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REVIEW
OF
SOURCES OF WATER
FOR
CAM RANH BAY AREA

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(Revised April, 1974)

by

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SCOPE

To make a brief review and study of the existing reports and available data on potential water sources for the Cam Ranh Bay Area and to evaluate and summarize this information in sufficient detail to enable AD/ETA to make a judgment as to the feasibility of developing these water sources.

OBJECTIVES

The major objective of this report was to make a preliminary evaluation of potential water resources available in the Cam Ranh Bay Area based on existing data, knowledge of the area and the judgment of various consultants. This study was intended to answer the following questions:

1. Are there sources, either local or within economical transmission distance, and if so in what quantities?
2. What additional studies, testing and data collection would be necessary for: (a) developing plans for the use of these water sources and (b) determining the limitations of such sources?

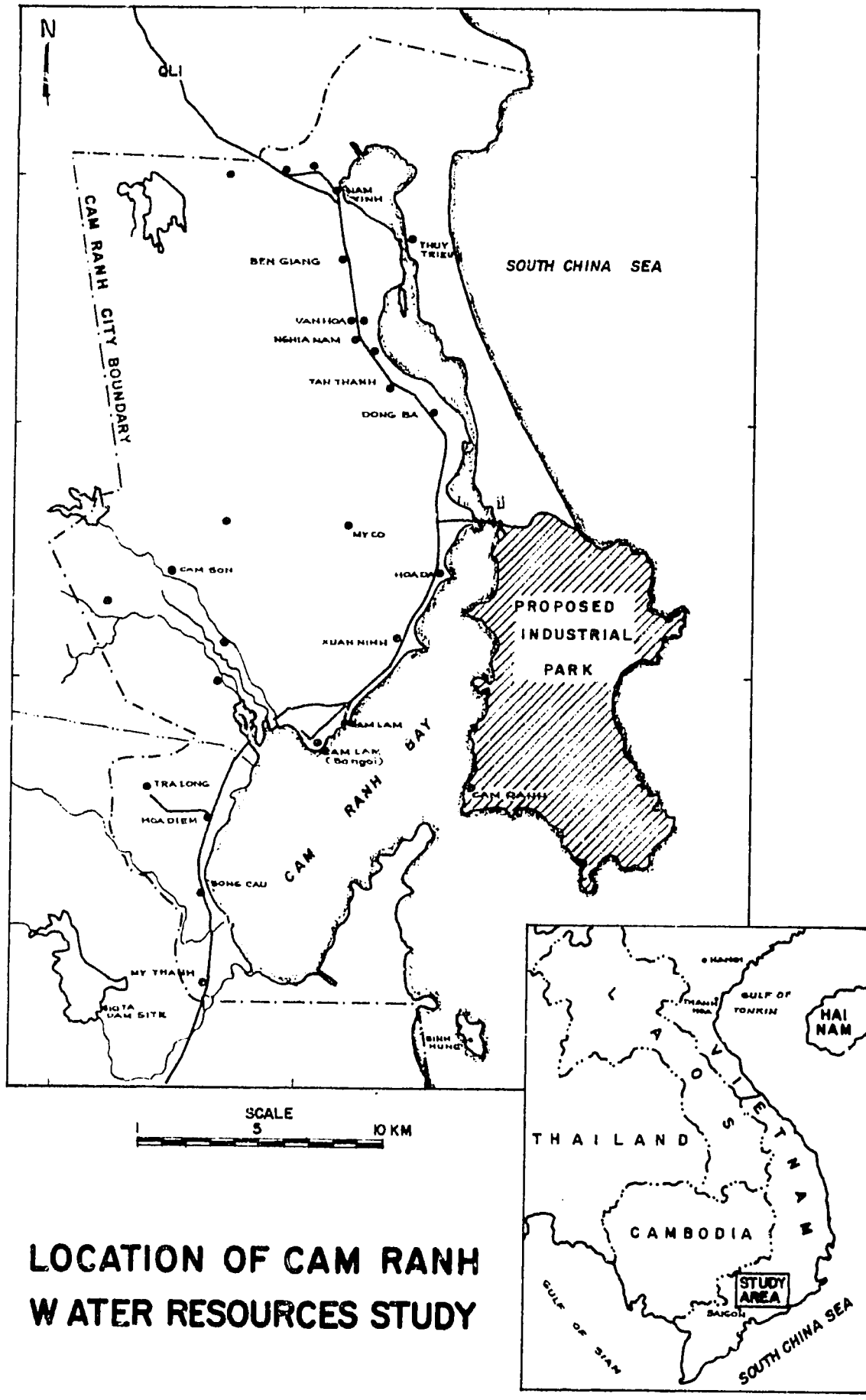
A secondary objective was to make a preliminary estimate of the cost of developing the most promising of these water sources to meet the needs of the proposed port and industrial center at Cam Ranh Bay.

PREVIOUS STUDIES

Several previous reports written on various aspects of the development of the Cam Ranh Bay Area have been reviewed and used as the basis for this report. These reports include:

1. "Planning Report on Cam Ranh Industrial Area and Harbor" by Nippon Koei Co., Ltd., November 1964.

FIGURE I



LOCATION OF CAM RANH WATER RESOURCES STUDY

2. "Development of Harbor Facilities for the Port of Cam Ranh" by Daniel, Mann, Johnson and Mendenhall, January 1966.
3. "Development of the Cam Ranh Region; Evaluation and Strategy" by Stanford Research Institute, December 1966.
4. "Cam Ranh Peninsula Water Supply" by Pope, Evans and Robbins International, Ltd., December 1966.
5. "Hydrology of Cam Ranh Peninsula" by William C. Rasmussen and Associates, Inc., June 1968.
6. "Hydrography and Water Supply of Lakes Ao Ho and Bau Ro, Cam Ranh Peninsula" by William C. Rasmussen and Associates, Inc., August 1968.
7. "Interim Report on Sources of Water for Cam Ranh City" by R.C. Gamer (USAID), 1967.
8. "Cam Ranh Water Resources Study" by The Ralph M. Parsons Company, July 1969.
9. "Evaluation of Existing Water Sources in the Proposed Industrial Zone at Cam Ranh Bay" by Geo Control, Inc., September 1973.
10. "Cam Ranh Industrial Park Feasibility Study" by Holmes & Narver, Inc. - Asiapac Fargo, Inc., February 1974.
11. "Survey Report on Industrial Development Project in Cam Ranh District" by Japanese Survey Mission, March, 1974.

Other reports, not specifically written for the Cam Ranh Area, have been reviewed and referenced in the text of this report.

THE PROBLEM

Many previous proposals to develop Cam Ranh Bay's magnificent setting and excellent natural harbor into a port and urban center have been

deferred, principally because of the lack of sufficient water and power. This area has a long and interesting history, generally related to the natural endowments of the harbor. First the French, then the Japanese in World War II, and finally the Americans have used the area for either military operations or sporadically limited commercial shipping. Yet all that has been accomplished is the development of a U.S. military base of questionable life and an unplanned community marked by the squatting and sprawl of refugees and people formerly associated with military-related employment. The future "City" of Cam Ranh still remains to be created. While the conditions for successful growth of the Cam Ranh Bay Area are much more favorable today than at any other time in Vietnam's history, this growth will be directly dependent upon the development of an adequate water supply. Today Cam Ranh Bay has no planned civilian water supply system and the only water drawn is from remmants of the existing military system on the peninsula and shallow wells along the mainland side where aggregations of population exist.

Cam Ranh city's approximately 115,000 inhabitants exist on only about 20 liters of water per capita per day. This shortage of water represents a potential health problem. The development of future industry, agriculture and to a limited degree port commerce are important reasons for emphasis on water if this area is to realize its natural and economic potential. To meet the demands of the proposed industrialization planned for Cam Ranh, a total of 100,000 m3/day (26 mgd) or more of water will be needed. Because the water resources within the area are sufficient to meet the present demand, plans to develop these resources should be implemented without delay to insure an adequate supply of water.

PRECIPITATION

The availability of local water sources in the Cam Ranh Area depends on precipitation and runoff, but since the local streams have very little flow during the dry season, water must be stored in either surface reservoirs or in permeable underground formations. Historical records of precipitation are available at Ba Ngoi and Nha Trang. Unfortunately, neither record is complete for the entire period over which data have been collected. Records taken at Ba Ngoi on Cam Ranh Bay during the periods 1927-44 and 1960-69 show a mean precipitation of 1,175 milimeters (46.4 inches) per year. However, precipitation in the minimum year was only 274 millimeters (about 11 inches), and the average for the lowest three-year period, 1961 through 1963, was only 507 millimeters (about 20 inches). The recorded amounts of rainfall at Ba Ngoi and Nha Trang are shown in Tables I. Regardless of the degree of accuracy or consistency of these records, they are the sole available guides to precipitation amounts and variations.

EVAPORATION

The only evaporation records available for the Cam Ranh Area were those made by The Ralph M. Parsons Company for the period April 1968 through March 1969. The mean daily evaporation for this period at Ba Ngoi was 5.7 mm, the maximum daily was 8.1mm while the total yearly evaporation was 2,099 mm (about 82.7 inches).

LONG-TIME MEAN RUNOFF

The only stream flow measurements in this area were those made by The Ralph M. Parsons Company for the 1968-69 period. Parsons' records for various water sheds in the Cam Ranh Area have been summarized in Table II and the locations shown on Figure II.

TABLE I

RECORDED RAINFALL AT BA NGOI (CL) AND NHA TRANG (NT)

1927-38 to 1968-69

Year	Station	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total Year
		Rainfall in Millimeters												
1927-28	CL	7	71	77	41	50	44	387	187	9	41	25	3	942
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1928-29	CL	44	40	117	12	61	170	230	65	121	36	0	0	896
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1929-30	CL	9	22	8	25	107	124	131	275	222	20	18	0	961
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1930-31	CL	24	133	33	7	58	110	39	679	448	24	1	T	1556
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1931-32	CL	22	93	32	7	34	57	307	81	12	0	0	0	645
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1932-33	CL	8	323	44	74	77	78	477	260	106	63	0	6	1516
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1933-34	CL	25	35	16	5	76	173	464	41	6	5	T	0	846
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1934-35	CL	16	253	34	4	47	129	170	118	8	na	na	na	910
	NT	na	na	na	na	na	na	na	na	na	18	6	na	na
1935-36	CL	na	na	na	na	na	na	na	na	na	97	0	34	na
	NT	53	127	7	11	1	200	344	780	174	na	na	na	na
1936-37	CL	0	78	67	22	34	189	65	257	124	0	0	0	836
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1937-38	CL	79	27	88	101	32	38	421	336	29	17	0	7	1175
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1938-39	CL	135	30	274	52	15	236	559	185	59	71	0	3	1619
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na

TABLE I

RECORDED RAINFALL AT BA NGOI (CL) AND NHA TRANG (NT) (Continued)
1927-28 to 1968-69

Year	Station	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total Year
		Rainfall in Millimeters												
1939-40	CL	31	56	34	0	154	161	959	87	na	na	na	na	na
	NT	na	na	na	na	na	na	na	na	na	22	33	4	na
1940-41	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	81	27	35	45	119	273	47	120	244	15	20	0	1026
1941-42	CL	na	na	na	na	na	na	na	na	na	86	0	6	na
	NT	6	105	51	26	7	103	127	176	110	62	4	29	806
1942-43	CL	136	0	43	150	170	489	719	311	66	0	T	0	1984
	NT	43	0	41	36	158	308	555	862	94	na	na	na	2097
1943-44	CL	42	53	72	32	25	181	485	333	86	42	38	13	1332
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1944-45	CL	13	136	124	T	18	133	155	104	185	419	na	na	na
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1945-46	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	na	na	na	na	na	na	na	na	na	na	na	na	na
1946-47	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	na	na	na	na	na	na	na	na	na	39	23	4	na
1947-48	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	312	149	26	81	187	156	442	31	91	11	0	55	1541
1948-49	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	72	45	4	30	74	144	358	248	125	15	22	32	1169
1949-50	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	27	29	7	21	127	193	331	453	146	46	13	24	1317

RECORDED RAINFALL AT BA NCOI (CL) AND NHA TRANG (NT) (Continued)
1927-28 to 1968-69

Year	Station	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total year
		Rainfall in Millimeters												
1950-51	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	27	17	60	15	56	143	352	278	74	8	3	36	1069
1951-52	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	81	36	3	164	63	117	160	523	79	39	17	13	1295
1952-53	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	39	55	51	19	83	95	414	106	45	33	33	2	975
1953-54	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	0	45	87	44	39	72	178	505	135	9	1	16	1131
1954-55	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	9	5	26	1	55	89	446	61	767	20	23	0	1502
1955-56	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	45	67	80	24	18	47	231	578	13	14	16	12	1145
1956-57	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	11	130	31	16	57	182	170	223	87	25	0	0	932
1957-58	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	9	10	40	38	37	142	265	57	54	65	11	37	765
1958-59	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	69	42	74	90	82	148	373	63	2	41	0	21	1005
1959-60	CL	na	na	na	na	na	na	na	na	na	na	na	na	na
	NT	49	85	50	69	43	79	132	122	243	27	15	18	932
1960-61	CL	na	na	na	na	na	na	na	na	na	6	T	T	na
	NT	19	53	42	31	47	298	223	457	53	48	19	17	1307
1961-62	CL	80	10	40	T	60	61	18	23	8	4	0	10	274
	NT	141	66	88	38	47	30	130	126	65	52	18	8	809

TABLE I

RECORDED RAINFALL AT BA NGOI (CL) AND NHA TRANG (NT) (Continued)
1927-28 to 1968-69

Year	Station	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total Year
		Rainfall in Millimeters												
1962-63	CL	T	7	2	T	4	39	591	159	2	0	2	T	806
	NT	1	51	13	38	4	168	350	331	26	14	3	1	1000
1963-64	CL	0	T	3	4	12	27	280	5	4	98	8	2	443
	NT	31	37	19	31	58	300	308	264	55	61	52	9	1225
1964-65	CL	14	157	77	T	72	34	188	408	315	0	0	31	1296
	NT	8	246	30	1	292	94	381	646	325	12	13	17	2065
1965-66	CL	27	72	52	32	98	222	787	516	899	220	0	71	2941
	NT	58	7	35	26	40	106	620	424	T	94	16	32	1458
1966-67	CL	12	381	80	41	74	197	456	957	0	na	na	7	na
	NT	69	126	10	29	80	166	262	268	396	143	7	10	1566
1967-68	CL	92	73	29	50	0	76	111	346	na	na	na	na	na
	NT	70	66	6	37	62	30	70	145	90	6	14	13	610
1968-69	CL	136	88	173	28	96	105	370	241	73	82	T	0	1392
	NT	164	56	59	19	54	103	444	244	56	121	na	na	1345*
Mean	CL	41.4	93.0	66.0	25.5	59.7	134	343	260	126	57.4	4.6	19	1178
	NT	57.5	64.7	37.9	37.7	68.9	150	297	311	136	38.6	14.7	15.7	1134

* Approximate

Streamflow measurements for a single year could not be expected to represent long-time mean annual flows, nor typical seasonal distribution. Nevertheless, meaningful extrapolation and interpretations are possible by use of concurrent records of related climatological factors. Parsons calculated the total water resources available to Cam Ranh City by using the mean annual flow and its monthly distribution. It was rather fortunate that the hydrologic year over which the climatic measurements were made by Parsons was quite close to the long term normal and extrapolations were not extreme. Also, at key potential reservoir sites, historical records could be easily synthesized to permit preliminary consideration of storage possibilities and dam designs.

GROUND WATER STORAGE

Storage in permeable underground formations is found in limited quantities in low alluvial belts along the peninsula or in alluvium in the lower reaches of rivers flowing into the bay.

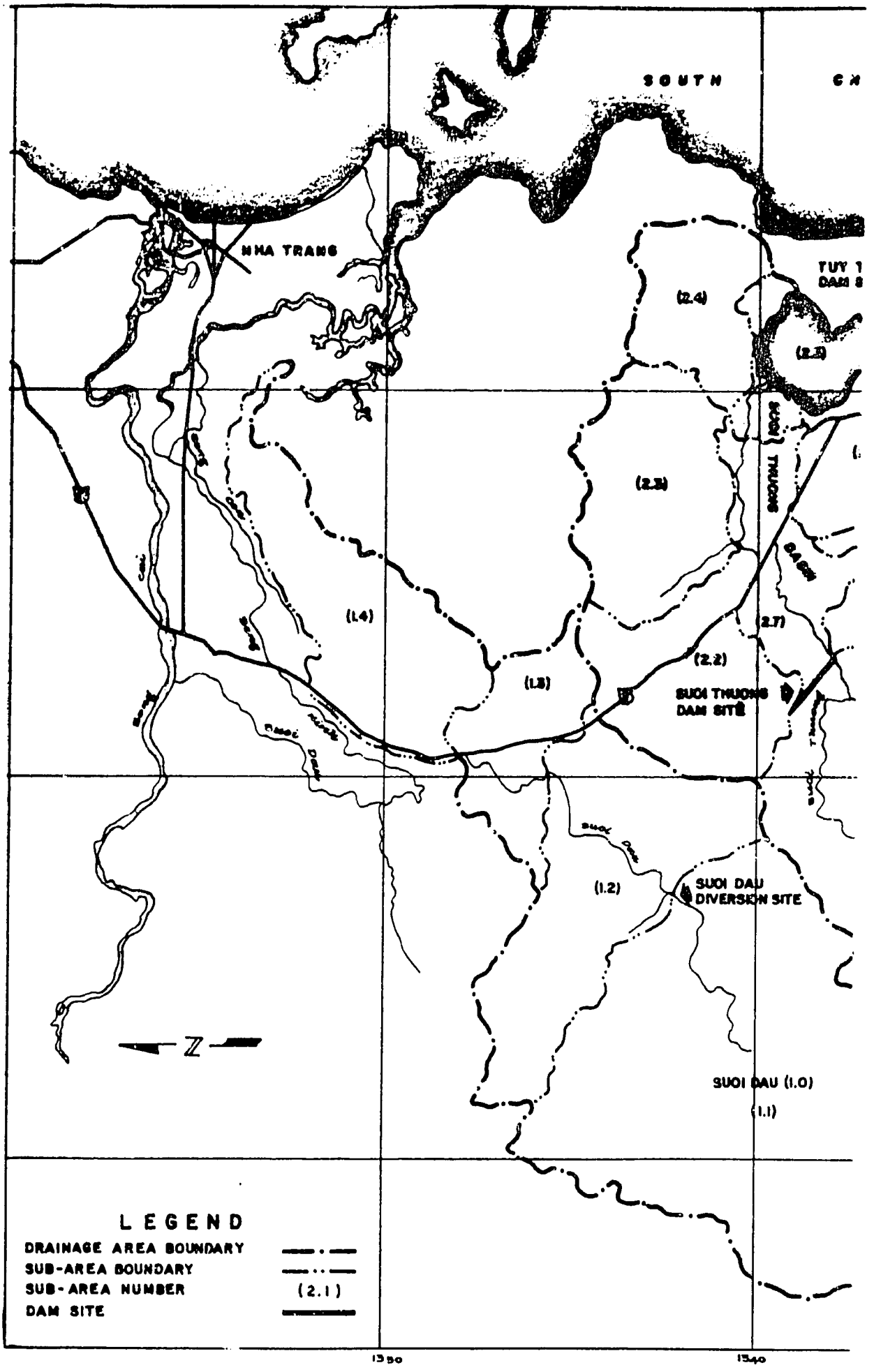
The mainland consists of a coastal shelf made up of loose beach and fan deposits abutting against step mountains of hard crystalline rocks. Two separate and unconnected water aquifers are present on the Cam Ranh Bay mainland. One is located in the fans fronting the Hon Rong mountain beneath and adjacent to the workers housing project and the other is in the alluvium of the Tra Duc Valley about one mile north west of Ba Ngoi.

Neither of these aquifers has the high yielding capacity required for development of a large municipal or industrial water supply, but they are the only ground-water resources on the mainland worth considering. Both are subject to salt-water intrusion if over-pumped. For example,

TABLE II

DRAINAGE AREAS

NAME AND NUMBER		AREA Km^2
Suoi Dau (1.0)		
1.1		93.8
1.2		34.3
1.3		14.4
1.4		25.5
	Total	168.0
Suoi Thuong (2.0)		
2.1		58.3
2.2		20.9
2.3		22.3
2.4		13.2
2.5		10.1
2.6		13.2
2.7		12.8
2.8		23.2
	Total	174.0
Suoi Tra Duc (3.0)		
3.1		62.2
3.2		11.2
3.3		18.7
3.4		18.4
3.5		3.5
	Total	114.0
Suoi Hanh (4.0)		
4.1		34.2
4.2		11.6
4.3		10.8
	Total	56.8
Song Can (5.0)		
5.1		42.3
5.2		6.8
	Total	49.1
Song Trau (6.0)		
6.1		66.1
6.2		3.2
	Total	69.3


SOUTH
NHA TRANG
TUY
DAM
(2.4)
(2.3)
(2.3)
SUOI THUONG
(1.4)
(2.7)
(2.2)
(1.3)
SUOI THUONG
DAM SITE
SUOI DAU
DIVERSION SITE
(1.2)
SUOI DAU (1.0)
(1.1)
N
LEGEND
DRAINAGE AREA BOUNDARY
SUB-AREA BOUNDARY
SUB-AREA NUMBER
(2.1)
DAM SITE
1350
1340

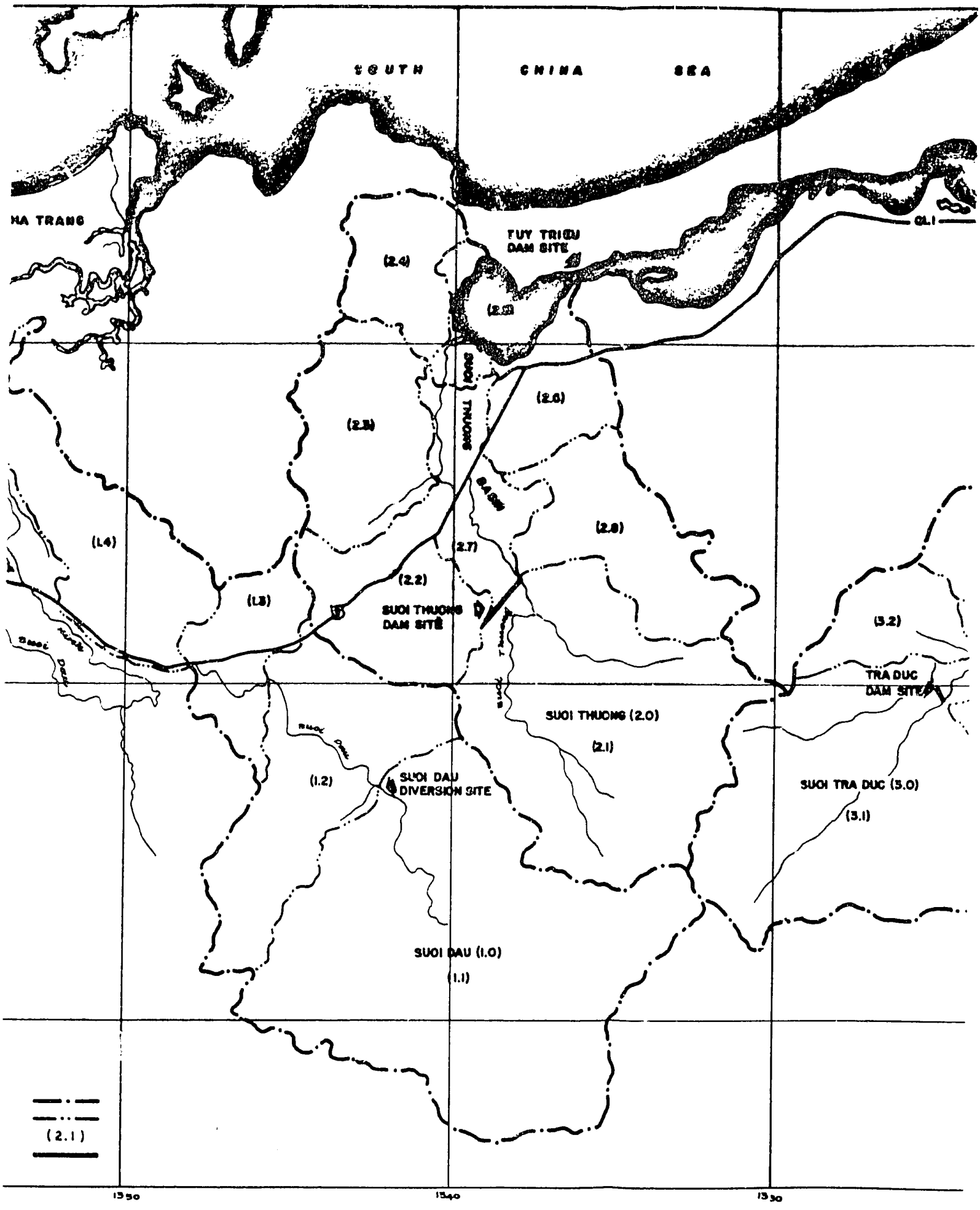
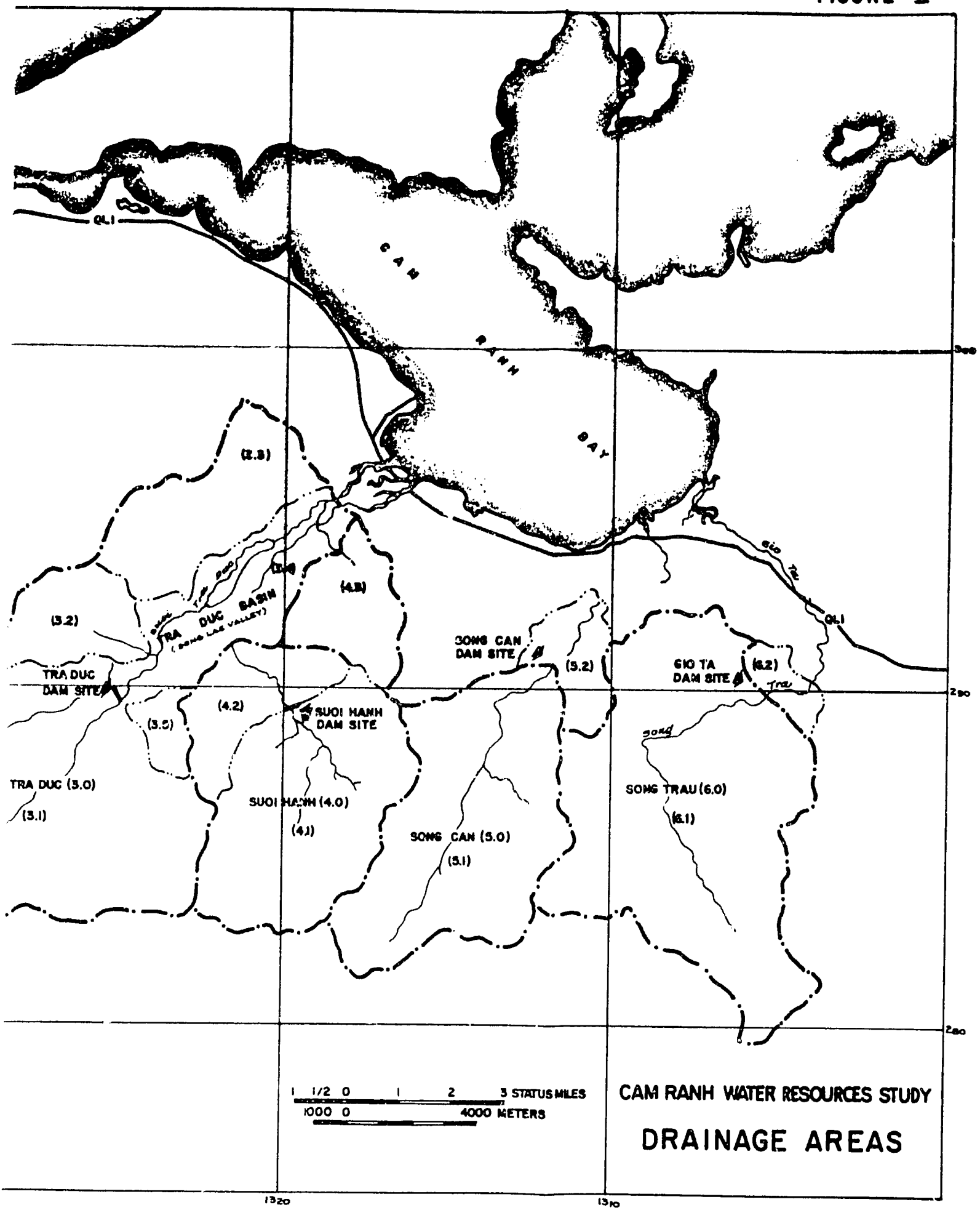

SOUTH CHINA SEA
HA TRANG
TUY TRIEU DAM SITE
(2.4)
(2.3)
(2.6)
(2.5)
(2.8)
(2.7)
(2.2)
(1.4)
(1.3)
SUOI THUONG DAM SITE
(3.2)
TRA DUC DAM SITE
SUOI THUONG (2.0)
(2.1)
(1.2)
SUOI DAU DIVERSION SITE
SUOI TRA DUC (3.0)
(3.1)
SUOI DAU (1.0)
(1.1)
(2.1)
1350
1340
1330

FIGURE II


CAM RANH BAY
QL.1
(2.3)
(3.2)
TRA DUC BASIN
(DONG LAC VALLEY)
TRA DUC DAM SITE
(4.2)
(3.3)
SUOI HANH DAM SITE
(4.3)
SONG CAN DAM SITE
(5.2)
GIO TA DAM SITE
(6.2)
Gio Tra
Song
TRA DUC (3.0)
(3.1)
SUOI HANH (4.0)
(4.1)
SONG CAN (5.0)
(5.1)
SONG TRAU (6.0)
(6.1)
1 1/2 0 1 2 3 STATUS MILES
1000 0 4000 METERS
CAM RANH WATER RESOURCES STUDY
DRAINAGE AREAS
1320
1310
300
290
280

it has been estimated that to supply the initial demands of the workers housing project, some 60 percent of all water falling onto the fan in a normal year would have to be absorbed and percolate downward to the water table. Porous as this area may be, it is hard to believe that this fan could absorb such a high percentage.

But assuming it could, an attempt to extract so much water seems impractical. Further, the Ralph M. Parsons Company (RMPCo) in its report stated, "The surplus yield of Suoi Tra Duc ground-water basin has been estimated by several experts (and is generally agreed) to be about 0.3 million cubic meters per year (0.2 million gallons per day). Since the capacity of the basin is considered to be only limited, it could not provide a reliable source of water supply for industrial use, but could provide a source of supply for some of the smaller hamlets in the vicinity".

The only other significant ground water basin in the area is located on the Peninsula. In 1968, William C. Rasmussen and Associates summarized the potential of this area as follows: "a sand and granite promontory facing the South China Sea and enclosing Cam Ranh Bay, has huge volumes of ground water in a fresh-water lens, bounded by salt-water interfaces. Careful management of this storage by pumping properly spaced wells and Lake Ao Ho, may eventually yield 22 million gallons a day (mgd) on a sustained basis. The military is currently taking about one-fifth that, and having difficulties." Rasmussen then goes on to discuss how improper location and management of the well fields have resulted in over-pumpage with resulting salt-water intrusion. In discussions with Dr. Rasmussen during 1971, he admitted that even

with a properly spaced well field and carefully controlled pumping, it would be impractical to expect to obtain much more than 5.0 mgd of water from the proposed industrial area on the Peninsula. And he quickly added that to attempt to extract more than 5.0 mgd would be a complex operating problem for even a highly-trained hydrologist, probably using a computer to analyze the ever-changing pumping conditions.

In their September, 1973 report, Geo Control, Inc. stated "The evaluation of the surface and ground water potentialities in the proposed industrial zone indicate that each of them could sustain, separately, the daily and annual expected demand of water of 5 million gallons per day. However, the ground water sources will require careful management to minimize the migration of salt water into the aquifer."

The fresh water aquifer on the peninsula is a huge underground lens supported by the denser salt water surrounding it. Rainwater percolates down through the sands and outward within the lens. During the rainy seasons, the water table rises and the bottom of the lens sinks. Under static conditions, the thickness of this lens is controlled by the height of the water table above sea level, because the fresh water column must balance the salt water pressure at the bottom of the lens in accordance with Ghyben-Herzberg principle. This simply states, for normal specific gravities of sea water (1.025) and fresh water (1.000), if the water table rises 4 ft. above sea level (h_f-h_s), the theoretical depth of the fresh water lens must be $h_s = 40\ (h_f - h_s)$ or 40 x 4 = 160 ft. Any pumping reduces the thickness of the fresh water lens and creates an upward and/or inward bulge at the fresh-salt

water interface. Because the volume of fresh water displaced is often very large, the fall of the water table may be slight and can go undetected until the well becomes saline.

As stated above, during the rainy season, the water table rises creating an unbalancing of pressures within the lens. The excess water flows out of the lens into the sea or bay until pressures of the fresh water lens equal the salt water pressure supporting the lens. The net volume of water flowing out of the lens is therefore the specific yield of the aquifer and is the theoretical volume of water that can be safely withdrawn for use. Assuming the lens has reached a static or equilibrium condition at the end of the dry season, we can calculate the volume of water that can be safely pumped as follows:

Area of proposed industrial zone	30 sq. m.
Mean Annual Rainfall	1,175 mm
Assumed Infiltration Rate	60%
Assumed Porosity of Aquifer	40%
Assumed Specific Yield of Aquifer	20%

The water table fluctuates yearly between ± 25m at the end of rainy season to low of ± 20m at end of dry season. Geo Control, Inc. states, "Experience indicates that the decline of the ground water table never exceeds 5 meters from the end of the wet season level."

Then the volume of water that flows out of the lens during the 7 months of the dry season is:

30×10^6 sq.m. x 5m(elev. diff.) x 0.4(porosity) x 0.2(specific yield)

$= \underline{12 \times 10^6 \ m^3}$

Annually this can be estimated as $12/7 \times 12 \times 10^6 m^3$

$= \underline{20.6 \times 10^6 \ m^3}$

This approximates the net volume of water available for use annually assuming the lens has reached equilibrium at end of each dry season. The input to the basin should equal the outflow and should be equal to the volume of precipitation during the mean year that filters into the aquifer:

$1.175 \times 20 \times 10^6$ sq.m. x 0.6 (infilt. rate) = 21.1×10^6 m

This closely checks the calculated outflow and translates into a daily flow of $21.1 \times 10^6 \times 264/365$ days = <u>15.2 mgd</u>

These values are for periods of mean precipitation. However, lets examine the conditions during a drought period such as occurred during the 1961-62 season when the annual rainfall dropped to a low of 274mm.

Volume of input = 0.274m x 30 x 10^6 sq.m. x 0.6 = <u>4.93×10^6 m</u>

or approximately 4.93 x 264/365 = <u>3.6 mgd</u>

This indicates that with a proposed pumping rate of 5 mgd, the rate of withdrawal will be greater than the volume of replenishment. While it is evident that during periods of low rainfall the usage exceeds the recharge, most of this deficit will be temporarily offset by water moving from those parts of aquifer beyond the 30 sq. m. industrial zone. Also, there is the real possibility that the excessive pumping will cause a temporary salt water wedge or bulge to intrude landward. This wedge would probably be gradually displaced with the return of adequate recharge. However, should this unbalanced pumping condition continue for extended periods, it would ultimately destroy the fresh water resource of the peninsula.

It should be recognized that the foregoing calculations and discussions involve approximations and are too general in terms of factual data to

guarantee that wells pumping 5 mgd will or will not start delivering saline water especially during a drought period. With a properly designed well field that is operated at pumping rates which maintain a balance between aquifer inflows and outflows, there is every reason to expect that 5.0 mgd of fresh water can be safely withdrawn from the Cam Ranh Peninsula without difficulties. However, any abuse of this valuable resource can quickly cause its loss or serious deterioration.

SURFACE STORAGE

The mountains adjacent to Cam Ranh Bay Area are steep and the canyons generally narrow. Attempts to divert the local streams that flow in these canyons are not technically feasible because it is apparent that the runoff from the various watersheds is too small during the dry season. However, it is possible to store the surplus wet-season runoff for release during dry periods. Those water supply development projects that could be considered technically feasible include the construction of dams and reservoirs along the Suoi Thuong, Suoi Tra Duc and Song Trau (Gio Ta site). Those not considered to be technically feasible according to the Parsons Study for various reasons include the Song Can Dam, the Suoi Dau diversion and the Thuy Trieu Dam. The net yearly available supply from each potential site studied is summarized in the following table:

TABLE III - MEAN YEARLY AVAILABLE WATER SUPPLY

Development Site	Drainage Area (Km^2)	Net Available Supply* ($m^3 \times 10^6$)
Suoi Dau	93.8	82.4
Suoi Thuong	58.2	33.7
Suoi Tra Duc	62.2	19.0
Song Can	42.3	8.2
Song Trau (Gio Ta)	66.1	45.5

* Totals do not include irrigation deficits.

From its study Parsons concluded "The construction of a dam downstream from the Song Trau drainage area, at the Gio Ta dam site, appears to be the most feasible scheme for providing water for the Cam Ranh City Area. The mean yearly yield of the drainage area is about 45.5 million cubic meters (33 million gallons per day) considerably in excess of some forecasted water demands. Surplus flow could be beneficially used as a supplementary supply for industrial installations on the Cam Ranh Peninsula, in the Phan Rang area, or for irrigated agriculture..... In summary, the construction of a dam and reservoir at the Gio Ta site appears to be the most desirable method for providing a firm water supply for industrial and domestic use in Cam Ranh City. The construction cost in the Western United States for a similar dam, spillway, reservoir and transmission system, designed to meet forecast demands of 17,300 cubic meters per day (4.56 mgd), is estimated to be about $8,137,000. If the project were constructed under present unsettled conditions, the constructed

cost probably would vary from 2.0 to 2.4 times this estimated cost. A larger dam could be constructed that would yield four time (20.0 mgd) the forecast water demands for an additional $1,900,000....."

See figures III and IV.

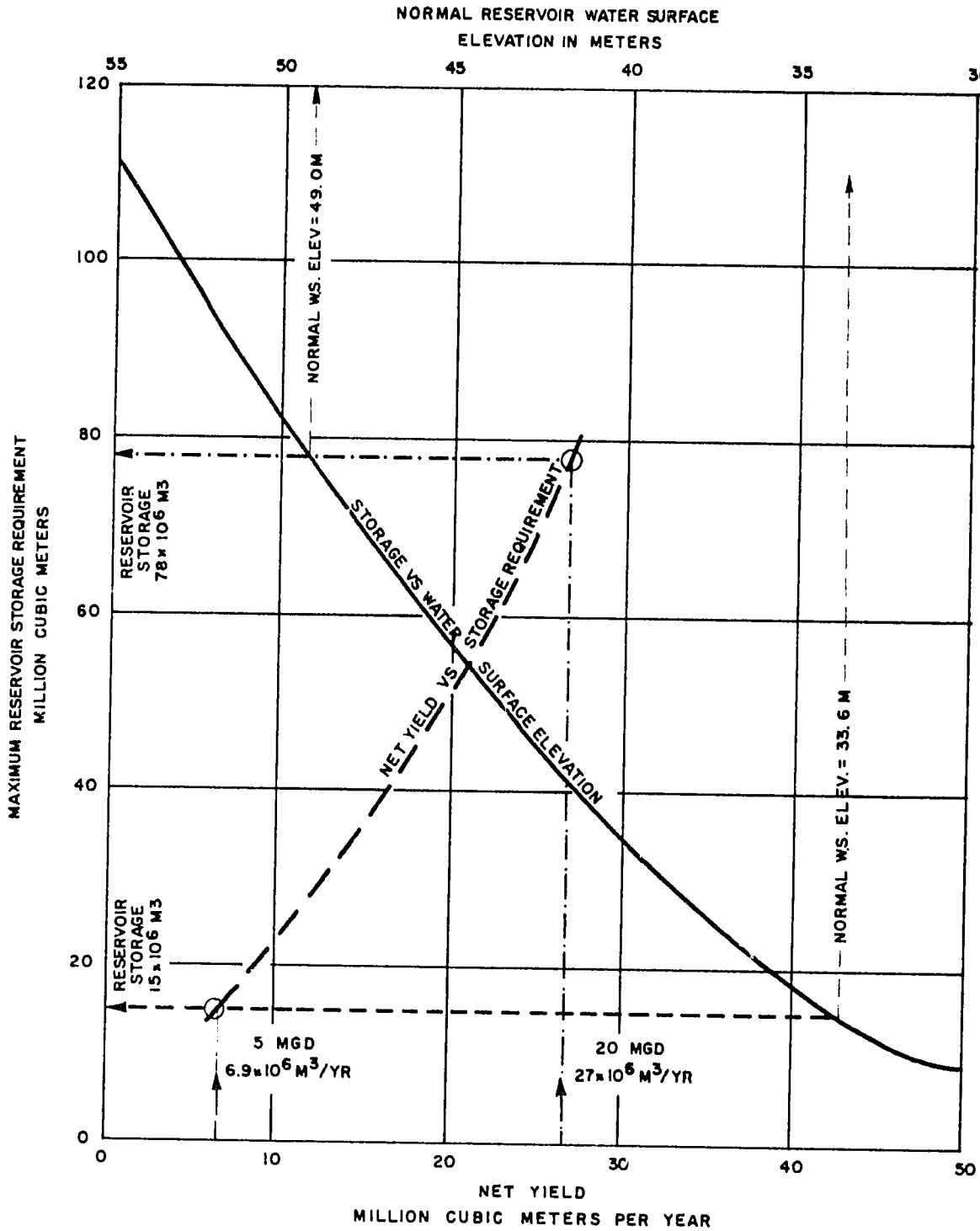
SOURCES FOR IMPORTED WATER SUPPLIES

There is strong evidence that adequate water supplies for Cam Ranh Area can be developed from local sources and that imported supplies should not be considered unless further studies indicate that imported water will be more economical. If an imported water supply is needed, it has been suggested by various consultants that the water may be available from either the Suoi Dau or the diversion of flows from the Da Nhim project and the Song Cai which are excess to the needs of the Phan Rang Irrigation Project. Parsons in its study stated, "Although the water development potential of the Suoi Dau is greater than any other single source in Cam Ranh area, direct diversion is not feasible because downstream irrigation requirements exceed mean stream flow 60 percent of the time during the dry season..... However, during the wet season it is estimated that about 75 million cubic meters could be impounded in a storage reservoir, and be beneficially used for irrigation downstream or exported to Cam Ranh City. The technical and economic feasibility of such a scheme is beyond the study scope of work, but it is recommended that it be given serious consideration in any future water supply study in the area".

WATER FROM THE DA NHIM PROJECT

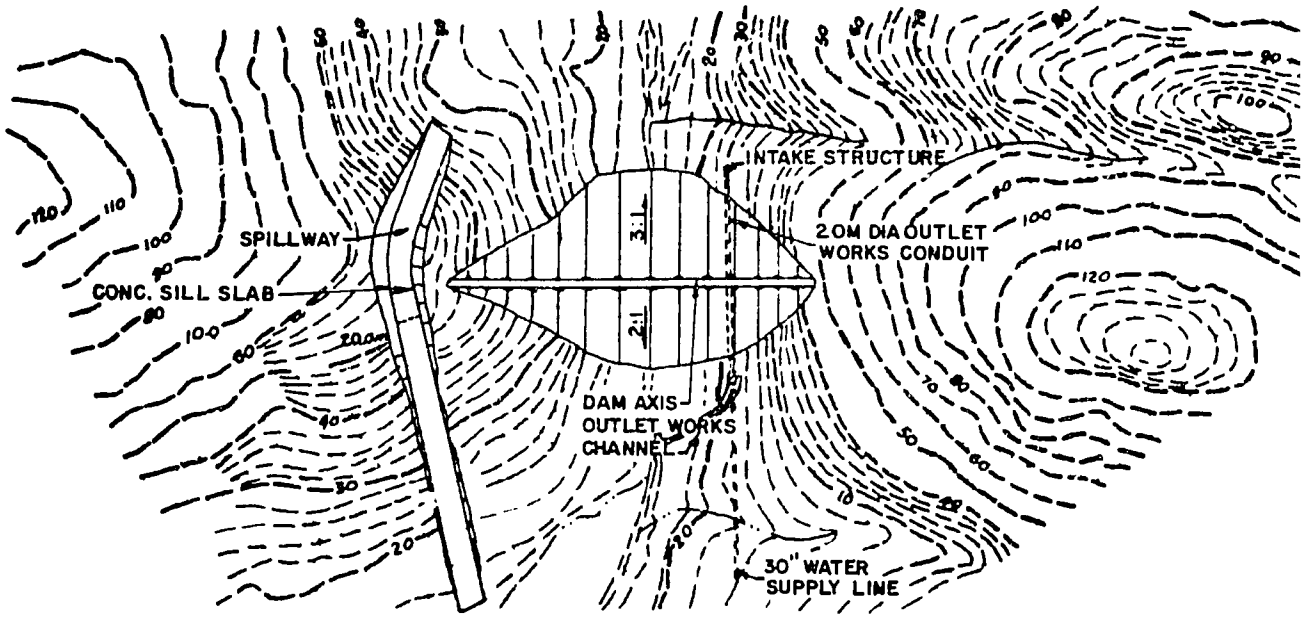
The firm sustained discharge rate that will become available from the Da Nhim Hydroelectric Project in generating 160,000 KW has been

FIGURE III



GIO TA RESERVOIR

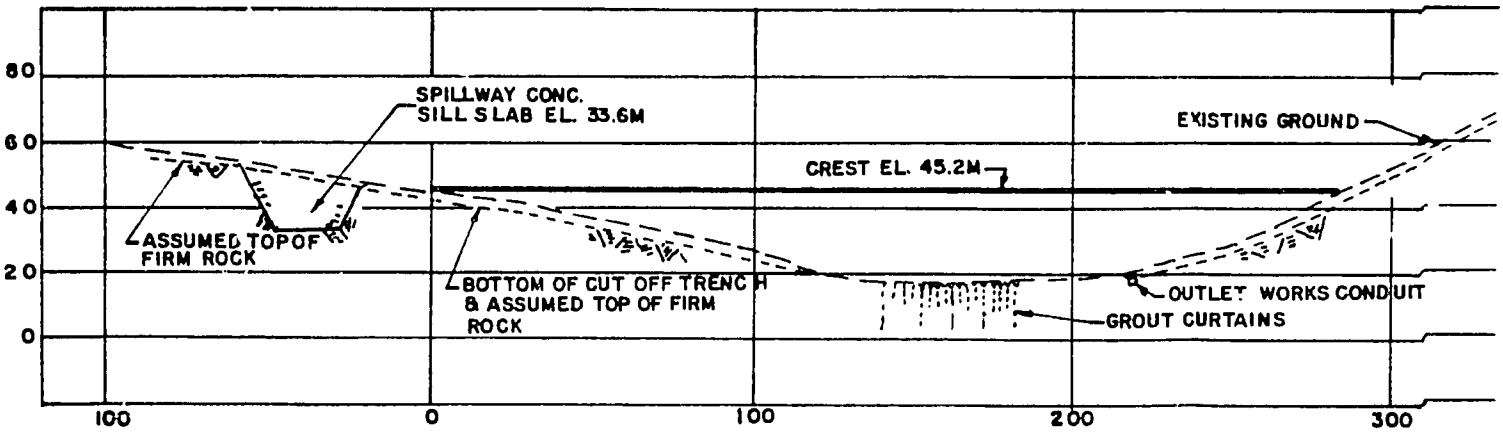
NET YIELD AND STORAGE REQUIREMENTS



PLAN

0 50 100 150

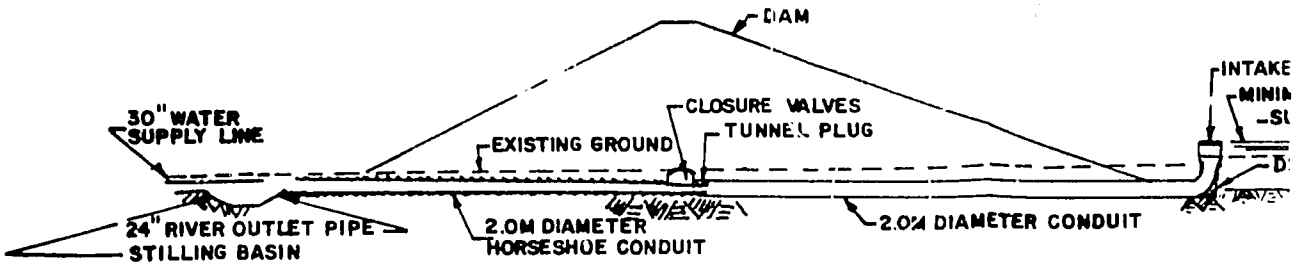
SCALE IN METERS



PROFILE ALONG AXIS OF DAM

0 10 20 30 40 50 60

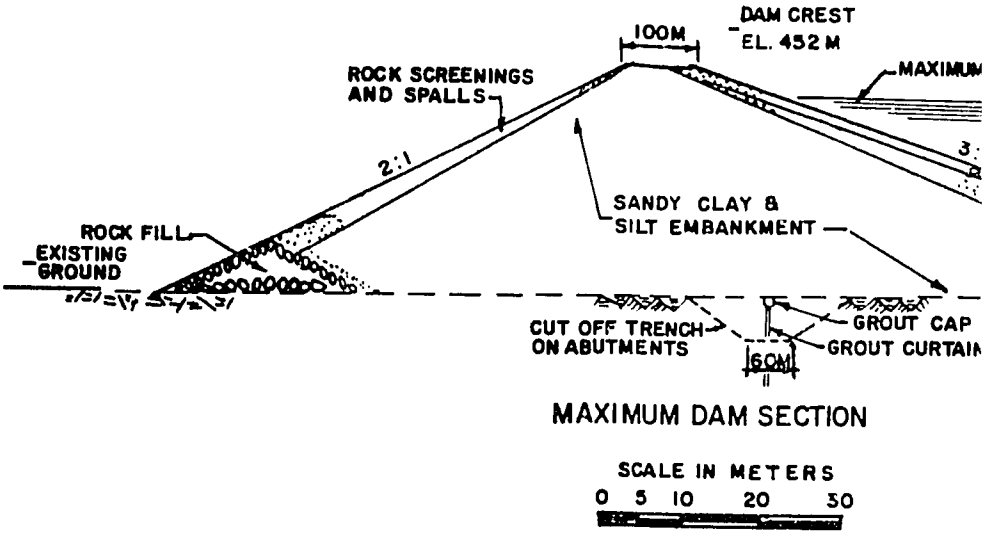
SCALE IN METERS



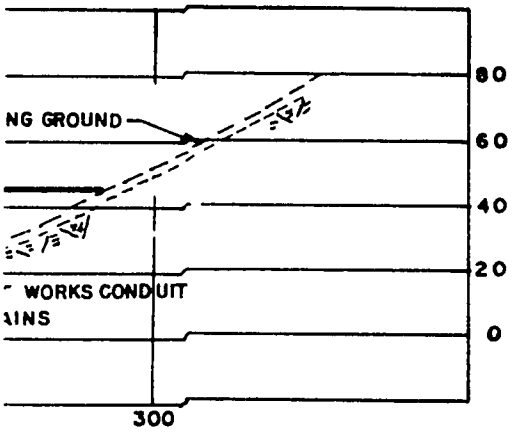
PROFILE OF OUTLET WORKS

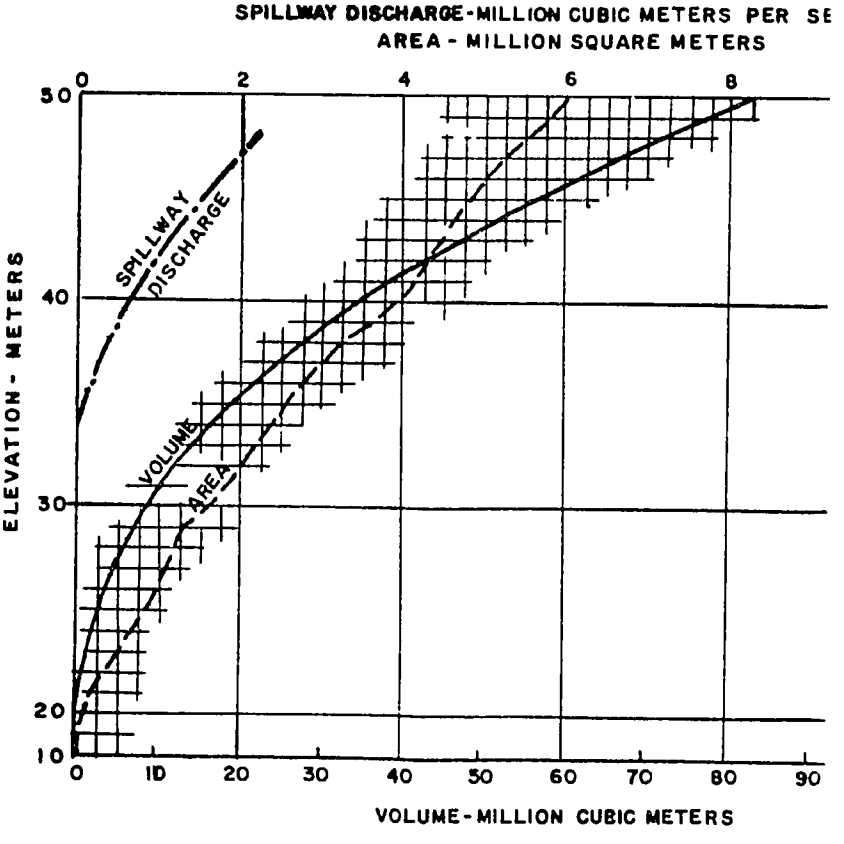
0 5 10 20 30

SCALE IN METERS

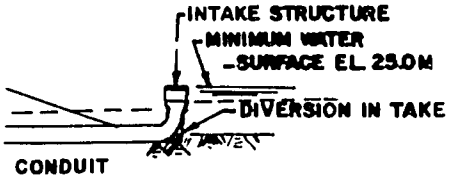


MAXIMUM DAM SECTION





AREA AND CAPACITY OF THE GIO TA RESE

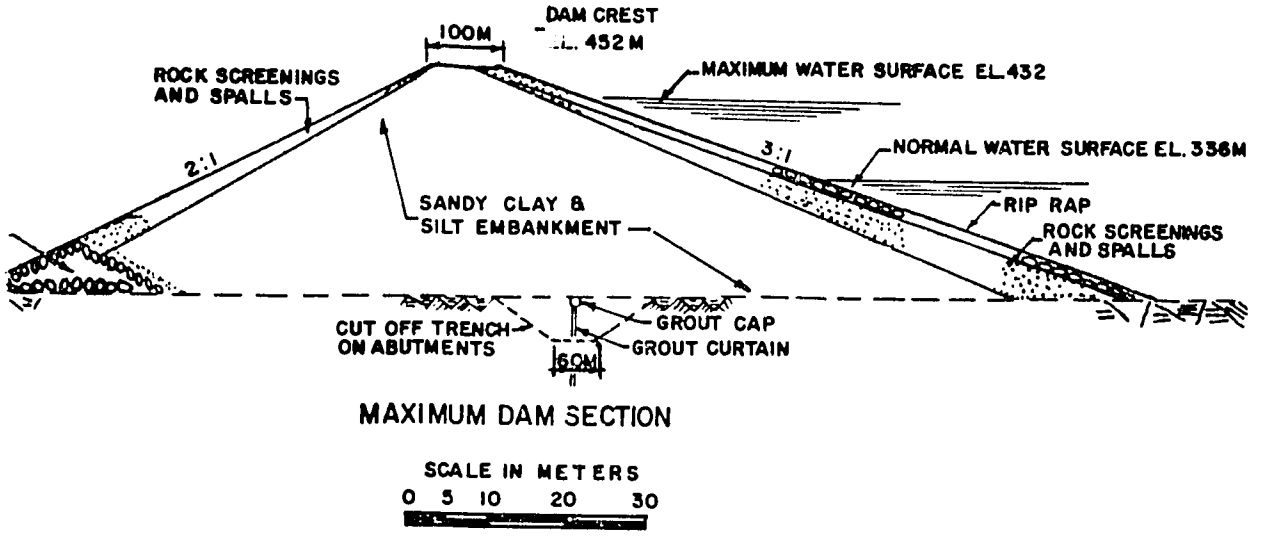


CAM RANH WATER RESOU

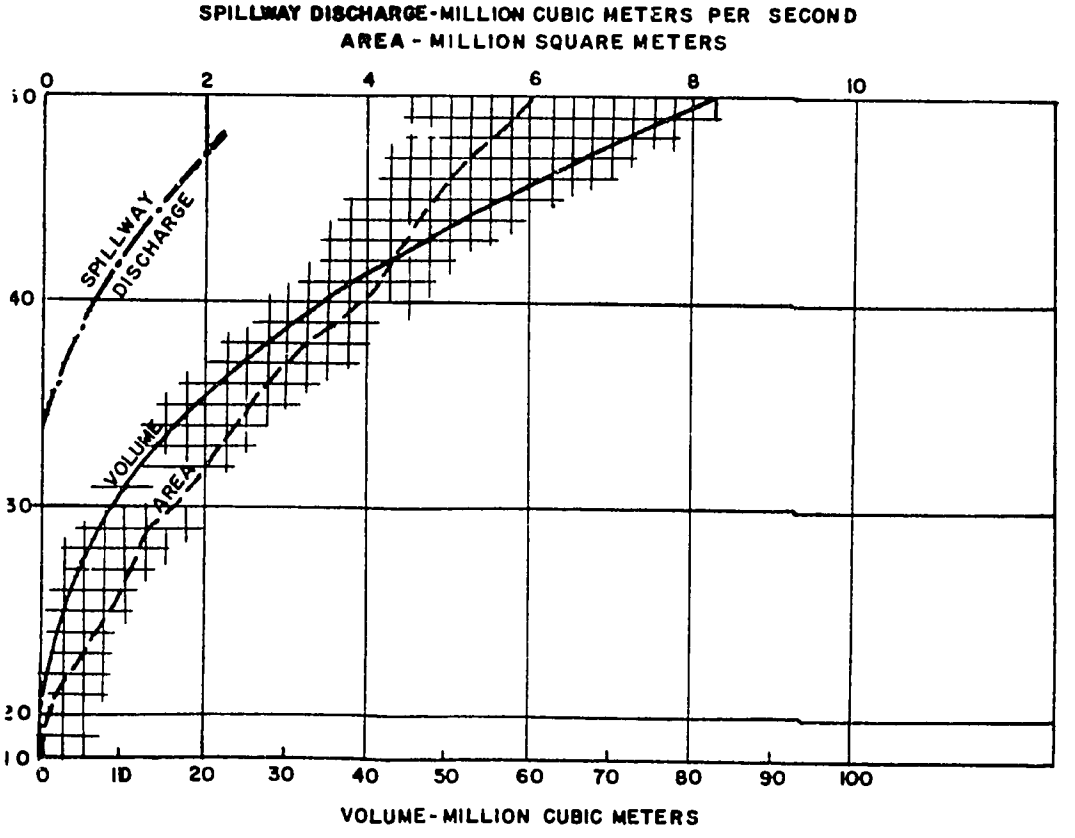
GIO TA DAM

PRELIMINARY

FIGURE IV



MAXIMUM DAM SECTION



AREA AND CAPACITY OF THE GIO TA RESERVOIR

CAM RANH WATER RESOURCES STUDY

GIO TA DAM

PRELIMINARY DESIGN

calculated to be 18 m^3/sec. However, according to a Japanese Study, this discharge drops to 15 m^3/sec during the dry season. This same report states, "With an additional volume of 6 m^3/sec from the Song Cai River which is the minimum natural flow even during the dry season, a total of 15 + 6 or 21 m^3/sec in all could be utilized. An extension scheme of the Da Nhim Power Station is under planning..... will be completed in 1978. This project is expected to increase the discharge from the power station by 7 m^3/sec even during the dry season, thus increasing the potential supply of water to (21 +7) 28 m^3/sec. An irrigation project has been underway in the Phan Rang Plain ever since 1963..... If the project is carried through as planned, a total of 24,000 ha. will require 26 m^3/sec of water for irrigation.

"In recent years, about 1,700 refugee families have been accomodated in the northwest sector of the Phan Rang Plain between Tan My and Krong Pha (near the Da Nhim Power Station). Cultivation of about 3,000 ha. of land is being planned to facilitate settlement of the refugees. This means that 3 m^3/sec of water for agricultural use must be set aside for consumption by refugee villages. Effective utilization of the Song Cai River, now under serious planning calls for building a dam on the Song Cai River in a gorge just above the plain and a reservoir with 100 to 120 million cubic meters capacity. Such a dam (Song Cai No. 1) will increase the discharge during the dry season to 12 m^3/sec. The balance sheet for water utilization of Da Nhim and the Song Cai can be summarized as follows:

Sources of Water:

Discharge from the Da Nhim Power Station	15 m^3/sec
Natural discharge of the Song Cai (during dry season)	6 "
Extension of Da Nhim Project	7 "
Reservoir on the Song Cai	12 "
Sub-Total	40 m^3/sec

Consumption:

Phan Rang Irrigation	26 m^3/sec
Refugee villages	3 "
Sub-Total	29 m^3/sec
Remainder	11 m^3/sec

In short, out of the 40 m^3/sec available resources, roughly 11 m^3/sec can be utilized as industrial water in Cam Ranh area, after the amounts needed for irrigation on Phan Rang Plain and for refugee are subtracted from the total supply."

We do not entirely agree with above analysis because the National Power Survey Report (NPSR) dated February, 1972 lists the discharge from all the Da Nhim (No. 1 thru No. 3) projects as 34.8 m^3/sec. Further, this report indicates that the No. 2 and No. 3 generating stations have less favorable ratios of annual benefits to annual costs and are, therefore, economically less attractive than some other projects. We believe it will be many years before Da Nhim Nos 2 and 3 are built, if ever. This would then reduce the total available discharge from the Da Nhim Projects to 32.0 m^3/sec.

Further complicating this problem is the recommendation by the NPSR that Da Nhim No. 1 be operated during dry seasons as only a peaking

station. If this recommendation is followed, it would further reduce the firm volume of water available to between 16 to 17 m^3/sec. With a need for a total of 29 m^3/sec for irrigation of the Phan Rang Plain and refugee villages, this potential water deficit must be obtained from storage of the Song Cai and probably would not be translated for many years into a source of water for the Cam Ranh Area.

WATER FROM SONG CAI

Plans for the Phan Rang Irrigation Project assume a minimum diversion of 4 m^3/sec from the Song Cai, and the maximum capacity of the diversion works is 6 m^3/sec. There presently is no storage in connection with this and therefore the figure of 4 m^3/sec represents a safe estimate of the firm minimum flow of this river during the driest seasons.

A stream which has a minimum flow of 4 m^3/sec may be expected to have an annual flow of several times this rate and with storage may add an additional 12 m^3/sec to the Phan Rang Irrigation Project. Any excess could be transported to the Cam Ranh Area to satisfy the indicated need of 1.0 m^3/sec. However, like the Da Nhim source, expensive storage, pumping and transmission facilities would be needed to transport this water into Cam Ranh. From an economic standpoint, it probably would not be as feasible a project as some of the others discussed earlier in this report.

DESALINATION OF SEA WATER

When investigating potential water supplies, consideration should be given to desalting of brackish waters. Under some circumstances desalination may have advantages over the development of natural water sources. The desalination processes fall into three general classes:

1. Evaporation or freezing, in which water is separated from brine by a phase change.
2. Electrodialysis, in which salt ions are removed using an electric current and appropriate membranes.
3. Reverse osmosis, in which water is separated from brine by use of pressure and an osmotic membrane.

In the latter two processes, energy requirements are proportional to salt concentration so their principal use is with brackish feed rather than sea water.

Of all the processes currently in use, the multi-stage flash (MSF) process has been used most extensively and in capacities greater than one million gallons per day. Despite the theoretical advantages of other processes, the MSF process is probably the recommended process for Cam Ranh because of its advanced state of development and application experience.

The Ralph M. Parsons Company estimated a 5.0 mgd plant (without a transmission and distribution system) would cost approximately $7.2 million and have an annual operating cost of $4.0 million. This indicates water from such a plant would have to be sold at approximately VN$ 187 per cubic meter. This cost is approximately four times the cost of water in other parts of Vietnam.

CONCLUSIONS AND RECOMMENDATIONS

An evaluation of both the short and long range water potentialities for the Cam Ranh Bay Area indicates the following:

1. That a properly spaced and operated well-field located on the peninsula in the vicinity of the proposed industrial zone can be expected to yield approximately 5.0 mgd of good quality water.

2. This well-field will require careful management to minimize the intrusion of salt-water into the aquifer.
3. That the other two ground water basins on the mainland have only limited quantities of water and are not worth developing except for use by the small local hamlets.
4. Local streams have insufficient dry weather flows to permit direct utilization for water sources without storage.
5. The construction of dams and reservoirs along the Suoi Thuong, Suoi Tra Duc and Song Trau (Gio Ta site) appear to be technically feasible.
6. The net yearly available supply from each potential site is:

Size	Net available supply ($m^3 \times 10^6$)	Daily supply (gals. $\times 10^6$)
Suoi Dau	82.4	7.5
Suoi Thuong	33.7	2.4
Suoi Tra Duc	19.0	1.4
Song Trau (Gio Ta)	66.1	33.0

7. There is strong evidence that adequate water supplies for Cam Ranh Bay Area can be developed from local sources and that importation of supplies should not be undertaken unless further studies indicate that imported water will be more economical.

It is recommended that the following local water supply sources be thoroughly evaluated in the order listed for the purpose of economic and technical feasibility:

1. The well-field located on Cam Ranh Peninsula for immediate needs.

2. Gio Ta Reservoir and Dam as the primary water source.

3. Impoundment of the Suoi Dau for long range needs.

The proposed study and design of the well-field on the peninsula is estimated to cost $250,000 and take approximately 9-12 months to complete. The study and design of the proposed well-field may be delayed until ground water usage in the area of the industrial park reaches 2.0 mgd. However, to further delay implementing the recommended study and design work would unnecessarily risk destroying most of the ground water resources in the southern half of the peninsula.

We strongly urge that the collection of streamflow and rainfall intensity-duration data on the Song Trau (Gio Ta) and Suoi Dau drainage basins be started as soon as possible. Additional delays would in all probability be translated into additional project costs.

After development of the peninsular ground water basin, the most feasible solution to Cam Ranh Bay's water supply needs appears to be the construction of a storage dam and transmission line on the Song Trau (Gio Ta). This project was estimated by Parsons in its study to cost a minimum of $16.3 million for the 5.0 mgd project and $20.0 million for the 20.0 mgd project. We disagreed with Parsons' estimates and decided to reestimate the costs based on using local labor. Basing our estimate on local unit cost information available from contracts, we estimated the 20.0 mgd dam and transmission line would cost approximately US$ 5.0 million and VN$ 1,304 million. In this estimate we deleted the cost of the treatment plant and some of the unnecessary distribution lines previously included in the Parsons estimate. Also we planned for all construction work to be

done by local contractors, but included American supervision. A breakdown of this cost estimate has been included as Appendix A. Because of the large discrepancy between the two cost estimates (Parsons' $20 million versus our $7.2 million) we recommend that a contract be negotiated with a qualified A&E firm to make a preliminary design and cost estimate for the construction of the Gio Ta Project should USAID decide to proceed with the development of a water supply for Cam Ranh Bay Area.

APPENDIX A

WATER SUPPLY COST ESTIMATE
GIO TA DAM
(20 mgd)

SUMMARY OF COSTS ESTIMATE

Item No.	Item Description	US$	VN$
1	Dam Foundation	43.193	56,503,080
2	Dam Embankment	191,730	408,016,600
3	Service Spillway	694,060	244,182,680
4	Outlet Works	67,045	61,267,000
5	Reservoir	330,000	44,260,000
	Sub-Total	1,326,028	814,229,360
	Contingencies, overhead & profit	331,507	203,556,640
	Total Dam Cost:	$1,657,535	VN$1,017,786,000
	Booster Pump Station	27,500	16,500,000
	Chlorination Station	11,000	5,500,000
	Transmission Lines	2,025,320	224,255,600
	Total, Project	3,721,355	1,264,041,600
	Field Investigation 8%	298,000	12,640,300
	Engineering Design 10%	372,000	12,640,400
	Supervision Construction 12%	447,000	15,200,000
	GRAND TOTAL	$4,838,355	VN$1,304,522,400
	Say	$ 5.0 million	VN$ 1,304 million

APPENDIX A

WATER SUPPLY COST ESTIMATE
CAM RANH CITY

SUMMARY OF TRANSMISSION PIPELINE COSTS
(Work to be done by VN contractor)

DOLLAR COSTS

Ductile Iron Pipe FOB Factory in U.S.

Dia.	Length	Unit Price	Cost
750mm	14,600m	$ 48.73	$ 712,000
600mm	4,700m	36.08	170,000
450mm	6,500m	23.98	155,870
400mm	5,100m	19.47	99,700
Sub-Total			$1,137,170
Fittings and Valves			113,717
Freight			774,433
Total Dollar Cost			$2,025,320

PIASTER COSTS

Clearing R/W	92,700 s.m.	400 VN$	37,080,000 VN$
Excavation	61,503 c.m.	820	50,432,460
Backfill	51,583 c.m.	820	42,298,060
Pipe Laying	30,900 l.m.	766	23,675,200
Valves & Fittings			5,918,800
Thrust Blocks			4,000,000
Pavement Repair			6,000,000
Bridge Crossings			10,000,000
Sub-Total			179,404,520
Plus 25% contingencies, overhead & profit			44,851,080
Total Piaster Cost			224,255,600 VN$