CAUCA RIVER REGULATION PROJECT

REPUBLIC OF COLOMBIA

FEASIBILITY REPORT

VOLUME II
APPENDIX

MARCH 1970

prepared for

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN
by
ELECTRIC POWER DEVELOPMENT CO., LTD.

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CONTENTS

UNITS AND CONVERSIONS

mm	millimeter	kg/sq.cm	kilogram per square centimeter
cm	centimeter	ton	metric ton
m	meter	m/sec	meter per second
km	kilometer	kW	kilowatt
sq.mm	square millimeter	MW	megawatt
sq.cm	square centimeter	kV	kilovolt
sq.m	square meter	kVA	kilovolt-ampere
sq.km	square kilometer	kWh	kilowatt-hour
ha	hectare	mill	U.S. mill
cu.m	cubic meter	US$	U.S. dollar
cu.m/s	cubic meter per second	PS	Colombian Peso
cu.m/s.day	cubic meter per second per day	p.p.m.	part per million
gr	gram	EL	the height above mean sea level
%	percent	°C	*centigrade*
rpm	revolutions per minute	Max.	maximum
kg	kilogram	Min.	minimum

1 m	39.37 inches	3.2808 feet
1 km	0.6214 mile	3,280.8 feet
1 n.m.	(1 nautical mile)	1,852 m
1 sq.m	1.196 sq.yards	10.764 sq.feet
1 sq.km	100 hectares	247.1 acres
1 ha	10,000 sq.m	2,471 acres
1 plaza	6,400 sq.m	
1 cu.m	1,000 liters	35.31 cu.feet
1 kg	2.2046 pounds	
1 ton	1,000 kilogram	2,204.6 pounds
1 *cu.ms*	35.31 *cu.ft/sec*	
°C	5/9 (°F–32°)	
1 US$	17.35 Colombian Pesos	
1PSI	0.07031 kg/sq.cm	

APPENDIX 1

HYDROLOGICAL AND METEOROLOGICAL DATA

APPENDIX 1 HYDROLOGICAL AND METEOROLOGICAL DATA

CONTENTS

1. Lista de Estaciones Hidrologicas

Lista de Estaciones Hidrologicas

No.	Estacion		Localizacion			Clase de Estacion			Periodo de registros
	Rio	Sitio	Long.	Lat.	Alt.	Limnigrafo	Limni-metro	Aforo	
1	Cauca	Salvajina	76°43'	2°57'	1,028.97	x(Oct. de 1946)		x	Agosto/46 hasta la fecha
2	Cauca	La Balsa	76°36'	3°06'	987.25	x(Nov. de 1960)		x	Agosto/45 hasta la fecha
3	Cauca	Tablanca	76°35'	3°08'	980.46		x		Junio/61 hasta la fecha
4	Cauca	La Bolsa	76°30'	3°12'	964.10		x	x	Marzo/55 hasta la fecha
5	Cauca	Hormiguero	76°29'	3°18'	955.55		x	x	Marzo/55 hasta la fecha
6	Cauca	Juanchito	76°29'	3°27'	949.07	x(Sep. de 1945)		x	Enero/34 hasta la fecha
7	Cauca	Puerto Issacs	76°29'	3°34'	944.90		x		Marzo/55 hasta la fecha
8	Cauca	Salento	76°28'	3°38'	943.08		x		Marzo/55 hasta la fecha
9	Cauca	Mediacanoa	76°21'	3°54'	933.66		x	x	Marzo/61 hasta la fecha
10	Cauca	Riofrio	76°16'	4°08'	924.15		x	x	Abril/55 hasta la fecha
11	Cauca	Pto. Pedrero	76°10'	4°19'	914.62		x		Septiembre/62 hasta la fecha
12	Cauca	Est. Bombas Roldanillo	76°08'	4°24'	911.50		x		Agosto/65 hasta la fecha
13	Cauca	Guayabal	76°06'	4°24'	911.77		x	x	Marzo/55 hasta la fecha
14	Cauca	La Victoria	76°03'	4°32'	907.41	x(Abr. de 1969)		x	Octubre/58 hasta la fecha
15	Cauca	Anacaro	75°58'	4°47'	901.98	x		x	Marzo/55 hasta la fecha
16	Cauca	La Virginia	75°53'	4°54'	889.00		x	x	Octubre/46 hasta la fecha
17	Ovejas	Abajo	76°36'	2°52'	1,263.10	x		x	Septiembre/64 hasta la fecha
18	Mondomo	Carretera Popayán-Cali	76°33'	2°53'	1,305.00		x	x	Julio/53 hasta la fecha
19	Palo	Arriba	76°21'	3°04'	1,060.00		x	x	Agosto/45 hasta la fecha
20	Cali	Bocatoma	76°34'	3°27'	1,055.00		x	x	Enero/36 hasta le fecha
21	Frayle	Buchitolo	76°21'	3°23'	980.80		x	x	Junio/61 hasta la fecha
22	Bolo	Arriba	76°18'	3°28'	978.00		x	x	Agosto/60 hasta la fecha
23	Timba	Timba	76°38'	3°07'	998.58		x	x	Agosto/46 hasta la fecha
24	Jamundi	Puente FF.CC.	76°33'	3°18'	966.58		x	x	Marzo/62 hasta la fecha
25	Claro	Potrerito	76°36'	3°15'	1,011.00	x		x	Enero/46 hasta la fecha
26	Pance	La Vorágine	76°36'	3°21'			x	x	Enero/62 hasta la fecha
27	Guadalajara	Arriba	76°16'	3°54'	1,070.00	x		x	Agosto/67 hasta la fecha
28	Tuluá	Mateguadua	76°10'	4°01'	1,115.00		x	x	Septiembre/45 hasta la fecha
29	La Vieja	Cartago	76°53'	4°06'	912.88	x		x	Agosto/45 hasta la fecha
30	Anchicayá	Las Playas	76°53'	3°33'	511.25	x		x	Marzo/67 hasta la fecha
31	Anchicayá	Murrapal	76°53'	3°34'	393.80	x		x	Enero/66 hasta Enero/69
32	Anchicayá	Danubio	76°54'	3°37'	200.11	x		x	Mayo/42 hasta Enero/69
33	Pichindé	Pichindé	76°37'	3°26'	1,540	x		x	Marzo/68 hasta Enero/69
34	La Teta		76°35'	3°03'	1,045	x		x	Jul/65 hasta Junio/69
35	Quinamayó		76°31'	3°02'	1,100	x	x	x	Agosto/65 hasta la fecha
36	Canal Interceptor	Navarro	76°28'	3°23'	955		x	x	Mayo/64 hasta la fecha
37	Palo	Puerto Tejada	76°26'	3°14'	966.47	x			Septiembre/45 hasta la fecha
38	Cañaveralejo		76°34'	3°25'	1,000	x		x	Noviembre/67 hasta la fecha
39	Cauca-San Francisco		76°40'	3°03'	1,010		x	x	Julio/68 hasta la fecha
40	Quebrada La Piscina	Anchicayá	76°55'	3°37'	250		x	x	Febrero/69 hasta la fecha
41	Bravo	Bocatoma	76°35'	3°56'	1,380	x		x	Diciembre/67 hasta la fecha
42	Guachal		76°28'	3°32'	955		x	x	Marzo/69 hasta la fecha
43	Cauca	Coconuco	76°30'	2°20'	2,200			x	Enero/56 hasta Junio/63

2. Lista de Estaciones Meteorologicas y Pluviometricas

Lista de Estaciones Meteorologicas y Pluviometricas

No.	Estacion	Localization			Clase de Estacion				Periodo de registros
		Long.	Lat.	Alt.	Principal	Corriente	Pluviografo	Pluviometro	
1	La Union Distrito de Riego	76° 03 W	4° 32 N	913 M	x				Febrero/67 hasta la fecha
2	Calima-Palermo	76° 33 W	3° 52 N	1,450 M	x	x			Agosto/65 hasta la fecha
3	Granja Las Gramas-Roldanillo	76° 05 W	4° 26 N	913 M		x			Octubre/65 hasta la fecha
4	Tierrablanca (Est.Bombas Roldanillo)	76° 06 W	4° 25 N	925 M		x			Junio/64 hasta la fecha
5	La Cayetana (Est. Bombas La Unión)	76° 03 W	4° 35 N	912 M		x			Junio/64 hasta la fecha
6	La Victoria (Casa San Pedro)	76° 03 W	4° 31 N	925 M		x			Julio/66 hasta la fecha
7	Zaragoza	75° 56 W	4° 43 N	940 M				x	Agosto/67 hasta Enero/69
8	Alto Anchicaya (Desembocadura Rio Verde)	76° 52 W	3° 32 N	630 M		x			Abril/67 hasta la fecha
9	Queremal	76° 44 W	3° 32 N	1,460 M		x			Junio/66 hasta la fecha
10	Tulua	76° 11 W	4° 04 N	1,025 M		x	x	x	Febrero/67 hasta la fecha
11	Aguablanca (Navarro)	76° 29 W	3° 26 N	980 M			x		Junio/64 hasta la fecha
12	Anchicaya-Danubio	76° 56 W	3° 38 N	400 M			x	x	Noviembre/42 hasta la fecha
13	Anchicaya-Murrapal (Guadualito)	76° 54 W	3° 35 N				x	x	Enero/66 hasta la fecha
14	Rio Verde	76° 48 W	3° 28 N	1,050 M			x		Abril/65 hasta la fecha
15	Colegio San Luis Gonzaga	76° 33 W	3° 27 N	1,066 M			x		Febrero/35 hasta la fecha
16	Instituto Salesiano	76° 33 W	3° 27 N	995 M			x		Abril/60 hasta la fecha
17	Planta Rio Cauca	76° 30 W	3° 27 N	962 M			x		Marzo/60 hasta la fecha
18	Planta Rio Cali	76° 33 W	3° 27 N	1,080 M			x		Octubre/53 hasta la fecha
19	La Leonera	76° 38 W	3° 27 N	1,800 M			x		Octubre/53 hasta la fecha
20	El Silencio	76° 42 W	3° 24 N	1,750 M			x		Octubre/53 hasta la fecha
21	Yanaconas	76° 36 W	3° 25 N	1,600 M			x		Octubre/53 hasta la fecha
22	La Balsa	76° 37 W	3° 07 N	970 M		x		x	Junio/68 hasta la fecha
23	Brasilia	76° 38 W	3° 26 N	1,800 M		x		x	Mayo/65 hasta la fecha
24	La Cascada-Anchicaya	76° 53 W	3° 36 N	320 M				x	Febrero/66 hasta la fecha
25	Bolívar	76° 12 W	4° 21 N	970 M				x	Abril/61 hasta la fecha
26	Pance Corea	76° 41 W	3° 22 N	2,580 M				x	Diciembre/64 hasta la fecha
27	Pance Topacio	76° 39 W	3° 18 N	2,300 M			x	x	Diciembre/64 hasta la fecha
28	La Teresita	76° 41 W	3° 25 N	2,200 M				x	Diciembre/66 hasta la fecha
29	Ca Colonia	76° 42 W	3° 27 N	2,040 M				x	Enero/65 hasta la fecha
30	La Floresta	76° 49 W	3° 22 N	685 M				x	Diciembre/64 hasta la fecha
31	La Fonda (Villa Carmelo)	76° 36 W	3° 23 N	1,400 M				x	Diciembre/64 hasta la fecha
32	La Margarita	76° 38 W	3° 26 N	2,040 M				x	Enero/65 hasta la fecha
33	Penas Blancas	76° 41 W	3° 23 N	3,200 M			x	x	Abril/65 hasta la fecha
34	San Emigdio	76° 31 W	3° 31 N	1,400 M				x	Diciembre/64 hasta la fecha
35	Rio Bravo	76° 35 W	3° 56 N	1,520 M				x	Abril/66 hasta la fecha
36	La Palmera	76° 30 W	4° 03 N	2,130 M				x	Abril/66 hasta la fecha
37	Lituania	76° 28 W	4° 04 N	1,870 M				x	Abril/66 hasta la fecha
38	La Morena	76° 28 W	4° 02 N	1,630 M				x	Abril/66 hasta la fecha
39	Hacienda El Cenit	76° 26 W	3° 16 N	980 M				x	Octubre/66 hasta la fecha
40	Yunde-Carrizal	76° 25 W	3° 28 N	1,000 M				x	Octubre/66 hasta la fecha
41	Toro (Hacienda Vesubio)	76° 07 W	4° 37 N	990 M				x	Julio/67 hasta la fecha
42	La Union-El Porvenir	76° 07 W	4° 33 N	1,020 M				x	Julio/67 hasta la fecha
43	El Higueroncito	76° 98 W	4° 28 N	980 M				x	Julio/67 hasta la fecha
44	El Higueron	76° 09 W	4° 27 N	980 M				x	Julio/67 hasta la fecha
45	Miravalle	75° 57 W	4° 31 N	1,030 M				x	Agosto/67 hasta la fecha
46	Obando	76° 58 W	4° 36 N	960 M				x	Agosto/67 hasta la fecha
47	Puerto Molina	76° 01 W	4° 38 N	970 M				x	Agosto/67 hasta la fecha
48	Cruces (Hacienda Vizcaya)	75° 55 W	4° 40 N	970 M				x	Agosto/67 hasta la fecha
49	Cartago-Santa Ana (Aeropuerto)	75° 56 W	4° 46 N	930 M				x	Agosto/67 hasta la fecha
50	Rozo	76° 21 W	3° 32 N	980 M				x	Septiembre/67 hasta la fecha
51	Salvajina	76° 43 W	2° 56 N	1,100 M				x	Noviembre/64 hasta la fecha
52	La Manuelita	76° 17 W	3° 35 N	1,030 M	x				Enero/32 hasta la fecha
53	Granja Experimental - Palmira	76° 20 W	3° 30 N	1,006 M	x				Enero/45 hasta la fecha
54	La Virginia	75° 54 W	4° 54 N	950 M				x	Enero/52 hasta la fecha
55	Meléndez	76° 32 W	3° 23 N	990 M	x				Diciembre/65 hasta la fecha
56	La Teta	76° 36 W	3° 02 N	1,100 M			x	x	Octubre/68 hasta Mayo/69
57	Villarica	76° 27 W	3° 11 N	970 M				x	Octubre/66 hasta la fecha
58	Caloto	76° 24 W	3° 02 N	1,125 M				x	Octubre/66 hasta la fecha
59	San Julian	76° 31 W	3° 07 N					x	Octubre/66 hasta la fecha
60	Guachene	76° 24 W	3° 08 N	1,050 M				x	Octubre/66 hasta la fecha
61	Ingenio del Cauca	76° 21 W	3° 16 N	980 M		x			Enero/65
62	Jamundi Puente Velez	76° 38 W	3° 13 N	1,170 M			x		Octubre/68 hasta la fecha
63	La Magdalena - Buga	76° 11 W	3° 52 N				x		Diciembre/68 hasta la fecha
64	Capaveralejo	76° 34 W	3° 25 N	1,150 M			x		Febrero/68 hasta la fecha
65	El Vinculo	76° 17 W	3° 52 N	1,030 M	x				Febrero/69 hasta la fecha
66	El Descanso	76° 35 W	3° 24 N	1,230 M				x	Febrero/69 hasta la fecha
67	El Faro	76° 36 W	3° 25 N	1,630 M				x	Enero/69 hasta la fecha
68	Las Brisas	76° 36 W	3° 25 N	1,260 M				x	Febrero/69 hasta la fecha
69	Los Cristales	76° 35 W	3° 25 N	1,350 M				x	Febrero/69 hasta la fecha
Estaciones de Electraguas:									
	Coconuco	76° 26 W	2° 20 N	2,300 M				x	Noviembre/46 hasta la fecha
	Piendamo	76° 31 W	2° 37 N	1,800 M				x	Diciembre/46 hasta la fecha
	Purace	76° 28 W	2° 27 N	2,646 M				x	Abril/59 hasta la fecha
	Popayan	76° 36 W	2° 27 N	1,790 M				x	Noviembre/52 hasta la fecha
	Silvia	76° 22 W	2° 37 N	2,400 M				x	Noviembre/46 hasta la fecha

3. Monthly Average Discharge of Cauca River

Gauging Station		Catchment Area (sq. km)	Recording Period
(1)	Salvajina	3,830	Oct. 1946-Sep. 1968
(2)	La Balsa	5,480	Oct. 1946-Sep. 1968
(3)	Juanchito	9,060	Oct. 1946-Sep. 1968
(4)	Mediacanoa	12,760	Oct. 1966-Apr. 1968
(5)	Riofrio	14,800	Oct. 1959-Sep. 1968
(6)	La Victoria	17,650	Oct. 1959-Sep. 1968
(7)	Anacaro	18,000	Nov. 1963-Apr. 1968
(8)	La Virginia	22,440	Oct. 1947-Mar. 1968

(1) Gauging Station Salvajina — Catchment Area (sq. km) 3,830

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	100.5	217.7	197.8	164.9	107.4	122.9	125.5	144.5	88.9	62.1	83.8	38.3	121.2
1947	51.6	121.1	144.0	128.7	106.3	74.6	61.0	72.6	94.6	94.1	77.1	73.6	91.6
1948	211.5	254.8	139.8	94.5	77.2	143.9	201.3	134.9	117.3	72.0	59.8	38.6	128.8
1949	92.6	135.1	122.9	149.1	150.6	119.6	126.5	160.1	120.9	98.0	78.8	63.5	118.1
1950	122.4	287.9	255.8	196.6	378.7	372.6	317.2	374.8	293.5	201.8	128.9	79.7	250.8
1951	126.7	268.7	335.6	224.3	207.8	184.1	130.0	145.0	124.9	118.5	72.9	65.2	167.0
1952	90.2	201.6	199.8	163.0	159.4	124.7	124.6	172.9	116.2	92.2	71.7	49.8	130.5
1953	62.2	147.0	240.9	150.8	124.8	100.0	126.9	127.9	106.1	81.6	59.1	54.2	115.1
1954	159.8	284.1	332.3	153.5	143.2	125.2	219.6	144.2	124.2	135.3	118.4	52.0	166.0
1955	164.3	257.3	343.6	233.6	122.4	210.3	213.8	193.2	164.8	147.3	92.7	84.2	185.6
1956	181.1	259.8	340.0	310.5	205.5	172.2	121.4	147.6	200.2	117.8	98.3	89.4	187.0
1957	168.0	187.1	238.5	183.5	95.7	130.9	136.1	195.6	164.9	90.4	63.6	46.2	141.7
1958	64.5	103.6	182.0	112.4	85.5	67.8	94.2	108.7	91.3	76.4	71.3	41.6	91.6
1959	56.2	133.2	160.7	138.9	83.7	62.9	77.5	119.6	127.8	104.7	59.3	52.1	98.0
1960	87.9	128.7	175.8	240.5	193.1	120.7	129.5	119.5	86.9	88.2	64.7	51.5	123.9
1961	80.1	172.6	229.5	111.1	90.9	77.7	141.8	88.8	119.1	101.2	71.7	41.9	110.4
1962	62.3	205.6	149.1	118.1	129.6	145.8	108.9	147.0	161.6	87.6	74.1	53.1	120.2
1963	94.2	161.7	267.3	121.1	218.4	152.4	227.7	209.3	132.1	93.9	82.2	49.4	150.8
1964	59.7	213.1	153.0	130.3	92.1	69.5	142.1	140.6	191.3	117.0	97.6	87.6	124.5
1965	120.8	189.5	226.3	162.5	106.0	77.7	126.5	141.6	74.1	77.4	55.4	45.0	116.9
1966	95.1	207.9	239.7	127.6	76.6	80.5	89.1	129.8	108.4	103.1	76.2	59.3	116.1
1967	112.6	274.0	605.5	195.3	199.0	187.9	132.0	137.4	160.0	120.6	91.9	50.2	188.9
1968	76.9	246.1	164.1	115.5	156.1	134.5	177.0	125.3	132.6	136.6	74.1	68.0	133.9
Average	106.1	202.5	236.6	162.0	143.9	132.9	145.6	151.3	134.8	105.1	79.2	58.0	138.2

(2) Gauging Station La Balsa — Catchment Area (sq. km) 5,480

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	147	336	283	238	149	176	178	216	133	91	108	53	175.7
1947	70	143	188	182	174	110	87	115	141	129	103	120	130.2
1948	319	391	199	138	111	198	310	225	178	109	90	62	194.2
1949	142	196	169	205	221	188	192	268	191	146	113	82	176.1
1950	179	480	405	279	607	407	326	406	318	212	143	95	321.4
1951	146	300	375	254	235	216	169	216	161	148	86	75	198.4
1952	132	285	289	242	219	167	166	231	164	125	98	63	181.8
1953	83	188	288	187	175	155	207	228	174	127	82	66	163.3
1954	222	418	403	171	168	163	258	205	171	178	165	98	218.3
1955	239	390	562	413	252	309	307	297	231	203	136	124	288.6
1956	252	343	531	574	398	304	223	225	257	182	153	148	299.2
1957	196	192	248	220	131	155	166	236	211	105	79	62	166.8
1958	86	137	230	159	147	119	138	167	140	103	91	58	131.3
1959	85	172	194	186	129	122	133	186	181	140	79	64	139.3
1960	116	170	185	240	215	159	175	168	126	123	99	88	155.3
1961	142	214	332	171	120	112	194	139	160	137	88	64	156.1
1962	83	277	181	164	179	201	165	203	222	122	104	76	164.8
1963	131	223	311	191	299	230	344	277	163	124	110	75	206.5
1964	89	301	191	161	120	93	238	207	233	145	122	111	167.6
1965	153	250	314	216	120	107	218	208	117	95	67	58	160.3
1966	131	304	342	174	103	118	122	172	142	127	93	76	158.7
1967	151	375	838	269	322	294	198	221	244	160	114	71	271.4
1968	120	369	235	158	234	203	283	192	213	186	97	101	199.3
Average	148.4	280.6	317.1	225.7	209.9	187.2	208.6	217.7	185.7	139.9	105.2	82.2	1,923.7

(3) Gauging Station Juanchito — Catchment Area (sq. km) 9,060

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	228	406	398	348	200	254	246	320	175	116	148	82	243.4
1947	91	268	280	250	213	133	118	163	195	185	139	148	181.9
1948	370	449	255	154	125	229	398	312	243	130	104	71	236.7
1949	177	251	217	257	297	244	257	319	256	204	149	119	228.9
1950	262	589	522	373	758	736	610	707	612	324	174	130	483.1
1951	184	-	311	393	467	-	-	-	222	213	115	105	-
1952	167	420	409	312	323	214	248	391	242	177	131	80	259.5
1953	117	297	427	279	232	192	340	344	232	163	116	95	236.2
1954	376	607	678	269	257	233	478	405	251	238	203	98	341.1
1955	301	589	689	591	250	405	500	405	348	290	183	160	392.6
1956	337	489	703	628	450	400	302	318	428	217	167	152	382.6
1957	344	319	386	360	174	269	319	408	357	162	100	80	273.2
1958	133	213	324	192	155	119	192	246	161	113	117	74	171.4
1959	95	230	285	254	144	129	160	263	287	184	110	91	186.0
1960	177	252	339	498	483	248	342	334	183	176	120	101	271.1
1961	155	318	427	183	171	157	319	214	210	180	112	72	209.8
1962	104	415	279	237	243	279	252	423	331	189	139	91	248.5
1963	197	325	400	262	393	330	496	449	285	194	175	100	300.5
1964	117	437	260	220	172	134	344	308	397	246	188	174	249.8
1965	229	369	415	293	185	156	330	369	180	121	93	78	234.8
1966	199	419	429	262	143	153	182	279	228	178	131	100	225.3
1967	208	436	836	288	349	343	249	296	315	191	138	84	311.1
1968	165	471	305	202	283	251	346	242	270	224	131	148	253.2
Average	205.8	389.5	417.0	308.9	281.2	254.9	319.5	341.6	278.6	192.0	138.4	105.8	269.0

(4) Gauging Station Mediacanoa — Catchment Area (sq. km) 12,760

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1966	214	470	497	262	141	159	188	319	253	186	134	107	244
1967	222	491	812	381	408	397	300	375	398	229	160	95	356
1968	191	483	381	242	324	298	393	-	-	-	-	-	-
Average	209.0	481.3	563.3	295.0	291.0	284.7	293.7	347.0	325.5	207.5	147.0	101.0	300

(5) Gauging Station Rio Frio — Catchment Area (sq. km) 14,800

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1959	104.5	275.5	310.5	306.5	170.3	144.4	190.4	357.8	374.5	(270.1)	131.1	112.1	229.0
1960	223.4	327.0	439.0	594.0	604.0	318.0	431.0	435.0	258.0	235.0	165.0	135.0	347.0
1961	223.6	460.8	-	-	232.8	203.3	405.6	298.5	271.8	(243.3)	147.1	99.0	-
1962	142.1	545.7	374.4	298.9	307.8	351.4	317.6	557.2	474.0	276.2	192.2	120.0	329.8
1963	271.9	382.7	472.3	318.1	485.4	432.6	617.6	593.3	356.2	231.7	200.0	114.5	373.0
1964	147.8	578.6	323.5	259.6	193.1	150.5	400.9	371.7	(511.2)	312.4	227.7	214.1	307.6
1965	246	398	443	317	195	154	356	430	222	148	105	100	259.5
1966	237	489	512	283	158	169	206	341	284	211	156	126	264.3
1967	233	495	828	440	440	431	343	432	448	280	205	125	391.7
1968	208	574	434	252	330	308	440	323	374	284	184	201	326.0
Average	203.7	452.6	459.6	341.0	311.6	266.2	370.8	414.0	357.4	249.2	171.3	134.7	314.0

(6) Gauging Station La Victoria — Catchment Area (sq.km) 17,650

(Unit : cu.m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1959	104	(282)	320	331	177	144	203	409	422	288	144	114	244.8
1960	242	356	455	687	713	333	471	493	275	252	-	139	-
1961	223	547	652	261	251	219	475	332	310	266	156	100	316.0
1962	141	616	396	305	309	371	370	691	603	299	200	127	369.0
1963	(320)	-	527	344	522	480	725	725	410	253	216	122	-
1964	152	574	322	274	193	159	385	390	557	339	265	240	320.8
1965	303	473	511	403	242	184	423	549	254	162	114	108	310.5
1966	261	531	562	303	172	180	213	350	311	237	170	137	285.6
1967	254	549	913	498	424	429	353	462	456	277	202	117	411.2
1968	213	579	454	266	340	323	466	358	414	306	198	214	344.3
Average	221.3	507.8	511.2	367.2	334.3	282.2	408.4	475.9	401.2	267.9	185.0	141.8	326.0

(7) Gauging Station Anacaro — Catchment Area (sq.km) 18,000

(Unit : cu.m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1963	-	431	494	322	552	474	667	675	419	251	229	150	-
1966	272	577	629	328	181	181	216	368	335	253	179	145	305.3
1967	268	612	1,007	544	451	459	379	512	520	300	213	121	448.8
1968	218	646	507	289	367	348	502						-
Average	252.7	566.5	659.3	370.8	387.8	365.5	441.0	518.3	424.7	268.0	207.0	138.7	377.0

(8) Gauging Station La Virginia — Catchment Area (sq.km) 22,440

(Unit : cu.m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1947	155	479	473	429	335	235	234	336	420	387	304	308	341.3
1948	673	766	562	280	203	363	639	563	517	257	202	144	430.8
1949	335	520	399	406	495	434	446	625	556	467	300	251	436.2
1950	539	1,025	880	700	1,372	1,396	1,210	1,417	1,459	770	450	269	957.3
1951	529	1,045	1,218	720	907	640	515	630	495	454	257	230	636.7
1952	386	879	782	550	546	398	497	845	601	393	284	177	528.2
1953	228	614	848	503	431	334	603	785	521	318	215	205	467.1
1954	729	1,075	1,186	584	502	414	730	749	568	566	468	234	650.4
1955	637	949	1,182	908	460	715	1,160	864	808	613	398	397	757.6
1956	821	1,109	1,352	1,191	840	758	657	653	903	473	321	297	781.3
1957	749	712	702	666	332	464	601	720	688	328	191	152	525.4
1958	255	393	620	321	255	199	348	490	337	193	226	143	315.0
1959	180	446	472	442	242	204	302	549	599	410	234	188	355.7
1960	392	517	576	882	901	454	618	703	445	387	273	241	532.4
1961	365	999	1,002	405	381	310	672	544	557	436	231	168	505.8
1962	221	847	516	395	380	472	520	932	780	436	305	204	500.7
1963	478	605	683	465	673	604	914	956	556	372	319	177	566.8
1964	243	880	484	403	282	242	610	539	831	545	408	381	487.3
1965	478	731	757	563	349	267	654	838	392	240	177	174	468.3
1966	431	866	791	419	242	252	310	520	503	324	227	195	423.3
1967	378	849	1,242	638	543	572	522	710	700	400	276	170	583.3
1968	336	921	686	407	506	500	-	-	-	-	-	-	-
Average	433.5	783.0	791.5	558.0	508.0	464.9	607.7	712.8	630.3	417.6	288.9	224.0	536.0

4. Monthly Average Discharge of Main Tributaries

	Tributary	Gauging Station	Catchment Area (sq. km)	Recording Period
(1)	Rio Mondomo	Carretera Popayan-Cali	185	Oct. 1954-Sep. 1967
(2)	Rio Palo	Arriba	926	Oct. 1946-Dec. 1965
(3)	Rio Timba	Timba	310	Oct. 1946-Mar. 1968
(4)	Rio Jamundi	Ferrocarril	98	Apr. 1962-Sep. 1968
(5)	Rio Fraile	Buchitolo	152	Dec. 1962-Apr. 1968
(6)	Rio Jamundi	San Antonio	-	Feb. 1946-Sep. 1968
(7)	Rio Claro	Potrerito	101	Jan. 1951-Aug. 1966
(8)	Rio Riofrio	Riofrio	143	Nov. 1946-Jun. 1959
(9)	Rio La Vieja	Cartago	2,800	Oct. 1946-Sep. 1968
(10)	Rio Ovejas	Abajo	640	Jun. 1946-Jan. 1968
(11)	Rio Quinamayo		178	Oct. 1965-Sep. 1966
(12)	Rio Teta		143	Oct. 1965-Sep. 1966

(1) Tributary Rio Mondomo — Gauging Station Corretera Popayan-Cali — Catchment Area (sq. km) 185

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1954	6.6	5.5	6.4	9.3	9.0	6.0	4.3	3.6	3.5	9.0	14.5	19.4	8.1
1955	14.8	7.6	10.7	12.0	9.2	7.0	6.2	3.1	3.0	5.3	8.0	13.6	8.4
1956	22.5	13.1	7.9	6.1	6.6	5.7	3.5	2.7	2.2	5.8	5.1	8.1	7.4
1957	8.0	4.7	6.5	6.2	9.7	7.1	4.5	3.2	2.8	3.2	3.4	4.1	5.3
1958	3.8	3.5	2.8	5.8	5.5	2.8	2.3	2.5	1.9	2.4	14.8	7.3	4.6
1959	5.0	3.8	4.1	3.4	4.6	5.0	3.0	2.5	2.3	4.7	5.2	4.8	4.0
1960	9.6	12.5	5.2	5.6	5.4	3.9	3.0	2.5	2.7	2.2	4.6	7.3	5.4
1961	3.7	4.5	5.8	10.1	5.2	3.8	3.4	2.3	1.9	1.3	6.6	2.8	4.3
1962	4.1	5.8	7.6	5.6	8.5	5.9	3.8	3.8	3.9	4.5	7.3	15.6	6.4
1963	6.2	7.0	8.9	17.7	11.9	7.5	4.3	3.7	3.9	5.2	9.9	4.9	7.6
1964	5.2	9.9	4.9	4.7	4.8	(3.3)	9.7	6.5	6.0	3.7	3.6	4.3	5.6
1965	3.7	5.9	8.0	7.5	5.3	4.9	6.6	6.6	5.5	(3.0)	2.6	2.5	5.2
1966	4.2	8.1	10.4	5.4	3.8	3.5	4.0	5.3	4.7	3.3	2.4	1.9	4.8
1967	3.1	7.1	15.7	6.2	6.1	7.3	6.0	6.1	5.6	3.4	2.4	2.1	5.9
Average	7.2	7.1	7.5	7.5	6.8	5.3	4.6	3.9	3.6	4.1	6.5	7.1	5.9

(2) Tributary Rio Palo — Gauging Station Arriba — Catchment Area (sq. km) 926

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	22.0	26.0	24.5	26.2	16.6	18.5	14.1	15.6	13.9	11.4	13.1	6.7	17.4
1947	7.8	17.3	11.5	15.6	13.3	9.2	7.9	11.1	13.1	12.6	10.9	9.1	11.6
1948	26.2	24.7	18.9	10.5	7.9	12.0	26.1	17.9	15.9	11.3	11.4	6.3	15.8
1949	8.9	12.1	10.7	14.8	14.9	11.2	12.6	14.1	14.7	16.3	12.2	(8.9)	12.6
1950	(18.7)	31.9	36.2	30.0	52.3	46.8	38.5	40.7	34.0	26.8	(19.5)	-	-
1951	-	-	-	-	-	-	-	-	16.5	19.5	12.9	8.8	-
1952	11.5	22.5	17.2	16.2	17.0	15.2	18.8	20.7	18.4	18.8	(18.2)	-	-
1953	10.4	20.8	23.4	14.0	12.2	10.5	14.6	16.1	13.9	13.8	9.1	8.0	13.9
1954	22.7	26.5	32.9	19.8	18.0	14.9	21.3	19.8	18.2	20.4	19.4	9.8	20.3
1955	27.6	40.0	45.8	(39.8)	16.6	(31.9)	36.3	27.7	24.5	23.3	16.2	13.4	28.6
1956	23.7	35.0	-	42.0	24.6	26.1	20.3	18.9	22.5	16.6	16.3	13.9	-
1957	24.3	21.9	27.1	19.8	13.8	19.1	20.9	24.4	22.2	15.3	9.6	7.5	18.8
1958	11.0	15.1	17.7	10.4	8.9	8.0	11.7	13.3	9.9	8.0	11.9	5.4	10.9
1959	7.7	15.3	19.4	17.7	10.2	10.3	10.8	14.8	17.9	15.7	7.1	5.8	12.7
1960	11.3	23.0	19.4	30.5	31.6	16.5	16.6	13.9	9.9	12.0	9.5	8.0	16.8
1961	17.6	23.9	35.8	13.5	17.8	19.8	29.6	16.2	18.8	18.1	13.6	8.2	19.4
1962	11.0	32.8	12.6	10.2	11.5	15.0	14.3	23.5	23.5	20.0	15.8	9.9	16.7
1963	22.3	23.8	33.8	20.5	30.9	24.3	47.6	30.2	19.0	14.5	11.6	6.2	23.7
1964	10.2	37.3	19.0	13.3	12.1	6.2	17.9	11.4	17.6	15.7	14.6	12.7	15.7
1965	18.3	19.4	(20.8)										-
Average	16.5	24.7	23.7	20.3	18.3	17.5	21.1	19.5	18.1	16.3	13.3	8.7	17.0

(3) Tributary: Rio Timba — Gauging Station: Timba — Catchment Area (sq. km): 310

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	8.4	35.0	41.9	-	-	-	-	-	-	-	4.2	3.6	-
1947	29	40	15	33	12	8	12	12	23	18	-	-	-
1948	-	-	-	11	8	14	18	26	19	7	5	5	-
1949	34	69	37	13	21	19	26	36	37	25	12	9	28.2
1950	34	555	50	22	49	47	44	102	32	19	19	9	40.2
1951	16	27	32	38	41	28	24	34	32	24	9	9	26.2
1952	10	20	45	23	15	10	17	37	17	10	8	6	18.2
1953	28.0	39.7	35.9	21.7	22.0	13.5	31.0	36.2	25.3	10.9	4.8	5.2	22.9
1954	23.2	62.2	53.2	(21.0)	19.3	22.5	47.0	37.6	24.0	21.2	10.9	4.9	28.9
1955	33.1	43.0	41.8	30.7	6.2	14.4	30.6	53.0	30.3	30.0	8.7	14.1	28.0
1956	36.9	23.7	28.5	42.5	51.4	31.7	51.6	45.7	64.9	19.5	10.2	11.5	34.8
1957	-	-	-	30.9	14.6	12.2	32.2	31.3	23.1	6.6	-	-	-
1965	16.7	36.3	20.5	23.4	16.6	(15.2)	38.9	27.4	16.5	7.9	5.2	(5.6)	19.2
1966	17.4	27.5	38.8	27.9	10.1	10.3	15.2	17.8	17.3	14.8	9.3	9.7	18.0
1967	13.4	25.1	17.8	-	-	(14.3)	15.3	33.5	23.2	9.9	6.5	6.0	-
1968	-	-	-	12.8	11.4	12.1							-
Average	23.1	38.7	35.2	25.1	21.3	18.1	28.8	37.8	27.5	16.0	8.7	7.6	26.5

(4) Tributary: Rio Jamundi — Gauging Station: Ferrocarril — Catchment Area (sq. km): 98

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1962							7.9	15.9	7.0	4.2	2.9	2.9	-
1963	5.0	8.4	9.2	4.1	9.1	8.6	9.4	10.4	7.0	3.7	2.8	1.4	6.6
1964	2.8	17.7	5.9	4.4	5.0	5.5	12.2	7.7	19.0	6.4	3.2	5.4	7.9
1965	8.5	15.3	12.4	5.9	3.7	6.5	15.9	14.6	4.7	1.8	1.7	1.2	7.7
1966	6.9	13.1	7.1	7.0	3.7	3.3	6.4	14.3	8.2	4.9	2.7	1.8	6.6
1967	7.0	11.8	18.2	8.1	9.7	11.3	6.2	11.1	11.4	3.3	1.5	1.7	8.4
1968	10.3	17.7	10.7	5.8	8.3	9.7	9.9	8.9	7.5	3.1	2.0	5.6	8.3
Average	6.8	14.0	10.6	5.9	6.6	7.5	9.7	11.8	9.3	3.9	2.4	2.9	7.6

(5) Tributary: Rio Fraile — Gauging Station: Buchitolo — Catchment Area (sq. km): 152

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1962			4.5	4.2	3.0	4.9	4.9	10.7	9.9	10.3	6.1	3.9	-
1963	10.8	(8.9)	13.2	8.3	13.0	8.6	17.6	14.8	8.4	8.7	7.5	6.8	10.6
1964	4.7	18.1	3.6	3.8	(2.6)	1.4	4.4	5.2	8.5	8.1	5.7	6.5	6.1
1965	6.5	(6.2)	7.7	5.7	1.7	2.1	12.8	9.9	7.2	7.8	4.5	4.1	6.4
1966	6.9	11.0	(5.5)	2.6	1.8	4.0	3.2	6.3	5.3	5.3	5.5	3.8	5.1
1967	4.2	8.7	14.9	5.6	6.4	8.6	6.5	12.9	14.7	11.8	10.4	4.2	9.1
1968	6.0	14.2	7.2	5.2	9.7	6.2	13.7						-
Average	65.2	11.8	8.1	5.1	5.5	5.1	9.0	10.0	9.0	8.7	6.6	4.9	7.5

(6) Tributary Rio Jamundi — Gauging Station San Antonio — Catchment Area (sq. km)

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	-	-	-	-	6.5	7.2	6.4	8.4	2.5	1.0	0.5	0.4	-
1947	1.8	-	-	5.4	-	-	-	-	-	-	-	3.1	-
1948	5.8	-	-	2.3	1.5	3.1	5.7	5.1	3.8	1.5	(1.1)	0.9	-
1949	4.0	7.5	5.1	6.5	7.3	6.4	5.1	6.3	7.0	(2.9)	1.4	3.0	5.2
1950	7.1	16.1	6.9	6.0	13.7	16.6	12.5	13.3	15.8	3.9	1.2	0.9	9.5
1951	3.1	8.5	7.4	2.9	6.9	2.4	2.2	3.8	2.4	2.2	1.0	1.1	3.7
1952	3.7	10.1	8.3	4.7	6.2	2.8	5.7	8.9	5.3	2.0	1.2	0.9	5.0
1953	3.2	5.4	9.0	6.6	2.9	3.2	8.4	8.1	3.8	1.9	0.8	1.0	4.5
1954	8.8	11.0	10.0	2.6	4.1	5.0	11.3	6.8	3.6	2.3	1.6	0.9	5.7
1955	8.8	13.1	11.2	7.4	2.8	7.7	7.6	3.8	4.8	3.5	2.1	3.0	6.3
1956	8.8	11.5	12.6	8.7	8.4	5.2	8.0	6.8	7.8	1.9	1.1	1.4	6.9
1957	-	6.5	5.9	5.7	3.0	4.8	7.4	6.1	3.7	1.3	1.0	1.2	-
1958	3.2	6.6	5.2	3.0	2.2	2.2	3.7	6.1	2.5	1.1	1.5	1.0	3.2
1959	1.7	5.1	6.9	4.8	1.7	2.8	4.7	6.7	9.4	2.3	1.3	0.9	4.0
1960	3.9	3.8	6.8	7.5	9.8	2.8	5.6	8.3	3.1	3.0	2.4	1.7	4.9
1961	1.6	3.5	4.6	2.8	2.4	2.7	5.6	3.4	4.9	2.3	1.2	1.6	3.1
1962	1.6	6.3	2.2	3.2	3.9	4.9	6.1	7.7	3.0	2.7	4.1	3.6	4.1
1963	3.6	5.9	4.6	2.2	5.8	4.8	5.3	8.2	5.6	2.1	1.6	1.9	4.3
1964	3.6	11.3	3.6	2.6	4.6	4.0	10.4	5.8	8.7	2.1	1.3	-	-
1965	-	-	-	(2.9)	2.8	2.4	8.5	6.8	1.2	0.4	0.4	1.2	-
1968	4.8	9.0	4.4	2.9	4.7	5.0	5.5	3.9	3.9	2.1	1.4	3.0	4.2
Average	4.4	8.3	6.7	4.5	5.1	8.0	6.8	6.7	5.1	2.1	1.4	1.6	5.0

(7) Tributary Rio Claro — Gauging Station Potrerito — Catchment Area (sq. km) 101

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1951	-	-	-	5.8	7.0	6.5	7.4	7.1	-	5.6	1.8	2.7	-
1952	7.3	12.0	9.7	9.9	9.8	4.1	8.6	12.4	8.8	4.4	2.4	1.5	7.6
1953	7.4	9.2	14.0	8.3	5.7	4.5	9.3	8.8	6.2	2.7	1.0	2.0	6.6
1954	9.8	10.8	10.8	5.3	6.1	6.7	11.7	10.8	6.7	4.3	3.6	1.9	7.4
1955	10.5	12.8	13.9	8.9	4.2	9.7	9.3	8.9	7.3	6.8	4.0	5.3	8.5
1956	12.4	11.6	12.9	10.0	9.9	5.9	10.9	9.7	11.0	3.9	3.2	3.9	8.8
1957	10.8	8.4	10.3	7.8	5.0	8.3	11.6	8.8	5.8	2.7	1.4	1.7	6.9
1958	7.0	10.6	9.6	5.0	3.7	4.3	7.0	9.5	4.2	1.9	3.4	1.3	5.6
1959	4.4	8.2	9.9	5.5	2.1	4.6	10.3	10.6	14.3	3.7	2.6	2.2	6.5
1960	6.5	8.3	11.2	8.7	10.8	5.8	11.5	12.6	4.8	4.0	2.2	2.2	7.4
1961	5.4	8.9	8.9	3.5	3.2	4.7	8.9	7.6	7.4	3.9	1.2	1.9	5.5
1962	4.6	13.4	6.5	5.4	6.7	9.3	9.7	11.6	7.1	2.8	2.7	2.8	6.9
1963	5.4	9.5	-	-	-	9.1	9.0	10.0	6.8	4.4	3.8	2.5	-
1964	4.6	11.3	5.1	3.4	4.4	5.4	12.5	7.3	10.7	4.5	4.1	6.7	6.7
1965	8.2	10.5	8.3	5.7	3.4	3.6	9.3	7.5	2.6	1.1	1.5	1.4	5.3
1966	5.9	8.3	5.5	5.8	3.4	3.9	-	8.7	7.7	6.2	3.2	-	-
Average	7.3	10.3	9.8	6.6	5.7	6.0	9.8	9.5	7.4	3.9	2.6	2.7	6.9

(8) Tributary: Rio Riofrio — Gauging Station: Riofrio — Catchment Area (sq.km): 143

(Unit : cu.m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	-	19.7	18.4	15.8	8.9	9.5	19.6	18.7	8.4	5.2	3.8	3.0	-
1947	4.6	17.6	17.0	12.0	9.7	8.4	8.1	14.2	19.6	18.4	11.3	14.9	13.0
1948	22.2	18.3	10.8	6.5	5.6	6.5	13.5	21.0	20.2	10.4	6.2	6.9	12.3
1949	14.5	18.0	11.5	10.4	14.8	14.8	13.9	22.1	22.0	15.5	9.3	12.9	15.0
1950	25.9	33.3	21.1	15.6	28.3	30.3	31.7	36.4	42.4	19.4	11.6	9.2	25.4
1951	18.2	-	-	16.2	25.6	(16.4)	-	-	-	10.6	8.6	8.3	-
1952	13.2	23.1	17.7	16.2	13.4	10.4	13.6	21.1	16.5	9.8	7.9	5.5	14.0
1953	10.5	19.9	20.6	12.6	9.6	12.8	18.4	20.5	11.2	11.6	7.4	11.7	13.9
1954	28.0	39.5	27.8	15.0	11.5	11.7	22.8	30.7	19.3	12.3	9.7	6.8	19.6
1955	21.2	31.3	27.9	17.8	15.1	28.4	33.2	39.8	37.1	22.6	16.8	32.9	27.0
1956	50.9	53.0	(41.0)	21.1	15.9	14.0	22.4	20.9	44.7	9.0	4.1	3.9	25.1
1957	25.1	18.3	14.1	10.2	6.1	8.3	15.3	18.1	13.8	4.1	1.9	1.1	11.4
1958	6.7	11.9	14.3	4.0	1.4	1.2	7.3	16.1	9.3	2.6	2.5	.6	6.5
1959	9.1	18.2	25.5	13.4	2.9	4.2	25.1	22.8	25.3	-	-	-	-
Average	19.2	24.8	20.6	13.3	12.1	12.6	18.9	23.2	22.3	11.6	7.8	9.1	16.7

(9) Tributary: Rio La Vieja — Gauging Station: Cartago — Catchment Area (sq.km): 2,800

(Unit : cu.m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1946	67	163	126	137	70	82	79	137	54	29	19	14	81.4
1947	29	101	75	90	65	43	50	68	73	65	53	59	64.3
1948	159	149	107	45	34	55	122	86	74	40	28	25	77.0
1949	63	108	66	61	55	62	56	96	81	72	43	44	67.3
1950	100	285	227	168	360	384	307	486	418	202	129	113	264.9
1951	186	373	320	202	-	-	-	-	-	63	41	33	-
1952	92	224	153	100	78	63	101	173	125	70	45	29	104.4
1953	34	107	156	74	53	48	119	169	102	52	26	39	81.6
1954	158	231	225	90	84	75	117	177	113	121	100	64	129.6
1955	137	221	265	154	75	160	294	158	148	114	73	70	155.8
1956	204	252	268	184	126	99	120	130	139	65	41	43	139.3
1957	122	153	125	83	54	65	95	121	82	41	28	22	82.6
1958	35	62	108	47	34	37	59	70	49	28	25	18	47.7
1959	33	93	100	67	42	41	55	93	94	55	54	32	63.3
1960	75	129	102	173	184	88	95	104	71	60	49	47	98.1
1961	100	166	224	68	83	75	105	75	75	54	59	30	92.8
1962	43	201	89	81	48	59	111	158	98	53	45	38	85.3
1963	99	130	122	70	86	106	171	122	66	61	47	35	92.9
1964	45	155	79	56	47	39	99	69	113	83	82	80	78.9
1965	93	102	136	73	46	38	113	151	53	29	24	25	73.6
1966	76	180	123	66	46	43	53	74	88	58	48	36	74.3
1967	80	214	243	83	78	97	89	124	113	56	40	34	104.3
1968	66	178	99	63	93	79	105	72	81	59	39	48	81.8
Average	91.1	172.9	153.8	97.2	83.7	83.5	114.3	132.4	105.0	66.5	49.5	42.5	97.5

(10) Tributary Rio Ovejas — Gauging Station Abajo — Catchment Area (sq. km) 640

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1964									19.6	11.2	11.4	9.9	-
1965	11.2	19.1	31.9	21.7	14.3	12.3	18.7	21.6	12.4	(9.1)	7.3	7.3	15.6
1966	13.2	26.6	34.5	17.4	11.8	10.9	12.4	17.0	14.8	10.0	7.0	5.4	15.1
1967	9.4	22.9	52.5	20.1	19.4	24.0	19.4	19.8	17.9	10.4	7.0	5.8	19.1
1968	8.3	21.9	16.7	13.7									-
Average	10.5	22.6	33.9	18.2	15.2	15.7	16.8	19.5	16.2	10.2	8.2	7.1	16.7

(11) Tributary Rio Quinamayo — Gauging Station — Catchment Area (sq. km) 178

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1965	4.6	5.7	4.0	-	-	-	-	-	-	-	0.6	0.7	15.6
1966	-	-	-	2.1	1.6	1.7	2.0	2.5	2.5	1.5	1.2	1.1	-
Average	4.6	5.7	4.0	2.1	1.6	1.7	2.0	2.5	2.5	1.5	0.9	0.9	-

(12) Tributary Rio La Teta — Gauging Station — Catchment Area (sq. km) 143

(Unit : cu. m/s)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1965	4.2	7.1	5.5	-	-	-	-	-	-	-	(0.9)	1.0	-
1966	2.5	6.1	-	2.5	1.4	1.2	2.2	4.6	3.2	1.7	(1.0)	-	-
Average	3.4	6.6	5.5	2.5	1.4	1.2	2.2	4.6	3.2	1.7	9.5	1.0	-

5. Monthly Average Precipitation

	Gauging Station	Elevation (m)	Recording Period
(1)	Popayán (Electraguas)	1,790	Jan. 1955-Sep. 1968
(2)	Popayán (Universidad)	1,790	Oct. 1930-Sep. 1968
(3)	Piendamo (Cauca)	1,850	Dec. 1947-Sep. 1968
(4)	Silvia (Cauca)	2,400	Dec. 1947-Sep. 1968
(5)	Coconuco (Cauca)	2,300	Dec. 1947-Sep. 1968
(6)	Purace	3,200	Nov. 1948-Sep. 1968
(7)	Munchique	2,500	Dec. 1947-Sep. 1968
(8)	EL Tambo (Cauca)	1,700	Dec. 1947-Sep. 1968
(9)	Suarez (Cauca)	1,060	Jan. 1952-Sep. 1968
(10)	Salvajina	1,100	Oct. 1965-Sep. 1968
(11)	La Balsa	1,005	Feb. 1952-Dec. 1962
(12)	Miranda	1,060	Oct. 1947-Sep. 1968
(13)	Jamundi (Potorerito)	1,010	Jun. 1946-Apr. 1968
(14)	Cali (Planta del Rio Cali)	1,080	Oct. 1953-Mar. 1968
(15)	Florida (Valle)	1,000	Jun. 1953-Sep. 1968
(16)	La Manuelita	1,030	Jan. 1932-Sep. 1968
(17)	Ansermanuevo	925	May 1946-Apr. 1968
(18)	Ortigal	1,002	Oct. 1965-May 1968
(19)	Caloto	1,125	Oct. 1967-Sep. 1968
(20)	La Union (Distrito de Riego)	913	Feb. 1967-Mar. 1968

(1) Gauging Station Popayan (Electraguas) — Elevation 1,790m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1955	-	-	-	48	118	52	181	79	46	56	45	109	-
1956	176	84	190	298	117	90	149	156	97	20	32	157	1,566
1957	98	102	109	150	279	223	104	153	21	33	19	70	1,361
1958	354	168	270	200	104	33	43	43	2	0	81	59	1,357
1959	176	148	240	67	168	60	173	164	103	22	49	49	1,419
1960	386	373	117	252	244	181	140	72	130	83	58	76	2,112
1961	359	302	258	157	73	158	191	35	70	63	42	89	1,797
1962	250	410	101	146	96	173	108	169	95	32	51	130	1,761
1963	263	392	298	69	194	138	280	167	148	45	24	29	2,047
1964	314	396	162	64	230	64	210	178	114	87	68	27	1,914
1965	150	153	257	84	-	-	201	84	12	4	18	99	-
1966	189	208	125	123	42	54	113	213	71	80	87	224	1,529
1967	339	336	420	83	222	193	79	76	86	8	2	67	1,911
1968	195	498	212	143	211	142	329	75	113	41	93	90	2,142
Average	249.8	274.6	212.2	134.6	161.4	120.1	164.4	118.9	79.1	41.0	47.8	91.1	1,743.0

(2) Gauging Station Popayan - Universidad — Elevation 1,790m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1930	142.3	126.6	233.4	198.9	(123.1)	104.1	164.0	42.3	95.9	25.7	26.3	37.4	1,320.0
1931	309.6	307.5	250.1	149.9	284.3	96.5	141.8	156.7	49.1	103.8	8.8	117.8	1,975.9
1932	193.7	522.0	195.3	249.3	157.8	92.1	73.1	108.1	48.0	15.0	33.9	92.7	1,781.0
1933	216.8	251.3	223.2	231.2	83.6	97.3	190.6	121.2	158.6	99.9	99.7	122.5	1,895.9
1934	196.6	621.0	391.2	110.2	283.3	101.3	52.6	131.7	97.4	24.6	58.2	160.4	2,228.5
1935	381.4	423.0	184.3	180.6	220.9	119.4	214.2	150.5	177.0	-	-	-	-
1944	-	-	-	-	-	-	-	-	154.65	40.3	19.0	73.9	-
1945	164.5	127.3	242.1	103.5	127.9	61.2	184.5	165.2	25.8	8.7	23.3	83.4	1,317.4
1946	228.3	392.3	207.6	189.7	182.9	102.2	120.4	132.6	16.8	11.9	0.9	52.7	1,638.3
1947	273.2	290.0	228.6	168.6	94.7	162.4	60.2	154.5	77.8	121.5	85.1	171.4	1,888.0
1948	300.5	237.5	105.7	143.3	278.5	176.1	216.7	94.5	19.3	50.1	20.6	75.3	1,718.1
1949	381.6	209.6	203.9	235.0	119.9	138.9	123.4	125.1	73.5	55.4	52.0	105.6	1,823.9
1950	426.1	338.3	231.3	270.3	286.8	336.6	239.3	238.9	127.4	36.1	41.8	79.1	2,652.0
1951	201.4	424.2	211.6	195.6	60.9	165.4	102.8	140.4	20.7	49.8	24.3	58.1	1,655.2
1952	172.9	267.8	225.8	259.4	101.9	199.0	98.4	138.0	28.8	40.5	10.6	55.8	1,598.9
1953	158.2	280.0	234.4	110.5	70.9	217.9	95.5	92.0	107.4	26.3	5.4	198.8	1,597.3
1954	278.1	355.1	247.2	68.6	131.8	175.3	249.9	77.7	110.7	55.5	23.6	16.7	1,790.2
1955	316.1	272.6	236.2	204.5	157.0	268.0	197.5	152.2	104.6	87.5	45.0	122.8	2,164.0
1956	291.1	375.3	-	207.6	204.3	118.0	120.6	152.6	132.0	14.7	40.9	133.8	-
1957	332.5	217.6	390.0	81.7	196.7	165.6	142.6	369.7	29.6	22.5	1.0	35.8	1,985.3
1958	265.5	283.3	295.0	190.1	80.0	131.6	126.1	112.9	89.3	1.6	61.3	40.9	1,677.6
1959	201.5	211.5	310.1	139.9	83.4	50.3	126.1	125.6	90.3	18.3	25.9	53.8	1,436.7
1960	269.6	268.7	120.4	179.4	189.0	161.1	112.4	63.4	72.2	59.0	58.9	51.3	1,605.4
1961	312.8	208.2	230.2	98.8	32.3	130.6	139.3	46.0	67.7	52.3	33.2	71.1	1,422.5
1966	-	-	261.5	78.2	105.6	107.0	236.5	142.5	90.0	52.5	39.0	120.0	-
1967	345.0	292.0	394.0	70.0	218.5	192.5	93.5	177.5	81.0	8.5	8.0	68.0	1,948.5
1968	228.0	486.5	278.0	119.0	199.5	168.0	295.0	(75.0	113.0	41.0	93.0	90.0)	2,186.0
Average	263.5	311.6	245.2	162.8	156.8	147.6	150.7	134.1	83.7	43.2	36.1	88.0	1,800.0

(3) Gauging Station Piendamo (Cauca) — Elevation 1,850 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947			(35)	132	59	146	60	120	98	85	37	86	-
1948	356	218	81	95	152	199	245	275	32	32	25	98	1,808
1949	92	168	213	217	251	152	148	242	83	80	49	76	1,771
1950	136	273	236	216	299	309	217	196	180	23	50	98	2,233
1951	200	247	(124)	152	122	169	83	37	37	41	31	51	(1,294)
1952	280	322	199	165	144	225	167	222	42	30	5	50	1,851
1953	63	116	122	62	89	157	145	225	111	38	21	212	1,361
1954	325	248	233	124	265	160	184	117	141	48	44	56	1,945
1955	291	211	349	236	158	284	130	177	107	122	51	72	2,188
1956	160	181	309	390	159	249	182	125	85	53	10	0	1,903
1957	250	85	207	128	119	272	207	145	5	9	5	126	1,558
1958	169	103	159	129	75	126	264	94	66	23	(103)	14	(1,325)
1959	200	307	-	179	-	130	61	137	137	2	56	24	-
1960	317	-	189	391	328	292	172	136	68	25	78	42	(2,038)
1961	243	161	274	150	120	282	240	68	55	72	1	54	1,720
1962	156	367	161	428	255	310	191	203	108	34	38	104	2,355
1963	240	303	299	231	302	179	289	180	98	48	66	92	2,327
1964	190	366	154	75	126	203	299	84	204	100	119	85	2,005
1965	217	277	332	148	28	152	306	157	15	4	49	46	1,731
1966	248	434	322	185	138	291	188	249	118	37	81	38	2,329
1967	220	364	478	184	276	325	147	165	84	52	14	48	2,357
1968	231	308	221	218	231	165	274	105	174	84	55	79	2,145
Average	218.3	253.0	199.9	192.5	176.0	217.1	190.9	157.2	93.1	47.4	44.9	70.5	1,912.2

(4) Gauging Station Silvia (Cauca) — Elevation 2,400 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947	-	-	94	158	100	31	19	49	56	21	33	62	-
1948	330	138	58	62	56	101	191	58	25	24	0	63	1,106
1949	83	76	92	332	126	82	87	44	38	5	31	68	1,064
1950	194	179	230	-	190	338	200	156	91	3	0	26	-
1951	114	153	157	189	177	125	138	99	-	42	0	29	-
1952	180	291	147	181	102	125	167	52	12	0	0	25	1,282
1953	82	314	169	56	43	137	110	103	27	0	0	265	1,306
1954	280	212	207	59	119	156	200	46	83	0	16	0	1,378
1955	303	211	226	129	92	247	149	111	103	61	0	66	1,698
1956	254	201	309	200	170	136	78	70	25	0	0	129	1,572
1957	299	120	131	110	67	129	184	256	10	0	0	-	-
1958	-	-	197	118	60	69	157	69	38	0	28	0	-
1959	183	217	141	78	74	121	104	125	86	0	0	0	1,129
1960	160	217	86	226	195	205	78	152	0	40	32	18	1,407
1961	250	156	236	173	56	260	215	0	59	18	0	60	1,483
1962	269	352	113	156	109	146	205	266	87	0	0	0	1,703
1963	164	62	261	179	325	153	243	224	143	32	0	0	1,786
1964	242	361	137	43	126	30	297	120	169	-	64	34	-
1965	117	150	113	44	1	5	89	109	9	23	9	39	698
1966	133	233	76	0	38	71	24	87	36	20	13	28	759
1967	134	277	245	3	40	129	133	52	37	27	5	7	1,089
1968	94	203	42	35	100	41	183	38	-	8	0	8	-
Average	193.3	206.2	157.6	120.5	107.5	129.0	147.8	104.0	56.7	15.4	11.0	44.2	1,297.3

(5) Gauging Station Coconuco (Cauca) — Elevation 2,300 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947	-	-	116	135	94	72	87	144	97	88	52	116	-
1948	270	213	50	72	119	95	198	89	35	-	-	23	-
1949	163	138	160	155	49	115	136	109	58	16	27	18	1,144
1950	288	359	256	221	235	-	-	-	327	37	48	30	-
1951	156	142	104	97	81	100	65	63	26	28	5	20	887
1952	43	86	34	22	23	56	41	18	18	5	1	3	350
1953	118	81	58	63	87	109	120	168	85	7	0	139	1,035
1954	231	233	237	9	228	146	127	142	162	29	50	12	1,606
1955	288	240	235	76	79	132	199	144	52	101	14	38	1,598
1956	83	97	253	121	108	106	51	164	79	15	-	76	-
1957	193	168	263	33	71	171	193	162	8	4	0	16	1,282
1958	128	123	88	126	-	37	170	131	43	1	130	52	-
1959	164	275	295	94	135	124	179	115	158	19	47	2	1,607
1960	325	218	169	208	216	159	184	150	28	107	57	13	1,834
1961	335	218	157	119	63	315	222	-	81	8	0	51	-
1962	408	824	11	137	65	263	51	285	175	4	106	55	2,384
1963	202	443	469	303	214	350	198	194	93	62	43	0	2,571
1964	222	291	74	31	15	109	229	105	132	103	88	31	1,430
1965	148	162	101	77	46	100	162	209	10	-	-	56	-
1966	152	345	226	52	68	276	168	152	98	93	37	112	1,779
1967	217	725	1,300	116	186	-	441	147	89	48	67	36	-
1968	210	926	363	130	358	224	204	355	124	116	64	173	3,247
Average	206.9	300.3	228.1	109.0	121.0	153.0	163.1	152.3	89.9	44.6	44.0	48.7	1,622

(6) Gauging Station Purace — Elevation 3,200 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1948	-	19	49	22	-	-	122	-	184	107	185	73	761
1949	78	-	-	82	39	92	112	114	-	-	-	82	599
1950	114	163	154	168	104	130	110	276	301	350	167	115	2,152
1951	154	204	153	124	223	178	181	222	333	431	226	147	2,576
1952	198	160	101	102	86	90	241	178	308	294	278	106	2,142
1953	246	332	173	115	70	170	207	264	292	760	240	128	2,997
1954	187	173	134	124	103	85	105	146	229	405	319	77	2,087
1955	-	181	161	115	61	112	89	113	94	237	102	63	1,328
1956	226	174	307	144	97	161	81	171	343	212	242	184	2,342
1957	170	127	348	29	78	95	106	252	192	177	124	53	1,751
1958	89	135	169	48	41	133	83	123	284	219	141	35	1,500
1959	322	115	293	67	99	124	197	214	182	150	76	80	1,919
1960	276	291	262	261	329	226	84	94	187	174	164	235	2,583
1961	392	184	354	130	67	142	265	92	173	250	242	109	2,400
1962	287	395	111	225	53	186	192	262	135	170	222	86	2,324
1963	291	271	378	228	224	72	291	202	143	111	130	149	2,490
1964	185	388	238	10	116	94	256	169	204	133	191	212	2,196
1965	231	228	395	231	13	94	293	242	155	210	121	140	2,353
1966	370	515	287	129	161	301	196	197	197	140	149	122	2,764
1967	304	595	642	121	160	384	202	234	205	268	257	201	3,573
1968	320	618	122	146	266	175	386	202	189	228	255	200	3,107
Average	233.7	263.4	241.6	124.8	119.5	152.2	180.9	188.4	216.5	251.3	191.6	123.7	2,187.8

(7) Gauging Station Munchique   Elevation 2,500m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947	-	-	378	243	-	-	37	137	113	109	-	253	-
1948	418	416	137	100	106	254	537	215	40	113	30	169	2,535
1949	353	429	409	459	279	294	185	228	166	49	111	83	3,045
1950	465	580	397	356	347	402	391	449	273	31	115	80	3,886
1951	340	575	440	285	228	302	150	207	37	62	42	155	2,823
1952	237	387	222	192	85	211	216	177	36	30	0	75	1,868
1953	333	389	322	229	126	169	108	244	103	23	19	294	2,359
1954	361	359	328	87	122	278	370	246	172	89	26	42	2,480
1955	447	497	400	278	164	254	319	250	150	114	100	253	3,226
1956	382	455	484	272	249	157	225	260	155	102	10	115	2,866
1957	418	265	383	113	119	163	195	365	73	20	0	58	2,172
1958	316	321	280	244	45	109	235	156	123	74	161	80	2,144
1959	479	585	566	251	93	181	397	261	308	28	188	103	3,440
1960	602	664	583	617	309	414	368	319	284	160	236	125	4,681
1961	483	592	605	249	139	344	484	127	142	88	64	83	3,400
1962	479	694	394	326	303	401	295	356	378	16	100	152	3,894
1963	412	662	390	326	292	243	480	312	172	122	132	79	3,622
1964	326	397	303	89	207	135	387	261	202	162	-	145	-
1965	395	375	455	286	62	140	415	-	3	23	41	262	-
1966	497	941	490	76	204	213	240	-	438	81	199	200	-
1967	566	896	721	337	429	311	139	272	179	77	26	120	4,073
1968	500	666	491	273	244	218	427	234	150	143	101	152	3,599
Average	419.5	530.7	417.2	258.5	197.7	247.3	300.0	253.8	168.0	78.0	85.1	139.9	3,120

(8) Gauging Station El Tambo (Cauca)   Elevation 1,700m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947	-	-	271.0	103.0	220.0	50.0	21.0	72.0	-	-	53.0	116.0	-
1948	440.0	198.0	129.0	74.0	136.0	186.0	209.0	161.0	31.0	53.0	16.0	102.0	1,735.0
1949	351.0	179.0	-	167.0	110.0	124.0	180.0	186.0	76.0	30.0	59.0	146.0	-
1950	260.0	256.0	95.0	129.0	317.0	229.0	262.0	(140.0)	117.0	19.0	(63.0)	-	-
1951	-	-	-	-	-	-	-	-	-	23.0	29.0	57.0	-
1952	350.0	250.0	257.0	257.0	67.0	76.0	190.0	124.0	9.0	21.0	2.0	2.0	1,605.0
1953	220.0	182.0	116.0	142.0	44.0	94.0	155.0	164.0	144.0	25.0	43.0	269.0	1,598.0
1954	345.0	413.0	278.0	100.0	97.0	200.0	235.0	100.0	97.0	62.0	42.0	56.0	2,025.0
1955	290.0	222.0	239.0	203.0	135.0	263.0	142.0	164.0	133.0	122.0	31.0	117.0	2,061.0
1956	265.0	345.5	324.5	426.5	242.0	74.5	337.0	154.0	57.0	0	4.0	8.0	2,238.0
1958	-	-	171.0	133.0	-	-	235.0	158.0	-	-	-	89.5	-
1966	-	-	-	-	-	(73.0)	109.0	148.0	227.0	71.0	98.0	163.0	-
1967	265.0	383.0	216.0	75.0	16.0	89.0	322.0	326.0	241.0	43.0	191.0	166.0	2,333.0
1968	342.0	460.0	256.0	155.0	135.0	97.0	313.0	109.0	55.0	52.0	81.0	113.0	2,168.0
Average	312.8	288.9	213.9	163.7	138.1	129.6	208.5	154.3	107.9	43.4	54.8	108.0	1,970

(9) Gauging Station Suarez (Cauca) — Elevation 1,060 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1952	-	-	-	153	146	99	201	236	84	39	12	32	-
1953	205	322	323	227	72	-	299	239	112	91	35	168	-
1954	454	705	330	144	212	187	248	200	95	163	57	91	2,886
1955	314	223	299	180	91	228	228	221	262	151	124	142	2,463
1956	250	238	278	295	293	125	183	197	290	110	59	243	2,561
1957	247	125	300	95	111	179	298	49	84	22	4	79	1,593
1958	177	237	95	85	63	122	417	189	61	45	40	127	1,658
1959	175	276	305	85	112	109	274	303	239	72	120	54	2,124
1960	225	316	399	276	273	267	358	278	38	165	126	137	2,858
1961	208	281	213	204	33	-	299	175	178	-	12	72	-
1962	266	463	193	147	196	410	198	239	-	14	44	18	-
1963	142	234	123	95	419	176	337	163	144	149	86	117	2,185
1964	289	265	313	-	-	-	-	-	-	-	-	-	-
1965	266	434	370	228	36	319	729	366	18	167	95	312	3,340
1966	526	602	579	213	70	430	270	531	348	125	148	24	3,866
1967	514	762	433	215	616	330	405	317	444	157	48	299	4,540
1968	523	760	181	254	180	165	693	668	631	270	439	803	5,557
Average	298.8	390.2	295.9	181.0	182.7	224.7	339.8	273.2	201.9	116.0	90.7	169.9	2,970

(10) Gauging Station Salvajina — Elevation 1,100 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1965	131.6	202.1	211.0	159.1	35.8	178.9	381.5	144.9	34.6	31.3	44.0	125.6	1,680.4
1966	200.4	343.9	221.8	78.5	72.1	229.1	148.2	208.8	144.4	72.5	109.8	71.6	1,901.1
1967	217.8	352.9	284.9	127.9	292.2	144.5	257.8	167.9	146.2	176.2	17.3	125.6	2,311.2
1968	272.5	259.0	160.0	133.3	152.9	152.1	306.9	152.7	215.6	97.3	253.6	254.6	2,410.5
Average	205.6	289.5	219.4	124.7	138.3	176.2	273.6	168.6	135.2	94.3	106.2	144.4	2,075.8

(11) Gauging Station La Balsa — Elevation 1,005 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1952	-	-	-	-	35	80	207	198	133	92	33	88	866
1953	311	217	225	144	97	182	196	205	37	45	6	175	1,840
1954	404	472	245	139	171	175	224	324	104	103	72	56	2,489
1955	292	250	291	160	74	313	225	156	172	128	75	187	2,323
1956	186	255	230	290	250	154	220	135	76	20	71	102	1,989
1957	310	95	148	116	115	122	124	280	15	42	10	71	1,448
1958	172	272	82	49	31	61	289	107	15	48	33	51	1,210
1959	115	96	261	6	50	95	82	165	216	27	44	59	1,216
1960	118	99	139	190	39	114	326	238	84	71	41	99	1,558
1961	229	156	87	108	50	76	140	91	11	107	0	69	1,124
1962	73	175	61										309
Average	221.0	208.7	176.9	133.6	91.2	137.2	203.3	189.9	86.3	68.3	42.8	95.7	1,488.4

(12) Gauging Station Miranda — Elevation 1,060m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1947	186	153	-	-	88	62	102	95	105	151	60	166	1,168
1948	254	172	32	95	23	234	228	140	20	-	-	-	1,198
1949	132	67	77	204	41	62	107	129	74	106	26	83	1,108
1950	231	210	122	234	299	226	186	332	107	38	40	42	2,067
1951	310	214	112	121	78	131	185	246	-	77	42	89	1,605
1952	157	343	213	162	113	96	154	147	53	62	24	104	1,628
1953	117	184	196	95	50	132	189	117	31	45	6	115	1,277
1954	230	133	143	61	110	132	132	53	88	49	23	59	1,213
1955	264	225	207	77	98	205	296	93	50	83	37	95	1,730
1956	235	115	217	142	166	180	127	132	92	10	7	50	1,473
1957	225	107	219	93	132	263	136	273	6	21	8	45	1,528
1958	195	127	46	42	34	68	209	128	15	19	60	24	967
1959	80	129	129	75	20	43	66	201	141	10	17	61	978
1960	173	199	161	196	102	130	244	190	67	137	100	47	1,746
1961	335	147	252	131	96	200	386	67	92	117	39	75	1,937
1962	137	348	154	98	229	300	233	298	116	45	73	92	2,123
1963	228	196	243	171	201	314	176	207	87	27	16	128	1,994
1964	145	373	92	15	194	90	273	136	208	107	109	79	1,821
1965	201	266	202	110	7	125	341	161	0	0	27	271	1,711
1966	249	351	137	0	49	98	134	387	169	21	167	66	1,828
1967	219	215	142	55	182	270	192	194	165	26	0	91	1,751
1968	242	268	131	131	241	51	281	111	160	9	78	131	1,834
Average	206.6	206.5	153.7	109.9	116.0	155.1	199.0	174.4	87.9	55.5	45.7	91.1	1,576.6

(13) Gauging Station Jamundi (Potrerito) — Elevation 1,010m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1946	-	-	-	-	-	-	-	-	35	77	21	35	-
1947	264	388	-	103	108	136	137	249	163	161	56	225	-
1948	214	177	111	22	82	169	236	301	52	48	28	78	1,518
1949	191	256	127	211	323	157	145	205	174	74	50	198	2,111
1950	276	363	199	180	378	331	464	245	374	23	53	23	2,909
1951	303	338	78	264	196	73	207	265	162	55	14	70	2,025
1952	274	386	247	233	82	64	304	235	172	58	40	132	2,227
1953	169	177	302	184	68	239	365	371	180	52	8	150	2,265
1954	545	387	246	47	208	290	572	262	83	71	71	60	2,842
1955	270	350	275	111	94	248	328	188	208	253	151	119	2,595
1956	299	249	224	184	283	158	295	160	240	50	11	79	2,232
1957	456	96	199	137	93	258	335	370	60	51	12	96	2,163
1958	277	214	114	69	46	58	441	366	36	93	232	77	2,023
1959	297	314	398	137	37	172	308	298	420	46	157	112	2,696
1960	496	223	596	58	32	19	90	69	14	42	24	23	1,686
1961	95	82	144	-	-	-	-	-	-	-	-	-	-
1962	199	250	90	122	203	206	197	332	83	42	78	69	1,871
1963	174	212	96	69	250	279	218	172	83	85	125	101	1,864
1964	147	385	260	35	123	106	341	256	292	156	108	-	-
1965	-	-	-	-	55	106	416	280	4	23	31	86	-
1966	227	352	142	54	44	182	182	355	143	63	112	21	1,877
1967	178	424	241	92	164	211	183	255	147	64	38	135	2,132
1968	416	233	157	76	133	163	183	-	-	-	-	-	-
Average	274.6	278.9	212.3	119.4	143.0	172.6	283.2	261.7	148.8	75.6	67.6	94.5	2,178.6

(14) Gauging Station Cali (Planta del Rio Cali) — Elevation 1,080 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1953	99.0	149.5	82.5	81.5	22.5	69.5	72.5	198.0	45.5	0.5	1.0	150.0	972.0
1954	144.5	244.0	25.5	24.5	6.5	44.0	141.0	94.5	186.5	24.5	7.5	20.0	963.0
1955	207.5	62.5	141.5	60.5	73.5	176.5	117.5	127.5	68.0	48.0	31.5	149.5	1,264.0
1956	115.0	133.0	127.0	150.0	102.0	38.0	95.0	173.0	124.0	67.5	29.5	80.0	1,234.0
1957	139.0	123.5	114.5	71.5	51.0	116.0	141.5	260.5	37.5	-	-	-	-
1958	-	92.5	123.5	41.5	72.5	95.5	229.0	173.5	30.0	32.0	38.5	29.5	-
1959	90.0	85.0	83.5	40.0	14.5	81.0	102.5	147.0	155.5	13.5	134.0	28.0	974.5
1960	121.0	92.0	150.0	96.5	122.0	49.0	200.5	106.5	13.5	57.0	65.0	54.5	1,127.5
1961	119.5	71.0	61.0	57.5	11.5	147.5	112.0	92.5	71.0	63.0	19.0	10.0	835.5
1962	152.5	70.0	69.0	72.0	23.5	81.5	111.5	164.0	29.0	42.5	103.5	56.5	975.5
1963	98.5	83.5	78.0	25.5	114.0	79.0	79.5	81.0	76.5	56.5	10.5	33.0	815.5
1964	47.5	105.0	41.5	8.0	8.5	39.0	148.5	111.0	130.5	20.5	19.5	52.5	731.0
1965	125.0	74.0	16.5	107.0	27.0	32.5	155.5	84.0	32.0	0	14.0	61.0	728.5
1966	63.5	171.5	75.5	46.0	65.5	27.5	56.0	83.5	88.0	23.0	63.0	20.0	783.0
1967	131.0	65.5	142.5	25.0	78.0	129.0	103.0	102.0	29.0	65.0	4.0	83.0	957.0
1968	72.0	65.0	83.0	54.0	101.0	61.0	-	-	-	-	-	-	-
Average	115.0	157.5	88.4	60.1	55.8	79.2	124.4	133.2	74.4	39.5	38.6	59.1	950.8

(15) Gauging Station Florida (Valle) — Elevation 1,000 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1953	-	-	-	-	-	-	-	-	32	104	13	87	-
1954	150	103	119	37	22	143	127	59	92	58	27	52	989
1955	296	189	224	63	68	246	270	64	57	60	22	55	1,614
1956	128	189	183	128	144	136	109	181	77	23	24	89	1,411
1957	211	80	181	102	120	173	135	221	4	21	3	37	1,288
1958	145.5	89.5	48	68	92	78	184	110	23	11	36	26	911.0
1959	69	118	112	45	46	27.5	106	186.5	128	61.5	42	60	1,001.5
1960	354	181	118	166	96	84.5	109.5	110	90	94.5	85	45	1,533.5
1961	214.5	105	234.5	40.5	47	93	256.5	15.5	107	83	45.5	20.5	1,262.5
1962	177.5	230	72	143	68	171	240	165	37	25	59	105.5	1,493
1963	98	250	164	76	223	170	281	147	64	64	23	69	1,629
1964	119	213	79	7	103	83	189	123	181	17	38	61	1,213
1965	130	88	116	54	15	119	329	117	75	10	53	156	1,262
1966	199	148	118	56	18	85	108	256	76	93	103	20	1,280
1967	175	231	118	69	139	121	111	173	53	28	0	93	1,311
1968	205	137	67	120	171	137	181	48	79	40	73	107	1,365
Average	178.1	156.8	130.2	78.3	91.5	124.5	182.4	131.7	73.4	49.6	40.4	67.7	1,304.2

(16) Gauging Station La Manuelita — Elevation 1,030m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1932				151.1	75.4	35.0	140.2	120.3	48.5	37.5	69.3	85.8	-
1933	160.7	84.3	49.5	-	-	-	-	-	-	-	-	-	-
1934	-	-	-	86.6	173.6	65.4	104.4	186.7	104.9	41.1	191.1	343.9	-
1935	238.7	189.9	-	64.9	123.2	127.0	204.5	211.7	66.0	38.6	72.1	78.5	-
1936	161.4	212.3	65.4	3.3	15.3	99.3	69.7	91.2	116.8	12.1	7.9	19.8	874.5
1937	162.6	72.5	136.8	99.8	97.1	252.3	67.5	179.4	55.1	26.9	20.3	133.7	1,304.0
1938	120.7	99.6	177.3	94.8	100.0	131.4	313.6	235.0	78.9	7.6	139.4	28.9	1,527.2
1939	125.3	309.0	210.0	40.5	32.5	59.5	83.8	86.5	34.4	8.0	25.9	96.4	1,111.8
1940	129.3	78.9	46.3	28.2	33.0	38.2	45.3	146.5	168.8	0	15.5	71.3	801.3
1941	164.7	68.6	121.0	39.2	74.1	22.9	-	86.7	32.7	54.8	17.6	43.0	-
1942	155.3	74.4	49.6	85.4	63.3	153.6	163.0	179.6	94.6	18.3	41.2	65.6	1,143.9
1943	148.8	114.1	74.6	141.6	129.6	159.4	308.3	73.6	87.4	38.1	63.3	39.5	1,378.3
1944	280.9	108.2	102.4	93.5	89.5	-	99.1	136.6	182.8	14.6	68.5	26.9	-
1945	128.3	49.0	115.3	63.3	36.0	42.5	174.0	134.2	36.1	24.9	34.0	32.5	870.1
1946	132.0	88.1	78.0	45.6	40.4	61.7	128.4	130.7	37.1	0	4.5	2.3	748.8
1947	62.8	149.8	75.8	71.9	78.2	40.4	44.1	80.0	85.3	77.4	54.6	97.3	917.6
1948	236.1	125.2	62.5	8.3	36.0	149.2	108.8	114.5	35.4	26.4	27.6	84.0	1,014.0
1949	143.1	85.7	58.3	62.2	77.4	83.0	89.4	87.9	50.3	71.3	54.7	49.6	912.9
1950	161.9	70.3	42.6	77.2	177.8	259.8	206.6	99.9	121.4	43.1	88.8	38.4	1,387.8
1951	196.5	120.9	84.8	47.0	106.5	49.9	109.6	176.5	26.4	73.3	27.6	61.0	1,080.0
1952	116.8	-	160.8	106.4	34.8	119.8	156.5	213.7	22.4	29.9	23.9	22.4	-
1953	140.2	101.1	73.2	89.9	23.6	99.8	210.7	174.6	47.5	27.1	0.5	113.5	1,101.7
1954	285.7	176.3	55.6	70.8	91.4	91.0	129.0	92.7	107.7	35.9	0	10.4	1,146.5
1955	152.9	91.5	105.6	79.7	8.2	130.0	202.9	317.0	47.1	19.5	6.1	26.2	1,186.7
1956	62.9	25.9	55.6	317.3	111.6	116.9	32.8	86.7	17.9	12.0	10.8	24.7	875.1
1957	51.2	10.7	131.6	52.7	65.8	66.6	146.4	192.0	23.9	25.2	16.5	35.5	818.1
1958	122.9	48.6	45.1	75.6	41.2	39.4	172.0	197.0	23.0	12.0	20.3	63.3	860.4
1959	114.7	113.6	101.6	7.7	34.0	32.0	65.0	125.0	86.0	46.0	63.0	9.0	797.6
1960	147.0	110.0	85.0	90.0	117.0	90.0	125.0	165.0	76.0	63.0	31.0	17.0	1,116.0
1961	145.0	98.0	97.0	125.0	21.0	47.0	170.0	33.0	23.0	40.0	9.0	54.0	862.0
1962	209.0	168.0	142.0	43.0	101.0	155.0	148.0	119.0	48.0	12.0	35.0	52.0	1,232.0
1963	148.0	133.0	55.0	66.0	171.0	44.0	136.0	104.0	109.0	69.0	22.0	58.0	1,115.0
1964	85.0	132.0	44.0	18.0	33.0	15.0	186.0	90.0	105.0	57.0	67.0	94.0	926.0
1965	98.0	116.0	19.0	42.8	29.2	60.6	341.7	83.0	35.5	11.5	37.8	85.2	960.3
1966	166.2	101.3	52.3	89.7	46.0	73.6	86.9	166.1	80.8	34.8	58.4	41.9	998.0
1967	129.0	64.3	138.7	35.8	122.4	114.8	132.1	140.3	125.0	126.7	18.1	82.3	1,229.5
1968	231.0	126.6	90.1	75.1	122.3	106.6	180.2	131.2	102.7	54.8	114.2	150.6	1,485.4
Average	151.8	109.3	88.3	74.7	75.9	95.2	145.2	138.6	70.7	35.8	43.3	65.0	1,058.0

(17) Gauging Station Ansermanuevo — Elevation 925 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1946	-	-	-	-	-	-	-	171	7	13	2	46	-
1947	72	141	70	56	46	42	124	189	198	123	28	183	1,272
1948	-	-	-	-	-	-	-	-	-	-	-	-	-
1949	145	84	66	73	59	140	146	95	137	112	113	109	1,279
1950	122	233	96	98	158	160	159	288	221	33	130	121	1,819
1951	139	-	-	118	123	102	141	190	112	82	158	155	-
1952	242	127	129	50	42	97	169	186	104	165	91	67	1,469
1953	152	169	192	48	68	124	232	171	43	37	14	183	1,433
1954	187	163	84	84	78	56	128	180	88	143	79	80	1,350
1955	206	110	249	54	89	173	278	102	151	119	76	119	1,726
1956	191	229	106	123	194	68	198	128	188	86	63	128	1,702
1957	243	100	100	53	48	115	132	168	33	33	10	37	1,072
1958	126	99	81	40	30	129	187	70	76	-	-	-	-
1959	270	80	133	38	28	151	136	161	264	64	104	77	1,506
1960	149	240	197	60	93	104	197	129	156	150	107	117	1,699
1961	179	118	84	87	73	192	144	51	116	119	47	118	1,328
1962	206	153	59	57	89	107	147	164	106	54	69	56	1,267
1963	148	85	46	87	135	143	282	113	-	102	76	83	-
1964	102	244	64	90	123	101	258	-	-	-	-	241	-
1965	96	78	83	69	-	131	507	207	55	16	77	156	-
1966	187	246	102	24	39	172	175	188	142	96	126	118	1,615
1967	(89)	181	124	33	113	99	202	-	-	94	75	97	-
1968	146	145	74	73	137	47	289	-	-	-	-	-	-
Average	161.8	151.3	107.0	67.4	88.3	116.8	201.5	155.3	122.1	86.4	76.1	1,145.5	1,468

(18) Gauging Station Ortigal — Elevation 1,002 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1965	161.9	172.9	99.6	68.7	25.7	70.5	231.4	84.0	3.4	8.7	65.7	76.7	1,069.2
1966	147.0	166.0	174.0	13.3	59.5	102.4	123.1	234.0	68.5	50.0	25.0	4.0	1,166.8
1967	159.0	211.0	76.0	39.0	175.0	90.0	135.0	226.0	82.0	59.0	13.0	52.0	1,317.0
1968	-	-	-	176.0	118.0	186.0	236.0	72.0	-	-	-	-	-
Average	156.0	183.3	116.5	74.3	94.6	112.2	181.4	154.0	51.3	39.2	34.6	44.2	1,184.3

(19) Gauging Station Caloto — Elevation 1,125 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1967	96	365	357	164	294	227	93	274	60	137	36	111	3,214
1968	257	337	124	125	175	125	232	157	-	42	142	105	1,821
Average	176.5	351.0	241	144.5	234.5	176.0	162.5	215.5	60	99.5	89	108	2,017.5

(20) Gauging Station La Union Distrito de Riego — Elevation 913 m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1967	-	-	-	-	(10.1)	78.3	152.5	129.5	91.7	34.0	40.2	134.2	-
1968	146.2	84.5	29.8	78.5	56.9	52.8	-	-	-	-	-	-	-
Average	146.2	84.5	29.8	78.5	33.5	65.6	152.5	129.5	91.7	34.0	40.2	134.2	1,020.2

6. Monthly Average Temperature

	Gauging Station	Elevation (m)	Recording Period
(1)	Ingenio La Manuelita	1,030	Jan. 1929-Sep. 1968
(2)	Colegio San Luis Gonzaga	1,066	Jan. 1933-Dec. 1958
(3)	La Union-Distrito de Riego	912	Oct. 1965-Sept. 1968
(4)	Melendez	990	Dec. 1966-Sept. 1968
(5)	Ortigal	1,002	Jan. 1965-May 1968

(1) Gauging Station Ingenio La Manuelita   Elevation 1,030m

(Unit : °C)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1929				24.3	24.3	25.8	24.9	24.1	24.0	24.6	24.7	24.3	-
1930	24.0	23.7	24.6	24.9	25.4	25.7	25.0	25.1	24.3	26.1	26.1	25.6	25.0
1931	23.6	25.6	25.0	25.3	25.3	25.5	25.0	24.3	24.1	23.5	24.3	24.1	24.6
1932	23.9	23.4	24.1	24.3	24.6	24.4	24.7	24.2	23.8	24.1	23.9	24.1	24.1
1933	23.9	23.6	23.7	23.7	23.6	24.1	24.1	24.2	23.3	23.6	23.4	23.6	23.7
1934	23.4	23.8	22.5	21.8	22.2	22.4	21.7	22.3	21.7	21.7	21.8	21.8	22.2
1935	21.2	21.2	21.5	21.7	21.1	22.2	21.1	21.1	21.7	21.7	21.7	21.7	21.5
1936	21.7	22.2	23.9	24.4	24.4	25.0	24.4	24.4	23.9	23.9	23.9	23.9	23.8
1937	23.9	23.9	23.9	23.9	23.3	23.9	23.9	23.9	23.9	23.3	23.3	24.4	23.8
1938	24.2	23.3	23.6	23.9	23.3	23.9	23.1	23.9	23.3	23.6	23.1	23.3	23.5
1939	23.3	23.3	22.8	22.2	22.8	23.9	23.1	23.6	24.2	25.0	24.4	25.3	23.6
1940	25.0	-	-	-	-	21.9	23.1	25.6	26.7	25.0	25.3	25.0	-
1941	24.4	23.6	24.2	24.4	25.0	25.3	25.0	25.3	25.0	25.0	24.4	24.2	24.6
1942	23.6	23.3	23.6	23.9	24.7	24.2	24.2	24.2	24.7	25.3	25.0	-	-
1943	-	-	-	-	-	24.2	23.6	23.3	22.8	23.9	23.3	23.9	-
1944	23.1	22.8	22.2	21.9	22.5	22.2	22.5	21.4	21.7	22.8	22.5	22.2	22.3
1945	21.4	20.8	20.0	22.8	23.1	23.3	22.5	21.4	22.2	23.1	23.1	24.2	22.3
1946	21.7	24.7	21.7	-	-	-	-	-	26.5	25.4	25.7	25.4	-
1947	24.7	24.1	25.7	25.6	26.4	26.3	25.9	25.3	25.0	25.3	25.3	24.7	25.4
1948	22.8	23.6	23.9	24.4	24.2	23.1	23.6	24.2	24.7	23.9	23.9	23.6	23.8
1949	23.6	23.3	23.1	22.9	22.9	22.4	22.7	22.5	21.9	21.7	21.9	23.3	22.7
1950	23.9	23.3	23.9	24.2	24.2	23.6	24.2	23.6	24.2	24.4	23.9	24.7	24.0
1951	23.6	23.6	23.9	23.6	23.3	24.4	23.6	23.3	23.9	23.3	24.2	24.2	23.7
1952	23.1	22.8	22.2	23.1	21.9	22.5	22.2	21.9	21.9	22.5	24.7	24.4	22.8
1933	24.2	24.2	23.9	23.6	24.4	25.0	24.4	23.9	24.4	23.3	23.6	22.5	24.0
1954	21.9	22.8	22.8	22.5	22.5	22.0	21.7	21.7	21.7	21.4	21.4	21.4	22.0
1955	-	24.2	22.8	23.1	23.3	22.5	22.2	22.7	22.2	22.2	21.6	21.9	
1956	21.9	23.9	23.6	22.8	23.3	24.4	23.9	23.6	23.1	23.3	23.3	23.3	23.4
1957	22.2	22.8	23.3	23.9	24.7	24.2	24.2	23.3	22.2	24.7	24.7	25.0	23.8
1958	24.2	24.2	23.1	24.8	24.3	24.1	23.4	22.9	23.0	23.3	22.9	23.9	23.7
1959	23.1	23.3	23.7	23.5	24.2	23.9	24.2	23.2	23.6	23.7	22.7	24.1	23.6
1960	23.9	23.1	23.8	23.3	23.2	23.6	23.1	23.1	23.1	23.5	23.7	23.9	23.4
1961	23.0	22.9	23.4	23.8	23.6	23.7	23.0	23.4	22.5	22.3	22.6	22.4	23.1
1962	22.0	21.0	21.7	22.4	21.9	21.5	21.7	21.9	22.2	22.6	23.0	23.1	22.1
1963	23.5	23.4	22.4	23.0	22.9	24.1	23.6	24.0	24.2	24.1	25.0	24.7	23.7
1964	25.0	23.5	24.6	24.0	25.5	26.0	24.7	24.8	23.5	24.0	24.1	23.1	24.4
1965	22.0	21.2	21.3	22.6	23.7	24.0	23.2	23.2	23.5	23.3	23.6	23.0	22.9
1966	22.7	22.7	22.8	23.1	23.6	24.1	24.1	23.7	23.5	23.5	23.4	23.2	21.7
1967	23.2	22.9	22.5	22.4	23.0	23.4	23.8	23.1	22.5	23.1	33.8	23.2	23.1
1968	23.7	23.3	23.2	23.3	23.2	23.2	(23.2)	(22.0)	(22.6)	(22.1)	(21.6)	(23.0)	22.9
Average	23.3	23.2	23.2	23.5	23.7	23.8	23.6	23.4	23.4	23.6	23.6	23.7	24.8

(2) Gauging Station Colegio San Luis Gonzaga — Elevation 1,066m

(Unit : °C)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1933				23.1	24.2	24.1	23.8	23.4	22.9	23.5	23.0	23.4	-
1934	22.6	22.1	22.5	22.6	23.0	23.6	23.4	22.9	22.9	22.9	23.6	24.2	23.0
1935	22.9	22.7	23.3	25.3	24.5	25.2	25.0	24.6	24.4	25.1	25.4	25.2	24.5
1936	24.6	23.8	25.2	25.2	25.3	25.2	24.9	24.3	23.7	24.5	25.0	24.8	24.7
1937	24.6	23.8	24.0	24.4	25.0	25.3	24.6	23.7	24.0	24.6	24.8	24.5	24.4
1938	24.5	24.0	24.1	25.1	25.3	24.1	23.4	23.6	24.2	24.0	23.6	24.6	24.2
1939	23.3	23.4	23.3	23.2	24.5	24.7	24.1	23.9	24.2	24.6	25.0	24.1	24.0
1940	23.6	24.0	24.2	24.7	25.5	25.5	25.1	25.0	24.8	25.2	24.7	24.7	24.8
1941	23.9	23.9	24.8	25.0	25.6	25.5	25.1	24.9	25.2	25.3	25.0	24.9	24.9
1942	24.8	24.6	25.1	25.6	25.5	24.9	24.6	24.7	24.2	25.1	24.8	24.5	24.9
1943	23.6	23.3	23.4	23.6	24.0	23.6	23.0	23.9	23.5	24.6	24.5	25.0	23.8
1944	23.6	24.2	23.7	24.0	24.5	24.5	24.5	23.7	23.4	24.7	24.5	24.1	24.1
1945	24.0	23.9	24.2	24.2	24.6	25.4	23.6	22.9	24.8	24.7	24.8	25.4	24.4
1946	23.2	23.5	24.2	24.4	24.8	24.4	23.4	23.1	24.9	25.2	25.2	24.9	24.3
1947	23.3	23.8	24.1	24.0	24.6	25.4	25.7	24.1	24.3	24.1	24.4	24.8	24.4
1948	23.5	24.2	25.4	26.2	26.0	25.0	23.5	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	22.3	22.1	23.1	23.1	22.5	23.0	23.5	22.8	23.5	-
1951	23.8	22.8	23.3	22.8	23.3	24.3	23.7	23.0	24.4	24.4	-	23.6	(23.6)
1952	24.4	23.8	24.2	24.1	24.0	24.2	23.4	23.3	23.4	23.6	24.0	24.0	23.9
1953	23.0	22.8	23.2	23.5	23.9	23.4	23.8	22.8	23.8	-	-	-	-
1954	-	-	22.5	23.3	23.5	23.5	22.9	23.1	23.0	22.8	23.5	24.0	-
1955	23.5	23.2	21.5	23.6	23.8	23.6	22.3	23.4	22.9	23.0	23.3	23.4	23.1
1956	22.3	22.5	22.3	22.3	22.8	23.8	23.5	23.1	23.3	23.3	23.6	22.6	23.0
1957	23.1	22.9	22.8	23.7	23.6	23.6	23.3	23.6	23.9	24.7	24.2	24.4	23.7
1958	23.3	23.8	24.2										
Average	23.6	23.5	23.7	24.0	24.3	24.4	23.9	23.6	23.9	24.3	24.3	24.5	24.8

(3) Gauging Station La Union - Distrito de Riego — Elevation 912m

(Unit : °C)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1965	22.7	22.6	22.9	22.8	24.1	24.0	23.0	23.5	23.9	23.8	24.0	23.8	223.4
1966	23.0	22.9	23.4	24.4	24.6	23.8	24.2	23.3	23.4	23.6	23.6	24.1	23.7
1967	23.2	22.8	22.8	23.6	23.3	23.9	23.7	23.1	22.7	23.3	23.8	23.7	23.3
1968	23.0	22.5	23.0	23.6	23.9	23.2	23.4	23.2	22.6	23.2	23.7	23.1	23.3
Average	23.0	22.7	23.0	23.6	23.9	23.7	23.6	23.3	23.2	23.5	23.8	23.7	23.4

(4) Gauging Station Melendez — Elevation 990m

(Unit : °C)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1966			23.3	24.4	24.6	24.5	24.5	23.7	23.7	23.8	23.6	23.7	-
1967	23.1	22.2	22.4	23.1	23.1	23.4	23.4	23.0	22.6	23.1	24.0	23.8	23.1
1968	22.9	22.3	23.0	22.9	23.2	22.4	22.8	23.1	22.6	23.5	24.2	23.3	23.2
Average	23.0	22.3	22.9	23.5	23.6	23.4	23.6	23.3	23.0	23.5	23.9	23.6	23.2

(5) Gauging Station Ortigal — Elevation 1,002m

(Unit : °C)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1965				23.9	24.2	23.9	22.6	23.0	23.0	22.9	22.9	23.7	-
1966	23.4	24.5	23.7	24.5	25.1	24.4	24.4	23.6	23.5	23.7	23.1	23.7	24.0
1967	23.8	23.4	23.2	23.4	23.8	24.0	24.2	24.0	23.3	23.5	24.1	23.9	23.7
1968	24.0	23.6	24.0	23.7	24.0	24.0	24.3	24.3					-
Average	23.7	23.8	23.6	23.9	24.3	24.1	23.9	23.7	23.3	23.4	23.4	23.8	23.9

7. Monthly Total Evaporation

	Gauging Station	Elevation (m)	Recording Period
(1)	Ingenio La Manuelita	1,030	Aug. 1959-Apr. 1968
(2)	Granja Experimental Palmira		Oct. 1965-Sep. 1968

(1) *Gauging Station* Ingenio La Manuelita — *Elevation* 1030m

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1959											119.1	127.0	-
1960	139.4	118.6	132.0	121.7	127.0	143.8	119.9	121.9	114.8	130.8	125.0	120.9	1,515.8
1961	122.2	126.0	123.7	132.3	145.0	134.9	118.9	128.3	108.0	143.0	140.5	146.0	1,568.8
1962	115.6	137.9	144.3	136.7	137.7	162.6	156.7	139.2	143.0	148.8	149.1	138.4	1,710.0
1963	201.7	158.0	130.0	165.6	162.3	154.7	219.5	156.0	123.2	143.5	138.7	135.4	1,888.6
1964	190.7	158.5	154.7	172.0	168.4	171.2	159.0	163.6	132.6	190.5	144.5	162.5	1,968.3
1965	180.1	75.7	157.2	153.2	170.4	189.0	90.2	113.8	131.6	120.7	144.8	134.4	1,661.1
1966	125.5	133.1	135.1	144.0	114.6	147.6	159.8	115.1	111.5	121.2	126.0	120.7	1.554.2
1967	135.1	125.7	124.0	106.2	108.0	120.1	131.1	132.8	116.3	140.7	133.4	135.9	1,509.3
1968	158.5	127.8	140.0	149.9	131.1	145.0	132.8						-
Average	150.6	127.7	136.5	141.0	139.1	150.6	141.7	133.8	122.6	142.4	134.3	134.3	1,672.0

(2) Gauging Station Granja Experimental Palmira

(Unit : mm)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1965	116.2	130.9	146.0	144.0	158.5	156.5	106.3	118.6	136.6	145.1	172.3	145.8	1,676.8
1966	145.4	112.5	108.6	179.3	165.1	140.4	104.9	92.3	129.0	149.8	150.9	168.4	1,646.6
1967	158.9	112.5	120.9	117.9	129.8	147.3	150.8	112.4	104.0	124.4	139.2	145.5	1,563.6
1968	160.0	-	-	-	-	-	-	-	96.7	114.8	130.9	112.9	-
Average	145.1	118.6	125.2	147.2	151.1	148.1	120.7	107.8	116.6	133.5	148.3	143.2	1,629.0

8. Monthly Average Relative Humidity

	Gauging Station	Elevation (m)	Recording Period
(1)	Ingenio La Manuelita	1,050	Aug. 1959-Apr. 1968
(2)	Granja Experimental Palmira		Oct. 1965-Sep. 1968

(1) Gauging Station Ingenio La Manuelita — Elevation 1,050m

(Unit : %)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1959											70.4	70.2	-
1960	74.1	73.5	73.6	74.2	(75.4)	72.6	73.8	76.9	(70.2)	76.1	77.1	77.7	(74.6)
1961	81.1	83.9	82.7	82.4	77.7	82.5	85.5	81.9	78.1	81.0	75.9	78.8	81.0
1962	82.1	85.4	81.8	81.1	(82.6)	83.7	84.0	(88.2)	85.7	79.5	82.2	81.2	(83.1)
1963	85.1	87.3	86.8	84.1	86.7	84.0	86.2	86.7	82.1	81.8	79.8	81.7	84.4
1954	81.7	86.5	83.5	76.6	81.9	79.1	83.8	81.5	75.9	-	-	-	-
1965	(92.7)	(93.5)	-	(85.3)	(75.7)	(75.3)	(81.1)	(78.6)	(76.6)	(78.5)	(71.3)	(74.8)	-
1966	(75.4)	(76.7)	(76.6)	(76.1)	(73.8)	(74.3)	(76.7)	(76.7)	(59.6)	(78.7)	(73.6)	(74.9)	(74.4)
1967	77.4	76.8	-	-	72.9	71.4	70.0	72.9	75.5	68.2	67.9	72.1	-
1968	76.2	80.0	78.8	76.6	81.1	80.4	79.6						
Average	80.6	82.6	80.6	79.6	78.6	78.1	80.1	80.4	75.5	77.8	73.7	76.4	79.5

(2) Gauging Station Granja Experimental Palmira

(Unit : %)

Month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
1965	74	76	74	74	67	69	73	75	67	66	66	68	70.8
1966	75	76	75	70	68	72	72	77	74	73	71	68	72.6
1967	72	75	75	71	73	72	76	82	84	81	79	78	76.5
1968	78	74	69	69	76	74	75	75	79	72	69	74	73.7
Average	74.8	75.3	73.3	71.0	7.10	71.8	74.0	77.3	76.0	73.0	71.3	72.0	73.4

APPENDIX 2

GEOLOGY AND EARTHQUAKE

APPENDIX 2 GEOLOGY AND EARTHQUAKE

CONTENTS

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I. GEOLOGY OF SALVAJINA SITE

CONTENTS

1. Introduction

The geology of Salvajina dam site has already been reported in detail in "The Salvajina Project Report" which had been prepared in 1965 jointly by CVC Hydroelectric Department and Acres International Limited.

In the abovementioned report, the general geology and geology of the dam site have been well studied and reported. Therefore, there is no need to make further investigation of the geology of Salvajina dam site at the stage of the feasibility study.

This report on the geology of Salvajina dam site was prepared after conducting some surface geologic survey and using the data of the Salvajina Project Report and the basic data described below.

(a) Topographic maps (scale 1 : 1,000) prepared by CVC.

(b) Salvajina Project, Basic Data Report of Foundation and Borrow Exploration, Volume I -Dam Site

(c) Salvajina Project, Basic Data Report of Foundation and Borrow Exploration, Volume 2 - Dam Site and Borrow Area.

The number and length of drill holes, auger holes and test pits which were executed at the time of preparing the Salvajina Project Report are as follows:

Drill hole	41 holes	Total length	2,075.25 m
Auger hole	57 holes	Total length	794.0 m
Test pit	58 holes	Total length	382.7 m

2. Topography

The Cauca River flows from southwest to northeast at the Salvajina site, and the topography around dam site is a steep gorge.

Near the dam axis, the width of the river is 30 m, the slopes of the both banks, between the river bed (elevation about 1,028 m) and elevation 1,140 m are about 50 degrees, and forms a V shaped valley. Near the top of this steep gorge, on the right bank, there is a small saddle at elevation 1,137 m and the slope from there upward is about 35 degrees up to elevation 1,200 m. On the left bank, the slope above the V shaped valley is about 30 degrees.

At the upstream and the downstream of the dam axis, the slopes of both banks are not so steep. They are 40 degrees at the upstream, and 20 to 30 degrees at the downstream.

3. Talus and River Terrace Deposit

(a) Talus

Main distribution areas of talus deposit around the dam site are as follows:

A site Right bank downstream of dam axis.

B site Left bank about 200 m upstream of the dam axis.

C site Left bank about 400 m downstream of the dam axis.

The area of site A is five hundred meters by four hundred meters and the depth of the deposit is 5 m (DH-5) to 50 m (DH-12), besides, river terrace deposit can be found below the talus deposit near the river bank. The materials which compose this talus are somewhat heterogeneous, and include much gravel at the place near the cliff and a good quantity of clayey soil at the downstream part. Gravel consists of shale and sandstone of varying sizes.

The area of site B is more than five hundred meters by three hundred meters and the depth of the deposit is confirmed to be as 35 m (DH-29). The deposit contains much gravels of shale and sandstone.

The area of site C is about three hundred meters by two hundred meters and the depth is confirmed to be 52 m by drill hole DH-24. It mainly consists of gravel, shale, and silty soil.

The overburden which partly covers the slope of the dam site is the product, weathered and remained in place, of the foundation rock. It belongs to the W_1 type of weathered material described in Chapter 4. 3. The material is mainly gravel and sandy soil.

(b) River Terrace Deposit

Terrace deposits around the dam site are found on both banks upstream and downstream of the dam axis.

The downstream deposit lies under the talus deposit and the material of both deposits are mixed near the boundary, and the elevation of the boundary is not clear, but it is assumed to be roughly at 1,050 m.

The depth of the terrace deposit is from 5 m (DH-4) to 30 m (DH-6) at the right bank and is confirmed to be 20 m at the left bank by drill hole DH-25.

The terrace deposit at the upstream site is small scale and the depth varies from 8 m (DH-17, 20) to 20 m (DH-18).

Permeability test of the deposit has not been performed; but according to the Salvajina Project Report, one drill hole at the downstream site encountered ground water with 0.7 kg/sq.cm pressure. The ground water level assumed by the data of each hole accords with the surface of the deposit. Judging from these data, it is presumed that the permeability of the deposits must be comparatively high.

4. Foundation Rock of the Dam

4.1 General

The rocks distributed around the Salvajina dam site is mainly of alternate layers of shale, quartzose sandstone and shale alternation and conglomerate.

The foundation of the dam consists mainly of this alternation. But at the downstream of the dam, the shale is prevailing, and the conglomerate is distributed further downstream than the shale.

Among the mentioned rocks, the dip and the strike of the quartzose sandstone and shale alternation near the dam axis are clearly observed, but the bedding place of other rocks is indistinct. Generally, the strike and dip of the alternation is N 10° – 40° W, 20° – 40° SW, that is, the direction of the strike is crossing the Cauca River perpendicularly or obliquely and dips upstream. The general structure near the dam site forms a homocline.

The thickness of a single layer is 0.5 m to 2 m. Each of the rock is very siliceous, hard and compact, but the shale and conglomerate, which are distributed downstream, are weathered and the surface is soft of brittle.

4.2 Fissures and Joints

The development of fissures and joints is remarkable in the entire outcrops on the cliff of the dam site. Regular exfoliations parallel to bedding plane are particularly characteristic. The gap of these planes of the exfoliations is generally several mm to several cm and some of them are over ten cm.

This phenomenon can be explained as follows:

The Cauca formation as a whole has undergone strong folding movement, and the homoclinic structure near the dam site is a part of this extensive folding. It is assumed that the fissures parallel to bedding which are found on the outcrop are a kind of fold fissures and probably develop to considerable depth. In fact, as can be seen on many data of permeability test in the boring holes, there are many places leaked easily like caves. The direction of strike and bedding angle at the dam site are N 15° – 60° W and 15° – 45° SW.

In addition to the exfoliation parallel to bedding planes, joints are also developing at this site. These joints can be observed at the ground surface. According to the data of core borings, these joints extend 10 m to 40 m into rock, and disappear at the deeper place. The main direction of the joints are N 30° – 50° E, 75° – 90° SE and EW – N 80° W, 70° – 80° NE.

The abovementioned fissures and joints are not pronounced in the shale, downstream of the dam axis.

4.3 Weathering

Weathering at this site can be divided in two types as follows.

W_1 Type

Rock is hard, but fissures and joints have developed remarkably, therefore rock is cracked and the surface of cracked rock has discolored to brownish orange or reddish brown. If this type of weathering advances more, the surface of the outcrop appears like debris. The boundary between weathered rock and fresh rock of deeper part has the tendency to change sharply in this type of weathering. Furthermore, it has a very high permeability.

W_2 Type

This type of weathering proceeds gradually but deeply, and thick residual soil remains on fresh rock The boundary between weathered rock and fresh rock is not very clear and extends deep into the rock.

The first type of weathering (W_1 type) can be observed around the dam axis including the cliff of both banks. According to the result of drill holes, weathering has developed roughly 10 m (DH-2) to 50 m (DH-3) at the right bank and from 13 m (DH-1) to 57 m (DH-37) at the left bank. In general, the influence of weathering is more severe at higher elevations than at lower elevations.

The second type of weathering (W_2 type) can be observed in the areas of shale. Weathering is most advanced in the slope of downstream of the left abutment, and the area 300 m downstream of the dam axis in the right abutment. The depth of weathering ranges from roughly 2 m (DH-35) to 40 m (DH-19) at both sites.

4.4 Fault and Weak Zone

Major fault can not be found in the outcrop near the dam site. The saddle on the right bank of the dam axis appears to be a fault from the topographic characteristic, but it is a saddle formed by erosion as described in the Salvajina Project Report.

Some thin sheared layers parallel to bedding plane can be found here and there. These sheared layers are not as strike fault. The weak layers are only 1 cm to 10 cm thick.

As described in 4.2, because of many fissures and joints, core recovery of drill holes is very poor. The no core parts are probably fold fissures or weak zone with soft layers, and may be assumed that considerable weak zones exist in the foundation.

4.5 Permeability of Foundation Rock

Permeability of the foundation rock was studied by analyzing data of the 36 of the 41 holes which had been drilled from 1963 to 1965.

The test were conducted under the following conditions.

Spacing	1.5 m interval (5 feet)
Testing time	5 minutes
Pressure at top of hole	3.5 kg/sq.cm (50 PSI)
	7.0 kg/sq.cm (100 PSI)
	14.0 kg/sq.cm (200 PSI)

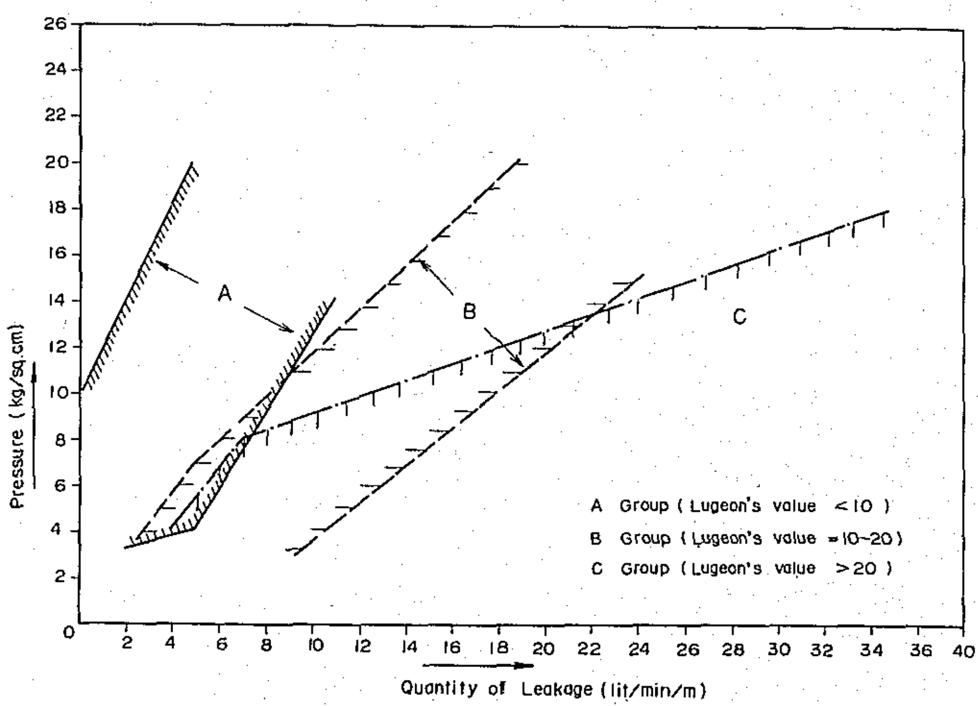
Reviewing the results of these tests, the variation of the quantity of leakage is conspicuous as a whole, and it is judged that Darcy's law is not applicable in the analysis of the data. Therefore, the Lugeon's unit is used to indicate the permeability of the foundation rock. All data are converted to the unit of lit/min/m/10 kg/sq.cm taking into account the head in the drill hole. Besides, data of tests performed at pressures lower than 10 kg/sq.cm or higher than 10 kg/sq.cm are converted into 1 kg/sq.cm unit and then changed to Lugeon's unit, but as the Lugeon's value obtained by this method is not exact, the analysis by the Lugeon's value is mainly performed by using the data of tests which had been performed at a pressure of 10 kg/sq.cm or near 10 kg/sq.cm.

The Lugeon's value thus obtained are divided as follows:

Lugeon's value (L)	Estimation of Permeability	Symbol
L < 5	Very low	a
L = 5 ~ 10	Low	b
L = 10 ~ 20	Medium	c
L = 20 ~ 30	High	d
L > 30	Very high	e

The relation between pressure and quantity of leakage is then studied to examine the relation between pressure and deformation of foundation rock. That is, the relation between the pressure and the quantity of leakage of each hole in the same symbol zone (Lugeon's value) is graphically depicted on Fig. 1.

Fig. 1 Diagram Showing Relation between Pressure and Quantity of Leakage



The abovementioned classification of Lugeon's value is again grouped as follows:

Lugeon's value (L)	Symbol	Group
L < 5	a	A
L = 5 ~ 10	b	A
L = 10 ~ 20	c	B
L = 20 ~ 30	d	C
L > 30	e	C

Group A

The reange of Lugeon's value is mainly from 0 to 10 and the relation between pressure and quantity of leakage is 2:1. The foundation rock which belongs to this group is scarcely deformed under a pressure higher than 14 kg/sq.cm.

Group B

The range of Lugeon's value is mainly from 10 to 20. The relation between pressure and leakage is in direct proportion. However, fissures are opened by pressure higher than 7 kg/sq.cm.

Group C

The Lugeon's value is more than 20 and the relation between pressure and leakage is over 1:3. It is judged from the amount of leakage that fissures in the foundation rock belonging to this group are open and extend to considerable depth.

For the estimation of the permeability at the Salvajina dam site, this site is divided into five divisions for the sake of convenience. The estimation of the permeability of each division is explained below.

(i) Right Abutment

The zone which is located 80 m upstream and downstream of the dam axis is identified as the right abutment area. Seven holes totalling 523 m in length had been drilled in this area.

Generally, the range from ground surface to 30 m or to 60 m belongs to group C, and group A or B deeper into rock. The boundary between group C and group A or B is distinct. Deformation of the foundation rock at the deeper places according to pressure rise is generally small.

Drill hole DH-13 at 1,220 m elevation is an exceptional hole. It belongs to group C from 0 m to 56 m. Deeper than 56 m, groups A and C varying from 5 m to 14 m are interbedded. This fact indicates that many irregular and opened fissures are prevailing down to the deeper part around drill hole DH-13.

(ii) Left Abutment

Six holes totalling 407 m in length had been drilled in this area. As compared with the right abutment area, the permeability of the foundation is generally high.

That is, all of the drill holes, except DH-1 and DH-3 near the river bed, penetrated interbedded layers of groups A, B and C in the whole length of the holes, and the boundary between these three groups is not so distinct as the right abutment. Besides, the quantity of leakage generally increases and the variation between the pressure and the quantity of leakage is remarkable.

(iii) Area Downstream of the Right Abutment

11 holes about 496 m in total length have been drilled. Permeability test had not been

practiced in 3 holes having a total length of 121 m. Talus or alluvial deposits is deep in this area. The exact length of the permeability test is 135 m.

The range from the surface of bedrock (under the deposit) to 10 m belongs to group C and the deeper part belongs to group A or B. Permeability is small compared with the abutment area. But in the range belonging to group A or B, the fissures have a tendency to open at 14 kg/sq.cm pressure.

(iv) Area Downstream of the Left Abutment

7 holes totalling 284 m have been drilled, however, the length of the permeability test is 164 m in total.

The character of this area is similar to that of the opposite bank, that is, from the surface of the bedrock to 10 m it belongs to group C and the deeper part belongs to group A or B.

In this area, the fissures in the foundation near the abutment area (DH-26, 35, 43) are deformed easily at pressures of 14 kg/sq.cm to 16kg/sq.cm.

But, on the other hand, the weak fissures are scarcely found at the location which is apart from the abutment area.

(v) Area Upstream of the Abutment Area

5 holes totalling 169 m have been drilled. However, the length of the permeability test is only 82 m in total. The results of the test indicate a high permeability in the whole area and belong to group C.

The permeability of the foundation rock at the proposed dam site can be summarized as follows.

At the right abutment area highly permeable foundation rock with Lugeon's value of more than 20 is distributed in layers of 30 m to 60 m. The left abutment is also of the same permeable foundation rock with thickness varying from 40 m to 80 m.

The deeper part of the foundation rock has low permeability but there are localized cracks.

The foundation rock has a tendency to deform underwater pressure which is more critical at the left aubtment than at the right abutment.

The permeability of the shale at the area downstream of the abutment area is lower than the alternate layers of quartzose sandstone and shale at the abutment area.

The foundation rock upstream of the abutment area has a high permeability.

4.6 Engineering Judgement on Foundation Rock

As a result of civil engineering and geological studies, an arch-gravity type was selected for the dam. The geological considerations in the case a dam of this type is to be constructed at this site area as given below.

(1) There is a fairly thick distribution of the W_2 type of weathered rock in the area around the dam axis. The horizontal thickness of this weathered rock is 10 m to 20 m from around EL. 1,030 m to around EL. 1,100 m and 20 m to 80 m above EL. 1,100 m. This weathered rock is unsuitable as a dam foundation and would be required to be excavated and discarded.

(2) The basal rock underlying the weathered rock is fresh and hard possessing sufficient bearing strength as a dam foundation. However, since development of cracks is marked in this basal rock it is judged that permeability would be high. Therefore, thorough grouting would be required for water cutoff. It would be necessary for plans to be made to carry out grouting operations to a

considerable depth.

(3) The geological investigations of the dam site have chiefly consisted of borings, but hereafter, more detailed geological data should be obtained utilizing adits to prepare a rock contour of high accuracy.

(4) As stated in Appendix 9, there is a necessity to carry out bearing tests and shearing tests at adits.

5. Geology at Powerhouse Site

The powerhouse is planned at the river bed. The thickness of river bed deposits in this vicinity is approximately 30m according to results of Borings DH-3 and DH-32. The bedrock underlying the sand and gravel has a slightly high number of cracks but, otherwise, is fresh and hard, and is suitable as a foundation for the powerhouse.

II GEOLOGY OF SAN FRANCISCO AND TIMBA SITE

CONTENTS

1. Introduction

The geological investigation for the San Francisco dam site was undertaken from April 1968 to March 1969. The results of this geological investigation have been reported in detail in the Interim Report[1/].

This Appendix is a summary of the abovementioned Interim Report and the results of further investigations of the river bed and right bank were carried out after September 1968.

The quantity of geological survey work performed at this dam site are as follows.

Drill holes	10	Total length	333 m
Adits	2	Total length	80 m
Pit	1	Total length	6 m
Auger holes	3	Total length	28 m

2. Geology of Dam Site (See App. 2, Dwg. No. 1 to No. 5)

The light-brown color outcrops seen at the dam site and the vicinity, except for where covered by topsoil in places, are almost all composed of residual soil of severely weathered shale and sandstone which are the basal rocks. The thickness of this residual soil is approximately 30 m on the dam axis at the left bank and 15 m to 35 m on the dam axis at the right bank. However, the basal rock underlying this residual soil is fresh, hard and dense shale in good condition.

The river bed is wide and covered with thick terrace deposit. The thickness of the sand and gravel deposit is 45 m to 50 m at the left bank and approximately 6 m at the right bank. The basal rock under this deposit is either good shale or sandstone as in the case of basal rock underlying the residual soil.

The geological problems in building a dam at this site will be as follows:

(1) Disposal of the thick residual soil covering both banks.

(2) Prevention of water leakage through the thick sand and gravel deposit on the river bed.

The residual soil, as described in the Interim Report have been completely weathered into clay (W_1 Type Weathered Zone in the Interim Report) and residual soil which is relatively consolidated in its present state (described as W_2 Type Weathered Zone in the Interim Report). The clayey residual soil is not suitable for foundation of impervious core of a fill type dam and must be excavated. But it is difficult to decide at the present stage of investigation whether the impervious core can be constructed on the latter relatively consolidated residual soil.

There are many open cracks in this weathered zone and it is conceivable that there will be leakage of water through these cracks so that it will be necessary to carry out preventive works. According to tests conducted at the Departamento de Ingenieria Civil, Universidad del Valle, for compressive strengths of test pieces of this weathered zone collected from adits, it was found to be 1,200 PSI in a dry condition. The strength dropped to 160 PSI in a moist state. Judging from this result, the question remains whether grouting can be performed on this weathered zone satisfactorily and if performed, whether the grouting will be effective. Therefore, whether or not this weathered zone can be utilized as the foundation for the core and if possible, the required depth of excavation should be decided based on the results of grounting tests at the site.

The preventive work for seepage of water through the sand and gravel deposit on the river bed can either be by grouting or blanket core. And taking into account utilization of the residual soil widely spreaded around the site, it is anticipated that the blanket core method would be more economical than grouting.

1/ The Interim Geologic Report about Timba Project, Yozo Fukutake of Japanese Mission, Aug. 1968.

Besides the above, there is a saddle at an elevation of 1,076 m on the right abutment. The width of this saddle, if the high water level of the dam is EL. 1,057 m, will be approximately 55 m in a horizontal direction. In consideration of the fact that residual soil is approximately 16 m deep from the ground surface and cracking is prominent in the hard shale underneath, cutoff work will also be necessary for this saddle.

The spillway is planned at the left bank of the dam site. Two proposals in the present study, a spillway roughly orthogonal to the river and one roughly parallel to the river were compared and investigated. The result was that the location of a spillway in a direction orthogonal to the river would require less excavation to reach fresh bedrock.

3. Geology of Timba Dam Site

The geology of the Timba dam site had been described in "The Timba Project Report[1], while the results of investigations by CVC on the left bank of the dam site are described in "Proyecto de Timba Informe Parcial" dated March, 1963.

The first report describes in detail the general geology as well as the geology of the dam site while the latter report gives details of field permeability tests and materials.

The quantity of survey work performed in the latter investigations is as follows.

Drill holes	24	Total Length	673.23 m
Test pits	10	Total Length	144.60 m

At downstream of the proposed dam site a broad flood plain spreads out along the Cauca River. The elevation of the river bed at the dam site is approximately 990 m while the width of the river bed is approximately 950 m.

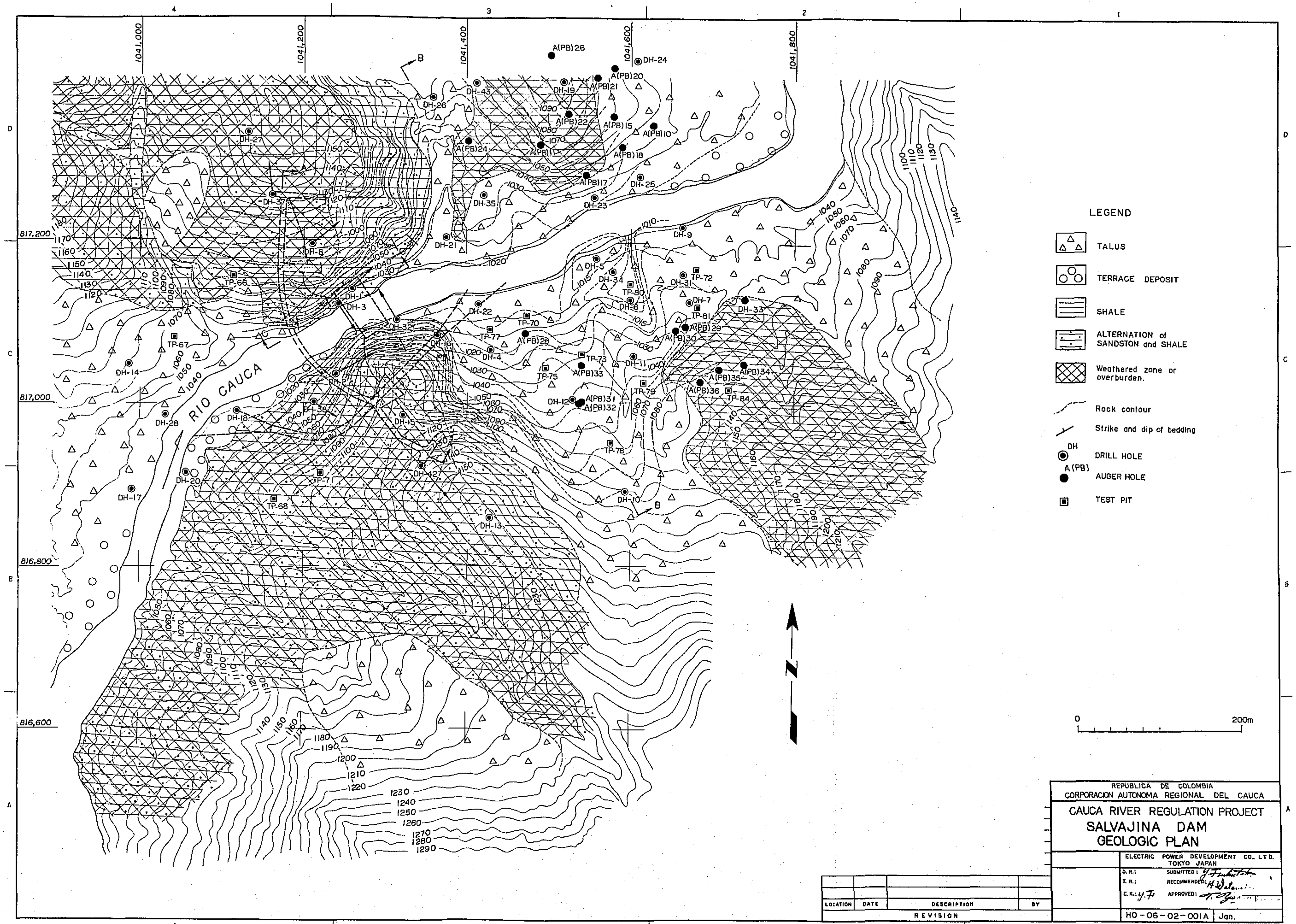
At the abutments of the dam site there are several saddles on both banks at elevations a little lower than the proposed reservoir high water level of EL. 1,027 m.

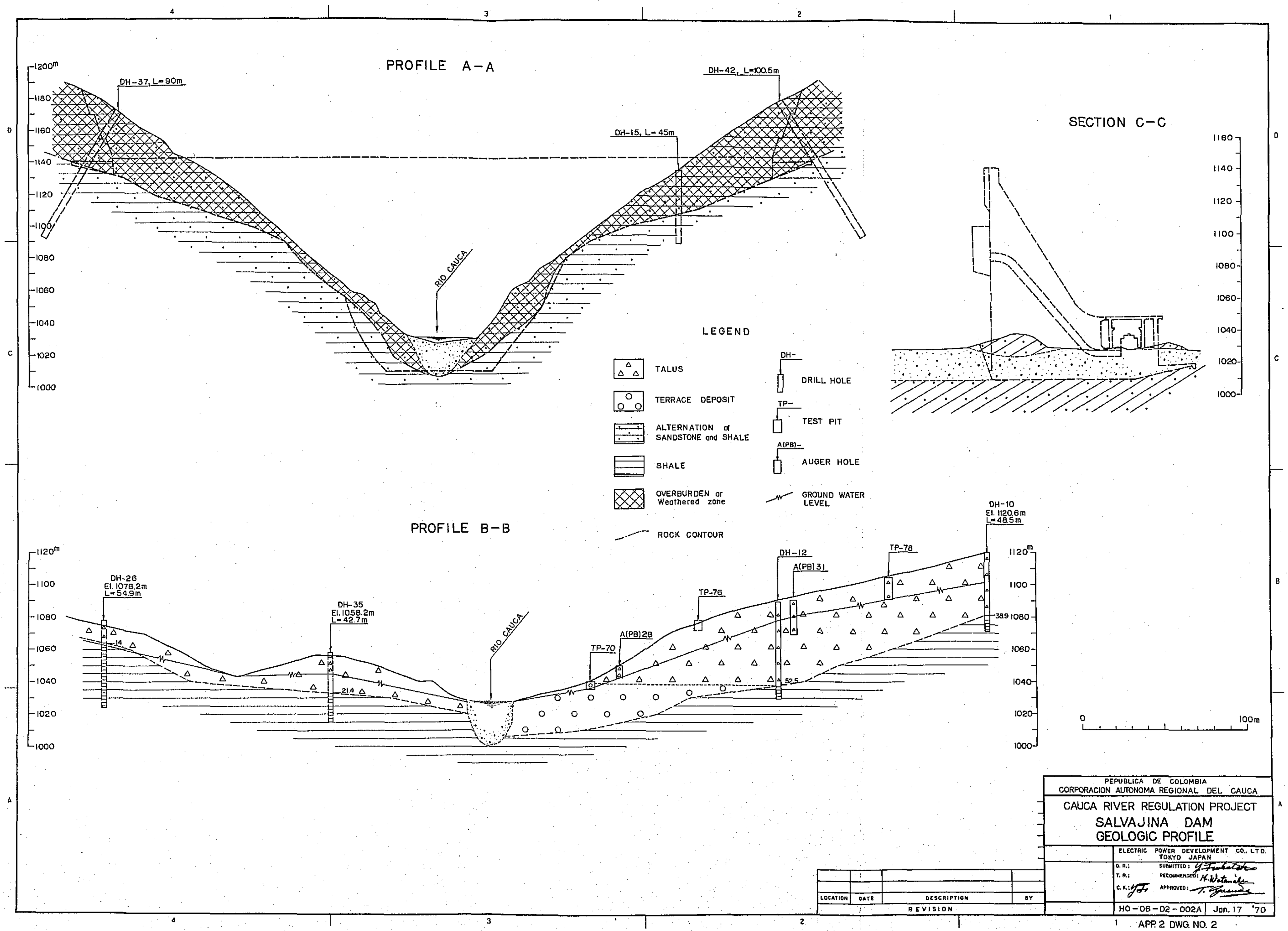
The geology of the dam site is composed of recent river bed sand and gravel deposit, old fan deposit and old river terraces. The depth of the recent river bed deposit is 5 m to 13 m. Weathering is pronounced with marked decomposition to clay of both fan and river terrace deposits so that it is difficult to distinguish between the two.

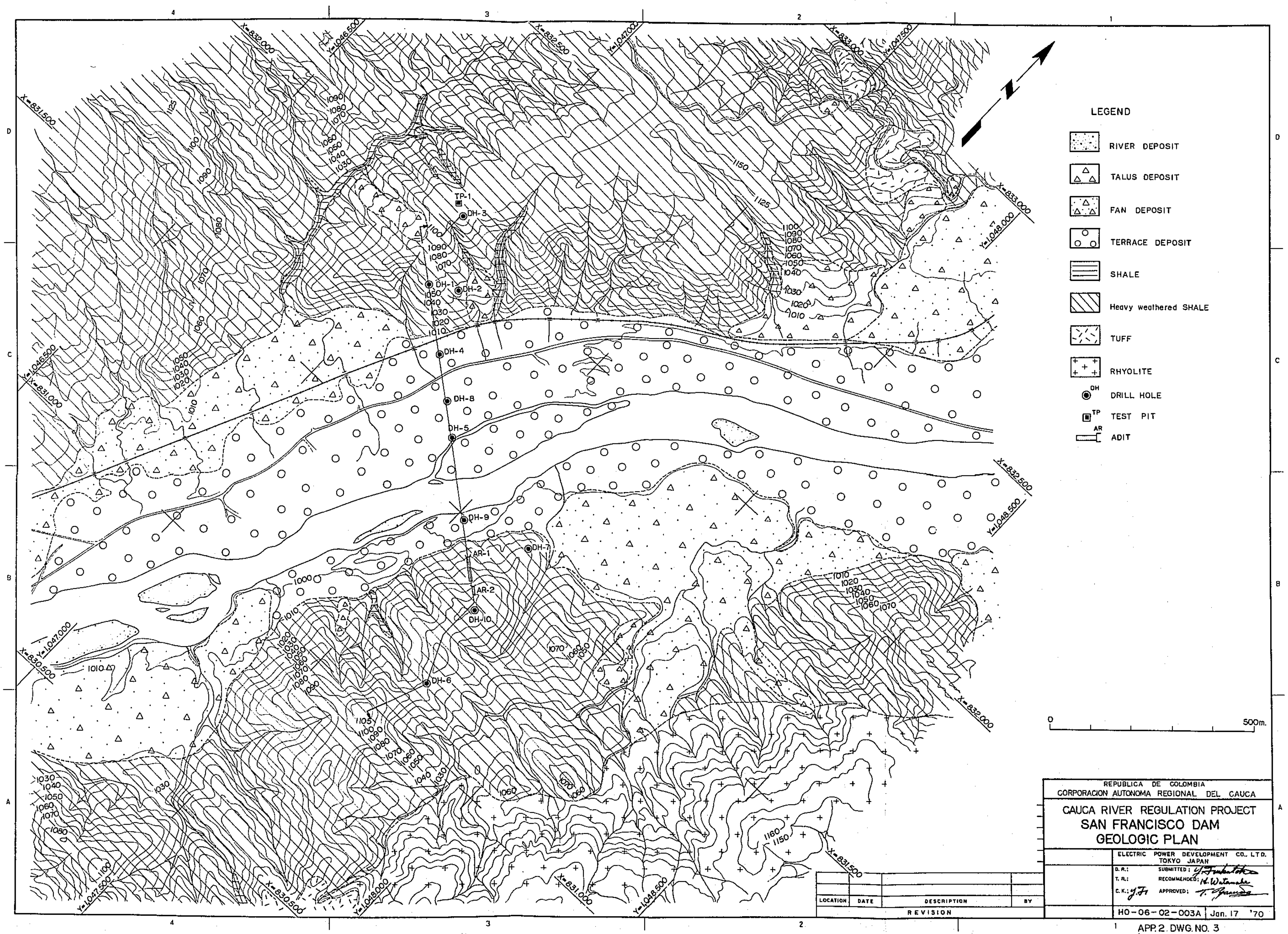
According to The Timba Project Report, the two deposits are termed as "conglomerate." These strata are composed of silty of sandy clay, sand and gravel of various shapes. The thickness of this conglomerate has not yet been confirmed but it might be several tens of meters or more. The conglomerate has been severely weathered and the properties differ as the depth increases from the ground surface. At the upper portion the gravel contained in the clayey deposit is weathered and is soft but in lower portion the gravel is remarkably fresh and hard and is well consolidated as a whole. However, as the geological age of this conglomerate is the Quaternary Period it is not true conglomerate which is completely consolidated. The degree of consolidation being such that the matrix and gravel are easily separated by hammer blow. Therefore, this should be given thorough consideration in design of the dam and other structures.

For details of the geology of this site the two reports mentioned hereinbefore should be referred to.

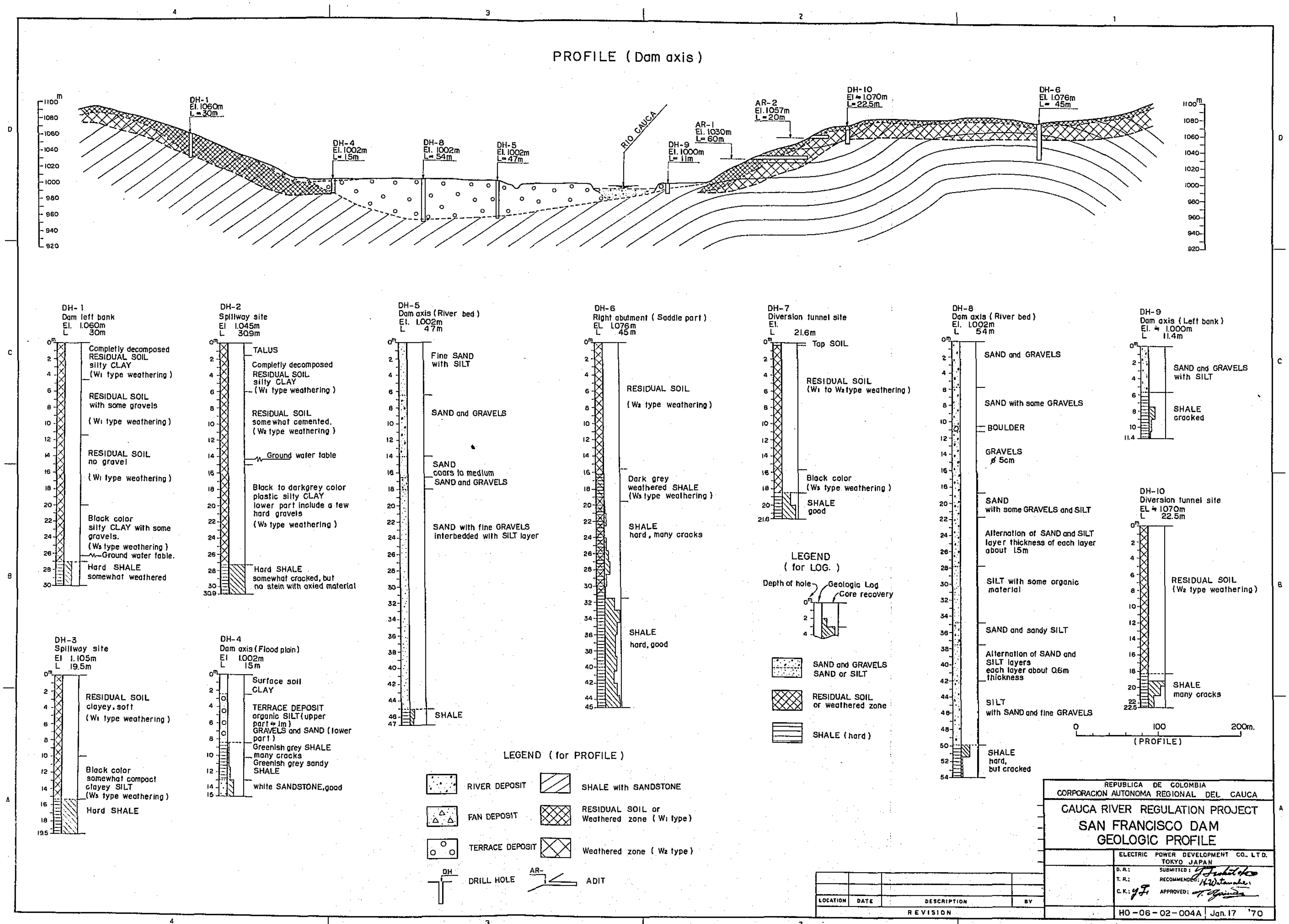
1/ The Timba Project, CVC, OLAP, G & H, TAMS, Apr. 1958.


LEGEND
TALUS
TERRACE DEPOSIT
SHALE
ALTERNATION of SANDSTON and SHALE
Weathered zone or overburden.
Rock contour
Strike and dip of bedding
DH
DRILL HOLE
A (PB)
AUGER HOLE
TEST PIT
0
200m
RIO CAUCA
REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
SALVAJINA DAM
GEOLOGIC PLAN
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
LOCATION
DATE
DESCRIPTION
BY
REVISION
HO-06-02-001A
Jan.
APP. 2 DWG. NO. 1


PROFILE A-A
DH-37, L=90m
DH-42, L=100.5m
DH-15, L=45m
RIO CAUCA
SECTION C-C
LEGEND
TALUS
TERRACE DEPOSIT
ALTERNATION of SANDSTONE and SHALE
SHALE
OVERBURDEN or Weathered zone
ROCK CONTOUR
DH- DRILL HOLE
TP- TEST PIT
A(PB)- AUGER HOLE
GROUND WATER LEVEL
PROFILE B-B
DH-26 El. 1078.2m L=54.9m
DH-35 El. 1058.2m L=42.7m
TP-70
A(PB)28
TP-76
DH-12
A(PB)31
TP-78
DH-10 El. 1120.6m L=48.5m
0 100m
REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
SALVAJINA DAM
GEOLOGIC PROFILE
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
LOCATION
DATE
DESCRIPTION
BY
REVISION
HO-06-02-002A
Jan. 17 '70
APP. 2 DWG. NO. 2

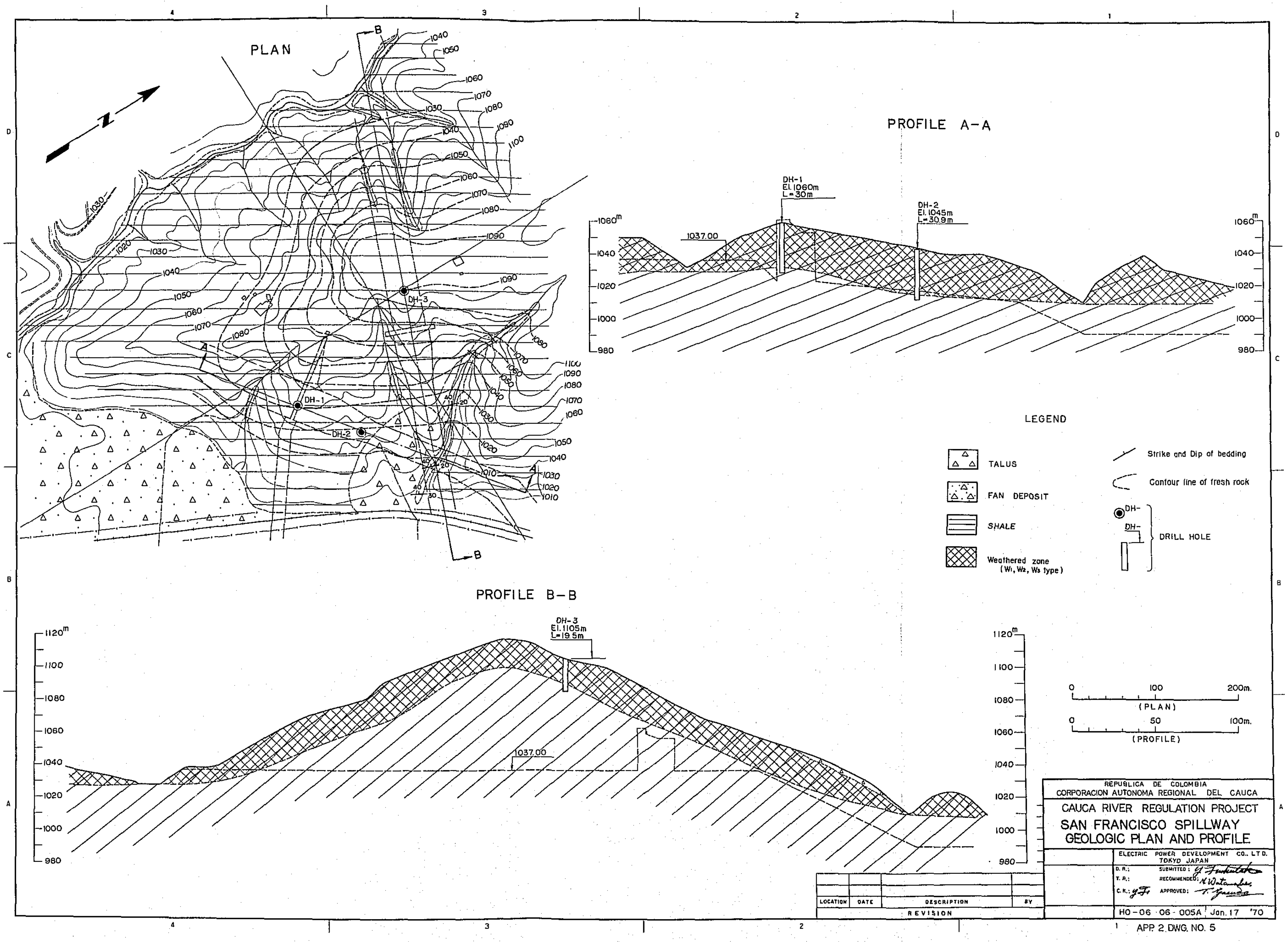

LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
FAN DEPOSIT
TERRACE DEPOSIT
SHALE
Heavy weathered SHALE
TUFF
RHYOLITE
DH DRILL HOLE
TP TEST PIT
AR ADIT
0 500m.
REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
SAN FRANCISCO DAM
GEOLOGIC PLAN
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
HO-06-02-003A
Jan. 17 '70
LOCATION DATE DESCRIPTION BY
REVISION

APP. 2. DWG. NO. 3



PROFILE (Dam axis)
DH-1 El. 1060m L=30m
DH-4 El. 1002m L=15m
DH-8 El. 1002m L=54m
DH-5 El. 1002m L=47m
RIO CAUCA
DH-9 El. 1000m L=11m
AR-1 El. 1030m L=60m
AR-2 El. 1057m L=20m
DH-10 El ≒ 1070m L=22.5m
DH-6 El. 1076m L=45m
DH-1
Dam left bank
El. 1.060m
L 30m
Completly decomposed RESIDUAL SOIL silty CLAY (W1 type weathering)
RESIDUAL SOIL with some gravels (W1 type weathering)
RESIDUAL SOIL no gravel (W1 type weathering)
Black color silty CLAY with some gravels. (W2 type weathering)
Ground water table.
Hard SHALE somewhat weathered
DH-2
Spillway site
El 1.045m
L 30.9m
TALUS
Completly decomposed RESIDUAL SOIL silty CLAY (W1 type weathering)
RESIDUAL SOIL somewhat cemented. (W2 type weathering)
Ground water table
Black to darkgrey color plastic silty CLAY lower part include a few hard gravels (W2 type weathering)
Hard SHALE somewhat cracked, but no stein with oxied material
DH-5
Dam axis (River bed)
El. 1.002m
L 47m
Fine SAND with SILT
SAND and GRAVELS
SAND coars to medium
SAND and GRAVELS
SAND with fine GRAVELS interbedded with SILT layer
SHALE
DH-6
Right abutment (Saddle part)
EL 1.076m
L 45m
RESIDUAL SOIL (W2 type weathering)
Dark grey weathered SHALE (W2 type weathering)
SHALE hard, many cracks
SHALE hard, good
DH-7
Diversion tunnel site
El.
L 21.6m
Top SOIL
RESIDUAL SOIL (W1 to W2 type weathering)
Black color (W2 type weathering)
SHALE good
LEGEND (for LOG.)
Depth of hole
Geologic Log
Core recovery
SAND and GRAVELS SAND or SILT
RESIDUAL SOIL or weathered zone
SHALE (hard)
DH-8
Dam axis (River bed)
El. 1.002m
L 54m
SAND and GRAVELS
SAND with some GRAVELS
BOULDER
GRAVELS ø 5cm
SAND with some GRAVELS and SILT
Alternation of SAND and SILT layer thickness of each layer about 1.5m
SILT with some organic material
SAND and sandy SILT
Alternation of SAND and SILT layers each layer about 0.6m thickness
SILT with SAND and fine GRAVELS
SHALE hard, but cracked
DH-9
Dam axis (Left bank)
El. ≒ 1.000m
L 11.4m
SAND and GRAVELS with SILT
SHALE cracked
DH-10
Diversion tunnel site
EL ≒ 1070m
L 22.5m
RESIDUAL SOIL (W2 type weathering)
SHALE many cracks
0 100 200m. (PROFILE)
DH-3
Spillway site
El 1.105m
L 19.5m
RESIDUAL SOIL clayey, soft (W1 type weathering)
Black color somewhat compact clayey SILT (W2 type weathering)
Hard SHALE
DH-4
Dam axis (Flood plain)
El 1.002m
L 15m
Surface soil
CLAY
TERRACE DEPOSIT organic SILT (upper part ≒ 1m) GRAVELS and SAND (lower part)
Greenish grey SHALE many cracks
Greenish grey sandy SHALE
white SANDSTONE, good
LEGEND (for PROFILE)
RIVER DEPOSIT
FAN DEPOSIT
TERRACE DEPOSIT
DRILL HOLE
SHALE with SANDSTONE
RESIDUAL SOIL or Weathered zone (W1 type)
Weathered zone (W2 type)
ADIT
LOCATION DATE DESCRIPTION BY
REVISION
REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
SAN FRANCISCO DAM
GEOLOGIC PROFILE
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
D. R.: SUBMITTED:
T. R.: RECOMMENDED:
C.K.: APPROVED:
HO-06-02-004A Jan. 17 '70

APP.2 DWG.NO.4


PLAN
N
DH-1
DH-2
DH-3
B
A
PROFILE A-A
DH-1
El. 1060m
L=30m
DH-2
El. 1045m
L=30.9m
1037.00
LEGEND
TALUS
FAN DEPOSIT
SHALE
Weathered zone (W1, W2, W3 type)
Strike and Dip of bedding
Contour line of fresh rock
DRILL HOLE
PROFILE B-B
DH-3
El. 1105m
L=19.5m
1037.00
0 100 200m.
(PLAN)
0 50 100m.
(PROFILE)
REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
SAN FRANCISCO SPILLWAY
GEOLOGIC PLAN AND PROFILE
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
LOCATION DATE DESCRIPTION BY
REVISION
HO-06-06-005A Jan. 17 '70
APP. 2 DWG. NO. 5

III SEISMIC DESIGN OF SALVAJINA DAM AND POWER PLANT

CONTENTS

1. Outline

Colombia is situated at the northern part of the Andean Zone which is one of the earthquake regions of the world[1/]. The Andean Zone has a unique topography as a result of rising of the huge Andes earth mass in consequence of the movement of the earth crust throughout the entire western coast of the South American Continent. The Andean Earthquake Zone is a belt running roughly north-south covering the Andes Mountain Range and the Pacific Coast. Therefore, Colombia which is located at the northern part of this belt has experienced a lot of earthquakes from ancient times. Internally, the earthquake area of the country may be divided into four zones[2/]. These are as follows:

(1) Cordillera Central Zone
(2) Cordillera Oriental Zone
(3) Cordillera Occidental Zone
(4) Northeast Zone

Earthquake observation in Colombia is being carried out actively, especially since installation of Bogota Observation Station.

According to Reference[2/], many severe earthquakes have occurred in the area around Pasto where four of the abovementioned earthquake zones converge. The characteristic of the earthquakes in this area is that they are tectonic earthquakes and it is thought many of the earthquakes have epicenters at depth of several tens of kilometers.

2. Seismicity of Salvajina Site

The Salvajina Site is located approximately 190 km northeast of Pasto and is sandwiched by the Cordillera Central Zone and the Cordillera Occidental Zone. Illustrating the epicenters and intensities of earthquakes which have occurred within a range of 150 km east-west and north-south with the Salvajina Site at the center based on Reference[2/], the result is as shown in Fig. 2. According to this figure, several earthquakes of Intensity III and II have occurred approximately 50 km south (at the northern part of Popayan City) of the Salvajina Site.

Although not precise because of scant data, shaly sandstone comprises the basal rock and it may be thought that a complex structure is presented through compression from folding action of the earth crust. Therefore, occurrence of tectonic earthquakes must be expected. It should be considered that the earthquake characteristics in this region will be a short period (about 0.5 seconds) with a relatively great acceleration.

3. Seismic Design of Salvajina Dam and Power Plant

For the above seismicity, it will be necessary to pay attention to the following points in seismic design of structures of the Salvajina Project.

(1) Some degree of movement should be expected in relation to geological structures or large faults.

(2) The earthquakes which can be expected will be so-called tectonic earthquakes and it is conceivable that earthquakes of high acceleration locally, in other words, earthquakes of strong seismicity locally can occur.

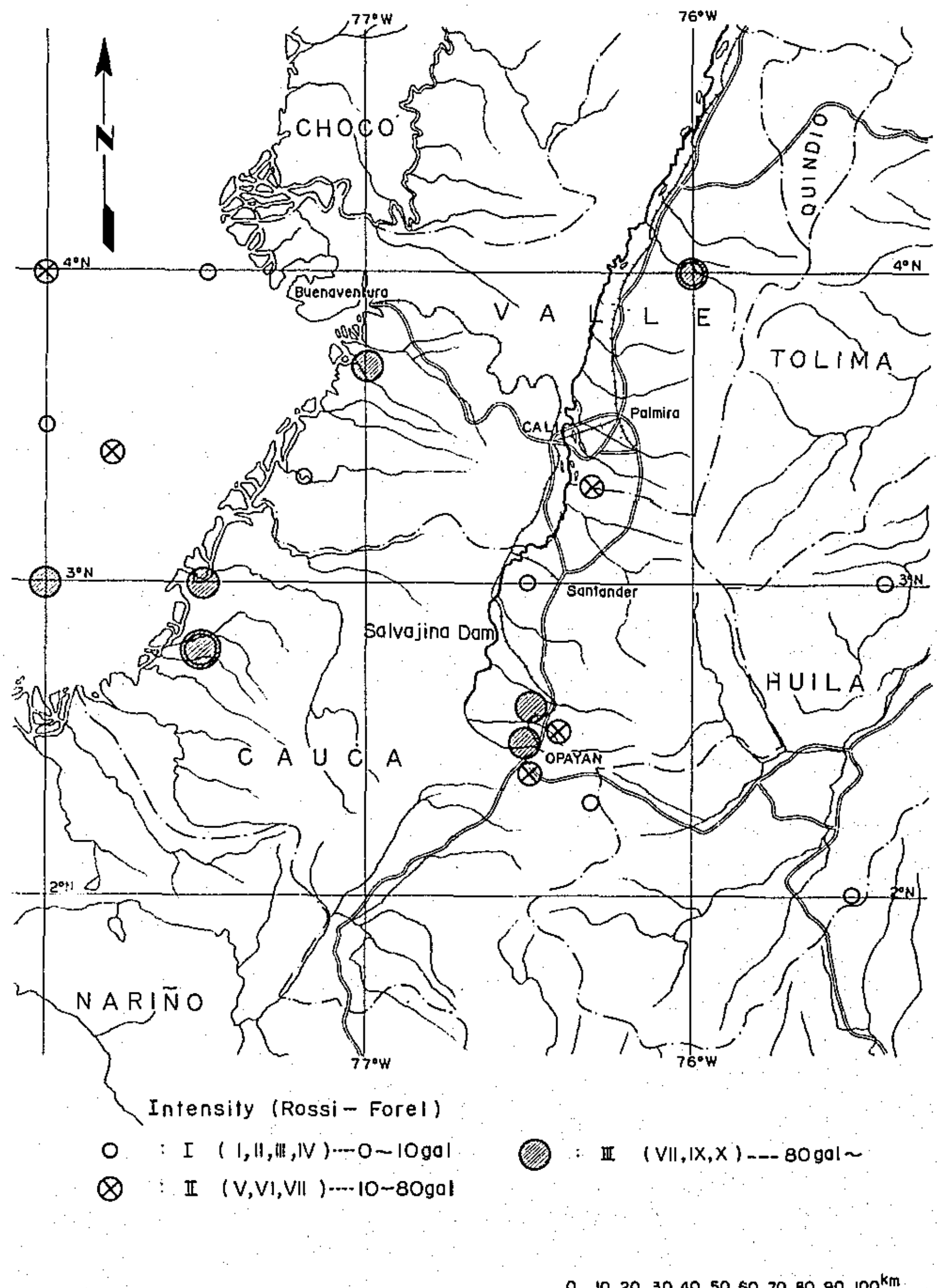
(3) Therefore, in design of structures, seismicity factor of about $K = 0.15$ should be adopted and the stability of structures at time of earthquake should be required to be checked.

Generally speaking, it should be considered that large arch-gravity dams of the height of 100 m or more and 400 m to 500 m crest length will show a kind of flexural vibration behavior due to earthquake movement. From actual records it is known that the crest of such a dam vibrates several times more than the foundation.

1/ Seismicity of the Earth, by B. Gutenberg and C.F. Richter
2/ Instituto Geofisico de Los Andes Colombianos

The natural period of a dam of this size is around 0.4 seconds with the damping coefficient of about several percent, and it is in the range of the predominant period of the foundation bedrock. Although there is possibility of occurring resonance like phenomenon in case of the earthquake of which the epicenter is close by and there are many waves of short periods, but in actual cases, earthquake vibration will be damped before reaching resonance because not all the energy of the movement would be absorbed in the dam. In an actual example experienced in Japan, an arch-gravity dam with a height of 150 m was subjected to an earthquake of a magnitude of 7.7 approximately 100 km from the epicenter. The expected maximum acceleration in the bedrock at the dam site is considered to be high, but a design seismic coefficient of K = 0.15 is considered to be appropriate.

Fig. 2 Intensity of Earthquake



APPENDIX 3

PRESENT STATUS OF AGRICULTURE IN CAUCA PLAIN

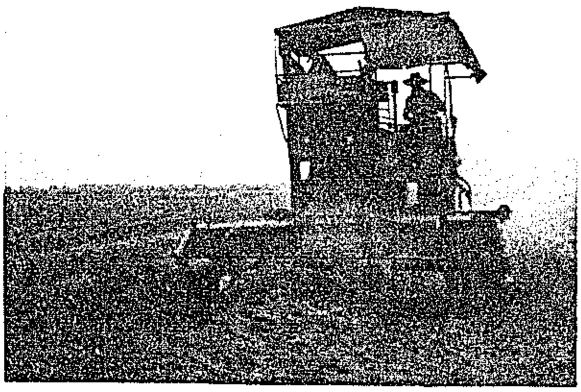
APPENDIX 3 PRESENT STATUS OF AGRICULTURE IN CAUCA PLAIN

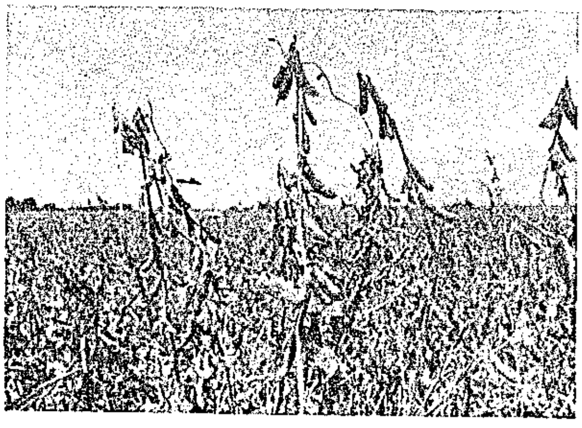
CONTENTS

List of Tables

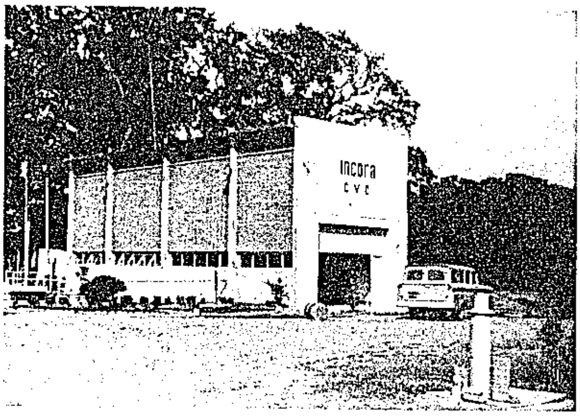
List of Figures

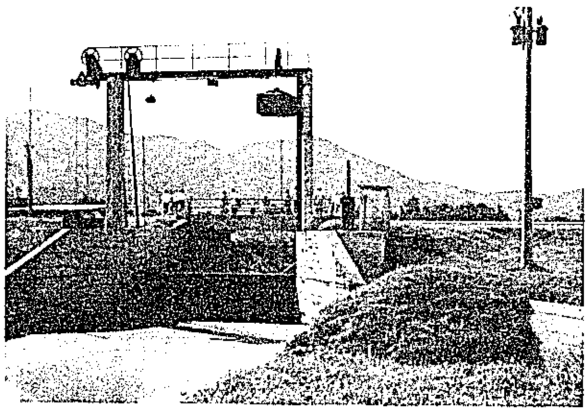
Agriculture in Cauca Plain

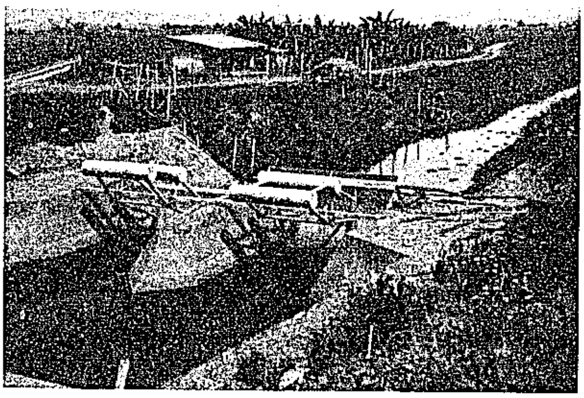




Irrigation and Drainage Facilities in R-U-T Project







1. Soil[1/]

Soils in the Cauca Plain are composed mainly of volcanic ash and water transported sediment of weathered shale, sand stone and diabase rock. The layer of topsoil generally has thickness of more than 120 cm, and its texture is of from sandy loam to clay. According to the topographical feature, soils are classified into soil associations of terrace, alluvial plain, levee, etc. (shown in Fig. 1). Principal characteristics for these soil series are shown in Table 1.

The cross section between Palmira and Yumbo shows a typical one of the Cauca Plain with regard to abovementioned soil associations. Soil associations of A_4, A_5, A_6, R are distributed in order from Cordillera Central to Cauca River. A_4 distributed near the mountain side consists mainly of coarse materials such as sand and gravel with pH 5 - 6.5. A_5 which is medium composition with pH 6.5 - 7.5 is distributed in the middle part of the Cauca Plain and A_6 is fine materials such as clay, loam with pH 7 - 8.5. Generally speaking, the organic matter is scarcely contained. Potassium content is gradually increasing from A_4 to A_6, 100 - 200 kg/ha in A_4, 300 - 400 kg/ha in A_5 and 400 - 500 kg/ha in A_6. Phosphate content is 5 - 20 kg/ha in A_4, 20 - 80 kg/ha in A_5, and 20 - 40 kg/ha in A_6.

Chemical properties are not necessarily favorable as mentioned above, but physical characteristics seem to be fairly good as shown in Table 1. That is, gradient of surface, tillage, water holding capacity and permeability, etc. are suitable for agriculture production. On the other hand, a fairly wide area with poor drainage is found and it is necessary to construct drainage facilities as well as to control flood to improve these unfavorable conditions. Based on the items in Table 1, soils of the Cauca Plain are classified into five classes from the standpoint of crop cultivation as shown in Fig. 2.

Class I - Ground surface is nearly level — Soils are moderately well drained and have adequate moisture holding capacity. Sufficient depth of topsoil easy to till and well suited as good or excellent crop land and pasture land. Soils in this class subjected to flooding are classified as Class III.

Class II - Soils of Class II are a little inferior to that of Class I in plant nutrients, drainage, etc. But they are regarded as fair or good crop land and pasture land under average management practices. Some soils in this class subjected to flooding are classified as Class III.

Class III - This class has an undesirable texture, low water holding capacity, poor drainage and is susceptible to flooding. It is regarded as poor or fair for crop land and fair or good for pasture under average management practices.

Class IV - This class is subjected to frequent flood and subterranean water table is high all the year round. Some are susceptible to erosion. This class is physically poor for cropping but good to poor for pasture for average management practices.

Class V - This class is poorly suited for agriculture and pasture because of excess-humidity, frequent flooding and large amount of gravel.

As shown in Fig. 2, the area classified as Class I extends in a belt zone located in both sides of Cauca River and the area of Santa Ana-Palmira-Guacari and Tulua-Bugalagrande. Area classified as Class V is dotted in the above belt zone of Class I. This class is mainly located in the old river bed or in the neighborhood of poor drainage condition. Furthermore, low swampy land classified as class V is found in Santander-Villarica, and soils with high alkali content are widely distributed in the area of Calipuerto and Rozo caused by poor drainage.

1/ (i) Clasificación por capacidad de uso del suelo del valle Geográfico del Rio Cauca. (Depto. Agropecuario, Sección de Suelos, CVC, Nov. 1966)
(ii) Reconnaissance soils survey of the flat part of the Cauca Valley. (William E. Reese, Dock Goosen. FAO 1957).
(iii) Análisis químicos y físicos de los suelos por Palmira (Sección Suelos, CVC).
(iv) Estudio detallado de suelos del Municipio de Palmira (Sección de Suelos, CVC).
(v) Propiedades físicas de algunos suelos del Municipio de Palmira (Tesis de Grado, 1964, Universidad Nacional de Colombia, Facultad de Agronomia).

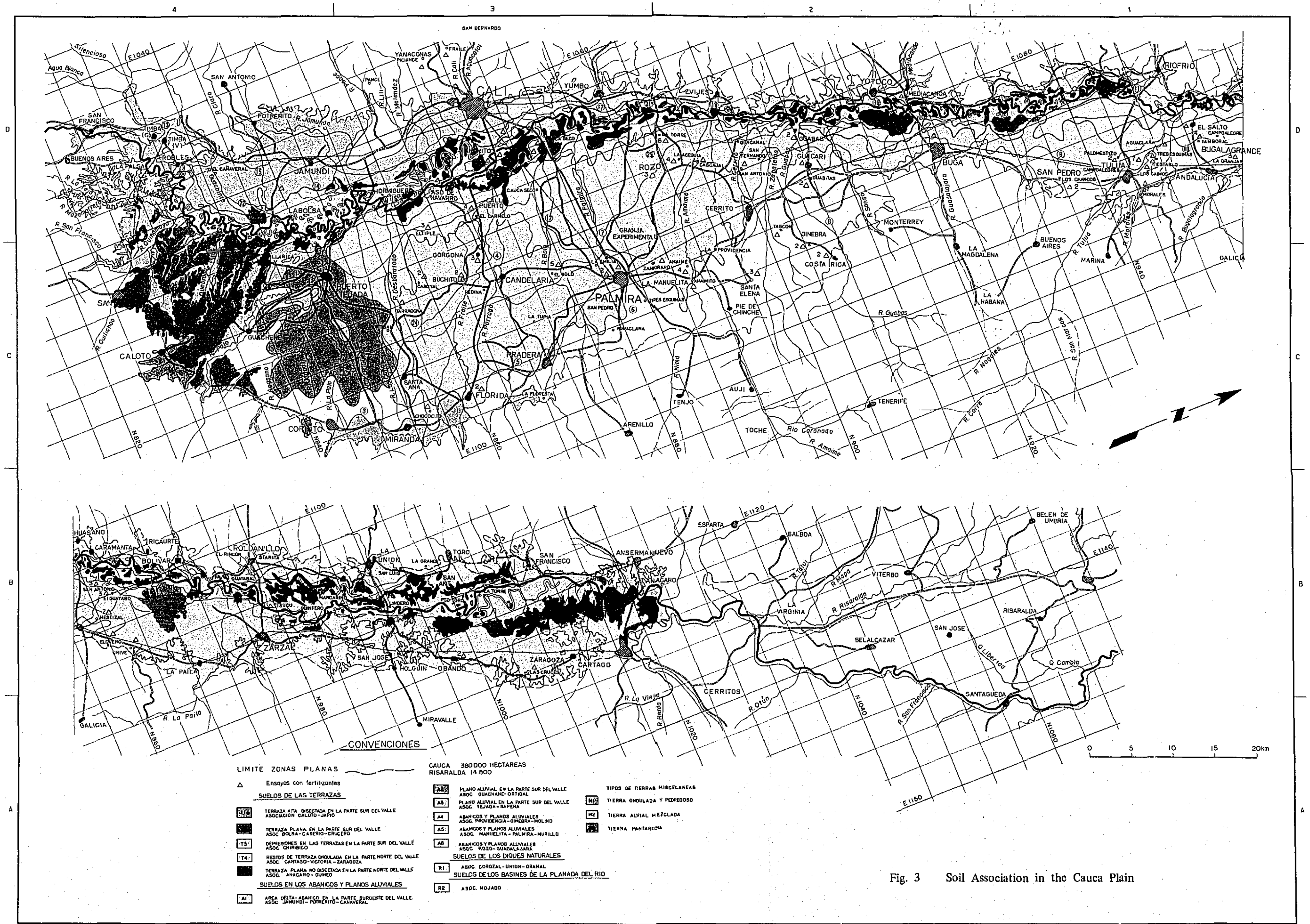


Fig. 3 Soil Association in the Cauca Plain

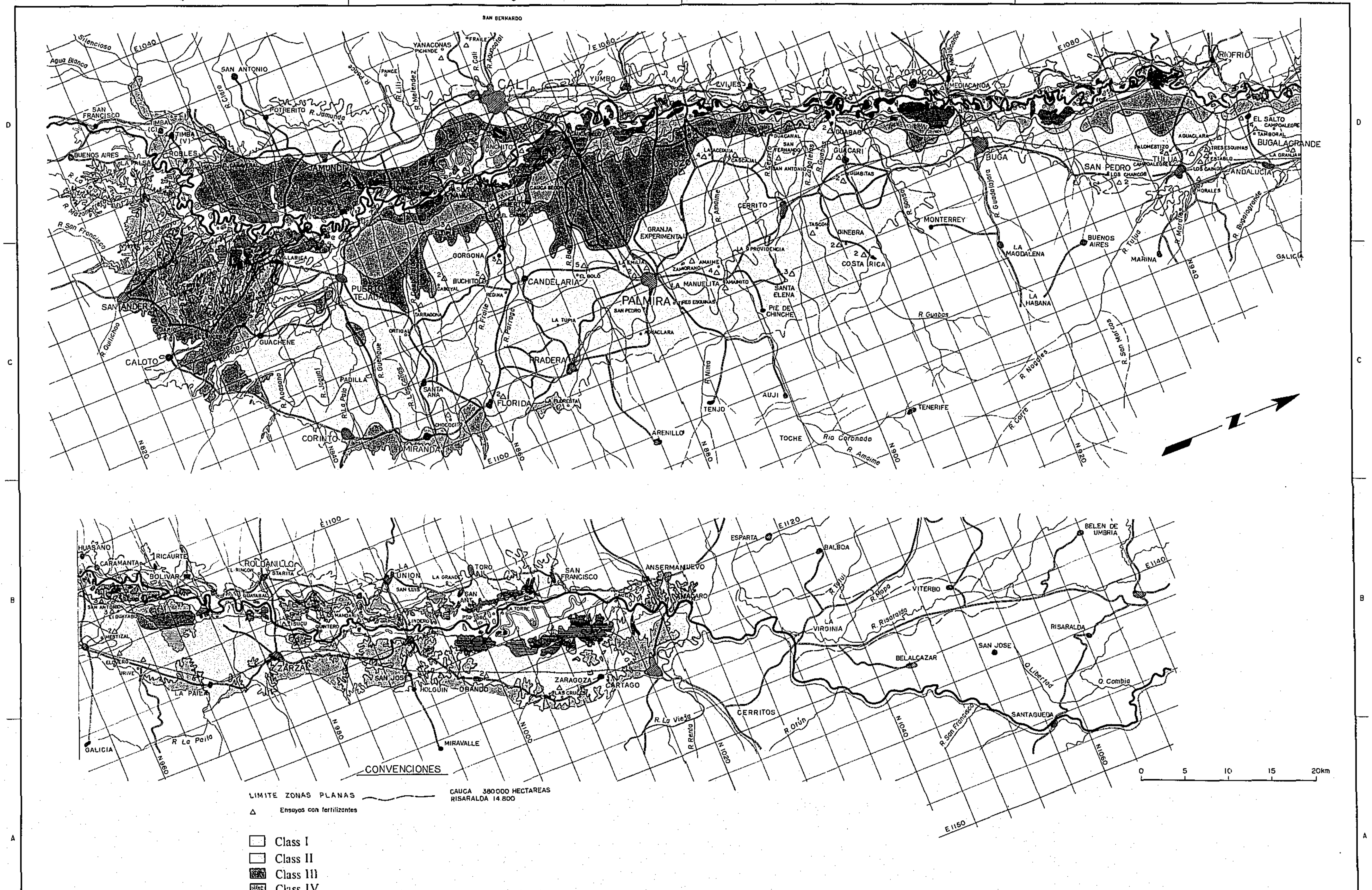


Fig. 2 Land Classification in the Cauca Plain

Table 1 Soil Classification

RESUMEN DE LAS CARACTERISTICAS MAS IMPORTANTES DE LAS SERIES DE SUELOS DEL VALLE DEL RIO CAUCA

Clasificacion por capacidad de Uso del Suelo del Valle Geografico del Rio Cauca (Dept. Agropecuarrio Seccion de Suelos Nov. 1966)

"Suelos de las terrazas"

Clase	SERIES	Posición fisiográfica	Símbole en el mapa (Asociacion) 1/	Material Parental	Relieve dominante	Clase de drenaje	SUELO 2/		SUB-SUELO		Textura	Permeabilidad	Duracion de la altura del nivel freatico 3/	Condiciones de humedad 4/	Inundabilidad
							Color	Consistencia	Color	Consistencia					
2	CALOTO	Terraza altamente disectada al Sureste del Valle	T1	Roca meteorizada pardo rojiza, Material de cenizas volcánicas (Tobas).	Ondulado pendiente suave	Moderadamente bien drenado	Pardo gris oscuro	Friable	Gris oscuro y amarillento	Friable	Franco arcillo limoso a arcillo limoso	Regular a pobre	Nula	Buena	Nula
2	JAPIO	Terraza alta disectada del Sureste del valle	T1	Roca meteorizada pardo rojiza, Material de cenizas volcánicas (Tobas)	Plano a ondulado	Imperfecto	Pardo muy oscuro		Pardo amarillento oscure moteado en rojo.	Duro cuando seco,	Franco arcilloso	Pobre	Mediana	Regular	Nula
3	BOLSA	Terraza plana al Sureste del Valle.	T2	Depósitos lacustres con abundantes cenizas volcánicas.	Pano a suavemente ondulado	Bien drenados	Parde muy oscuro.	Duro cuando seco.	Pardo rojizo oscuro.	Duro cuando seco.	Arcillo limoso a franco arcilloso	Regular	Nula	Buena	Nula
3	CASERIO	Terraza plana al Sureste del Valle.	T2	Depósitos lacustres con abundantes cenizas volcánicas.	Casi plano	Moderamente bien drenado.	Negro a pardo gris muy oscuro.	Duro cuando seco.	Pardo oscuro a pardo gris muy oscuro.	Duro cuando seco.	Arcillo limoso a franco arcilloso	Regular	Breve	Buena	Nula
3	*CRUCERO*	*Terraza plana al* Sureste del Valle.	T2	*Depósitos la*custres con abundantes cenizas volcánicas,	*Plano*	*Pobre*	*Negro a* pardo gris muy oscuro.	*Friable*	Pardo amarillento con meteaduras pdo. amarillentas y rojizas.	*Plástico*	Arcillo limoso a arcilloso.	Pobre	Prolongado	Pobre	Nula
4	CHIRIBICO	Depresiones en áreas de las *terrazas* del sureste del Valle.	T3	Mezcla de materiales aluvia*les y de origen* lacustre.	Ligeramente *plano.*	Muy pobre	Negro	Plástico	Gris con meteaduras pardo amarillentas.	Plástico	Arcillo a arcillo limoso.	Alta	Prolongado	Excesivo	Frecuente
4	CARTAGO	Restos de colinas onduladas en la parte norte del Valle.	T4	Cenizas volcánicas tierras diatomáceas arena y grava, todo en estractificaciones.	Ondulado a ligeramente escarpado.	Moderadamente bien drenado	Pardo gris oscuro a muy oscuro	Duro cuando seco.	Gris muy oscuro a pardo amarillento oscuro.	Duro cuando seco.	Franco arenoso Franco arcilleso arenoso y Frco. arcilloso.	Buena	Nula	Regular	Nula
2	VICTORIA	Restos de colinas onduladas en la parte norte del Valle	T4	Cenizas volcánicas tierras diatomáceas arena y grava, todo en estractificaciones.	Plano a ligeramente plano.	Imperfecto	Pardo gris oscuro a muy oscuro.	Friable	Pardo gris oscuro y presencia ocasional de meteadúras prdo. amarill.	Duro cuando seco.	Franco arcillo limoso a Frco. arcilloso.	Pobre	Mediana	Regular	Nula
4	ZARA-GOZA	Restos de colinas onduladas en la parte norte del Valle.	T4	Cenizas volcánicas tierras diatomáceas arena y grava, todo en estractificaciones.	Depresiones	Pebre	Pardo gris muy oscuro.	Plástico	Pardo gris muy oscuro.	Plástico	Arcillo limoso arcilleso	Muy pebre	Prolongado	Pobre	Frecuente
3	ANACARO	Terraza plana no disectada al noreste del Valle.	T5	Depósitos lacustres con materiales de cenizas volcánicas y tierra diatomacea.	Plano a ligeramente plano.	Imperfecto	Negro a gris muy oscuro.	Friable	Pardo gris muy oscure.	Duro cuando seco.	Franco arcillo limoso a Frco. arcilloso.	Pobre	Mediana	Regular	Nula
4	ZARA-GOZA	Restos de colinas onduladas en la parte norte del Valle.	T4	Cenizas volcánicas tierras diatomáceas arena y grave, todo en estractificaciones.	Depresiones	Pobre	Pardo gris muy oscuro.	Plástico	Pardo gris muy oscuro.	Plástico	Arcillo limoso arcilloso	Muy pobre	Prolongado	Pobre	Frecuente
3	ANA-*CARO*	Terraza Plana no *disecotda la* noroste del Valle.	T5	Depósitos lacus*tres con mate*riales de cenizas volcánicas y tierra diatomacea.	Plano a *ligera*mente plano.	Imper*fecto*	Negro a gris muy oscuro.	Friable	Pardo gris muy oscuro.	Friable	Franco arcilloso	Regular a Bueno.	Mediano	Regular	Ocasional
2	GUINEO	Terrazas planas no disectadas al noreste del Valle.	T5	Depósitos lacustres con materials distemaceos y cenizas volcánicas.	Plano a ligeramento plano.	Imperfecto	Negro a gris muy escuro	Friable	Láminas con variaciones prdas. y Mot. gris oscuro.	Duro cuando seco.	Franco arcilloso	Regular a Bueno.	Mediano	Regular	Ocasional

"SUELOS DE LAS PLANICIES"

3	CORO-ZAL	Planada natural	R1	Aluviones estratificados con texturas gruesas y medianas.	Ligeramente plano a suavemente ondulado.	Bien drenado	Prdo. amarillento a pardo gris oscuro.	Friable	Pardo y pardo amarillento.	Friable	Franco limoso a franco arcillo limoso.	Bueno	Breve	Bueno	Ocasional
3	UNION	Planada natural	R1	Aluviones estratificados con texturas gruesas y medianas.	Ligeramente plano a suavemente ondulado.	Moderadamente bien drenado	Varios tonos de pardo.	Friable	Varios tonos de pardo	Duro cuando seco.	Franco arcillo limoso a franco arcilloso.	Bueno	Breve	Bueno	Ocasional
3	GRAMAL	Planada natural	R1	Aluviones estratificados con texturas gruesas y medianas.	Casi plano	Imperfecto	Negro, gris muy oscuro y pardo gris muy oscuro.	Friable	Pardo amarillento oscuro con meteaduras pardo grises.	Duro cuando seco.	Franco arcillo limoso a franco arcilloso.	Pobre	Prolongado	Regular	Frecuente

"SUELOS DE LAS ZONAS ENCHARCABLES"

4	MOJADO	Area de la planicie de inundación del río Cauca.	R2	Aluviones del río Cauca de texture fina.	Plano	Drenaje pobre	Negro a pardo gris muy oscuro	Plástico	Gris oscuro con meteaduras pardas.	Plástico	Arcillo limoso a arcilloso.	Muy pobre	Muy prolongado	Muy pobre	Frecuente

5 Tierras pantanosas, aluviales mezclades, Onduladas pedregosas.

CONVENCIONES:

1/ Para asociaciones de Suelos.

2/ Capa siguiente a la capa arable.

3/ Breve 0 - 2 meses
Mediano 2 - 4 meses
Prolongado 4 - 8 meses
Muy Prolog. 8 - 12 meses

4/ Condiciones de humedad que afectan el normal crecimiento de la mayor parte de los cultivos.

Chemical and Physical Analysis of Soil in Palmila

Soil of Palmira-Rozo area is classified as Class III in Fig. 2 because of poor drainage.

Detailed investigations carried out by CVC (Fig. 3), reveal problems of saline and alkali soil which are found in this area. According to soil analysis shown in Tables 2(1), 2(2), soils are generally regarded as heavy soils with high clay content. pH value of A-layer is more or less neutral. On the other hand, pH value and sodium content of B-layer is higher than A. Even though the content of organic matter is rather low (2 - 5%), the basic exchangeable capacity and fertilizing effect seem to be greater because of heavy clay content. In Table 3 is shown irrigation engineering index of soils in the same area, such as specific weight, field capacity, water equivalent, etc.

Table 2(1) Chemical Analysis of Soil in Palmira

Sample No.	Horizontal Layer (cm)	pH	Miliequivalent for 100 grs of Soil								Relation of Nitrogen & Carbon			Texture
			Ca	Ma	K	Na	H	Total Basis	Sodium	Basic Exchange Capacity	N	C	C/N	
136A	0-40	7.70	32.14	3.19	0.97	0.32	18.56	36.62	0.9	55.18	0.132	1.86	13.98	Clay
	40-70	6.78	30.02	3.82	0.23	0.42	20.93	34.49	1.2	55.42	0.062	0.56	9.03	Clay
1,067A	0-35	6.60	4.04	8.60	0.59	2.11	7.44	15.34	13.8	22.78	0.136	1.02	7.50	Loan
	35-60	8.35	5.77	10.61	0.67	3.88	0.81	20.93	18.5	21.74	0.048	0.22	4.58	Silty Loam
M-1526	10-50	8.25	5.05	16.93	1.76	17.10	-	40.84	42.0	30.23	0.15	0.53	3.53	Clay
	50-100	8.95	5.16	10.43	1.21	14.53		31.54	46.0	10.64	0.05	0.08	1.60	Clay
M-1535	0-10	7.10	8.51	9.61	0.57	11.39	-	30.08	37.0	26.53	0.49	1.05	2.14	Silty Loam
	10-30	8.30	8.25	12.31	0.71	28.74		44.83	53.0	34.27	0.17	0.64	3.76	Clay
M-1543	0-30	7.00	19.11	11.96	1.98	0.81	-	33.86	2.4	32.09	0.24	2.21	9.08	Clay
	30-55	7.35	15.95	12.04	0.80	1.87		30.66	6.1	29.40	0.14	0.47	3.28	Clayey Loam

Table 2(2) Chemical Analysis of Soil in Cauca Plain

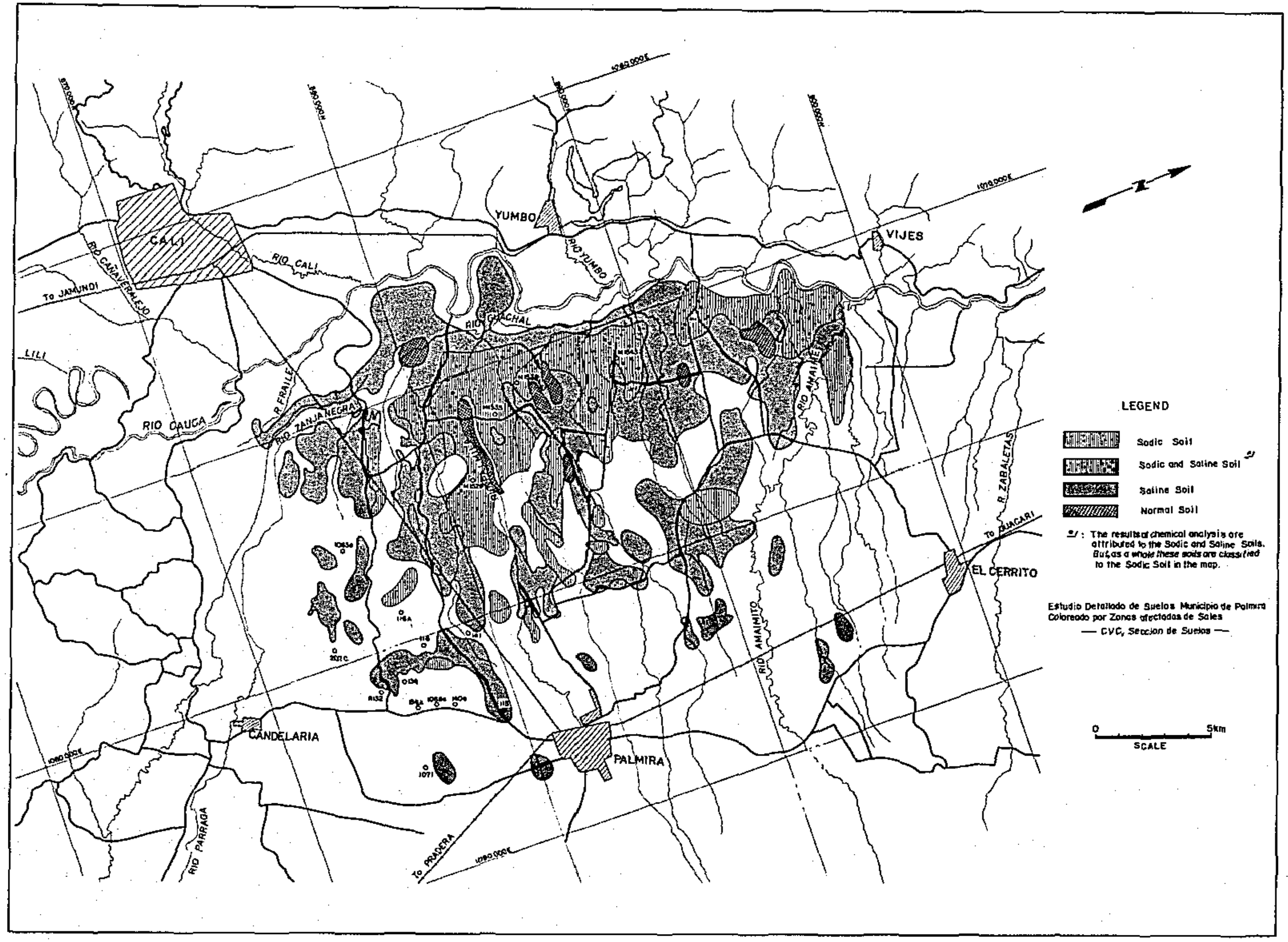
Sample No.	pH	P_2O_5 (mg/100gr)	Phosphate Absorption	CaO (%)	Al_2O_3 (mg/100gr)	MgO (mg/100gr)	MnO_3 (mg/100gr)	Fe Fe^{3+}	Fe Fe^{2+}	K_2O (mg/100mg)	NH_4N (mg/100mg)	NO_3N (mg/100gr)	Cl as NaCl (g/100gr)
1	5	<0.1	<500	0.15	5	25	<0.2	++	+	0~3	2.5~5	2.5~6.25	0.005~0.01
2	5	<0.1	1,250~1,500	<0.07	5	15	<0.2		+	0~3	<1.0	1.25~2.50	<0.005
3	4.5	<0.1	700~850	<0.07	0	25	<0.2	+	+	0~3	<1.0	1.25~2.50	0.005~0.01
4	6	15~20	<500	0.15	0	25	<0.2	+	+	0~3	2.5~5	1.25~2.50	0.005~0.01
5	5.5	15~20	<500	0.15	0	25	<0.2	+	+	0~3	2.5~5	1.25~2.50	0.05
6	6.5	1.0	<500	0.15	0	15	<0.2	+	+	0	2.5	1.25~2.50	
7	7.0	20	<500	0.15	0	15	<0.2	+	+	8	<1.0	6.25	
8	6.5	1.0~2.5	<500	0.15	0	25	<0.2	+	+	0	<1.0	1.25	
9	6~6.5	2.5~5.0	600	0.15	0	15~25	<0.2	+	+	0	<1.0	1.25	
10	5.5	5~7.5	<500	0.15	0	25	<0.2	+	+	8	2.5	2.5	
11	5.5	<0.1	2,000	0.10	0	25	<0.2	+++	+	3	1~2.5	0.5	<0.005
12	5.5~6.0	<0.1	<500	0.15	0	15	<0.2	+++	+~++	3	2.5	2.5	<0.005
13	4.5~5.0	0.1~1.0	2,000	<0.07	10	5	<0.2	+	+	0	2.5	0.5	<0.005
14	4.0~4.5	7.5~10	1,500	0.10	5	25	~0.5~	+++	+	3	1~2.5	2.5~6.25	0.01
15	4.0~4.5	7.5~10	1,500	<0.07	5	15~25	~0.5~	+++	+~++	0	2.5~5.0	1.25	<0.005
16	5.0	<0.1	850~1,000	0.15	0	15	~0.5~	+++	+	0	2.5	1.25~2.5	<0.005
17	5.5~6.0	<0.1	1,000~1,250	0.20>	0	25	<0.2	+++	+	0	2.5	2.50	<0.005
18	6.5	<0.4	<500	0.20>	0	25	<0.2	++	+	15	2.5	6.25	<0.005
19	7.0	<0.1	<500	0.15	0	15	~0.5~	+++	+	0	2.5	2.50~6.25	<0.005
20	5.5	<0.1	<500	0.15	0	25~30	<0.2	+++	+	15	2.5	1.25	<0.005
21	5.0~5.5	1.0	<500	0.15	<5	25	<0.2	+++	+	0	2.5~5.0	6.25	<0.005
22	4.5	<0.1	1,000~1,250	<0.07	<5	25	~0.5~	+++	+	15	2.5	6.25	<0.005
23	5.0~5.5	<0.1	<500	1	<5	15~20	~0.5~	+++	+	3	2.5~5.0	1.25~2.50	<0.005
24	5.5~6.0	<0.1	<500	2	<5	15~20	~0.5~	++~+++	+	0	2.5~5.0	1.25	0.01
25	5.5~6.0	<0.1	<500	1	<5	10~15	~0.5~	++~+++	+	30	2.5~5.0	6.25	0.10~0.15

Table 3 Physical Analysis of Soil in Palmira

Sample Number	Horizontal Layer	PH	Organic Matter (%)	Texture				Specific Weight		Porosity (%)	Soil Index of Irrigation Engineering (%)				Remarks
				Sand (%)	Loam (%)	Clay (%)	Texture	Apparent	Real		Hygroscopic Coefficient	Wilting Point	Moisture Equivalent	Field Capacity	
113	A	6.3	2.02	45.28	43.28	11.44	Loam	1.56	2.24	30.40	4.93	9.53	24.65	28.86	Hor. Layer
	B	7.4	0.32	52.56	44.92	2.52	Sandy Loam	1.59	1.98	19.70	5.63		25.17	25.22	A: 0 ~ 30.4 cm
															B: 30.4 ~ 10.8 cm
141	A	6.9	1.96	38.96	48.00	13.04	Loam	1.53	2.74	44.17	7.44	12.70	37.26	45.73	
	B	7.5	0.54	30.56	51.28	18.16	Silty Loam	1.44	2.46	41.47	6.79		29.75	35.65	
207C	A	6.9	2.93	27.68	55.28	17.04	Silty Loam	1.56	2.83	46.29	8.59	12.83	40.76	44.16	
	B	6.8	3.15	45.68	48.88	5.44	Sandy Loam	1.48	2.50	40.80	7.61		38.81	39.06	
1,068A	A	7.4	2.63	33.28	45.92	21.80	Loam	1.54	2.42	36.37	8.30	20.42	38.61	38.84	
	B	8.7	1.54	25.26	40.42	34.32	Clayey Loam	1.78	2.74	35.04	8.76		39.83	43.62	
1,071	A	6.9	3.95	21.68	42.42	35.90	Clayey Loam	1.60	2.28	29.82	8.91		39.53	47.09	
	B	7.4	4.19	25.56	36.28	38.16	Clayey Loam	1.46	2.12	31.14	8.51		38.24	38.62	

Propiedades Fisicos de Algunos Suelos del Municipio de Palmira
(Tesis de Grado 1964, Universidad Nacional de Colombia, Facultad de Agronomia)

Fig. 3 Soil Classification of Palmira



2. Agricultural Management and Land Tenure

According to the census[1/] of 1964, total population in Departamento del Valle del Cauca was 1,733,053 of which 529,544 were engaged in various economic activities as shown in Table 4. In Departamento del Valle del Cauca, 171,744 people or 32.50% of the total population were engaged in agriculture and fishery and this value is fairly low compared to the average (47.30%) for Colombia as a whole.

Table 4 Population for Economic Activities

Actividad Economica	Departamento del Valle del Cauca	Departamento del Cauca
1. Agricultura, silvicultura, caza y pesea	171,744	135,011
2. *Industrias extractivas*	6,862	4,409
3. Industrias de transformación	100,336	9,660
4. Construcción	30,468	4,941
5. Electricidad, gas, agua y servicios sanitarios	1,879	210
6. Comercio	63,451	8,010
7. Transportes, almacenaje y comunicaciones	29,166	2,395
8. Servicios	104,888	20,357
9. Otras actividades	20,750	2,013
Total	529,544	187,006
Total Population of Dept.	1,733,053	607,197

In Table 5, the number of farms and area of land by farm size in Departamento del Valle del Cauca are shown based on the census in 1959[2/], although this data is a little older. According to this table, only 2% of total land was occupied by farms under 3 hectares in size which constituted 40% of the farmers, while 8.4% of farmers occupied 70% of the total land. The former is considered as farms that are managed by their own labor and the latter is regarded as well organized agriculture enterprises employing large machines[4/] and labor hired.

Table 5 Number of Farms and Area of Land by Size of Farms

Size of Farm	No.of Farms	Ratio of Total Firms (%)	No.of Hectares	Ratio of Total Land (%)
Under 3 ha	20,808	40.9	24,268	2.1
3 ~ 10	14,692	28.9	85,580	7.3
10 ~ 50	11,078	21.8	238,046	20.4
50 ~ 100	2,069	4.1	142,257	12.2
100 ~ 500	1,883	3.7	390,166	33.4
500 ~ 1,000	215	0.4	143,672	12.3
Over 1,000	78	0.2	143,958	12.3
Total	50,823	100	1,167,947	100

Land ownership in farm management is classified by size in Table 6[3/]. The ratio of owned land is 76% and the ratio of rented land is 13%.

1/ XIII Censo Nacional de Población. Resumen General (Julio 15 de 1964 DANE. Cuadro 2.3.34).

2/ Censo Agropecuario del Valle del Cauca, 1959, (Cuadro 1) (Universidad del Valle, Septiembre de 1963).

3/ Ditto (Cuadro 6).

4/ According to Cuadro 55, about 4,000 tractors were already in use in 1959 and by oral investigation at SAJA, some 7,000 - 8,000 tractors and 2,000 - 3,000 combines are said to be operating in the Cauca Plain.

Table 6 Pattern of Land Tenure by Size of Farms

Size of Farm	Owned Land		Rental Land		Others 1/	
	ha.	%	ha.	%	ha.	%
Under 3 ha	17,562	2.0	4,667	3.2	2,039	1.6
3 ~ 10	55,223	6.2	22,452	15.2	7,905	6.2
10 ~ 50	166,619	18.7	50,468	34.1	20,960	16.4
50 ~ 100	107,640	12.1	20,527	13.8	14,090	11.1
100 ~ 500	319,445	35.8	33,547	22.7	37,174	29.2
500 ~ 1,000	126,484	14.2	5,597	3.8	11,590	9.1
Over 1,000	99,461	11.1	10,749	7.3	33.748	26.5
Total	892,433 (76%)	100	148,007 (13%)	100	127,507 (11%)	100

1/ Occupied without title

3. Present Situation of Land Use

First impression in the reconnaissance of the Cauca Plain is that a large portion of land is used for pasture land. Domestic animals, mostly cattle and milch cows, are raised in the pasture land. Next is the extensive plantations of sugar cane under good management. In these plantations there are large tracts of land growing of annual crops. Generally speaking, 50% of the whole Cauca Plain is being used for pasture or cattle grazing, 25% is for sugar cane fields and the remaining 25% is used mainly for annual crops and some permanent crops.

Table 7(1), which is from the census of land utilization in 1966 1/ shows the actual situation of land utilization in Departamentos del Cauca and del Valle del Cauca, including some mountain areas. Some information 2/ on land use of the riparian area of Cauca River is given in Table 7(2), which has been obtained from the flood damage report of 1966 by CVC. From this table it can be seen that the cropping ratio of annual crops reaches 30%, and pasture area ratio is 45% 50%. These are nearly the same as those for the whole of Dept. del Valle, but there appears some difference in the cropping ratio of permanent crops between Table 7(1) and Table 7(2).

Table 7(1) Land Utilization in Dept. Valle & Cauca (Unit: ha)

Departamento	Investigation Area	Annual Crops		Permanent Crops	Pasture Land 2/		Total
		1st Season	2nd Season		Natural	Artificial	
Cauca	896,931 (100) 1/	20,933	41,360	114,216 (12.7)	301,682	99,669	401,351 (44.7)
Valle del Cauca	747,637 (100) 1/	49,470	50,358	186,357 (24.9)	298,150	28,291	326,441 (43.7)

1/ figures in parenthesis are %

2/ natural pasture: including artificial pasture sown 5 years ago.

1/ Encuesta Agrícola Nacional, 1966 (DANE).

2/ Informe sobre evaluación de pérdidas causadas por las inundaciones en los Departamentos del Valle y Norte del Cauca en Diciembre de 1966, CVC.

Table 7(2) Land Utilization in Dept. Valle & Cauca

Land Utilization	Dept. Valle del Cauca		Dept. Cauca.	
	Area (ha)	Ratio of total (%)	Area (ha)	Ratio of total (%)
Annual Crops.	23,759	31.5	2,734	30.3
Permanent Crops	6,533	8.7	510	5.6
Intercultivated Crops	1,825	2.4	582	6.5
Pasture	38,202	50.4	4,020	44.5
Other use	4,959	6.1	1,178	13.0
Total	72,278	100	9,023	100

4. Utilization of Pasture Land

In the Cauca Plain, 40 to 50% of the total land is used as pasture land for cattle raising as described before. Grasses are of the short species, Para, Pangola or Pasto Comun, etc., and their nutrient values are shown in Table 8 by symbols TDN and DCP.

Table 8 TDN and DCP Value of Pasture1/

Pasture	TDN2/ (%)	DCP3/ (%)
Pará	10.4	2.1
Pangola	9.4	2.2
Puntero	15.7	1.2
Guinea	10	1.5
Elefante Merker	12.3	1.7
Sorgo forrajero	79.8	12.2
Caña forrajero	16.3	2.4
Alfalfa	14.8	4.6
Burmuda	61.1	5.8

1/ Alimentación del Ganado en la America Latina. (Prensa Medica Mexicana, De Alba, J. 1958)

2/ Total digestible nutrient

3/ Digestible crude protein

Some kinds of grasses are artificially grown, but most of pasture lands are classified as natural pasture. Artificial pasture lands account for 9% in Dept. del Valle and 25% in Dept. del Cauca as shown in Table 7(1). Many artificial pastures are found in the vicinity of Puerto Tejada in Dept. del Cauca1/. It is quite possible in the Cauca Plain to produce sufficiently fresh grass required for cattle because of the favorable climate conditions all the year round. Furthermore, on account of extensive land available for grass land, it has been practiced to follow local protecting grazing or rotational grazing. The grazing unit of cattle per plaza is estimated as one head and the proportion of milch and beef cattle is 40% and 60% respectively.

Almost all of cattle is native species, and some foreign species of Holstein or Cebu are introduced. Quite intensive raising of milch cow is found in the vicinity of Cali and big towns in each municipality. However, generally, quite extensive management mainly for cattle raising is common.

1/ Evaluación Agroeconómica del Proyecto de Irrigación Río Palo, Departamento del Cauca, 1963 CVC.

5. Cultivation of Principal Crops

There is little difference of temperature throughout the year in the Cauca Plain. Moreover, rotation of two cycles of wet and dry seasons in a year gives favorable agricultural condition to seeding and harvesting. In the Cauca Plain, during the first season from February to July - August, principal crops, such as cotton, maize, soybean, sorghum, rice and bean, etc., are planted. And the five main crops, except for cotton, are cultivated in the second season from August to December - January with some rotational patterns when necessary.

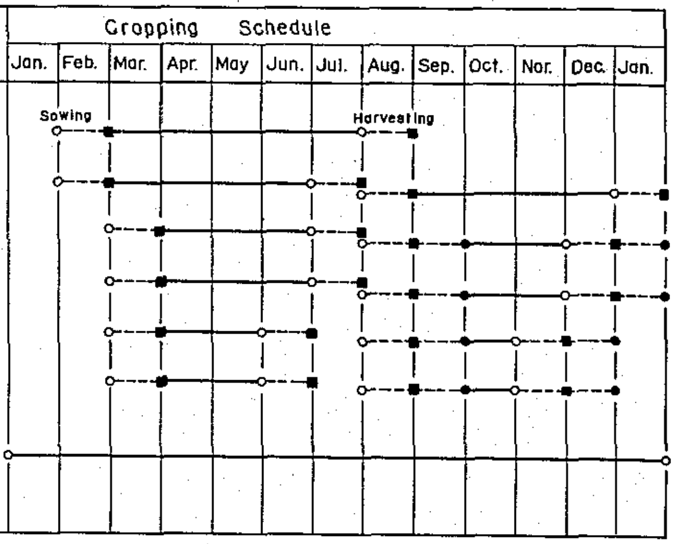
Five months are necessary for cotton cultivation, and if cultivated in the second season, flowering and maturing periods fall the wet season. For this reason cotton is cultivated in the first season only.

Rice has been cultivated by the broadcasting method in the lower flat area, where irrigation water is relatively easy to acquire. Three or four months are necessary for bean, or soybean and four or five months for maize. These annual crops are considered very effective in the second season after harvesting cotton to achieve two cultivations in a year with rotation in turns. Almost all work, such as land leveling, sowing, weeding and harvesting, etc., are performed by mechanical tractors and combines, etc. due to the large unit area of cropping. Besides the six crops mentioned above, some vegetables such as tomato, onion, etc. which bring higher income are planted in a small scale even though intensive manual work is required for nursery or transplanting, etc.

Sugar cane, which is one of the typical perennial crops in the Cauca Plain, is planted on a large scale. Some 25% of the flat part of the Cauca Plain is sugar cane and most of it belong to big plantations owned by Ingenios. Fourteen or eighteen months are necessary for sugar cane to fully ripen. Canes newly planted are generally cut several times, but the production decreases according to the repetitions of ratoon. Average yield and cropping schedule of the principal crops are shown in Table 9.

Table 9 Average Yield and Cropping Schedule

Crop	Average Yield (kg/ha)
Cotton	1,700
Rice	3,000
Maize	2,800
Sorghum	2,500
Soybean	2,000
Bean	1,500
Sugarcane	80,000



Cropping ratio of the second season in 1966 in the area along Cauca River is assumed from the information given by CVC[2] and shown in Table 10 (2).

1/ Desarrollo Agricola del Valle del Cauca. Censo de Seis Cultivos (IFA, 1967, Bogotá).

2/ Informe sobre evaluación de pérdidas causadas por las inundaciones en los Departamentos del Valle del Cauca y Norte del Cauca (Deciembre 1966, CVC).

Table 10(1) Cropping Ratio in First Season (Unit : plaza, %)

Municipios	Algodon	Arroz	Frijol	Maiz	Sorgo	Soya	Total
Andalucia	175 (4.6)	80 (2.1)	65 (1.7)	2,057 (54.0)	166 (4.4)	1,255 (33.1)	3,798 (100)
Buga	672 (15.3)	58 (1.3)	35 (0.8)	1,120 (25.6)	793 (17.1)	1,705 (38.9)	4,384 (100)
Bolivar	26 (2.6)	104 (10.6)	13 (1.3)	369 (37.4)	244 (24.8)	231 (23.4)	987 (100)
Cali	45 (1.5)	–	632 (21.0)	1,183 (39.3)	443 (14.7)	698 (23.2)	3,001 (100)
Candelaria	125 (2.8)	30 (0.7)	248 (5.6)	2,763 (62.6)	127 (2.9)	1,132 (25.6)	4,425 (100)
Cerrito	673 (17.9)	248 (6.6)	360 (9.6)	1,152 (30.7)	366 (9.7)	969 (25.7)	3,768 (100)
Florida	30 (5.0)	–	–	292 (48.0)	–	285 (47.0)	607 (100)
Ginebra	–	568 (21.6)	13 (0.5)	1,058 (40.3)	185 (7.1)	800 (30.5)	2,624 (100)
Guacari	1,715 (37.8)	223 (4.9)	54 (1.2)	1,242 (27.4)	508 (11.2)	800 (17.6)	4,542 (100)
Jamundi	–	1,700 (58.4)	–	321 (11.0)	677 (23.2)	220 (7.5)	2,924 (100)
Palmira	2,628 (21.5)	264 (2.2)	426 (3.5)	4,500 (36.8)	483 (3.9)	3,913 (32.0)	12,214 (100)
Pradera	–	–	133 (7.7)	977 (54.7)	–	672 (37.6)	1,782 (100)
Rio Frio	–	–	4 (0.4)	436 (40.0)	500 (45.9)	150 (13.7)	1,090 (100)
San Pedro	157 (6.3)	103 (4.2)	20 (0.8)	549 (22.1)	884 (35.6)	769 (31.0)	2,482 (100)
Tulua	395 (6.5)	135 (2.2)	12 (0.2)	2,819 (46.5)	1,688 (27.8)	950 (15.8)	6,007 (100)
Trujillo	40 (8.4)	–	–	236 (49.6)	200 (42.0)	–	476 (100)
Vijes	–	–	115 (66.5)	52 (30.0)	–	6 (3.5)	173 (100)
Yotoco	465 (18.7)	–	53 (2.1)	986 (39.6)	362 (14.5)	620 (24.9)	2,486 (100)
Yumbo	1,150 (51.8)	80 (3.6)	121 (5.5)	107 (4.8)	430 (19.4)	336 (15.1)	2,224 (100)
Total	8,296 (13.8)	3,599 (6.0)	2,304 (3.9)	22,219 (37.3)	8,056 (13.5)	15,519 (26.0)	59,994 (100)

Table 10(2) Cropping Ratio in Second Season in the Area along the Cauca River

(Unit : %)

Crop	Investigated Area		Flooded Area	
	Valle	Cauca	Valle	Cauca
(Annual Crops)	(31.5)	(30.0)	(38.2)	(30.4)
cotton	–	–	–	–
rice	7.3	2.3	5.6	0.7
maize	39.0	46.5	37.8	33.5
bean	4.5	7.1	4.4	8.4
soybean	38.5	14.7	40.3	19.4
sorghum	9.4	28.5	10.2	37.6
others	1.3	0.9	1.7	0.4
	100	100	100	100
(Perennial Crops)	(8.7)	(5.6)	(5.9)	(4.2)
sugar cane	70.0	18.3	25.6	12.7
platano	10.5	62.0	27.0	74.0
yuca	0.9	11.6	2.3	1.2
others	18.6	8.1	45.1	12.1
	100	100	100	100
(Pasture Land)	(50.5)	(44.5)	(51.0)	(58.0)
(Other Uses)	(9.3)	(19.9)	(4.9)	(7.4)

6. Development of Principal Agricultural Production and Tendency of Its Consumption

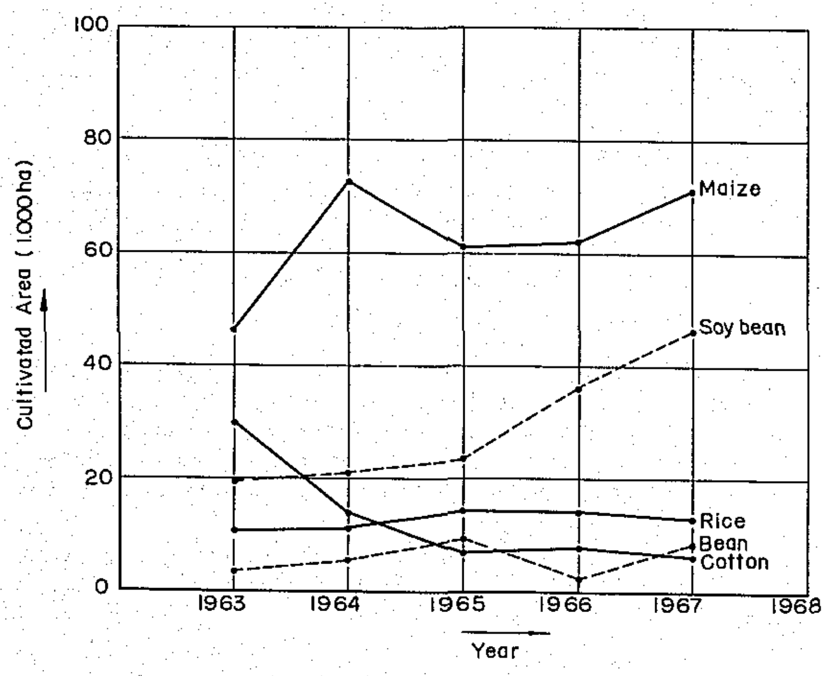
The trend of planting area for main crops, except sugar cane, in these few years is plotted in Fig. 4[1/] Cultivation of maize and sorghum has remarkably increased in these years, because most of their products are sent to processing industry mainly for the concentrated forages. Soybean is also one of the promising crops because there is an assured market on the oil processing industry. Cotton is not necessarily a profitable crop for the producer on account of the unstable price, therefore the planting area has been rather constant in the past few years. Planting area of rice is also constant owing to high production cost and the restriction of area. Concerning bean, there is the problem of plant disease and consequently the area has been constant or decreasing.

On the other hand, there is an increasing tendency in the national per capita consumption of main agricultural products as seen in Table 11[2/] Considering growth of population[3/] in the future, consumption of main agriculture products is estimated to increase by 50~100% of the present value in the next 10 ~15 years.

Table 11 Consumption of Agricultural Products

Agricultural Products	Consumption per Capita 1965 (Kg)	Consumption per Capita 1970 (Kg)	Annual Growth Rate (%)
Cotton	3.5	4.0	2.5
Maize	56.4	60.0	1.2
Soybean	2.8	3.1	2.3
Rice	21.6	24.5	2.5
Sorghum	3.9	6.9	12.0
Bean	2.9	2.9	–

Fig. 4 Trend of Cultivated Area for Main Crops



1/ Compiled by CVC in 1968 from data of "Banco de la Republica, etc."
2/ Control de Inundaciones en el Valle del Cauca (Banco Interamericano de Desarrollo, 1968).
3/ XIII Censo Nacional de Poblacion. Resumen General. (Julio 1964). Annual increasing ratio. Whole Colombia 3.2% Dept. Valle del Cauca 3.5%.

7. Present Status of Drainage and Irrigation 1/

7.1 Drainage

Flood and inundation in the area along the Cauca River and its tributaries are recurring phenomena each year. Specially, the depressed area or lower land close to the river has been affected by flood and stagnancy of water. In some areas along Cauca River and its tributaries, aggressive land owners have constructed small levees for their own land. Recently these levees are gradually increasing year by year, and a total length of 180 km have been constructed or were under construction in November 1968. But because of individual levee construction, existing levees are not continuous and are not efficiently designed and executed.

Reflecting the abovementioned facts, when flood comes, it is very common that overflow occurs at some part where levees are not yet constructed or levees easily fail which results in inundation of the lower area near the river. On the other hand, back-water effect of Cauca River contributes much of its flooding. That is when the Cauca River discharge increases and its water surface raises. This high level of the river stops the inflow of tributaries resulting in the overflow of water.

In some progressive big farms, drainage canals, pumping facilities have been installed not only for flood protection in the wet season but also for keeping good drainage condition of their farms. And in other farms, except for during flood time, networks of small stream or drains in the Cauca Plain are working effectively for drainage.

Thus, farmland from La Balsa to Zarzal which have been suffering severe damages by floods and inundation in November almost every year is estimated to be 10,000 or 15,000 hectares. Besides the area directly flooded or inundated, some poorly drained fields are also found in depressed areas. Back-water or rainfall is stagnated in this area after recession of flood and there remains an over-humid condition for a long time.

7.2 Irrigation

Water from the Cauca River, its tributaries and, furthermore, subterranean water have been used for irrigation in some areas in the Cauca Plain. A few concrete structures with fixed weir are found in the main tributaries. But generally the stream is dammed up with timber or stone structues to draw water in a rather primitive method.

These intake facilities and canals are mostly constructed by the private user. Therefore, in some of them the diversion sites are very close to each other and the individual canals are running to the same direction in a complicated route. In some riparian farms along the Cauca River there are found fixed or semi-fixed pumping stations. Sometimes, the water pumped up is sent to the sprinkler by using booster facilities. In the farms using subterranean water, the distribution canals are well arranged in their fields because water sources are located in their own farms.

The approval for utilization of river water is given to the users according to law 1/ which stipulates that the volume of water which can be drawn shall be less than 50% of the discharge at any time for one user. However, this approval is controlled by the authority 2/ depending on the number of users or kind of crops. In view of the fact that the permissions are given in proportion of discharge, the available quantity of water is not constant for the user throughout the year and there is no assured supply of irrigation water even though they have the permissions.

Thus, there happen sometimes big drought problems on crop cultivation in the area where sufficient irrigation water can not be obtained at the most needed period or in the area where irrigation water can not be obtained at all.

1/ Except for Aguablanca and Roldanillo (1st. Stage Project). Both projects were already completed and are attaining splendid agricultural production with well organized irrigation and drainage facilities.

2/ CVC. Ministerio de Agricultura, Zona Agropecuaria del Valle del Cauca. Gobernacion del Departamento del Valle del Cauca.

Though the annual amount of rainfall is not necessarily small in the Cauca Plain, monthly effective rainfall is not enough for evapotranspiration on account of irregular distribution of rainfall. Furthermore, no effective rainfall in the months of July, August and September happened several times in the past 15 years. These drought months unfortunately coincide with the sowing time of the second crop as well as harvesting time of the first crop, therefore consecutive term of drought in this period has critically affected the cropping rotation.

APPENDIX 4

PROBABLE MAXIMUM FLOOD

SEDIMENT TRANSPORTATION AND DEPOSITION IN RESERVOIR

EVAPORATION FROM RESERVOIR SURFACE

APPENDIX 4 PROBABLE MAXIMUM FLOOD SEDIMENT TRANSPORTATION AND DEPOSITION IN RESERVOIR EVAPORATION FROM RESERVOIR SURFACE

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I. Probable Maximum Flood

Although the Cauca River Basin is situated out of the severe meteorological phenomena such as hurricanes and easterly waves, moisture-laden air blowing in from the Pacific Ocean can cause storm rainfalls in the basin.

The precipitable water of such air should normally be studied on the basis of hydrologic and meteorological records of the entire basin. But since the necessary records are lacking, such meteorological data as dewpoint at Popayan2/, the high altitude wind velocity at Guayaquil3/ indicated in the reference report1/ were utilized to estimate the precipitable water of the Salvajina catchment area as described below.

The precipitable water in the air column corresponding to the maximum dewpoint of Fig. 1 was regarded as that of the Salvajina basin (Fig. 2). The Moisture Inflow Index (MII) for Probable Maximum Precipitation (PMP) was obtained multiplying this precipitable water by the maximum wind velocity of Fig. 3. As for the MII for historical storms, a value corresponding to the time of occurrence of flood at the Salvajina is desirable to be used, but here the precipitable water corresponding to the average dewpoint of Fig. 1 and the average wind velocities of the various atmospheric layers of Fig. 3 were used to obtain the results as indicated in Table 1.

From the above study, the maximizing factor (MF) becomes 3.38 (See Fig. 4)

Table 1. Moisture Inflow Index (MII) and Maximizing Factor (MF)

Item \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Dewpoint (°C)	17.1	19.1	17.9	17.3	17.5	17.6	16.2	16.2	19.8	19.0	19.0	19.8
Max. Precipitable Water (inch)	0.59	0.75	0.68	0.62	0.65	0.65	0.54	0.54	0.78	0.76	0.76	0.78
Ave. Max. Dewpoint (°C)	16.5	16.5	16.4	16.4	16.3	16.2	15.4	15.2	15.8	16.2	16.6	16.8
Ave. Max. Precip. Water (inch)	0.55	0.55	0.54	0.54	0.53	0.53	0.49	0.44	0.50	0.57	0.56	0.59
Ave. Max. Wind Speed (mps)	4.0	4.5	4.4	5.3	5.3	7.1	6.9	8.2	6.1	3.5	3.4	3.8
MII for Historical Storm	2.20	2.48	2.38	2.86	2.81	3.76	3.38	3.61	3.05	2.00	2.00	2.24
Max. MII for PMP	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Maximizing Factor	3.07	2.72	2.84	2.36	2.40	1.80	2.00	1.87	2.21	3.38	3.38	3.00

The probable maximum flood at the Salvajina site is estimated to be 3,600 cu. m/s multiplying the historical maximum flood of 1,070 cu. m/s (January 1956) by the abovementioned maximum value of 3.38.

On the Timba Project Report, for the estimations of probable maximum flood, the Hershfield Method was applied by Mr. V. A. Mayers. Therefore, the probable maximum flood at Salvajina Reservoir was estimated on the same basis using precipitation data of 6 observation sites in and near the Salvajina catchment area – Suarez, Piendamo, Silvia, Coconuco, Popayan and Munchique.

The basin average of maximum daily precipitable water and maximum antecedent 5-day precipitable water based on these data was listed in Table 2. According to this table, the conversion factor from maximum daily precipitable water to maximum antecedent 5-day precipitable water is 1.43 to 1.72 as shown in Table 3.

Considering the characteristics of the precipitation type in this area, and assuming the ratio of basin to station probable maximum precipitation as 0.45, probable maximum antecedent 5-day precipitation of the Salvajina catchment area becomes about 370 mm.

1/ Spillway Design Flood for Cauca River above Timba Dam. Vance A. Mayers INGETEC-G&H-TAMS, CVC July – 1962
2/ Ditto Fig. 5.
3/ Ditto Table 9

Fig. 1 Max.(12hr persisting) Dewpoint at Popayan

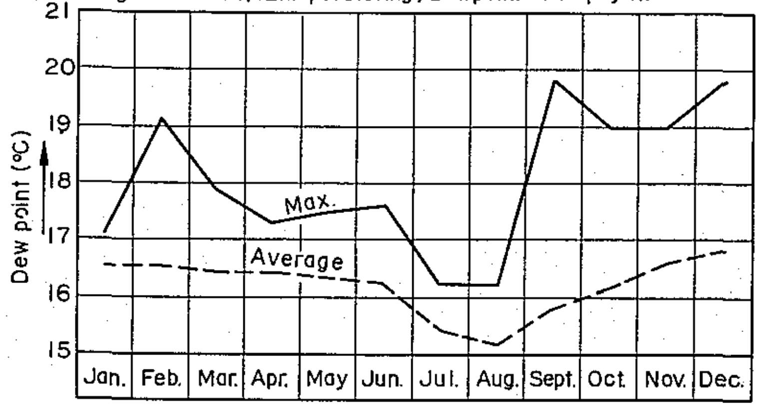


Fig. 2 Precipitable Water in the Layer from 2.2km to 10km

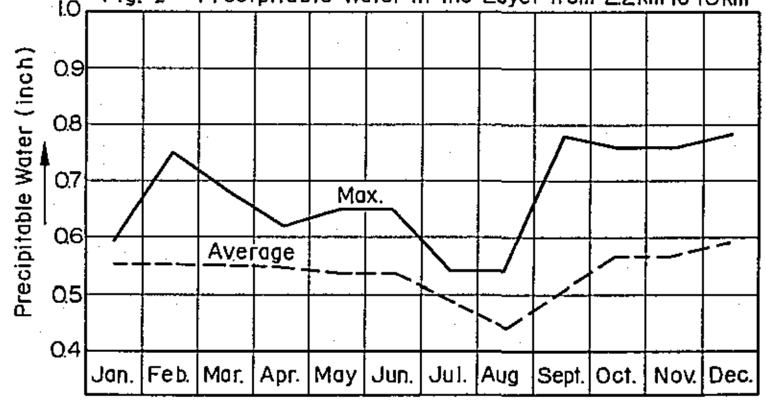


Fig. 3 Mean Monthly Wind Resultants (m/sec)

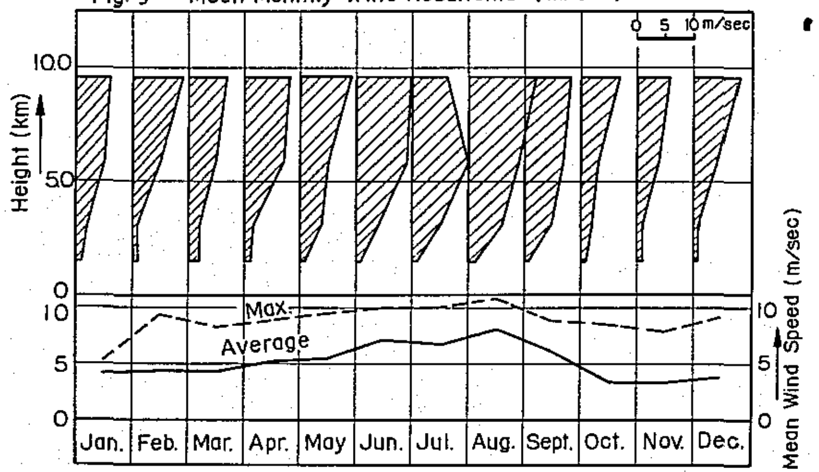


Fig. 4 Seasonal Variation of Probable Max. Precipitation

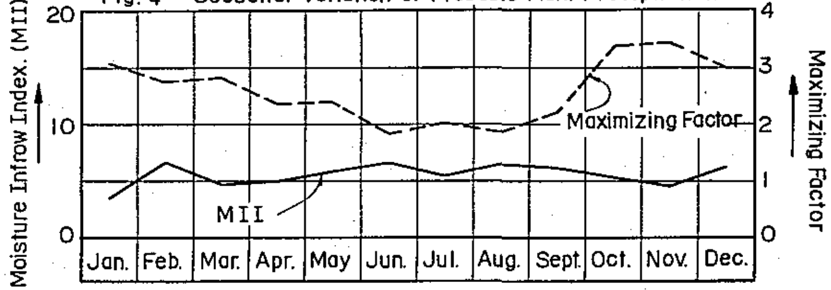


Table 2 Maximum Daily Precipitation and Maximum Antecedent 5-day Precipitation

	Max. Daily Precipitation in mm 1/						Max. Antecedent 5-Day Precipitation in mm							Flood Discharge at Salvajina (cu. m/s)	
	Suarez	Pien-damo	Silvia	Coco-nuco	Popa-yan 2/	Mun-chique	Suarez	Pien-damo	Silvia	Coco-nuco	Popa-yan 2/	Mun-chique	Basin Ave.	Daily Ave.	Daily Peak 3/
1955	63	52	53	45	84	72	35	85	52	42	60	108	58	641	700
56	62	62	40	33	140	56	79	35	78	71	9	86	57	835	1,070
57	67	78	53	40	198	67	40	45	46	55	55	92	52	451	548
58	73	72	52	36	138	70	24	80	132	47	47	141	71	505	672
59	66	57	45	63	88	153	38	–	–	–	3	14	–	325	325
60	98	86	45	63	82	190	158	89	37	79	92	411	109	660	795
61	97	84	40	68	91	140	113	94	73	30	70	213	81	457	576
62	66	70	44	105	95	120	–	32	79	90	36	118	–	305	423
63	76	63	33	120	84	137	17	122	75	41	118	167	80	500	583
64	80	77	35	68	90	83	57	73	103	55	113	84	79	425	508
65	107	68	48	33	38	133	66	96	39	10	87	129	60	387	387
66	136	76	43	95	48	117	186	144	48	103	53	167	110	402	494
67	124	102	67	167	76	102	90	127	32	295	71	199	143	902	978
68	135	80	60	113	73	100	104	120	37	173	109	187	118	598	655

1/ Max. daily precipitation is for max. observational rainfall plus one-half adjacent day.

2/ The records come from that of Popayan (Electraguas)

3/ The records come from the daily peak discharge of the proposed flood month.

Table 3 Conversion Factor from Maximum Daily Precipitation to Maximum 5-day Precipitation

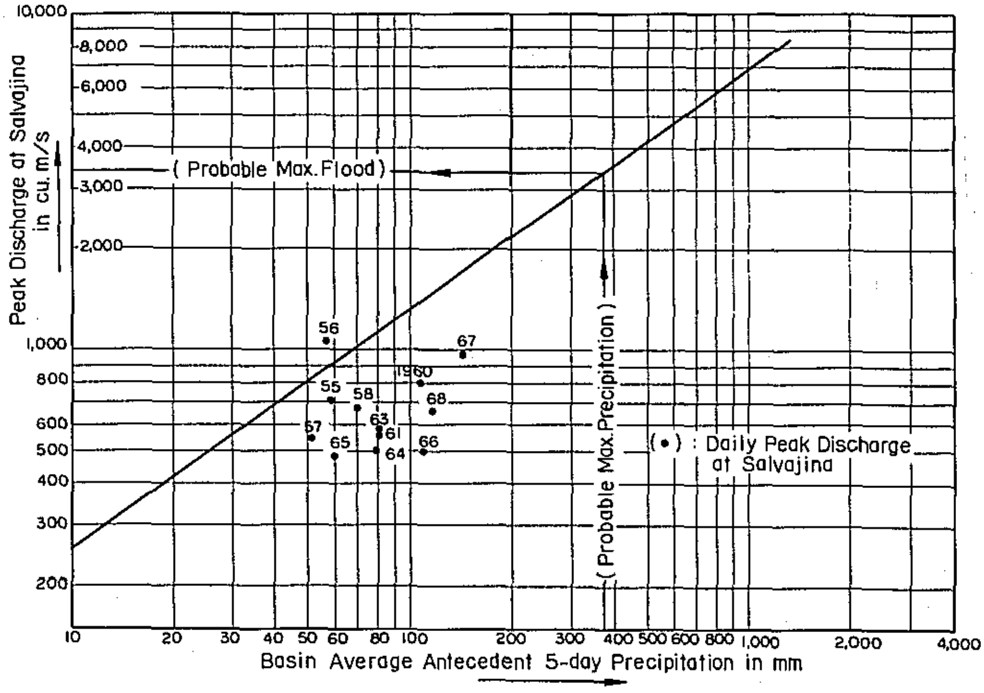
Station	Record	Max. of Record (mm)	Ave. of Record (mm)	Coeff. of Variation (%)	PMP (mm)	Ratio of PMP to Max.Record	Remarks	
(Max. Daily Precipitation)							(Thiessen Coefficient)	
Suarez	1955 - 1968	136	89	29.2	479	3.5	Suarez	14.6
Piendamo	1955 - 1968	102	73	17.8	261	3.6	Piendamo	19.3
Silvia	1955 - 1968	67	47	19.2	182	2.7	Silvia	17.5
Coconuco	1955 - 1968	167	75	29.2	656	3.9	Coconuco	25.6
Popayan	1955 - 1968	198	95	41.0	680	3.4	Popayan	16.4
Munchique	1955 - 1968	190	109	34.8	678	3.6	Munchique	6.6
Basin Ave.		139			476		total	100.0(%)
(Max. Antecedent 5-Day Precipitation)								
Suarez	1955 - 1968	186	78	64.1	825	4.4	Ratio of Max. Record 200/139 = 1.43	
Piendamo	1955 - 1968	144	88	38.7	598	4.2	Ratio of PMP 818/476 = 1.72	
Silvia	1955 - 1968	132	64	45.4	493	3.7		
Coconuco	1955 - 1968	295	84	85.6	1,170	4.0		
Popayan	1955 - 1968	118	66	53.2	585	5.0		
Munchique	1955 - 1968	411	151	59.0	1,482	3.6		
Basin Ave.		200			818			

The relationship between annual maximum flood discharge and antecedent 5-day precipitation at the Salvajina site is shown in Fig. 5, which nearly satisfies the relationship proposed in the Report.1/

Therefore, the probable maximum flood at the Salvajina dam site is estimated to be 3,400 cu. m/s, which corresponds to the abovementioned maximum antecedent 5-day precipitation of 370 mm.

As a result, the probable maximum flood of 3,500 cu. m/s is finally adopted in this Report.

Fig. 5 Relation between Probable Maximum Flood and Antecedent 5-day Precipitation



II. Sediment Transportation and Deposition in Reservoir

The relation between sediment transportation at the Salvajina site and the river discharge 2/ is given by the following equation:

$$Q = 21.73 \times T^{0.268}$$

where Q : river discharge in cu. m/s
T : sediment transportation in ton/day

Using the daily average runoff at the Salvajina site for the 23 years from 1946 through 1968, the annual average sediment transportation becomes approximately 2.1×10^6 tons, and 560 ton/sq.km.

The deposition in Salvajina Reservoir will have a total volume of 75×10^6 cu.m in 50 years and 150×10^6 cu.m in 100 years after completion of the reservoir assuming 20% of it as bed load sediment and 75% of trap efficiency and apparent specific gravity of 1.3.

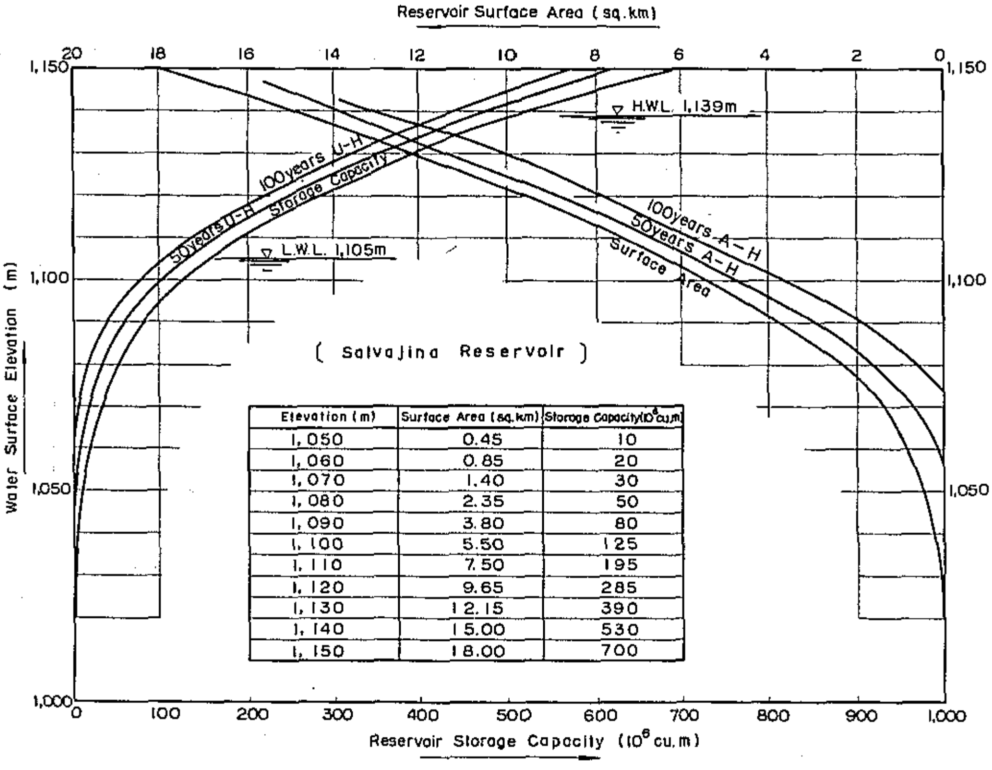
Based on the above study, the revised area-capacity curves for the reservoir, after 25, 50 and 100 years obtained by using the area-increment method3/, were shown in Fig. 6.

1/ Spillway Design Flood for Cauca River above Timba Dam. Vance A. Mayers, INGETEC-G&H-TAMS, CVC July–1962

2/ The Salvajina Project, Volume 2 Figures 53, CVC, Feb. 1965

3/ Distribution of Sediment in Large Reservoirs, USBR Hydraulic Engineers, Commissioner's Office

Fig. 6 Area-Capacity Curve of Salvajina Reservoir



Elevation (m)	Surface Area (sq.km)	Storage Capacity (10^6 cu.m)
1,050	0.45	10
1,060	0.85	20
1,070	1.40	30
1,080	2.35	50
1,090	3.80	80
1,100	5.50	125
1,110	7.50	195
1,120	9.65	285
1,130	12.15	390
1,140	15.00	530
1,150	18.00	700

III. Evaporation from Reservoir Surface

The inundation area of Salvajina Reservoir is presently covered by vegetation and it is estimated that annual evapotranspiration from this vegetation is 1,229 mm as given in Table 4.

Table 4 Net Evaporation-Precipitation Correction Factors

Month	Average Evaporation 1/ (mm)	Water Surface Evaporation 2/ (mm)	Temperature 3/ (°C)	Consumptive Use of Native Vegetation 4/ (mm)	Precipitation Consumes (mm)	Net Correction (mm)
Jan.	141	99	23.5	101	101	− 2
Feb.	139	97	23.7	101	101	− 4
Mar.	151	106	23.8	103	103	+ 3
Apr.	142	99	23.6	103	103	− 4
May	134	94	23.5	104	104	−10
Jun.	123	86	23.5	105	105	−19
Jul.	142	100	23.6	105	105	− 5
Aug.	134	94	23.7	104	104	−10
Sep.	134	94	23.7	103	103	− 9
Oct.	151	106	23.3	101	101	+ 5
Nov.	128	90	23.2	100	100	−10
Dec.	137	96	23.2	99	99	− 3
Total	1,656	1,161		1,229	1,227	−68

1/ Monthly average pan evaporation at La Manuelita

2/ Area - Factor = 0.7

3/ Monthly average temperature at La Manuelita

4/ Estimated by Blaney-Criddle Formula, K = 0.65

After completion of Salvajina Reservoir, the above evapotranspiration would be replaced by evaporation from the water surface.

Since there are no evaporation records available from the Salvajina basin, the measurement of class-A pan evaporation at La Manuelita is employed, and assuming area factor at 0.7, the evaporation from the reservoir surface is estimated at 1,161 mm annually and the net correction is estimated at (-)68.

Therefore, in comparison with before construction of the reservoir, the evaporation loss would be reduced by 68 mm. A loss of this degree is minute and does not warrant consideration in calculation of the balance of water.

APPENDIX 5

DAM TYPE

List of Drawings

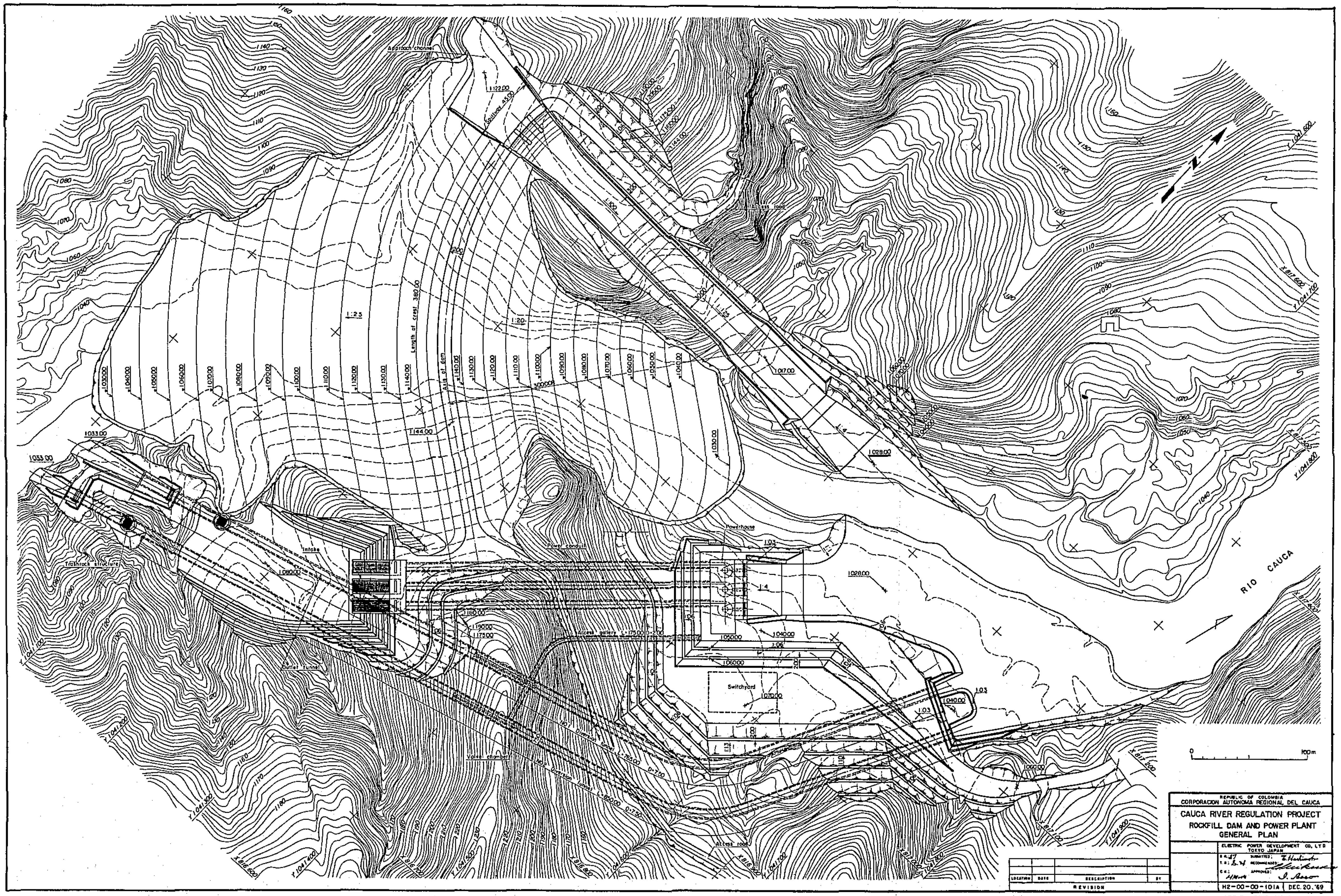
For Salvajina Dam, comparison studies were carried out of alternatives for rockfill dam, gravity dam and arch-gravity dam. A dome-type arch dam is not suitable on account of the geology of the site. In connection with the abovementioned three types of dam, preliminary designs were carried out. A brief explanation of each type of dam is given hereunder.

For the layout of the rockfill dam, several dam axes were selected and comparisons were made with layout of either underground or surface-type power plant. The location of the spillway was limited to the left bank side because of geological reason. The tunnel for diversion of the river during construction was designed with the capacity of 1,070 cu.m/s, which is the maximum past flood corresponding to a return period of 50 years. As for the outlet, it was designed that the above diversion tunnel be utilized as outlet works in later stage. The optimum arrangement of the dam and power plant layout is as shown in App. 5, Dwg. No. 1 to 4. Excavated muck from the dam and other structures will be used for the dam embankment while the excavated material from the vicinity of the power plant on the right bank side will be suitable for core material. It is possible for other excavated material to be used as filter or rock material in accordance with its quality. Other remaining embankment material can easily be obtained from the area surrounding the dam.

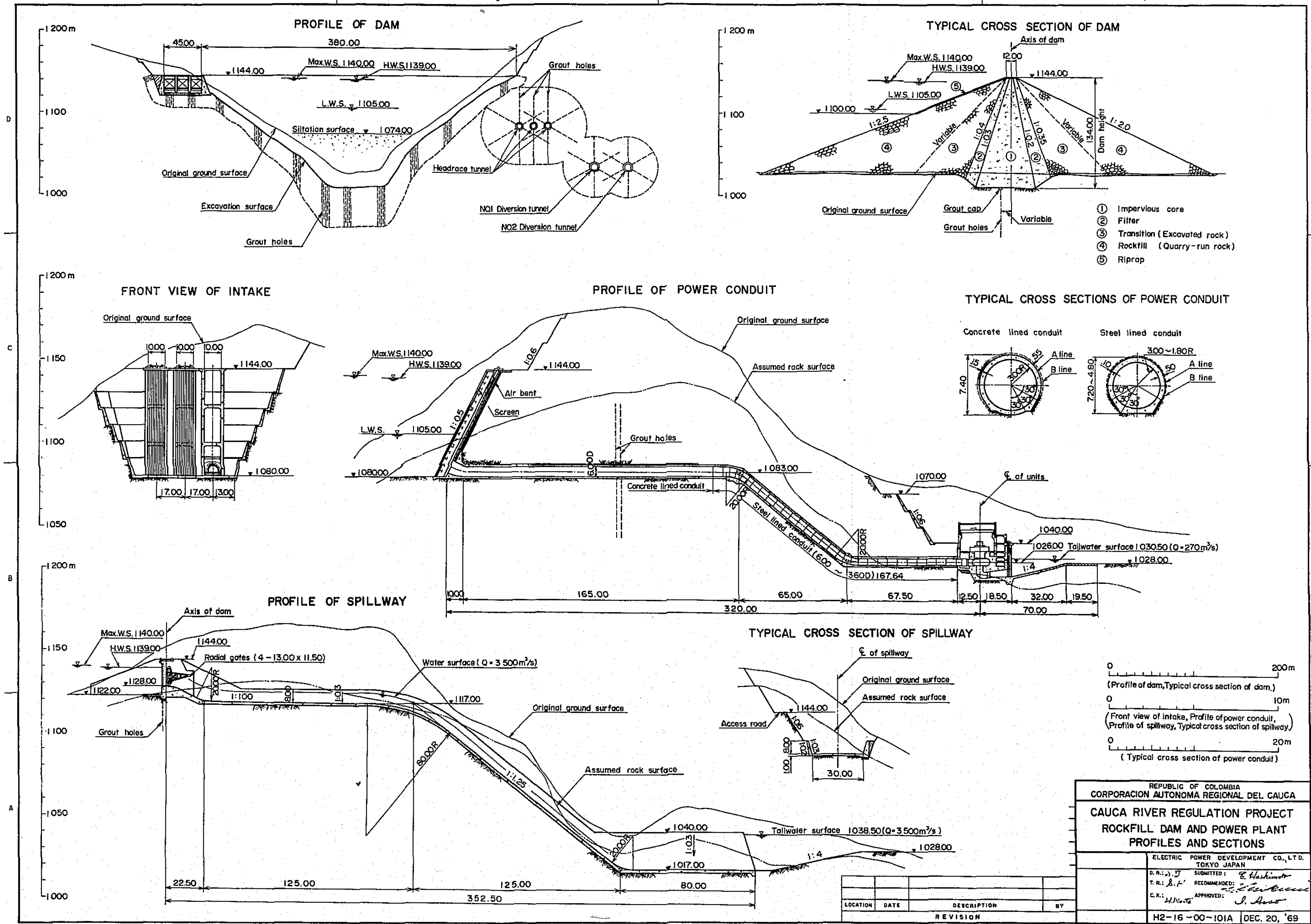
With respect to the gravity dam, the axis was selected at the narrowest part of the valley to reduce the concrete volume of the dam. The spillway was located at the middle of the dam so that overflowing floods fall to the middle of the river while the power plant was located on the left bank on account of the topographical and geological features. The diversion tunnel for care of river during construction was located in the right bank mountainside with a capacity of approximately 600 cu.m/s, corresponding to a flood return period of 5 years. Diversion waterway in the dam is not appropriate because of the narrow width of the valley. The outlet was installed in the dam body.

The arch-gravity dam is discussed in Chapter 7 of General Report.

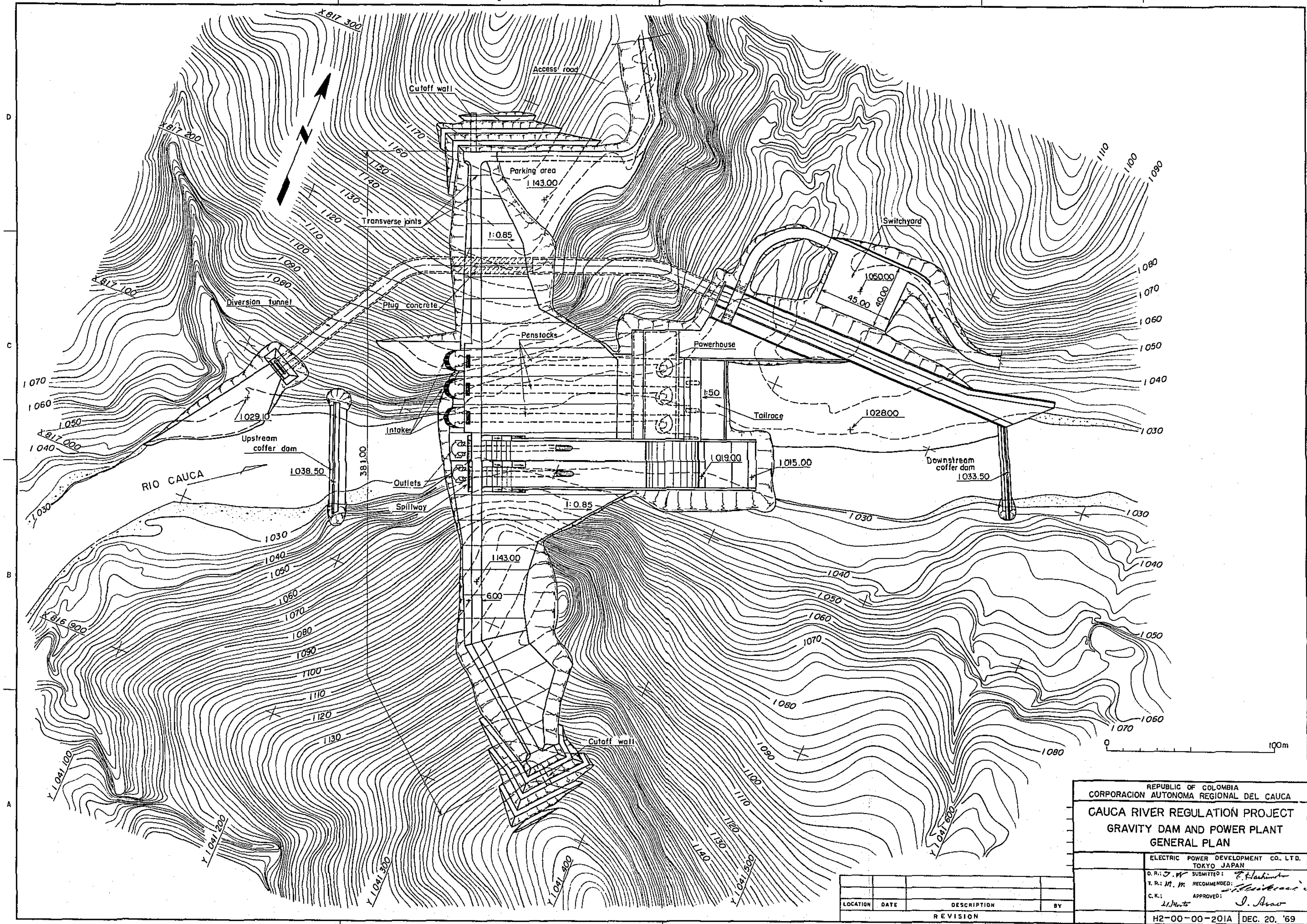
After carrying out preliminary design of these three types of dam, a comparison was made of the construction costs, construction periods, etc . As a result, it was determined that an arch-gravity dam is the most economical with a difference of construction cost close to U.S.$1,500,000 less than the rockfill or gravity dam.


Approach channel
Spillway
Access road
Length of crest 380.00
Axis of dam
1:2.5
1:2.0
Intake
Trashrack structure
Outlet tunnel
Powerhouse
Power conduit
Access gallery
Switchyard
Valve chamber
Access road
RIO CAUCA
0
100m
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
ROCKFILL DAM AND POWER PLANT
GENERAL PLAN
ELECTRIC POWER DEVELOPMENT CO., LTD
TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
LOCATION
DATE
DESCRIPTION
BY
REVISION
H2-00-00-101A
DEC. 20. '69

APP. 5 DWG. NO. 1

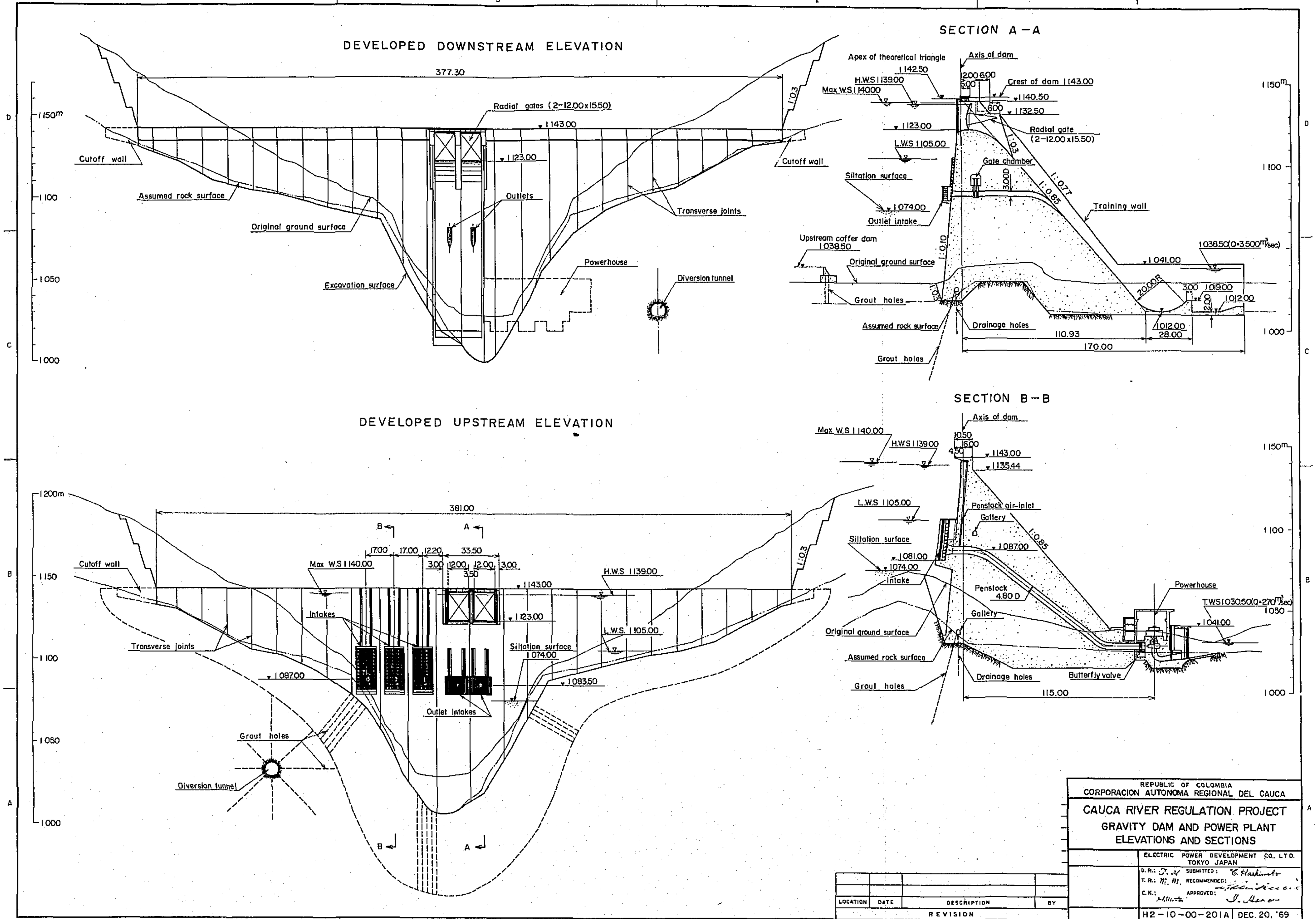

PROFILE OF DAM
45.00
380.00
1144.00
Max.W.S. 1140.00
H.W.S. 1139.00
L.W.S. 1105.00
Siltation surface 1074.00
Grout holes
Original ground surface
Excavation surface
Headrace tunnel
NO1 Diversion tunnel
NO2 Diversion tunnel
TYPICAL CROSS SECTION OF DAM
Axis of dam
12.00
1144.00
1100.00
1:2.5
1:2.0
Variable
1:0.4
1:0.3
1:0.2
1:0.35
Dam height 134.00
Grout cap
Grout holes
Variable
① Impervious core
② Filter
③ Transition (Excavated rock)
④ Rockfill (Quarry-run rock)
⑤ Riprap
FRONT VIEW OF INTAKE
Original ground surface
10.00 10.00 10.00
1080.00
17.00 17.00 13.00
PROFILE OF POWER CONDUIT
Original ground surface
Assumed rock surface
1:0.6
1:0.5
Air bent
Screen
1080.00
Grout holes
6.00
1083.00
Concrete lined conduit
Steel lined conduit (6.00 ~ 3.60D) 167.64
20.00R
1070.00
1:0.6
℄ of units
1040.00
1026.00
Tailwater surface 1030.50 (Q=270 m³/s)
1028.00
1:4
10.00 165.00 65.00 67.50 12.50 18.50 32.00 19.50
320.00
70.00
TYPICAL CROSS SECTIONS OF POWER CONDUIT
Concrete lined conduit
Steel lined conduit
A line
B line
7.40
7.20~4.80
3.00~1.80R
PROFILE OF SPILLWAY
Axis of dam
Max.W.S. 1140.00
H.W.S. 1139.00
1144.00
Radial gates (4 − 13.00 x 11.50)
1128.00
1122.00
Water surface (Q=3 500 m³/s)
1:100
8.00
1:0.3
1117.00
Original ground surface
80.00R
1:1.25
Assumed rock surface
Grout holes
1040.00
Tailwater surface 1038.50 (Q=3 500 m³/s)
1:0.3
1028.00
1:4
1017.00
22.50 125.00 125.00 80.00
352.50
TYPICAL CROSS SECTION OF SPILLWAY
℄ of spillway
Original ground surface
Assumed rock surface
1144.00
Access road
1:0.5
30.00
0 200m
(Profile of dam, Typical cross section of dam.)
0 10m
(Front view of intake, Profile of power conduit, Profile of spillway, Typical cross section of spillway)
0 20m
(Typical cross section of power conduit)
LOCATION DATE DESCRIPTION BY
REVISION
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
ROCKFILL DAM AND POWER PLANT
PROFILES AND SECTIONS
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
H2-16-00-101A
DEC. 20, '69

APP. 5 DWG. NO. 2



REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
GRAVITY DAM AND POWER PLANT
GENERAL PLAN
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
H2-00-00-201A
DEC. 20, '69
LOCATION
DATE
DESCRIPTION
BY
REVISION
SUBMITTED:
RECOMMENDED:
APPROVED:
Access road
Cutoff wall
Parking area
1 143.00
Transverse joints
1:0.85
Diversion tunnel
Plug concrete
Penstocks
Powerhouse
Switchyard
1 050.00
45.00
40.00
1:50
Tailrace
1 028.00
Intakes
1 029.10
Upstream
coffer dam
1 038.50
381.00
Outlets
Spillway
RIO CAUCA
1 019.00
1 015.00
Downstream
coffer dam
1 033.50
6.00
Cutoff wall
X 817 300
X 817 200
X 817 100
X 817 000
X 816 900
Y 1 041 100
Y 1 041 200
Y 1 041 300
Y 1 041 400
Y 1 041 500
Y 1 041 600
0
100m

APP. 5 DWG. NO. 3


DEVELOPED DOWNSTREAM ELEVATION
377.30
Radial gates (2-12.00x15.50)
1143.00
1123.00
Cutoff wall
Assumed rock surface
Original ground surface
Outlets
Transverse joints
Powerhouse
Diversion tunnel
Excavation surface
1150m
1100
1050
1000
SECTION A-A
Apex of theoretical triangle
1142.50
Axis of dam
H.W.S 1139.00
Max W.S 1140.00
Crest of dam 1143.00
1140.50
1132.50
Radial gate
(2-12.00x15.50)
L.W.S 1105.00
Gate chamber
Siltation surface
1074.00
Outlet intake
Training wall
Upstream coffer dam
1038.50
Original ground surface
1041.00
1038.50(Q=3,500m³/sec)
Grout holes
Assumed rock surface
Drainage holes
110.93
170.00
1012.00
28.00
1019.00
1012.00
20.00R
1:0.77
1:0.85
1:0.3
1:0.10
DEVELOPED UPSTREAM ELEVATION
381.00
Cutoff wall
Max W.S 1140.00
H.W.S 1139.00
L.W.S 1105.00
Intakes
Transverse joints
Siltation surface
1074.00
1087.00
1083.50
Outlet intakes
Grout holes
Diversion tunnel
1200m
1150
1100
1050
1000
SECTION B-B
Axis of dam
Max W.S 1140.00
H.W.S 1139.00
1143.00
1135.44
L.W.S 1105.00
Penstock air-inlet
Gallery
1087.00
Siltation surface
1081.00
1074.00
Intake
Penstock
4.80 D
Powerhouse
T.W.S 1030.50(Q=270m³/sec)
1041.00
Original ground surface
Assumed rock surface
Grout holes
Drainage holes
Butterfly valve
115.00
1:0.85
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
GRAVITY DAM AND POWER PLANT
ELEVATIONS AND SECTIONS
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
LOCATION
DATE
DESCRIPTION
BY
REVISION
H2-10-00-201A
DEC. 20, '69

APP. 5 DWG. NO. 4

APPENDIX 6

STUDY OF LAND RECLAMATION IN THE CAUCA PLAIN

APPENDIX 6 STUDY OF LAND RECLAMATION IN THE CAUCA PLAIN

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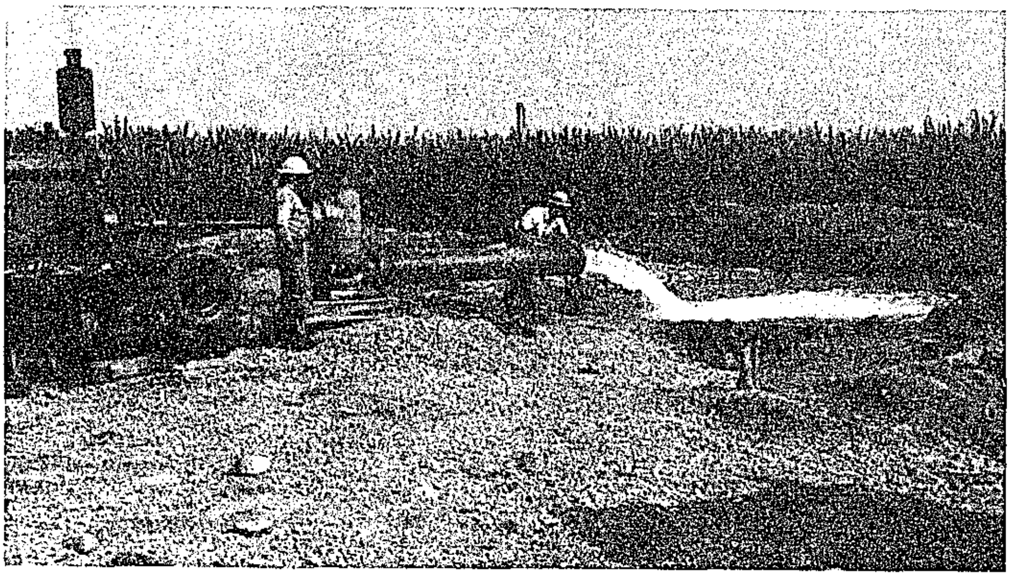
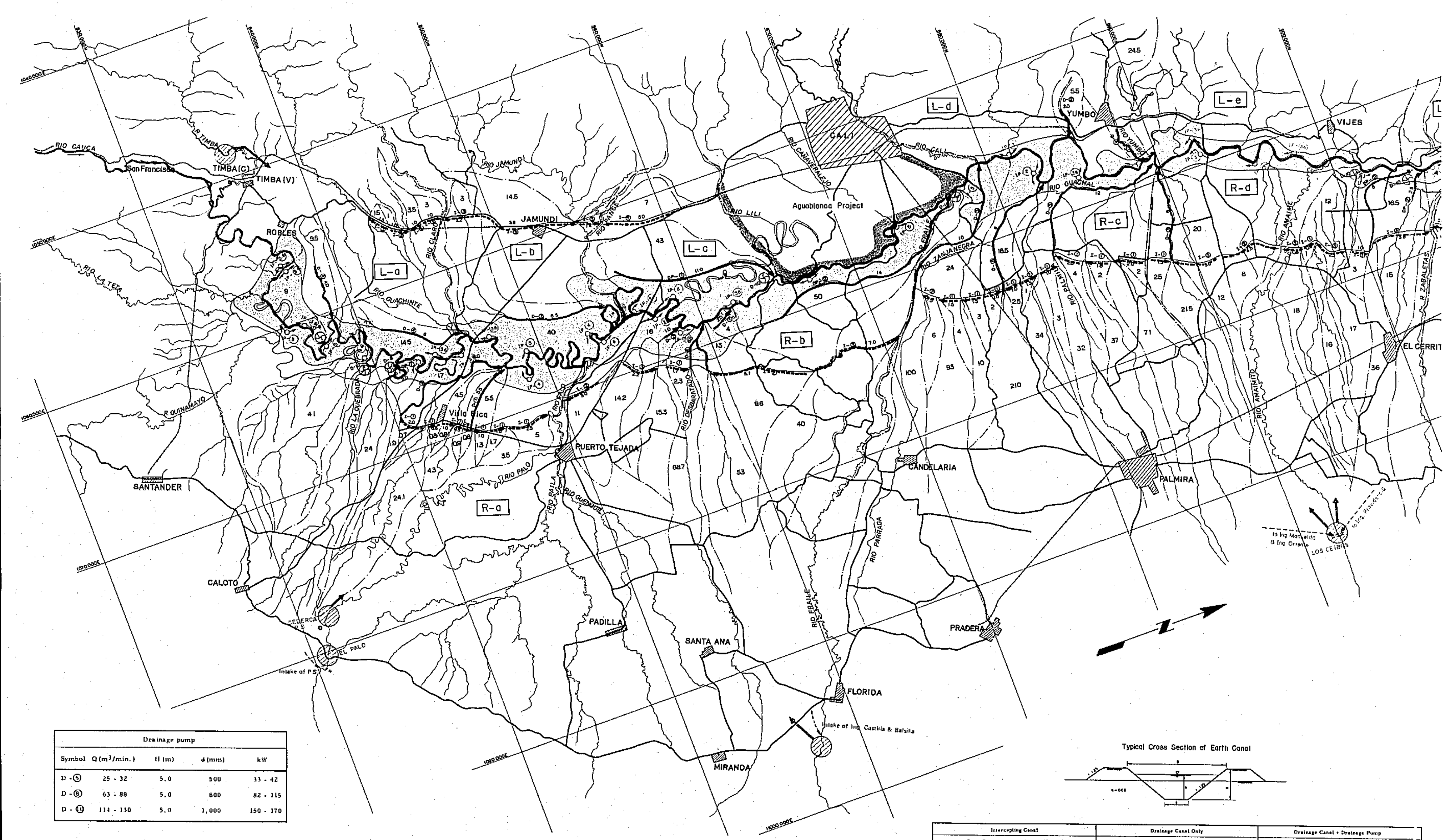
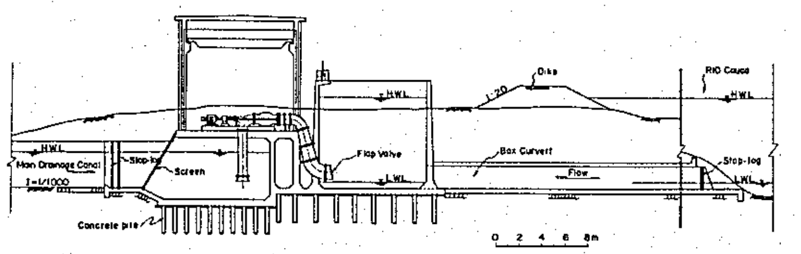
Utilization of Subterranean Water



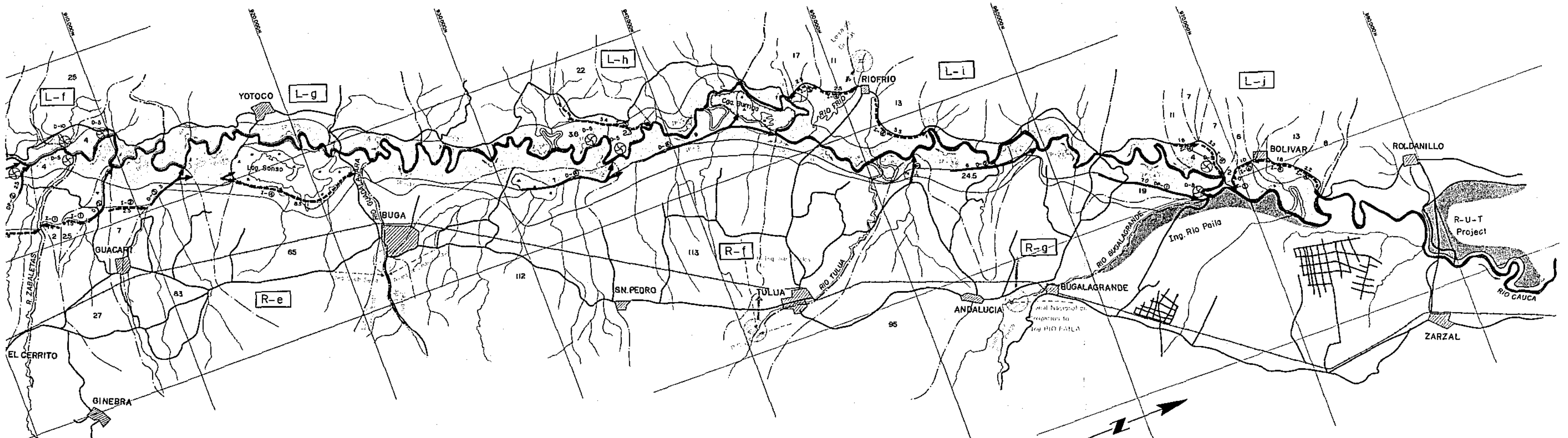


Drainage pump				
Symbol	Q (m³/min.)	H (m)	ϕ (mm)	kW
D - ⑤	25 - 32	5.0	500	33 - 42
D - ⑧	63 - 88	5.0	800	82 - 115
D - ⑪	114 - 130	5.0	1,000	150 - 170

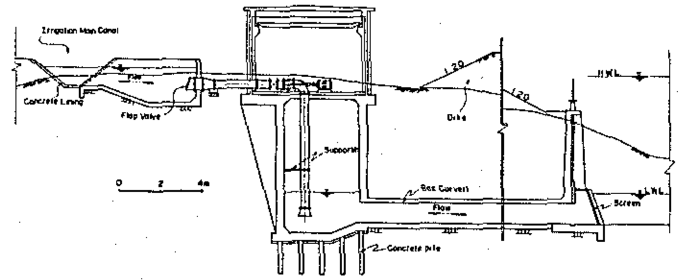


Typical Cross Section of Earth Canal

Intercepting Canal								Drainage Canal Only								Drainage Canal + Drainage Pump							
Symbol	Q (m³/s)	Design Q	B (m)	b (m)	H (m)	h (m)	I	Symbol	Q (m³/s)	Design Q	B (m)	b (m)	H (m)	h (m)	I	Symbol	Q (m³/s)	Design Q	B (m)	b (m)	H (m)	h (m)	I
I - ①	- 2.5	2.0	4.75	1.00	1.50	1.10	1/1,000	D - ①	- 10.0	5.0	7.00	1.50	2.20	1.60	1/1,000	DP - ①	- 10.0	5.0	7.00	1.50	2.20	1.60	1/1,000
I - ②	2.6 - 5.0	4.0	6.30	1.30	2.00	1.50	1/1,000	D - ②	10.1 - 20.0	15.0	10.15	2.40	3.10	2.30	1/1,000	DP - ②	10.1 - 30.0	20.0	11.25	2.50	3.50	2.60	1/1,000
I - ③	5.1 - 15.0	10.0	9.00	2.00	2.80	2.00	1/1,000	D - ③	20.1 - 50.0	40.0	14.50	4.50	4.00	3.10	1/1,000	DP - ③	30.1 - 50.0	40.0	14.50	4.50	4.00	3.10	1/1,000
I - ④	15.1 - 40.0	30.0	13.50	4.00	3.80	2.80	1/1,000	D - ④	50.1 - 80.0	70.0	19.50	7.00	5.00	3.90	1/1,500								
I - ⑤	40.1 - 70.0	60.0	17.50	5.00	5.00	3.60	1/1,000	D - ⑤	80.1 - 100.0	100.0	22.50	8.00	5.80	4.40	1/1,500								



Symbol	Irrigable Area (ha)	Q (m^3/min.)	H (m)	φ (mm)	kW
IP-①	300	7.2	6.0	300	11.3
IP-②	500	12.0	6.0	350	18.8
IP-④	800	19.2	6.0	400	30.0
IP-⑤	1,000	24.0	6.0	500	38.0



Summary of Structurs for Irrigation and Drainage Works

Left Side Bank Area

Item \ Job Division	L-a	L-b	L-c	L-d	L-e	L-f	L-g	L-h	L-i	L-j	Sub-total
Project Area (ha)	9,000	8,000	6,300	500	1,500	500	1,500	5,800	2,300	1,400	32,800
Drainage Works (Main) – Drainage Canal: Drainage Area (D.A; Sq.km) and Canal Length (C.L; km)	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL
Intercepting Canal I-①	- -	- -	- -					- -	- -	- -	- -
Intercepting Canal I-②	1.0 1.0	- -	- -					- -	- -	- -	1.0 1.0
Intercepting Canal I-③	8.0 3.5	5.0 3.6	- -					- -	- -	2.0 1.0	15.0 8.1
Intercepting Canal I-④	- -	- -	7.0 5.0					- -	24.0 8.0	52.0 10.0	83.0 23.0
Intercepting Canal I-⑤	- -	14.5 5.8	- -					22.0 5.4	17.0 2.5	- -	53.5 13.7
Intercepting Canal Total	9.0 4.5	19.5 9.4	7.0 5.0	- -	- -	- -	- -	22.0 5.4	41.0 10.5	54.0 11.0	152.5 45.8
Drainage Canal Only D-①	- -	- -			- -						- -
Drainage Canal Only D-②	- -	- -			5.5 2.0						5.5 2.0
Drainage Canal Only D-③	24.0 10.0	40.0 6.5			24.5 3.0						88.5 19.5
Drainage Canal Only D-④	- -	- -			- -						- -
Drainage Canal Only D-⑤	- -	- -			- -						- -
Drainage Canal Only Total	24.0 10.0	40.0 6.5	- -	- -	30.0 5.0	- -	- -	- -	- -	- -	94.0 21.5
Drainage Canal + Drainage pump DP-①			43.0 11.0								43.0 11.0
Drainage Canal + Drainage pump DP-②			- -								- -
Drainage Canal + Drainage pump DP-③			- -								- -
Drainage Canal + Drainage pump Total	- -		43.0 11.0	- -	- -	- -	- -	- -	- -	- -	43.0 11.0
Dranage pump: Dranage Area (sq. km)	9.0	-	43.0	-	-	25.0, 6.0	-	3.6 2.3	-	4.0	90.9
Dranage pump: Dranage Discharge (Cu.m/min)	126	-	594	-	-	348, 54	-	50, 32	-	55	-
Dranage pump: No. of Units x pumping Stations φ500mm	-	-	-	-	-	2 x 1	-	2x1, 1x1	-	2 x 1	7 units
Dranage pump: No. of Units x pumping Stations 800	2 x 1	-	-	-	-	-	-	-	-	-	2 units
Dranage pump: No. of Units x pumping Stations 1000	-	-	5 x 1	-	-	3 x 1	-	- -	-	-	8 units
Dranage pump: Total kW	170	-	780	-	-	460, 70	-	70, 40	-	70	1,660
Irrigation Works – Irrigation Area (ha)	2,000	2,800	2,000	300	1,500	500	1,500	1,800	1,600	1,100	15,100
Irrigation Discharge (Cu.m/min)	96.0	134.4	96.0	14.4	72.0	24.0	72.0	86.4	76.8	52.8	724.8
Irrigation pump (from Rio Cauca) No. of Units x pumping Stations φ300mm	-	-	-	2 x 1	-	2 x 2	-	2 x 2	2 x 2	2 x 2	16 units
Irrigation pump (from Rio Cauca) 360	2 x 4	2 x 2	2 x 2	-	2 x 3	-	2 x 3	2 x 1	2 x 2	2 x 1	36 units
Irrigation pump (from Rio Cauca) 400	-	2 x 1	-	-	-	-	-	2 x 1	-	-	4 units
Irrigation pump (from Rio Cauca) 500	-	2 x 1	2 x 1	-	-	-	-	-	-	-	4 units
Irrigation pump Total kW	150	210	150	50	110	80	110	140	120	80	1,200
Irrigation pump (Underground Water and Others) (ha)	7,000	5,200	4,300	200	-	-	-	-	700	300	17,700

Right Side Bank Area

Item \ Job Division	R-a	R-b	R-c	R-d	R-e	R-f	R-g	Sub-total	Total
Project Area (ha)	6,600	9,600	9,800	9,300	1,800	5,500	4,200	48,800	81,600
Drainage Works (Main) – Drainage Canal: Drainage Area (D.A; Sq.km) and Canal Length (C.L; km)	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL	DA CL
Intercepting Canal I-①	13.9 9.4	2.3 1.7	23.5 13.1	6.5 3.3	4.5 2.9			50.7 30.4	50.7 30.4
Intercepting Canal I-②	- -	20.6 8.7	6.0 1.5	8.0 4.5	7.0 2.5			41.6 17.2	42.6 18.2
Intercepting Canal I-③	- -	54.2 9.2	- -	44.0 9.3	- -			98.2 18.5	113.2 26.6
Intercepting Canal I-④	- -	- -	- -	- -	64.5 8.5			64.5 8.5	147.5 31.5
Intercepting Canal I-⑤	- -	- -	- -	- -	- -			- -	53.5 13.7
Intercepting Canal Total	13.9 9.4	77.1 19.6	29.5 14.6	58.5 17.1	76.0 13.9	- -	- -	255.0 74.6	407.5 120.4
Drainage Canal Only D-①	8.9 5.5	4.0 2.0	- -	- -	- -	- -	- -	12.9 7.5	12.9 7.5
Drainage Canal Only D-②	44.5 8.0	45.5 1.0	- -	- -	31.0 4.0	- -	24.5 6.0	145.5 19.0	151.0 21.0
Drainage Canal Only D-③	- -	- -	- -	56.0 6.0	89.5 3.0	- -	95.0 2.0	240.5 11.0	329.0 30.5
Drainage Canal Only D-④	- -	146.5 9.0	- -	- -	- -	225.0 16.0	- -	371.5 21.0	371.5 21.0
Drainage Canal Only D-⑤	- -	- -	892.0 30.0	- -	- -	- -	- -	892.0 30.0	892.0 30.0
Drainage Canal Only Total	53.4 13.5	196.0 8.0	892.0 30.0	56.0 6.0	120.5 7.0	225.0 16.0	119.5 8.0	1,662.4 68.5	1,756.4 110.0
Drainage Canal + Drainage pump DP-①	24.0 2.0	- -		- -			19.0 7.0	43.0 9.0	86.0 20.0
Drainage Canal + Drainage pump DP-②	- -	50.0 14.0		55.5 10.5			- -	105.5 24.5	105.5 24.5
Drainage Canal + Drainage pump DP-③	- -	- -		- -	-	-	- -	- -	- -
Drainage Canal + Drainage pump Total	24.0 2.0	50.0 14.0	- -	55.5 10.5	- -	- -	19.0 7.0	148.5 33.5	191.5 44.5
Dranage pump: Dranage Area (sq. km)	24.0, 41.0	50.0	-	[illegible]	-	-	19.0	254.5	345.4
Dranage pump: Dranage Discharge (Cu.m/min)	330, 570	690	-	[illegible]	-	-	264	-	-
Dranage pump: No. of Units x pumping Stations φ500mm	-	-	-	2 x 1	-	-	-	2 units	9 units
Dranage pump: No. of Units x pumping Stations 800	4 x 1	-	-	-	-	-	3 x 1	7 units	9 units
Dranage pump: No. of Units x pumping Stations 1000	5 x 1	6 x 1	-	10x1, 9x1	-	-	-	10 units	38 units
Dranage pump: Total kW	430, 750	900	-	[illegible]	-	-	350	5,670	7,330
Irrigation Works – Irrigation Area (ha)	3,200	4,600	2,500	1,200	2,000	2,900	2,400	18,800	33,900
Irrigation Discharge (Cu.m/min)	153.6	220.8	120.0	57.6	96.0	139.2	115.2	902.4	1,627.2
Irrigation pump (from Rio Cauca) No. of Units x pumping Stations φ300mm	2 x 3	2 x 1	-	2 x 4	-	2 x 3	2 x 2	26 units	44 units
Irrigation pump (from Rio Cauca) 360	2 x 3	2 x 1	2 x 1	-	2 x 4	2 x 2	2 x 2	26 units	62 units
Irrigation pump (from Rio Cauca) 400	2 x 1	2 x 4	-	-	-	-	2 x 1	6 units	10 units
Irrigation pump (from Rio Cauca) 500	-	2 x 3	2 x 2	-	-	2 x 1	-	12 units	16 units
Irrigation pump Total kW	240	350	190	90	150	220	180	1,420	2,620
Irrigation pump (Underground Water and Others) (ha)	3,400	5,000	7,300	8,300	1,800	2,600	1,800	30,000	47,700

Description of Diversion Facility of Main Tributary

Water Resources	Available Discharge (cu.m/s)	Gross Water Requirement per 1,000 ha (cu.m/s)	Irrigable Area (ha)	Intake Facilities: Proposed Facility	Intake Facilities: Existing Facility
Cauca River		0.59	33,900	66 pumping station Marginal Canal	
Rio Palo	5.5	0.55	4,500	Diversion Weir Near EL Palo	Intake of CEDFRCA Power Station
Rio Fraile	1.2	0.55	1,500	Diversion Weir Near Florida	Intake of Ing. Castilla & Ing. Balsilla
Rio Amaime	2.4	0.54	3,100	Diversion Weir Near Los Ceibos	Intake of Ing. Manuelita, Ing. Oriente & Ing. Providencia
Rio Tulua	1.8	0.57	4,700	Diversion Weir Near Tulua	Intake of Ing. San Carlos etc.
Rio Bg. Grande	3.2	0.58	3,900	Diversion Weir Near Bg. Grande	Intake of Canal Nacional de Irrigacion to Ing. Rio Paila
Rio Timba	2.7	0.38	5,000	Diversion Weir Near Timba	
Rio Claro	0.6	0.38	1,300	Diversion Weir Near Potrito	
Rio Frio	3.0	0.52	4,000	Diversion Weir Loma de Guaca	

LEGEND

- River
- Irrigated Area by Cauca River
- Irrigated Area by Subterranean Water and Tributary
- Drainage Pumping Station
- Drainage Canal (Symbol ; D-1, Canal Length ; 5 km)
- Intercepting Canal (Symbol ; I-3, Canal Length ; 3 km)
- Drainage Area (10 sq.km)
- Job Division
- Main Road
- Proposed Intake Facility
- Existing Intake Facility
- Irrigation Pump and Marginal Canal

0 5 10km

Fig. 1 General Plan of Land Reclamation in Cauca Plain

1. General Description

In the General Report, drainage works covered 81,600 ha of land on both banks of the Cauca River. In this appendix, a project area of approximately 200,000 ha of the Cauca Plain is considered for land reclamation scheme including irrigation and drainage works mainly from the standpoint of irrigation.

The nature of the project study is of preliminary grade, and therefore, further studies should be promoted which would include investigations of subterranean water, preparation of topographic maps from aerial photographs and soil classifications.

Because of the relatively large annual rainfall and the rich runoff of the Cauca River and its tributaries, irrigation problems are generally treated optimistically. But, as an actual problem, very frequently adequate supply of irrigation water is not available when it is most needed and the normal growing of crops has adversely affected by drought almost every year in all parts of the area.

In some Haciendas having with well-organized irrigation system, they have overcome this obstacle and have achieved good agriculture production. In view of this situation, it is evident that there is need to establish irrigation system for the development of agriculture in the Cauca Plain.

The Cauca Plain can be irrigated by three water sources: the flow of the Cauca River, its tributaries and subterranean water. The basic assumption for the irrigation study is as follows (See Fig. 1).

1. Tributaries of Cauca River will be utilized for irrigation of the higher lands.
2. Water of Cauca River will be utilized for irrigation in the riparian zone along the river.
3. In the middle part of the Cauca Plain, water of Cauca River or subterranean water will be utilized for irrigation.

Particularly regarding the utilization of water resources, considerations should be taken as follows.

For Cauca River and its tributaries:

(a) Establishment of water right to enable assured utilization of water at any time including the dry season.
(b) The unification or improvement of intake facilities for main canals and appropriate connection to the distribution canals.
(c) Establishment of irrigation practice.

For Subterranean water:

(a) It is necessary to know the storage capacity and the hydraulic constants of the aquifer, etc. according to scientific researches.
(b) The availability of water, design and location of new wells should be decided according to the results of studies.

2. Estimation of Water Requirement

2.1 Evapotranspiration

Evapotranspiration of each crop was studied by Blaney-Criddle formula. Maximum monthly temperature at Cali and La Manuelita stations was regarded as representative in the Cauca Plain. These records are well arranged for a long term and shows rather higher temperatures than other stations. Value of day time hour at latitude 4°N was regarded as that of the Cauca Plain. Ratio (p) of monthly day time hour to the annual value is shown in Table 1.

Consumptive use coefficient (K) of main crops shown in Table 1 was determined referring to existing reports.[1/] Though the evapotranspiration is changeable according to the growing stages of crops, as a preliminary study, the average seasonal K values were applied and no considerations were taken into account of seasonable changes.

Table 1 Consumptive Use by K Value

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Remarks
Max. monthly temp.														
Cali (°C)		26.2	26.0	25.5	25.7	25.0	25.2	25.3	25.4	25.4	24.8	24.6	25.4	
La Manuelita (°C)		25.6	26.4	26.3	25.9	25.6	26.7	26.1	26.1	25.6	25.0	25.6	25.7	
Daytime hour		715	719	725	732	739	742	740	734	728	721	716	713	N4°
p Value (%)		8.19	8.25	8.32	8.39	8.45	8.50	8.48	8.42	8.34	8.27	8.21	8.18	
Consump. Use ($\frac{mm}{Month}$)														
[Cali]	K Value													Crop
	1.0	167.9	152.1	167.1	164.6	168.9	165.1	170.2	169.4	162.6	163.8	157.0	171.2	Rice
	0.9	151.1	136.9	150.4	148.1	152.0	148.6	153.2	152.5	146.3	147.4	141.3	154.1	Sugar Cane
	0.8	134.3	121.7	133.7	131.7	135.1	132.1	136.2	135.5	130.1	131.0	125.6	137.0	Maize, Sorghum
	0.7	117.5	106.5	117.0	115.2	118.2	115.6	119.1	118.6	113.8	114.7	109.9	119.8	Beans & Others
	0.65	109.1	98.9	108.6	107.0	109.8	107.3	110.6	110.1	105.7	106.5	102.0	113.0	Soybean
	0.6	100.7	91.3	100.3	98.8	101.3	99.1	102.1	101.6	97.6	98.3	94.2	102.7	Cotton
[La Manuelita]	K Value													
	1.0	165.6	153.4	170.2	165.4	171.2	170.9	173.2	172.2	163.3	164.6	160.5	165.6	
	0.9	149.0	138.1	153.2	148.9	154.1	153.8	155.9	155.0	147.0	148.1	144.5	149.0	
	0.8	132.5	122.7	136.2	132.3	137.0	136.7	138.6	137.8	130.6	131.7	128.4	132.5	
	0.7	115.9	107.4	119.4	115.8	119.8	119.6	121.2	120.5	114.3	115.2	112.4	115.9	
	0.65	107.6	99.7	110.6	107.5	111.3	111.1	112.6	111.9	106.1	107.0	104.3	107.6	
	0.6	99.4	92.0	102.1	99.2	102.7	102.5	103.9	103.3	98.0	98.8	96.3	99.4	

2.2 Effective Rainfall

According to the standard practice of CVC[2/] rainfall of more than 10 mm/day is regarded as effective. Precipitation and effective rainfall at three stations Jamundi, Cali and La Manuelita – in these fifteen years are exhibited in Table 2. At Jamundi annual precipitation is over 2,000 mm, and annual effective rainfall is 1,852 mm, which is a ratio of 86%.

Minimum monthly effective rainfall of 50 mm/month at Jamundi can supply about 40% of necessary consumptive use of crops. On the other hand, at Cali and La Manuelita, annual effective rainfall is about 700 mm, and minimum effective rainfall of 15 - 20 mm/month can only supply about 10% of consumptive use of crops.

However, occurrence of no effective rainfall in dry season and even in wet season were recorded at these stations, several times in these 15 years, as shown in Table 2. This is the reason for the necessity of irrigation in the Cauca Plain in the long run.

1/ The Unified Development of Power & Water Resources in Cauca Valley (Jan. 1956, OLAP, G&H, KTAM)
Proyecto La Victoria-Cartago-Estudio de Factibilidad (Informe CVC No. C-10877 Agosto 1966)

2/ Departamento de Aguas, CVC.

Table 2 Effective Rainfall in Cauca Plain

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
[Jamundi]													
1. Monthly Ave. Precip. (R mm)	106.7	120.2	197.6	299.0	269.3	132.5	74.5	83.0	86.7	308.0	260.4	211.2	2,149.1
2. Monthly Ave. Eff. Rainfall (E mm)	78.2	101.6	153.0	273.0	235.2	123.3	52.6	686	67.3	263.2	234.9	200.9	1,851.8
3. E/R (%)	73.4	84.5	77.5	91.2	87.5	93.2	70.2	82.4	77.7	85.5	90.2	95.0	86.2
4. Years with No Eff. Rain	1	1	1	0	0	2	1	3	2	0	0	0	
[Cali]													
1. Monthly Ave. Precip. (R mm)	60.5	52.8	80.4	124.4	133.4	74.4	36.7	38.6	59.1	116.2	102.5	88.6	967.6
2. Monthly Ave. Eff. Rainfall (E mm)	37.4	35.0	53.7	90.1	102.8	47.8	15.5	24.4	43.2	83.3	75.6	64.8	673.8
3. E/R (%)	661.8	66.4	66.8	72.4	77.0	64.4	42.2	63.2	73.0	71.6	73.9	73.2	69.6
4. Years with No Eff. Rain	2	5	1	0	0	3	5	6	4	0	0	0	
[La Manuelita]													
1. Monthly Ave. Precip. (R mm)	80.4	67.8	80.6	152.3	139.0	63.7	39.4	26.4	51.1	133.9	101.1	98.5	1,034.2
2. Monthly Ave. Eff. Rainfall (E mm)	61.9	51.2	54.2	122.6	109.1	40.3	20.9	13.9	34.5	114.4	69.7	52.0	744.7
3. E/R (%)	77.0	75.2	67.0	80.5	78.5	63.3	53.1	52.6	67.5	85.5	68.9	52.8	72.0
4. Years with No Eff. Rain	2	2	1	1	0	2	6	2	5	0	2	1	

2.3 Water Requirement

Irrigation water requirement (net and gross) for various annual crops and sugar cane was estimated as shown in Table 3, based on the cropping ratio mentioned in 7.2. These figures were obtained from the combination of effective rainfall and evapotranspiration at Jamundi, Cali and La Manuelita. The irrigation efficiency of 0.65 was applied, except for rice field, which is 0.50. Conveyance efficiency of 0.80 was also applied in the table.

2.4 Capacity of Irrigation Facilities

Capacity of irrigation facilities should be sufficient to supply enough irrigation water, even at the time when there is no effective rainfall.

Gross water requirement in parenthesis of Table 3 is necessary in June, July, August and September and in these months effective rainfall was not taken into consideration.

3. Surface Water Resources for Irrigation

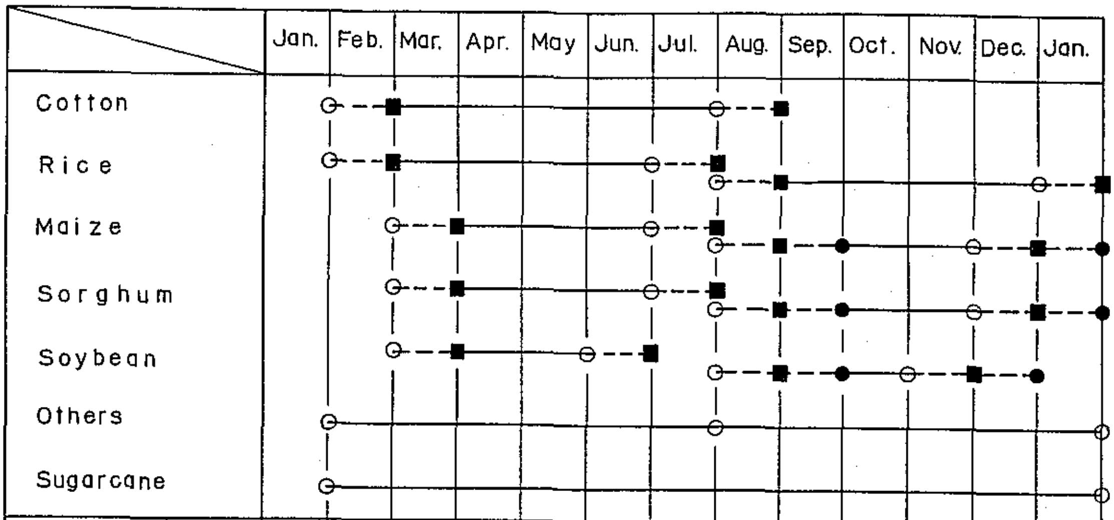
3.1 Water Quality

The suitability of the Cauca River and four tributaries for irrigation water was studied in Table 4. Sodium absorption ratio and electric conductivity are both less than their allowable limit. It is, therefore, evident that the river water is suitable for irrigation use.

3.2 Available River Discharge and Irrigable Area

The minimum discharge of the Cauca River is about 70 cu.m/s at Juanchito in dry season, but after completion of the Cauca River Regulation Project it will increase to 130 cu.m/s. The discharge of the Cauca River will be adequate for irrigation purpose. Therefore, irrigable area by the use of the Cauca River is provisionally estimated at 33,900 ha on the basis mainly of topographic aspects. This area can be irrigated by pumps and marginal canals with an average water requirement of approximately 20 cu.m/s.

Table 3 Water Requirement



		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
R – a.b.c Cu : La Manuelita ER : La Manuelita	N.W.R	122	54	237	36	102	440	284	272	336	52	241	251	122
	G.W.R	153	68	296	45	128	550 (800	355 424	340 383	420 598)	65	301	314	153
R – d Cu : La Manuelita ER : La Manuelita	N.W.R	101	51	262	40	102	432	248	306	380	378	256	248	101
	G.W.R	126	64	328	50	127	540 (790	310 384	382 450	475 680)	472	320	310	126
R – e.f Cu : La Manuelita ER : La Manuelita	N.W.R	103	24	225	40	110	448	264	255	337	59	248	244	103
	G.W.R	129	30	281	50	138	560 (810	330 392	319 360	420 596)	74	310	305	129
R – g Cu : La Manuelita ER : La Manuelita	N.W.R	100	21	239	46	120	465	270	207	296	400	223	222	100
	G.W.R	125	26	290	58	150	582 (832	338 400	283 326	370 520)	500	279	278	125
L – a.b.c Cu : Cali ER : Jamundi	N.W.R	138	43	22	—	—	91	261	170	301	—	—	—	138
	G.W.R	173	54	38	—	—	114 (810	327 515	213 472	377 810)	—	—	—	173
L – d.e Cu : Cali ER : Cali	N.W.R	180	87	268	166	112	376	290	390	390	249	249	303	385
	G.W.R	225	109	335	208	140	470 (772	363 416	305 390	350 438)	238	244	273	225
L – f Cu : La Manuelita ER : La Manuelita	N.W.R	155	103	258	17	84	374	323	345	365	41	248	272	155
	G.W.R	194	129	323	21	105	468 (780	404 484	431 488	446 652)	51	310	340	194
L – g.h.i.f Cu : La Manuelita ER : La Manuelita	N.W.R	114	24	252	50	133	417	308	273	365	62	252	242	114
	G.W.R	143	30	316	63	166	521 (718	386 456	342 385	445 520)	78	315	303	143
Inundated Area Cu : La Manuelita ER : La Manuelita	N.W.R	108	37	251	43	113	469	294	261	343	184	253	247	108
	G.W.R	135	46	314	54	142	586 (842	368 438	327 368	430 610)	230	317	309	135
Sugar Cane Field Cu : La Manuelita ER : La Manuelita	N.W.R	518	516	589	156	267	675	802	839	669	200	445	577	518
	G.W.R	648	646	737	195	334	845 1,140	1,000 1,160	1,050 1,150	835 1,009)	250	556	712	648

C.U : Consumptive Use N.W.R : Net Water Requirement
E.R : Effective Rainfall G.W.R : Gross Water Requirement
Figure in the parentheses : Water requiremeut with no effective rainfall

Table 4 Chemical Analysis of River Water

	CO_3 (Meg/l)	HCO_3 (Meg/l)	Cl (Meg/l)	Ca (Meg/l)	Mg (Meg/l)	Na (Meg/l)	K (Meg/l)	Conductivity Micro-mho	Date of Sampling
Rio Cauca									
Juanchito	0	0.40	0.10	0.401	0.216	0.25	0.05	90.4	Aug. 1968
Mediacanoa	0	0.38	0.10	0.803	0.653	0.20	0.05	130.4	Aug. 1968
Rio Bugalagrande	0	1.00	0.20	0.752	0.583	0.16	0.02	137.6	Oct. 1968
Rio Jamundi	0	0.22	0.02	0.357	0168	0.08	0.05	120.8	Aug. 1968
Rio Palo	0	0.65	0.20	1.104	0.885	0.35	0.35	180.0	Feb. 1967
Rio Timba	0	0.32	0.05	0.487	0.415	0.10	0.02	75.4	May 1968

Analisis Quimico de Algunos Afluentes del Rio Cauca.

In the case of tributaries for irrigation water sources, the minimum discharge corresponding to a return period of once in ten years was regarded as the available water. Using the runoff data of tributaries in Table 5, the available discharge of each tributary will be as given in Table 6. The irrigable area which can rely on this available discharge is estimated as shown in Table 6, where the maximum gross water requirement is also shown, and the efficiency of intake from the river is assumed to be 70%.

Table 5 Annual Minimum Discharge of Main Tributaries

River \ Year	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	Min. Discharge of 1/10 Probability
Rio Palo	4.4	5.6	5.1	7.4	14.4	6.5	9.1	4.9	8.1	10.2	9.0	5.3	3.7	2.3	4.9	6.9	4.4	4.0	–	3.5
Rio Fraile	–	–	–	–	–	–	–	–	2.3	3.0	3.4	2.3	1.7	0.9	2.4	2.2	0.9	–	–	2.4
Rio Amaime	3.1	3.8	2.9	2.7	2.3	–	3.2	4.1	3.5	7.0	5.3	–	–	–	–	–	–	–	–	2.4
Rio Tulua	3.8	4.2	4.0	5.8	5.2	5.6	4.6	4.1	5.5	6.4	8.2	4.3	–	–	–	–	–	–	–	3.8
Rio Bugalagrande	2.8	4.6	5.1	6.6	7.0	4.8	4.8	4.9	3.0	4.0	–	–	–	–	–	–	–	–	–	3.2
Rio Timba	2.3	5.0	4.0	6.0	6.5	5.9	2.9	2.9	2.8	5.6	–	–	–	–	–	–	–	–	–	2.7
Rio Claro	0.6	1.6	0.7	1.1	3.2	0.9	0.9	0.5	1.1	2.6	1.9	0.9	0.9	1.2	1.0	0.9	1.3	1.8	–	0.6
Riofrio	2.6	5.1	4.5	6.5	6.7	6.0	4.8	5.8	6.0	7.6	1.95	0.1	–	–	–	–	–	–	–	3.0

Beletin Hidrologico-1952 (Instituto Nacionol de Aprovechomiento de Aguas y Fomento Electrico)
Informacion Hidrologica, Zona 6 - Alto Cauca – 1964, 1967.

Table 6 Available River Discharge and Irrigable Area by Water of Tributaries

	Available River Discharge (cu.m/s)	Gross Water Requirement per 1,000 ha. (cu.m/s)	Irrigable Area (ha)
Cauca River	130	0.59	33,900
Rio Palo	3.5	0.55	4,500
Rio Fraile	1.2	0.55	1,500
Rio Amaime	2.4	0.54	3,100
Rio Tulua	3.8	0.57	4,700
Rio Bg. Grande	3.2	0.58	3,900
Rio Timba	2.7	0.38	5,000
Rio Claro	0.6	0.38	1,100
Rio Frio	3.0	0.52	4,000

4. Diversion Scheme from River

Some intake facilities have already been constructed on the bank of Cauca River and main tributaries. Some of them are adequate for available river discharges and some have less capacity compared to available river discharges. Most of these facilities are rather primitive or obsolete and the complexity of the canal system has obstructed the effective utilization of water. It is therefore essential to unify or improve old irrigation facilities and organize the irrigation system for better usage and for assured supply of irrigation water at any time.

Details and concrete studies or designs have not been made, but some general concepts on the diversion scheme are proposed as follows. The irrigation water for the area which is located close to levees along the Cauca River will be supplied by 66 pumping stations and marginal canals. In other areas not irrigable by marginal canals, irrigation canals from tributaries or intercepting canals can be utilized. The main tributaries have sufficient head to permit gravity diversion.

Diversion facilities will consist of movable weir combined with sand-flash gate and fixed weirs, etc. Intake facilities should be constructed on a topographically favorable side of the river and water will be distributed to the opposite side if necessary. (See Table 7 and Fig. 1)

Table 7 Description of Diversion Facility of Main Tributaries

Water Resources	Available Discharge (cu. m/s)	Irrigable Area (ha)	Gross Water Requirement (cu. m/s)	Intake Facility	
				Proposed Facility	Existing Facility
Cauca River	130	33,900	20.0	66 pumping stations Marginal Canal	
Rio Palo	3.5	4,500	2.5	Diversion Weir near El Palo	Intake of CEDERCA Power Station
Rio Fraile	1.2	1,500	0.8	Diversion Weir near Florida	Intake of Ing. Castilla & Ing. Balsilla
Rio Amaime	2.4	3,100	1.7	Diversion Weir near Los Ceibos	Intake of Ing. Manuelita, Ing. Oriente & Ing. Providencia
Rio Tulua	3.8	4,700	2.7	Diversion Weir near Tulua	Intake of Ing. San Carlos etc.
Rio Bg. Grande	3.2	3,900	2.3	Diversion Weir near Bg. Grande	Intake of Canal Nacional de Irrigacion to Ing. Rio Paila
Rio Timba	2.7	5,000	1.9	Diversion Weir near Timba	
Rio Claro	0.6	1,100	4.2	Diversion Weir near Potrerito	
Rio Frio	3.0	4,000	2.1	Diversion Weir Loma de Guacas	

5. Utilization of Subterranean Water

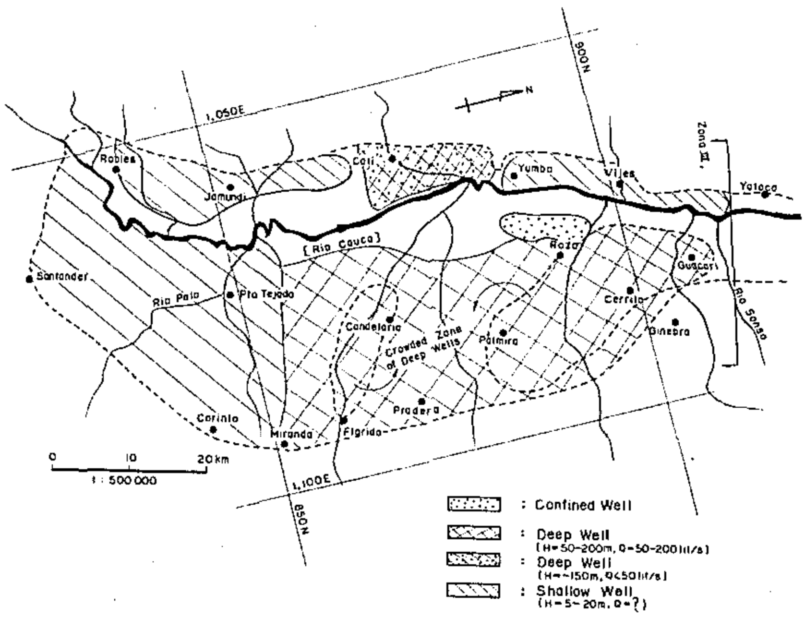
5.1 Present Status of Utilization of Subterranean Water.

5.1.1 General

The sources of subterranean water in this area are infiltration of rainfall and seepage from rivers. The Cauca plain which is gently sloping and rolling, contains an excellent storage layer of 100 m to 200 m deep consisting of clay, loam, sand and gravel. It is quite natural that large amount of storage of subterranean water can be expected from this layer and in many places water has been pumped up from wells for irrigation and domestic purposes.

The location of some existing 600 wells in Zone III[1/] is shown in Fig. 2. (attached in the back-cover) Wells are classified into three categories, called Pozo Profundo, Aljibe and Saltanto and the geographical distribution of these three kinds of wells in Zone III is shown in Fig. 3. About two thirds of them are classified as Pozos Profundos and information concerning depth, water quantity, water table and geological profile, for about one third of these wells are given in the data compiled by Colpozos, Smith and other firms.

Fig. 3 Utilization of Subterranean Water in Zona III



According to these data and the investigation of CVC, main features of wells and classification are shown in Table 8. The general characteristics of wells are summarized in Table 9.

Note: Geological Condition given in the "Unified Development of Power and Water Resources in the Cauca Valley (January 1956.)" is as follows.

The quaternary deposits of the Cauca River and its tributaries have originated the "Valle" formation, which extends over the entire alluvial plain. Between Cali and Palmira, the quaternary reaches a thickness of at least 180 m; north and south of this zone the depth is at least 50 m and probably more. The quaternary material consists principally of gravel, sand, sandy clay and clay; sometimes it forms more or less coherent conglomerates, cemented together by iron-hydroxide. The material is fluviatile and the strata are generally horizontal. The location of the quaternary has been governed by sedimentation of material transported by the Cauca River and its tributaries. Cuts show silt, sand and gravel in alternate layers as governed by low or high river stages. The foot-hills of the Cordillera Central and Occidental are formed by quaternary and tertiary strata, which are the only strata able to contain groundwater in exploitable quantities. The main tertiary formations are situated in the north between Buga and Cartago, and consist generally of clay-like or sandy material with some gravel, conglomerates, slates, schists and some igneous material.

A considerable part of the flow of the tributaries disappears by infiltration into the subsoil, the so-called dejection cones of these tributaries situated at the border of the flat part of the Cauca Valley. Because of this phenomenon, there should be a slowly moving and wide underground flow of water in a direction oblique to the Cauca River flow. Some of the strata, especially in the tertiary, might contain underground "lakes", formed by large porous deposits which are filled rapidly during the rainy seasons. The "loose" sand and gravel layers are the ideal groundwater conductors, which in the flat zone of the Cauca Valley often have a thickness of between 10 and 20 m and a large superficial area.

1/ CVC is now investigating subterranean water in Zone III, Cali, Zone II – Tuluá, and Zone I Cartago.

Table 8 Classification of Existing Wells in Cauca Plain

MUNICIPIO	SIMBOLO del POZO	POZO PROFUNDO — PROFUNDIDAD de la PERFORACION (m) ~50	50~100	100~150	150~200	200~	NO IN-FORM	PRODUCCION RECOMENDABLE (lit/sec) ~50	50~100	100~150	150~200	200~250	250~300	300~	NO IN-FORM	TOTAL (POZO)	ALJIBE — PROFUNDIDAD (m) ~10	10~20	20~	NO IN-FORM	TOTAL (POZO)	SAL-TANTE (POZO)	GRAND TOTAL (POZO)
PALMIRA	V_p	3	38	20	3	3	25	1	3	4	13	4	5	-	62	92	-	-	-	-	-	3	94
CALI	V_c	11	11	10	4	-	14	17	1	-	-	-	-	-	32	50	7	4	1	7	19	1	70
CERRITO	V_{ce}	-	21	6	1	-	25	3	7	5	3	5	-	-	30	53		-		-	-	-	53
CANDELARIA	V_{cn}	4	13	9	-	-	28	4	2	4	11	2	-		31	54	-	-	-	-	-	-	54
YUMBO	V_{yu}	6	17	8	1	-	27	9	1	-	-	-		1	48	59	3	4		3	10	-	69
PRADERA	V_{pr}	-	5	2	-	-	6	-	1	1	1	-	1	-	9	13	-	-		-	-	-	13
JAMUNDI	V_j	3	3	-	-	-	-	3	-	-	-	-	-	-	3	6	-		-	$(7^m$-$17^m)$	38	-	44
VIJES	V_v	1	1	-	-	-	3	-	-	-	-	-	-	-	5	5	5	2	1	-	8	-	13
GUACARI	V_{gu}	-	4	4	-	-	15	-	-	1	3	-	1	-	18	23	-	-	-	-	-	-	23
GINEBRA	V_g	-	4	3	-	-	3	-	2	-	-	-	-	-	8	10	-	-	-	-	-	-	10
FLORIDA	V_f	2	1	3	-	-	2	1	-	1	-	-	-	-	6	8	-	-	-	1	1	-	9
PUERTO TEJADA	C_{pt}	-	1	1	-	-	2	-	-	-	2	-	-	-	2	4	35	4	-	6	45	-	49
BUENOS AIRES	C_{ba}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$(4^m$-$13^m)$	5	-	5
CALOTO	C_{ca}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	$(4^m$-$20^m)$	20	-	20
SANTANDER	C_{san}	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	$(4^m$-$22^m)$	31	-	32
MIRANDA	C_{mi}	2	6	1	-	-	-	1	1	-	4	-	1	-	2	9	7	1	-	3	11	-	20
(TOTAL)		32	125	68	9	3	150	39	18	16	37	11	8	1	257	387 (66.4%)					188 (32.2%)	8 (1.4%)	583 (100%)

Table 9 Description of Wells

Wells	Location	Depth (m)	Quantity Pumped up (lit/sec)	Remarks
Pozo Profundo (Deep Well) 387 wells	El Hormiguero-Miranda ~Rio Sonso	50~150	50~200	About 90% of wells are mainly used for irrigation and in the area of Cali Yumbo mainly used for industry.
	Cali ~ Yumbo	50~150	~50	Many deep wells which can produce 150 ~ 200 lit/sec are found in the vicinity of Palmira.
				Casings with dia. 10 ~ 20 inch, borehole or submerged pumps with motor or diesel engine (100 ~ 200 HP) are installed.
Aljibe (Sharrow Well) 188 wells	Santander ~ El Horm.-Miranda	5 ~ 20		Almost of all are used for domestic water. Concrete casings with dia. 1 ~ 2^m
	Robles ~ Jamundi	5 ~ 20	unknown	A few collecting pond are found in these districts.
	Yumbo ~ Vijes	5 ~ 20		
Saltante (Confined well) 7 wells	Rozo	70~200		Almost of them are found in the vicinity of Rozo.

5.1.2 Subterranean Water Table

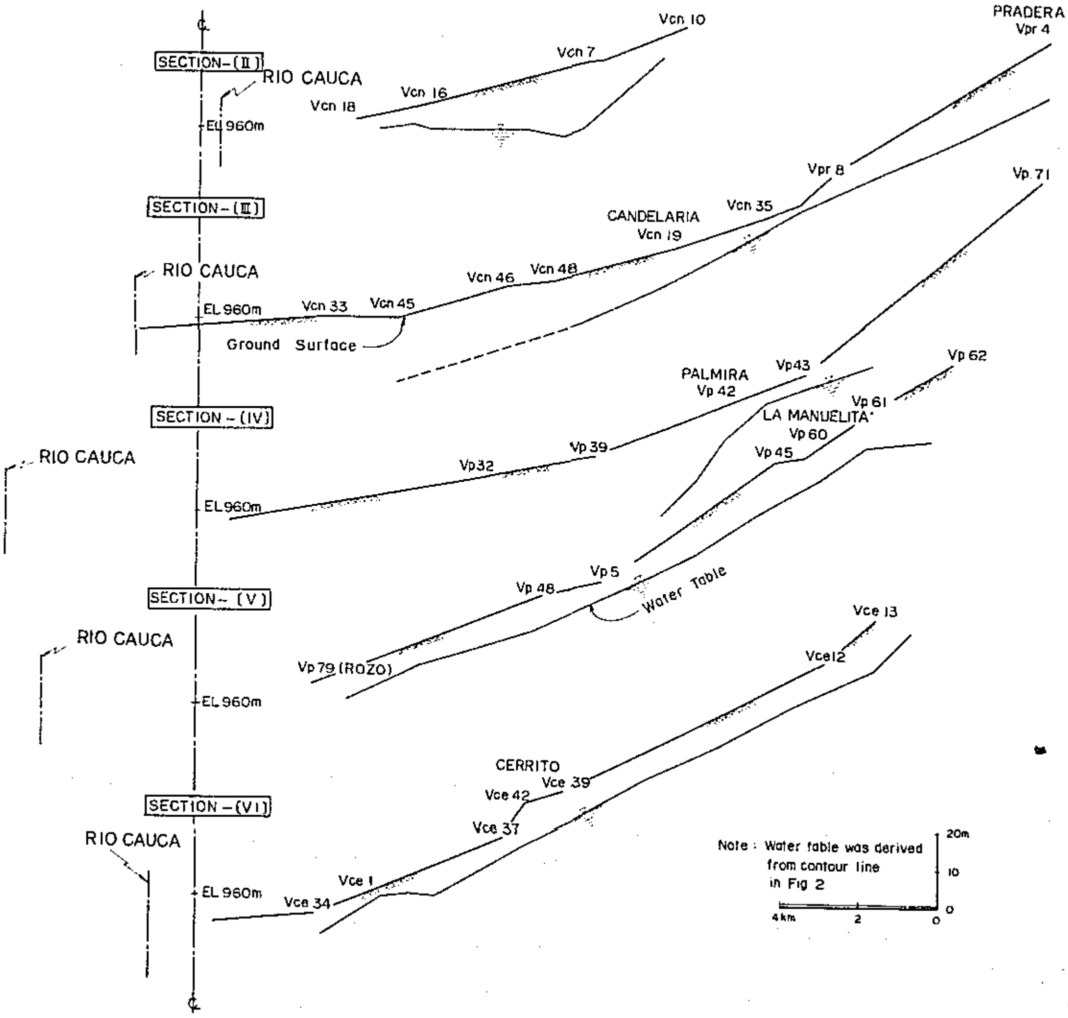
The static level of water in the area of Candelaria, Palmira and Cerrito is summarized in Table 8 and the contour line of water table in this area is drawn in Fig. 2. The static water level is found about 10 m below the ground surface and nearly parallel with it.

The average hydraulic gradient of the water table from the foot of Cordillera Central to Cauca River is regarded as 1/100 – 1/200 as shown in Fig. 4.

Section 1/	Area	Average hydraulic gradient
III – III	Pradera - Candelaria	1/200
IV – IV	Vicinity of Palmira	1/125
V – V	La Manuelita - Rozo	1/200
VI – VI	El Cerrito	1/170

1/ Cross sections which were selected at every 10 km interval at right angles to the flow of Cauca River.

Fig. 4 Hydraulic Gradient of Subterranean Water



5.1.3 Capacity of Wells

Production data of each well from which irrigation water is now being pumped up are available for one third of all deep wells (see Table 8). According to these data, the wells with a depth of about 100 m have an average production capacity of 100 - 200 lit/s. in Zone III.

5.1.4 Geological Profile

Geological profiles of the cross sections traversing Cauca River at right angle for every 10 km interval are shown in Fig. 2. Because the Cauca Plain is composed of flood plain and alluvial fan, the geological profile is complicated consisting of many layers. Among these alternate layers consisting of clay, loam, sand and gravel, thick sandy or gravel layer is especially good permeable layer or aquifer.

Excellent aquifers are assumed to be distributed depending on topography and geological condition, and generally speaking, the Cauca Plain contains favorable aquifers.

Chemical analysis of subterranean water is tabulated in Table 10. According to this table, all samples, are classified C_2S_1 or C_3S_1. Consequently, the subterranean water in the Cauca Plain is suitable for irrigation.

Table 10 Chemical Analysis of Subterranean Water

POZO No. (Vp)	Classification of Water	pH Potenciometrico a 20°C	Conductividad Electro a 25°C	Carbonate en CO_3 (meq/l)	Bicarbonates en HCO_3 (meq/l)	Sulfatos en SO_4 (meq/l)	Clorurus en Cl (meq/l)	Calcio en Ca (meq/l)	Mancesio en Mg (meq/l)	Sodio en Na (meq/l)	Potasio en K (meq/l)	Solidos disvoltos totales (p.p.m.)
15	C_2S_1	7.48	550	0.268	5.107	0.840	6.301	3.467	1.693	0.880	0.030	270
23	C_3S_1	7.25	1,300	0	8.908	5.360	8.344	5.015	6.605	2.830	0.010	920
5	C_2S_1	8.00	230	0.384	1.920	0.140	1.452	0.454	0.041	1.420	0.010	158
33	C_2S_1	6.88	490	0.576	4.224	1.840	8.243	2.559	2.090	0.550	0	357
55	C_2S_1	7.20	510	0.816	4.704	0	5.941	2.813	2.179	0.470	0.020	306
58	C_2S_1	7.25	500	0.460	5.107	0	4.052	2.487	2.501	0.410	0.010	333
66	C_2S_1	6.94	390	0	4.080	0.440	3.501	2.024	1.794	0.330	0.010	273
71	C_2S_1	–	380	0.384	3.552	0.080	4.502	1.836	1.693	0.450	0.010	255
44	C_2S_1	7.28	580	0.614	3.145	0.700	5.447	3.740	1.729	0.850	0.050	363
41	C_2S_1	7.20	575	0.384	5.496	1.450	4.900	3.354	1.054	0.820	0.030	352
Aljibe (23)	C_3S_1	7.25	1,300	0	8.908	5.360	8.344	5.015	6.605	2.830	0.010	920
Aljibe (22)	C_3S_1	7.63	1,200	0.768	7.372	4.400	7.844	2.910	5.057	4.280	0.030	850

Evaluacion de Acuiferos, CVC.

5.2 Studies on Utilization of Subterranean Water

At present, subterranean water is widely utilized in the Cauca Plain as mentioned above and further development is anticipated in the future. However, decrease of production because of interference between each well or destruction of aquifers by excessive pumping, etc., has occurred in the area where wells are closely spaced.

Location of wells should be carefully decided to prevent the abovementioned problems and to maintain their lives. They should be determined on the basis of studies of storage capacity, hydraulic constants of aquifer and geological profile, etc.

An estimate of the value of transmissibility is as follows according to data compiled by Colpozos. Table 11 and Fig. 5 show the relation between depression of water level and time elapse when pumping up is increased from Qi to Qi + 1. The order of 10^{-2} – 10^{-3} sq.m/s was obtained as shown in Table 12 by the Chow or Jacob method. Besides these values in Table 12, nearly the same values were obtained in the step-pumping test conducted by Colpozos (Table 13). As an indication of the specific capacity, unit production per 1 m drawdown of water level is also given in the Table 13.

Table 11 Depressing Process of Wells

V_{pr}-3 (Colp. 49-1)

T (hr·m)	ΔT (sec)	Depress (m)	S (m)
① 2^h25	–	11.6	–
30	300	15.2	3.6
35	600	15.8	4.2
40	900	15.8	4.2
45	1,200	15.8	4.2
50	1,500	16.0	4.4
55	1,800	16.2	4.6
13.10	2,700	16.2	4.6
25	3,600	16.3	4.7
40	4,500	16.4	4.8
55	5,400	16.5	4.9
14.10	6,300	16.6	5.0
25	7,200	16.7	5.1
② 4.25	–	20.7	–
30	300	25.2	4.5
35	600	25.4	4.7
40	900	25.4	4.7
45	1,200	25.5	4.8
55	1,800	25.5	4.8
5.10	2,700	25.8	5.1
25	3,600	25.9	5.2
40	4,500	26.1	5.4
55	5,400	26.2	5.5
6.25	7,200	26.2	5.5

V_p-33 (Colp. 71)

T (hr·m)	ΔT (sec)	Depress (m)	S (m)
① 15.00	–	16.5	–
18.00	10,800	18.3	1.8
21.00	21,600	18.6	2.1
0.00	32,400	19.5	3.0
② 14.00	–	11.3	–
17.00	10,800	12.8	1.5
20.00	21,600	13.1	1.8
22.00	28,800	13.1	1.8

Colp-10U (Yumbo)

T (hr·m)	ΔT (sec)	Depress (m)	S (m)
② 14.30	–	12.2	–
45	900	15.6	3.4
15.00	1,800	16.2	4.0
30	3,600	16.2	4.0
16.00	5,400	16.5	4.3
17.00	9,000	16.5	4.3
④ 19.30	–	21.6	–
45	900	26.5	4.9
20.00	1,800	26.9	5.3
30	3,600	27.2	5.6
21.00	5,400	27.5	5.9
22.00	9,000	27.5	5.9

V_{ce}-19 (Colp. 91)

T (hr·m)	ΔT (sec)	Depress (m)	S (m)
① 6.00	–	9.2	–
8.00	7,200	9.7	0.5
10.00	14,400	10.0	0.8
12.00	21,600	10.3	1.1
15.00	32,400	10.3	1.1
17.00	39,600	10.3	1.1

Note: [Q]

V_{pr}-3

① : 72.5 ~ 90.0 lit/sec

② : 103.0 ~ 124.0 lit/sec

V_p-33

① : 144 ~ 156 lit/sec

② : 114 ~ 121 lit/sec

Colp-10U

② : 9.2 ~ 10.7 lit/sec

④ : 12.6 ~ 14.6 lit/sec

V_{ce}-19

① : 104 ~ 114 lit/sec

Table 12 Transmissibility Coefficiency

Observed Well	Water Quantity (Q)	Depression at match Point (S)	Depression in a Log-Cycle (ΔS)	Value of Well Function (W(u))	Transmissibility (T) CHOW.	Transmissibility (T) JACOB.
	(10^{-3} cu.m/s)	(m)	(m)		(10^{-3}sq.m/s)	(10^{-3}sq.m/s)
1. V_{pr}-3 (1) (Colp. 49-1)	17.5	4	1.0	8	2.8	3.2
2. V_{pr}-3 (2) (Colp. 49-1)	21.0	5	0.75	(15)	4.4	5.0
3. V_{pr}-33 (1) (Colp. 71)	12.0	2.5	2.5	2.3	0.9	0.9
4. V_{pr}-33 (2) (Colp. 71)	7.0	1.8	1.1	4	0.8	0.7
5. V_{ce}-19 (Colp.-91)	10.0	1.0	1.0	2.3	1.8	1.8
6. Colp-10U (2) (Yumbo)	1.5	4.0	1.0	8	0.2	0.3
7. Colp-10U (4)	2.0	5.5	1.25	9	0.3	0.3

CHOW'S Formula : $T = \frac{Q}{4\pi S} W(u)$, JACOB'S Formula : $T = \frac{2.3 \cdot Q}{4\pi \Delta S}$

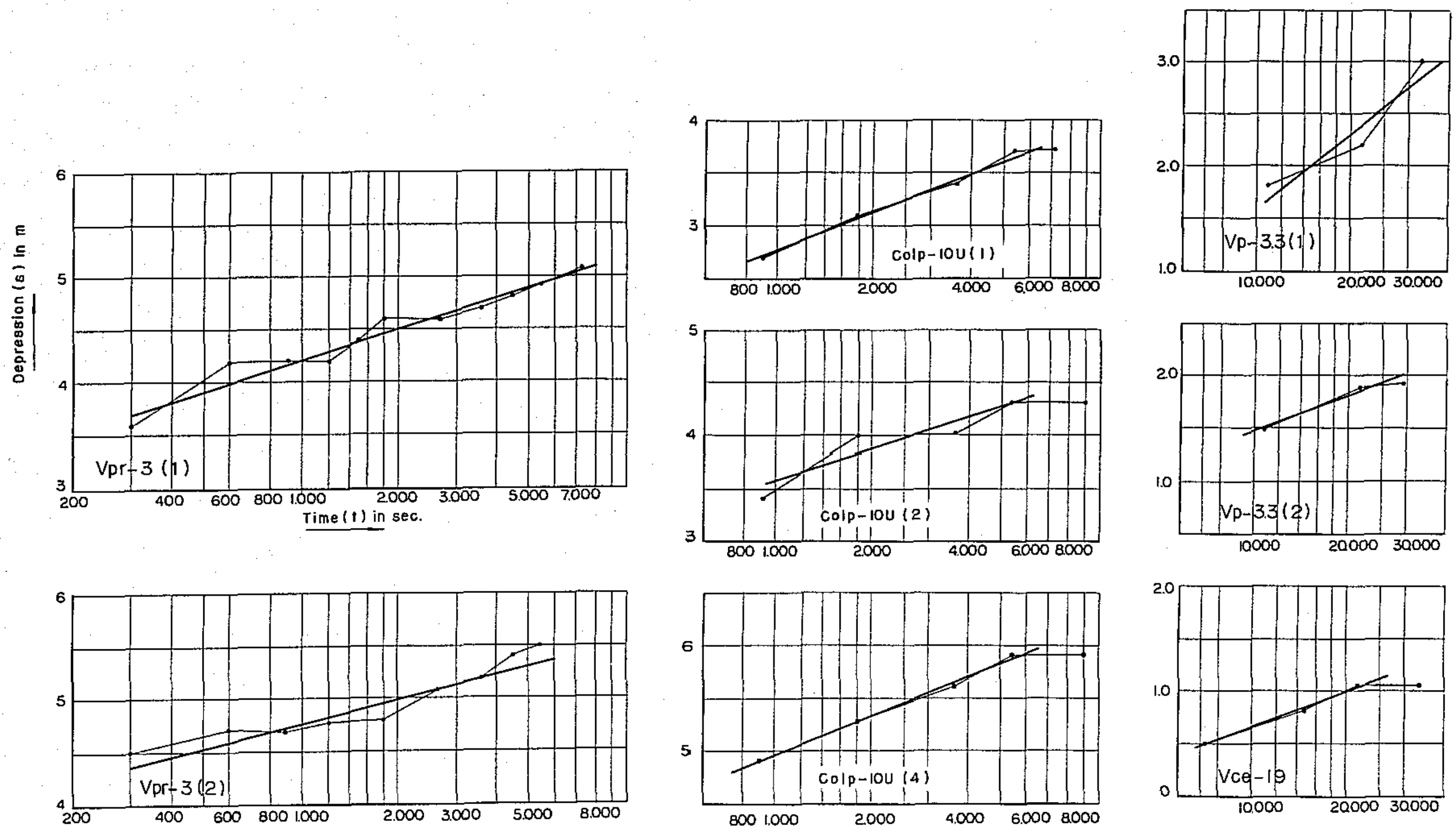


Fig. 5 Relation between Depression and Time

Table 13 Step Pumping Test and Its Specific Capacity

Time (hr-min)	Depression from Static Level (m)	Water Quantity (G.P.M)	Specific Capacity (cu.m/ day·m)
V_{pr}-3. Colp. 49-1			
11.40	11.6	1,150	540
12.30	15.2	1,500	540
14.35	20.3	1,700	460
V_{pr}-6. Colp. 64			
4	10.4	1,250	420
7	13.4	1,480	610
13	15.2	1,635	590
19	18.3	1,900	570
1	20.7	2,290	600
V_{pr}-33. Colp. 71			
5	7.0	1,250	980
8	8.5	1,580	1,000
11	10.7	1,810	920
17	12.8	1,930	820
24	16.5	2,230	740
6	18.3	2,440	730
V_{ce}-2. Colp. 85			
6	7.0	1,350	1,050
13	8.8	1,480	910
20	10.0	1,700	930
1	11.4	1,940	930
6	12.2	2,030	910

Time (hr-min)	Depression from Static Level (m)	Water Quantity (G.P.M)	Specific Capacity (cu.m/ day·m)
V_{ce}-19. Colp. 91			
16	11.3	2,290	1,100
19	13.1	2,410	1,000
23	14.0	2,450	960
V_{ce}-26. Colp. 65			
22	5.0	1,560	1,700
7	5.9	1,810	1,680
13	6.6	1,980	1,640
19	7.2	2,060	1,570
1	7.6	2,150	1,540
Colp. 76-2 (Ing. Providencia)			
16	3.2	1,600	2,720
6	4.1	1,810	2,400
13	4.4	1,880	2,360
3	4.5	1,910	2,330
11	5.2	2,030	2,110
9	5.2	2,030	2,110
13	5.8	2,150	2,030
11	7.6	2,460	1,770
16	8.7	2,630	1,650

Time (hr-min)	Depression from Static Level (m)	Water Quantity (G.P.M)	Specific Capacity (cu.m/ day·m)
Colp. 107-12. (Pto. Tejada)			
19	4.6	1,400	1,660
22	4.7	1,420	1,640
1	4.8	1,440	1,630
3	4.9	1,460	1,630
6	5.2	1,480	1,560
9	7.2	1,680	1,280
12	7.3	1,710	1,280
15	7.9	1,820	1,260
18	8.2	1,880	1,250
21	9.0	1,920	1,160
V_{ce}-49B. Colp. 82			
6	4.2	1,300	1,680
9	5.4	1,780	1,800
15	7.3	1,900	1,420
18	8.2	2,150	1,440
21	10.0	2,360	1,260
0	10.9	2,570	1,280
3	12.2	2,740	1,220
6	13.7	2,960	1,180

6. Drainage

Drainage works in the project area are described in detail in Chapter 6 and Chapter 7 of the General Report. The studies here refer to subsurface drainage. It is necessary to install subsurface drains to release soils from excess-humidity in the area where the soils are always wet because of poor topographical condition or where the water table is always high on account of infiltration from higher land.

Subsurface drainage is believed to be better than open channel closely spaced for efficient operation of heavy machines. The low area of poor drainage where good results can be expected through the application of subsurface drainage is assumed to be 3,000 - 5,000 ha in Cauca Plain. The cost for these facilities is estimated to be approximately 350 thousand dollars and this cost is included in the drainage works referred to in Chapter 9 of the General Report.

Information or quantitative data required for designing subsurface drains such as the depth of permeable or impermeable layer and intake rate, etc., should be studied in a later stage, but the following factors are applied in the present study.

(1) Basic drainage rate (q) is assumed as 3 - 5 mm/day. This value is deemed to be reasonable because drainage discharge from soils is estimated at 90 or 110 mm/month in the wet season in the detail calculation of water balance of La Victoria-Cartago Project[1/]

1/ Proyecto La Victoria – Cartago, Estudio de Factibilidad, Apendices C, (Informe CVC No. C-10877, Agosto-1966)

(2) Soil layer in which the drain will be located is considered as homogenous and its hydraulic gradient (k) is assumed to be 0.2 ~ 0.5 m/day.

(3) The relation between hydraulic head and drain spacing as shown in Fig. 6 is obtained by Hooghoudt Formula and Ernst Formula[1/]. If the drain is set at a depth of 1.50 m ~ 2.00 m, the water table can be kept 1.00 m below ground surface. The distribution of drains will depend upon topography, scale of farms and sources of infiltration water, etc., as collectors are to be installed generally parallel to contour lines, laterals will be at right angle to contour lines.

Note:

Hooghoudt Formula

$$L^2 = \frac{8K_2 hd}{q} + \frac{4K_1 h^2}{q}$$

$(D = \infty)$

Ernst Formula

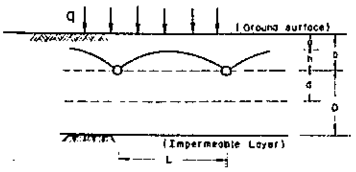
$$h = \frac{qL}{\pi K} \ln \frac{L}{U}$$

$(D > L/4)$

Ernst General Formula

$$h = q\frac{Dv}{K_1} + \frac{qL^2}{8KD} + \frac{qL}{\pi K} \ln \frac{Do}{U}$$

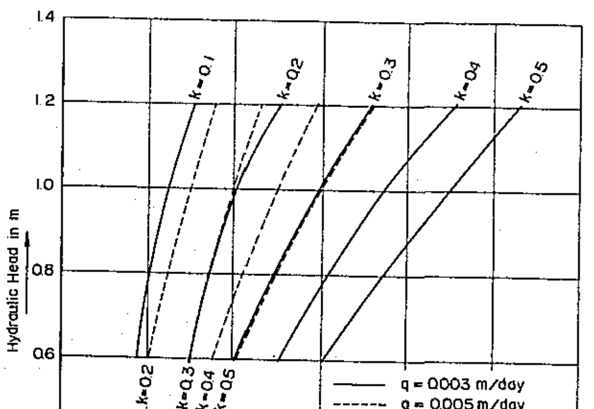
In the case of $D > L/4$, h_v and h_h resistance are negligible compared with the radial resistance.



– Notations –

L : drain spacing in (m)
q : drain discharge in (m/day = cu.m/day.sq.m)
K_2 : hydraulic conductivity of the layer below the drains in (m/day)
K_1 : hydraulic conductivity of the layer above the drains in (m/day)
h : height of water table above the drain level midway between drains in (m) (available hydraulic head).
d : thickness of "equivalent layer" in (m)
U : wetted perimeter in (m)

Fig. 6 Hydraulic Head and Drain Spacing for Subsurface Drainage



1/ Some Nomographs for the Calculation of Drain Spacings. (International Institute for Land Reclamation and Improvement. Bulletin 8, 1965, Holland).

7. Economic Analysis of Land Reclamation

7.1 *Estimate of Agricultural Income by Main Crops without and with Project*

(1) Though estimates of agricultural production at present differ to some extent depending on regions and cropping periods, the average yields were assumed on the basis of oral investigations and existing data. The productions with project were assumed based on the data of areas already developed, or on high yield farms under good management in the Cauca Plain. The yield will increase by 25% - 33% over the present value after the drainage and irrigation scheme is completed.

(2) Concerning the production cost at present, appreciable variations were found depending on the pattern of agricultural management. The production cost against gross income was estimated using average ratio of agricultural expense to gross income obtained from reference data1/. For future production cost, 20% increment of cost was applied in order to achieve high yield. Rental of farm land was excluded from the production cost mentioned above, because about 76% of land in the Cauca Plain is privately owned.

(3) Agricultural product was evaluated in monetary terms by means of the yield multiplied by the unit price which producers would receive. The unit prices of agricultural products are variable according to variety, quality and balance of demand and supply, etc. In this study the prices delivered at the farm from 1968 to 1969 were applied.

(4) The cultivating time of sugar cane is about one and a half years. The production averaged to one year was assumed as the annual yield. The price of sugar cane which the sugar factory would collect from "Proveedores" (suppliers) was regarded as the unit price.

(5) The revenues from milch and meat cows raised in pasture lands were regarded as the benefit of the pasture land and not from intensive dairy farming. The number of cattle raised per ha is an average of 1.6 heads at present in flat area and 60% of which are meat cows and 40% are milch cows. In the future, 2.5 heads of cattle per ha are estimated because of improvement of pasture and forage. The economic life of milch cow is considered as 8 years and the period for raising beef cattle is considered as 2 years.

Taking the above factors into consideration, production, without and with project, were estimated as shown in Table 14 and Table 15.

7.2 *Assumption of Cropping Ratio without and with Project*

The cropping ratio without project in Table 16 was estimated from Tables 10(1) and (2) in Appendix 3. Pasture now occupies 50% of land, but it is anticipated that pasture area will decrease and cattle raised per ha will increase by improvement of feed grasses and by introduction of intensive cattle raising. Thus, it was assumed that more than one half of pasture land will be converted to field for annual crops during the economical analysis period of 50 years. The cropping ratio of maize, soybean and sorghum would increase in the future because of the increasing demand and assured markets for these products. The cropping area of cotton, rice and bean was assumed to be the same acreage in the future.

1/ 1) Rentabilidad de Diversos Cultivos Agricolas y Explotaciones Ganaderas en el Valle del Cauca. (*Universidad del Valle, Facultad de Ciencias Economicas, Cali Marzo de 1966*)
2) Desarrollo Agricola del Valle del Cauca, Censo de Seis Cultivos. (*Instituto de Fomento Algodonero, Bogota, 1967*)
3) The Elaboration compiled from data of "Banco Republica, etc" by CVC, 1968

Table 14 Agricultural Income without Project

Crop	Gross Income			Production Cost	Net Income	Remarks
	Yield (kg/ha)	Price ($/ha)	Gross Income ($/ha)	($/ha)	($/ha)	
Cotton	2,000	4.8	9,600	6,290	3,310	
Rice	3,000	1.6	4,800	3,500	1,300	
Maize	2,500	1.5	3,750	2,050	1,700	
Soybean	2,000	2.0	4,000	2,560	1,440	
Bean	1,500	4.0	6,000	3,420	2,580	
Sorghum	2,500	1.0	2,500	1,140	1,360	
Sugar cane	80,000	0.07	5,600	2,600	3,000	
Platano	15,000	0.67	10,000	2,800	7,700	
Pasture	A-Class Milch Cow	0.3 head				Milk production
	B-Class Milch Cow	0.3	2,570	1,540	1,030	A-Class 2,000 lit/year
	Meat Cow	1.0				B-Class 530 lit/year
		1.6 head/ha				

Table 15 Agricultural Income with Project

Crop	Gross Income			Production Cost	Net Income	Remarks
	Yield (kg/ha)	Price ($/ha)	Gross Income ($/ha)	($/ha)	($/ha)	
Cotton	2,500	4.8	12,000	7,550	4,450	
Rice	4,000	1.6	6,400	4,200	2,200	
Maize	3,500	1.5	5,250	2,460	2,790	
Soybean	2,600	2.0	5,200	3,070	2,130	
Bean	2,000	4.0	8,000	4,100	3,900	
Sorghum	3,200	1.0	3,200	1,370	1,830	
Sugar cane	100,000	0.07	7,000	3,120	3,880	
Platano	17,000	0.67	11,390	2,760	8,630	
Pasture	A-Class Milch Cow	1.0 head				Milk production
	B-Class Milch Cow	1.0	6,400	3,600	2,800	A-Class 2,500 lit/year
	Meat Cow	0.5				B-Class 810 lit/year
		2.5 head/ha.				

7.3 Estimation of Agricultural Benefit

Based on the above assumption 7.1 and 7.2, the agricultural net income without and with project was estimated as shown in Tables 14 and 15. The average annual growth of net income of 1,500 or 2,500 pesos per ha given in Table 16 will be attributable to the flood control and land reclamation scheme.

7.4 Project Cost and Annual Expenses

Capital investment for reclamation of 81,600 ha is roughly estimated to be 40,822 thousand dollars based on the designs of R-U-T Project and other projects already in service. (See Chapter 9 in General Report)

Table 16 Estimated Cropping Ratio and Agricultural Benefit without and with Project

	R-a.b.c		R-d		R-e.f		R-g		L-a.b.c		L-d.e		L-f		L-g.h.i.j		Inundation Area	
	F[1]	S[2]	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S
Annual Crop (%)	25		22		30		53		16		28		14		38		37	
	55		50		60		60		50		55		50		50		60	
Cotton	1	–	9	–	4	–	2	–	–	–	27	–	–	–	4	–	10	–
	2	–	6	–	3	–	2	–	–	–	9	–	2	–	3	–	8	–
Rice	1	1	8	8	4	4	3	3	63	63	7	8	–	–	4	4	5	5
	2	2	4	4	2	2	3	3	20	20	2	2	–	–	3	3	3	3
Bean	6	7	7	12	1	1	1	2	–	–	9	15	37	40	2	2	5	5
	6	6	6	8	2	4	2	33	6	10	9	9	20	20	2	4	3	3
Maize	54	40	39	38	31	30	57	54	10	9	7	7	32	25	44	40	43	37
	36	36	36	34	33	33	55	37	20	20	9	11	30	30	40	29	45	37
Sorghum	2	6	7	8	28	30	4	5	19	20	25	35	–	–	30	30	10	13
	9	11	10	12	25	17	7	8	30	20	37	31	8	10	30	20	12	13
Soybean	23	33	29	33	31	30	32	35	7	7	20	30	18	20	15	20	25	38
	36	36	36	40	33	42	30	47	20	26	31	44	30	30	20	40	27	42
Others	13	13	1	1	1	5	1	1	1	1	5	5	13	15	1	4	2	2
	9	9	2	2	2	3	2	2	4	4	4	4	10	10	2	4	2	2
Perennial crop (%)	10		13		5		3		6		2		5		20		6	
	10		15		5		10		10		5		5		20		10	
Pasture (%)	55		55		55		42		30		30		66		40		52	
	20		20		20		20		20		20		30		20		20	
Other use (%)	10		10		10		2		48		40		15		2		5	
	15		15		15		10		20		20		15		10		10	
Gross Income(P.S/ha)	4,700		4,500		4,200		5,700		2,900		3,700		3,900		5,100		5,000	
	8,800		9,000		8,700		9,500		8,300		7,800		9,000		7,900		9,100	
Net Income(P.S/ha)	1,900		1,800		1,700		2,300		1,000		1,500		1,500		2,400		2,100	
	3,900		4,000		3,900		4,100		3,500		3,500		4,000		3,900		4,200	
Increment of Income (P.S/ha)	2,000		2,200		2,200		1,800		2,500		2,000		2,500		1,500		2,100	

Upper Line: without project Lower Line: with project

1/ First season

2/ Second season

It is estimated that the capital investment for development of 120,000 ha which will be irrigated by subterranean water and tributary water will be 43,000 thousand dollars. (See Table 17 (1).

Construction costs per unit area, annual expenses and cost of irrigation water by source are given in Table 17(2). From this table it will be noted that the cost of water from each source is almost the same. Therefore, the utilization of subterranean water is considered highly appropriate as source of irrigation water because it can be developed independently on a small scale which could be realized at a small amount of investment.

7.5 Economic Justification of Land Reclamation

The estimated average construction cost per ha of land reclamation is US$360 - 500 and annual expenses are estimated to be US$44 - 61.

On the other hand, annual benefit amounts to US$87 - 144 as described in 7.3. Consequently, the benefit-cost ratio of the land reclamation project together with flood control works is approximately 2.2 which indicates that the project is economically sound.

Table 17(1) Construction Costs of Reclamation Project

	Project Area (ha)	Construction Cost (10^3 US$)
Reclamation Works	81,600	40,822
Drainage Works		19,198 1/
Irrigation Works		21,624
Irrigation Works in the Future	120,000	43,000
Total	201,600	83,822
Average Construction Costs	201,600	420

1/ Refer to Chapter 6 in General Report.

Table 17(2) Cost of Irrigation Water by Source

Sources of Irrigation Water	Construction Cost per ha. (US$)	Annual Expense (US$)	Cost 4/ (mills/cu. m)
(1) Cauca River			
Pumping Facilities	40	8	
Irrigation Canals	220	27	
Total	260	35	4.9
(2) Tributaries			
Diversion Facilities	60	7	
Irrigation Canals	300	37	
Total	360	44	6.1
(3) Subterranean Water			
(i) 1/ Pumping Facilities	60	12	
Irrigation Canals	220	27	
Total	280	39	5.4
(ii) 2/ Pumping Facilities	50	10	
Irrigation Canals	220	27	
Total	270	37	5.2
(iii) 3/ Pumping Facilities	50	10	
Irrigation Canals	220	27	
Total	270	37	5.2

1/ Gross head: 20 m, Depth of well: 80 m, Water quantity: 6 cu.m/min.
2/ Gross head: 22 m, Depth of well: 80 m, Water quantity: 9 cu.m/min.
3/ Gross head: 25 m, Depth of Well: 150 m, Water quantity: 12 cu.m/min.
4/ Annual amount of net water requirement: 7,170 cu.m/ha.

APPENDIX 7

RIO OVEJAS INTAKE PROJECT

List of Tables

The purpose of the Rio Ovejas Intake Project is to increase power benefit by diverting river discharge of the Rio Ovejas which joints to the Cauca River at 3 km downstream from Salvajina Dam.

The Rio Ovejas Intake Project consists of intake facilities and a tunnel of approximately 5 km in length conducting water to Salvajina Reservoir in order to increase the inflow into the reservoir to reinforce power generation. The outline of the project is as shown in Dwg. No. 1 of Chapter 7.

The runoff feature at the projected intake site on the Rio Ovejas is as follows.

Catchment area	900 sq. km
Annual average discharge	23 cu.m/s
Annual average runoff	740 x 10^6 cu.m
Maximum monthly average discharge	74 cu.m/s in Dec. 1966
Minimum monthly average discharge	7.6 cu.m/s in Sep. 1966

(Note: Runoff data for period from October 1965 to September 1967)

The monthly average discharge of the Rio Ovejas at the intake site in 1958, which is considered to be a critical dry year, was estimated as shown in Table 1 utilizing the relation between measured runoff of the Rio Ovejas and runoff at Salvajina.

Table 1 Available Discharge of the Rio Ovejas at the Intake Site in 1958 (Critical Dry Year)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Annual Average
Estimated Discharge of the Rio Ovejas in 1958 (cu.m/s)	11.5	18.1	32.0	19.9	14.8	11.9	16.6	19.0	16.0	13.5	12.5	7.4	16.1
Conversion Factor between Discharge and Power (kW/cu.m)	638.6	544.7	696.3	750.1	750.4	745.4	740.4	20.8	831.2	842.4	828.4	762.9	746.2
Intake Capacity of 10 cu.m/s													
Intake Rate (%)	46.2	26.6	13.6	32.8	36.6	27.8	36.7	32.8	39.6	68.5	92.5	89.0	–
Available Discharge (cu.m/s)	5.3	4.8	4.4	6.5	5.4	3.3	6.1	6.2	6.3	9.2	11.6	6.6	6.3
Intake Capacity of 20 cu.m/s													
Intake Rate (%)	75.3	52.6	27.1	65.5	73.0	59.3	73.5	65.6	78.8	99.7	100.0	100.0	–
Available Discharge (cu.m/s)	8.7	9.5	8.7	13.0	10.8	7.1	12.2	12.5	12.6	13.5	12.5	7.4	10.7
Intake Capacity of 30 cu.m/s													
Intake Rate (%)	100.0	67.7	47.0	91.3	97.6	84.5	93.5	92.0	97.8	100.0	100.0	100.0	–
Available Discharge (cu.m/s)	11.5	12.3	15.0	18.2	14.4	10.1	15.5	17.5	15.6	13.5	12.5	7.4	13.6

On the basis of monthly average discharge in 1958, three alternatives of intake capacity, 10 cu.m/s, 20 cu.m/s and 30 cu.m/s were compared, taking into account the power benefit to be accrued to each alternatives and necessary capital investment. Monthly average intake quantities and economic comparison are as shown in Table 2.

From this comparison, it can be concluded that the case of intake of 20 cu.m/s will be the most advantageous of the three.

In the case of intake of 20 cu.m/s, the generating cost will be very cheap at 7 centavos per kWh, and it can increase the potential of Salvajina Power Plant about 10%. Therefore, the Ovejas Intake Project can be realized whenever it becomes necessary for CVC power supply balance.

Table 2 General Description

	Intake Capacity		
	10 cu.m/s	20 cu.m/s	30 cu.m/s
Annual Average Intake (cu.m/s)	6.3	10.7	13.6
Annual Energy (10^6 kWh)	41.2	70.1	88.5
Power Benefit1/ (10^6 pesos)	4.3	7.3	9.2
Capital Investment (10^6 pesos)	34.5	55.0	72.0
Annual Expense2/ (10^6 pesos)	3.1	5.0	6.5
Benefit Cost Ratio	1.38	1.47	1.42
Energy Cost per kWh (Centavos/kWh)	7.5	7.0	7.3

1/ Power benefit: 10.4 centavos/kWh

2/ Annual expense rate to capital investment: 9%

APPENDIX 8

DIVERSION SCHEME TO PACIFIC OCEAN

LIST OF FIGURE

One of the benefits of the Cauca River Regulation Project would be a scheme for diversion of water to the Pacific Ocean for power generation purpose.

The western side of Cordillera Occidental facing the Pacific Ocean is of comparatively steep topography and the coastline is reached in a horizontal distance of about 50 km from the mountain peaks. The Pacific Ocean side of the mountain range belongs to a heavy rainfall zone and the annual precipitation is roughly about 4,000 mm. It is logical to consider plans for power generation taking advantage of the steep topography of this area. Up to the present, major power stations of the CVC System such as Anchicaya Power Plant and Calima No. 1 Power Plant have been constructed on the Rio Calima and Rio Dagua in this region, while currently the largest power station in the CVC System, Alto Anchicaya Power Station, is being built on the Rio Anchicaya.

A plan to conduct the rich runoff of the Cauca River at a point near elevation 1,000 m to the Pacific Ocean side for hydroelectric power generation deserves consideration. Especially in the case a large scale reservoir is constructed in the upper basin of the Cauca River for regulation of the runoff of the river, a diversion project will be highly worth consideration.

In 1957, CVC acquired the services of OLAPS, Gibbs & Hills, TAMS, consulting engineers who carried out a brief study of the diversion scheme to the Pacific Ocean as an component feature of the Timba Project. At that time, since data necessary for preparation of topographical maps of the project area or establishment of plans for geological investigations, etc. were not available, a very preliminary study was made. According to this study, an intake is proposed near the Vijes site on the Cauca River to conduct a maximum of 260 cu.m/s of water. This water is to be conducted through a tunnel with an inner diameter of 8 m and a length of approximately 20 km passing through the narrowest part of the Cordillera Occidental to Bitaco Reservoir on the Rio Bitaco, a tributary of the Rio Dagua. Water stored in Bitaco Reservoir is to be utilized at three power stations to be constructed in steps downstream along the Rio Dagua taking advantage of a total head of 850 m to generate 7×10^9 kWh annually with an aggregate installed capacity of 1,327 MW.

Although construction of tunnels totalling approximately 42 km is to comprise the major part of the work requiring an enormous capital cost, it is estimated that the energy cost is comparatively cheap and the conclusion of the study is that this project will be worth consideration in the future with the growth of power demand in Colombia.

In the present report of the Cauca River Regulation Project, a brief examination of this diversion project was made from a new standpoint applying new data of reservoir regulation.

When the Cauca River Regulation Project is completed, the runoff of the river will be regulated by Salvajina Reservoir, and the dry season discharge at the dam site of 40 cu.m/s will be increased to approximately 100 cu.m/s which means an increase in dry season discharge of 60 cu.m/s. Since the dry season discharge at the downstream Vijes site will also increase by about 60 cu.m/s, in order to prevent adverse effects on water utilization at the downstream of the Cauca River, such as industrial water, irrigation water or abatement of river contamination, only the increase in dry season discharge was decided to be diverted at Vijes. With this diverted flow plus the natural flow of the Rio Dagua of 17.5 cu.m/s and assuming that the sites of tunnels and power stations are the same locations as contemplated in the 1957 Report, the plan was examined for a plant factor of about 0.6. The results are an installed capacity of about 900 MW which will produce approximately 4.7×10^9 kWh annually and the total project construction cost of approximately 4,800 million pesos considering a construction period of about 10 years. Assuming an annual generating cost of 9%, the energy cost would be in the range of approximately 0.1 P.S./kWh.

This generating scheme if examined from the unit cost of energy cannot be considered to be highly economical at present, while there are many technical problems in excavating a 20 km long tunnel within an economical construction period. Therefore, this diversion scheme is not considered to be a promising project which should be started in the near future. In the future, however, after more economical hydroelectric sites in Colombia should have all been developed, this site may become feasible as one of the major hydroelectric resources in the country.

Furthermore, this Pacific Ocean diversion scheme will have great bearing on the future irrigation, portable and industrial water utilization plans of the Cauca River on the downstream of Vijes. As mentioned in 6.4.2, the contamination of the Cauca River which presently has become extremely serious will be greatly alleviated by the increase of discharge from 70 cu.m/s to 130 cu.m/s at Juanchito. And considering that it is very difficult to fundamentally prevent worsening of present contamination of the Cauca River, because of the rapid growth of industry and population around Cali, there may be justifiable reason that the diversion scheme should be dropped in favor of the effect of alleviation of contamination brought about by regulation at Salvajina Dam.

Also, regarding the hydroelectric development of the Dagua River basin, the matter of whether to divert water from the Cauca River or to develop the potentials of the Dagua River only should be determined after more careful and detail studies. Moreover, considering the construction period for the longest tunnel, which is almost 20 km long, for diversion and also the fact that the project will become economical only after the entire scheme is completed, there are great many problems. Therefore, the scheme cannot be included in the electric development program of Colombia for the near future.

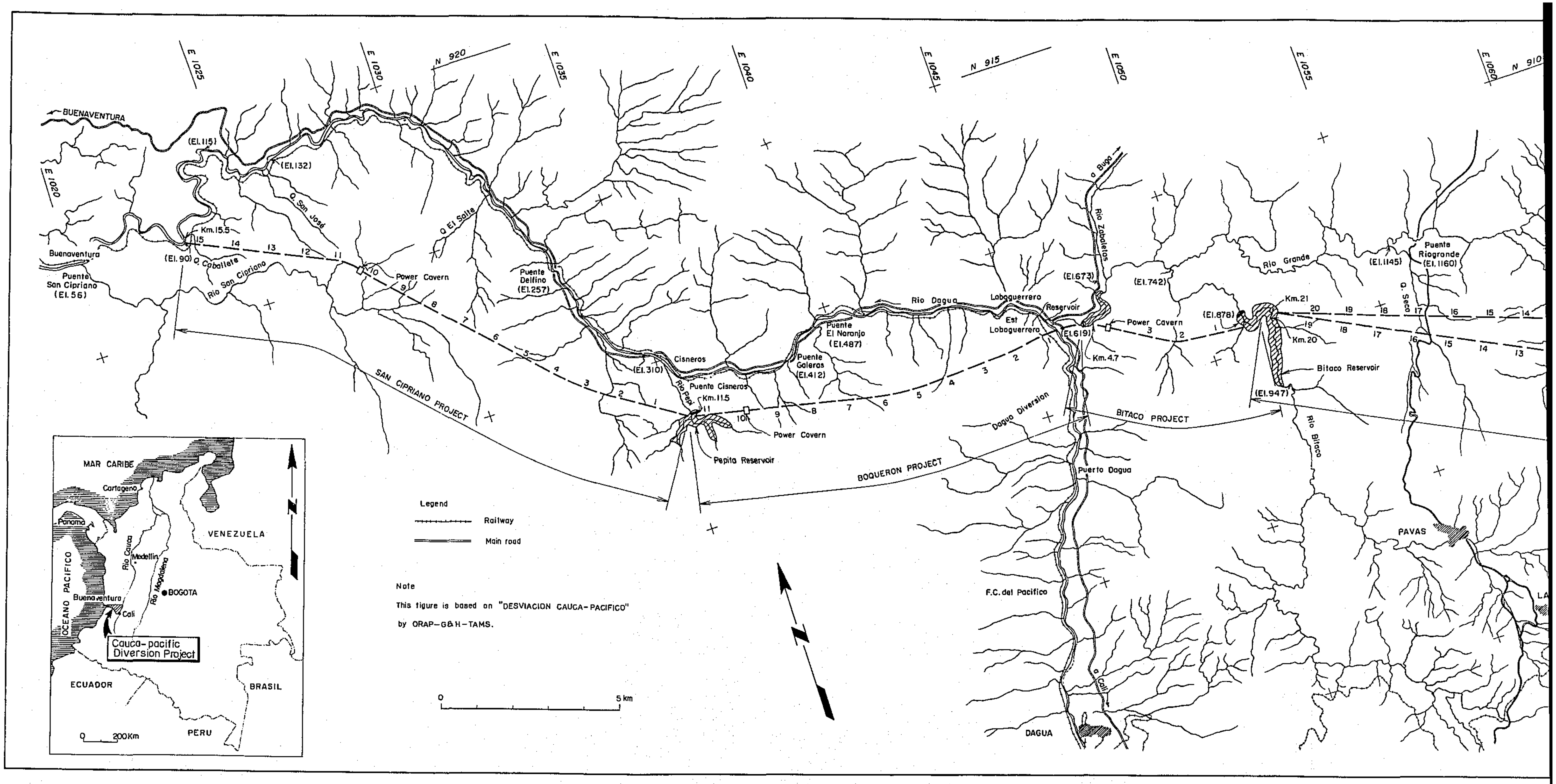


Fig. 1 Cauca-Paci

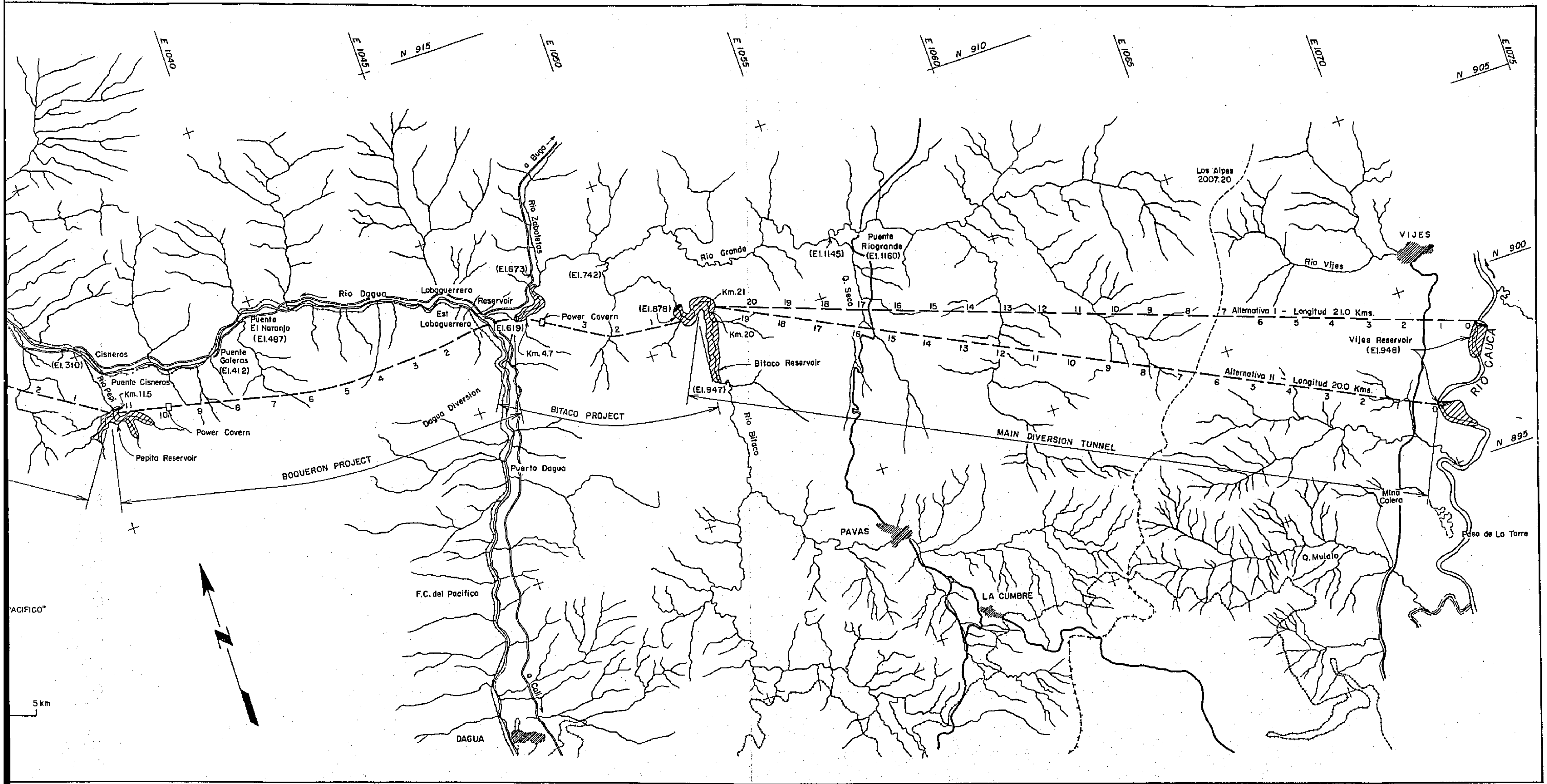


Fig. 1 Cauca-Pacific Diversion Project

APPENDIX 9

SURVEYS AND INVESTIGATIONS HEREAFTER REQUIRED

APPENDIX 9 SURVEYS AND INVESTIGATIONS HEREAFTER REQUIRED

CONTENTS

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1. Investigations Required for Definite Plan Study

The investigations which should be undertaken for the definite plan study and for construction purpose are as described below.

(a) Land Surveys

The additional topographical survey are necessary for design of structures of the project such as dam and powerhouse except for the area which has already been executed by CVC. The disposal area downstream of the dam is thought to be missing as far as topographical maps are concerned and supplemental survey for this area must be carried out. For the Cauca River levees and the drainage works the following topographical surveys are necessary:

Topographical surveys for the area of the levees and drainage works.

Routes surveys for the projected levees, drainage canals and intercepting canals.

Topographical maps of construction sites of appurtenant structure of the river levees and drainage canals (pump houses, bridges, gates, etc.) and of the regulation ponds.

(b) Geological Surveys

Geological surveys of the dam site were performed to a fairly extensive degree employing drill holes, auger holes and test pits at the time of preparation of "The Salvajina Project Report". However, investigations by adits have not yet been carried out. An arch-gravity dam is being considered for this site now. As the geological conditions of the foundation will be more important than in the case of a rockfill type dam, investigations were planned based mainly on adits. The types of adits and general quantities are as given below. The outline of the locations of investigations are given in Fig. 1.

	Number	Total Length
Right Bank		
Adit	9	400 ~ 450m
Boring	5	300m
Left Bank		
Adit	9	320 ~ 370m
Boring	5	300m

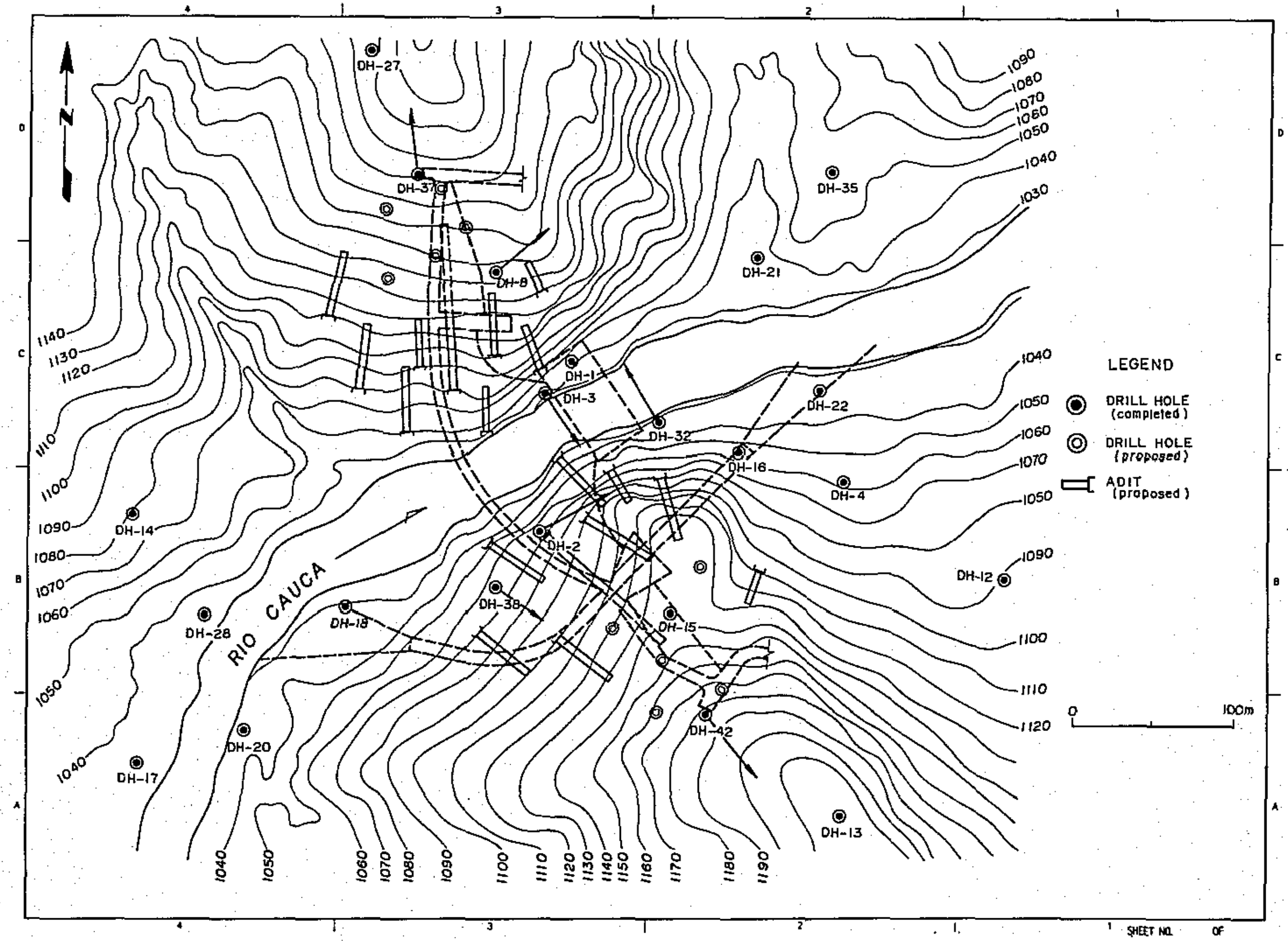
(c) Tests of Bedrock at Site

Although the gorge portion of the river at the dam site has comparatively hard bedrock which is thought to be favorable as a foundation of an arch-gravity dam, there is development of cracks on the other hand and weathering which is prevailing deeper at the higher elevation. Therefore, taking advantage of the adits mentioned in the preceding section, various tests of the bedrock such as modules of elasticity and strength should be carried out at the site to obtain a sufficient grasp of the dynamic properties of the bedrock necessary for dam design for use of the definite plan study of the dam.

(d) Others

Further soil test for embankment material of river levees and investigations of foundation conditions for each structures are necessary.

Fig. 1 Location of Future Geologic Investigation



2. Investigations Necessary for Construction Purposes

(a) Land Surveys

Parallel to the definite study, surveys must be carried out for the routes of access roads, the transmission line, aggregate borrow areas and temporary facilities.

(b) Investigations of Aggregate and Cement

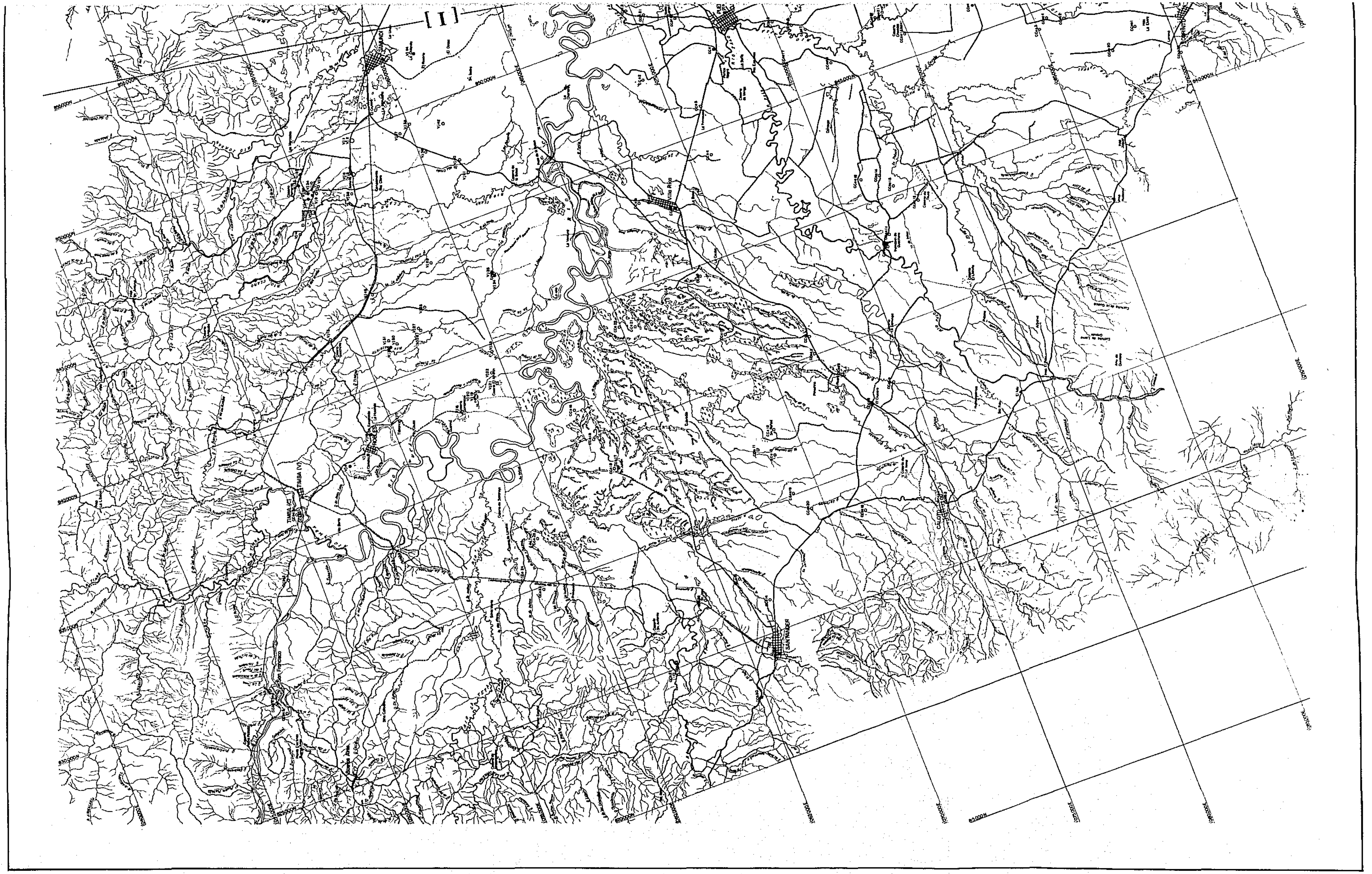
The river bed deposit near Suarez is to be excavated and crushed to manufacture concrete aggregate. For this purpose, grading, physical and crushing tests for this deposits should be carried out and the quarry area and available quantities should be confirmed. As for cement, the product from Yumbo cement factory will be used and thorough investigations and tests of the quality should be performed.

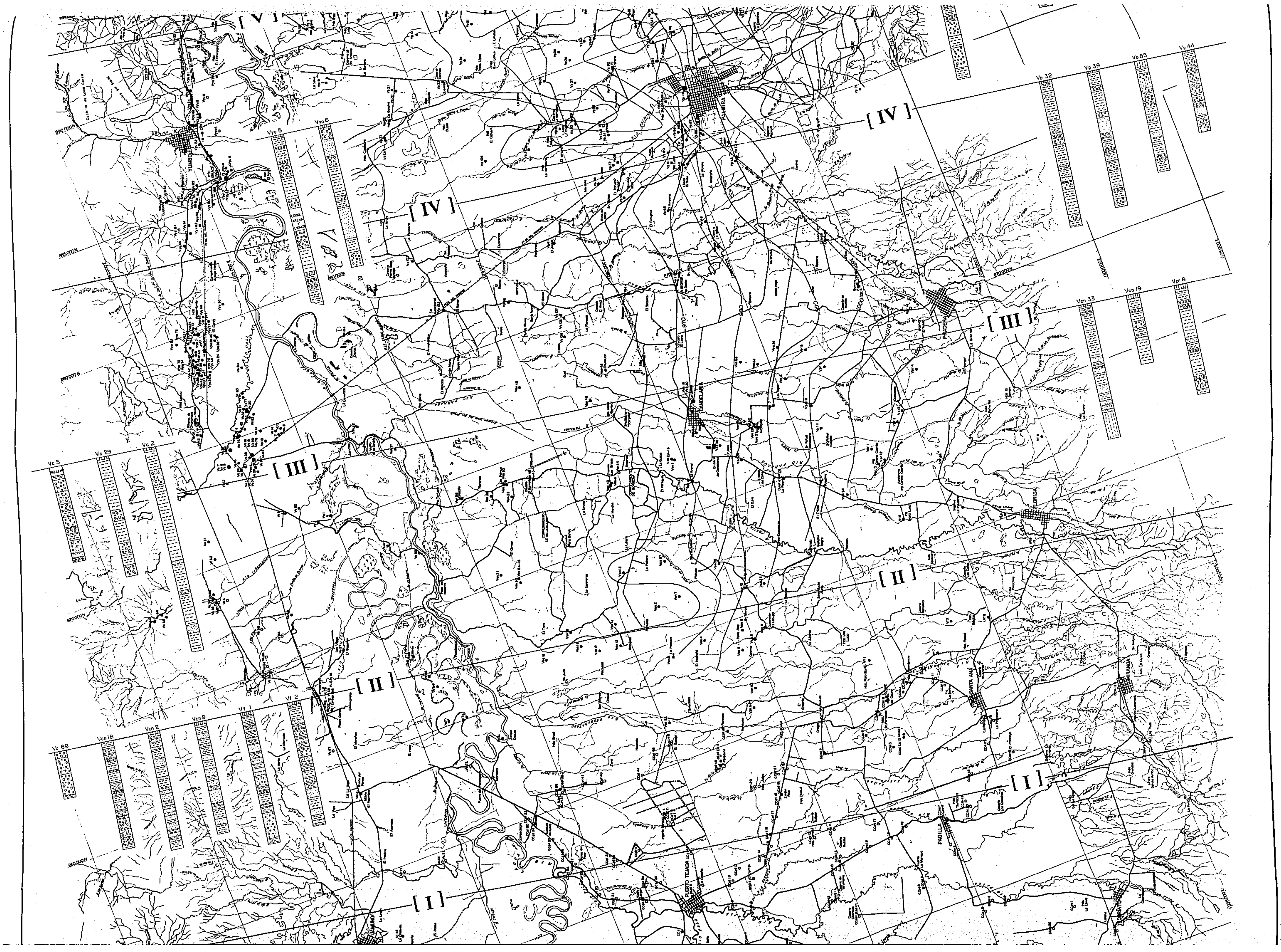
(c) Concrete Design Tests

Concrete design tests to obtain the required strength and properties using the minimum cement content should be carried out giving consideration to the available quality and quantity of aggregate and construction plans for the aggregate plant, etc. in order to determine the most economical design mixture from an overall standpoint.

(d) Hydraulic Model Tests of Spillway

Parallel to definite plan study of the dam, hydraulic model tests of the spillway should be conducted to study the capacity of the spillway, effect of overflowing water on the dam and powerhouse, etc. As the powerhouse is to be constructed immediately downstream of the dam and flood is to be discharged from the roof of the powerhouse, such items as the distance of jump of flood discharge, scouring at the tailrace, the fluctuation in water level, etc. should also be clarified in this test and the data obtained should be utilized in design of the spillway and powerhouse.





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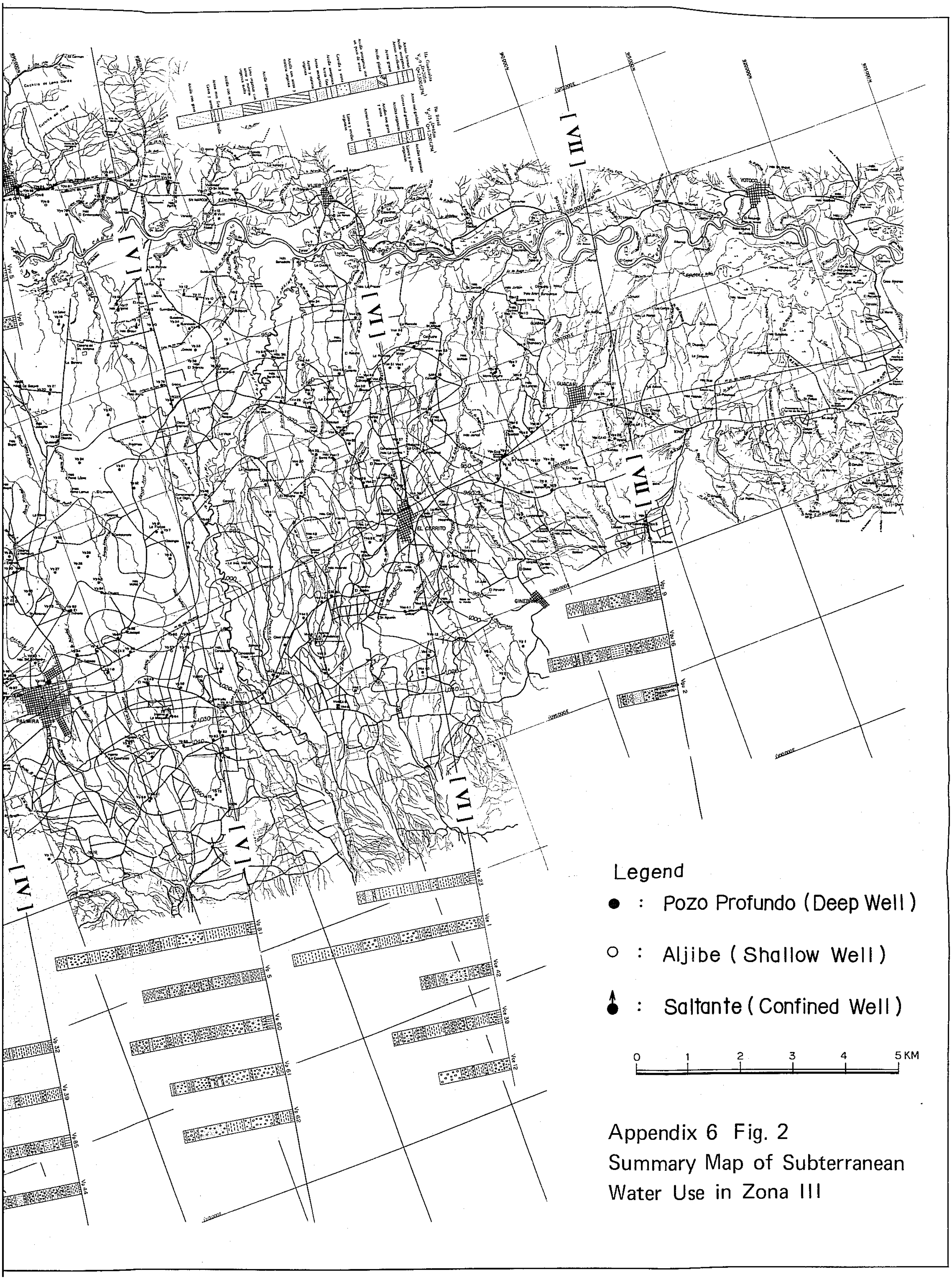

Appendix 6 Fig. 2
Summary Map of Subterranean
Water Use in Zona III