E-7. Water Quality

In the course of the field survey, water quality investigation of surface water at 23 sites was carried out twice in October, 1988 and June, 1989.

Location	Electric Conductivity (umho/cm)	PH	Dissolved Oxygen (PPM)	Tomperature (°C)
1. Project area (1/)				
Lam Se	73	7.5	6.13	37.5
Huai Khum Kham	55	7.2	7.02	33.0
Huai Kham Phak Wan	35	8.1	8.91	37.5
Huai Na Khai	57	7.6	5.70	36.0
Huai Soob	35	6.9	5.68	30.5
2. Basin Study Area (2/)				
Huai Wang Luang	170	6.6	4.46	31.0
Upper Sebok	110	6.8	4.37	30.0
Huai Sabaek (M.109)	50	7.4	5.73	29.0
Lam Sebai (M.128)	40	7.5	5.51	29.0
Huai Phong (M.126)	70	7.3	5.27	30.0
Lam Sebai (M.32)	75	6.4	4.55	29.5
Huai Pra Rot	200	6.5	3.97	29.0
Huai Phai	75	6.8	5.58	28.0
Huai Charan	67	7.0	5.92	29.5
Huai Na Saeng	160	6.7	5.96	29.0
Huai Phra Lao	50	7.4	6.13	30.5
Huai Ta Tieo (M.127)	60	7.5	6.33	30.0
Huai Khu Lu	45	7.6	5.98	30.5
Huai Sa Phu (M.132)	95	8.8	6.65	33.0
East of M.132	35	7.5	6.06	30.5
East of M.132	35	7.3	6.06	29.5
M.110	45	7.8	6.17	31.0
Huai Mak	42	8.1	6.15	32.0

Note : 1/ : June 19 - 22, 1989
2/ : Oct. 25 - 26

TABLE E-1 : NET AMOUNT OF WATER TO BE REPLACED FOR CROPS (1/4)

(CORN, GROUNDNUTS) ------- LAM SE PROJECT

(1) Depth	(2) Available Moisture (AM)	(3) Ratio of Moisture Extraction	(4) (2)/(3)	(5) Restricting Layer of Moisture	(6) TRAM
cm	mm		mm		mm
0 ~ 15	8.2	0.4	20.5	*	20.5
15 ~ 30	8.2	0.3	27.3		
30 ~ 45	7.8	0.2	39		
45 ~ 60	7.8	0.1	78		

Note: 1/: $AM = \frac{1}{100} (Fc - Wp) \cdot Sa \cdot D$

Fc: Field Capacity (%)

Wp: Wilting Point (%)

Sa: Aparent Specific Gravity (g/cm^3)

D : Depth (mm)

2/: TRAM: Total Readily Available Moisture

TABLE E-1 : NET AMOUNT OF WATER TO BE REPLACED FOR CROPS (2/4)
(CORN, GROUNDNUTS) --- HUAI KHUM KHAM PROJECT

(1) Depth	(2) Available Moisture (AM)	(3) Ratio of Moisture Extraction	(4) (2)/(3)	(5) Restricting Layer of Moisture	(6) TRAM
cm	mm		mm		mm
0 ~ 15	13.8	0.4	34.5	*	34.5
15 ~ 30	13.8	0.3	46.0		
30 ~ 45	14.7	0.2	73.5		
45 ~ 60	14.7	0.1	147.0		

Note: 1/ : $AM = \frac{1}{100} (Fc - Wp) \cdot Sa \cdot D$

Fc: Field Capacity (%)

Wp: Wilting Point (%)

Sa: Aparent Specific Gravity (g/cm^3)

D : Depth (mm)

2/ : TRAM: Total Readily Available Moisture

TABLE E-1 : NET AMOUNT OF WATER TO BE REPLACED FOR CROPS (3/4)

(CORN, GROUNDNUTS, ETC.) --- HUAI NA KHAI PROJECT

(1) Depth	(2) Available Moisture (AM)	(3) Ratio of Moisture Extraction	(4) (2)/(3)	(5) Restricting Layer of Moisture	(6) TRAM
cm	mm		mm		mm
0 ~ 15	4.6	0.4	11.5	*	11.5
15 ~ 30	4.6	0.3	15.3		
30 ~ 45	6.3	0.2	31.5		
45 ~ 60	6.3	0.1	63.0		

Note: 1/: $AM = \frac{1}{100} (Fc - Wp) \cdot Sa \cdot D$

Fc: Field Capacity (%)

WpP Wilting Point (%)

Sa: Aparent Specific Gravity (g/cm^3)

D : Depth (mm)

2/: TRAM: Total Readily Available Moisture

TABLE E-1 : NET AMOUNT OF WATER TO BE REPLACED FOR CROPS (4/4)
(CORN, GROUNDNUTS, ETC.)-- HUAI SOOB PROJECT

(1) Depth	(2) Avairable Moisture (AM)	(3) Ratio of Moisture Extraction	(4) (2)/(3)	(5) Restricting Layer of Moisture	(6) TRAM
cm	mm		mm		mm
0 ~ 15	8.4	0.4	21.0	*	21.0
15 ~ 30	8.4	0.3	28.0		
30 ~ 45	9.9	0.2	49.5		
45 ~ 60	9.9	0.1	99.0		

Note: 1/ : $AM = \frac{1}{100} (Fc - Wp) \cdot Sa \cdot D$

Fc: Field Capacity (%)

Wp: Wilting Point (%)

Sa: Aparent Specific Gravity (g/cm^3)

D : Depth (mm)

2/ : TRAM: Total Readily Available Moisture

TABLE E-2 : EVAPOTRANSPIRATION ESTIMATED BY MODIFIED PENMAN METHOD

Station: Ubon Rachathani (Latitude: 15°15, Altitude: 123 m MSL)

Month	Radiation Term						Aerodynamic Term					Adjustment Factor	Reference Crop Evapotranspiration ETo	
	Weighting	Net Radiation (mm/day)					Weighting Factor	Wind Function	Vapour Pressure (mbar)					
	W.	Ra	Rs	Rns	Rnl	Rn	1-W	f(u)	ea	ed	ea-ed	C	mm/day	mm/month
Jan.	0.72	12.2	8.2	6.1	2.0	4.1	0.28	0.57	29.0	18.9	10.1	0.39	4.50	140
Feb.	0.75	13.5	8.8	6.6	2.3	4.3	0.25	0.53	33.4	21.0	12.4	1.07	5.20	146
Mar.	0.78	14.8	9.1	6.8	1.5	5.3	0.22	0.52	39.2	24.3	14.9	1.10	6.42	199
Apr.	0.78	15.6	9.3	7.0	1.3	5.7	0.22	0.51	41.5	27.4	14.1	1.09	6.57	197
May	0.77	15.9	8.9	6.7	1.1	5.6	0.23	0.52	39.6	29.7	9.9	1.01	5.55	172
Jun.	0.77	15.8	7.9	5.9	0.9	5.0	0.23	0.58	38.0	30.4	7.6	0.98	4.77	143
Jul.	0.76	15.8	7.9	5.9	0.9	5.0	0.24	0.58	37.0	30.0	7.0	1.06	5.06	157
Aug.	0.76	15.7	7.4	5.5	0.8	4.7	0.24	0.59	36.1	30.0	6.1	1.04	4.61	143
Sep.	0.76	15.0	7.1	5.3	0.8	4.5	0.24	0.48	35.7	29.6	6.1	1.07	4.41	132
Oct.	0.75	14.0	8.0	6.0	1.2	4.8	0.25	0.58	34.7	26.7	8.0	1.04	4.95	153
Nov.	0.74	12.6	7.9	6.0	1.6	4.4	0.26	0.73	31.7	22.8	8.9	1.01	4.95	148
Dec.	0.72	11.8	7.6	5.7	1.7	4.0	0.28	0.68	28.8	19.9	8.9	0.93	4.25	132
Average	0.76	14.4	8.2	6.1	1.3	4.8	0.25	0.57	35.4	25.9	9.5	1.03	5.10	155

TABLE E-3. CROPPING CALENDAR AND RELEVANT IRRIGATION FACTOR (1/3)

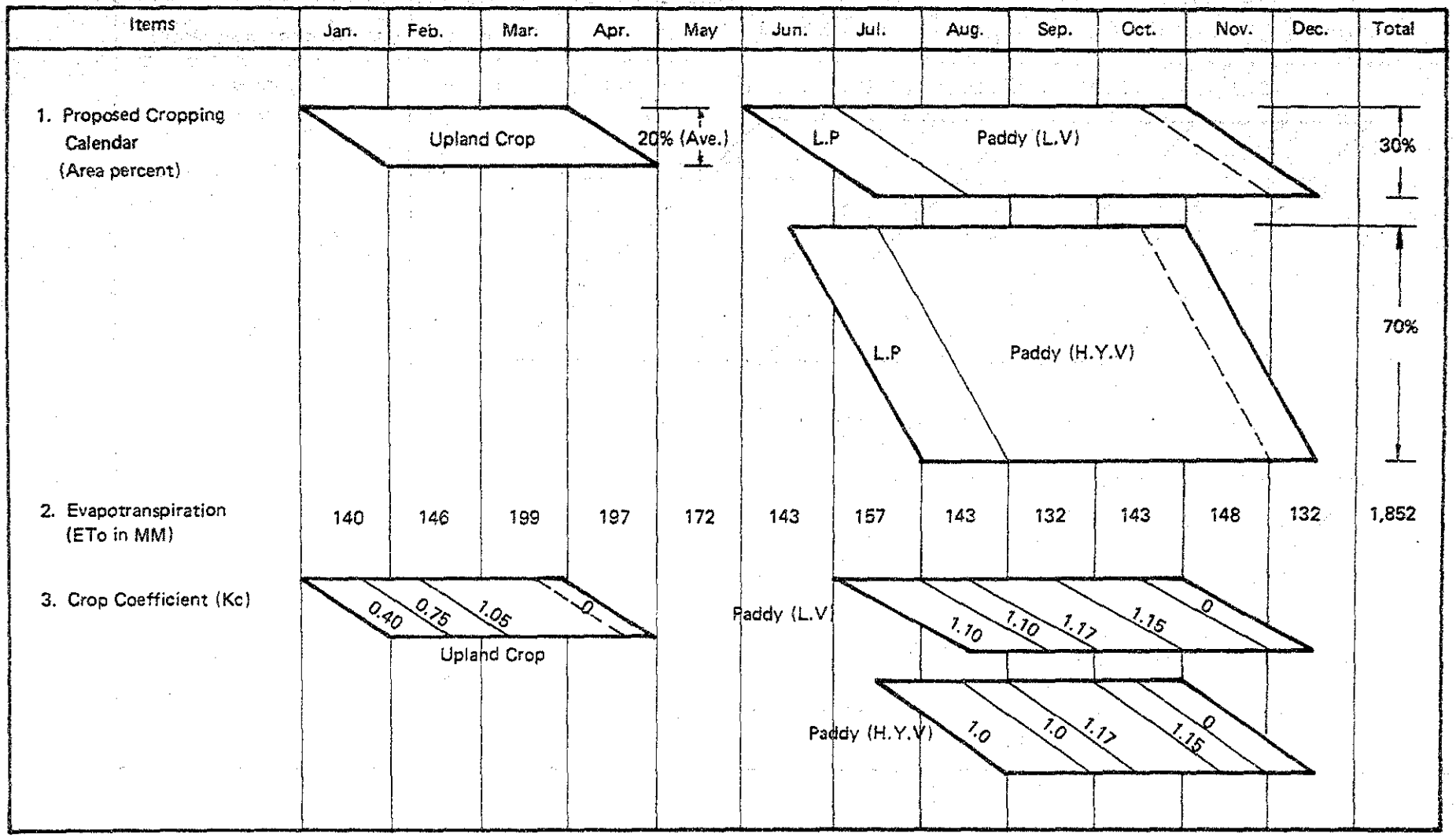


TABLE E-3. CROPPING CALENDAR AND RELEVANT IRRIGATION FACTORS (2/3)

	JUL.			AUG.			SEP.			OCT.			NOV.			DEC.
ETo in mm	157			143			132			143			148			132
Crop Coefficient (Kc)				Paddy (L.V)												
				1.0			1.0			1.17			1.15			0
— Average Kc	0.04	0.11	0.18	0.26	0.32	0.34	0.36	0.37	0.38	0.38	0.37	0.30	0.21	0.13	0.05	—
				Paddy (H.Y.V)												
				1.0			1.0			1.17			1.15			0
— Average Kc	—	0.01	0.07	0.15	0.22	0.29	0.34	0.35	0.36	0.38	0.38	0.31	0.21	0.13	0.05	—
Crop Consumption Use (ETcrop in mm)																
Paddy (L.V)	6	17	28	37	46	49	48	49	50	54	53	43	31	19	7	
Paddy (H.Y.V)	—	2	11	21	31	42	45	46	48	54	54	44	31	19	7	

TABLE E–3. CROPPING CALENDAR AND RELEVANT IRRIGATION FACTORS (3/3)

	DEC.	JAN.			FEB.			MAR.			APR.			TOTAL
ETo in mm		140			146			199			197			
Crop Coefficient (Kc)	Pre-Irri.	Upland Crop												
		0.4			0.75			1.05			0			
Average Kc		0.02	0.07	0.13	0.20	0.25	0.31	0.33	0.35	0.29	0.18	0.06		
Crop Consmpution Use (Etcrop in mm)														
Upland		3	10	18	29	37	45	66	70	58	35	12	—	383
Pre-Irrigation	13	27	27	13										80
Total	13	30	37	31	29	37	45	66	70	58	35	12	—	463

TABLE E-4 : FIELD WATER REQUIREMENT ON 10 DAY BASIS

Unit: mm

(Wet Season Paddy)

Month		Paddy-L.V. (30%)				Paddy-H.Y.V. (70%)				Average
		L P	ET cr.	Perc.	Total	L P	ET cr.	Perc.	Total	
Jun.	E	10	-	-	10	-	-	-	-	3.0
	M	27	-	-	27	3	-	-	3	10.2
	L	47	-	-	47	18	-	-	18	26.7
Jul.	E	55	6	3	64	37	-	-	37	45.1
	M	53	17	7	77	53	2	1	56	62.3
	L	35	28	11	74	53	11	5	69	70.5
Aug.	E	20	37	18	75	49	21	12	82	79.9
	M	3	46	20	69	27	31	13	71	70.4
	L	-	49	22	71	10	42	18	70	70.3
Sep.	E	-	48	20	68	-	45	20	65	65.9
	M	-	49	20	69	-	46	20	66	66.9
	L	-	50	20	70	-	48	20	68	68.6
Oct.	E	-	54	20	74	-	54	20	74	74.0
	M	-	53	20	73	-	54	20	74	73.7
	L	-	43	14	57	-	44	13	57	57.0
Nov.	E	-	31	11	42	-	31	11	42	42.0
	M	-	19	7	26	-	19	7	26	26.0
	L	-	7	2	9	-	7	2	9	9.0
Total		250	537	215	1,002	250	455	182	887	921.5

(Dry Season-Upland Crop)

Month		Upland Crop			
		L P	ET cr.	Perc.	Total
Dec.	E	-	-	-	-
	M	-	-	-	-
	L	13	-	-	13
Jan.	E	27	3	-	30
	M	27	10	-	37
	L	13	18	-	31
Feb.	E	-	29	-	29
	M	-	37	-	37
	L	-	45	-	45
Mar.	E	-	66	-	66
	M	-	70	-	70
	L	-	58	-	58
Apr.	E	-	35	-	35
	M	-	12	-	12
	L	-	-	-	-
Total		80	383	-	463

TABLE E-5 : VILLAGE POND

Items	Type 1	Type 2	Type 3	Total
Area of Pond	1.6 ha	0.8 ha	0.48 ha	
Dimension	130m x 130m	90m x 90m	70m x 70m	
Depth	2.0 m	2.0 m	2.0 m	
· Lam Se (BA-5)	2	1	2	5
· Huai Khum Kham (BO-11)	1	3	7	11
· Huai Kham Phak Wan (BO-13)	-	1	4	5
· Huai Na Khai (BO-18)	-	1	9	10
· Huai Soob	1	-	4	5
Total	4	6	26	36

TABLE E-6 : VILLAGE POND LIST (1/2)

Name of Project	Amphoe & Tambon	Muban	Population (1989)	Scale of Pond	Remarks
Lam Se (BA-5)	° Leong Nok Tha			ha (Rai)	
	Hong Sang	1. Non Daeng	699	0.8 (5)	
	Kutchiang Mee	1. Sawad Noi	895	1.6 (10)	
		2. Kud Kook	525	0.48 (3)	
		3. Nong Bua	229	0.48 (3)	
		4. Kut Khaedon	899	1.6 (10)	
Huai Khum Kham (BO-11)	° Trakan Phutphon				
	Kon-Sai	1. Dong Muang	526	0.48 (3)	
		2. Suk Samran	161	0.48 (3)	
		3. Kon Sai	607	0.8 (5)	
		4. Hua Saphan	209	0.48 (3)	
	Kasem	1. Kasem	583	0.8 (5)	
		2. Ban Kok	415	0.48 (3)	
		3. Muaod Air	192	0.48 (3)	
		4. Kham Saming	1,862	1.60 (10)	
		5. Nong Or	726	0.8 (10)	
		6. Kung Bhudthakan	343	0.48 (3)	
		7. Nong Tao	433	0.48 (3)	

TABLE E-6 : VILLAGE POND LIST (2/2)

Name of Project	Amphoe & Tambon	Muban	Population (1989)	Scale of Pond	Remarks
Huai Kham Phak Wan	° Trakan Phutphon			ha (Rai)	
(BO-13)	Kusakon	1. Kusakon	730	0.8 (5)	
		2. Jik	252	0.48 (3)	
		3. Kung Yai	202	0.48 (3)	
		4. Kung Noi	350	0.48 (3)	
		5. Sri Suk	445	0.48 (3)	
Huai Na Khai	° Tan Sum				
(BO-18)	Na Khai	1. Na Khai	692	0.8 (5)	
		2. Non Jik	429	0.48 (3)	
		3. Non Yang	342	0.48 (3)	
		4. Don Khwang	200	0.48 (3)	
		5. Don Wai	308	0.48 (3)	
		6. Kok Khai	275	0.48 (3)	
		7. Kham Hee	117	0.48 (3)	
		8. Hong Daeng	108	0.48 (3)	
		9. Kok Samran	155	0.48 (3)	
	Kham Wa	1. Huai Du	457	0.48 (3)	
Huai Soob (TL-6)	° Si Muang Mai				
	Don Yai	1. Kok Sawang	78	0.48 (3)	
	Kom Rai	1. Nong Chuak	1,159	1.6 (10)	
		2. Park Huai Daeng	260	0.48 (3)	
		3. Nong Nok Tha	180	0.48 (3)	
		4. Na Kham Noi	50	0.48 (3)	

TABLE E-7 : WATER SUPPLY FOR DRINKING AND DOMESTIC USE (1/2)

Project	Amphoe & Tambon	Muban	Population (1989)	Population (Supply)	Supply Water[1/] (ℓ/S)	Remarks
Lam Se (BA-5)	Leong Nok Tha					
	Hong Sand	1. Non Daeng	699	655	0.43	
	Kutchiang Mec	1. Sawad Noi	895	839	0.55	
		2. Kud Koole	525	492	0.32	
		3. Hong Bua	229	214	0.14	
		4. Kut Khaedon	899	843	0.55	
		Total			1.99	0.002 m^3/S
Huai Khum Kham (BO-11)	Trakan Phutphon					
	Kon-Sai	1. Dong Muang	526	493	0.32	
		2. Suk Samran	161	151	0.10	
		3. Kon Sai	607	569	0.37	
		4. Hua Saphan	209	196	0.13	
	Kasem	1. Kasem	583	546	0.36	
		2. Ban Kok	415	389	0.25	
		3. Muaod Air	192	180	0.12	
		4. Kham Saming	1,862	1,746	1.14	
		5. Nong Or	726	680	0.44	
		6. Kung Bhudthakan	343	321	0.21	
		7. Nong Tao	433	406	0.26	
		Total			3.70	0.004 m^3/S

Note: 1/ Conveyence losses of 20% is included.

TABLE E-7 : WATER SUPPLY FOR DRINKING AND DOMESTIC USE (2/2)

Project	Amphoe & Tambon	Muban	Population (1989)	Population (Supply)	Supply Water (ℓ/S)	Remarks
Huai Kham Phak Wan (BO-13)	Trakan Phutphon					
	Kusakon	1. Kusakon	730	684	0.44	
		2. Jik	252	236	0.15	
		3. Kung Yai	202	189	0.12	
		4. Kung Noi	350	328	0.21	
		5. Sri Suk	445	417	0.27	
		Total			1.19	0.001 m^3/S
Huai Na Khai (BO-18)	Tan Sum					
	Na Khai	1. Na Khai	692	649	0.42	
		2. Non Jik	429	402	0.26	
		3. Non Yang	342	321	0.21	
		4. Don Khwang	200	187	0.12	
		5. Non Wai	308	288	0.18	
		6. Kok Khai	275	257	0.16	
		7. Kham Hee	117	109	0.07	
		8. Hong Daeng	108	101	0.06	
		9. Kok Samran	155	145	0.09	
	Kham Wa	1. Huai Du	457	428	0.27	
		Total			1.84	0.002 m^3/S
Huai Soob (TL-6)	Si Muang Mai					
	Don Yai	1. Kok Sawang	78	73	0.04	
	Kom Rai	1. Nong Chuak	1,159	1,087	0.70	
		2. Park Huai Daeng	260	243	0.15	
		3. Nong Nok Tha	180	168	0.11	
		4. Na Kham Noi	50	46	0.03	
		Total			1.03	0.001 m^3/S

TABLE E-8 : WATER SUPPLY FOR CATTLE AND BUFFALOES (1/2)

Project	Name of Amphoe & Tambon	Name of Muban	Cow (head)	Buffaloes (head)	Supply Water (ℓ/S)
Lam Se (BA-5)	Leong Nok Tha				
	Hong Sand	1. Non Daeng	121	325	0.36
	Kutchiang Mec	1. Sawad Noi	72	264	0.27
		2. Kud Kook	96	118	0.17
		3. Nong Bua	25	123	0.12
		4. Kut Khaedon	51	532	0.47
		Total	365	1,362	1.39
Huai Khum Kham (BO-11)	Trakan Phutphon				
	Kon-Sai	1. Dong Muang	104	169	0.21
		2. Suk Samran	33	65	0.07
		3. Kon Sai	66	188	0.15
		4. Hua Saphan	72	41	0.08
	Kasem	1. Kasem	34	165	0.16
		2. Ban Kok	18	126	0.11
		3. Muaod Air	20	35	0.04
		4. Kham Saming	20	170	0.15
		5. Nong Or	70	180	0.20
		6. Kung Bhudthak	42	115	0.13
		7. Nong Tao	33	104	0.11
		Total	512	1,358	1.41

TABLE E-8 : WATER SUPPLY FOR CATTLE AND BUFFALOES (2/2)

Project	Name of Amphoe & Tambon	Name of Muban	Cow (head)	Buffaloes (head)	Supply Water (ℓ/S)
Huai Kham Phak Wan (BO-13)	Trakan Phutphon				
	Kusakon	1. Kusakon	24	175	0.16
		2. Jik	40	68	0.09
		3. Kung Yai	6	42	0.04
		4. Kung Noi	54	65	0.09
		5. Sri Suk	250	200	0.35
		Total	374	550	0.73
Huai Na Khai (BO-18)	Tan Sum				
	Na Khai	1. Na Khai	106	224	0.26
		2. Non Jik	33	123	0.13
		3. Non Yang	55	145	0.16
		4. Don Khwang	127	74	0.15
		5. Non Wai	150	100	0.19
		6. Kok Khai	13	100	0.09
		7. Kham Hee	25	30	0.04
		8. Hong Daeng	39	72	0.09
		9. Yok Samran	7	55	0.05
	Kham Wa	1. Huai Du	57	-	0.04
		Total	612	923	1.20
Huai Soob (TL-6)	Si Muang Mai				
	Don Yai	1. Kok Sawang	6	23	0.02
	Kom Rai	1. Nong Chuak	141	372	0.41
		2. Park Huai Daeng	-	58	0.04
		3. Nong Nok Tha	-	20	0.02
		4. Na Kham Noi	-	20	0.02
		Total	147	493	0.51
	Total		2,010	4,686	5.2

TABLE E-9 : WATER SUPPLY FOR FISHERIES

Project	Scale / Demand [1/] (ℓ/S)	10 rai 0.92	5 rai 0.46	3 rai 0.28	Total
◦ Lam Se					
	Number of Pond	2	1	2	5
	Water Use	1.8	0.5	0.6	2.9
◦ Huai Khum Kham					
	Number of Pond	1	3	7	11
	Water Use	0.9	1.4	2.0	4.3
◦ Huai Kham Phak Wan					
	Number of Pond	-	1	4	5
	Water Use	-	0.5	1.1	1.6
◦ Huai Na Khai					
	Number of Pond	-	1	9	10
	Water Use	-	0.5	2.5	3.0
◦ Huai Soob					
	Number of Pond	1	-	4	5
	Water Use	0.9	-	1.1	2.0
Total					
	Number of Pond	4	6	26	36
	Water Use	3.6	2.9	7.3	13.8

$$Q = \frac{A \times 1{,}600 \times D \times 1{,}000}{86{,}400 \times 1{,}000 \times 0.8} = 0.023 \quad A.D.$$

Where;

Q = Water use for fisharies (ℓ/S)

A = Muban pond scale in rai

D = Mean Evaporation from water surface = 4 mm/day

0.8= (1-0.2); Conveyence Loss = 20%

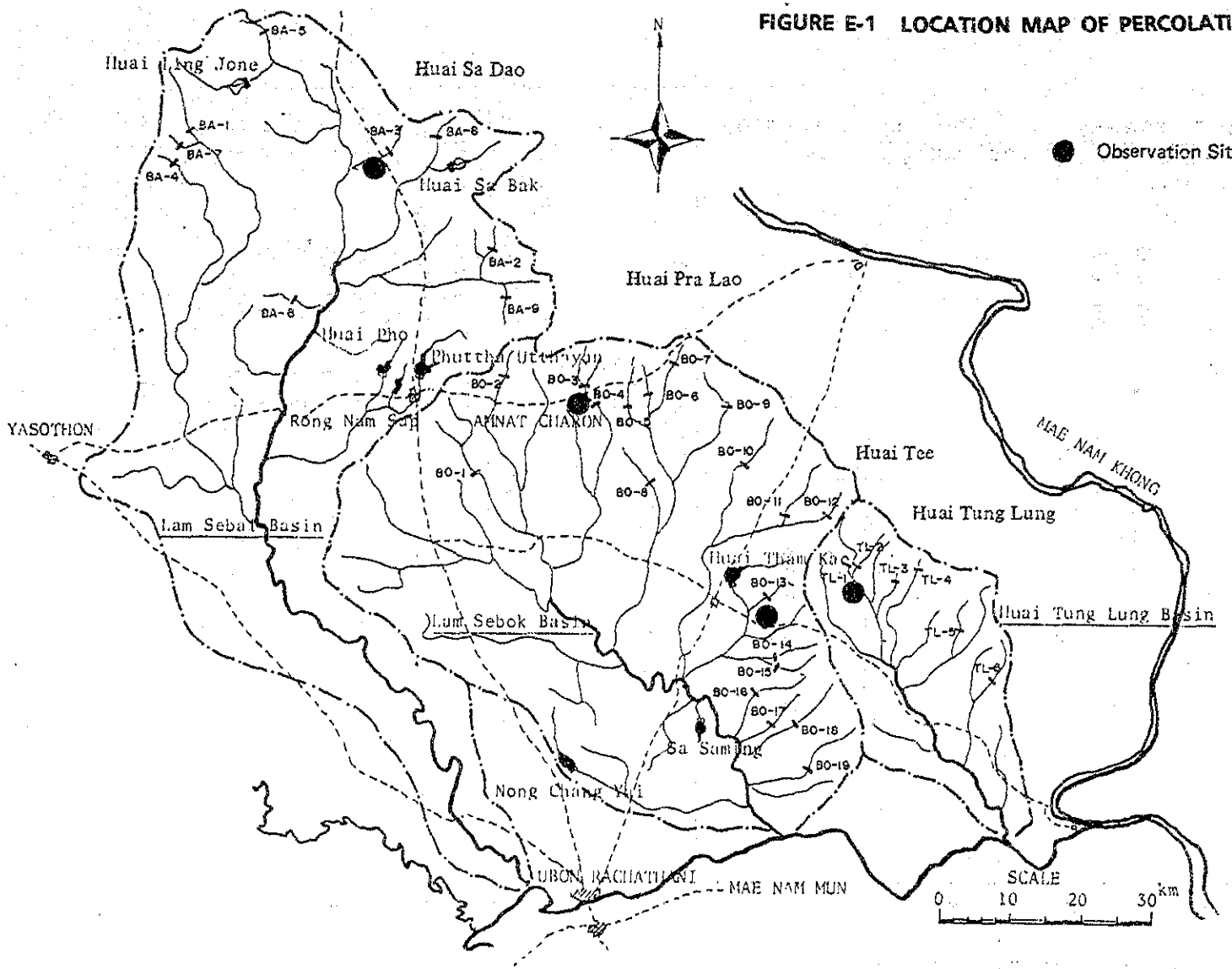
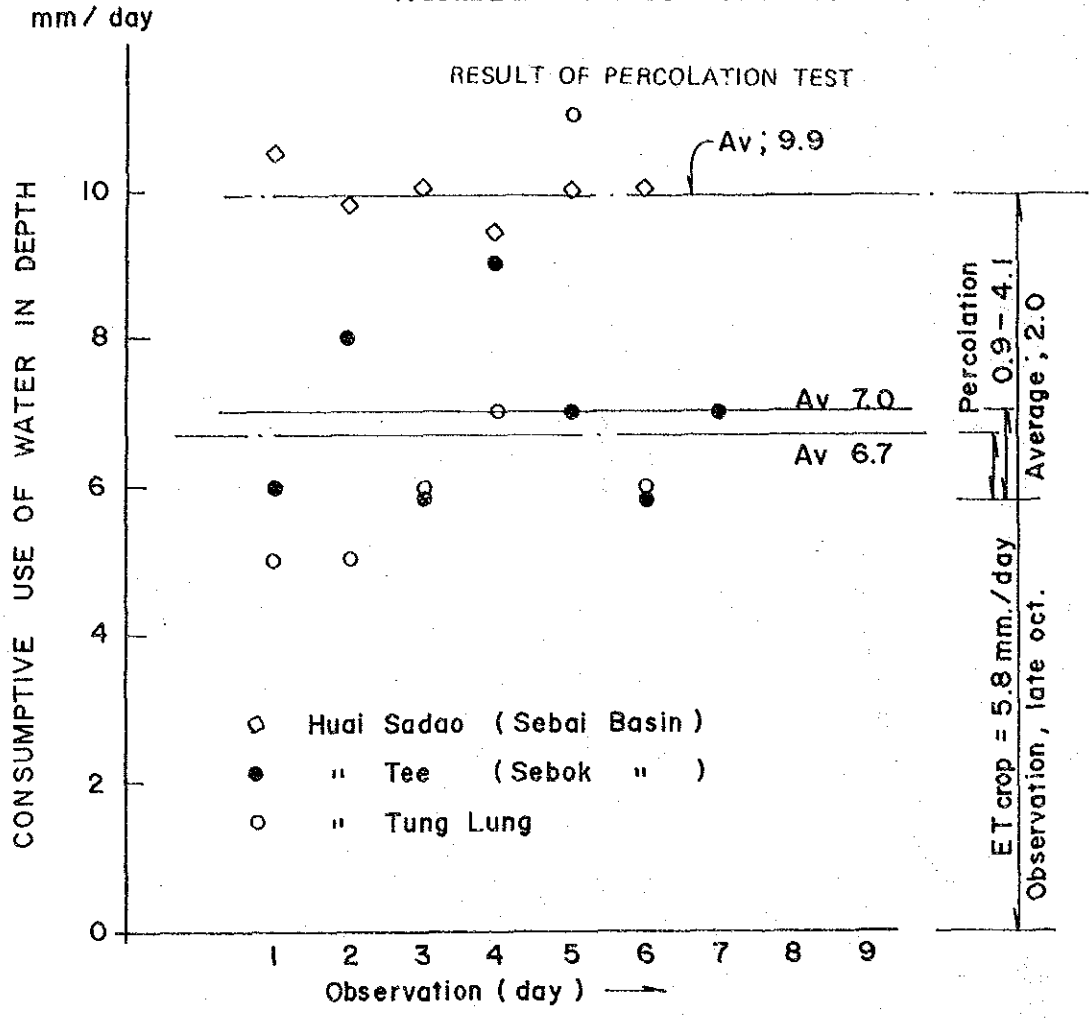


FIGURE E-1 LOCATION MAP OF PERCOLATION TEST

FIGURE E-2 : RESULT OF PERCOLATION TEST



PERCOLATION RATE

Day	SEBAI		SEBOK		H.T.L.	
	Reading	Diff.	Reading	Diff.	Reading	Diff.
0	24.05 cm.	mm.	27.30 cm.	mm.	24.10 cm.	mm.
1	23.00	10.5	26.70	6.0	23.60	5.0
2	22.02	9.8	25.90	8.0	23.10	5.0
3	21.02	10.0	25.30	6.0	22.50	6.0
4	20.08	9.4	24.40	9.0	21.80	7.0
5	19.08	10.0	23.70	7.0	20.70	11.0
6	18.08	10.0	23.10	6.0	20.10	6.0
7	-	-	22.40	7.0	-	-
Average		9.9		7.0		6.7

FIGURE E-3 : INFILTRATION CAPACITY (1/4)

(Lam Se Project; Ban Hong Dang)

$D = C \cdot T^{n}$

$I = C \cdot n \cdot T^{n-1}$

	C	n	Ib
(1)	9.2	0.64	51.1
(2)	13.0	0.47	17.3

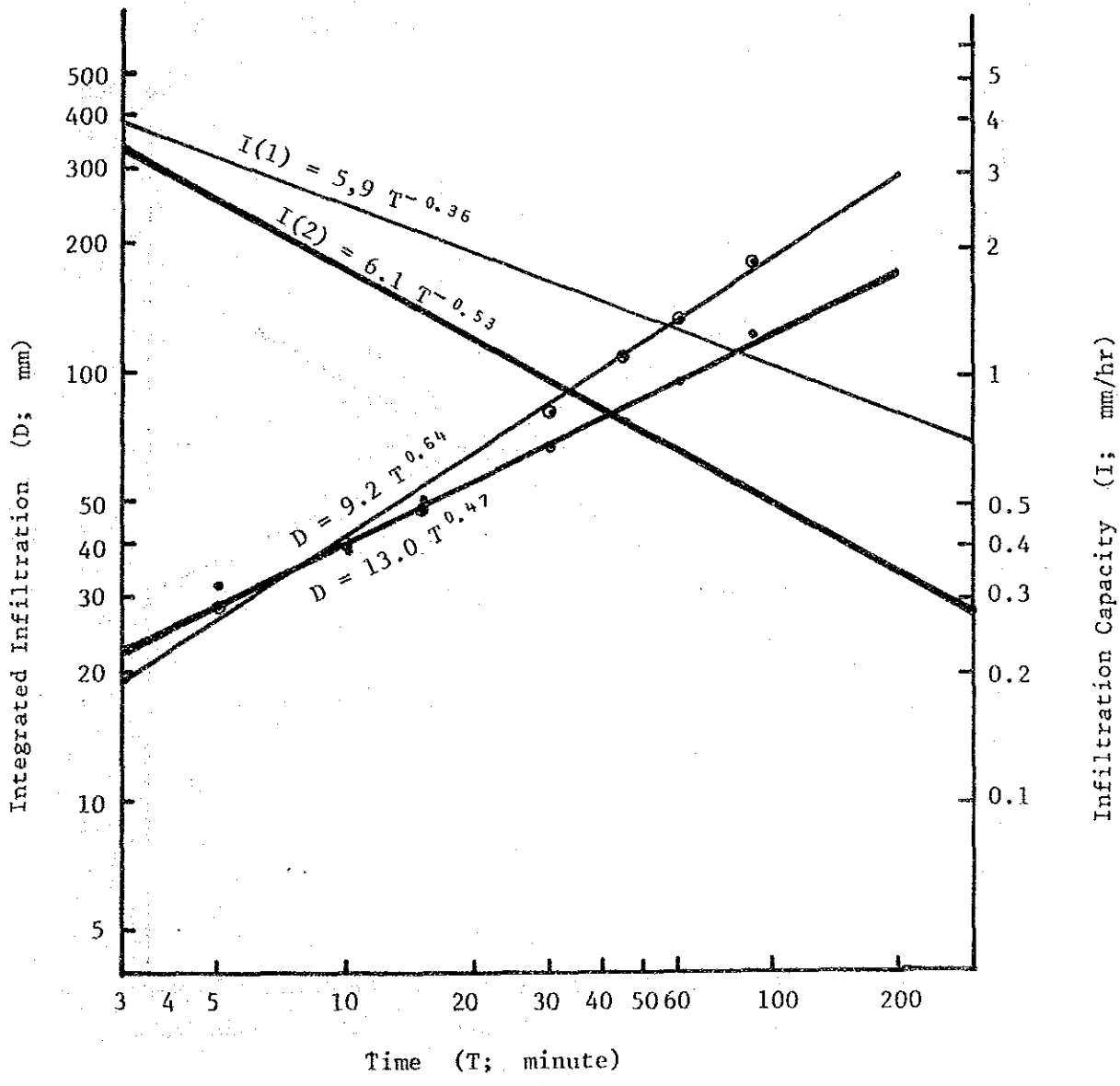


FIGURE E-3 : INFILTRATION CAPACITY (2/4)

(Huai Khum Kham Project
; Ban Kon Sai)

		C	n	Ib
$D = C \cdot T^n$	(1)	4.8	0.72	49.4
$I = C \cdot n \cdot T^{n-1}$	(2)	8.2	0.55	21.8

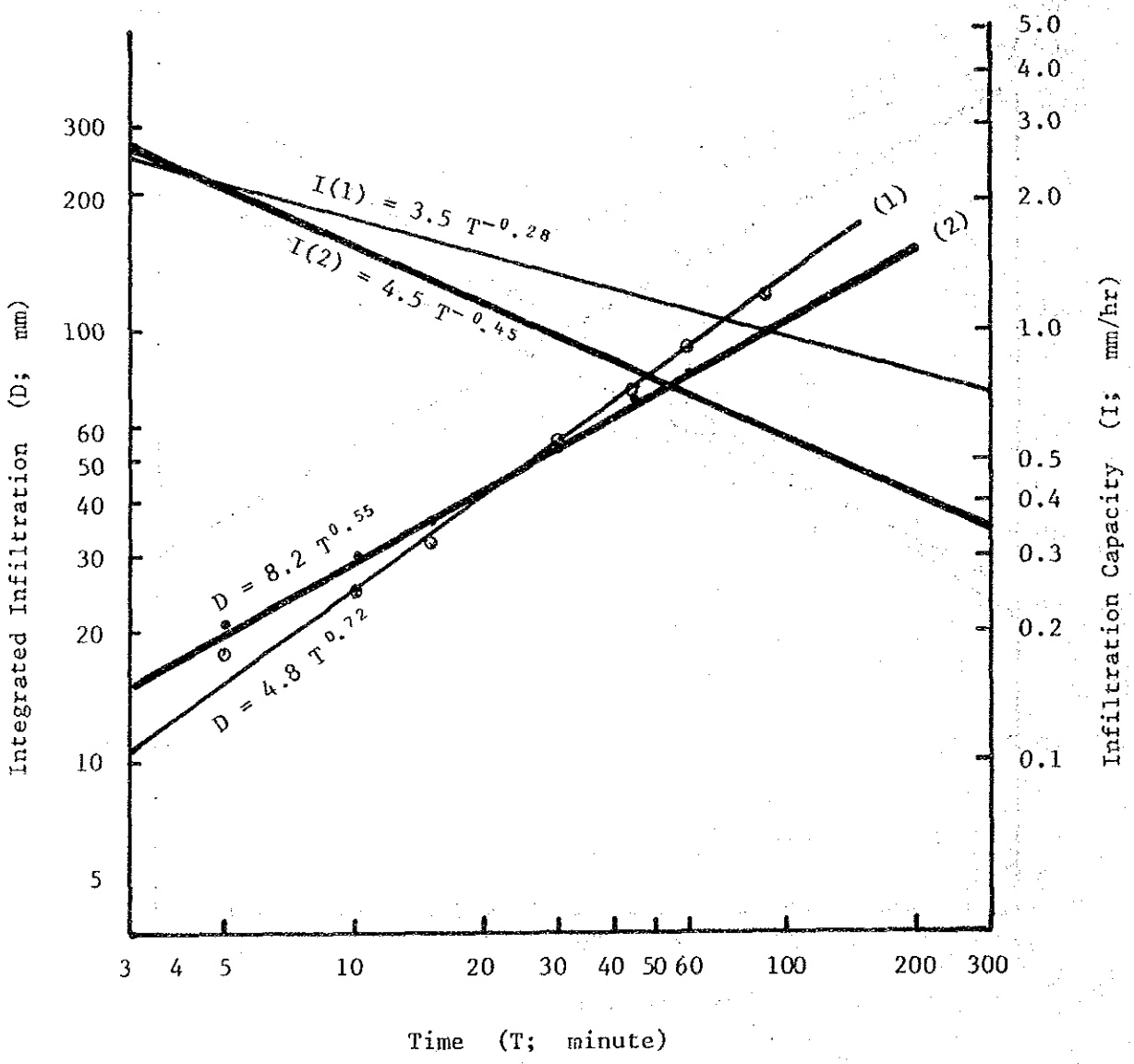


FIGURE E-3 : INFILTRATION CAPACITY (3/4)

(Huai Na Khai Project: Ban Non Chick)

$D = C \cdot T^{n}$

$I = C \cdot n \cdot T^{n-1}$

	C	n	Ib
(1)	11.5	0.74	137.4
(2)	9.1	0.63	46.6

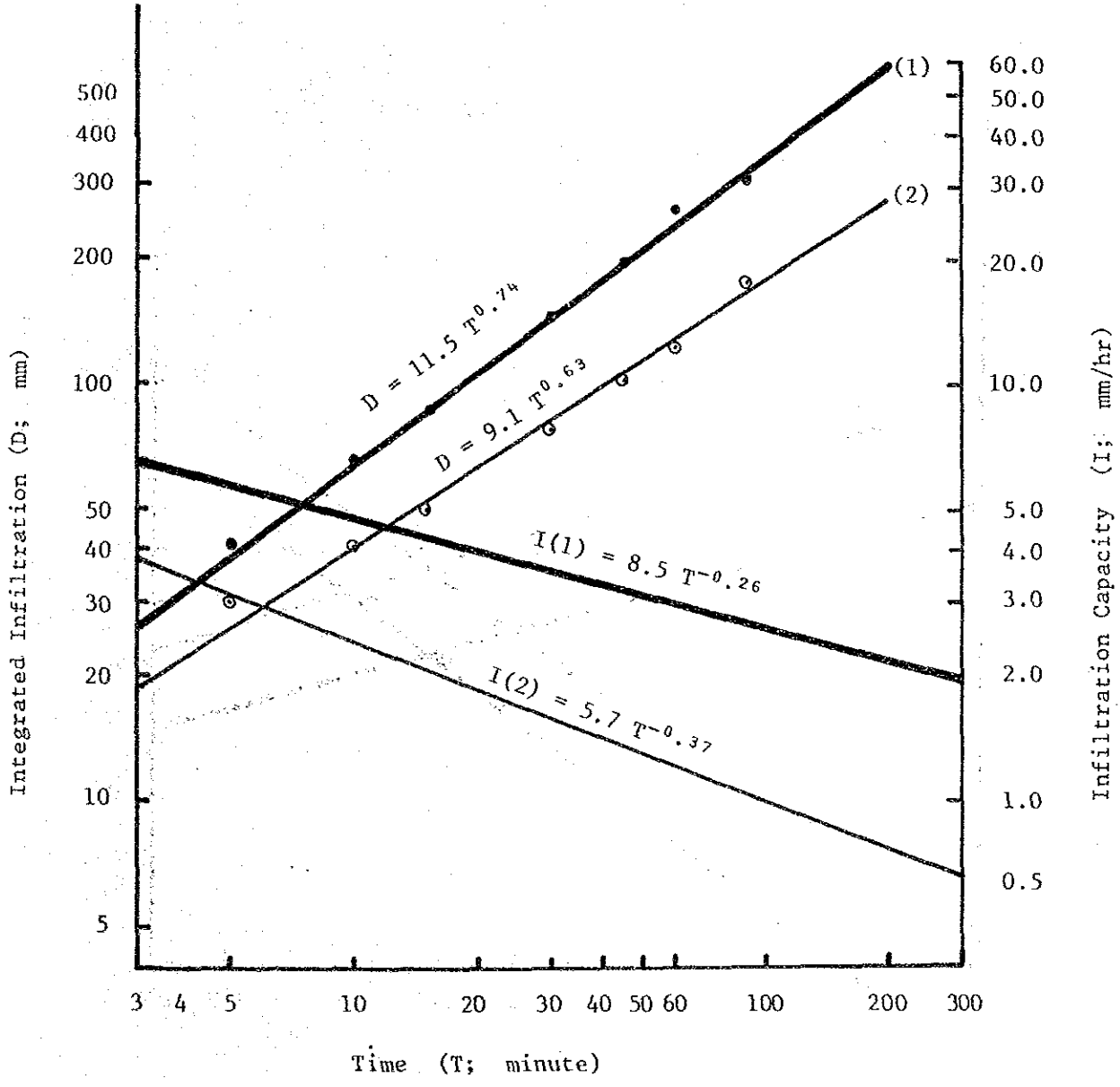


FIGURE E-3 : INFILTRATION CAPACITY (4/4)

(Huai Soob Project: Ban Nong Chuak)

$D = C \cdot T^{n}$

$I = C \cdot n \cdot T^{n-1}$

	C	n	Ib
(1)	1.9	0.69	15.6
(2)	1.0	0.73	11.1

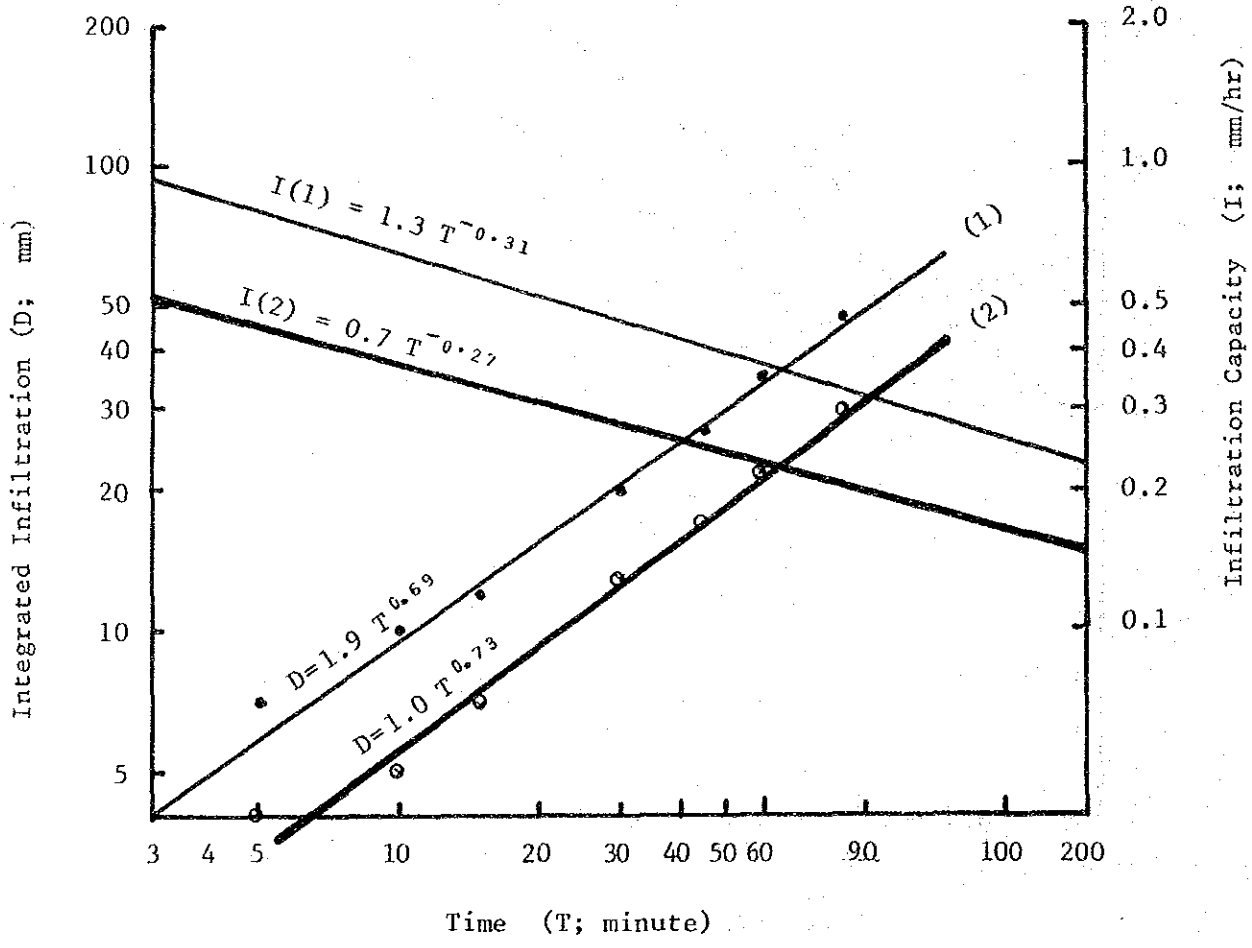
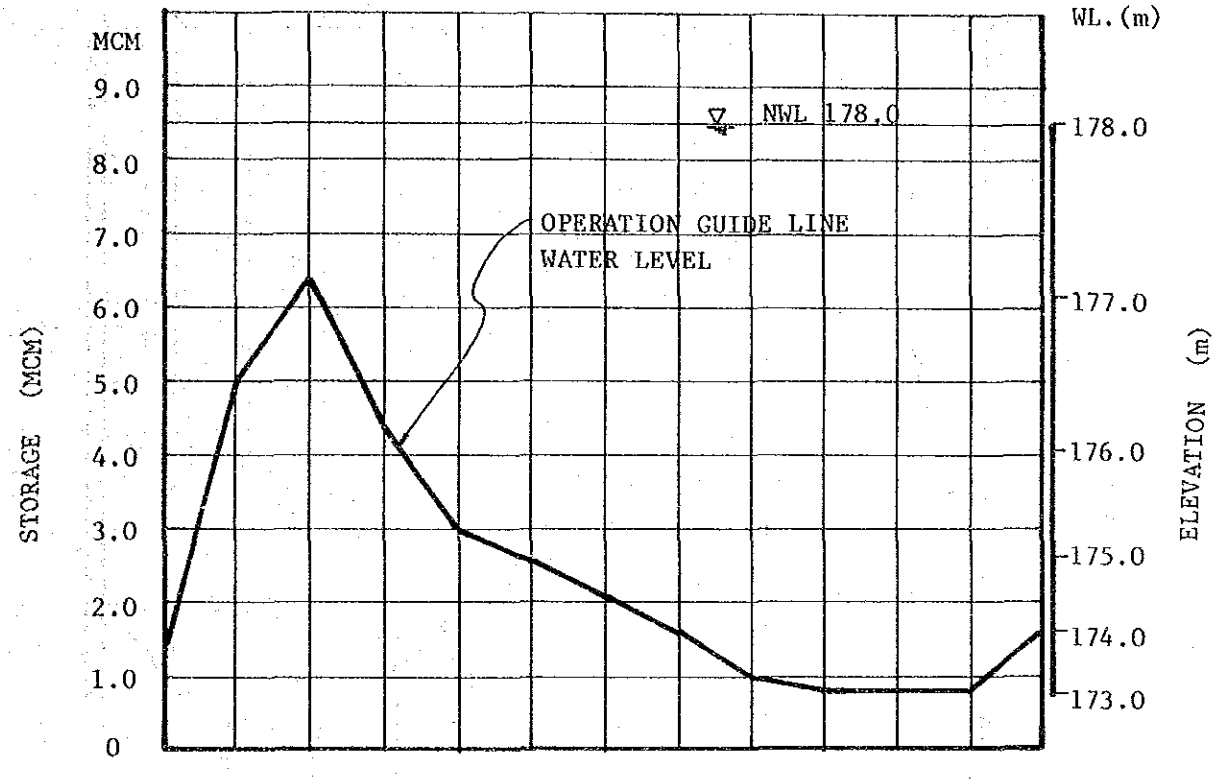


FIGURE E-4 : OPERATION GUIDE LINE (WATER LEVEL) (1/5)

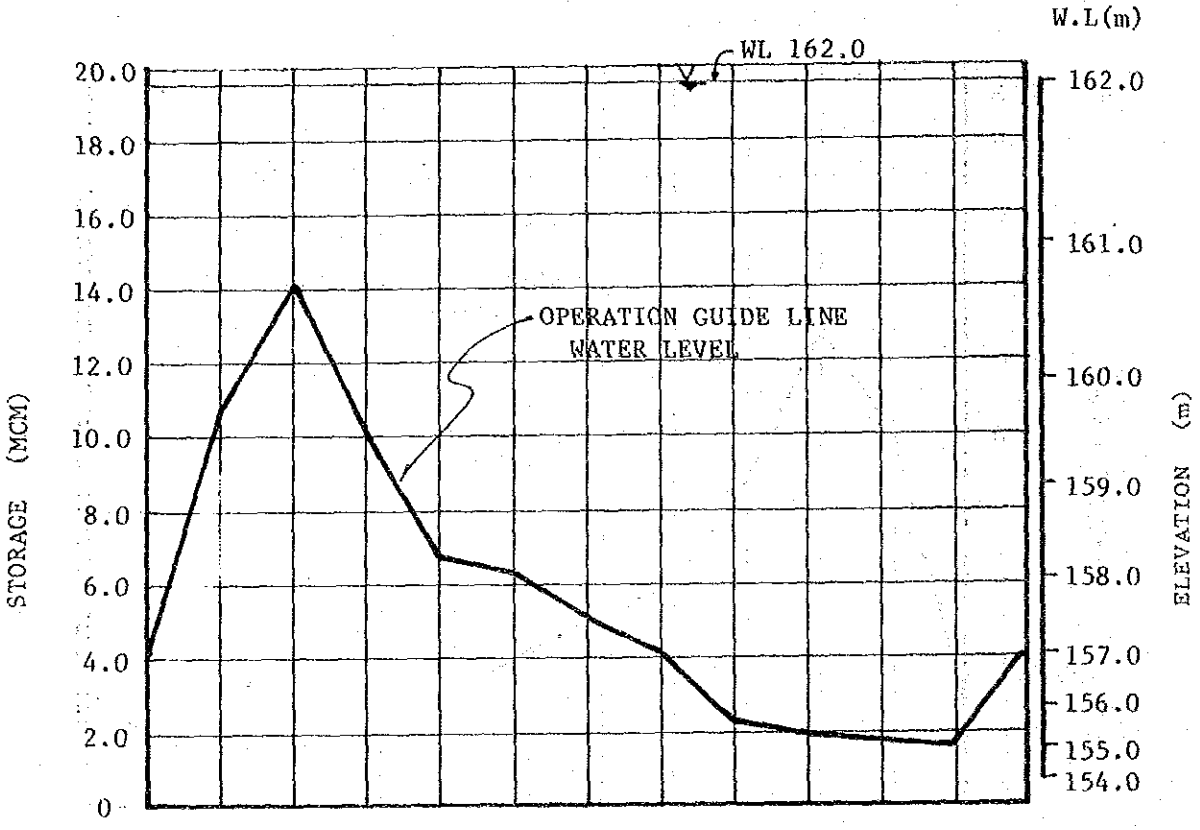
(LAM SE RESERVOIR)



	WL (m)	ACC. Str. (MCM)	Eff. Str. (MCM)
	173.9	1.84	1.5
Aug.	176.4	5.34	5.0
Sep.	177.1	6.74	6.4
Oct.	176.2	4.84	4.5
Nov.	175.2	3.34	3.0
Dec.	174.9	2.94	2.6
Jan.	174.6	2.44	2.1
Feb.	174.0	1.94	1.6
Mar.	173.3	1.34	1.0
Apr.	173.0	1.14	0.8
May	173.0	1.14	0.8
Jun.	173.0	1.14	0.8
Jul.	173.9	1.84	1.5

FIGURE E-4 : OPERATION GUIDE LINE (WATER LEVEL) (2/5)

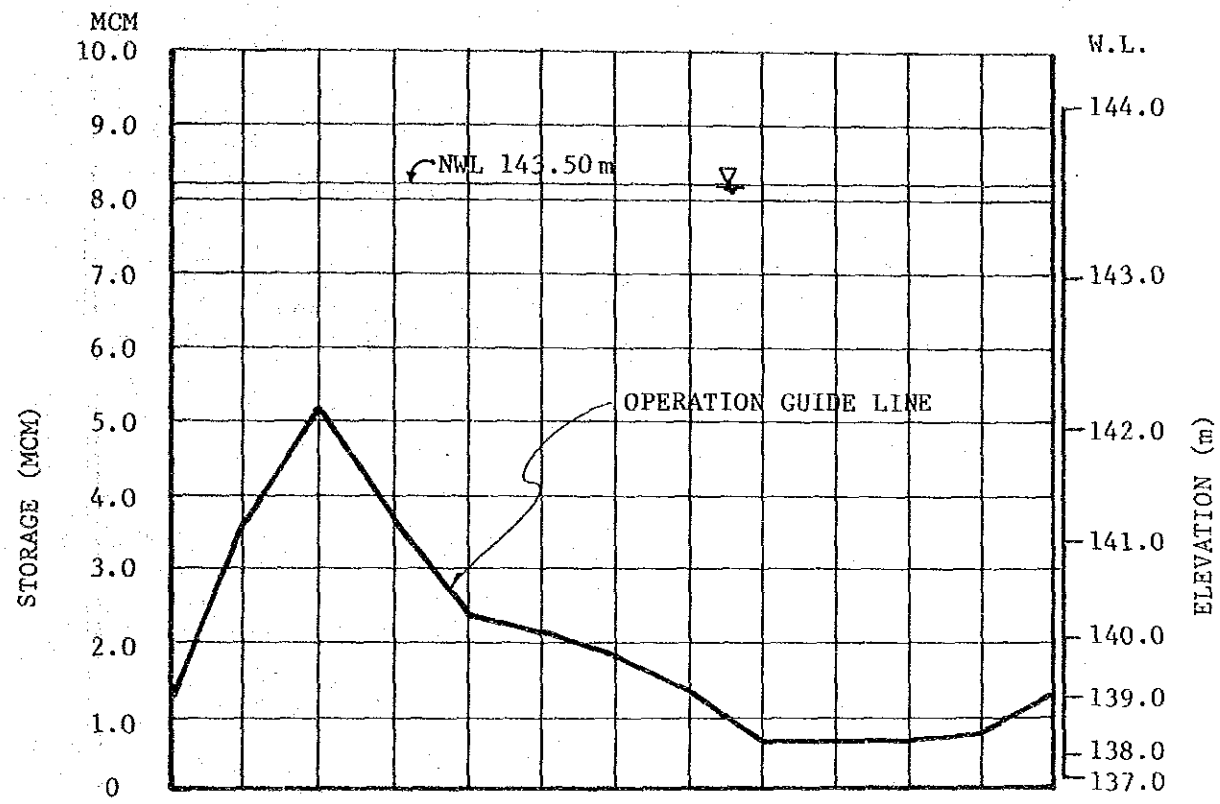
(HUAI KHUM KHAM RESERVOIR)



	WL	ACC. Str.	Eff. Str.
	(m)	(MCM)	(MCM)
Aug.	157.0	4.55	4.0
Sep.	159.6	11.05	10.5
Oct.	160.7	14.55	14.0
Nov.	159.5	10.95	10.4
Dec.	178.3	7.35	6.8
Jan.	158.1	6.85	6.3
Feb.	157.4	5.55	5.0
Mar.	157.1	4.75	4.2
Apr.	155.8	2.95	2.4
May	155.3	2.55	2.0
Jun.	155.2	2.35	1.8
Jul.	155.1	2.25	1.7
	157.0	4.55	4.0

FIGURE E-4 : OPERATION GUIDE LINE (WATER LEVEL) (3/5)

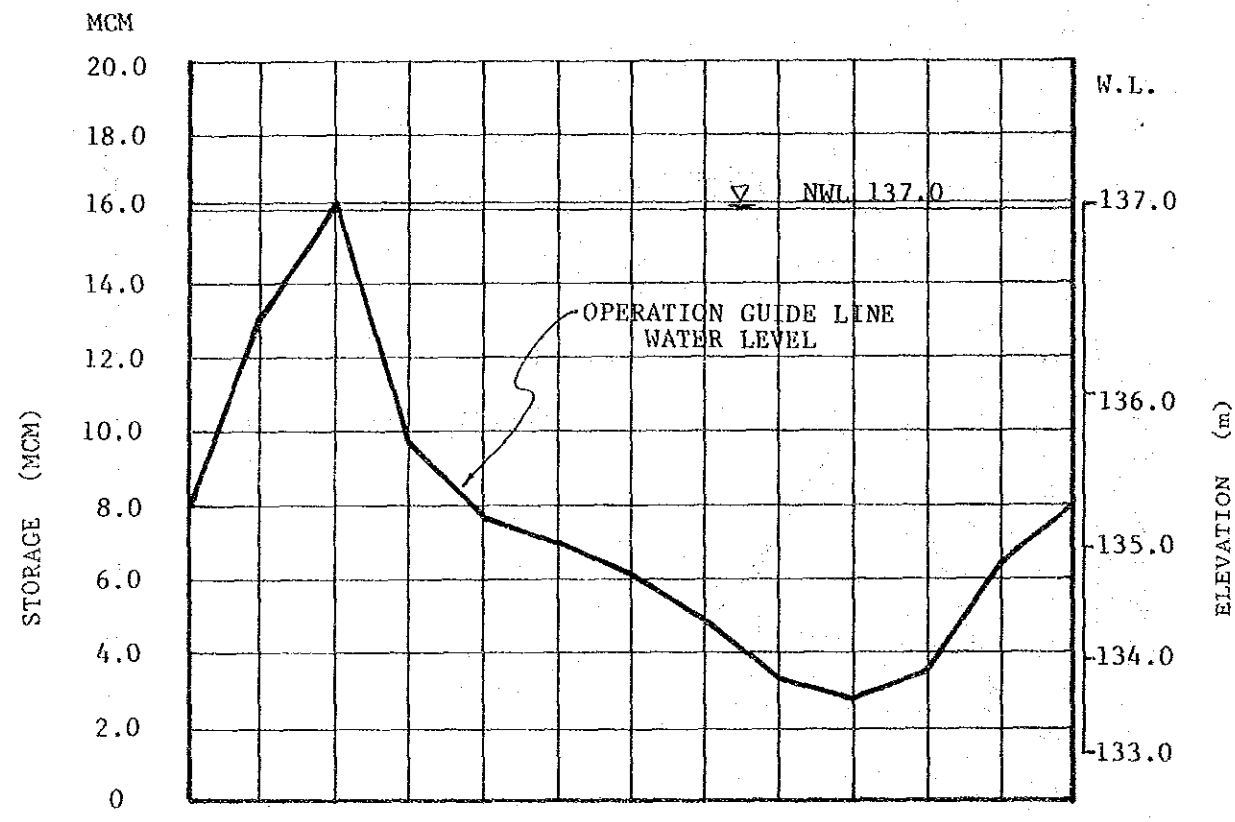
(HUAI KHAM PHAK WAN RESERVOIR)



	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Eff. Str. (MCM)	1.4	3.7	5.2	3.7	2.4	2.2	1.8	1.4	0.7	0.6	0.6	0.7	1.4
Acc. Str. (MCM)	1.6	3.9	5.4	3.9	2.6	2.4	2.0	1.6	0.9	0.8	0.8	0.9	1.6
WL (m)	139.1	141.2	142.1	141.2	140.3	140.1	138.6	139.1	138.1	137.9	137.9	138.1	139.1

FIGURE E-4 : OPERATION GUIDE LINE (WATER LEVEL) (4/5)

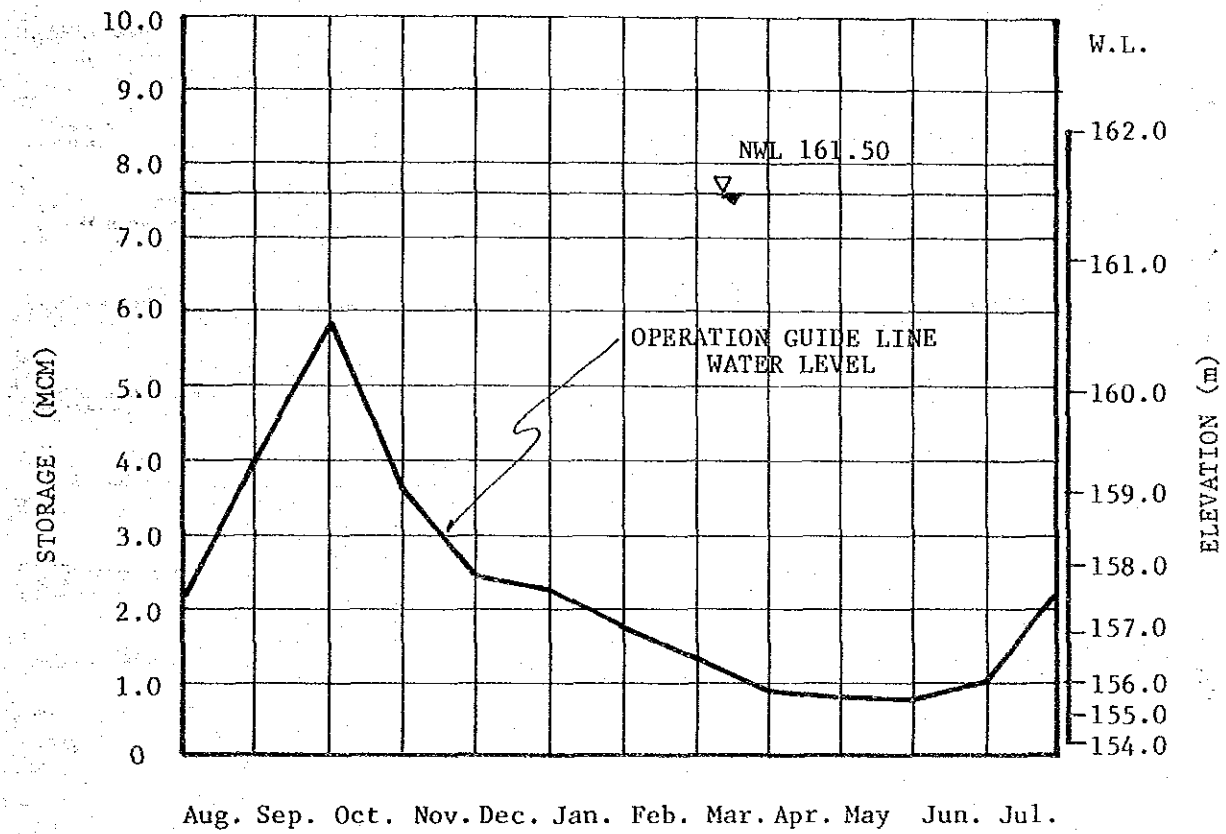
(HUAI NAKHAI RESERVOIR)



	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Eff. Str. (MCM)	8.0	11.0	16.11	9.5	7.7	7.0	6.2	5.0	3.4	3.0	3.6	6.5	8.0
ACC. Str. (MCM)	10.67	13.67	18.78	12.17	10.37	9.67	8.87	7.67	6.07	5.67	6.27	9.17	10.67
WL (m)	135.3	136.0	137.0	135.7	135.3	135.0	134.8	134.4	133.8	133.7	133.9	134.9	135.3

FIGURE E-4 : OPERATION GUIDE LINE (WATER LEVEL) (5/5)

(HUAI SOOB RESERVOIR)



	WL	ACC. Str.	Eff. Str.
	(m)	(MCM)	(MCM)
	157.7	2.48	2.2
	159.3	4.28	4.0
	160.6	6.08	5.8
	159.0	3.9	3.62
	157.9	2.8	2.52
	157.7	2.58	2.3
	157.2	2.08	1.8
	156.5	1.68	1.4
	155.7	1.18	0.9
	155.5	1.08	0.8
	155.3	0.98	0.7
	155.9	1.28	1.0
	157.7	2.48	2.2

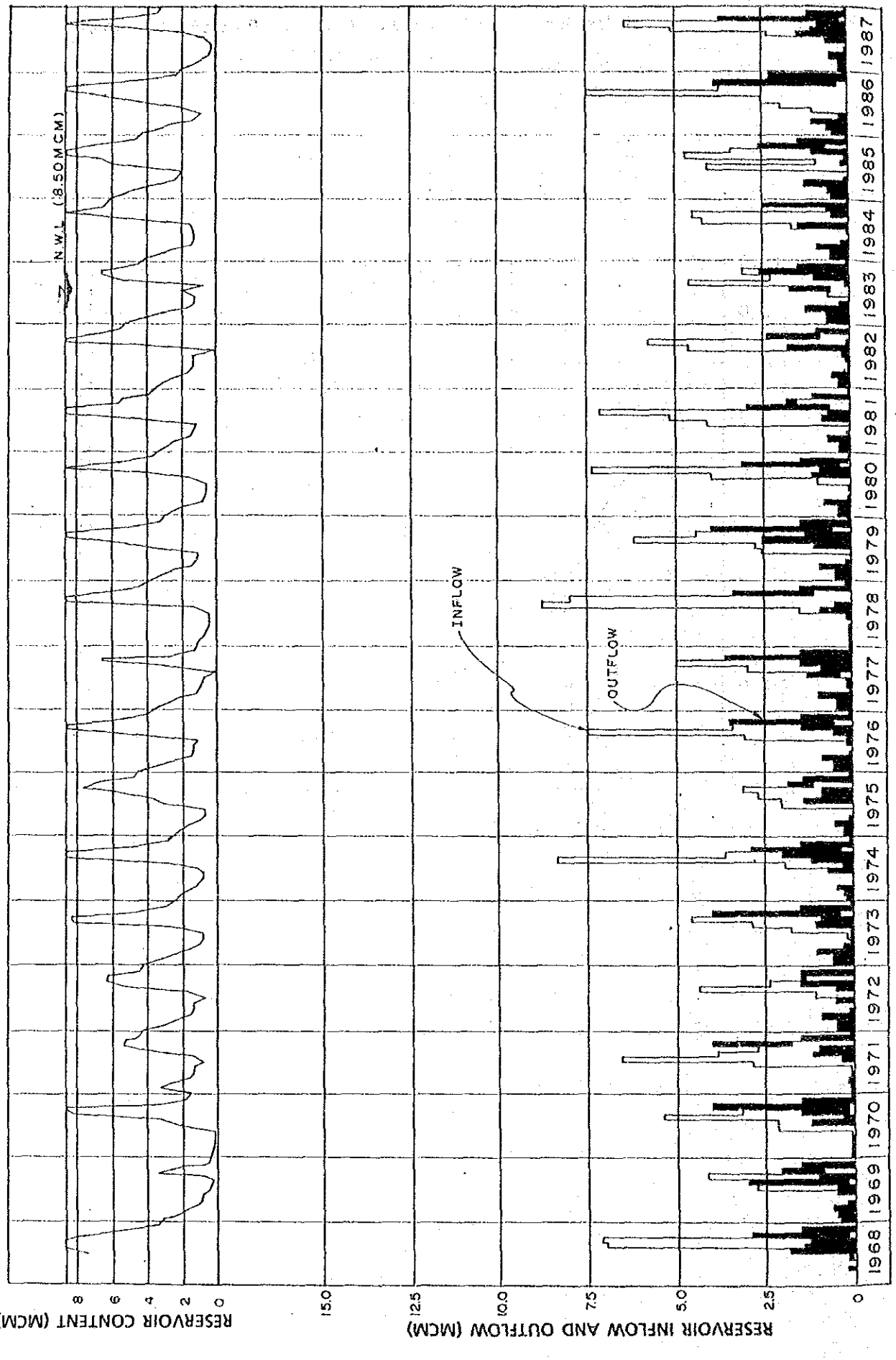


FIGURE E-5 RESERVOIR OPERATION STUDY ; LAM SE (BA-5) (1/5)

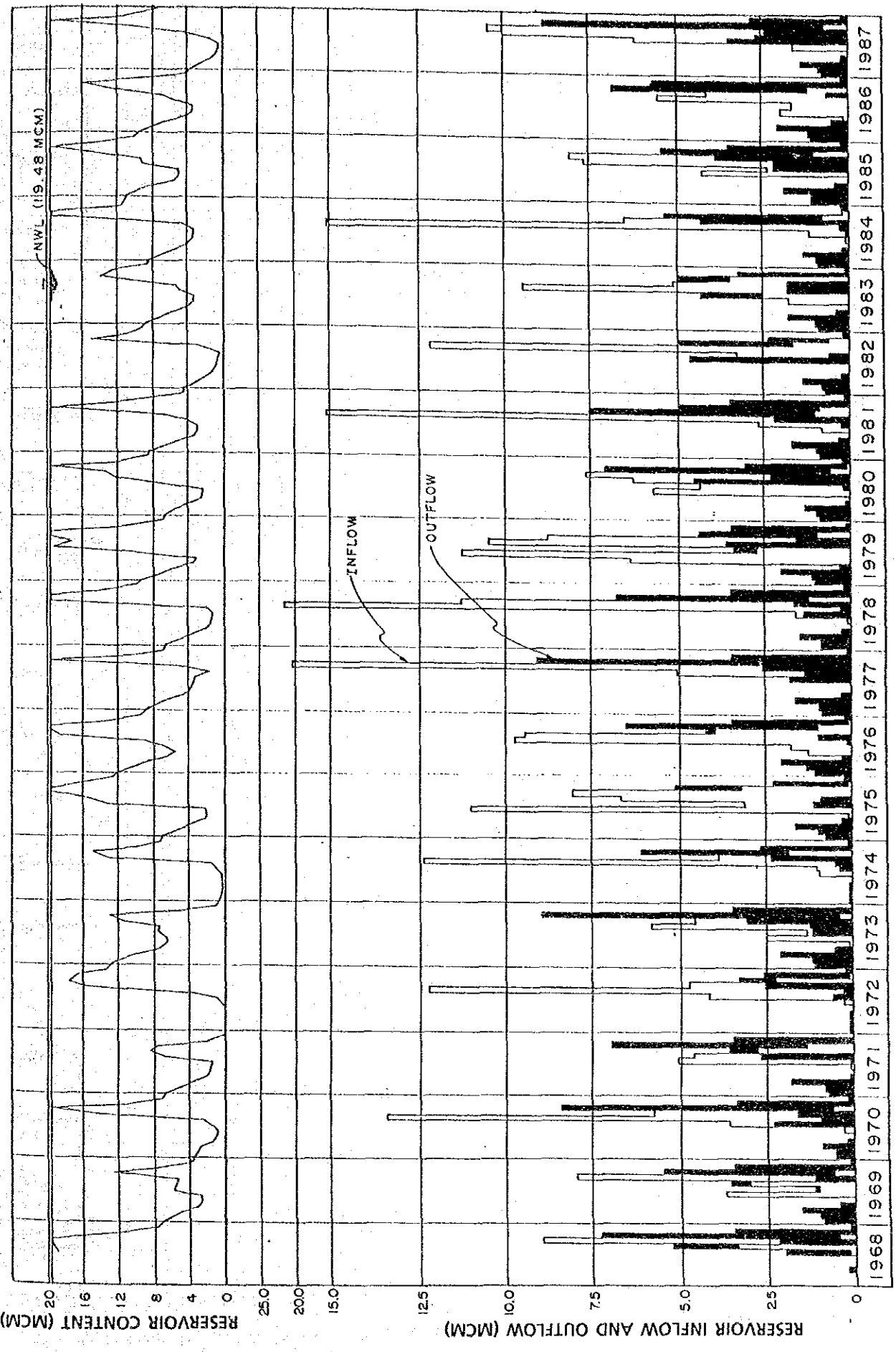
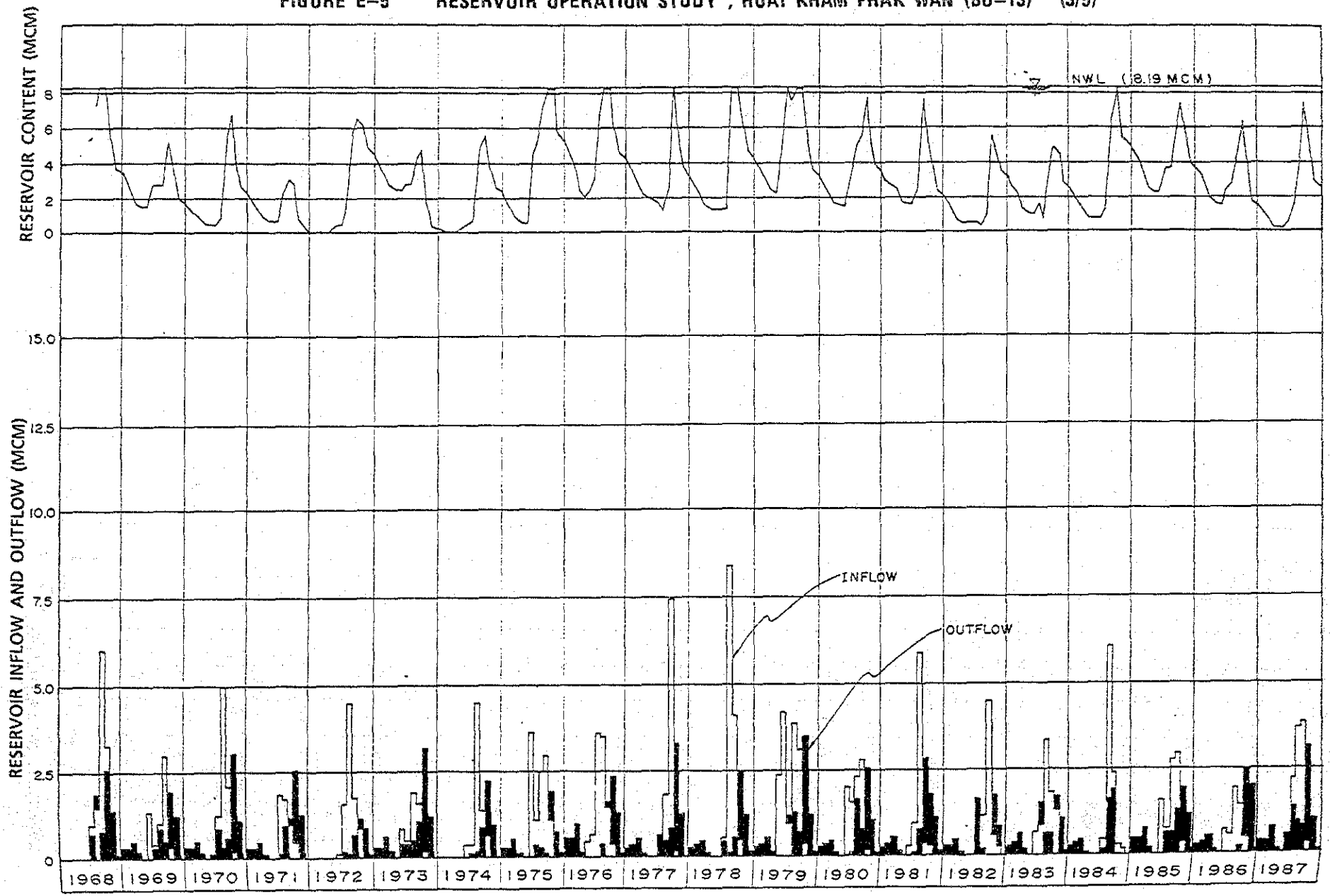


FIGURE E-5 RESERVOIR OPERATION STUDY ; HUAI KHUM KHAM (BD-11) (2/5)

FIGURE E-5 RESERVOIR OPERATION STUDY ; HUAI KHAM PHAK WAN (BO-13) (3/5)



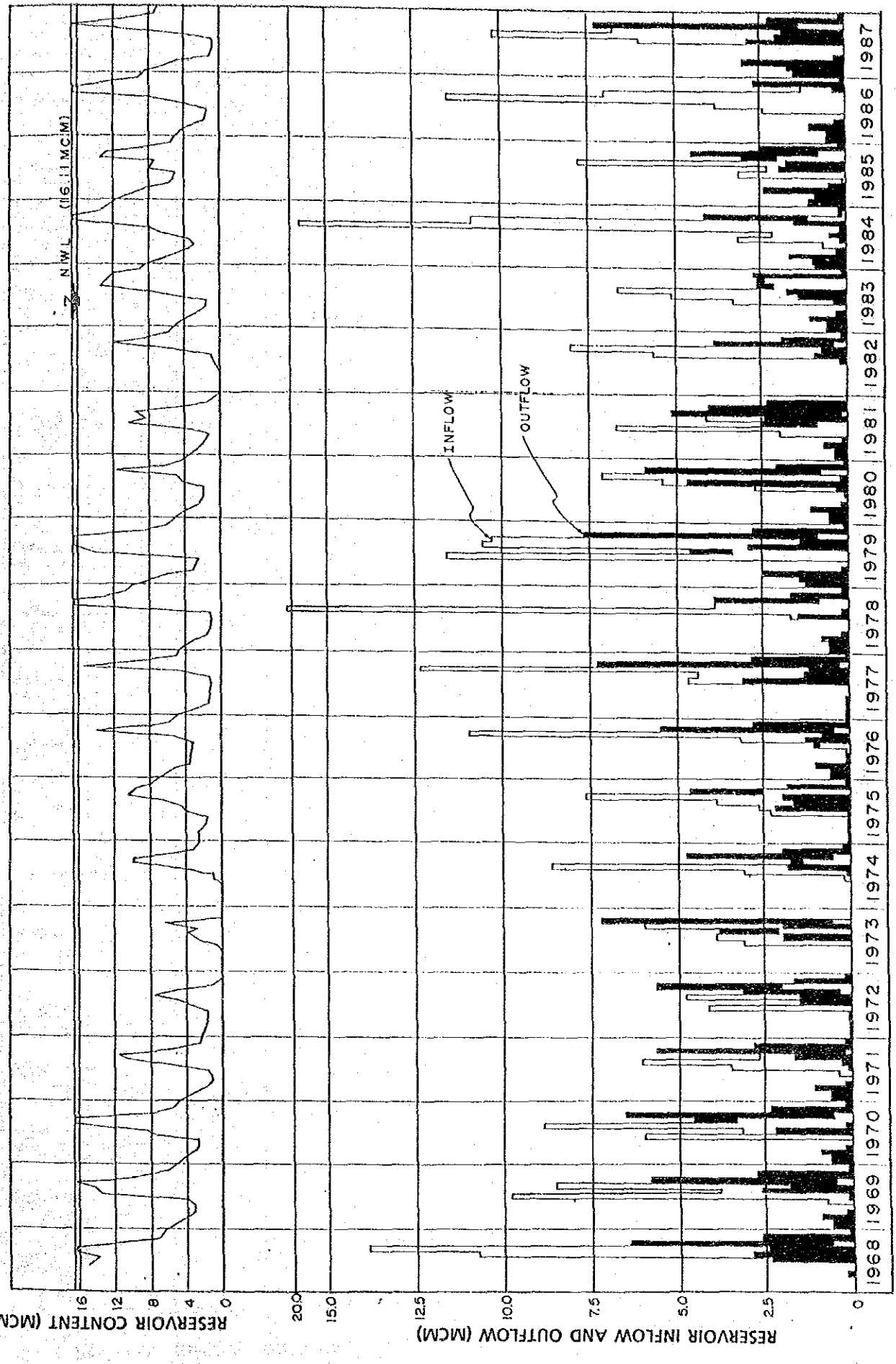


FIGURE E-5 RESERVOIR OPERATION STUDY ; HUAI NA KHAI (BD-18) (4/5)
NWL (116.11 MCM)
INFLOW
OUTFLOW
RESERVOIR CONTENT (MCM)
RESERVOIR INFLOW AND OUTFLOW (MCM)
16
12
8
4
0
20.0
15.0
12.5
10.0
7.5
5.0
2.5
0
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987

FIGURE E-5 RESERVOIR OPERATION STUDY ; HUAI SOOB (TL-6) (5/5)

FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (1/19)

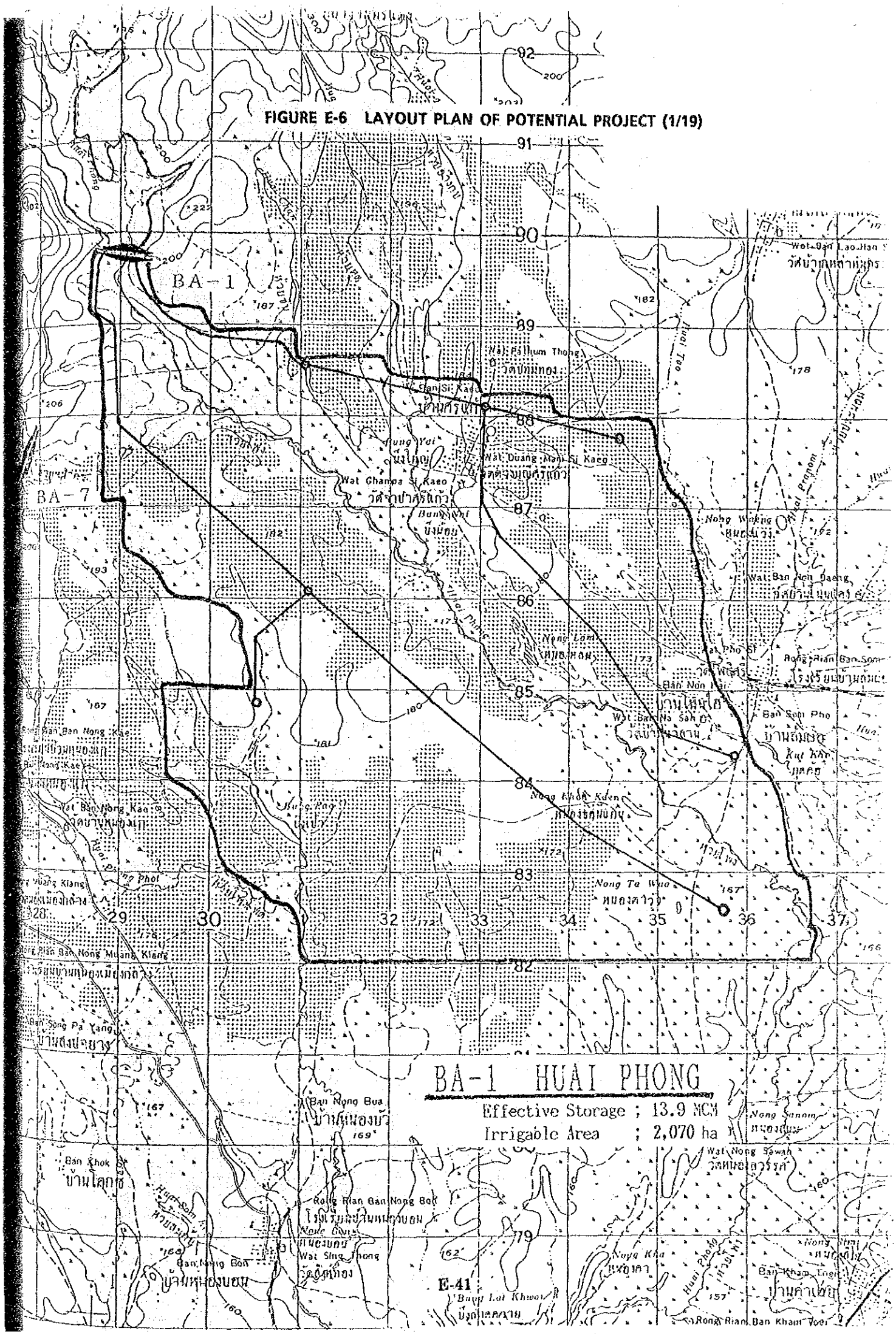
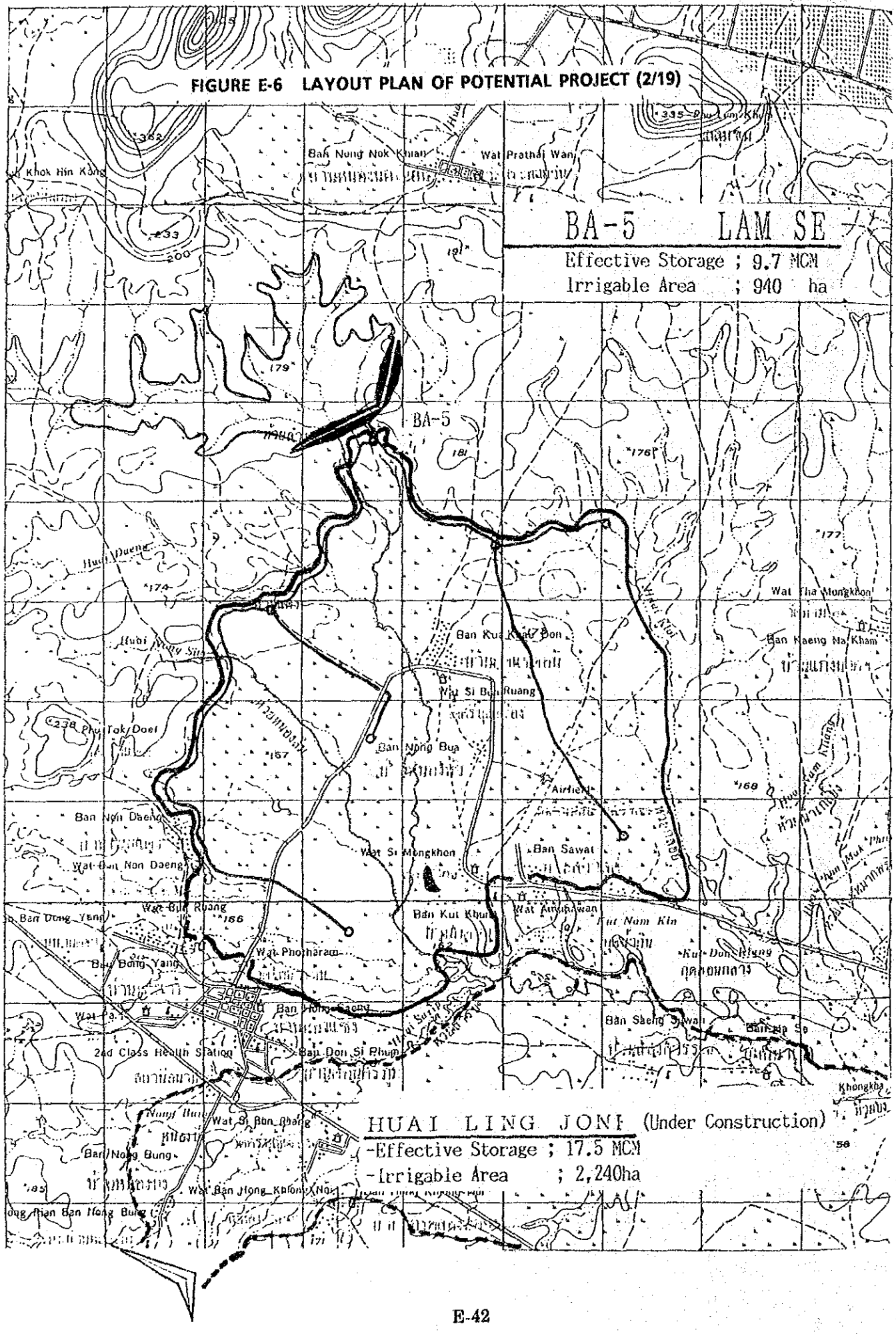


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (2/19)



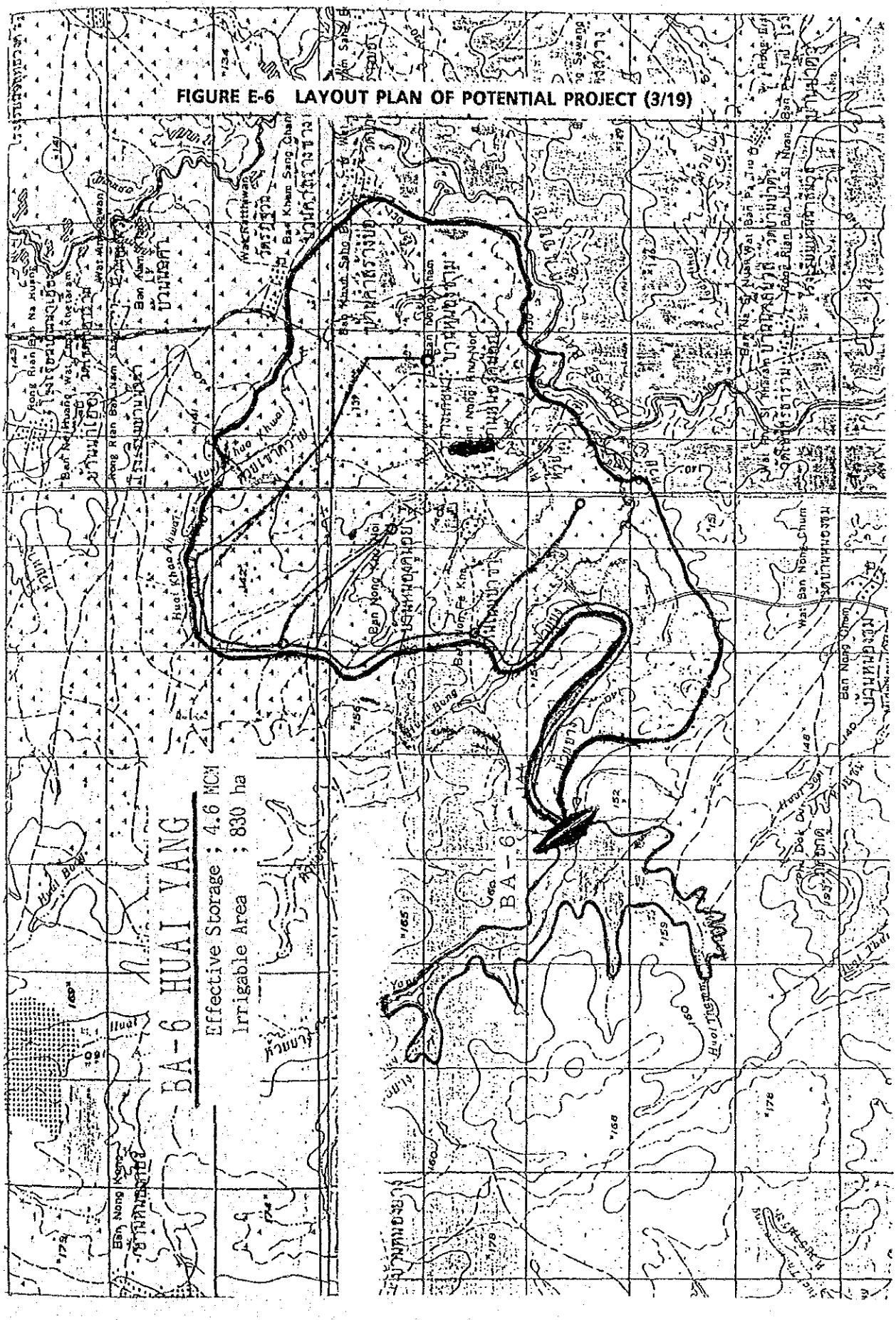


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (3/19)

FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (4/19)

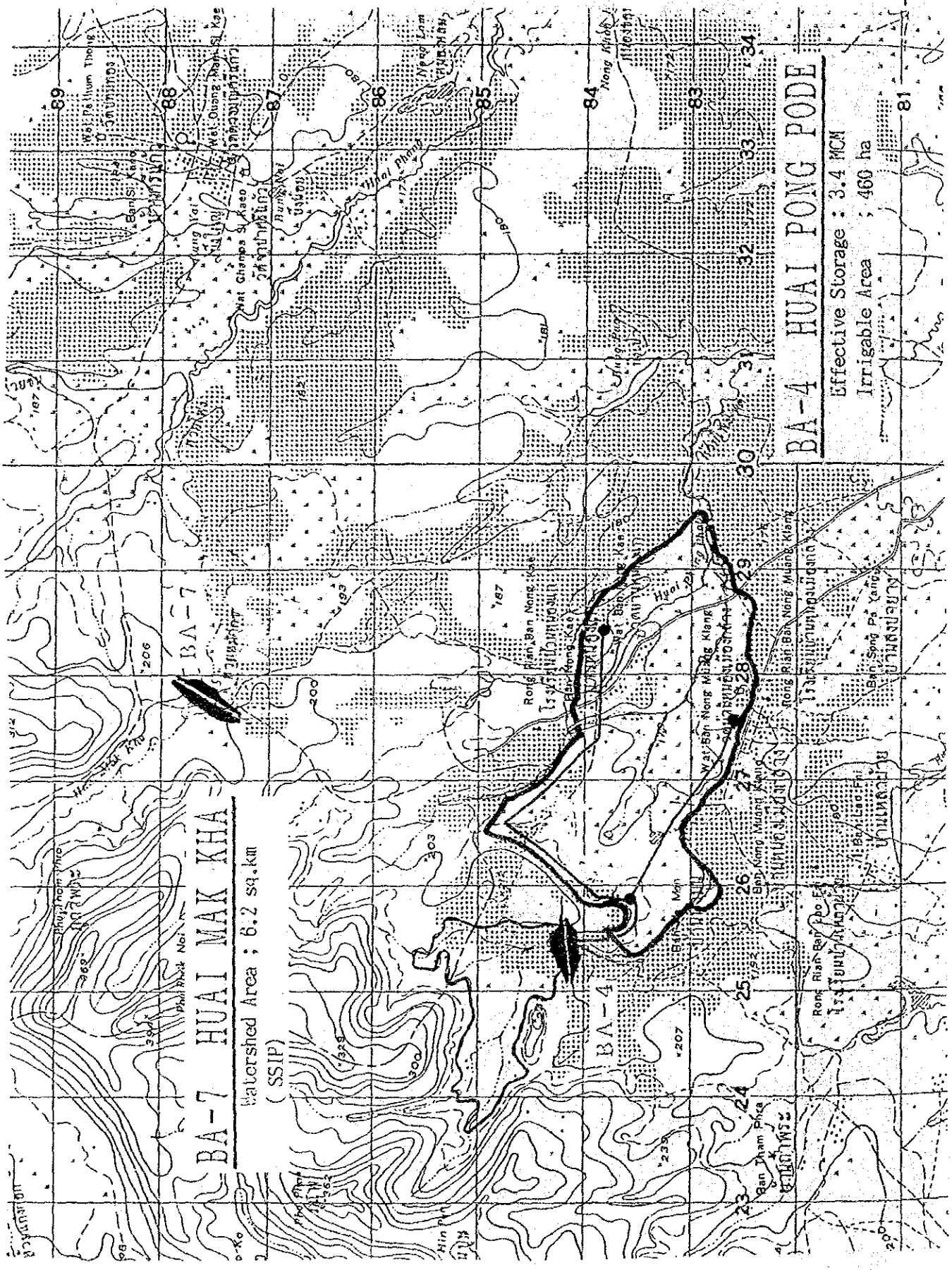


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (5/19)

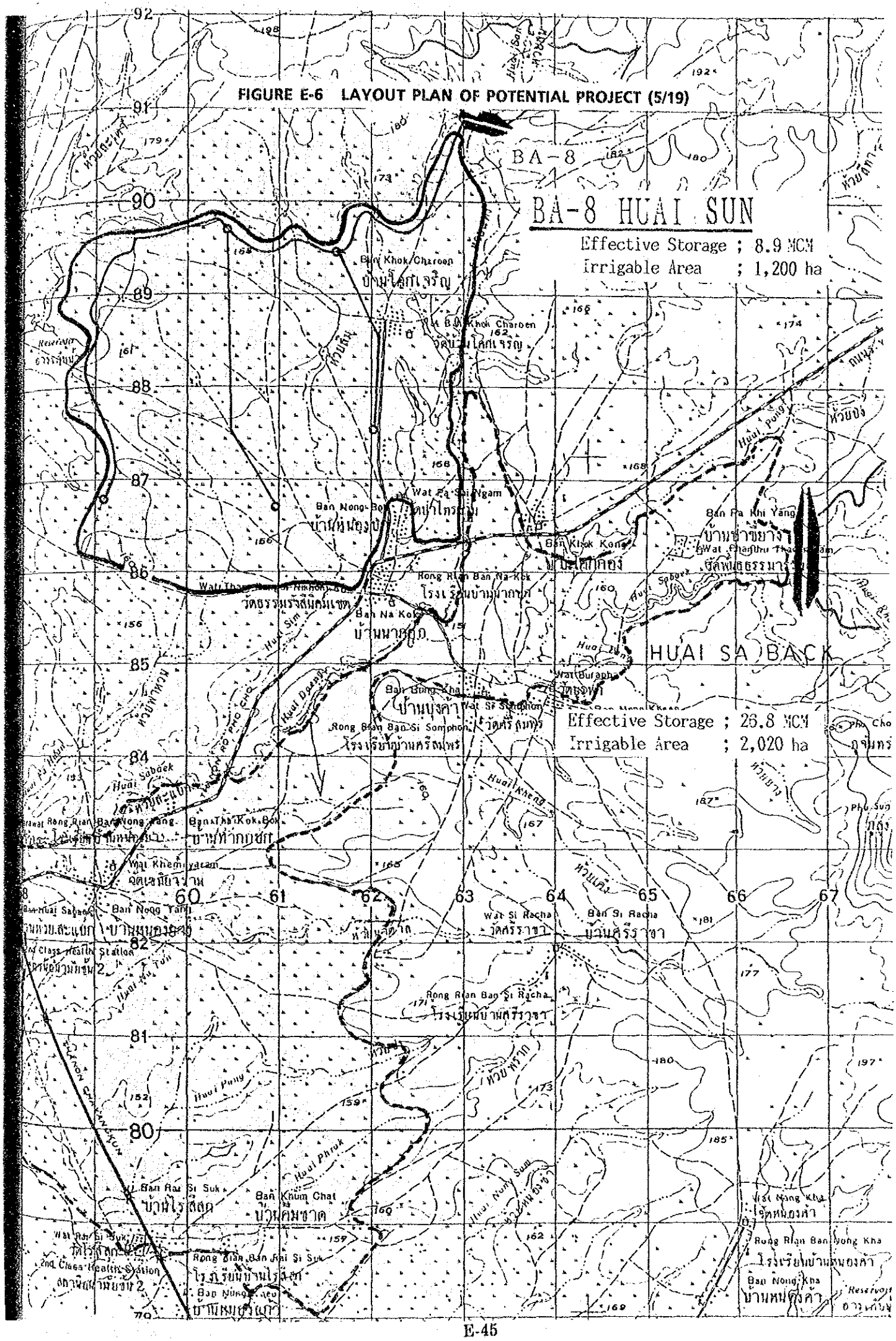


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (6/19)

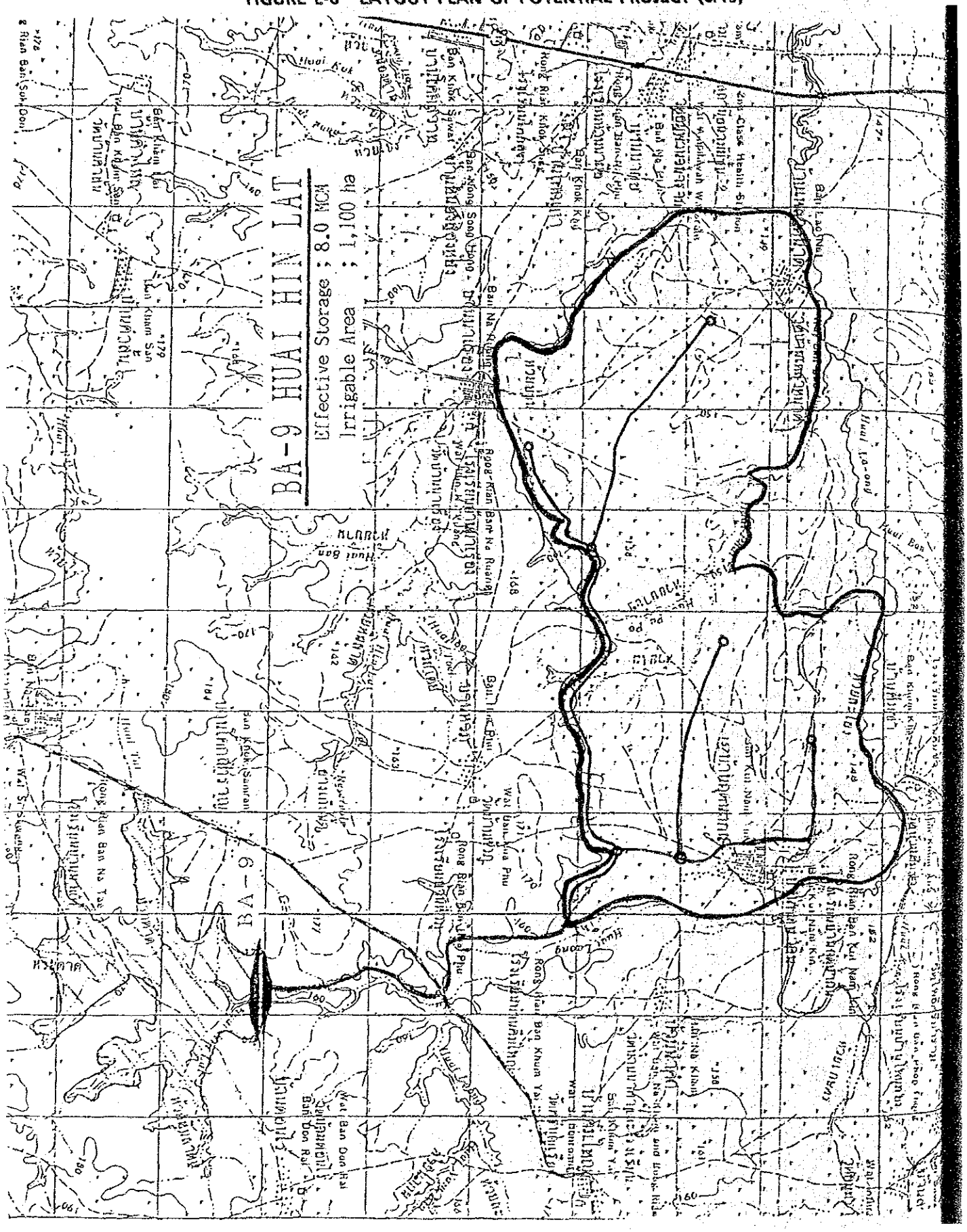


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (7/19)

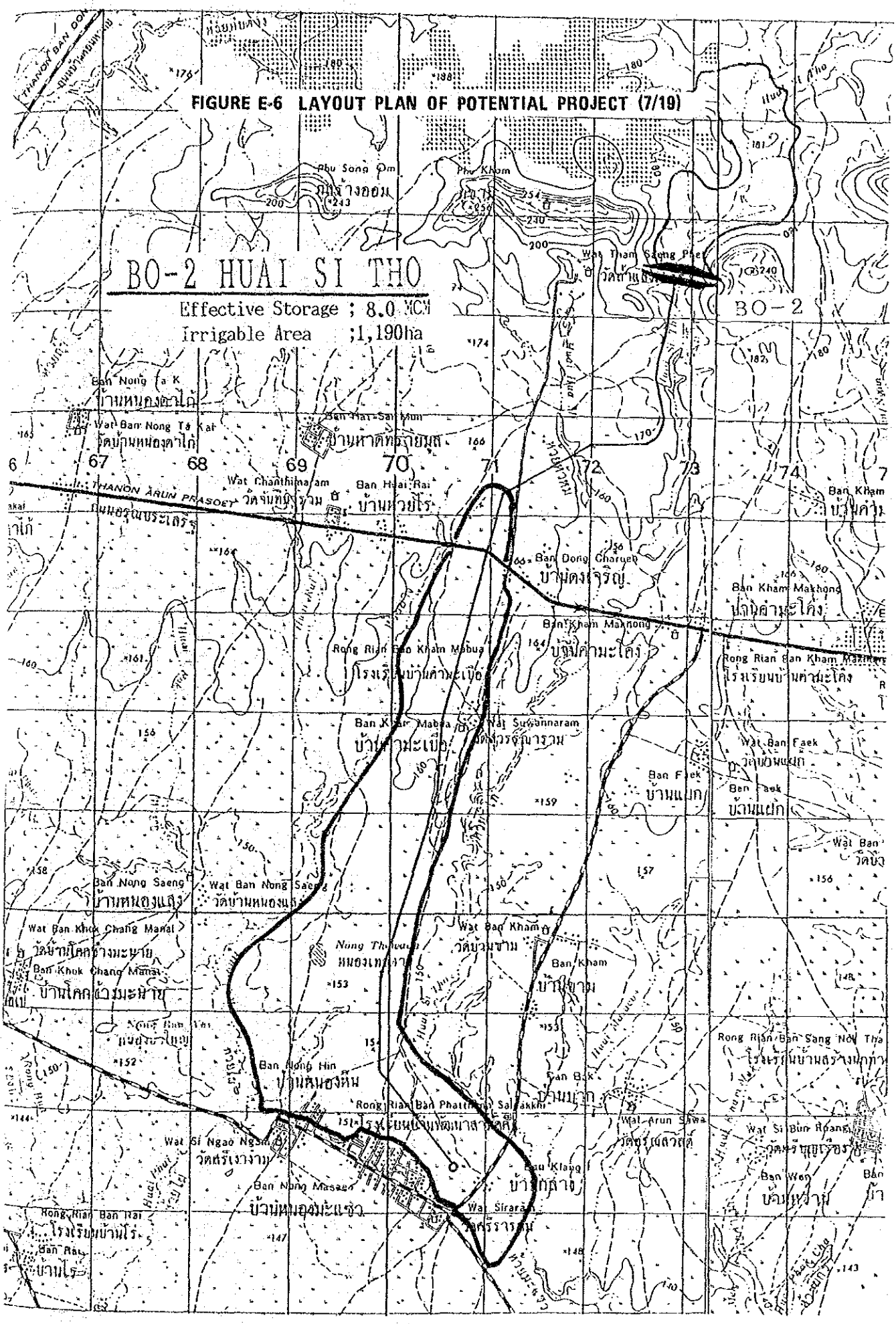


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (9/19)

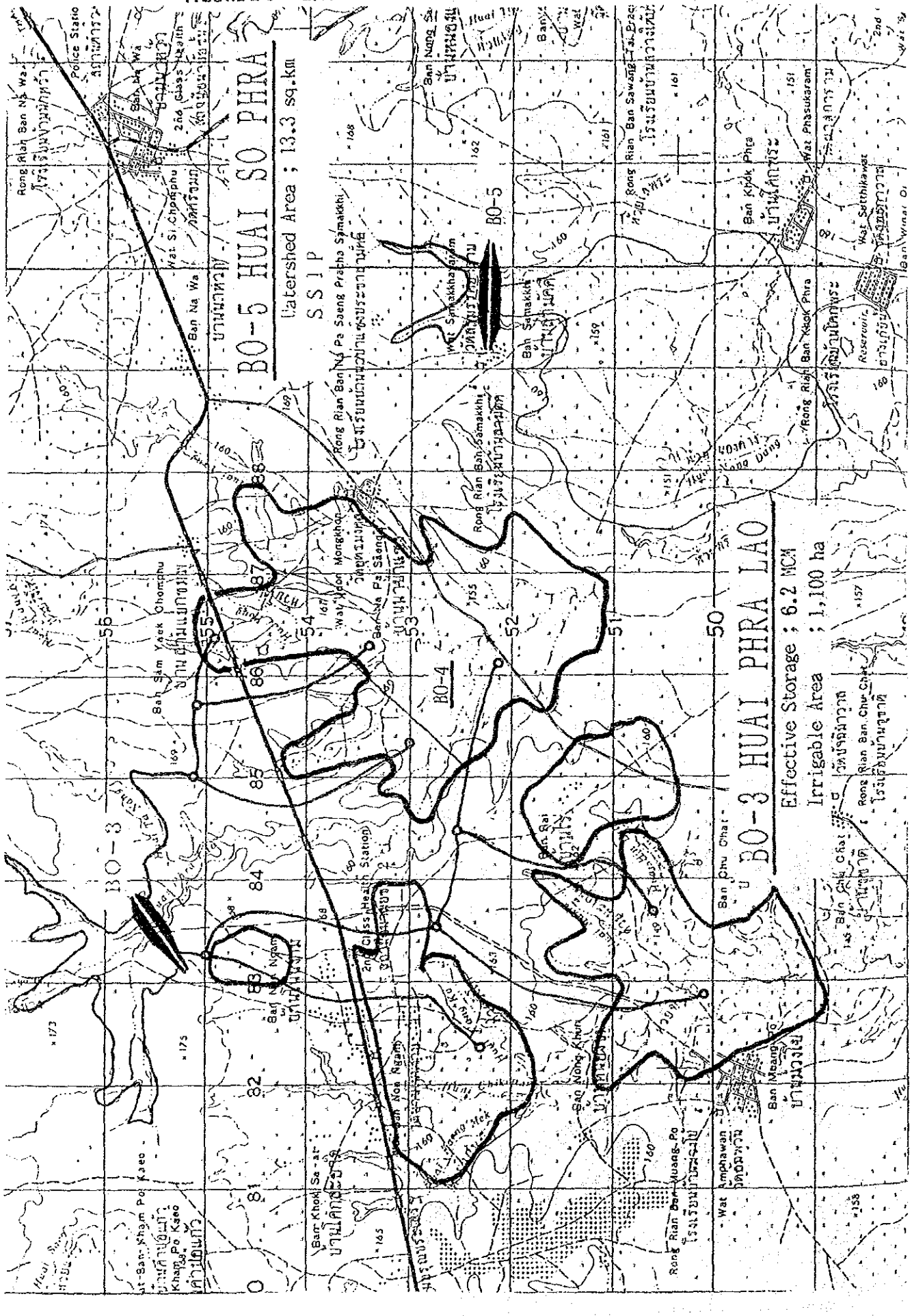


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (9/19)

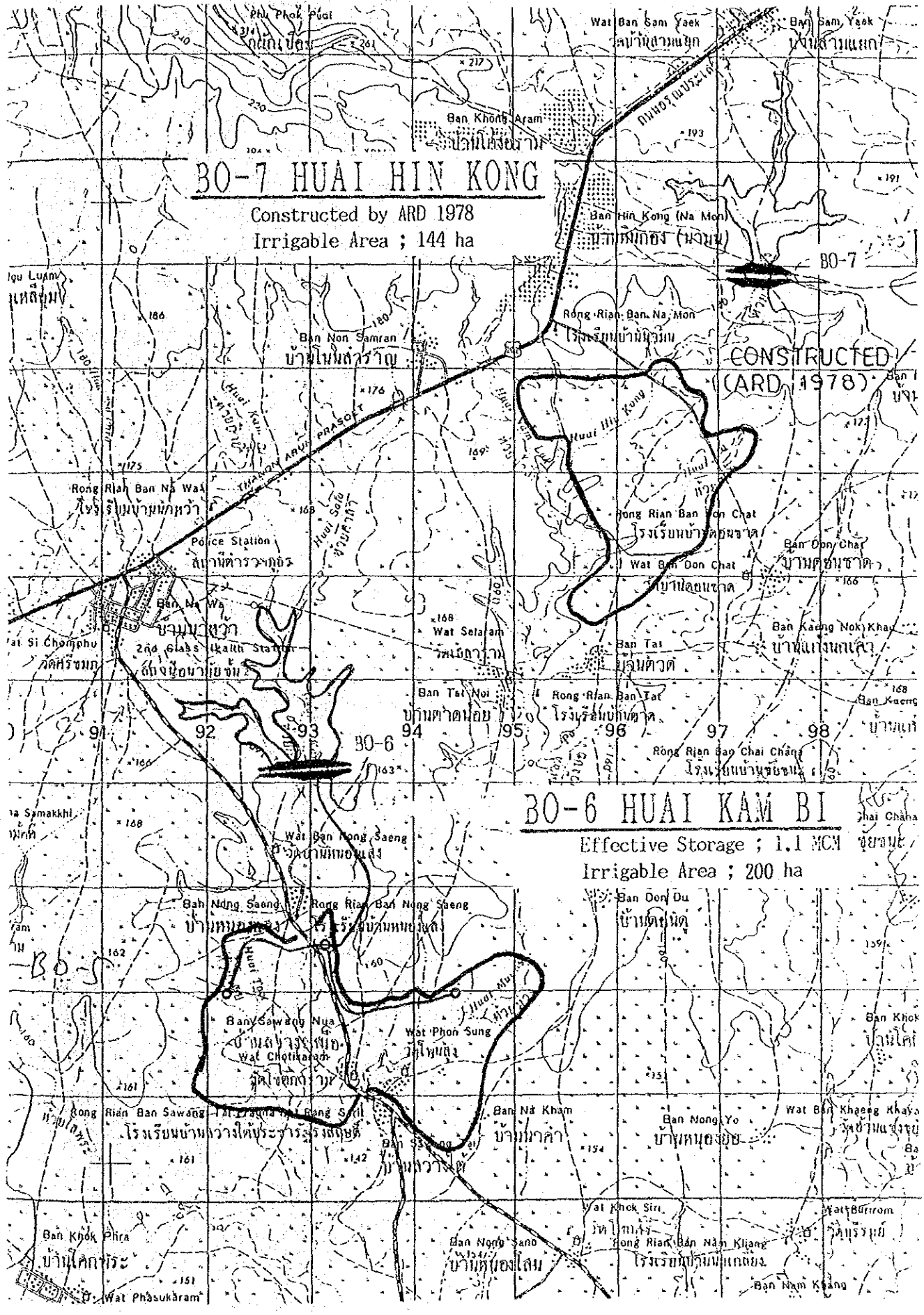


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (10/19)

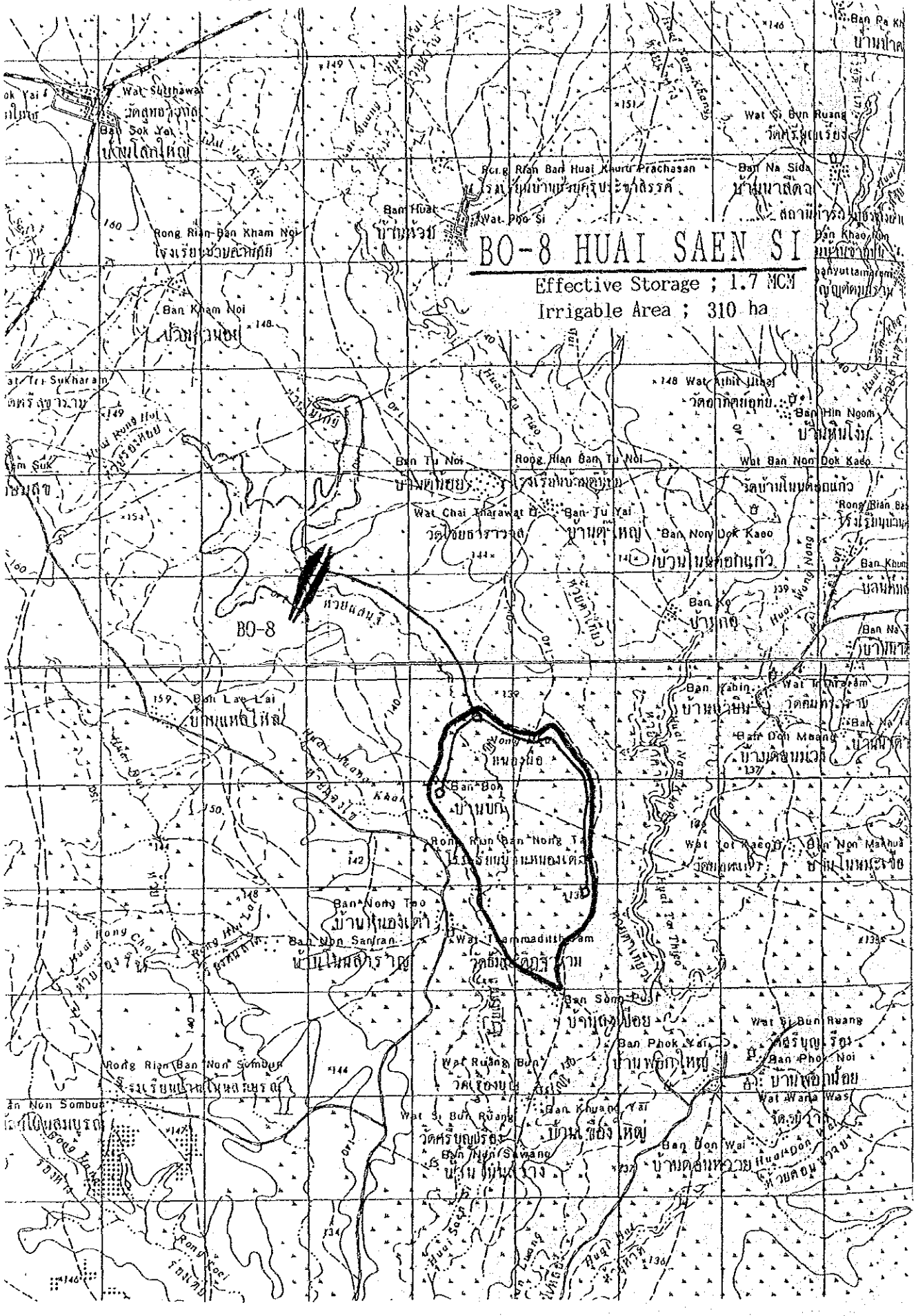


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (11/19)

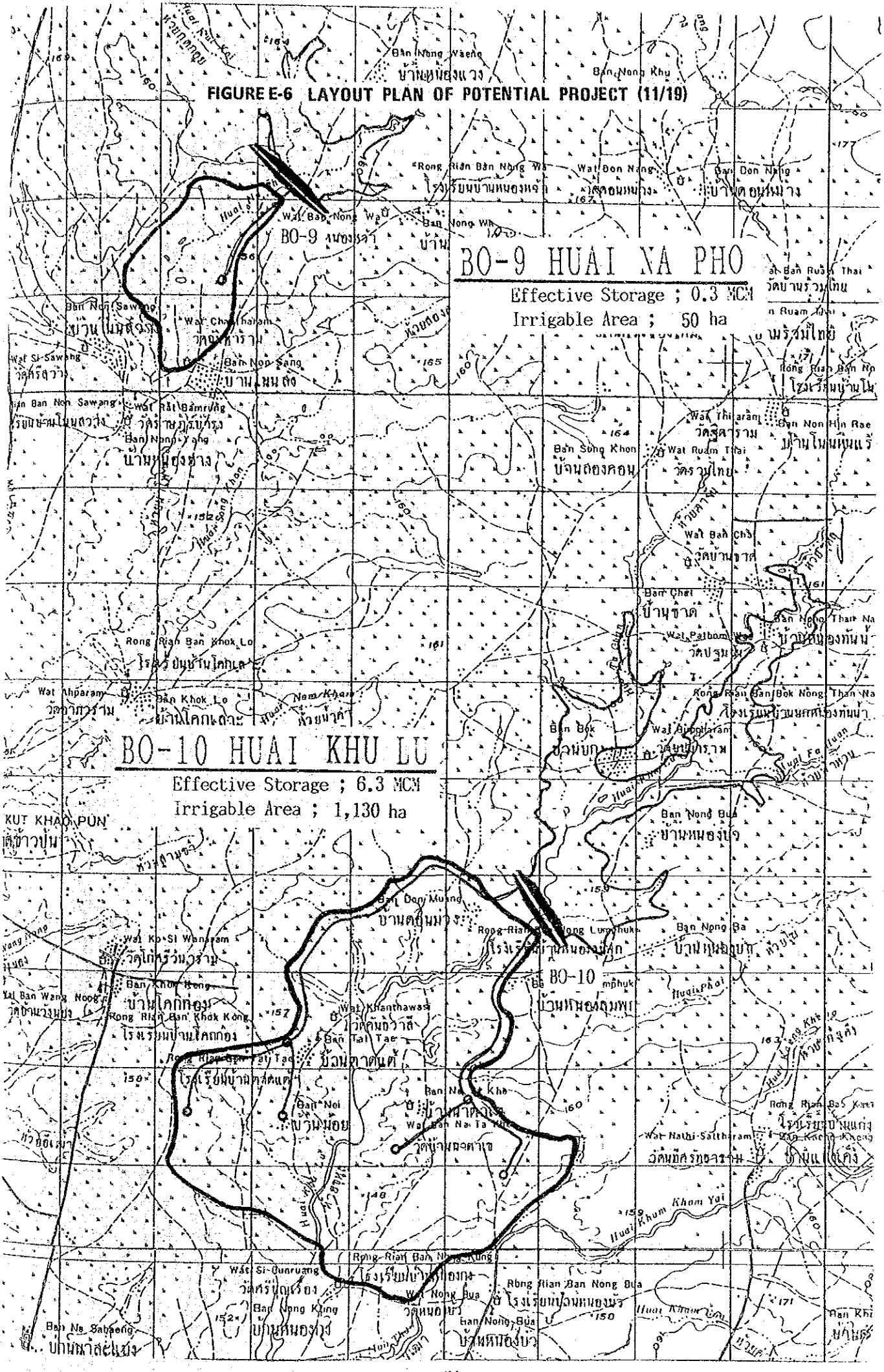


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (12/19)

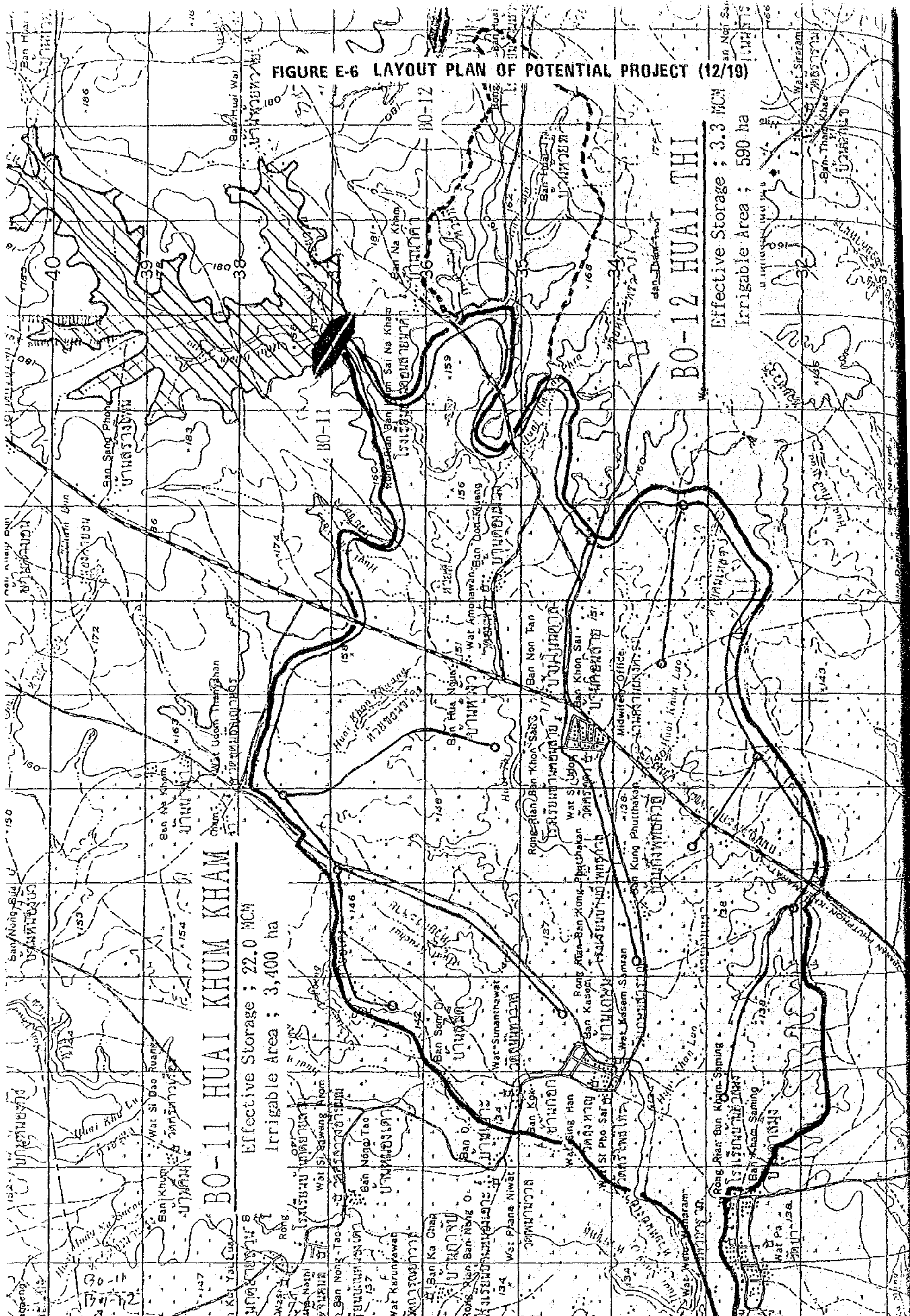


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (13/19)

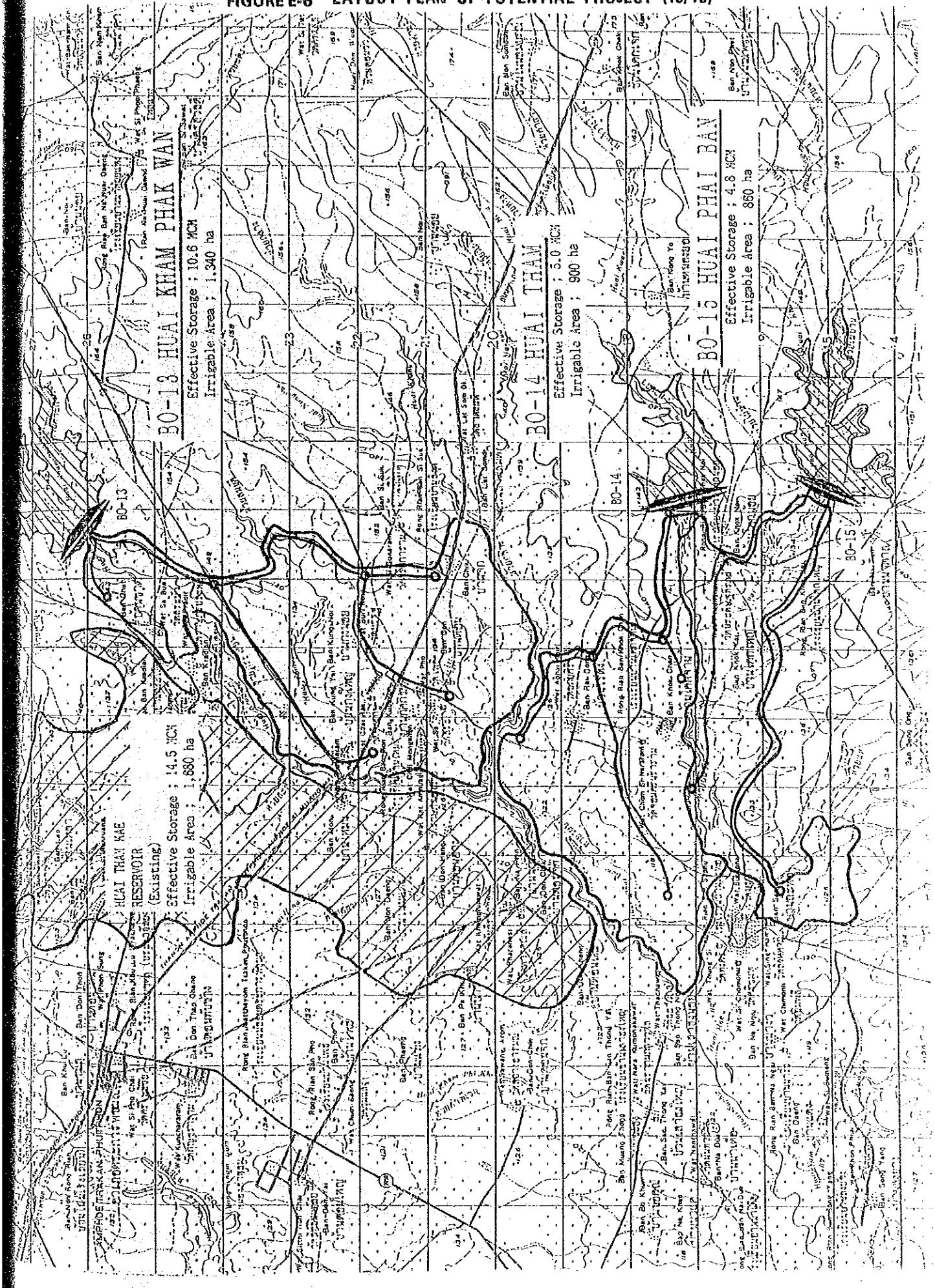


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (14/19)

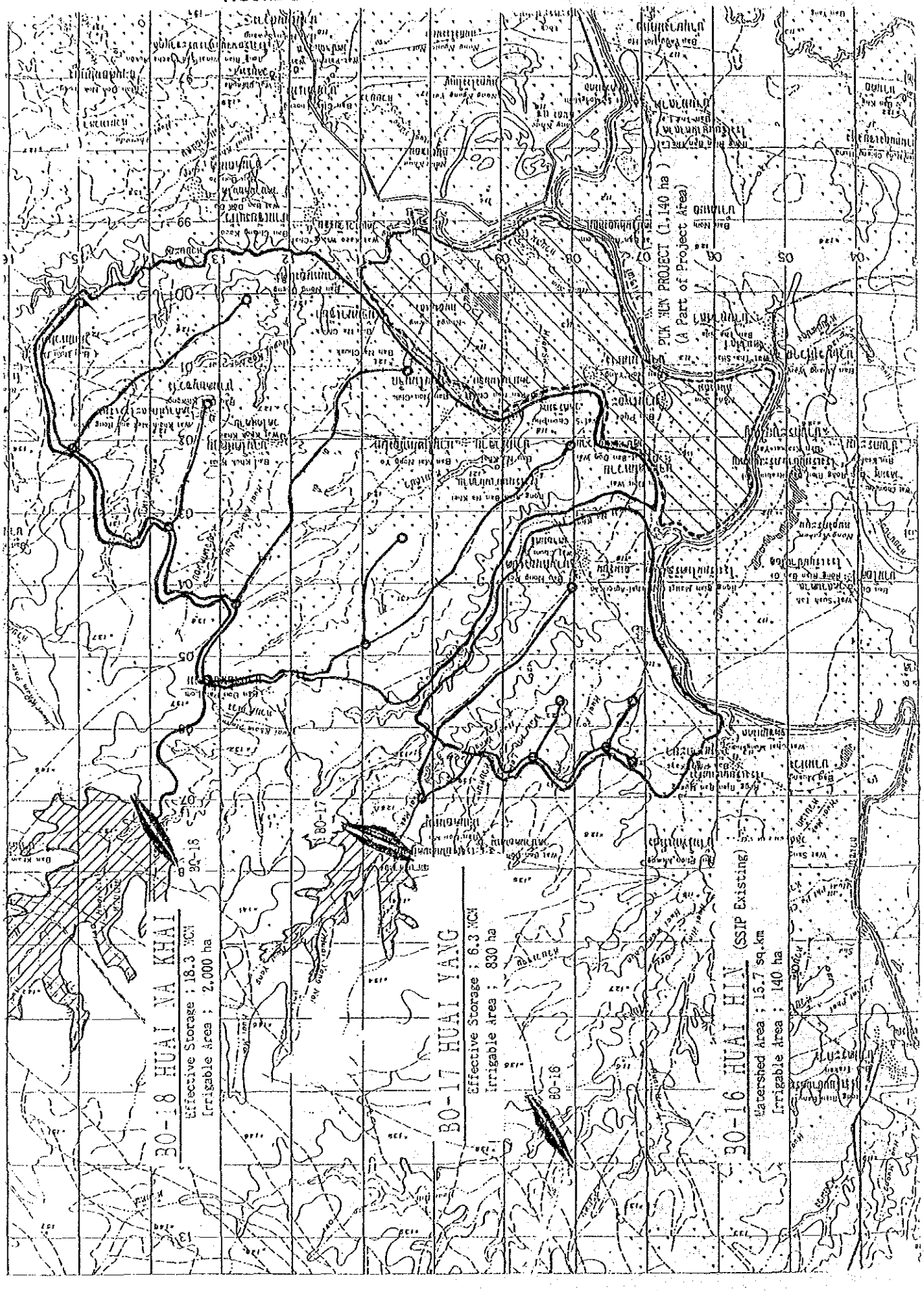


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (15/19)

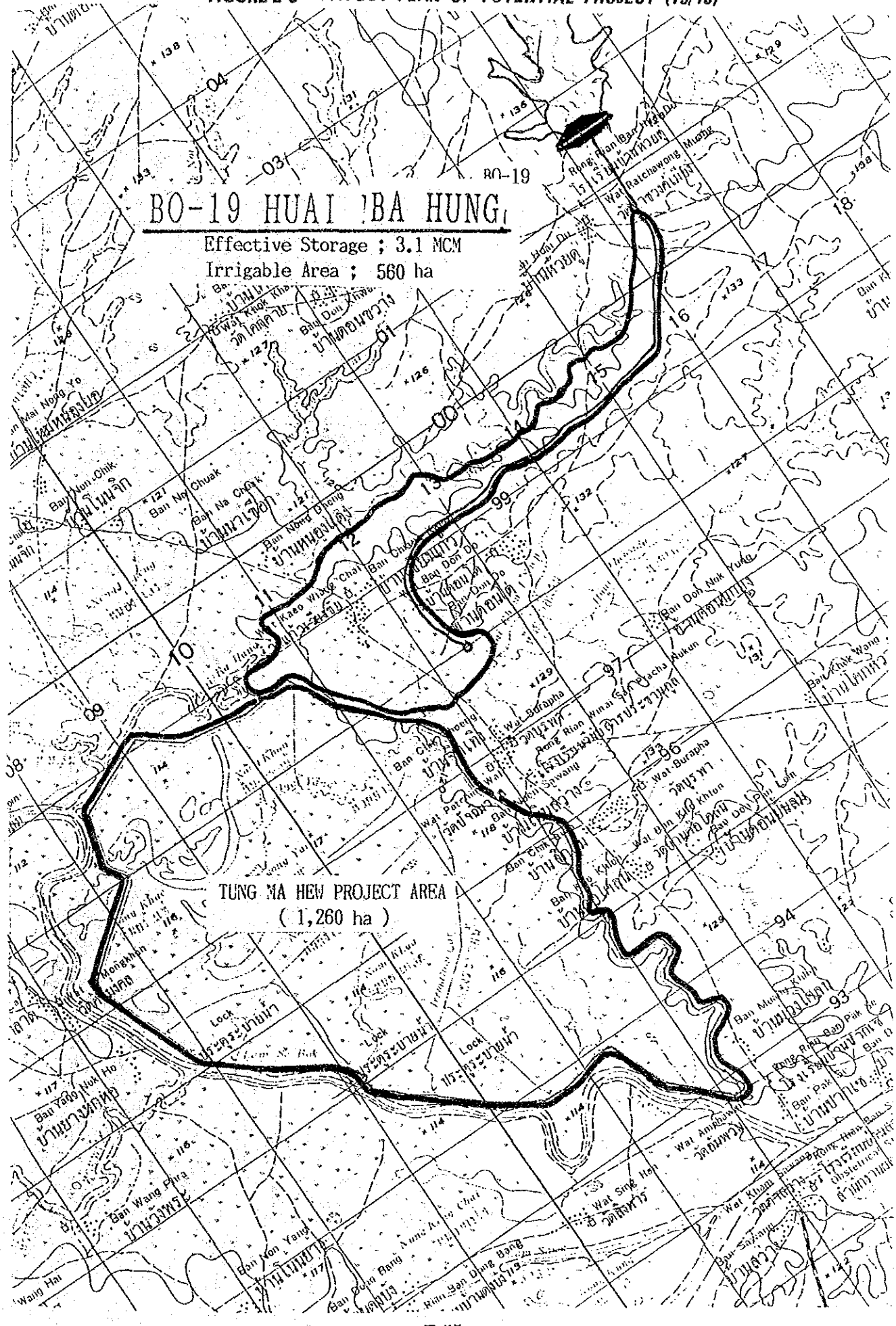


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (16/19)

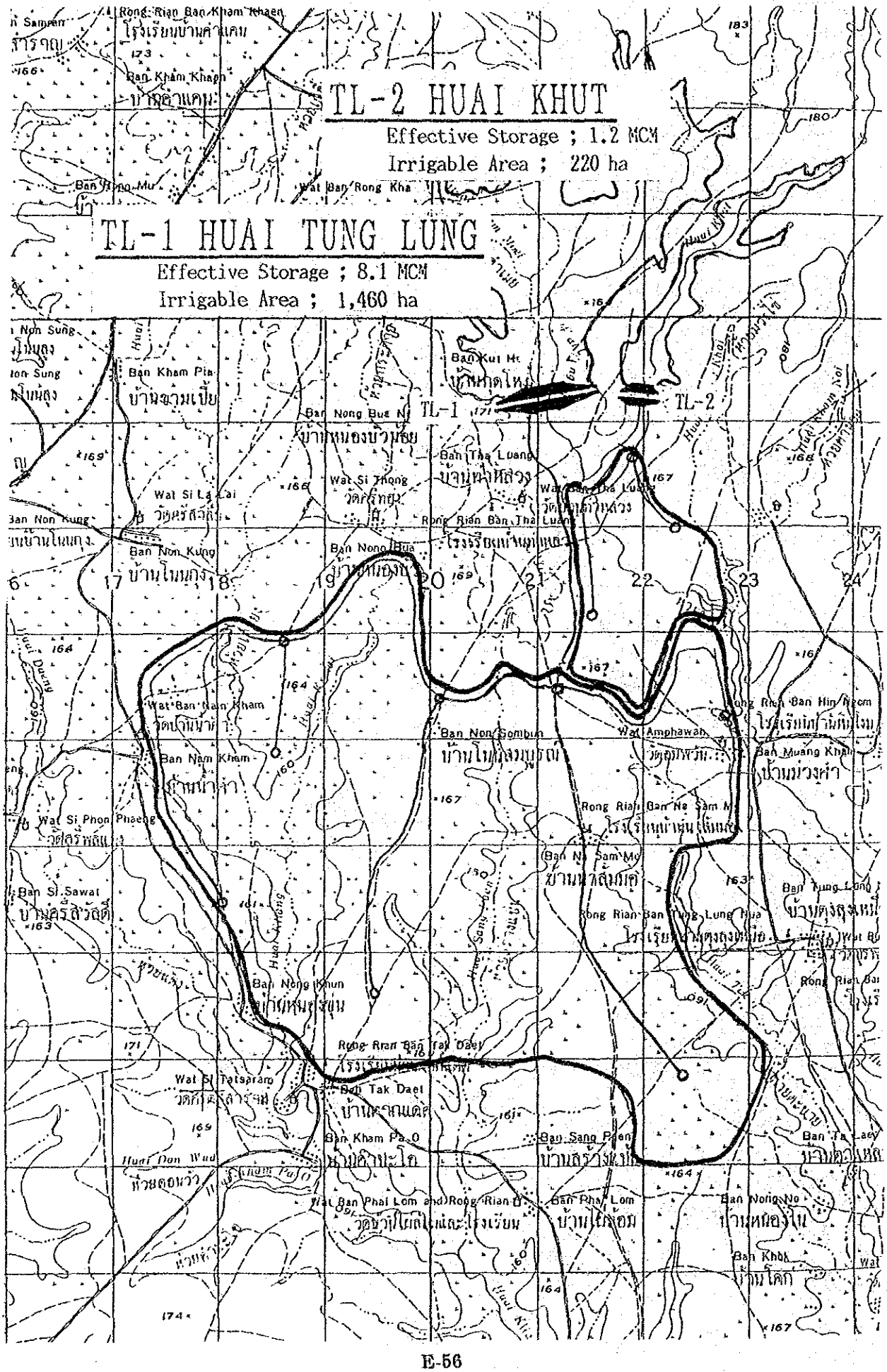


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (17/19)

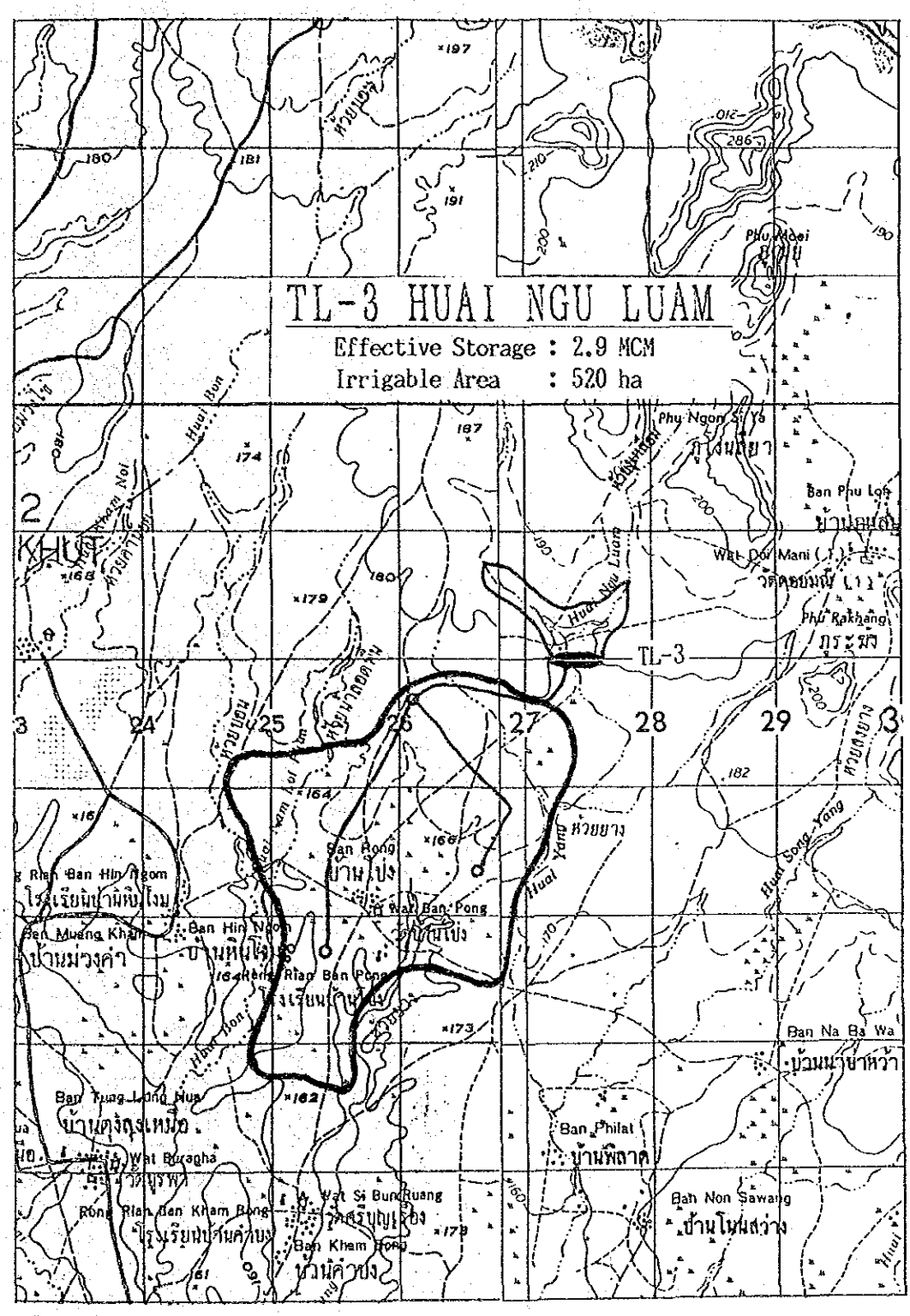


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (18/19)

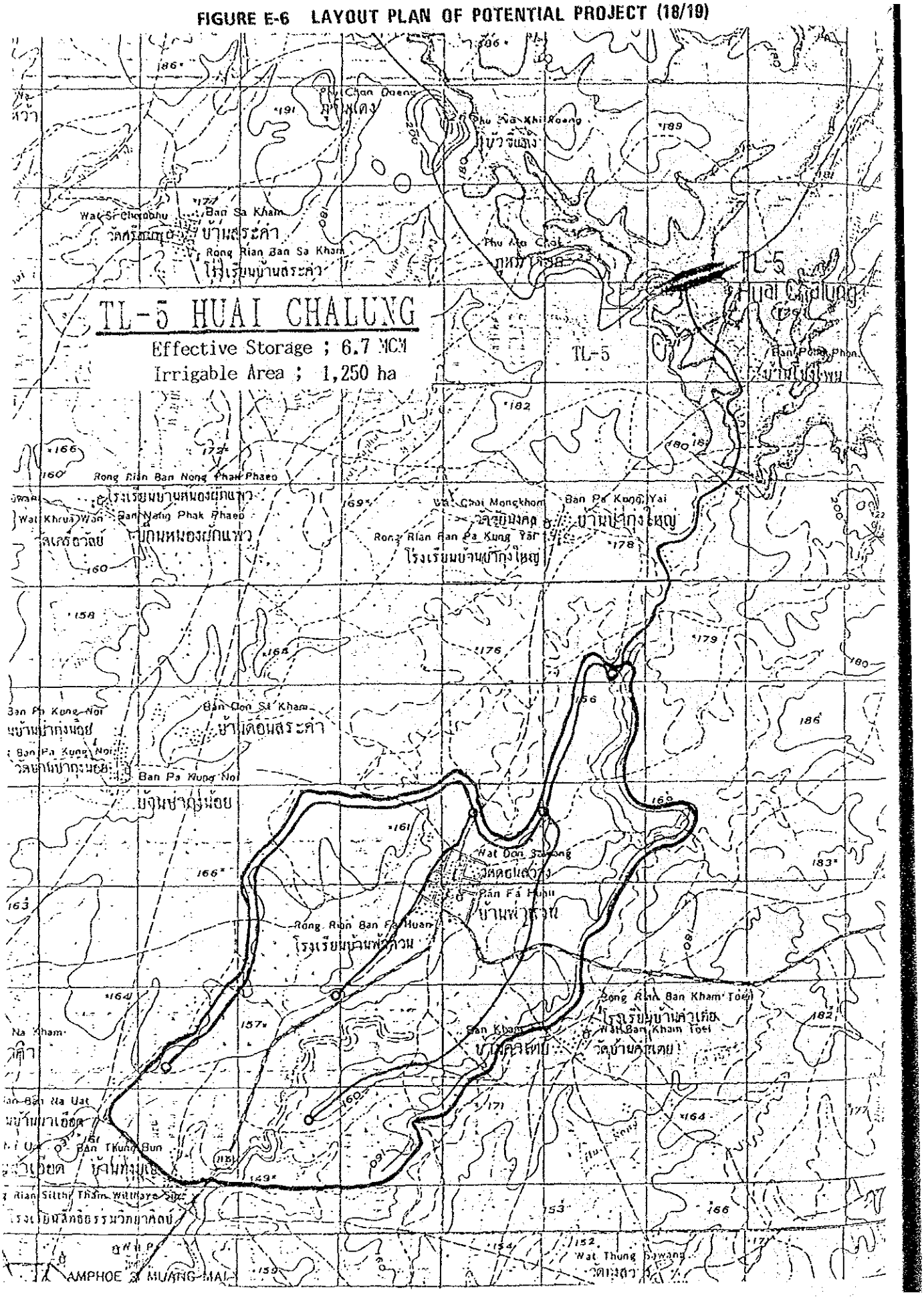
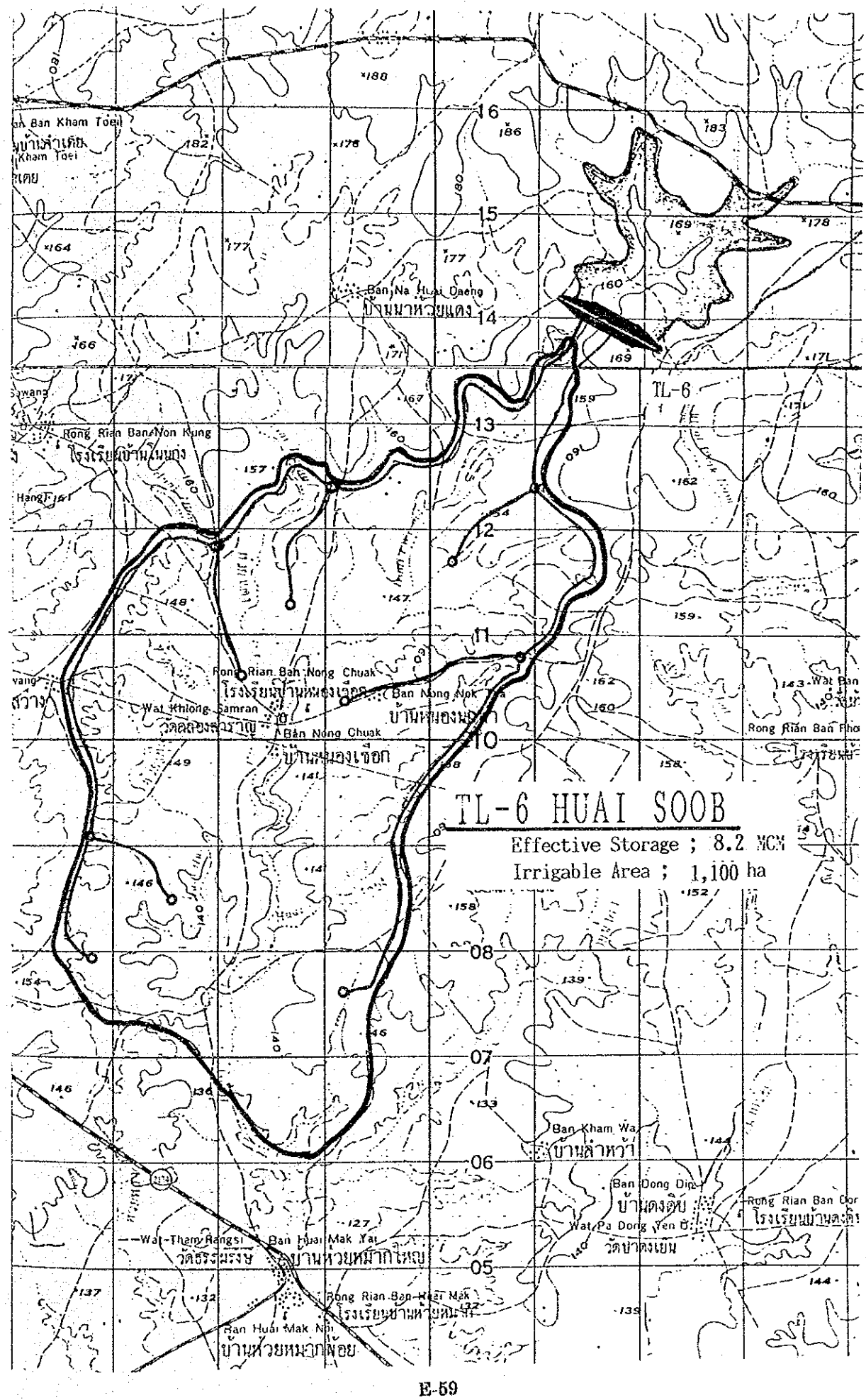


FIGURE E-6 LAYOUT PLAN OF POTENTIAL PROJECT (19/19)



APPENDIX F. WATER RESOURCES DEVELOPMENT

APPENDIX F. WATER RESOURCES DEVELOPMENT

F-1. Water Resources in the Basin

F-1-1 Present Conditions

(1) Existing Water Resources in the Northeast

Regarding surface water resources, reservoir construction is one of the most applicable means for their development. The capacity of reservoirs constructed and under construction as of the end of 1988 by RID and EGAT which are leading agencies for such development in Thailand is shown in Figure F-1 and Table F-2 by region.

The figure indicates that about 30% of the total surface runoff in Thailand is stored in those reservoirs on the assumption that the surface runoff would be about 30% of rainfall.

However, the Northeastern region as well as the Southern region are in very poor condition with water resources development; namely, its share of reservoir capacity is only 14% of the total of Thailand and its utilization rate of runoff is approximately 13%. As for groundwater resources, Table F-1 shows the regional characteristic of groundwater.

Figure F-2 presents the rate of irrigable area to the cultivation area, showing that about 23% of the total cultivation area in Thailand are equipped with irrigation facilities, and the Central and Western regions are most developed while the Northeast region is left undeveloped, as low as 6.5%. Among provinces in the Northeast region, the rates of provinces of Ubon Rachathani and Yasothon are below the average of the Region, 4.8% and 2.6%, respectively. Figure F-3 indicates the correlation between the rate of irrigable area and the average yield of paddy.

(2) Existing Water Resources in the Sebai-Sebok Basin

The total acreage of the basin covering three sub-basins of Sebai, Sebok and Tung Lung is 8,540 sq.km and the average annual rainfall and its runoff are about 1,600 mm and 580 mm, respectively.

In the basin, there are six existing and two under-construction medium scale irrigation projects, and 119 small scale irrigation projects by RID and 80 projects by other government agencies as shown in Table F-3 and F-4. As

shown in Table F-5, the total reservoir capacity of those projects is 135.2 MCM which can control only three percent of total runoff in the basin. The table also indicates that among three basins the development level of Sebok and Tung Lung basins is lower than that of Sebai basin.

As for the water resources development in the basin, the following problems were recognized;

a) Distribution of rainfall fluctuates yearly and seasonally, namely repetition of drought and rain ; and about 90 percent of annual rainfall concentrate in the rainy season from May to October. Therefore, water shortage problems for irrigation will occur even in the rainy season, especially at the initial stage of the growing periods.

b) Runoff from the area is hardly controlled for irrigation purpose due to lack of water resource facilities.

c) Topography of the area, flat plain and small watershed area, does not allow the construction of large scale dams and reservoirs.

d) The forest land as one of influent water resources was decreased by 3.18 million rai during 13 years period from 1973 to 1985 in Ubon Ratchathani province and 0.15 million rai during 10 years period from 1970 to 1985 in Yasothon province.

e) The basin is covered with mostly thin sandy soils of low water holding capacities.

f) There are a number of small scale reservoirs having such problems as sedimentation, slope erosion of dam body, destruction of spillway, etc. Therefore, rehabilitation of those facilities by dredging of ponds, repairing of facilities and improvement of O & M method shall be required.

g) As for the construction of dam, good embankment materials especially core material are limited in volume due to sandy soil prevailing in the basin.

F-1-2. Development Plan

(1) MOAC's Policy

The Ministry of Agriculture and Cooperatives (MOAC) has set forth an operation plan (1998-1991) relevant to land and water resources development in association with the Sixth National Plan. Although the Government has

tried to develop water resources for many years, about 80 percent of cultivated land still relies on rain water which is an obstacle to increase agriculture production and income of farmers. The major factors that restrict the expansion of irrigation area are: 1) physical limitation of water resources development, and 2) ineffective utilization of previously constructed large scale irrigation projects. To overcome such difficulties in the expansion of irrigation area, MOAC has decided the following policy;

- to accelerate the implementation of medium scale irrigation project in order to increase irrigable area at average rate of 200,000 rai (32,000 ha) per year;
- to improve and increase the efficiency of utilization of large scale irrigation projects by providing a suitable project administration system for close cooperation among government agencies concerned and by encouraging the private sectors to participate in agricultural development; and
- to develop and rehabilitate small scale irrigation projects including groundwater development project into the basin development system.

(2) RID Plan

In line with the MOAC's policy as mentioned above, RID, a leading agency for irrigation project has scheduled to implement three large scale, 35 medium scale and 471 small scale irrigation projects during the three years period of 1989 to 1991 as shown in Table F-6. By completing these large and medium scale irrigation projects, storage capacities and irrigable area are expected to increase by about 600 MCM and 157,000 rai (25,100 ha), respectively, and thus the total irrigable area will come up to 27 percent of the total cultivated land in Thailand.

(3) Demarcation of Project Scale

According to the regulation for national water resources administration revised by the Prime Minister's Office and effected on April 14, 1988, the scope of large, medium and small scale water resources projects was defined as follows;

- Large scale water resources projects mean every type of projects that have a storage capacity of more than 100 MCM or a reservoir area of more than 15 sq.km or an irrigation area of more than 80,000 rai

(12,800 ha), and furthermore a construction period of more than four years;

- Medium scale water resources projects mean every type of projects that have a storage capacity of not more than 100 MCM or a reservoir area of not more than 15 sq.km or an irrigation area of not more than 80,000 rai (12,800 rai), and furthermore a construction period of one to four years;
- Small scale water resources projects are projects for which reservoirs, ponds, irrigation canals, deep wells, shallow wells, or other are constructed, and moreover the construction cost is not more than 10 Million Baht and a construction period is within one year.

F-2. Basin Development

F-2-1. Development Plan

(1) Available Water Resources

The study area of 8,540 sq.km composed of the three basins has a total of 4,936 MCM runoff on an annual average. About 40% of the total area are already utilized for the catchment areas of existing projects as shown in Table F-7. So that, the rest area of about 5,000 sq.km is available for potential water resources of new projects, and its annual runoff is estimated at about 3,000 MCM.

(2) Development Plan

In order to facilitate effective use of the water resources included with existing projects, the following development plans will be introduced to the study area.

- Medium scale project;

  There are many potential reservoir sites nearby mountain-sides. Development of medium scale water resources is considered to be more profitable than that of small scale ones because of scale merit. According to the existing projects, the rate of catchment area to irrigable area of the medium scale and small scale project is about 3.0 and 20, respectively.

- Small scale project;

  To the areas where are not covered with the medium scale project, small scale water resources projects with ponds or weirs shall be introduced.

- River pumping project;

  To the flat lands where are lower than 130.0 m MSL along the three main rivers, pumping projects from those rivers shall be introduced.

- Rehabilitation of existing project;

  Rehabilitation projects by means of dredging ponds, repairing facilities and constructing distribution systems shall be promoted with high priority because of low investment.

F-2-2. Rehabilitation Scheme

(1) Medium Scale Irrigation Project

The existing six medium scale irrigation projects were reviewed for their functions. The 13.5 m high dam of Puttha Utthayan project was rehabilitated in 1987 under the USAID. Huai Tamkhae dam having a height of 18.5 m was recently constructed (1986). Other four dams ranging four to six meter in height do not need rehabilitation works.

Irrigation canals of Huai Pho and Rong Nam Sap project constructed in 1952 to 1953 have to be rehabilitated by concrete lining and modified for the enlargement of canal conveyance capacities. The rehabilitation of irrigation canals of Puttha Utthayan and Nong Chang Yai were completed by RID during the period 1982 to 1987.

With regard to the on-farm development, terminal irrigation facilities shall be constructed for a total area of 3,827 ha including irrigable areas under the projects of Huai Pho, Rong Nam Sap, Nong Chang Yai and Huai Tamkhae; for which RID will start the works in 1989 for Huai Tamkhae project (1,680 ha) and Rong Nam Sap project (67 ha), as given in Table F-9.

(2) Tung Ma Hew Project

Tung Ma Hew project having an area of 1,260 ha is situated on the downstream reaches of the Sebok river and is used to be irrigated with pumped water. The area suffered considerable damages from high floods in 1968 and 1978, and since then, irrigation has not been practiced except small scaled areas irrigated temporarily with portable pumps. Farmers have strong request for rehabilitation of project facilities. Summaries of rehabilitation works are as follows;

- Irrigable area : 1,260 ha
- Pumping station : 6 units x 150 HP x 1.5 cu.m/s
- Main canals : 9.9 km
- Secondary canals : 18.0 km
- Flood protection dike : 9.0 km
- Fish ponds : 4 ponds

F-2-3. New Development Scheme

(1) Storage Scheme

a) Medium Scale Irrigation Project

Sebai Basin;

Hills at an elevation of 100 to 200 meter above mean sea level extend in the north of the basin, and possible dam sites are mostly located on the fringe of the hills, ranging from 160 to 180 meter in elevation. Seven of possible dam sites are selected. Many small scale irrigation projects were constructed on the relatively flat terrace with an elevation of 115 to 130 meter above mean sea level.

Sebok Basin;

Many tributaries join the Sebok river in the northeast of the basin, having a relatively sharp grade of 1/500 to 1/1,000. Many possible dam sites in the upper reaches of the tributaries having topographic characteristics of folds of hills could be found in the said basin. 14 possible dam sites were selected, and there are many possible dam sites other than 14 selected sites, but are of small scale. In the southwestern basin, there exist relatively flat hills where possibilities of construction of medium scale dams and reservoirs are less. Nong Chang Yai exiting project is the only an exception.

Tung Lung Basin;

Topography of the Tung Lung basin is similar to that of the Sebok basin. Five possible dam sites were selected in the upper reaches of the tributaries with an elevation of 150 to 170 m above mean sea level.

As a result of reconnaissance site surveys and preliminary studies on the project scale, 26 of medium irrigation projects of storage schemes have been identified, as detailed in the Section F-2-5. Summarize of 26 medium scale irrigation project are given as under (refer to Table F-10)

Summary of Medium Scale Irrigation Project

Basin	Nos. of Project	Catchment Area (sq.km)	Storage (MCM)
Sebai	7	147.0	50.6
Sebok	14	387.8	97.0
Tung Lung	5	124.7	26.8
Total	26	659.5	174.4

b) Small Scale Irrigation Project

There are potentialities of small scale water resources development on the middle terrace of 2,173 sq.km with an elevation of 130 to 160 meter above mean sea level.

From the experience of the small scale irrigation projects implemented by RID in the Sebai basin (refer to Table F-8), the followings are learnt; 1) runoff from 40 percent watershed is used for storage schemes and 60 percent for river diversion schemes, ii) average watershed area is 10 sq.km for one storage scheme and 33 sq.km for one run-of-river scheme, and iii) an average storage capacity per project is about 0.5 MCM, or equivalent to 0.04 MCM per sq.km of watershed area.

Basing on the above-mentioned results, it is assumed that 87 small scale storage projects and 40 small scale river diversion projects could be constructed within the lands having the area of 2,173 sq.km, as summarized below;

Potential Small Scale Storage Projects

Item	Basin			
	Sebai	Sebok	Tung Lung	Total
1. Watershed Area (sq.km)				
Total	742	1,533	557	2,832
MSIP-Storage	147	387.8	124.7	659.5
SSIP-Storage	238	458	173	869
SSIP-River Diversion	357	687.2	259.3	1,303.5
2. Number of Project				
SSIP-Storage	24	46	17	87
SSIP-River Diversion	11	21	8	40
3. Storage Capacity (MCM)	9.5	18.3	6.9	34.7

c) Irrigable Area

RID prepared topographic maps (scaled 1:10,000) for selected 10 dams and reservoirs. Reservoir operation studies for these 10 medium scale irrigation projects were conducted for the purpose of estimating irrigable area. Irrigable area for another 16 projects was assumed based on results of the said operation studies. Irrigable area of small scale storage projects was assumed on condition that a 20 sq.km watershed secure irrigation water for 100 ha of paddy

fields. Irrigable area with the proposed storage schemes is given as follows;

Irrigable Area with Storage Scheme

Item	Basin			Total
	Sebai	Sebok	Tung Lung	
1. Medium Scale Project				
Nos. of Project	7	14	5	26
Irrigable Area (ha)	7,000	14,460	4,550	26,010
2. Small Scale Project				
Nos. of Project	24	46	17	87
Irrigable Area (ha)	1,190	2,290	870	4,350

Beneficial areas are selected among existing paddy fields located just downstream of the proposed reservoirs so as to enable gravity irrigation. In accordance with the provision of Thai government, any small scale irrigation project shall be planned and implemented by the governmental agencies in response to official application from villagers concerned. In this sense, locations of the small scale irrigation projects can not be identified at present, however, for the sake of drawing an overall basin development plan, a trial has been made to show potential project sites on the maps deemed technically feasible in due consideration of topographic conditions and availability of water resources.

(2) Run-of-River Scheme

a) River Diversion and River Pumping

Irrigation projects of run-of-river scheme to draw free-flowing water are proposed in areas where there is no possibility of storage project. Being situated below the adjacent field level, the streams have to be lifted either by pumps located relatively near the irrigation area or by a diversion structure that may have to draw the water at considerable distance upstream. A diversion structure is constructed across a river to raise its water level to a controllable elevation, from where it can flow by gravity through an irrigation canal to an irrigation area. Therefore, the location of a river diversion is limited to such rivers with a moderate grade. River

pumping is proposed where a river has a flat grade, which otherwise require a high diversion structure and long supply canals to enable gravity irrigation.

Monthly irrigation water requirements and probable monthly runoff were compared to determine the critical month in irrigation planning, and it is known that November is the critical month in rainy season paddy irrigation and require a watershed area as wide as 50 times as wide as a paddy field area.

Selection of favorable sites for river diversion and river pumping on the topographic maps has resulted in the development of runoff from 2,016 sq.km watershed for river diversion and 1,303.5 sq.km watershed for river pumping. River pumping projects are distributed over the lowlying areas with an elevation below 130 m above mean sea level along the main rivers.

Potential Run-of-River Projects

Item	Basin			
	Sebai	Sebok	Tung Lung	Total
Watershed Area (sq.km)				
- River Pumping Projects	1,039	853	124	2,016
- River Diversion Projects	357	687.2	259.3	1,303.5
Total	1,396	1,540.2	383.3	3,319.5

b) Irrigable Area

Potential irrigable areas by river diversion are marked on the topographic maps after consideration of topographic information. As for potential irrigable areas by river pumping, only the extent of areas deemed suitable for pumping are marked on the map and the number of projects is not indicated as stated before. It may be said in this connection that one unit of pump with a bore diameter of 300 inch can draw water enough to irrigate about 100 ha of paddy fields.

Irrigable Area with Storage Scheme

Item	Basin			
	Sebai	Sebok	Tung Lung	Total
1. River Pumping				
Irrigable Area (ha)	2,080	1,700	250	4,030
2. River Diversion				
Nos. of Project	11	21	8	40
Irrigable Area (ha)	710	1,370	520	2,600
Total (ha)	2,790	3,070	770	6,630

(3) Projects Related to Pak Mun Project

According to the report prepared by EGAT, summaries of the Pak Mun multipurpose project are given below ;

- Multipurpose project for development of hydropower generation, agriculture and fisheries;
- To keep normal water level at El.108.0 m by construction of a 17 m high dam across the downstream reaches of the Mun river;
- To generate 280 GWH per annum of hydropower with 4 units of 34 MW power plant;
- To supply pumped irrigation water for farm land of 25,600 ha; and
- To develop fisheries of the Mun River

The Pak Mun project controls annual runoff of 24,000 MCM from the watershed area (117,000 sq.km) inclusive of the Sebai-Sebok basin (8,540 sq.km) by constructing a dam and reservoir having an effective storage capacity of 115 MCM for multipurpose uses. The Sebai-Sebok irrigation development project has proposed to provide for storage dams with a combined capacity of about 210 MCM, far less than the annual runoff of the Pak Mun river.

The Pak Mun project will secure water for pumped irrigation of 25,600 ha areas, of which a 1,140 ha area is located on the downstream reaches of the Sebok river. The Tung Ma Hew area situated downstream of the above pumped irrigation area is preferably to be joined in the Pak Mun project. Furthermore, there are vast lowlying paddy fields along the both banks of the Sebai and Sebok rivers, of which 4,140 ha of paddy fields located on the downstream