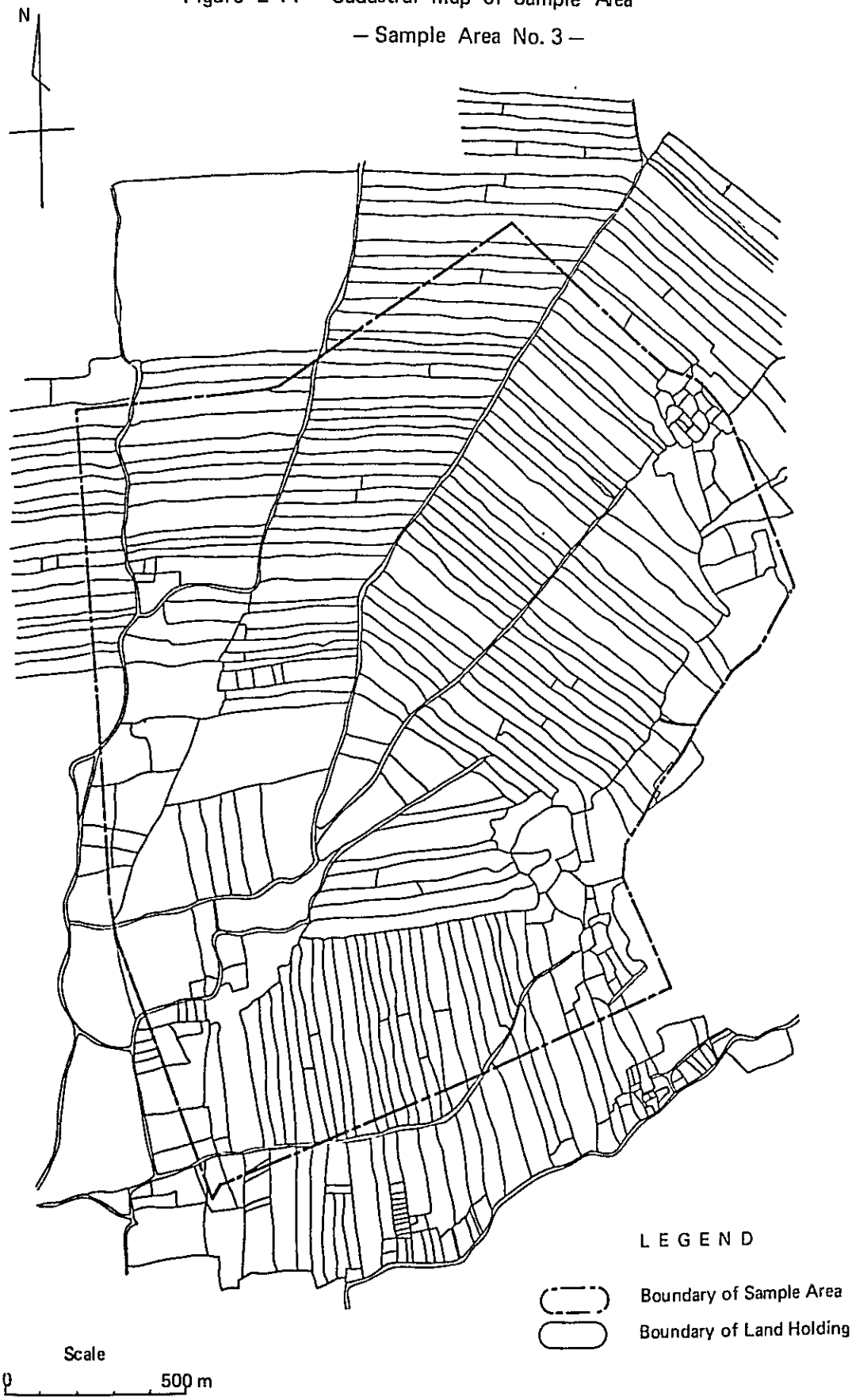


Figure E-12 Cadastral Map of Sample Area
— Sample Area No. 4 —

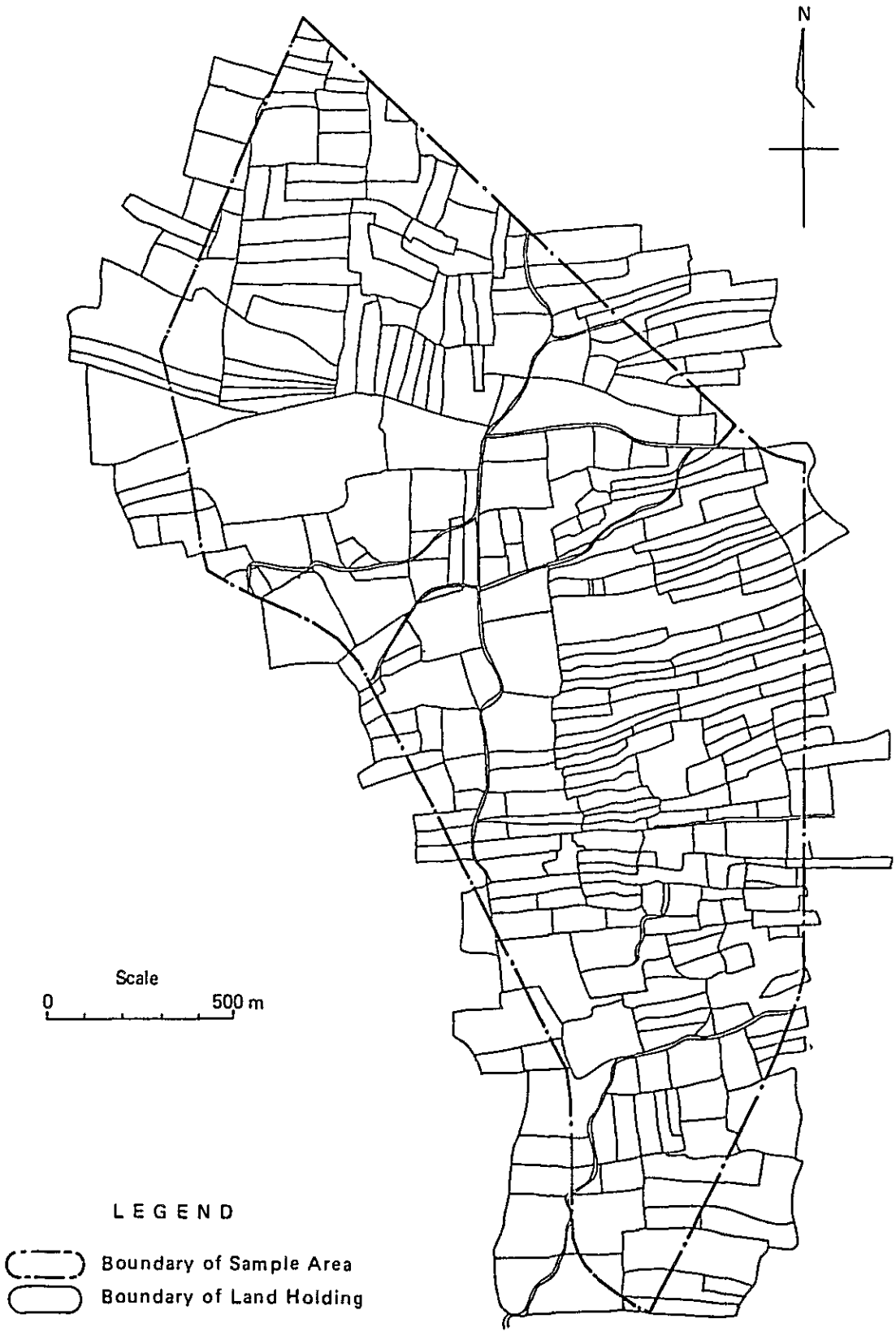


Figure E-13 Cadastral Map of Sample Area
– Sample Area No. 5 –

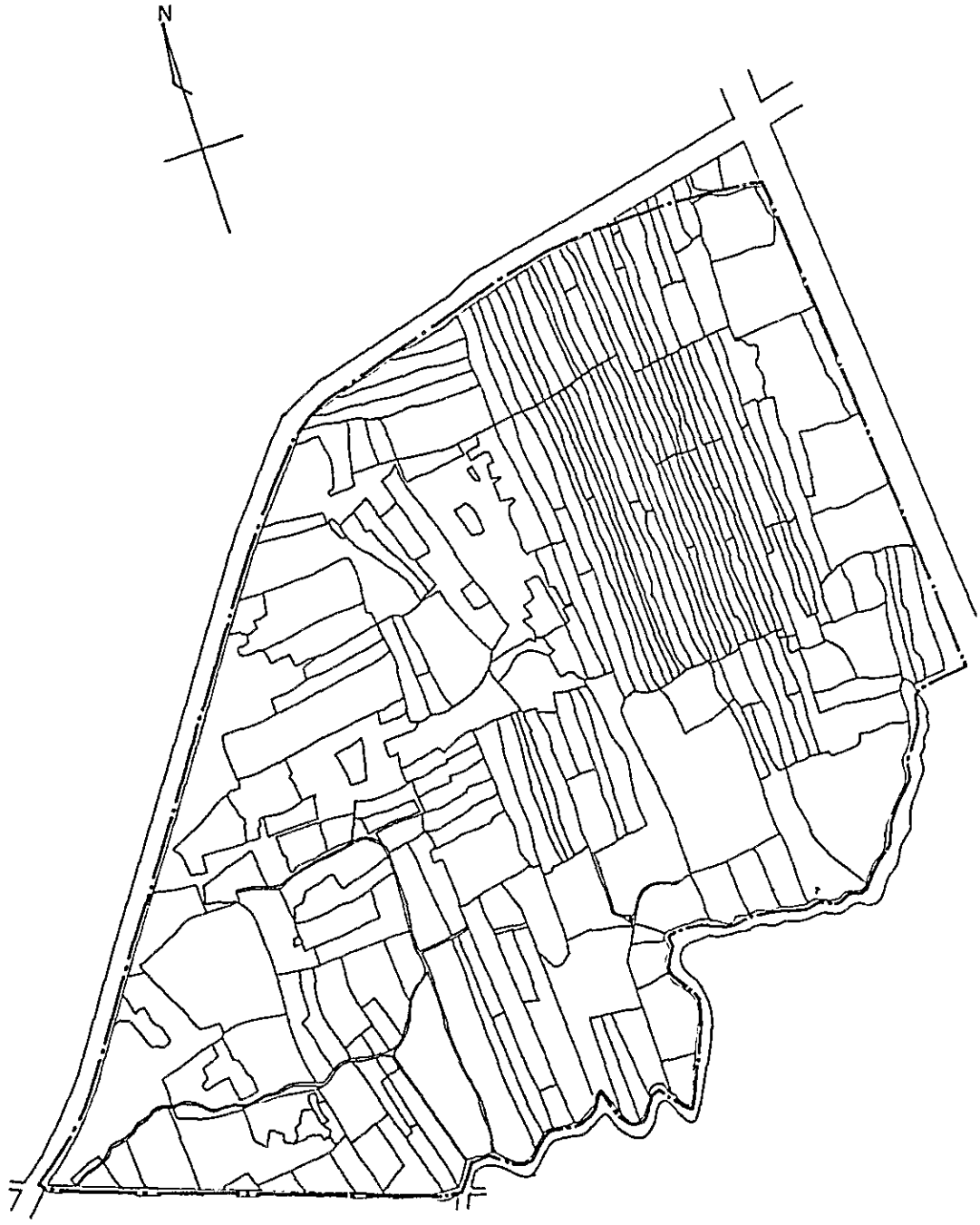


Figure E-14 Distribution of Ground Elevation

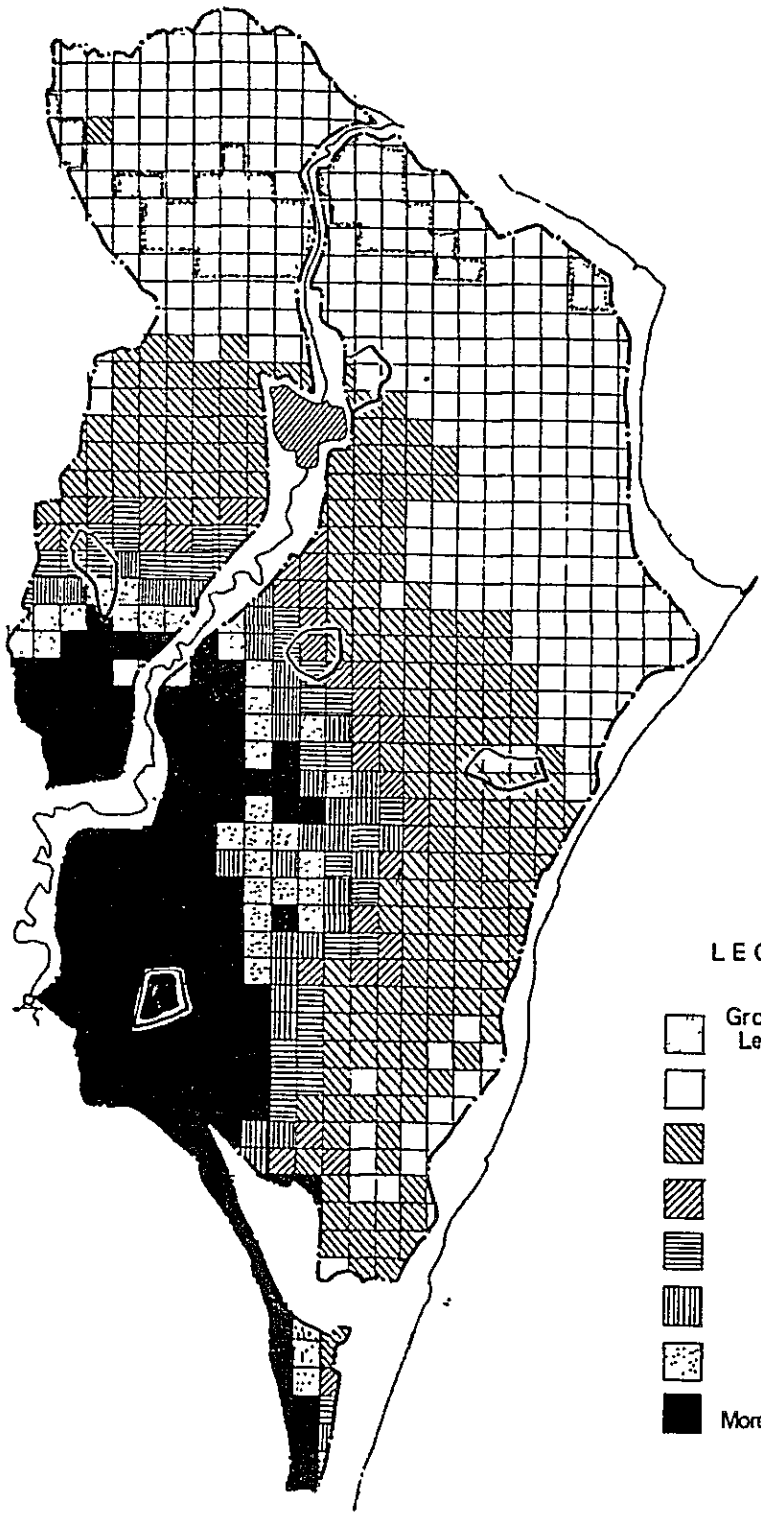


Figure E-15 Distribution of Ground Surface Slope

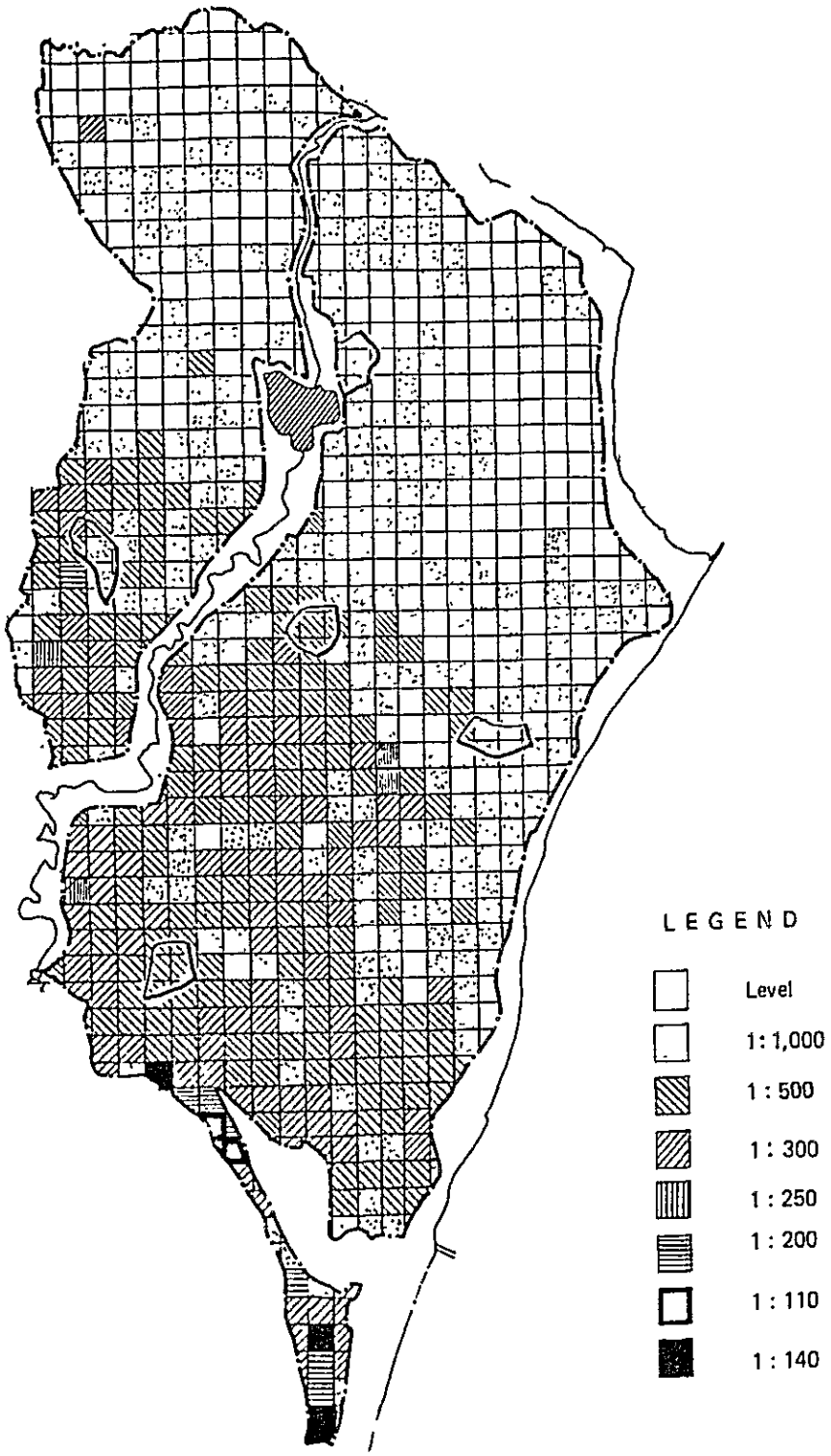


Figure E - 16 Distribution of Salinity

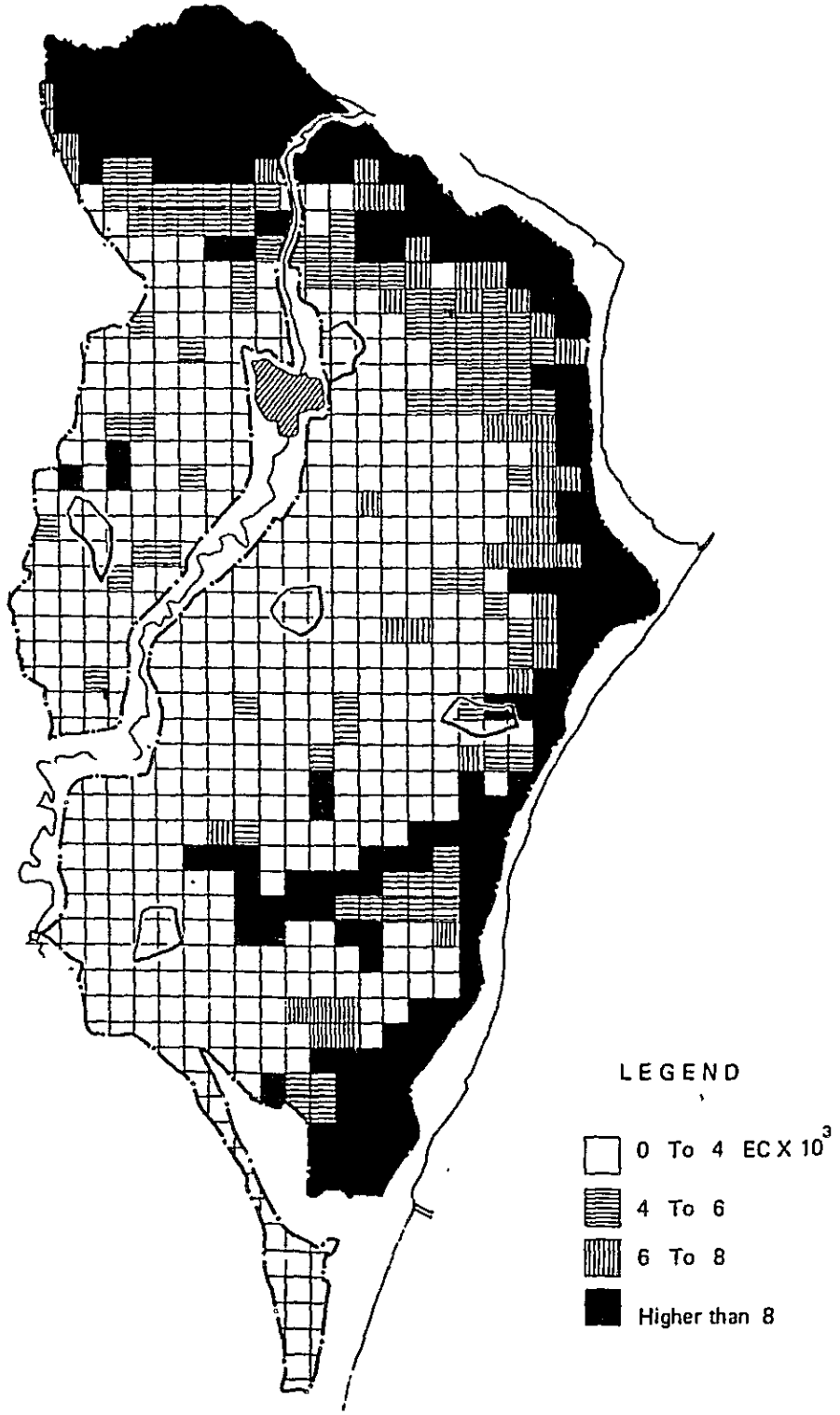


Figure E - 17 Distribution of Present Land Use

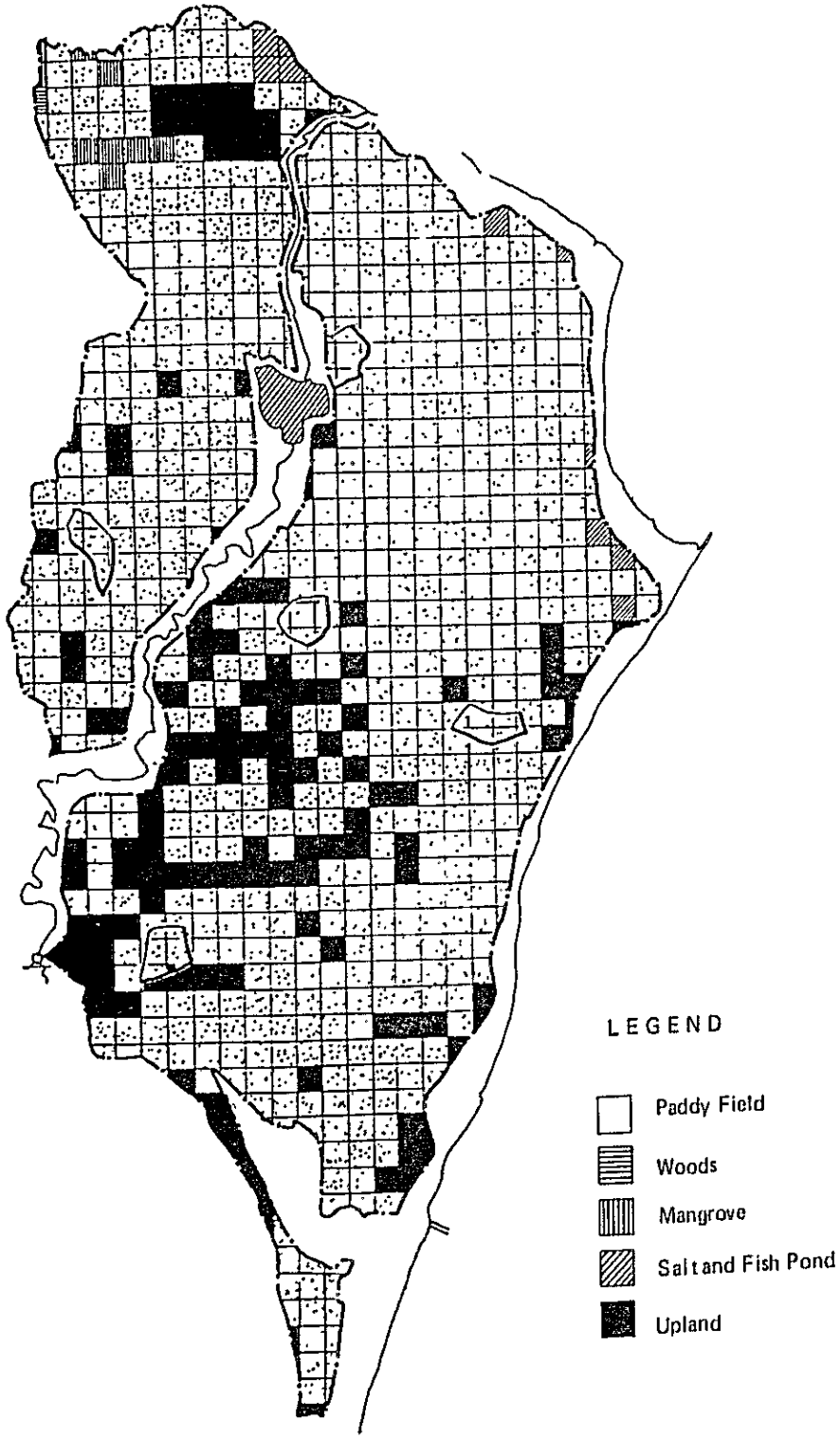


Figure E - 18 Implementation Area of Type A and B

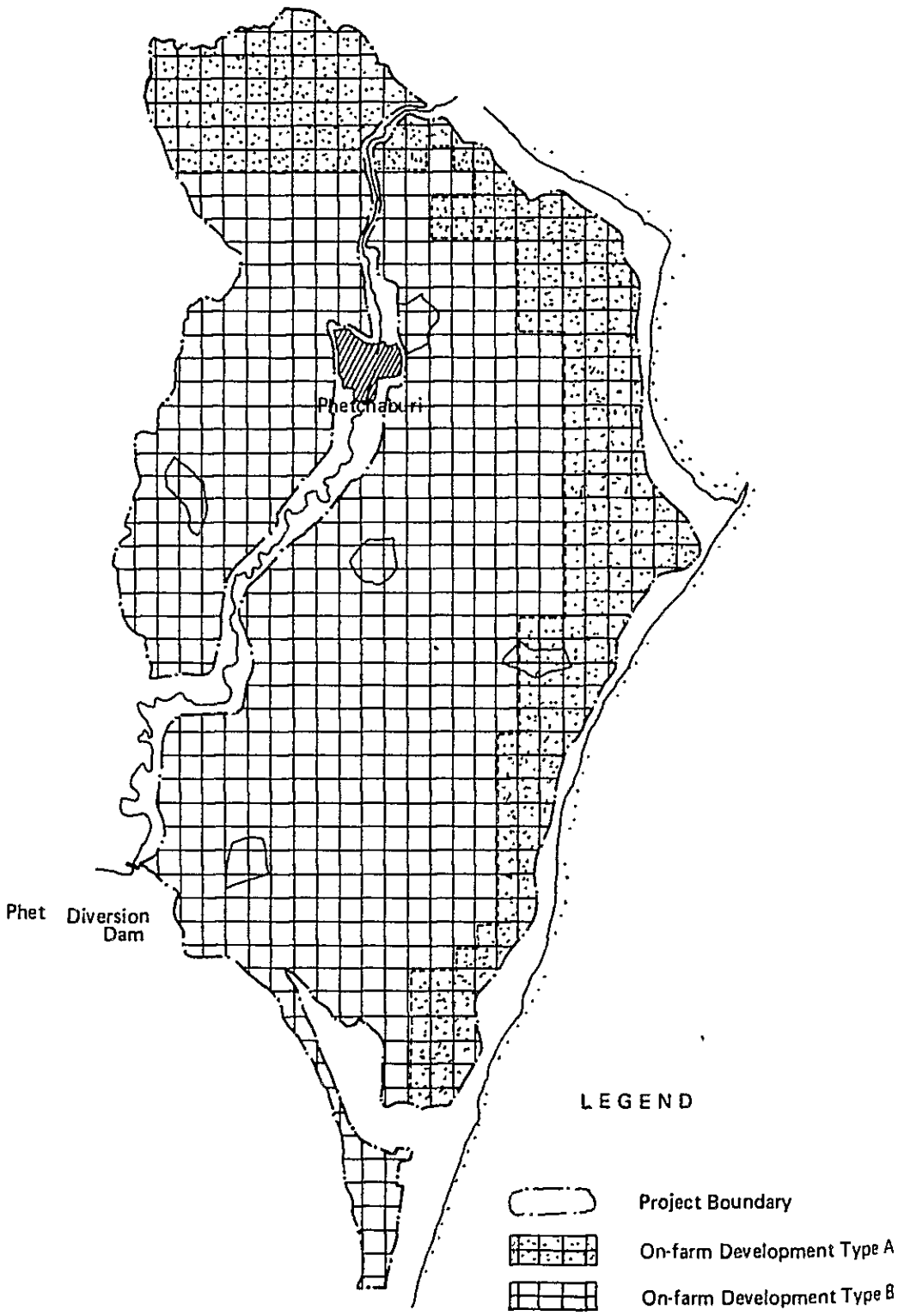
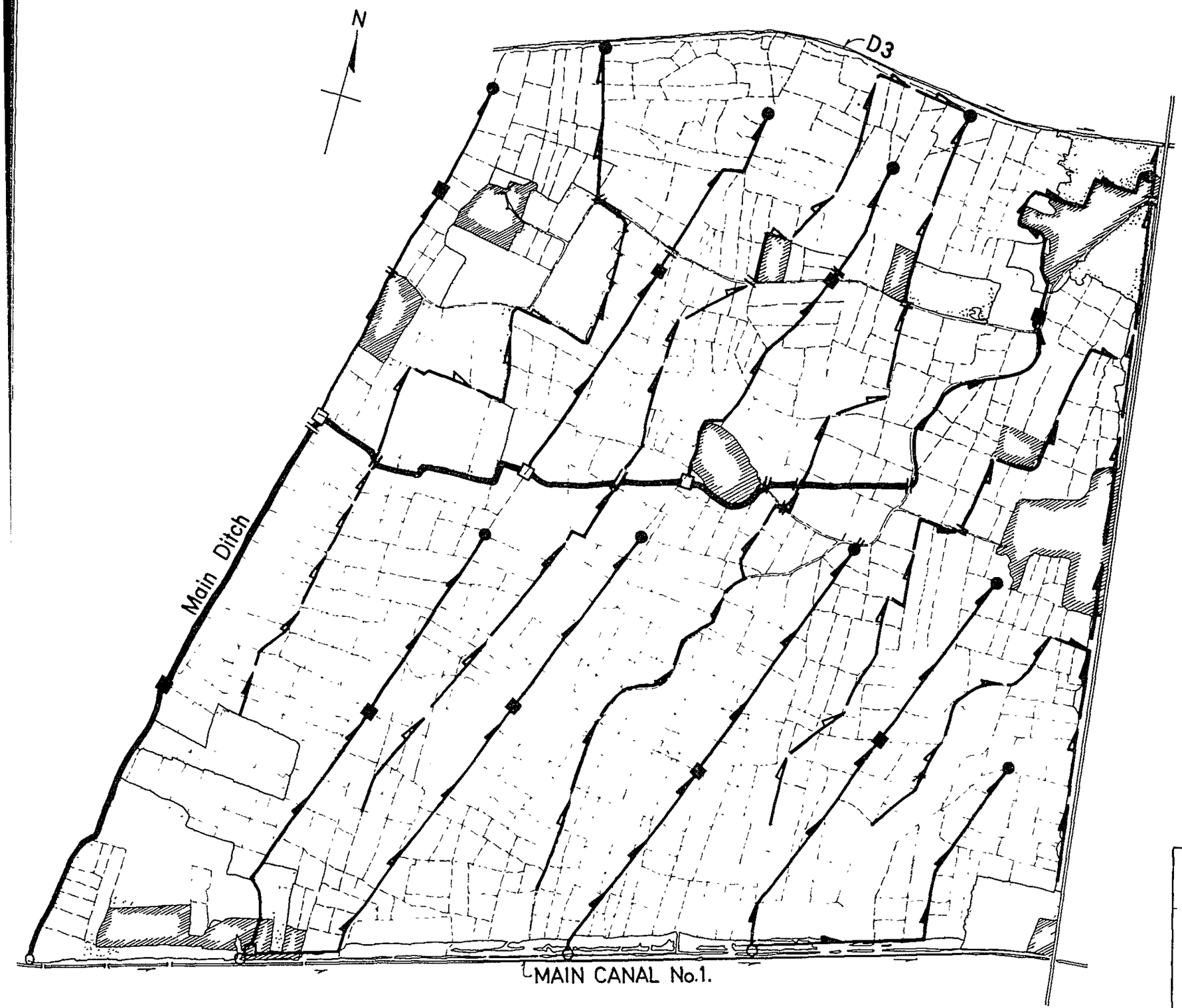


Figure E-19 Layout of Type A On-farm Development, Sample Area No. I

Figure E - 20 Layout of Type B On-farm Development, Sample Area No. 1



LEGEND

- Residential Area
- Upland
- Farm Plot, existing
- Ditch
- Drain
- Farm Turn-out
- End Check
- Division Box
- Check
- Crossing

SCALE
0 100 200 300 400 m

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THE PHETCHABURI KAENG KRACHAN IRRIGATED AGRICULTURE DEVELOPMENT PROJECT

ON FARM DEVELOPMENT
SAMPLE AREA No.1.

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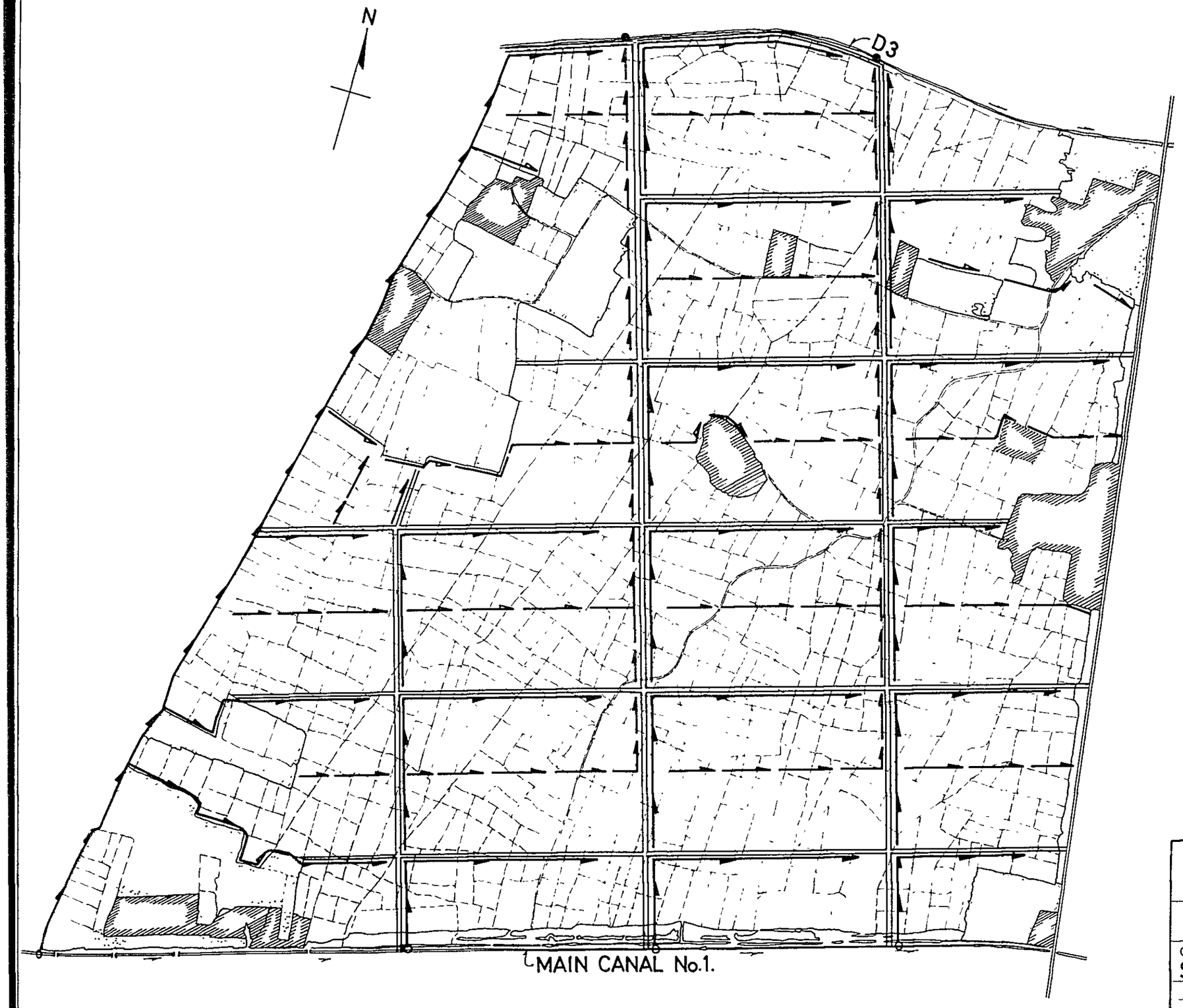
Figure E-21 Layout of Type C On-farm Development, Sample Area No.1



LEGEND

- Residential Area
- Upland
- Farm Plot, existing
- Ditch
- Drain
- Farm Road
- Farm Turn-out
- End Check

SCALE
0 100 200 300 400 m

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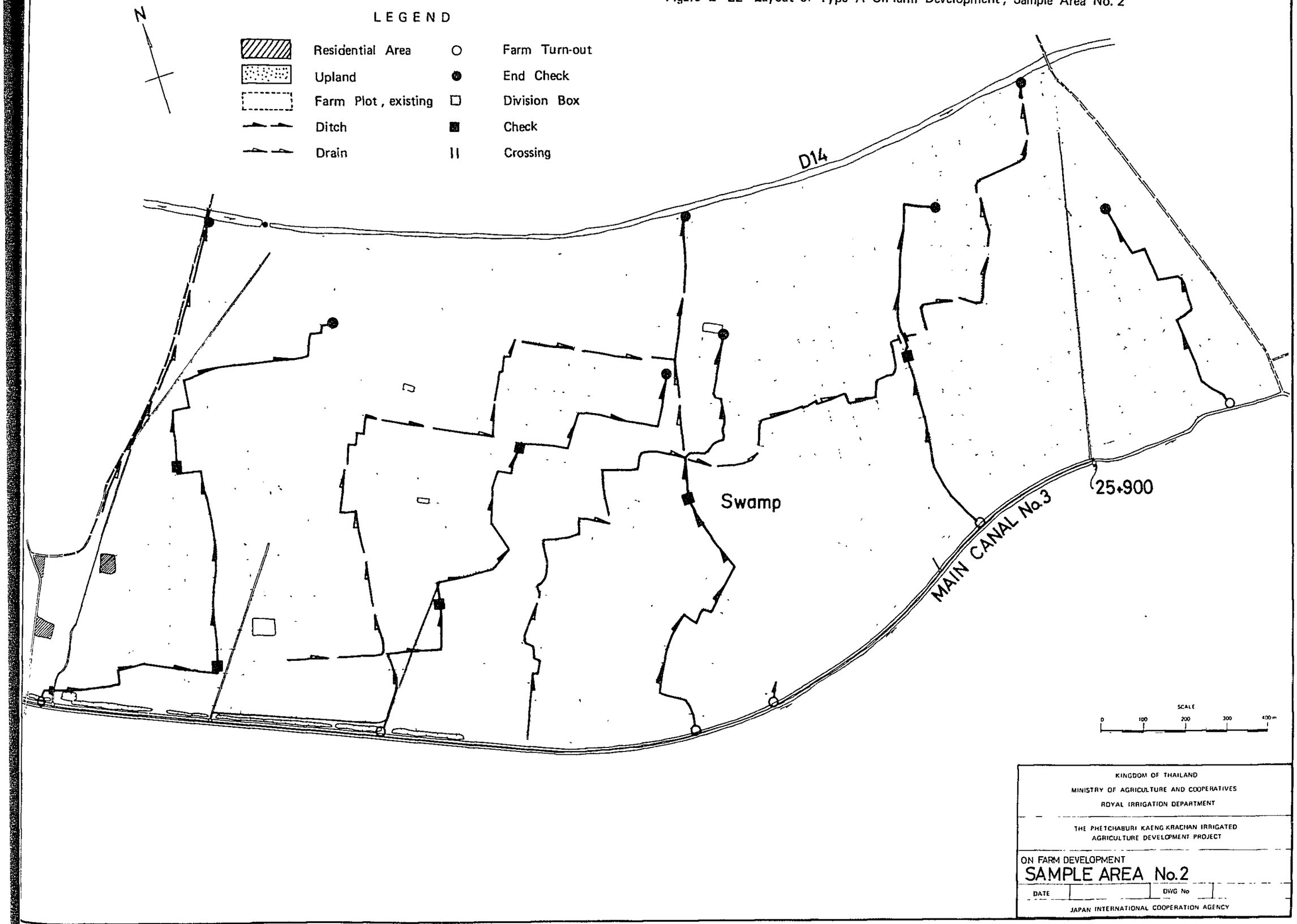
Figure E - 22 Layout of Type A On-farm Development, Sample Area No. 2



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SAMPLE AREA No.2

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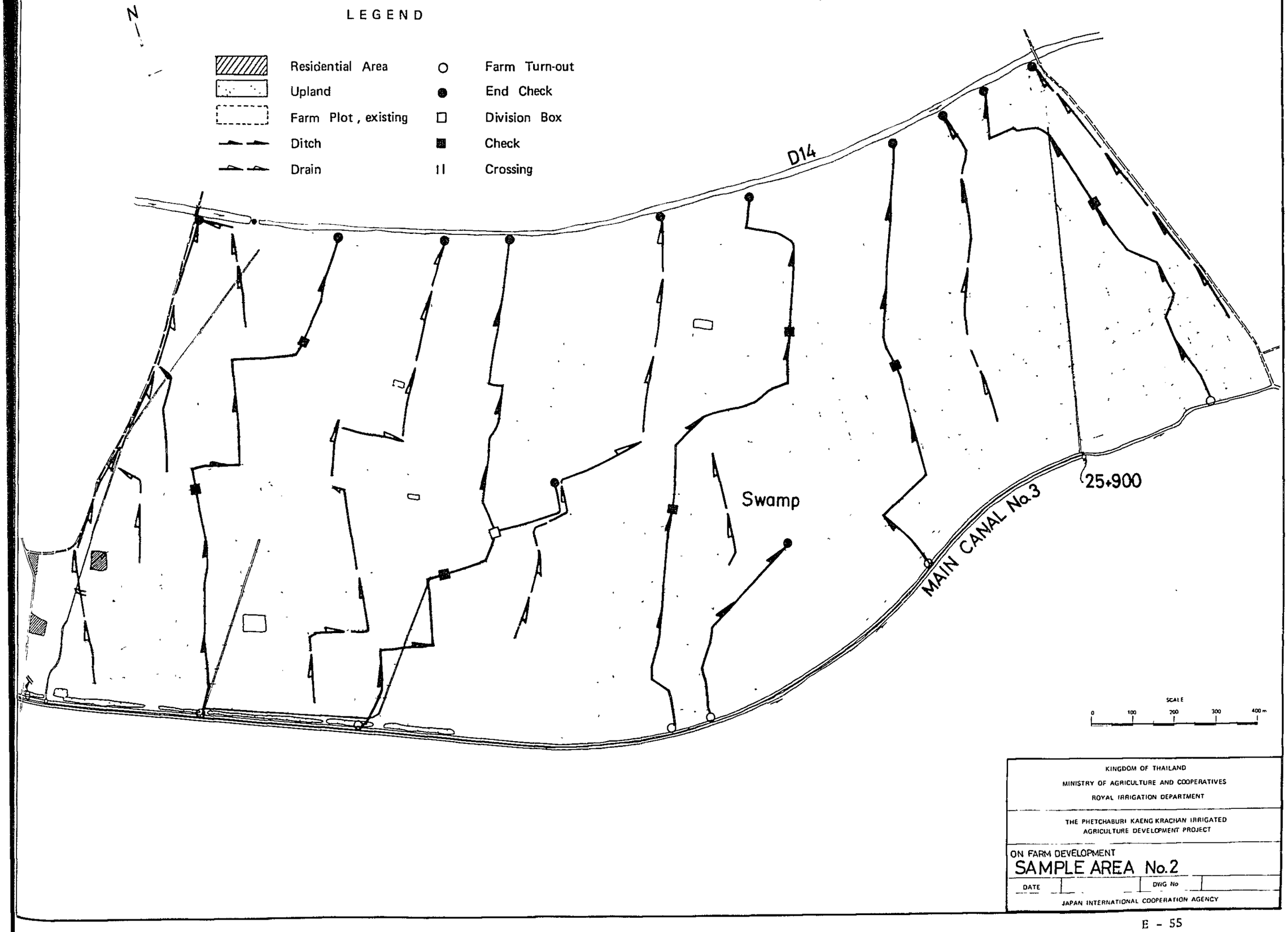
Figure E - 23 Layout of Type B On-farm Development, Sample Area No. 2



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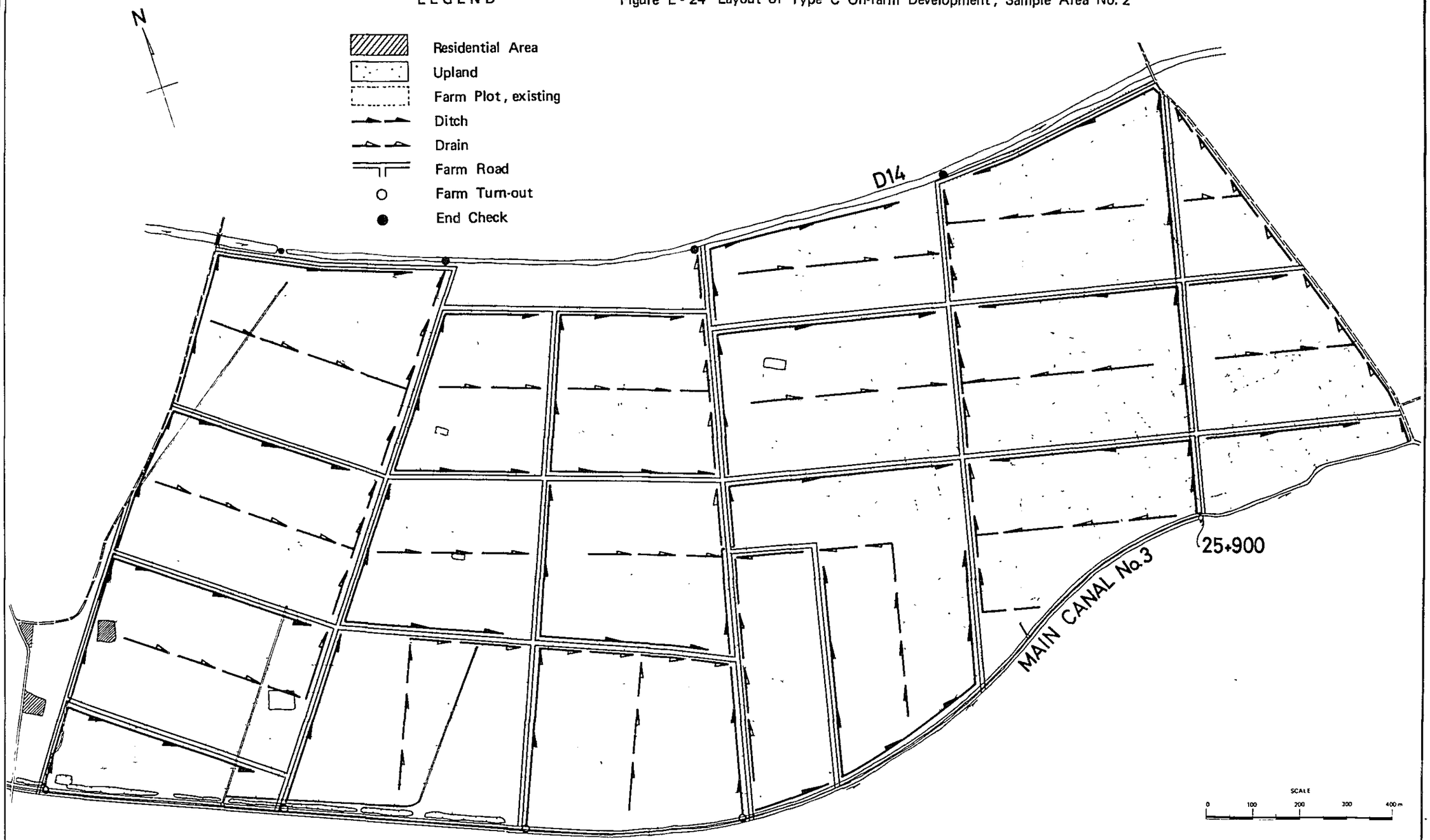
ON FARM DEVELOPMENT SAMPLE AREA No.2	
DATE	DWG No
JAPAN INTERNATIONAL COOPERATION AGENCY	

LEGEND

Figure E - 24 Layout of Type C On-farm Development, Sample Area No. 2



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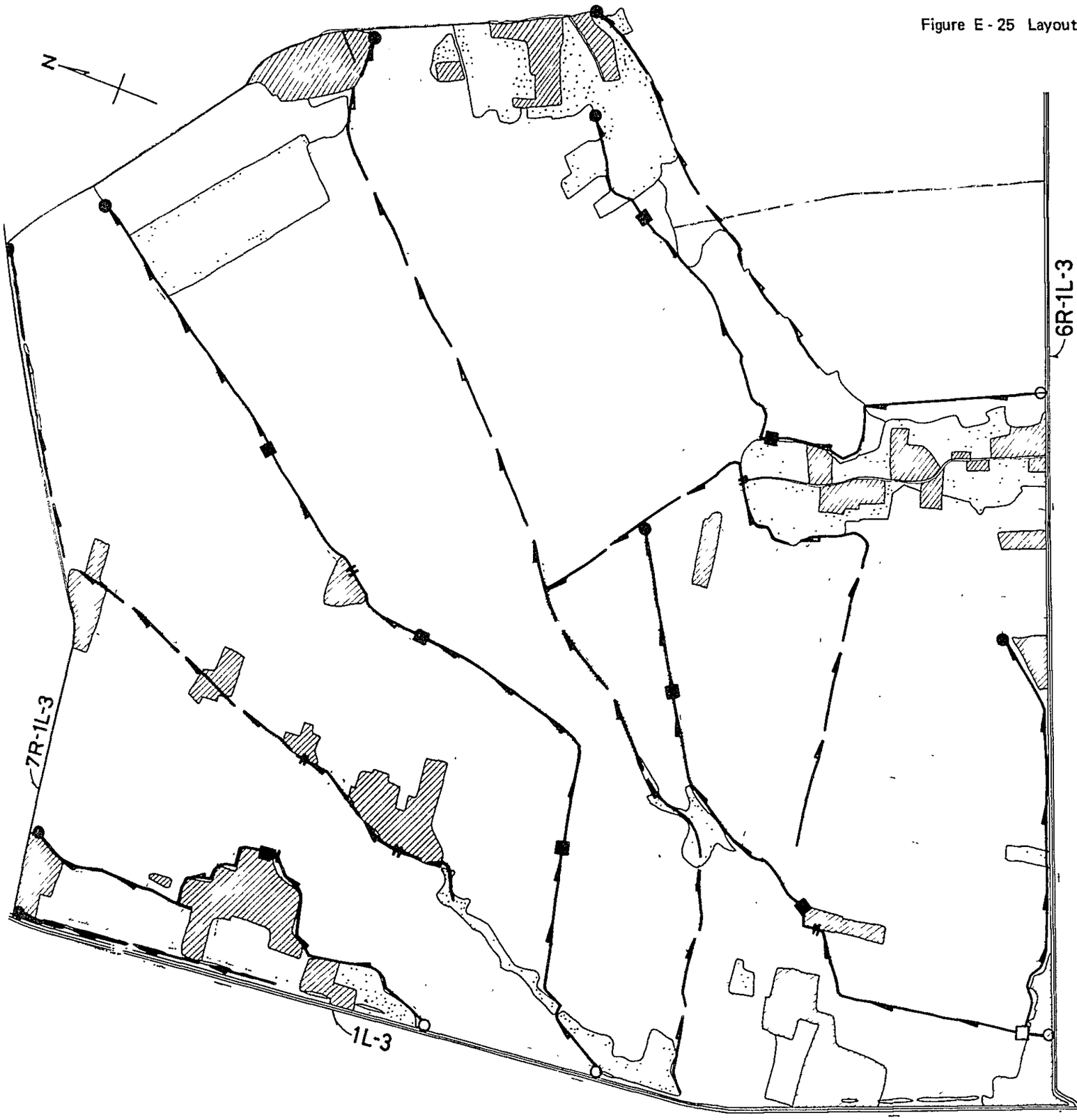
ON FARM DEVELOPMENT
SAMPLE AREA No.2

DATE | DWG No

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure E - 25 Layout of Type A On-farm Development, Sample Area No. 3



LEGEND

- Residential Area
- Upland
- Farm Plot, existing
- Ditch
- Drain
- Farm Turn-out
- End Check
- Division Box
- Check
- Crossing

SCALE
0 100 200 300 400 m

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ON FARM DEVELOPMENT
SAMPLE AREA No.3.

DATE | DWG No

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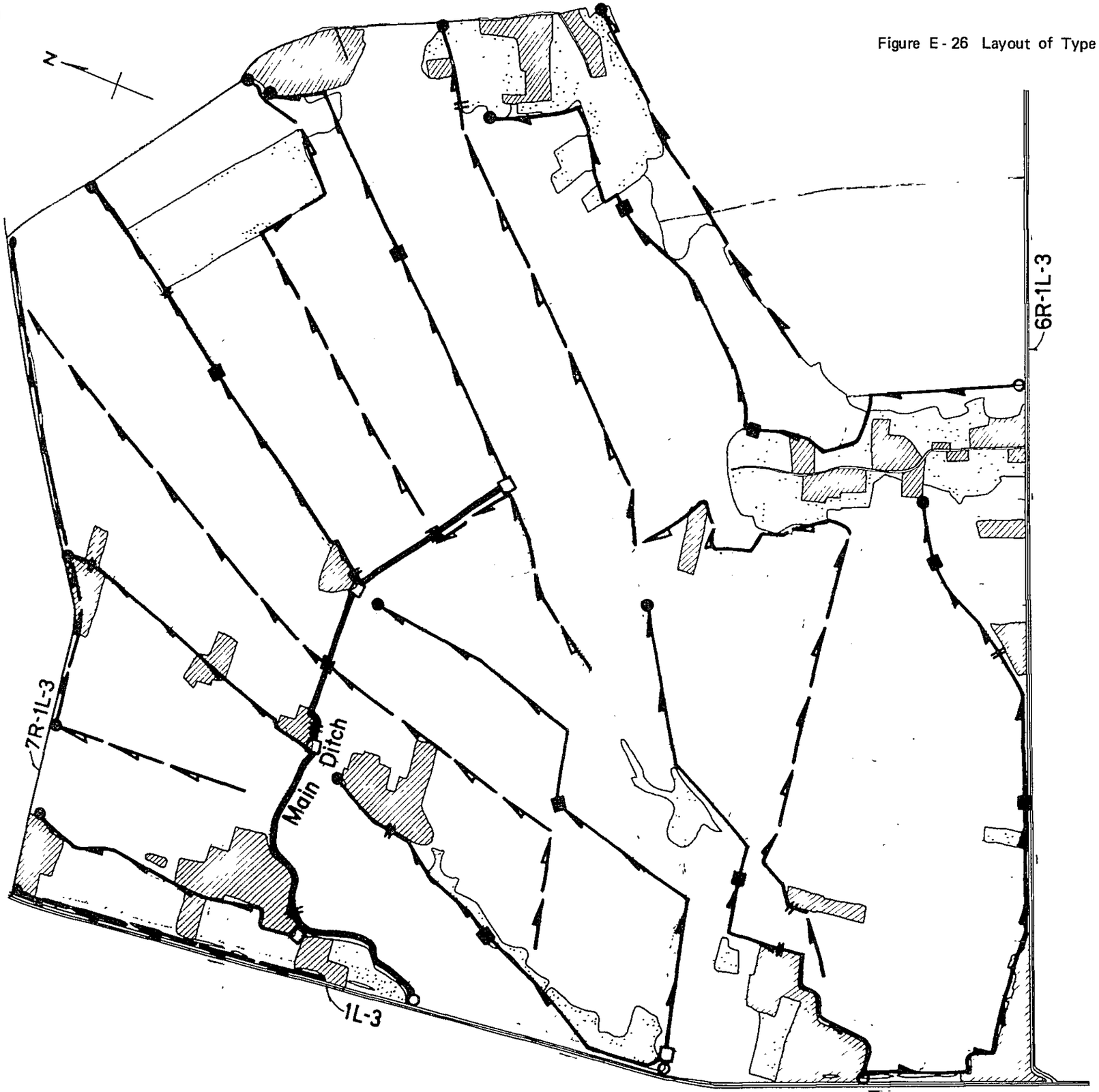
Figure E - 26 Layout of Type B On-farm Development, Sample Area No. 3



LEGEND

- Residential Area
- Upland
- Farm Plot, existing
- Ditch
- Drain
- Farm Turn-out
- End Check
- Division Box
- Check
- Crossing

SCALE
0 100 200 300 400 m

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ON FARM DEVELOPMENT
SAMPLE AREA No.3.

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Figure E - 27 Layout of Type C On-farm Development, Sample Area No. 3

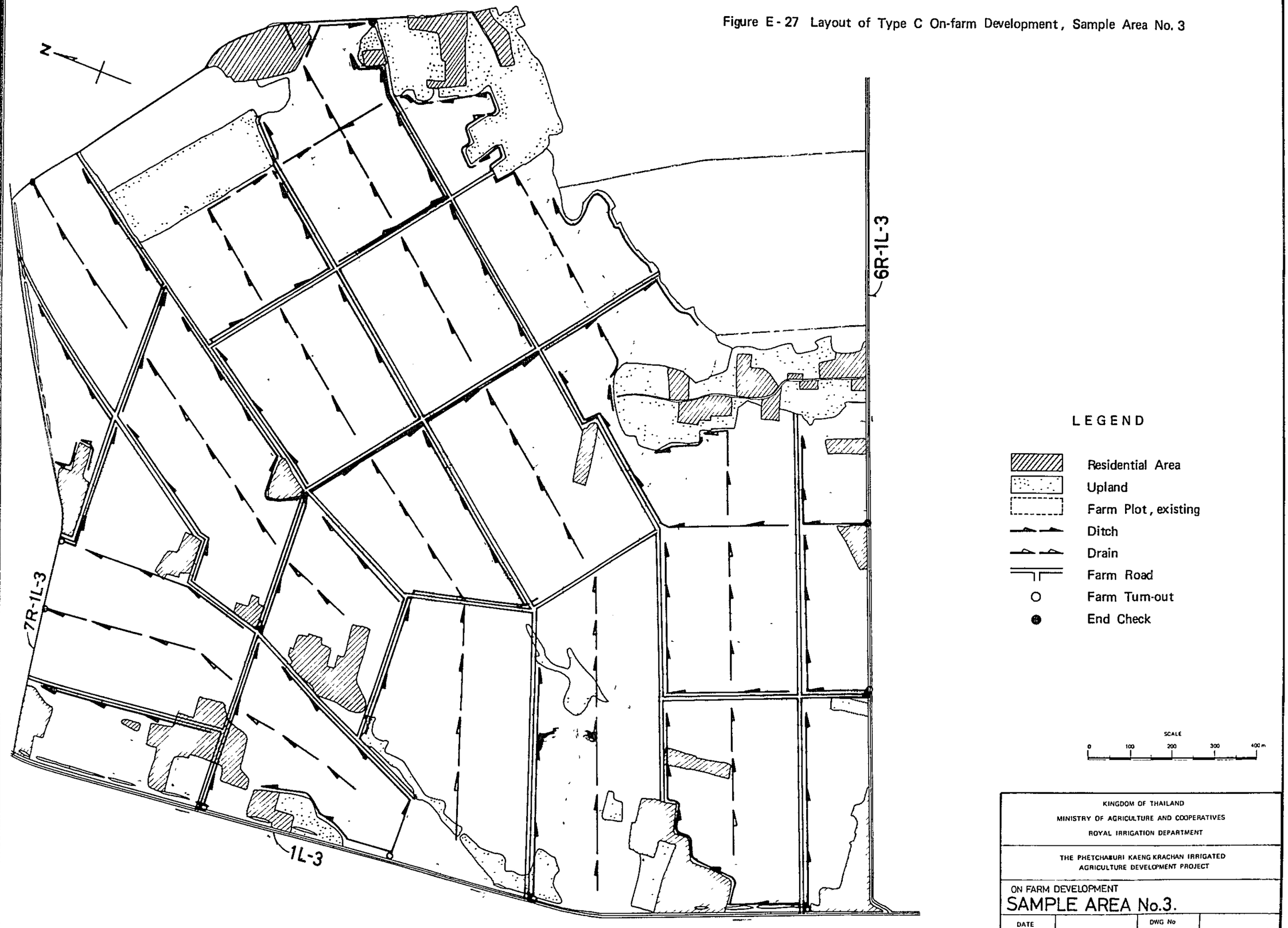

Figure E - 28 Layout of Type A On-farm Development, Sample Area No. 4