Table 8.3.1 RIVER DISCHARGE GENERATION (KOK-ING-NAN WATER DIVERSION PROJECT) (KOK RIVER)

YEAR	<<-----					MONTHS						----->>	WET-SEASON	DRY-SEASON	ANNUAL TOTAL
	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(1)	(2)	(3)			
1974	78.98	116.35	123.25	167.00	478.92	489.84	214.91	221.54	274.08	143.35	71.87	63.18	1695.46	747.81	2443.28
1975	50.31	81.37	150.26	321.14	617.56	813.34	514.55	298.68	196.22	129.31	94.86	72.10	2715.52	624.18	3339.70
1976	61.38	95.51	93.55	164.80	452.89	428.38	335.74	262.36	145.46	121.92	80.85	71.43	1737.72	576.56	2314.27
1977	77.47	125.30	79.16	303.84	327.46	600.38	446.60	319.75	196.57	176.91	97.90	82.23	2077.19	756.38	2833.57
1978	71.88	103.52	131.80	557.03	706.54	838.82	546.80	304.51	200.75	134.19	90.04	74.62	3085.49	674.99	3760.48
1979	57.91	81.13	132.40	151.68	418.07	440.54	284.23	132.04	110.19	83.91	61.79	43.77	1558.95	438.69	1997.64
1980	38.00	43.44	99.46	360.65	427.74	717.05	381.54	219.28	160.57	79.44	81.04	64.44	2205.71	466.94	2672.65
1981	57.26	173.96	198.29	489.29	843.75	665.26	471.80	414.31	244.00	160.20	106.40	89.99	3082.70	831.81	3914.50
1982	97.02	84.40	215.40	247.08	751.26	656.11	501.77	273.66	172.27	137.75	96.48	83.14	2645.29	671.05	3316.34
1983	61.20	68.30	96.81	226.08	605.67	672.03	522.88	512.80	355.26	173.51	119.72	91.36	2636.27	869.34	3505.61
1984	72.89	93.66	128.12	331.00	422.60	620.65	426.27	253.19	151.76	120.21	83.66	68.33	2181.83	590.50	2772.32
1985	61.12	106.79	134.94	293.12	577.92	692.87	337.67	484.70	255.25	156.95	106.35	88.07	2521.22	774.53	3295.75
1986	73.92	116.51	115.78	283.08	303.44	377.16	219.60	177.89	114.66	124.49	75.77	66.16	1476.95	571.51	2048.47
1987	50.96	49.63	90.10	151.73	451.55	351.79	213.09	230.58	133.81	93.29	69.05	54.77	1488.84	451.52	1940.36
1988	60.50	119.38	137.17	286.75	713.26	544.37	304.86	251.35	159.85	111.96	76.74	68.17	2237.75	596.58	2834.33
1989	50.16	74.73	148.13	360.73	474.93	592.63	577.62	301.89	181.60	128.80	90.94	82.04	2455.94	608.26	3064.20
1990	58.53	111.13	164.93	365.31	336.49	421.80	307.53	253.13	144.42	107.54	73.08	58.39	1849.19	553.08	2402.27
1991	62.80	76.28	191.16	239.77	544.55	580.76	336.62	281.26	171.90	125.38	97.17	73.33	2174.12	606.86	2780.98
1992	50.83	44.54	57.39	230.05	305.63	314.75	195.90	185.95	135.88	94.95	60.70	48.85	1289.66	435.75	1725.41
1993	34.19	59.89	86.81	306.57	394.21	463.22	317.10	210.42	132.26	124.49	86.97	73.55	1778.31	511.35	2289.66
1994	55.62	82.33	143.75	348.11	872.14	792.19	410.65	237.09	236.90	150.87	103.74	83.11	2803.94	712.58	3516.52
1995	65.63	87.50	102.88	275.88	1075.94	1005.07	287.47	250.02	149.05	115.25	98.72	73.58	2997.26	589.73	3587.00
1996	64.83	97.23	186.49	336.67	961.92	832.65	413.63	302.36	178.43	97.23	170.31	336.67	3033.73	944.70	3978.43
AVE.	61.45	90.99	130.78	295.54	568.02	604.86	372.56	277.34	182.66	125.73	91.05	83.10	2249.09	634.99	2884.08

Table 8.3.2 RIVER DISCHARGE GENERATION (KOK-ING-NAN WATER DIVERSION PROJECT) (ING RIVER)

YEAR	MONTHS (4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(1)	(2)	(3)	WET-SEASON	DRY-SEASON	ANNUAL TOTAL
1974	8.57	10.84	3.65	17.45	349.71	382.36	115.43	106.99	19.57	40.73	5.70	3.77	975.58	89.17	1064.75
1975	3.64	3.77	96.13	177.86	517.94	537.13	247.37	75.39	21.58	5.74	3.52	3.76	1651.82	42.01	1693.83
1976	3.64	10.41	.00	11.83	139.99	157.17	281.97	153.28	12.77	17.85	.45	.00	744.23	45.12	789.36
1977	10.02	13.76	.00	74.51	259.87	535.47	362.40	158.47	24.36	34.22	3.40	3.77	1390.72	89.52	1480.24
1978	3.65	18.09	.95	360.26	410.29	504.55	158.74	48.15	11.80	3.77	2.92	.00	1482.94	40.23	1523.17
1979	.00	14.94	75.88	74.21	152.98	129.59	14.77	15.93	.58	.00	.00	.00	463.36	15.51	478.88
1980	.00	.63	.56	208.93	461.85	742.29	234.86	28.68	24.12	3.76	.00	.00	1677.17	28.51	1705.68
1981	1.49	18.58	.00	260.92	321.10	188.85	3.77	112.74	34.11	3.77	.00	.00	887.38	57.95	945.33
1982	14.09	9.50	.00	20.42	98.74	166.53	134.63	35.66	3.71	.00	.00	.00	455.98	27.30	483.28
1983	.00	3.04	.00	3.77	235.77	327.62	194.09	144.08	22.57	3.77	.84	.00	905.32	30.22	935.54
1984	.02	16.62	27.13	97.94	307.28	446.59	83.80	86.33	4.25	3.77	.00	.00	1049.07	24.65	1073.72
1985	.15	11.69	.00	76.24	349.92	208.26	38.69	247.55	105.49	3.77	1.78	.00	920.67	122.88	1043.54
1986	2.94	38.99	.00	65.77	194.66	224.27	57.04	66.35	8.34	9.15	.33	.00	608.09	59.76	667.84
1987	.84	2.69	.00	2.16	138.17	300.51	195.33	108.31	9.55	3.77	.00	.00	744.47	16.85	761.33
1988	.00	124.16	103.31	113.28	286.95	172.82	28.92	49.45	3.77	1.11	.00	.00	754.73	129.04	883.77
1989	.00	1.38	43.77	134.61	158.07	261.63	326.73	54.06	3.77	3.77	.35	.10	978.86	9.37	988.23
1990	.04	4.60	.00	108.14	293.75	162.30	35.51	97.94	6.71	1.33	.00	.00	697.65	12.67	710.33
1991	.00	9.76	25.13	32.40	155.77	394.18	89.61	77.72	4.14	.88	.00	.12	774.82	14.90	789.72
1992	.00	.00	.00	3.77	61.60	116.01	45.65	69.56	23.70	31.70	3.40	8.08	296.58	66.88	363.45
1993	22.49	26.65	.92	119.47	70.27	152.58	7.55	64.12	7.43	.37	.00	.00	414.91	56.93	471.84
1994	32.57	60.23	92.32	258.48	953.61	963.36	116.53	16.19	31.54	4.86	.00	6.34	2400.48	135.54	2536.02
1995	4.03	24.76	.00	64.86	852.31	799.72	153.73	90.40	10.87	4.54	2.32	1.11	1961.02	47.64	2008.66
1996	7.04	32.51	10.64	92.47	297.77	306.31	76.11	85.03	7.46	32.51	10.25	92.47	868.35	182.24	1050.59
AVE.	5.01	19.89	20.89	103.47	307.32	355.66	130.57	86.62	17.49	9.35	1.53	5.20	1004.53	58.47	1063.00

Table 8. 3.3 Average Monthly Discharge Diverted from Kok River

Year	June	July	August	September	October	November	December
1974	45.2	59.2	56.7	34.9	76.0	81.2	97.2
1975	54.7	64.5	5.2	17.4	87.2	109.3	69.6
1976	34.3	58.3	123.6	91.5	63.0	84.8	51.6
1977	29.0	88.0	81.9	1.4	47.5	89.7	69.7
1978	46.9	47.5	36.3	15.4	111.3	111.6	71.2
1979	48.5	53.8	104.4	117.1	97.3	48.4	39.1
1980	36.5	43.4	34.0	4.9	86.8	80.4	57.0
1981	72.7	79.0	71.8	102.0	138.2	117.4	86.3
1982	73.4	84.4	116.6	112.4	112.9	100.3	61.1
1983	35.5	74.6	90.5	54.9	106.1	121.9	124.4
1984	47.0	86.4	52.6	23.3	115.5	89.4	53.8
1985	49.3	70.9	51.5	98.7	115.1	84.2	85.5
1986	42.4	67.0	94.6	87.3	77.9	65.2	40.7
1987	33.0	53.2	76.7	66.8	60.8	84.2	47.5
1988	50.3	97.6	73.2	111.7	108.1	92.1	56.7
1989	54.3	99.2	118.8	79.1	59.1	110.2	64.4
1990	60.4	92.5	56.3	113.7	108.1	92.8	51.2
1991	68.6	84.7	106.1	30.5	113.7	100.4	61.0
1992	21.0	74.8	103.5	111.2	69.5	68.2	48.2
1993	31.8	99.8	125.7	119.1	110.3	77.1	46.9
1994	52.4	77.3	0.0	0.0	118.6	86.9	84.0
1995	37.7	82.4	2.1	5.3	93.7	88.6	52.9
1996	68.4	78.9	69.4	62.7	122.8	106.6	63.3
Average	47.5	74.7	71.8	63.5	95.6	90.9	64.5

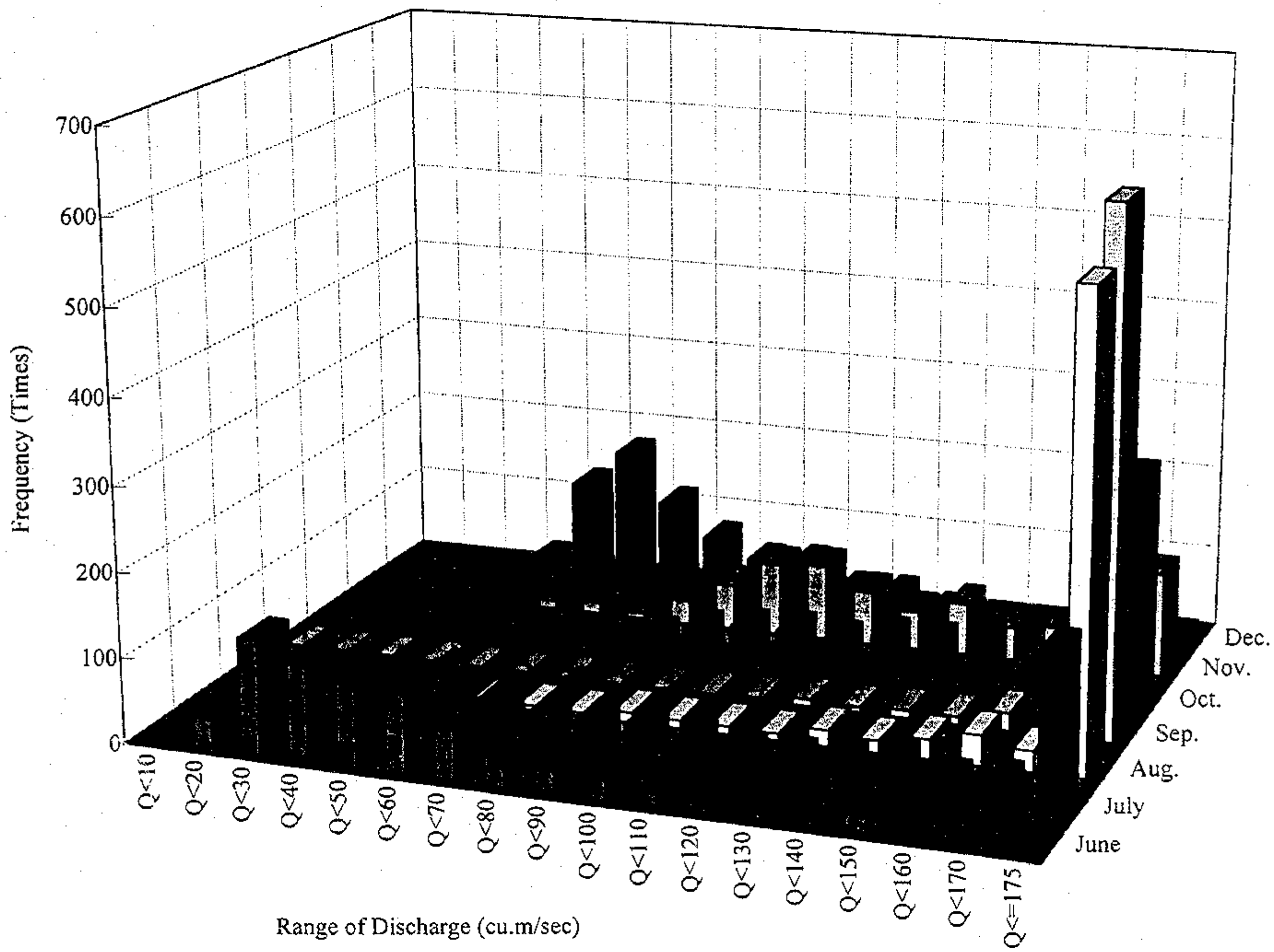
Table 8.3.4 Average Monthly Discharge Diverted from Ing River

Year	June	July	August	September	October	November	December
1974	1.3	6.2	113.0	140.1	40.9	39.2	6.9
1975	35.2	63.1	169.8	157.6	87.7	27.6	7.7
1976	0.0	4.2	49.7	57.6	100.0	56.2	4.5
1977	0.0	26.4	91.4	173.6	127.5	58.1	8.6
1978	0.3	126.3	138.7	159.6	56.3	17.6	4.2
1979	27.8	26.3	54.3	47.5	5.2	5.8	0.2
1980	0.2	50.7	139.3	170.1	83.3	10.5	8.6
1981	0.0	85.5	103.0	68.8	1.3	41.3	12.1
1982	0.0	7.2	35.0	61.0	47.8	13.1	1.3
1983	0.0	1.3	83.6	120.1	68.8	52.8	8.0
1984	9.9	34.7	109.0	146.8	29.7	31.6	1.5
1985	0.0	27.0	123.5	76.3	13.7	90.7	37.4
1986	0.0	23.3	69.0	82.2	20.2	24.3	3.0
1987	0.0	0.8	48.2	108.2	69.3	39.7	3.4
1988	37.9	40.2	101.8	63.3	10.3	18.1	1.3
1989	16.0	47.7	56.1	95.9	115.9	19.8	1.3
1990	0.0	36.8	95.2	59.5	12.6	35.9	2.4
1991	9.2	11.5	55.2	144.5	31.8	28.5	1.5
1992	0.0	1.3	21.8	42.5	16.2	25.5	8.4
1993	0.3	42.4	24.9	55.9	2.7	23.5	2.6
1994	33.8	91.6	175.0	175.0	41.3	5.9	11.2
1995	0.0	23.0	172.9	169.7	54.5	33.1	3.9
1996	3.9	32.8	105.6	112.3	27.0	31.2	2.6
Average	7.6	35.2	92.9	108.2	46.3	31.7	6.2

Table 8.3.5 Average Monthly Discharge Passing through Ing-Yot Tunnel

Year	June	July	August	September	October	November	December
1974	46.5	65.4	169.6	175.0	116.9	120.4	104.2
1975	89.9	127.6	175.0	175.0	174.9	136.9	77.2
1976	34.3	62.5	173.3	149.1	163.0	141.0	56.1
1977	29.0	114.4	173.3	175.0	175.0	147.8	78.4
1978	47.3	173.7	175.0	175.0	167.6	129.3	75.4
1979	76.3	80.1	158.6	164.6	102.5	54.2	39.3
1980	36.7	94.0	173.3	175.0	170.1	90.9	65.5
1981	72.7	164.5	174.8	170.8	139.5	158.7	98.4
1982	73.4	91.7	151.6	173.4	160.6	113.4	62.4
1983	35.5	75.9	174.1	175.0	175.0	174.7	132.4
1984	56.9	121.1	161.5	170.1	145.2	121.1	55.3
1985	49.3	98.0	175.0	175.0	128.8	174.9	123.0
1986	42.4	90.3	163.7	169.5	98.1	89.5	43.6
1987	33.0	53.9	124.8	175.0	130.1	123.9	50.8
1988	88.1	137.8	175.0	175.0	118.4	110.2	58.0
1989	70.3	147.0	174.9	175.0	175.0	130.1	65.7
1990	60.4	129.3	151.5	173.2	120.7	128.7	53.6
1991	77.8	96.2	161.3	175.0	145.4	128.8	62.4
1992	21.0	76.1	125.3	153.7	85.7	93.6	56.6
1993	32.2	142.2	150.6	175.0	113.0	100.6	49.5
1994	86.3	168.9	175.0	175.0	159.9	92.8	95.2
1995	37.7	105.4	175.0	175.0	148.2	121.7	56.7
1996	72.3	111.7	175.0	175.0	149.8	137.7	65.9
Average	55.2	109.9	164.7	171.7	141.9	122.6	70.7

Figure 8.3.1 Frequency of Discharge Passing through Ing-Yot Tunnel



CHAPTER 9.

PROJECT WATER ALLOCATION PLAN

CHAPTER 9. PROJECT WATER ALLOCATION PLAN

The Chapter 9 of the Supporting Report contains the following tables to provide more information regarding "9.2 Scenarios of Water Allocation" of the Main Report.

9.2 Scenarios of Water Allocation

Table 9.2.1 A-1 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
		Existing	Future	Existing	Future	Area (10^3 rai)	Demand (MCM)
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,021.0	1,675.7	1,888.9	115.2	213.2
Sub-total		1,234.2	1,856.7	2,150.8	3,156.8	622.5	1,006.0
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,258.9	1,303.0	1,258.9	-44.1	-44.1
Sub-total		1,718.8	1,702.0	1,766.3	1,752.1	-16.8	-14.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,279.9	2,978.7	3,147.8	71.1	169.1
Total (1)+(2)		2,953.0	3,558.7	3,917.0	4,908.9	605.7	991.9
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	397.5	909.1	735.4	-93.9	-173.7
Sub-total		522.2	599.0	948.2	1,051.4	76.8	103.2
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	49.0	0.0	98.0	49.0	98.0
Fish Pond	1,450.0	0.0	10.5	0.0	15.2	10.5	15.2
Field Crops	1,300.0	0.0	56.0	0.0	72.8	56.0	72.8
Vegetable	1,100.0	0.0	10.5	0.0	11.6	10.5	11.6
Dry Paddy	1,850.0	0.0	224.0	0.0	414.4	224.0	414.4
Sub-total		0.0	350.0	0.0	612.0	350.0	612.0
Total (1)+(2)		522.2	949.0	948.2	1,663.4	426.8	715.2
Grand Total		3,475.2	4,507.7	4,865.2	6,572.3	1,032.5	1,707.1

Table 9.2.2 A-2 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
		Existing	Future	Existing	Future	Area (10^3 rai)	Demand (MCM)
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,129.2	1,675.7	2,089.0	223.4	413.3
Sub-total		1,234.2	1,964.9	2,150.8	3,356.9	730.7	1,206.1
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,258.9	1,303.0	1,258.9	-44.1	-44.1
Sub-total		1,718.8	1,702.0	1,766.3	1,752.1	-16.8	-14.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,388.1	2,978.7	3,347.9	179.3	369.2
Total (1)+(2)		2,953.0	3,666.9	3,917.0	5,109.0	713.9	1,192.0
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	439.6	909.1	813.3	-51.8	-95.8
Sub-total		522.2	641.1	948.2	1,129.3	118.9	181.1
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	49.0	0.0	98.0	49.0	98.0
Fish Pond	1,450.0	0.0	10.5	0.0	15.2	10.5	15.2
Field Crops	1,300.0	0.0	56.0	0.0	72.8	56.0	72.8
Vegetable	1,100.0	0.0	10.5	0.0	11.6	10.5	11.6
Dry Paddy	1,850.0	0.0	224.0	0.0	414.4	224.0	414.4
Sub-total		0.0	350.0	0.0	612.0	350.0	612.0
Total (1)+(2)		522.2	991.1	948.2	1,741.2	468.9	793.1
Grand Total		3,475.2	4,658.0	4,865.2	6,850.2	1,182.8	1,985.0

Table 9.2.3 A-3 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
						Area (10^3 rai)	Demand (MCM)
		Existing	Future	Existing	Future		
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,225.3	1,675.7	2,266.8	319.5	591.1
Sub-total		1,234.2	2,061.0	2,150.8	3,534.6	826.8	1,383.9
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,258.9	1,303.0	1,258.9	-44.1	-44.1
Sub-total		1,718.8	1,702.0	1,766.3	1,752.1	-16.8	-14.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,484.2	2,978.7	3,525.7	275.4	547.0
Total (1)+(2)		2,953.0	3,763.0	3,917.0	5,286.8	810.0	1,369.7
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	477.0	909.1	882.5	-14.4	-26.6
Sub-total		522.2	678.5	948.2	1,198.5	156.3	250.3
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	49.0	0.0	98.0	49.0	98.0
Fish Pond	1,450.0	0.0	10.5	0.0	15.2	10.5	15.2
Field Crops	1,300.0	0.0	56.0	0.0	72.8	56.0	72.8
Vegetable	1,100.0	0.0	10.5	0.0	11.6	10.5	11.6
Dry Paddy	1,850.0	0.0	224.0	0.0	414.4	224.0	414.4
Sub-total		0.0	350.0	0.0	612.0	350.0	612.0
Total (1)+(2)		522.2	1,028.5	948.2	1,810.5	506.3	862.3
Grand Total		3,475.2	4,791.5	4,865.2	7,097.3	1,316.3	2,232.1

Table 9.2.4 B-1 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
		Existing	Future	Existing	Future	Area (10^3 rai)	Demand (MCM)
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,187.1	1,675.7	2,196.1	281.3	520.4
Sub-total		1,234.2	2,022.8	2,150.8	3,464.0	788.6	1,313.2
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,444.1	1,303.0	1,444.1	141.1	141.1
Sub-total		1,718.8	1,887.2	1,766.3	1,937.3	168.4	171.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,631.2	2,978.7	3,640.2	422.4	661.5
Total (1)+(2)		2,953.0	3,910.0	3,917.0	5,401.3	957.0	1,484.3
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	462.2	909.1	855.0	-29.2	-54.1
Sub-total		522.2	663.7	948.2	1,171.0	141.5	222.8
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	0.0	0.0	0.0	0.0	0.0
Fish Pond	1,450.0	0.0	0.0	0.0	0.0	0.0	0.0
Field Crops	1,300.0	0.0	0.0	0.0	0.0	0.0	0.0
Vegetable	1,100.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry Paddy	1,850.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total		0.0	0.0	0.0	0.0	0.0	0.0
Total (1)+(2)		522.2	663.7	948.2	1,171.0	141.5	222.8
Grand Total		3,475.2	4,573.6	4,865.2	6,572.3	1,098.4	1,707.1

Table 9.2.5 B-2 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
		Existing	Future	Existing	Future	Area (10^3 rai)	Demand (MCM)
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,129.2	1,675.7	2,396.2	223.4	720.5
Sub-total		1,234.2	1,964.9	2,150.8	3,664.1	730.7	1,513.3
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,444.1	1,303.0	1,444.1	141.1	141.1
Sub-total		1,718.8	1,887.2	1,766.3	1,937.3	168.4	171.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,573.3	2,978.7	3,840.3	364.5	861.6
Total (1)+(2)		2,953.0	3,852.1	3,917.0	5,601.4	899.1	1,684.4
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	439.6	909.1	932.9	-51.8	23.8
Sub-total		522.2	641.1	948.2	1,248.9	118.9	300.7
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	0.0	0.0	0.0	0.0	0.0
Fish Pond	1,450.0	0.0	0.0	0.0	0.0	0.0	0.0
Field Crops	1,300.0	0.0	0.0	0.0	0.0	0.0	0.0
Vegetable	1,100.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry Paddy	1,850.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total		0.0	0.0	0.0	0.0	0.0	0.0
Total (1)+(2)		522.2	641.1	948.2	1,248.9	118.9	300.7
Grand Total		3,475.2	4,493.2	4,865.2	6,850.3	1,018.0	1,985.1

Table 9.2.6 B-3 Case of Dry Season Water Allocation Plan

Beneficial Area and Crops	Unit Irrigation Demand	Irrigation Area (103 rai)		Water Demand (MCM)		Incremental	
						Area	Demand
		Existing	Future	Existing	Future	(10^3 rai)	(MCM)
1. Chao Phraya Delta							
(1) Upper Zone (Irrigable Area 3,956,000 at Present to 3,750,000 rai in Future)							
Sugarcane	1,300.0	173.0	285.0	224.9	370.5	112.0	145.6
Fruit Trees	2,000.0	67.6	260.1	135.2	520.2	192.5	385.0
Fish Pond	1,450.0	15.7	62.1	22.8	90.0	46.4	67.3
Field Crops	1,300.0	64.4	178.8	83.7	232.4	114.4	148.7
Vegetable	1,100.0	7.7	49.7	8.5	54.7	42.0	46.2
Dry Paddy	1,850.0	905.8	1,391.3	1,675.7	2,574.0	485.5	898.3
Sub-total		1,234.2	2,227.0	2,150.8	3,841.8	992.8	1,691.1
(2) Lower Zone (Irrigable Area 3,386,000 at Present to 3,050,000 rai in Future)							
Sugarcane	875.0	2.3	5.4	2.0	4.7	3.1	2.7
Fruit Trees	1,250.0	255.6	271.2	319.5	339.0	15.6	19.5
Fish Pond	925.0	121.4	128.8	112.3	119.1	7.4	6.8
Field Crops	900.0	2.5	2.2	2.3	2.0	-0.3	-0.3
Vegetable	800.0	34.0	35.5	27.2	28.4	1.5	1.2
Dry Paddy	1,000.0	1,303.0	1,444.1	1,303.0	1,444.1	141.1	141.1
Sub-total		1,718.8	1,887.2	1,766.3	1,937.3	168.4	171.1
(3) Whole Delta (Irrigable Area 7,342,000 at Present to 6,800,000 rai in Future)							
Sugarcane		175.3	290.4	226.9	375.2	115.1	148.3
Fruit Trees		323.2	531.3	454.7	859.2	208.1	404.5
Fish Pond		137.1	190.9	135.1	209.2	53.8	74.1
Field Crops		66.9	181.0	86.0	234.4	114.1	148.5
Vegetable		41.7	85.2	35.7	83.1	43.5	47.4
Dry Paddy		2,208.8	2,835.4	2,978.7	4,018.1	626.6	1,039.4
Total (1)+(2)		2,953.0	4,114.2	3,917.0	5,779.2	1,161.2	1,862.1
2. Lower Nan Basin							
(1) Existing Irrigation System (Phitsanulok Stage1 + DEDP Pump) (Irrigable Area 1,059,000 to 1,119,600 rai)							
Fruit Trees	2,000.0	0.0	78.4	0.0	156.8	78.4	156.8
Fish Pond	1,450.0	0.4	16.8	0.6	24.4	16.4	23.8
Field Crops	1,300.0	25.3	89.5	32.9	116.4	64.2	83.5
Vegetable	1,100.0	5.1	16.8	5.6	18.5	11.7	12.9
Dry Paddy	1,850.0	491.4	541.7	909.1	1,002.1	50.3	93.0
Sub-total		522.2	743.2	948.2	1,318.1	221.0	369.9
(2) System Expansion (Phitsanulok Stage2 + DEDP Pump) (Irrigable Area 700,000 rai in Future)							
Fruit Trees	2,000.0	0.0	0.0	0.0	0.0	0.0	0.0
Fish Pond	1,450.0	0.0	0.0	0.0	0.0	0.0	0.0
Field Crops	1,300.0	0.0	0.0	0.0	0.0	0.0	0.0
Vegetable	1,100.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry Paddy	1,850.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total		0.0	0.0	0.0	0.0	0.0	0.0
Total (1)+(2)		522.2	743.2	948.2	1,318.1	221.0	369.9
Grand Total		3,475.2	4,857.4	4,865.2	7,097.3	1,382.2	2,232.1

CHAPTER 11.

PROJECT FACILITY PLAN

CHAPTER 11 PROJECT FACILITY PLAN

11.1 Basic Plan of Project Facility

11.1.2 Overall Topographical and Geological Conditions

(1) Preparation of Map and Geological Data

(a) Topographical Survey by Thai Side and JICA

List of topographical survey maps and drawings by Thai side and JICA are shown in Table 11.1.2.(1)-1.

Table 11.1.2.(1)-1 List of Collected Survey Drawings

Name of Site	Length (m) Area (ha)	Kind of Survey	Scale (Horizontal)	Scale (Vertical)	No. of Sheets	Remarks
A. Carried out by JICA Side						
1.Nam Mae Kon	2.027	Profile Cross Sec.	1/5,000 1/200	1/100 1/100	1 3	 @250m,12sec.
2.Nam Mae Kok- Lao	4.112	Profile Cross Sec.	1/5,000 1/200	1/100 1/100	1 7	 @250m,23sec.
3.Nam Rong Chae	17.142	Profile Cross Sec.	1/10,000 1/200	1/100 1/100	2 11	 @500m,44sec.
4.Nam Loi	13.170	Profile Cross Sec.	1/5,000 1/200	1/100 1/100	2 8	 @500m,27sec.
5.Nam Ma-up	7.0 ha 1.638	Topo. Map Profile Cross Sec.	1/1,000 1/200 1/200	 1/200 1/200	1 1 8	for Yao Flood Control Dam @100m, 9sec.
6.Nam Mae Yao		Cross Sec.	1/200,400	1/100,200	20	48sec.
7.TEM & TDEM	16.085	Profile	1/500,2500	1/500,2500	12	12 lines
B. Carried out by Thai Side						
1.Topographical Map		Topo. Map	1/10,000		73 9	 10-12,14-17,19-20
2.Nam Mae Kok	30.000	Profile Cross Sec.	1/10,000 1/500	1/100 1/100	4 14	 @500m
3.Nam Mae Ing	34.500	Profile Cross Sec.	1/4,000 1/200 1/200	1/100 1/100 1/100	5 15 4	 @500m @500m
4.Nam Mae Ing-Lao	20.000	Profile Cross Sec.	1/4,000 1/200	1/100 1/100	3 10	 @500m
5.Nam Mae Yao		Cross Sec.	1/100	1/100	3	@500m
6.Diversion Canal(1)	12.281	Profile	1/4,000	1/100	4	
7.Diversion Canal(2)	10.819	Profile	1/4,000	1/100	4	
8.Diversion Canal(3)	23.775	Profile	1/4,000	1/100	8	
9.Lao Diversion Canal	13.244	Profile	1/4,000	1/100	4	

(b) Geological Data

The list of collected maps and geological data for study of the project are as follows.

Geological map

Geological map of North Thailand (1977) by DMR, 1/250,000 in scale

Sheet 1 (Nan)
Sheet 2 (Chiang Rai)
Sheet 3 (Phayao)

Geological map (1988-1996) by DMR, 1/50,000 in scale

Chiang Rai (sheet No.4948-1)
Ban Waen Khong (sheet No.5047-1)
Amphoe Pong (sheet No.5047-2)
Ban Tham (sheet No.5047-3)
Amphoe Chun (sheet No.5047-4)
Amphoe Chiang Kham (sheet No.5048-2)
Amphoe Thoeng (sheet No.5048-3)
Ban Mae Pao Luang (sheet No.5048-4)

Aerial photograph

Aerial photographs by RID, about 150 sheets with 1/30,000 in scale, including interpretation map as for aerial photograph, 1/50,000 in scale

Drilling report

Exploratory drilling report by RID, 1996
Exploratory drilling report by RID (total 3 volumes), 1997
Exploratory drilling report (Yao flood control dam) by RID, 1997
Exploratory drilling report by JICA (total 5 volumes), 1998

Seismic survey report

Seismic refraction survey report by RID (1 sets), 1998
Seismic reflection survey report by RID (1 sets), 1998

Other data

Data of a variety of in-situ tests and results of laboratory tests (rock tests with drilling core and soil tests) performed by RID

Results of the electromagnetic prospecting performed by JICA

(2) Hydraulic Conditions of Three Rivers

(a) Kok River

The Kok river, a tributary of the Mekong River, has a length of 157 km and a catchment area of 10,875 km^2. The average riverbed slope is 1/2,770 in the river stretch between the confluence of the Mekong river and the existing Chiang Rai weir located at 67 km upstream from the confluence. While it steepens at 1/1,250 in the upstream reaches of the weir as given in Figures 11.1.2 (2)-1 to 11.1.2 (2)-3.

The river depth of the Kok river, which is defined as a difference between the lowest riverbed and river bank, is ranging between 3 m to 5 m in the downstream reaches where the Kok River remarkably meanders and is the flood prone area. It is deepened to 4 m to 7 m in the upstream reaches along Chiang Rai City. The river width is 80 m to 100 m at the riverbed and 100 m to 150 m between both riverbanks. Especially, flood dyke is provided for the downstream reaches with 12 km from the existing Chiang Rai weir and its width between dykes on the left and right banks is about 300 m.

The backwater effect of the Mekong to the Kok river is limited into the downstream reaches of about 30 km from the confluence, judging from the riverbed elevation of the Kok River and the estimated probable flood water level of 367 m with a return period of 100 years at Sop Kok.

The existing Chiang Rai weir is constructed for irrigation development by the Department of Energy Development and Promotion (DEDP) in 1994. The DEDP schedules to complete the construction of irrigation system in 1999. The Project plans to operate this weir for diversion of the river water in the Kok River into the Sirikit dam in the Nan River through the Ing and Yao rivers during the wet season. The plan and profile of the Chiang Rai weir are shown in Figures 11.1.2 (2)-4 and 11.1.2 (2)-5.

In the up-and downstream reaches of the Chiang Rai weir, 13 private companies are taking river sand material by installing their dredgers in the Kok River through a year. Due to this sand mining, the sedimentation in the reservoir seems not to be a serious problem for operation of the weir based on the river cross sections surveyed in 1996 by the RID after completion of the construction of the weir.

The existing Chiang Rai Weir and the proposed intake structure lay on the deep alluvial plain with a width of 5 km to 7 km. According to the geological investigation by the Team J/V, alluvial plain mainly consists of fine to coarse sand with loose condition.

(b) Ing River

The Ing river, a tributary of the Mekong river, has a length of 300 km and a catchment area of 7,120 km^2. Through the river reaches of the Ing River, it remarkably meanders with a width of 500 m to 2 km.

The average riverbed slope of the Ing river is 1/8,350 in the river reaches of about 100 km from the confluence with the Mekong river, while it slightly changes to 1/6,170 in the upstream reaches as given in Figures 11.1.2 (2)-6 and 11.1.2 (2)-9.

The river depth of the Ing River, which is defined as a difference between the lowest riverbed and riverbank, is ranging between 6 m to 10 m in the river reaches between the confluence with the Mekong river and the Lao river. The river channel in this stretch has a width of 30 m to 50 m at the riverbed and 100 m to 150 m between the riverbanks.

While, in the river reaches upstream from the confluence with the Lao river, the depth of the channel becomes shallow as 3 m to 5 m and the river width is 15 m to 40 m at the riverbed and 20 m to 50 m between both river banks.

The Mekong river largely affects water level of the Ing river. According to the recorded maximum water level at Chiang Khong, the probable flood water level at the confluence with the Ing river is estimated at EL. 352.7 m which is corresponding to the riverbed elevation at 110 km upstream from the confluence. While, during the dry season, the water level in the lower reaches of about 10 km is influenced by the water level of the Mekong river.

The Ing river with a very gentle riverbed slope, remarkable meandering channel and the backwater effect of the Mekong river results in forming wide flood prone areas along the river course. Especially, the river reaches of about 37 km between Ban Pang Mot Daeng and Amphoe Thoeng has a bottle-neck at the existing bridge of the road with a route number 1020.

While, three tributaries of the Lao, Loi and Chae joins in this river stretch which forms a wide inundation area of about 5 km^2, where is categorised into bush area in terms of land use, and inundation depth of about 1 m to 2 m even during normal wet season. Flooding in this area has contributed to regulating flood discharges in the downstream reaches.

The Ing diversion dam and intake structure are planned to lay on the Ing alluvial plain which is composed of clay with soil classification of CL to CH up to depth of 12 m and sand with gravel from SM to SP in deeper layer than 12 m.

(c) Yao River

The Yao river, a tributary of the Nan river, has a length of about 70 km and a catchment area of 883 km2. The average riverbed slope of the Yao river is 1/1,090 in the river reaches of about 14 km from the confluence with the Nan River, and it steepens to 1/500 in the upstream reaches for Ban Pang Puk. The average riverbed slope in further upstream is gentle as 1/990 to the proposed flood control dam site as given in Figures 11.1.2 (2)-10 to 11.1.2 (2)-12. The upstream river reaches planned to be a reservoir by the proposed flood control dam have rather steep slope of 1/270.

The Yot river, which is planned to connect with the Ing-Yot tunnel by the channel, joins the Yao River at 47.5 km upstream from the confluence with the Nan river and has a steep slope of 1/210. As well as the Yot river, the Yao river joins many tributaries such as the rivers of Mong, Ki, and Pao, which have a catchment area of less than 100 km2.

Villages, which has suffered from flooding under the present condition and will be affected by the Project, are: 1) Song Khwae, 2) Hang Thung, 3) Pang Puk, 4) Sop Pet, 5) Nam Mong, 6) Pang Sa, 7) Wang Phang, 8) Haen, 9) Tut, 10) Na Nun and Son, and 11) Sop Yao. These villages have been developed in the narrow area along the river course of the Yao River in order to cultivate dry season crops and vegetables for their lives.

In most of these village areas, significant flood damages were caused in 1996, which is the largest flood in their memory. Especially, in Ban Na Nun, village people had to evacuate to neighbouring elementary school for three (3) weeks during flooding. Also, the flood with high flow velocity in 1996 washed out several houses in Ban Song Khwae and Ban Hang Thung along the upstream reaches.

According to hearing about flooding in the past to village people, lowland of Ban Na Nun has suffered from flood damage every year due to backwater effect of the Nan River. Downstream part of Ban Song Khwae has damaged four times in 1989, 1994, 1995 and 1996 by the flood during last decade. In other villages, they have not experienced flooding excluding in 1995 and 1996.

(4) Geological Condition along Route and at Damsite

The outlines of the distribution and characteristic of each formation are as follows.

(a) Carboniferous to Triassic sedimentary rocks

*Doi Mun formation (**CPdm**)*

This formation is belonging to oldest group called Chiang Kham group, which is composed of three formations, Doi Mun, Nam Bong and Huai Krai formation, belonging to Carboniferous - Permian in age and is located on the north area of the Ing-Yot No.2 tunnel alignment and is corresponding to the national border area between Thai and Laos. It shows feature of high and steep mountain. **CPdm** is characterized with low grade metamorphosed rock such as schist, phyllite, slate and metamorphosed sandstone associated with quartzite.

*Nam Bong formation (**CPnb**)*

This formation is located along major part of Ing-Yot No.2 tunnel alignment and consists of dark grey phyllite, slate and metamorphosed sandstone. These rocks are commonly associated with quartzite, tuff, and calcareous or siliceous shale. Major part of the formation is characterised by fine alternation of foliated slate and metamorphosed sandstone. These rocks are usually hard but breakable along bedding plane or slaty cleavage, and are sometimes broken along slickenside. Furthermore, fault on a small scale along the bedding plane of quartzite is frequently found out.

*Huai Krai formation (**CPhk**)*

This formation is located at the upstream area (from 3 km to 7 km in section, approximately) of the Ing-Yot No.2 tunnel and consists of grey to dark grey slate and weakly metamorphosed sandstone associated with quartzite, and limestone or calcareous shale. Characteristics of this formation are similar to that of Nam Bong formation (**CPnb**). Furthermore, this formation abuts on Nam Bong formation with thrust fault, which elongates along the Fai river, at about 7 km point from inlet of the Ing-Yot No.2 tunnel. A part of fault sheared zone was also observed at drilling DHB8.0SP as fractured and softened slate.

*P2 formation (**P 2**)*

This formation is located on the isolated mountains between Kok alluvial plain and Ing alluvial plain and is characterised by limestone which is mentioned on published geological map as "Ban Mae Pao Luang (1/50,000 in scale)" by DMR. Furthermore, the existence of this limestone was also observed at the drilling DHKI-7 on the canal alignment.

*P3 formation (**P 3**)*

This formation is located at the mountain ranges between Kok alluvial plain and Ing alluvial plain and is mentioned on published geological map as "Ban Mae Pao Luang (1/50,000 in scale)" by DMR. Furthermore, this formation appears around the inlet of Kok-Ing No.2 tunnel alignment (from inlet to 4 km in section). Characteristics of this formation are an alternation of foliated slate, sandstone and limestone layer, and are breakable along bedding or slaty cleavage.

PTR formation (PTR)

This formation is located on the east and west wing area of the mountains between Kok alluvial plain and Ing alluvial plain. Along tunnel alignments, this formation exists on the latter part of Kok-Ing No.1 tunnel and also the latter part of Kok-Ing No.2 tunnel. This formation contacts with P3 formation and consists of dark grey shale interbedded with sandstone. Characteristics of the fresh rocks are hard but breakable along bedding. Moreover, rocks characteristics of P3 formation and this formation are similar to those of Huai Krai and Nam Bong formation.

(b) Middle-Upper Triassic sedimentary rocks

Huai Fak formation (TRhf)

This formation is mainly located on the first part of the Ing-Yot No.2 tunnel (from 1 km to 4 km in section, approximately) and latter part of the Ing-Yot No.2 tunnel (from 30 km to outlet in section). It also exists around the Yao flood control dam. The formation consists of greenish grey tuff and sandstone frequently interbedded with thin layer of dark grey shale. In this case, original components of the tuff are mostly replaced by microcrystalline quartz, and rock facies indicates subjection of intense silicification. Rock characteristics of the fresh rocks are massive, hard to very hard but breakable by moderate to hard hammer blow along potential cracks.

Pa Lae Formation (TRpl)

This formation is located on about halfway place of the Ing-Yot No.2 tunnel (from 28 km to 30 km in section) and around the outlet (from 46 km to 47 km and 49 km to 51 km in section). This formation forms unique shape mountain, for example the Doi Pha Deang mountain located nearby Ban Pang Tham, and consists of limestone and clayey limestone which shows hard and massive facies. Limestone caves are frequently formed in the mountain, and dolines are also found out on ground surface.

Doi Pong Nok (TRpn)

This formation is located around the Ing-Yot No.1 tunnel and inlet area of the Ing-Yot No.2 tunnel forming lower hills. The formation consists of shale and sandstone alternation associated with tuff and is characterised by reddish brown colour facies. In general, these rocks are strongly weathered up to the depths and are medium hard to soft easily breakable along bedding.

(c) Permian-Triassic igneous rock series

Granite (PTRgr)

The Granite is located on the mountain area between Kok alluvial plain and Ing alluvial plain and is distributed along the anticline axis elongated NE to SW direction around the inlet of Kok-Ing No.2 tunnel. Rock facies show medium to coarse grained biotite granite and granodiorite porphyry as similar facies of granite.

*PTRv (**PTRv**)*

This formation is composed of two kinds of rock types ;

<Tuff and Dacite>

These rocks are thrust over limestone of **TRpl** (Pa Lae formation) around halfway place of the Ing-Yot No.2 tunnel (about 29 km point from tunnel inlet) and consists of greenish gray tuff and dacite. The tuff consists of quartz, plagioclase and volcanic lithic fragment and contains lapilly of basalt and serpentine. Rock characteristics of the fresh rocks are massive and hard but breakable along slaty cleavage by ordinary hammer blow.

<Lappilly tuff and Tuff>

These rocks are located around the inlet of Ing-Yot No.2 tunnel (about 1 km to 2 km point from tunnel inlet) and consists of greenish gray and purplish gray tuff, lapilly tuff and are intruded by porphyrite or granite porphyry. Rock characteristics of the fresh rocks are medium hard to hard.

(d) Jurassic sedimentary rocks

As a result of new transgression in Jurassic, a series of formation was formed on the Pre-Jurassic basement. These Jurassic sedimentary basins were formed on the Chiang Rai plain, the Ing plain and the Chiang Kham basin. These formation series are made up of **Jnn** (Na Ngan formation) to **Jmt** (Mae Tam formation). One alternative route of Kok-Ing tunnel (C route) is selected to pass through hill and lower mountain area which is underlain by these formations.

*ms 3 formation (**ms 3**)*

This formation is located on hill and low mountains around the Ing diversion weir and the Ing-Yot No.1 tunnel alignment and consists of tuff, tuff breccia, conglomerate with greenish gray, reddish brown. Rock characteristics of the fresh rocks are medium hard to hard as a whole.

*ms 3-5 formation (**ms 3-5**)*

This formation is located on lower hill area extending on the east side of Ing river and consists of reddish brown sandstone and shale which are weathered up to the depths. Rock characteristics of the fresh rocks are soft to medium hard to soft and easily breakable along bedding. Furthermore, this formation is equal to Doi Pong formation of existing geological map "Amphoe Chiang Kham (1/50,000 in scale)" by DMR.

*Na Ngan formation (**Jnn**)*

This formation is located on the alternative route of Ing-Yot tunnel (C route) and consists of sandstone, shale and conglomerate.

*Phu Kham formation (**Jpk**)*

This formation is also located on the alternative route of Ing-Yot tunnel (C route) and consists of quartzitic sandstone and shale.

ms 5-3 formation (ms 5-3)

This formation is merely described in the existing geological map "North Thailand (1/250,000 in scale)" by DMR, which is expressed by the existence at the mountain top area on the Ing-Yot tunnel No.1 alignment but is not mentioned on the existing geological map "Ban Waen Khong (1/50,000 in scale)" by DMR. Furthermore, according to the existing geological map "North Thailand" (1/250,000 in scale) by DMR, this formation which is composed of tuff, sandstone and shale, is also described as to be located nearby the planned Yao flood control dam. In this case, the existence of the former could not be confirmed at the field while the existence of the latter has been clarified by the field survey works.

Mae Tam formation (Jmt)

This formation is also located on the alternative route of the Ing-Yot tunnel (C route) and consists of siltstone and sandstone.

(e) Jurassic igneous rock series

Andesite (an)

Andesite which abutting on Granite (PTRgr) of Permian-Triassic igneous rock series is located on the mountainous area between Kok alluvial plain and Ing alluvial plain.

Tuff (Jv and Msv)

This formation which consists of rhyolite and rhyolitic tuff is located on the mountainous area between Kok alluvial plain and Ing alluvial plain and is supposed to be located on the middle of Kok-Ing tunnel No.1 (about 0.5 km to 2 km from tunnel inlet). Rock feature of this formation is medium soft to soft, moderately to slightly weathered and intensely fractured up to the depths.

(f) Tertiary to Quaternary sediments

Huai Sieo (Ths)

This formation is located on the northern area of the alternative route of Ing-Yot tunnel (C route) forming of gentle slope or flat plain and consists of semi-consolidated clay, silt and sand.

Terrace deposit (Qt)

The terrace features are located around the Chiang Rai alluvial plain and the Chiang Kham basin. This formation consists of unconsolidated clay, silt, sand, gravel and laterite (red soil).

Alluvial deposit (Qa)

The alluvial deposit is distributed over the alluvial plain area around the Kok river, Ing river and Lao river etc. and consists of loose and soft unconsolidated clay, silt, sand and gravel.

(g) Tertiary volcanic rock series

Basalt (Bs)

Basalt is located on a ridge of hill which passes the Kok-Ing No.2 tunnel alignment. As a result of electromagnetic prospecting, the bottom end of this basalt is supposed to be located at about 50 m in depth, therefore, the tunnel position may not encounter basalt formation except for some intrusions.

(h) Geological Structure

At the project area, the main structural features which are made up of faults on a large scale show that the axes of anticline and syncline and the directions of arrange of each formation trend from the northeast to the southwest direction as a whole. Also, direction of the mountain ranges between Kok alluvial plain and Ing alluvial plain and that of Ing alluvial plain together with the long axis of Chiang Kham basin and mountain ranges located on the east of Chiang Kham basin are also characterized by the topographical features reflected by the above geological structure. Taking these structural features into consideration, it is recognized that the Kok-Ing No.1 and No.2 tunnel alignment, and the Ing-Yot No.2 tunnel alignment traverse some major faults which mainly trend northeast-southwest direction.

Geological Investigation by Thai Side and JICA

The items and quantities of geological investigation performed for project are summarized in the following tables.

< List of Tables >

Table 11.2.1.(2)-1, Table11.2.1.(2)-2 ..... Location, drilling depth and accompanied test of drilling

Table 11.2.1.(2)-3, Table11.2.1.(2)-4 .....List of survey lines for seismic refraction prospecting

Table 11.2.1.(2)-5 .....List of survey lines for seismic reflection prospecting

Table 11.2.1.(2)-6 .....List of survey lines for electromagnetic prospecting survey

Table11.2.1.(2)-1 Location, Drilling Depth and Accompanied Test of Drilling (1)

Location	Hole No.	Drilling Depth (m)	Ground Height(EL.m)	Coordinate of Location		Geophysics Logging	Lugeon Test (Times)	Permeability Test (Times)	S.P.T. (Times)	Rock Test (Samples)	Performed by	Drilled Year
				X-coord.	Y-coord.							
Kok intake	DHKI-A1	30.0	389	596,800	2,205,280	---	---	---	29	---	Thai side	1997
	DHKI-B1	30.0	389	591,100	2,202,730	---	---	---	29	---	Thai side	1997
Kok-Ing canal route	DHKI-B2	30.0	391	593,780	2,200,400	---	---	---	30	---	Thai side	1997
	DHKI-B7	30.0	397	606,290	2,190,630	---	---	---	21	---	Thai side	1997
	DHKI-B8	20.0	367	618,230	2,182,290	---	---	---	19	---	Thai side	1997
	DHKI-B9	20.0	372	617,100	2,175,370	---	---	---	20	---	Thai side	1997
	DKI-2	30.0	389	591,740	2,201,950	---	---	---	29	---	Thai side	1997
	DKI-4	30.0	385	598,800	2,199,080	---	---	---	25	---	Thai side	1997
	DKI-5	20.0	386	601,000	2,198,400	---	---	---	10	---	Thai side	1997
	DKI-6	20.0	387	606,480	2,192,420	---	---	---	19	---	Thai side	1997
	DKI-7	20.0	392	606,740	2,191,000	---	---	---	19	---	Thai side	1997
	DKI-8	20.0	373	617,600	2,183,720	---	---	---	20	---	Thai side	1997
Kok-Ing canal (south route)	DHKI-B4	30.0	395	598,100	2,193,900	---	---	---	12	---	Thai side	1997
	DHKI-B5	30.0	397	600,000	2,190,600	---	---	---	17	---	Thai side	1997
	DHKI-B6SP	30.0	397	602,920	2,192,120	O	---	---	14	---	Thai side	1997
Kok-Ing No.1 tunnel	DHKBJT1-1SP	70.0	430	604,090	2,197,150	O	---	---	---	3	Thai side	1997
Kok-Ing No.2 tunnel	DHKB-1	70.0	436	610,000	2,190,000	---	3	---	---	1	Thai side	1997
	DHKB-2	65.0	426	613,830	2,188,900	---	3	---	---	1	Thai side	1997
	DHK-EXTRA7	50.0	480	610,400	2,189,800	---	3	---	---	---	JICA side	1997
Kok-Ing No2. tunnel (B-J route)	DHKBJT2-1	65.0	435	610,200	2,193,300	---	3	---	---	3	Thai side	1997
	DHKBJT2-2	55.0	420	611,730	2,192,250	---	3	---	---	---	Thai side	1997
	DHBJ-4.5	165.0	520	613,100	2,190,650	O	7	---	---	4	JICA side	1998
Ing diversion weir	DHID-1	40.0	362	624,300	2,175,400	---	---	---	39	---	Thai side	1997
	DHID-2	40.0	362	624,410	2,175,400	---	---	---	39	---	Thai side	1997
	DHID-3	40.0	364	624,600	2,175,400	---	---	---	40	---	Thai side	1997
Ing -Yot No.1 tunnel	DHIY-1	50.0	394	627,500	2,174,500	---	4	---	---	---	Thai side	1997
	DHIY-2	30.0	373	628,690	2,174,480	---	3	---	10	---	Thai side	1997
Ing-Yot No.2 tunnel adit	DH1AD1	65.0	482	640,570	2,174,400	---	3	---	---	---	Thai side	1997
	DH2AD1SP	90.0	495	645,550	2,174,000	O	---	---	---	---	Thai side	1997
	DH3AD1	60.0	530	648,300	2,169,850	---	3	1	9	1	Thai side	1997
	DH4AD1	65.0	535	649,000	2,160,000	---	3	---	---	---	Thai side	1997
	DH5AD1	70.0	550	654,290	2,155,780	---	3	---	---	---	Thai side	1997
	DH6AD1SP	120.0	660	657,350	2,154,940	O	6	---	---	3	Thai side	1997
	DH7AD1	60.0	460	665,410	2,146,680	---	3	---	---	2	Thai side	1997

Table11.2.1.(2)-2 Location, Drilling Depth and Accompanied Test of Drilling (2)

Location	Hole No.	Drilling Depth (m)	Ground Height(EL.m)	Coordinate of Location X-coord.	Coordinate of Location Y-coord.	Geophysics Logging	Lugeon Test (Times)	Permeability Test (Times)	S.P.T. (Times)	Rock Test (Samples)	Performed by	Drilled Year
Ing-Yot No.2 tunnel	DHB-1	40.0	383	635,150	2,173,750	---	3	---	1	---	Thai side	1996
	DHB-2	45.0	388	636,030	2,174,000	---	3	---	5	---	Thai side	1996
	DHB-3	55.0	402	635,710	2,175,520	---	3	---	19	---	Thai side	1996
	DHB-4	120.0	463	638,820	2,175,580	---	3	---	5	---	Thai side	1996
	DHB-5	120.0	461	644,940	2,174,990	---	3	---	6	---	Thai side	1996
	DHB-6	150.0	482	652,550	2,156,750	---	3	---	6	---	Thai side	1996
	DHB-7	60.0	383	665,840	2,145,420	---	3	---	5	1	Thai side	1996
	DHB-8	50.0	375	668,140	2,144,030	---	3	---	10	1	Thai side	1996
	DHA-1	60.0	403	635,050	2,177,260	---	3	---	1	1	Thai side	1996
	DHA-2	70.0	412	636,230	2,177,510	---	3	---	1	---	Thai side	1966
	DHB0	35.0	382	634,570	2,174,520	---	3	---	9	---	Thai side	1997
	DHB0.6	50.0	390	634,820	2,175,420	---	3	---	---	1	Thai side	1997
	DHB1SP	80.0	420	636,500	2,174,770	O	---	---	---	1	Thai side	1997
	DHB8SP	145.0	488	642,420	2,175,870	O	6	---	---	2	Thai side	1997
	DHBJ-16.5	200.0	532	648,900	2,171,420	O	7	---	---	6	JICA side	1998
	DHBJ-18.0	205.0	537	649,350	2,170,160	O	7	---	---	4	JICA side	1998
	DHBJ-22.5	220.0	547	650,000	2,166,890	O	7	---	---	4	JICA side	1998
	DHBJ-26.0	300.0	619	651,150	2,160,550	O	4	---	---	4	JICA side	1998
	DHBJ-33.0	310.0	638	655,000	2,157,250	O	7	---	---	5	JICA side	1998
	DHB46SP	100.0	420	665,670	2,146,630	O	---	---	---	3	Thai side	1997
	DHB49	60.0	390	668,240	2,145,820	---	3	---	---	---	Thai side	1997
	DHB50SP	90.0	420	668,830	2,145,170	O	---	---	---	1	Thai side	1997
Ing-Yot tunnel (south route)	DHC-1	42.0	387	628,480	2,159,310	---	3	---	3	1	Thai side	1996
	DHC-2	65.0	410	629,500	2,153,000	---	3	---	11	1	Thai side	1996
Yao flood control dam	DH1	50.0	322	678,015	2,141,785	---	7	11	1	---	Thai side	1997
	DH2	80.0	284	678,095	2,141,845	---	7	25	---	---	Thai side	1997
	DH3	60.0	296	678,135	2,141,875	---	14	18	3	---	Thai side	1997
	DH4	50.0	331	678,187	2,141,925	---	---	40	4	---	Thai side	1997
	DH5	30.0	328	678,470	2,142,120	---	5	12	3	---	Thai side	1997
	DH6	30.0	316	678,515	2,141,946	---	4	8	3	---	Thai side	1997
Total	64 holes	4632.0					170	115	546	54		

* S.P.T. : Standard penetration test

* The test contents of geophysics logging are as follows.

(1) Caliper logging, (2) Full waveform sonic logging, (3) Electric logging, (4) Resistivity logging, (5) Natural Gamma logging

Table11.2.1.(2)-3 List of Survey Lines for Seismic Refraction Prospecting (1)

Line Name	Location	Length (m)	Coord. of Starting Point		Coord. of Ending Point		Performed by
			X-coord.	Y-coord.	X-coord.	Y-coord.	
SKIT-1-1	Kok-Ing No.1 tunnel inlet (main)	400	601,425	2,198,150	601,805	2,198,005	Thai side
SKIT-1/1	Kok-Ing No.1 tunnel inlet (sub)	400	601,740	2,198,230	601,555	2,197,890	Thai side
SKIT-1-2	Kok-Ing No.1 tunnel outlet (main)	1,000	603,435	2,197,355	604,215	2,196,705	Thai side
SKIT-1/3	Kok-Ing No.1 tunnel outlet (sub)	300	603,345	2,197,250	603,530	2,197,490	Thai side
SKIT-1/4	Kok-Ing No.1 tunnel outlet (sub)	400	603,880	2,196,725	604,165	2,197,035	Thai side
SKI-1, SKIT-2	Kok-Ing No.2 tunnel inlet (main)	4,800	606,190	2,191,650	610,128	2,189,900	Thai side
SKIT-2/2RR	Kok-Ing No.2 tunnel inlet (sub)	500	609,860	2,190,320	609,689	2,189,850	Thai side
SKIT-3/1RR	Kok-Ing No.2 tunnel outlet (main)	800	613,670	2,188,635	614,435	2,188,370	Thai side
SKIT-3/2RR	Kok-Ing No.2 tunnel outlet (sub)	500	614,220	2,188,740	614,033	2,188,279	Thai side
Line IY	Ing-Yot No.1 tunnel (main)	1,925	626,540	2,174,395	628,475	2,174,500	Thai side
SB0(Main)	Ing-Yot No.2 tunnel inlet (main)	3,100	634,350	2,175,370	637,475	2,175,615	Thai side
SB0(SubA)	Ing-Yot No.2 tunnel inlet (sub)	500	634,800	2,175,620	634,827	2,175,127	Thai side
SB0(SubB)	Ing-Yot No.2 tunnel inlet (sub)	500	635,680	2,175,675	635,830	2,175,195	Thai side
SB0(SubC)	Ing-Yot No.2 tunnel inlet (sub)	600	637,055	2,175,780	636,620	2,175,360	Thai side
S2B0(Main)	Ing-Yot No.2 tunnel inlet (main)	1,100	635,720	2,174,275	636,650	2,174,830	Thai side
S2B0(Sub)	Ing-Yot No.2 tunnel inlet (sub)	500	636,360	2,174,950	636,635	2,174,535	Thai side
SAd1(Main)	Ing-Yot No.2 tunnel Adit No.1(main)	1,000	640,495	2,174,025	640,995	2,174,890	Thai side
SAd1(Sub)	Ing-Yot No.2 tunnel Adit No.1(sub)	500	640,435	2,174,320	640,795	2,174,030	Thai side
SAd2-RFR1	Ing-Yot No.2 tunnel Adit No.2(main)	400	645,280	2,173,350	645,105	2,172,990	Thai side
SAd3-RFR1	Ing-Yot No.2 tunnel Adit No.3(main)	500	648,300	2,169,700	647,825	2,169,854	Thai side
SAd3-RFR2	Ing-Yot No.2 tunnel Adit No.3(sub)	500	648,086	2,169,507	648,257	2,169,977	Thai side
SAd4-RFR2	Ing-Yot No.2 tunnel Adit No.4(main)	600	648,906	2,160,205	649,020	2,159,616	Thai side
SAd4-RFR1	Ing-Yot No.2 tunnel Adit No.4(sub)	650	649,170	2,160,005	648,631	2,159,686	Thai side
SAd5-RFR1	Ing-Yot No.2 tunnel Adit No.5(main)	300	654,410	2,155,900	654,181	2,155,705	Thai side
SAd5-RFR2	Ing-Yot No.2 tunnel Adit No.5(sub)	500	654,566	2,155,725	654,131	2,155,971	Thai side
SAd6-RFR1	Ing-Yot No.2 tunnel Adit No.6(main)	500	657,120	2,155,040	656,799	2,155,423	Thai side
SAd6-RFR2	Ing-Yot No.2 tunnel Adit No.6(sub)	500	656,683	2,155,205	657,164	2,155,343	Thai side
SAd7-RFR1	Ing-Yot No.2 tunnel Adit No.7(main)	400	665,400	2,146,650	665,702	2,146,389	Thai side
SAd7-RFR2	Ing-Yot No.2 tunnel Adit No.7(sub)	500	665,494	2,146,857	665,390	2,146,367	Thai side
SB49-RFR1	Ing-Yot No.2 tunnel outlet(main)	800	668,810	2,145,250	669,308	2,144,624	Thai side
SB49-RFR2	Ing-Yot No.2 tunnel outlet(sub)	600	669,230	2,145,203	668,738	2,144,858	Thai side

* Line name SKIT-2 corresponds to SKI-1/2RR as line name of tunnel survey line

Table11.2.1.(2)-4 List of Survey Lines for Seismic Refraction Prospecting (2)

Line name	Location	Length (m)	Coord. of Starting Point		Coord. of Ending Point		Performed by
			X-coord.	Y-coord.	X-coord.	Y-coord.	
SKI-B20(Main)	Kok- Ing tunnel south route(main)	1,035	-----	-----	-----	-----	Thai side
SKI-B20(Sub)	Kok- Ing tunnel south route(sub)	345	-----	-----	-----	-----	Thai side
SB0(Main)	Ing-Yot No.1 tunnel (main)	990	-----	-----	-----	-----	Thai side
SB0(Sub)	Ing-Yot No.1 tunnel (sub)	495	-----	-----	-----	-----	Thai side
NY-A	Yao dam - dam axis	440	-----	-----	-----	-----	Thai side
NY-B	Yao dam - left saddle	220	-----	-----	-----	-----	Thai side
NY-C	Yao dam - cross section toward dam axis	385	-----	-----	-----	-----	Thai side
Total	38 lines	29,485					

Table11.2.1.(2)-5 List of Survey Lines for Seismic Reflection Prospecting

Line Name	Location	Length	Coord. of Starting Point		Coord. of Ending Point		Performed
		(m)	X-coord.	Y-coord.	X-coord.	Y-coord.	by
SKIT1-RFL1	Kok-Ing No.1 tunnel (along the road)	1,200	602,855	2,197,965	602,190	2,197,155	Thai side
SKIT2-RFL1	Kok-Ing No.2 tunnel (center part of alignment)	1,000	612,955	2,188,865	612,030	2,189,195	Thai side
SB0(Main)	Ing-Yot No.2 tunnel, between inlet and adit No.1	4,500	637,475	2,175,615	642,000	2,176,000	Thai side
SB0(Sub)	Ing-Yot No.2 tunnel, near adit No.1	900	641,450	2,176,300	641,820	2,175,500	Thai side
S2B0(Main)	Ing-Yot No.2 tunnel, near inlet	1,600	636,650	2,174,830	638,000	2,175,652	Thai side
S2B0(Sub)	Ing-Yot No.2 tunnel, near inlet	900	637,845	2,175,165	637,130	2,175,525	Thai side
S2B0-RFL1	Ing-Yot No.2 tunnel, between inlet and adit No.1	1,100	639,095	2,175,520	638,055	2,175,935	Thai side
S2B0-RFL2	Ing-Yot No.2 tunnel, between inlet and adit No.1	800	639,555	2,175,330	639,095	2,176,205	Thai side
SB8-RFL1	Ing-Yot No.2 tunnel, between adit No.1 and No.2	900	642,320	2,175,490	642,450	2,176,475	Thai side
SB10(Ext)	Ing-Yot No.2 tunnel, between adit No.1 and No.2	500	645,050	2,174,950	645,550	2,174,800	Thai side
SB10(W)	Ing-Yot No.2 tunnel, between adit No.1 and No.2	600	644,530	2,174,830	644,550	2,175,450	Thai side
SB10(E.E)	Ing-Yot No.2 tunnel, between adit No.1 and No.2	900	645,050	2,174,700	645,360	2,175,550	Thai side
SAd2-RFL2	Ing-Yot No.2 tunnel, adit No.2 (along the road)	1,300	644,895	2,172,965	645,230	2,174,020	Thai side
SB16(Main)	Ing-Yot No.2 tunnel, between adit No.2 and No.3	1,000	649,195	2,171,525	648,495	2,172,255	Thai side
SB16(Sub)	Ing-Yot No.2 tunnel, between adit No.2 and No.3	900	648,745	2,171,125	649,095	2,172,065	Thai side
SAd3-RFL1	Ing-Yot No.2 tunnel, adit No.3 (along the road)	900	647,695	2,169,515	648,250	2,170,205	Thai side
SB17(Main)	Ing-Yot No.2 tunnel, near adit No.3	1,000	649,035	2,170,305	650,045	2,170,150	Thai side
SB17(Sub)	Ing-Yot No.2 tunnel, near adit No.3	700	649,425	2,169,960	649,665	2,170,435	Thai side
SB21(Main)	Ing-Yot No.2 tunnel, between adit No.3 and No.4	1,100	649,415	2,167,055	650,515	2,166,815	Thai side
SB21(Sub)	Ing-Yot No.2 tunnel, between adit No.3 and No.4	700	650,125	2,166,470	650,350	2,167,245	Thai side
SB35(Main)	Ing-Yot No.2 tunnel, adit No.6	2,000	657,335	2,155,665	658,740	2,154,255	Thai side
SB35(Sub)	Ing-Yot No.2 tunnel, adit No.6	800	657,320	2,155,065	658,290	2,155,325	Thai side
SAd7-RFL1	Ing-Yot No.2 tunnel, adit No.7 (along the road)	1,600	665,905	2,145,250	665,535	2,146,670	Thai side
SB46(Main)	Ing-Yot No.2 tunnel, near adit No.7	900	665,335	2,147,255	665,505	2,148,045	Thai side
SB48(Main)	Ing-Yot No.2 tunnel, near outlet	1,100	668,445	2,145,625	667,730	2,146,350	Thai side
SB48(Sub)	Ing-Yot No.2 tunnel, near outlet	800	668,425	2,145,960	668,065	2,145,455	Thai side
SB49-RFL1	Ing-Yot No.2 tunnel, outlet	1,500	668,485	2,144,670	668,525	2,145,905	Thai side
Total	27 lines	31,200					

* Survey line length is described on the basis of "Seismic Reflection Survey Report, Volume 2, Seismic Velocity Contour Interpretation".

Report, Volume 2, Seismic Velocity Contour Interpretation".

* Survey line length by location map on the above report are as follows, S2B0-RFL1 : 1,000 m, SB16 (Main) : 900 m, SB21 (Sub) : 800 m
* The whole line of SB0 (Main), S2B0 (Main), SB10 (Ext) and SB35 (Main) line are located on tunnel alignment.

SB48 (Main) line is located in parallel towards tunnel alignment.

Table 11.2.1.(2)-6 List of Survey Lines for Electromagnetic Prospecting Survey

Site No. / TDEM line		Coordinates (A) - Start point of line -			Coordinates(B) - End point of line -			Line length	No. points
		Easting	Northing	(EL.m)	Easting	Northing	(EL.m)	(km)	(Nos.)
TEM	TMB3.0	610,735	2,191,989	573	613,190	2,190,567	537	2.9	146
	TMB3.9	638,039	2,175,421	481	639,425	2,175,622	497	1.4	71
	TMB8.1	642,300	2,175,900	491	642,681	2,175,777	500	0.4	21(6)
	TMB11a	644,967	2,174,972	468	645,573	2,174,176	501	1.0	51
	TMB11b	645,752	2,174,252	523	645,274	2,174,103	482	0.5	26
	TMB11c	645,126	2,174,515	490	645,332	2,174,244	541	0.34	18(18)
	TMB11d	645,419	2,174,625	564	645,601	2,174,387	509	0.3	16
	TMB11e	645,569	2,174,676	621	645,751	2,174,438	541	0.3	16
	TMB46.0	665,270	2,147,150	465	665,877	2,146,355	425	1.0	51
	KOK-ING B	point sounding							15
							sub-total	8.14	455
TDEM	TDEMB29.4	653,231	2,160,066	935	654,126	2,159,719	1292	1.0	21
	TDEMB30.0	654,005	2,158,937	950	654,741	2,157,190	640	2.4	49
	TDEMB35.0	657,600	2,155,400	581	659,061	2,154,035	801	2.0	41
							sub-total	5.4	111
							total	13.54	566

Analysis of Geological Condition

The results of drilling investigation are compiled in the following tables.

< Drilling investigation >

Table 11.2.2-1, Table 11.2.2-2..... Summary of drilling results (classification of geological condition of each borehole)

Table 11.2.2-3, Table 11.2.2-4..... Summary of drilling results (classification of rock mass class of each borehole)

The results of in-situ test performed by use of drilling hole are compiled in the following tables. Furthermore, for easy use and understanding, the following correlative figures are also presented.

< Standard penetration test >

Table 11.2.2-5 to Table 11.2.2-11.....Results of standard penetration test

Figure 11.2.2-1.....Relationship between depth and N-value (Kok intake)

Figure 11.2.2-2.....Relationship between depth and N-value (Kok-Ing water diversion canal between Kok intake and No.1 tunnel)

Figure 11.2.2-3.....Relationship between depth and N-value (Kok-Ing water diversion canal between No.1 tunnel and No.2 tunnel)

Figure 11.2.2-4.....Relationship between depth and N-value (Kok-Ing water diversion canal between No.2 tunnel and Ing-weir)

Figure 11.2.2-5.....Relationship between depth and N-value (Ing weir)

< Lugeon test >

Table 11.2.2-12 to Table 11.2.2-15.....Results of Lugeon test
Table 11.2.16... ....Results of M.H.T. (multi hydraulic tester)
Figure 11.2.2-6.....Relationship between depth and Lugeon value (Kok-Ing tunnel etc.)
Figure 11.2.2-7.....Relationship between depth and Lugeon value (Ing-Yot No.2 tunnel)
Figure 11.2.2-8.....Relationship between depth (EL.m) and Lugeon value (Kok-Ing tunnel etc.)
Figure 11.2.2-9.....Relationship between depth (EL.m) and Lugeon value (Ing-Yot No.2 tunnel)

< Geophysical logging test >

Table 11.2.2-17, Table 11.2.2-18.....Results of geophysical logging of each borehole
Table 11.2.2-19.....Summary of Vp (P-wave velocity) data by full waveform sonic logging
Table 11.2.2-20.....Summary of Vs (S-wave velocity) data by full waveform sonic logging
Table 11.2.2-21.....Summary of resistivity (short normal) data by electric logging
Table 11.2.2-22.....Summary of resistivity (long normal) data by electric logging
Figure 11.2.2-10....Histogram for Vp (P-wave velocity) data of each borehole
Figure 11.2.2-11.....Histogram for Vs (S-wave velocity) data of each borehole
Figure 11.2.2-12.....Histogram for resistivity (short normal) data of each borehole
Figure 11.2.2-13.....Histogram for resistivity (long normal) data of each borehole

The results of laboratory test performed by use of drilling core are compiled in the following tables. Furthermore, for easy use and understanding, the following correlative figures are also presented.

< Laboratory test >

Table 11.2.2-23, Table 11.2.2-24.....Results of laboratory test
Table 11.2.2-25, Table 11.2.2-26.....Correlation of results between rock test and in-situ test
Table 11.2.2-27, Table 11.2.2-28.....Correlation of P-wave velocity by different measurement method
Figure 11.2.2-14.....Relationship between Unit weight and uniaxial compressive strength
Figure 11.2.2-15.....Relationship between Vp (ultrasonic velocity) and uniaxial compressive strength
Figure 11.2.2-16.....Relationship between Vp and Vs (ultrasonic velocity)
Figure 11.2.2-17.....Relationship between Vp (ultrasonic velocity) and Vp (sonic logging)

The results of seismic survey, which is classified as refraction prospecting survey and reflection prospecting survey, are compiled in the following tables.

< Seismic survey >

Table 11.2.2-29, Table 11.2.2-30.....Results of refraction prospecting survey (P-wave velocity)
Table 11.2.2-31, Table 11.2.2-32.....Results of refraction prospecting survey (thickness of velocity layer)
Table 11.2.2-33.....Results of reflection prospecting survey (P-wave velocity)
Table 11.2.2-34, Table 11.2.2-35... ...Results of reflection prospecting survey (characteristics of analyzed section)

The results of drilling investigation and in-situ test (Lugeon test and permeability test) at the Yao flood control dam are compiled in the following tables and figures. The results of geological investigation (test pitting and augerhole drilling) at the proposed borrow area are also compiled in the following tables. Furthermore, the results of soil test including the grain size accumulation curve of soil materials are shown hereinafter.

< *Yao flood control dam* >

Table 11.2.2-37 to Table 11.2.2-38.....Summary of drilling results at the Yao flood control dam

Table 11.2.2-39 to Table 11.2.2-40.....Results of Lugeon test at the Yao flood control dam

Table 11.2.2-41.....Results of test pitting and augerhole drilling at the proposed borrow area

Table 11.2.2-42.....Results of soil test at the proposed borrow area

Figure 11.2.2-18....Relationship between depth and Lugeon value at the Yao flood control dam

Figure 11.2.2-19....Grain size accumulation curve of soil materials at the borrow area

The results of water quality analysis are compiled in the following tables and figures.

< *Water quality analysis* >

Table 11.2.2-43.....Results of water quality analysis

Figure 11.2.2-20....Stiff diagram of water quality

< *Appendix* >

1. Results of full waveform sonic logging (original data).....Table 11.2.2-A1 to Table 11.2.2-A13
2. Results of geophysical logging (original data).....Table 11.2.2-A14 to Table 11.2.2-A24

Geological Investigation Performed by JICA

Geological investigations performed by JICA are composed of the deep drilling with the depth of more than 200 m. and electromagnetic prospecting survey (TEM and TDEM method) located near the tunnel elevation in the areas which are covered by overburden of about 500 to 1,000 m in thickness, in the high mountainous areas of the Ing-Yot No.2 tunnel.

(1) Deep Core Drilling Investigation Performed by JICA

Following results of the Conceptual Planning Study completed in March of 1997, the deep core drilling investigation became necessary to obtain information to complete the design of the tunnel and related facilities, particularly along the mountainous part of the Ing-Yot No.2 tunnel route. The objectives of this survey are to obtain deep geologic information on lithological features, geologic structure and hydraulic characteristics. The technical means to achieve this purpose are as follows.

- Coring
- Lugeon Test
- Water-pressure test
- Geophysical logging
- Laboratory test by drilling core

In total seven boreholes, with a total hole depth of 1,450 m, were drilled near the proposed tunnel alignment, as shown below and in Figure 11.2.3-1.

Site No. / Boring hole		Coordinates		Elevation (1/10,000 map)	Level of Tunnel	Drilling Depth	In-situ Testing Section (depth) (Sonic logging)	
		Easting	Northing	(EL.m)	(EL.m)	(m)	from (m)	to (m)
Site 1	DHBJ-4.5	613,120	2,190,640	525	375	165	100	153
Site 2	DHBJ-16.5	648,958	2,171,465	530	345	200	11	199
Site 3	DHBJ-18.0	649,375	2,170,200	535	345	205	78	201
Site 4	DHBJ-22.5	650,000	2,166,900	545	345	220	25	220
Site 5	DHBJ-26.0	651,224	2,160,524	620	342	300	38	300
Site 6	DHBJ-33.0	654,850	2,157,250	635	340	310	19	301
Site 7	DHB-EXTRA7	610,400	2,189,800	480	375	50	---	---

(a) Drilling Works

Core drilling of the six bore holes was carried out utilizing a medium-hard application bit rotated by hydraulic rotary drilling rigs; the Acker mark III, JKS BOYLES and a LONGYEAR 38. These drilling systems are capable of boring to depths of over 375 m with an HQ wireline system.

PQ-size (122.6 mm in diameter) or HQ-size (96 mm in diameter) wireline coring, with 1.5 to 3 m long double core barrels and a wireline diamond impregnated bit, was performed in the rock formations. As a flushing media, a polymer slurry, which provided the necessary lubrication and transport of cuttings from the drilling depth, was properly employed in fracture zones.

(b) Lugeon test

Lugeon tests, using an air packer configuration, were carried out after drilling over select intervals in the cored boreholes. Due to the great depth, the pneumatic packers were inflated with bottled nitrogen or water hand pumped at pressures ranging from 15 to 40 bar. The test sections generally had a length of five meters. Each test consists of six increasing pressure stages and five decreasing pressure stages (0.5 - 2.0 - 4.0 - 6.0 - 8.0 - 10.0 - 8.0 - 6.0 - 4.0 - 2.0 - 0.5 kgf/cm^2).

(c) Water pressure measurements

Water pressure measurements were carried out near the tunnel section and were conducted at the same depth interval as that of the Lugeon test. The measurements were achieved by installing the pressure logger at a depth of less than 30 m below the groundwater level. The measurements of water pressure in each hole during each time interval was conducted for about 12 hours or until the water level in the hole recovered to the existing level.

(d) Geophysical Logging

Geophysical logging was conducted immediately after completion of drilling so that the sonde could be set in the borehole before any collapse could take place. The geophysical logging performed are as follows.

- Caliper logging (RG PRO LOGGER by Robertson Geologging Limited)
- Natural gamma logging (GEOLOGGER-3030 MARK-2 by OYO corporation)
- Electric logging (GEOLOGGER-3030 MARK-2 by OYO corporation)
- Spontaneous potential logging (GEOLOGGER-3030 MARK-2 by OYO corporation)
- Full wave sonic logging (RG PRO LOGGER by Robertson Geologging Limited)

Caliper logging

A single arm is activated for upward logging runs and provides an accurate measurement of borehole diameter as well as side-walling the sonde.

Natural gamma logging

An unconsolidated sodium lodide crystal, coupled to a photo-multiplier, is used to measure natural radioactivity. An active caliper is used to relate the detectors response to the standard unit.

Electric logging (Resistivity logging)

The resultant potential between the 16"/64" electrode (short normal and long normal) and remote bridle electrode is used via Ohm's law correction for a geometric factor to provide resistivity.

Spontaneous potential (SP) logging

The spontaneous potential (SP) logging is a record of the electrical potential developed between the borehole fluid and the surrounding formation

Full waveform sonic logging

The fully compensated sonic sonde provides the average formation velocity / transit time from which porosity, rock strength and lithology determinations can be made.

(e) Laboratory Test

With the aim of clarifying the physical, dynamic and petrologic property of rock bodies which form the tunnel section, laboratory tests were carried out on rock samples taken from drill holes. The tests and their standard designation are as follows.

Type of Laboratory Test	Items of Testing	Reference to:
Test for physical property	Specific gravity and absorption test	ASTM C127
Test for dynamic property	Unconfined compression test	ASTM D2938
	Point load test	-
	Tensile strength	ASTM D 2936
	Ultrasonic velocity	ASTM D 2845
Test for petrologic property	Petrologic observation by optical microscope	-
	X-ray diffraction analysis	-

(f) Results of drilling works

Results of the drilling works were presented in the "Report of Exploratory Core Drilling JICA Feasibility Study". This report is divided into five volumes, containing the following main report and appendix 1 to 4.

- Main report
- Appendix I (Geologic log of drill holes, Lugeon test)
- Appendix II (Geophysical logging and laboratory test)
- Appendix III (Photograph of core box)
- Appendix IV (Summary data of geological logging in-situ and geophysical logging)

(2) Electromagnetic Prospecting Survey

(a) Purpose of Geophysical Survey

As a result of the Conceptual Plan Study, completed in March 1997, the Tem and TDEM method was found to be more adequate than the other methods considered, seismic prospecting and resistivity prospecting, particularly along the deep tunnel horizon planned beneath a rugged mountain area. Furthermore, this study requires that the TEM and TDEM survey be used to solve the following engineering problems:

(1) Mapping of the base of the basalt formation in the Kok-Ing No.2 tunnel

(2) Confirmation of zones of fractured and faulted formation near the tunnel elevation

(3) Confirmation of both geological structure and location of fissure and fault zones near the Phu Sang waterfall spring

(4) Mapping of the base of the limestone (TRpl, Pa Lae formation)

(5) Determination of the geological structure near the tunnel elevation in areas covered by overburden of about 500 to 1000 m thick in the high mountain areas of the Ing-Yot No.2 tunnel

To obtain information capable of solving the problems listed above, two types of measurement configurations were utilized. These correspond to the shallow transient electromagnetic soundings (TEM) and long offset measurements (TDEM). Two systems, PROTEM 47 and 57, were employed for the TEM survey for determination of shallower sections using a loop source as mentioned in (1), (2) and (3), and TDEM system was applied for resolution of the deeper sections in (4) and (5).

The survey objectives for each line are given in following table.

Site No. / Line name		Line length (km)	No. points (Nos)	Applied method	Survey objectives and Geologic information to be surveyed *1
TEM	TMB 3.0	2.9	146	PROTEM47	(2) fault / PTRgr (granite) / P3 (s.s.&shale)
	TMB 3.9	1.4	71	PROTEM47	(2) fault / TRhf (s.s.&tuff) / CPhk (meta-s.s.)
	TMB 8.1	0.4	21	PROTEM57	(2) fault / CPhk (meta-s.s.) / CPnb(slate)
	TMB 11.0 a	1.0	51	PROTEM57	(3) fault, fissure / CPhk(meta-s.s.)
	TMB 11.0 b	0.5	26	PROTEM57	(3) fault, fissure / CPhk(meta-s.s.)
	TMB 11.0 c	0.34	18	PROTEM57	(3) fault, fissure / CPhk (meta-s.s.)
	TMB 11.0 d	0.30	16	PROTEM57	(3) fault, fissure / CPhk (meta-s.s.)
	TMB 11.0 e	0.30	16	PROTEM57	(3) fault, fissure / CPhk (meta-s.s.)
	TMB 46.0	1.0	51	PROTEM47	(2),(4) fault / limestone / TRhf (s.s.&tuff)
	KOK-ING B	-	15 *2	PROTEM57	(1) fault / basalt / P3 (s.s.&shale)
TDEM	TDEMB 29.4	1.0	21	TDEM	(4) fault / TRpl (limestone)
	TDEMB 30.0	2.4	49	TDEM	(5) fault / TRhf (s.s.&shale)
	TDEMB 35.0	2.0	41	TDEM	(5) fault / TRhf (s.s.&shale)

NOTE *1 : ( ) refer to above paragraph.

2 : Kok-Ing B line is performed by point sounding.

During the course of this study 455 shallow transient electromagnetic (TEM) soundings in total were performed and total 111 deep, long offset (TDEM) measurements were made. Furthermore, the field investigation works and analysis/studying as for these were performed from January to March, 1998 and from October to December, 1998, respectively, by JICA survey team.

(b) The Transient Electromagnetic Method

The transient, or time-domain, electromagnetic method, often referred to as TEM or TDEM, is a method in which the ground is energized by an induced magnetic field and the response is measured as a function of time to determine the resistivity of the earth beneath the observation point as a function of depth.

In this method, a steady current is passed through a loop of wire placed on the surface of the earth (TEM), which is inductively linked to the earth or is driven into the earth through buried plate electrodes (TDEM). The fact that loop sources, which have no direct contact with the earth can be used, makes this method suitable in areas where high surface resistivity prohibit the use of conventional direct current methods. This would include regions covered by desert, sand dunes or extrusive volcanic.

In practice, the direct loop current is abruptly interrupted and the secondary field, which arises due to eddy currents induced in the earth, can be measured in the absence of the primary field. The eddy currents migrate from the transmitter loop into the earth and the pattern resembles the propagation of a 'smoke ring'. Figure 11.2.3-2 shows the TEM survey configuration and transient curves. The rate of change of the magnetic field depends upon the underground resistivity structure. Given a poorly conductive medium, the receiver coil output voltage, which is proportional to the time rate of change of the secondary magnetic field, is initially large but decays rapidly. The response of a good conductor is initially lower but the voltage decays slowly. Figure 11.2.3-3 shows these conditions. The time derivative of the transient magnetic field, which results from these currents, can be measured by a coil sensor.

The decay of the secondary field measured at the surface can be analyzed to determine the resistivity of the earth at the target depth. The resistivity of geological materials is highly dependent upon porosity, saturation, and pore fluid resistivity. Resistivity sounding, therefore, yields information about water content and quality, and TEM resistivity measurement is a valuable structural mapping tool for groundwater study.

The TEM method was selected for this survey for the following reasons; (1) stability of the transmitter signal, (2) lack of static shift, (3) no near field phenomena, (4) uniqueness of the results, (5) high production rate and (6) suitability of the ungrounded source in rock desert.

The TDEM method was employed for the following reasons; (1) stability of the transmitter signal, (2) lack of static shift, (3) no near field phenomena, (4) uniqueness of the results, (5) high production rate and (6) deep sounding capabilities.

(c) Equipment

TEM system

The primary components of the TEM system are a transmitter, a sensor coil and a receiver. Two transmitters, an EM-47 and an EM-57, were used in this survey. The EM-47 is a battery-powered transmitter which is capable of operating at high frequencies. It can be used to resolve shallow resistive units such as surface dune sands and dry alluvium. It is a low power transmitter, however, and has a limited depth of penetration. The EM-57 operates at lower frequencies and is powered by a gasoline motor generator providing a higher output current, leading to a greater depth of penetration. By combining measurements made from both sources, both the shallow and deep sections can be adequately resolved.

A responsive high frequency receiver coil with an effective area of 31.4 m^2 and an internal signal preamplifier was used for EM-47 measurement and a more sensitive low frequency coil with an area of 100 m^2 was used in the EM-57 measurement.

The receiver, a PROTEM 57 (C) unit, samples the coil response at a series of prescribed time intervals amount from each turn-off of the loop current. There are 20 geometrically spaced gates or channel positions in each time range. Decay voltages were recorded at two EM-47 transmitter base frequencies (uh-237.5 and h-25Hz) and at three EM-57 base frequencies (H-25, M-6.25 and L-2.5Hz) during the course of this survey. A reference cable is used to establish the precise timing between the transmitter and receiver.

TDEM system

The primary components of the TDEM system are a transmitter, a sensor coil and a receiver. The TDEM transmitter is powered by a 150KVA diesel powered generator which is capable of producing a 3 phase voltage of more than 440V at 50HZ. The 3 phase AC current is full-wave rectified creating a DC current of as much as 100A. In practice, however, the output current of the transmitter is limited by the combination of the electrode contact resistance, cable resistance and the resistance of the earth.

Electrodes were created by digging a total of twenty pits, about 1meter wide, 2 m long and 2 m deep separated by 1 m, nominally. A galvanized steel plate 1.5 by 2 m was placed crosswise into each hole with connecting wires attached to each corner of the plate. Each of the 20 electrodes was then connected to the current cable in parallel, to lower the net electrode impedance. Water was added to each pit before refilling them with soil to increase conductance. Three electrodes were created in the vicinity of Ban Pang Thum and were used in pairs, separated by about 3 and 4 km, to illuminate the various surveys lines. Finally, each of the electrode plates was dug up at the completion of the survey and the electrode areas were leveled to their original form.

The transmitter can be used to resolve the deep resistivity structure of the earth in areas where the tunnel bore is at great depth. It is a very high power transmitter (nearly 70KVA) and has a large depth of penetration. The current is switched on and off by a high speed transistor and the polarity of the current is reversed during "off" times by mechanical switches. The transmitter is controlled by a precise, highly stable crystal clock and the frequency of operation can be chosen in 1 second increments.

A responsive high frequency air core receiver coil with an effective area of 50 m^2 or a very sensitive low frequency coil with a magnetically permeable core and an area of 9,000 m^2 can be used with this system. The coil is connected to a signal preamplifier which has notch and low-pass filters for noise rejection prior to telemetry to the receiver.

The receiver contains filters, amplifiers and an offset potentiometer for signal conditioning and noise rejection and a crystal clock, which is synchronized with the transmitter clock at the beginning of each day to assure proper timing. When the current is turned off, the clock generates a trigger signal. This signal is sensed by a PC with a 16 bit A/D converter connected to the receiver and the analog coil voltage is then sampled at series of time intervals that are delayed by a prescribed amount from each turn-off of the loop current. There are 1024 linearly spaced gates or channel positions in each time range. The sampling frequency can be chosen by software control. A transmitter period of 8 seconds was used for this survey and decay voltages were recorded at a frequency of 4Khz for most sounding and at 2Khz in some areas which were more conductive.

The digital data is stored on the PC hard disk drive and backed up on floppy disk. At the end of each day the data was transfers to the hard disk of the office computer for processing and backed up on two magneto-optical disks.

(d) Measurement configuration

TEM

In this survey a square transmitter loop 100 m on a side was used to allow a high production rate while maintaining a high signal level and data quality. Measurements were made at a spacing of 20 m within the loop in areas of low response. On this half of the survey lines the loop was moved along the line at 100 m intervals. On the other half of the survey lines, measurements were made at 5 stations inside the loop and at two stations outside of the loop, up to 80m from the center of the loop. On these lines, the loop was moved 180 m at a time. The loop was typically energized with a current of two to three amperes for high frequency EM-47 measurements and a current of about fifteen amperes for lower frequency EM-57 soundings.