C4 FLOOD ANALYSIS

C4.1 Flood Records

C4.1.1 General

The objective of the flood analysis is to determine the design flood for the spillway and its appurtenant structures inclusive of the diversion facility. The spillway is designed to have a capacity of discharging the flood equivalent to 1,000-year probable flood in accordance with the design standard for reservoir type dam with similar scale to the Dong Nai No.3 and No.4 dams in Vietnam. While, a 20-year probable flood is adopted as the design flood for diversion facility.

The water level observation at new streamflow gauging station installed in this feasibility study has just commenced in the wet season of 1999. Since a design flood of the spillway is determined at a rather long return period of 1,000 years as mentioned above, the period of runoff records observed at the new streamflow gauging station is insufficient for estimating the design floods. On the other hand, rainfall records in the Project catchment are available for about 50 years. Accordingly, it is determined that the estimate of probable floods is made based on the relationship between rainfall and runoff.

For the purpose of converting rainfall into runoff, the unitgraph method is employed in this feasibility study. In addition, the consistency of the results of flood analyses carried out by means of the unitgraph method is verified through comparison with those by the storage function model method.

C4.1.2 Past Flood Records in Middle and Upper Reaches

In general, the flood in the thunderstorm season is fairly less than that in the typhoon season in the magnitude of runoff in the Project catchment.

In the vicinity of the Dong Nai No.3 and No.4 dam sites, there were no streamflow gauging stations on the Dong Nai mainstream till a new streamflow gauging station has been installed at the Dong Nai No.3 dam site in the course of the field investigation for this feasibility study that has been conducted mainly for the period from early May to early October 1999. On the other hand, the major flood records observed at the following streamflow gauging stations (SGSs) are indicative of the flood characteristics in the middle and upper catchment of the Dong Nai River:

- Dran SGS near existing Dran Dam of Da Nhim HPP (abandoned after completion of Dran Dam in 1964)
- Dai Ninh SGS
- Ta Lai SGS

The locations of above stream gauge sites and their water level observation periods are depicted in Figure C2.1 and Figure C2.2, respectively. The past flood records observed at these locations are discussed hereunder.

(1) Flood Records at Dran SGS (CA=775 km^2)

The characteristics of flood runoff in upper reach of the Dong Nai River can be assessed from the flood records at Dran SGS which was operational under existing Da Nhim HPP until early 1960's. The Design Report on Da Nhim Hydropower Project presents the observed and estimated annual maximum peak discharges at Dran SGS between 1932 and 1960. Of the annual maximum peak discharges, the largest and second largest floods are as follows:

No.	Annual maximum peak discharge (m^3/sec)	Date of Occurrence
1	2,500*	4 May 1932
2	1,500	20 Oct. 1952

Note: *; estimated by means of the rational formula.

It is said that the 1932 flood is the largest one among those that occurred in the upper catchment of the Dong Nai River until early 1960's. According to the said report, it was caused by the characteristic typhoon, although it occurred in the thunderstorm season of April to May. On 4 May 1999, the extraordinary rainstorm took place over the upper catchment after the consecutive 10 fair days. The daily rainfalls at Da Lat, Arbre-Broye, Honba and Diom (near Dran) amounted to 307 mm, 533 mm, 377 mm and 650 mm, respectively, so that the average rainfall of the Dran dam catchment was estimated to amount to 400 mm to 450 mm. It was reported that about 150 persons and 100 houses were lost due to the 1932 flood. Since the water level records of the 1932 flood were not available, the past study estimated the magnitude of the flood at 2,000 to 2,500 m^3/sec by means of the Rational formula applying the average basin rainfall and runoff coefficient of 0.5 to 0.65. However, it is uncertain if the estimated peak discharge is sufficiently accurate.

The 1952 flood with a maximum peak discharge of 1,500 m^3/sec was caused by the tropical influence of typhoon. The flood hydrograph observed at the Dran streamflow gauging station showed that the discharge increased from 300 m^3/sec to 1,500 m^3/sec within several hours. Thus, it is assessed that the large-scale floods in upper reach of the Dong Nai River occur under the strong influence of typhoon.

(2) Flood Records at Dai Ninh SGS (CA=1,933 km^2 including 775 km^2 at Dran dam site)

Table C4.1 shows the annual maximum peak discharges observed at existing Dai Ninh streamflow gauging station between 1981 and 1995, which were abstracted from the Basic Design Report on Dai Ninh Hydropower Project, prepared in July 1997. The whole water level records at Dai Ninh SGS were observed after completion of the upstream Dran dam. However, the peak-cut effect of existing Dran reservoir on floods at Dai Ninh is considered insignificant in consideration of its comparatively small reservoir area of 9.7 km^2 at FSL. The largest instantaneous peak discharge of 925 m^3/sec took place between October 9 and 10, 1993. It has to be noted that the magnitude of 1993 flood at the Dai Ninh SGS is smaller than the 1952 flood at the upstream Dran SGS mentioned above, the second largest flood thereat. As seen from Table C4.1, the annual maximum floods mostly occurred in the changeable season of September to October presumably under the influence of typhoon.

(3) Flood Records at Ta Lai SGS (CA=9,625 km^2 including 775 km^2 at Dran dam site)

Flood hydrographs at Ta Lai SGS during the wet season are shown together with their corresponding rainstorm records in Figure C4.1, based on existing mean daily discharge records at Ta Lai SGS. Moreover the annual maximum mean daily discharges at Ta Lai SGS are tabulated in Table C4.2. There is a tendency that annual maximum peak discharge at Ta Lai SGS so often takes place in August categorized into the summer season. This implies that the long-lasting rain in August which take place in the middle reach of the Dong Nai River has a dominant influence on occurrence of large-scale flood at Ta Lai SGS. At Ta Lai SGS, the largest peak discharge was observed at 3,260 m^3/sec on 22 August 1987.

From the above flood records in middle and upper reaches of the Dong Nai River, it is considered that the large scale floods at the Dong Nai No.3 dam site with a catchment area of 4,361 km^2 would be caused under influence of both typhoon and long-lasting rain.

C4.2 Frequency Analysis for Recorded Annual Maximum Peak Discharges

To examine the magnitude of flood in the middle and upper reaches of the Dong Nai River, the flood frequency analysis was made for annual maximum peak discharges observed at existing Dai Ninh and Ta Lai SGSs, which are shown in Tables C4.1 and Table C4.2, respectively. The flood frequency analysis was carried out by using the following three (3) distributions:

i) Iwai,
ii) Log Pearson Type III, and
iii) Gumbel

Out of the above distributions, the Iwai's method developed by the application of the log normal distribution is frequently used in Japan for the frequency analysis. The results of the flood frequency analysis are shown in Table C4.3. The Table reveals that the Gumbel's distribution gives the highest probable values of 20-year return period at both of these two SGS. The estimated 20-year probable floods and recorded maximum floods at these SGSs were compared and then the largest flood was transposed to the Dong Nai No.3 dam site with a catchment area of 4,361 km^2 by using the following Creager's equation:

$$Q_p = 46 \times C \times A^{\alpha}$$

$$\alpha = 0.894 \times A^{-0.048} - 1$$

where, C :Creager's coefficient (Creager's C value)
A :Catchment area in $mile^2$
Q_p :Specific discharge in $feet^3/sec/mile^2$

It is accepted that the above Creager's C values of the design floods for the different river basins become almost equal regardless of their catchment areas, provided that the basin characteristics affecting the flood occurrence that include the rainfall amount and intensity, topography, geology, vegetation, etc. are quite similar one another. The Creager's C values for 20-year probable floods and recorded maximum floods at Dai Ninh and Ta Lai SGSs were calculated by the Creager's formula as summarized below:

Flood	Dai Ninh SGS (CA=1,933 km²*)		Ta Lai SGS (CA=9,625 km²*)	
	Discharge (m^3/sec)	Creager's C-Value	Discharge (m^3/sec)	Creager's C-Value
- Recorded Maximum Flood	925	9.6	3,260	18.2
- 20-year Probable Flood	1,157	12.0	2,680	14.5

Note : * ; include a catchment area of 775 km^2 at existing Dran dam.

It is found through the above examination that the largest Creager's C value come to 18.2 among the 20-year probable floods and recorded maximum floods in the middle reaches. The largest Creager's C value is equivalent to 2,482 m^3/sec at the Dong Nai No.3 dam.

C4.3 Rainfall Analysis

C4.3.1 Probable Basin Average Rainfall

To estimate the probable rainfalls of various return periods at the proposed Dong Nai No.3 and No.4 dam sites, the annual maximum daily basin average rainfall was estimated by applying the Thiessen's Polygon shown in Figure C4.4. The estimated annual maximum daily basin average rainfalls are listed in Table C4.4. Out of the 45 samples of annual maximum basin average daily rainfalls shown in Table C4.4, the value of the year 1952 is outstandingly high as compared with those of other years, showing that the heavy rainfall (375.0 mm/day at Da Lat, 254.0 mm/day at Bao Loc and 184.7 mm/day at Lien Khuong) occurred over the entire catchment on the date.

The frequency analysis for the daily basin average rainfalls was carried out by using the three (3) distributions mentioned in the foregoing Subsection C4.2. The results of the frequency analysis are summarized below:

Return Period	Probable Daily Rainfall (mm)			Maximum Value
	Iwai	Log Pearson Type III	Gumbel	
5-year	81	76	93	93
20-year	107	120	136	136
50-year	123	161	163	163
100-year	136	199	183	199
200-year	148	245	204	245
1,000-year	177	395	251	395

The above Table shows that the probable daily basin average rainfall estimated by Log Pearson Type III gives the largest values for return periods of more than 100-year, while that the largest ones for return periods of less than 100-year are derived by the Gumbel distribution. This indicates that the samples applied to the frequency analysis has a considerable large skew attributable to the largest value of 1952. Taking into account the safer side design of the dam/spillway and its appurtenant structures, the maximum value among those estimated by the three (3) distributions was adopted for each of the different return periods.

C4.3.2 Probable Maximum Precipitation (PMP)

For the time being, the basic data such as dew point, humidity, etc. which are required to estimate a PMP of the Project catchment by means of the meteorological approach in consideration of the upper physical limits of moisture source are not available. Accordingly, the PMP value was estimated by means of the following two different methods:

i) Statistical method utilizing the Herschield's empirical formula
ii) Method generalized by the World Meteorological Organization (WMO)

(1) Statistical method utilizing the Herschield's empirical formula

An attempt was made to estimate the PMP by using the following Herschield's empirical formula:

$$X_{max} = \mu + k \cdot \sigma$$

Where, Xmax is the extreme value of 24-hour rainfall and k value is empirically derived from the records in the United States, and μ and σ are mean and standard deviation, respectively.

To determine the PMP for the Project catchment, the two (2) rainfall stations, Da Lat and Lien Khuong, were selected to estimate the extreme 24-hour point rainfall. The maximum daily rainfall records at these two stations are tabulated in Table C4.5. Consequently, the extreme 24-hour point rainfall at Da Lat and Lien Khuong were estimated to be 554 mm and 481 mm, respectively.

In order to convert the point rainfall into the basin average rainfall, the relation between the point and area rainfall depths was examined regarding large rainstorms which occurred in and around the Project catchment. As shown in Table C4.6, the reduction factor which means a ratio of the basin average rainfall for a catchment area of 4,361 km2 at the Dong Nai No.3 dam site to point rainfall is derived to in a wide range of between 0.292 to 1.047. Adopting a higher value of 0.90 as the reduction factor for the Project catchment, the probable maximum daily basin average rainfall was derived at 499 mm/day.

(2) Method generalized by the World Meteorological Organization (WMO)

The PMP value was estimated in accordance with the procedures suggested by WMO in the publication titled "Manual for Estimation of Probable Maximum Precipitation". Figure C4.3 shows the depth-area-duration curve of 24-hour probable maximum precipitation on Vietnam, which is presented in the publication. Further, it is suggested to apply the 24-hour value to the planned areas after making the following adjustments:

i) Adjustments for distance inland
ii) Adjustment by latitude
iii) Barrier adjustment
iv) Adjustment for basin topography

The 24-hour probable maximum precipitation for a gross catchment area of the Dong Nai No.3 was derived to be 754 mm/day from the curve sown in Figure C4.3. To transpose it to the Dong Nai No.3 catchment, the said four adjustment factors were estimated to be 1.00, 0.93, 0.98 and 1.00, respectively, so that the combined adjustment factor was derived to be 687 mm/day as shown in Figure C4.3. As a result, the PMP for a gross catchment area of the Dong Nai No.3 was estimated at 687 mm/day.

(3) Adopted PMP

There is a large difference between the PMP values estimated by the above two methods (1) and (2). As long as the isohyetal map of the PMP for the whole Mekong River basin which was prepare by the WMO, the PMPM values in a watershed of the Mekon River basin located near to the Dong River basin range approximately between 600 and 700 mm. Therefore, it is determined to adopt 687 mm/day estimated by the method (2) above as the PMP value for the Dong Nai No.3 scheme.

C4.3.3 Design Rainfall

The rainstorm records at rainfall station in the middle reach of the Dong Nai River, as shown in Figure C2.2, are available for 48 years from 1950 to 1997 except some years that have no records. Out of those rainstorm records, that in 1952 was selected to determine the rainfall patterns of the probable rainfalls estimated above, since it is ranked at the largest basin average daily rainfall in the middle reach of the Dong Nai River since 1950's. In the 1952 rainstorm, the heavy rainfall occurred on 20 October 1952, while rainfall amounts on dates after and before October 20 were very less. The duration of the design rainfalls is determined to be sixteen (16) days based on the 1952 rainstorm. The design rainfalls for probable rainfalls of various return periods were constructed by multiplying a ratio of the probable daily rainfall to the basin average rainfall on 20 October 1952.

C4.3.4 Runoff Coefficient

The runoff coefficient of large-scale floods were examined based the major floods at Ta Lai SGS and the corresponding rainfall records, which are illustrated in Figure C4.4. Table C4.7 shows the runoff coefficients for their major floods observed at Ta Lai SGS. As long as the flood records at Ta Lai are concerned, the runoff coefficients are derived to be as very small as 0.46 to 0.64 as shown in Table C4.7.

In this Study, therefore, 0.7 is taken as the runoff coefficient for the project catchment for the following reasons:

(i) First of all, the runoff coefficients for major floods observed at Ta Lai SGS falls in the values of less than 0.7 as mentioned above.

(ii) In the detailed design for Ham Thuan HPP - Da Mi HPP, the flood analysis was carried out by means of five different methods. Out of them, a runoff coefficient of 0.7 was applied to estimate the probable floods of 10-year to 2,000-year return periods in estimating the probable floods using the following rational formula:

$$Qmax = C \times Ri \times A$$

Where, Qp: Flood peak discharge (m^3/sec)
C: Runoff coefficient
Ri: Rainfall intensity during flood concentration time (mm/hour)
A Catchment area (km^2)

In the flood analysis on Ham Thuan HPP - Da Mi HPP, the rational formula with a constant runoff coefficient of 0.7 resulted in reasonable estimate of the probable floods for the planned two dams. Since the catchment of the Ham Thuan HPP - Da Mi HPP is located adjacent to the catchment of the Dong Nai No.3 and No.4 CHPP, it is judged appropriate to adopt a runoff coefficient of 0.7 in this flood analysis.

(iii) In Japan, a runoff coefficient of 0.7 is adopted to estimate the probable floods of any return periods for the mountainous areas where no flood records for determining the runoff coefficient are available. Also for the river basins in the South-East Asian countries including Indonesia that exhibit similar runoff characteristics to the Dong Nai River basin, a runoff coefficient of 0.7 has been usually adopted to estimate the probable floods.

C4.4 Flood Hydrograph Analysis by Unitgraph Method on Dong Nai No.3 Scheme

C4.4.1 Derivation of Unitgraph

Since the hourly rainfall records in the project catchment were not sufficiently available, the unitgraph at the Dong Nai No.3 dam was derived based on flood hydrograph observed at Ta Lai SGS by applying the dimensionless unitgraph method.

The flood hydrograph at Ta Lai SGS on 22 August 1987 has the largest peak discharge among floods observed thereat since 1979. Besides, it is considered that the 1987 flood was caused by the comparatively short duration of rainfall, while most of the observed hydrographs at Ta Lai SGS seems to result from long-term and complicated rainfall over the catchment. Taking into the suitability of the observed flood hydrographs at Ta Lai SGS, the 1987 flood was selected to derive an unitgraph at the Dong Nai No.3 dam site.

The unitgraph was derived through the dimensionless flood hydrograph through defining the flood concentration time and unit rainfall. Since the flood records at the Dong Nai No.3 and No.4 dam sites are not sufficiently available, the flood concentration time at the Dong Nai No.3 dam site was estimated by the Kraven's formula and Rziha's formula that are so often used to estimate it in the absence of the hydro-meteorological records. The Kraven's formula defines that a flood velocity is 7.56 km/hour for the average river bed slope of less than 1/200 that conforms to the Project catchemnt. With the flood velocity, the flood concentration time is derived at about 28 hours (=212.3 km/7.56 km/hour).

The Rziha's formula is expressed as follows:

$$T = L / (72 \cdot (H/L)^{0.6})$$

Where, T : flood concentration time in hour
L : river course length in km
H : difference of elevation between the proposed Dong Nai 3 dam site and origin of the river in km

The flood concentration time at the Dong Nai No.3 dam site was calculated at about 73 hours. On the other hand, PECC2 estimated it at about 30 hours in the pre-feasibility study report using the Snyder's formula. Finally, the concentration time was determined to be 36 hours based on those calculation results.

Using the dimensionless hydrograph and flood concentration time, an unitgraph at the Dong Nai No.3 dam site was constructed for an unit rainfall of 1 mm as shown in Figure C4.5. The unit time is fixed at six (6) hours.

C4.4.2 Hydrographs of Probable Floods

The flood hydrographs of various return periods at the Dong Nai No.3 dam site were worked out by applying the design rainfalls to an unitgraph derived in the foregoing Paragraph (1). In the estimate, the design rainfalls on a daily data basis were converted into six (6) hour rainfall by using the following Mononobe's formula:

$$R_t = R_{24} \cdot (T/24)^{1/3}$$

Where, R_t : Rainfall occurring during T hours (mm)
R_{24} :Daily rainfall (mm)
T: Time (hours)

The four 6-hour rainfalls in each day which were calculated by the above formula were arranged so that the largest 6-hour rainfall takes place in the second 6-hour duration. Consequently, the probable floods at the Dong Nai No.3 dam site were derived as shown in Figure C4.6 and summarized below:

Probable Floods and PMF at the Dong Nai No.3 Dam site

Return Period	Flood Peak Discharge (m^3/sec)
5-year	1,813
20-year	2,585
50-year	3,070
100-year	3,717
200-year	4,543
1,000-year	7,237
PMF	13,938

C4.5 Flood Hydrograph Analysis by Storage Function Model Method on Dong Nai No.3 Scheme

C4.5.1 Concept of Storage Function Model

To check the consistency of the probable floods estimated by the unitgraph method in the previous Section C4.4, the flood hydrographs were constructed with the storage function model. The storage function model is expressed by the following equations:

$$S = k \cdot Q^P$$

$$dS/dt = (1/3.6) \cdot f \cdot r \cdot A - Q$$

Where, S : Basin storage (m^3)
Q : Runoff from subbasin (m^3/sec)
K, P : Constant
T : Time (sec)
F : Runoff coefficient
r : Basin average rainfall (mm/hour)
A : Catchment area

C4.5.2 Estimate of Probable Floods by Storage Function Model

The basin model was set up by dividing the catchemnt basin of the Ta Lai SGS into five (5) subbasins as shown in Table C4.8, for each of which the constant values of K and P were attempted to be determined so that the calculated flood hydrograph almost coincide with the observed one. The initial values of these constants were given by the following empirical formula and then they were both increased at the same rate until the best coincidence of the calculated and observed flood hydrographs is obtained:

$$K = 118.84 \cdot I^{0.3}$$

$$P = 0.175 \cdot I^{-0.235}$$

Where, I : average river bed slope

The best coincidence was obtained through the aforesaid trial and error calculation when the constants of K and P are given as shown in Table C4.8, and the calculated flood hydrographs with those constant values are illustrated in Figure C4.7 together with the observed ones.

In succession, the flood hydrographs of various return periods at the Dong Nai No.3 dam site were constructed by applying to the storage function model the same probable rainfall data with those used in the above unitgraph method. The results of the flood analysis by storage function model are graphically shown in Figure C4.6. The PMF estimated by the storage function model becomes almost same with that by the unitgraph method, while the probable floods of the smaller return periods by the former method gives the smaller magnitudes than those by the latter method.

Taking into account the uncertainty associated with the flood analysis, it is determined that the probable floods estimated by the unitgraph method at this feasibility study stage.

C4.6 Crosscheck of Estimated Design Flood for Spillway and Diversion Facility of Dong Nai No.3 Scheme

In the present feasibility study, the design flood for dam and spillway of the Dong Nai No.3 and No.4 is adopted to be PMF. Besides, these dams need to keep a sufficient freeboard against the 10,000-year probable flood. While, a 20-year probable flood is adopted as the design flood for diversion facilities.

In the present feasibility-grade design, the design floods for spillway and diversion facilities are determined through adopting the probable floods estimated by the flood analysis using the unitgraph method. The design floods and PMF estimated in the present feasibility study are listed below together with their Creager's C value mentioned in the foregoing Section C4.2:

Structure	Probable Flood Adopted for Design	Peak Discharge (m^3/sec)	Creager's C Value
• Diversion facility	20-year probable flood (design flood)	2,585	19.0
• Spillway	1,000-year probable flood (design flood)	7,237	53.2
	PMF	12,480	91.4

For the purpose of cross-checking of the estimated design floods, they are compared with design flood and PMF or 10,000-year probable flood adopted for other large dams in Vietnam in terms of the Creager's C value. Figure C4.8 shows the design floods and PMF adopted in large dams in Vietnam. From the Figure, it is assessed that the design flood and PMF are in an acceptable range in terms of the Creager's C value. It is generally accepted that the design flood corresponding to a Creager's C value of 100 gives an upper limit in Southeast Asia region including Vietnam. Therefore, the estimated PMF is applicable as the upper limit to verify the safety of the dam.

C4.7 Estimate of Probable Floods and PMF for Residual Catchment Area Intervening Dong Nai No.3 and No.4 Dam Sites

Because of the small regulating capacity of the Dong Nai No.4 reservoir, it is not economically viable to construct the Dong Nai No.4 scheme independently without provision of the Dong Nai No.3 scheme. In implementing the Dong Nai No.3 and No.4 Combined Hydropower Project, therefore, the Dong Nai No.4 scheme needs to be completed at the same time with the Dong Nai No3 scheme or after the completion of the Dong Nai No.3 scheme. Accordingly, it is estimated that the flood at the Dong Nai No.4 is a sum of the outflow released from spillway of the Dong Nai No.3 dam and flood taking place in the residual catchment between the Dong Nai No.3 and No.4 dam sites.

To estimate the probable floods and PMF for the residual catchment, the Nakayasu's unit hydrograph method was applied in consideration of the smaller catchment area of 149 km^2. It is generally accepted that the synthetic unitgraph method developed in Japan is suitable for ths catchemnt consisting of mountainous area with the comparatively smaller catchment of less than 1,000 km^2, but not necessarily limited thereto, giving the conservative peak discharges.

The concept of Nakayasu's unit hydrograph is expressed below:

(a) Flood peak

$Qp=1/3.6 \times AR0/(0.3 + T3)$

(b) Rising curve (0<t<Tp)

$Q/Qp=(T/Tp)$

(c) Recession curve

$1.0 < Q/Qp < 0.3$

$Q/Qp = 0.3 \times (T-Tp)/T3$

$0.3 < Q/Qp < 0.09$

$Q/Qp = 0.3^{(t-Tp+0.5 \times T3)/(1.5 \times T3)}$

$0.09 < Q/Qp^{(t-Tp+1.5 \times T3)/(2.0 \times T3)}$

Where,
- Q: Ordinate of unit hydrograph at time t (m^3/sec)
- Qp: Peak discharge of unit hydrograph (m^3/sec)
- A: Catchment area (km^2)
- R0: Unit rainfall in unit time (mm)
- Tp: Rising time (hour)
- T3: recession time from peak to (0.3 x Qp) (hour)

In order to determine values of Tp and T3, the following equations were empirically introduced by Dr. Nakayasu:

$Tp=Tg + 0.7 \times Tr$

$T3=0.47 \times (AL)^{0.5}$ (L<15 km)

$Tg=0.4 + 0.058 \times L$ (L>15 km)

$Tg=0.21 \times L^{0.7}$

Where, TG: Lag time of discharge from the catchment (hour)

Tr: Unit time of rainfall (hour)

Taking a nit time at one hour, the unit hydrograph for the residual catchment is derived as shown in Figure C5.9. Consequently, the probable floods and PMF for the intervening catchment were estimated by applying to the Nakayasu's unit hydrograph the probable rainfalls and PMP set up for the project catchemnt in the foregoing Section C4 as below:

Probable floods and PMF for Intervening Catchemnt of the Dong Nai No.4 dam (C.A.=149 km^2)

Return Period	Flood Peak Discharge (m^3/sec)
20-year	330
30-year	358
200-year	588
1,000-year	1,632
PMF	1,823

Figure C4.10 shows the inflow flood hydrograph of PMF at the Dong Nai No.4 dam site which is a combined hydrograph of outflow from spillway of Dong Nai No.3 dam and PMF for the intervening catchment at the event of occurrence of PMP in entire catchment. Owing to the much shorter time of hydrograph for the intervening catchemnt, as seen from the Figure, the flood peak discharge at the Dong Nai No.4 dam site is dominated by the outflow from the Dong Nai No.3 spillway.

C5 SEDIMENTATION STUDY

C5.1 General

During the field reconnaissance, it was found that the mountainous area in catchment of existing Dran dam was remarkably deforested, probably due to shifting cultivation activated by the mountain people, although it was blessed with dense forest till the Da Nhim HPP was constructed. Several years ago, there was a fear that an intake structure of the Da Nhim HPP had been clogged with augmented sediment inflow into existing Dran reservoir. From such a aspect, one of the main objectives of the study on Rehabilitation on Da Nhim Power System that was carried out under JICA in 1994 was to clarify an extent of the sediment deposition in Dran reservoir. The reservoir cross survey conducted in the past study clarified that both of dead and effective storage capacities had been lost to a considerable extent due to the sediment deposition therein. On the basis of the reservoir cross section survey, the annual sediment inflow rate was roughly estimated at 700 m^3/year, although the successive follow-up investigations are required to finally determine the rates. From the past study results, the sediment transport in the upper reach is foreseen to increase because of the aggravated condition of the basin resulting from the deforestation.

Also at the vicinity of the Dong Nai No.3 and No.4 dam sites, the shifting cultivation is regularly and habitually conducted by the local inhabitants. It has to be noted that in general the sediment transport rates is to increase with development of lands in the catchment. Therefore, the sedimentation study needs to be carried out taking into consideration increase of erosion rate attributed to expansion of land uses in future, which will be accelerated with increase of population in the middle and upper reaches of the Dong Nai River.

Since the Dong Nai No.3 and No.4 combined hydropower project is planned to be developed as a reservoir type project, the sedimentation study aims ultimately at determining the sediment volume transported into the planned reservoirs and it's deposition rate therein. The sedimentation study was made primarily based on the results of the suspended load measurements on the Dong Nai mainstream. The water sampling for the suspended load analysis was carried out at Ta Lai SGS between 1985 and 1990. Those suspended load data at Ta Lai SGS that were provided by EVN to the Study Team during the field investigation were used to analyze the sediment yield at the proposed Dong Nai No.3 and No.4 dam sites.

C5.2 Long-Term Suspended Load Yield

The sediment load is broadly divided into suspended and bed loads, out of which the bed load moves downstream along the river bed. Usually, the suspended load contained in streamflow is quantified through the suspended load measurements, while it is not possible to accurately measure the bed load in natural river. In the usual estimate, the rate of bed load transport is assumed to be equivalent to 10 to 20% of that of the suspended load. Aiming at making it's estimate conservative, 20% is adopted as the ratio for the Dong Nai No.3 and No.4 combined hydropower project.

Tables C5.1 shows the results of laboratory tests for the suspended load analysis which were conducted regarding water samples collected at Ta Lai SGS. On the basis of the results of the suspended load measurement, a rating curve of the suspended load was established based on all the measurement as shown in Figure C5.1 and below:

$$Q_S = 0.0038 \bullet Q^{2.1}$$

where, Q_S : Daily suspended load transport in m^3/day

Q : Mean daily discharge in m^3/sec

On the other hand, the values of suspended load yield shown in Figure C5.1 distribute comparatively in a wide range against a discharge. In general, the suspended load exponentially increase with discharge so that the estimate of the suspended sediment transport largely depends on the samples at the flood time. The suspended load measurement in a high flow deems somewhat lacking for working out the fair rating curve. Taking into such uncertainties associated in the estimate, the following rating curve was set up as a conservative one by applying the samples giving the higher suspended yield for each of the two stream gauging stations:

$$Q_S = 0.0175 \bullet Q^{2.0}$$

The conservative suspended load rating curve at Ta Lai SGS is also shown in Figure C5.1. For the purpose of conservative estimate, the latter formula was adopted. The long-term suspended load transports at Ta Lai SGS were simulated by applying the aforesaid rating formulae to the mean daily discharges. Consequently, the mean annual suspended load yield was estimated at 1.687 million m^3 as shown in Table C5.2, which corresponds to a specific sediment transport of 191 m^3/km^2/year for the the Project catchment. The specific sediment transport is equivalent to a denudation rate of about 0.2 mm/year.

Figure C5.2 shows the denudation rates estimated and/or adopted for large dams in Vietnam. In general, there is a tendency that the denudation rate becomes smaller with catchment area, in case the conditions of basins which are concerned with sediment yield are almost common. Figure C5.2 doesn't exhibit such a tendency, but shows that a denudation rate of about 0.2 mm is adopted for the dam planning in Vietnam as a whole, which is quite close to the value estimated above.

C5.3 Sediment Deposition in the Planned Reservoirs

The design code in Japan specifies that the reservoir life is taken at 100 years, unless the facilities for flushing sediments deposited in the reservoir are provided in the dam body or its appurtenant structures. In the present study, the sediment deposition volumes in the planned reservoirs were estimated adopting the reservoir life of 100 years in consideration of sediment traps by upstream reservoirs.

To estimate the net sediment yields at the planned dam sites, the sediment transport rates for the upstream reservoirs were determined based on the Brunei's curve shown in Figure C5.3. The trap efficiencies of the Dong Nai no.3 and No.4 reservoirs are derived to be 0.97 and 0.80, respectively, from the Brunei's curve. The sediment deposition volumes in the Dong Nai No.3 and No.4 reservoirs were calculated as follows:

Estimated Sediment Deposition for the Reservoir Life

No.	Name of dam	Sediment inflow (10^6 m^3)	Trap efficiency (%)	Sediment Deposition Annual (10^6 m^3/year)	For reservoir life of 100 years (10^6 m^3)
1.	Dong Nai No.3 reservoir (Sediment inflow from the catchment area of 4,341 km^2)	0.087	97	0.85	84.6
2.	Dong Nai No.4 reservoir				
	Sediment inflow from intervening catchment (149 km^2)	(0.03)			
	· Outflow from Dong Nai No.3 reservoir	(0.03)			
	Total of i) and ii)	0.06	82	0.05	5.1

The storage capacity curves of the Dong Nai No.3 and No.4 reservoirs are shown in Figure C5.3. The present feasibility study contemplates that the Dong Nai No 3 and No.4 dams have the sediment storage capacity of 298.2 and 63.1 million m^3, respectively. Accordingly, both reservoirs have enough capacity to store sediment inflow for 100 years.

Furthermore, the above rates of sediment inflow to the Dong Nai No.3 and No.4 reservoirs are estimated on the assumption that sediment inflow from catchment above Dai Nih dam site wholly reaches the Dong Nai No.3 dam site. In actuality, however, a considerable quantity of the sediment yields is expected at Dran dam and Dai Ninh dam, since these hydropower projects consisting of water transbasin projects convey most of inflow discharges to other river basins with exception of large-scale flood. Therefore, the contemplated Dong Nai No.3 and No.4 reservoirs have a sufficient allowance with respect to their sedimentation problems.

C6 HYDROLOGICAL EFFECTS ON DOWNSTREAM REACH

C6.1 Envisaged Adverse Effects on Downstream reach Due to Construction of the Project

From the hydrological and environmental aspects, it was conceived that the Dong Nai No.3 and No.4 Combined hydropower project might have adverse effects on the downstream reach:

i) Adverse effect on ecosystem of the Cat Tien National Park, which may be caused by reduction of the wets season flow, as well as the downstream reach due to the daily peak power operation of the Dong Nai No.4 Power Plants during the wet season.

ii) Adverse effect on irrigation and potable water use in the downstream reach, which might be caused by daily peak power operation during the dry season.

Figure C6.1 shows the monthly inflow into the Dong Nai No.3 reservoir and monthly outflow from the Dong Nai No.4. The annual reduction rate which represents a ratio of annual maximum outflow from the Dong Nai No.4 dam/power house to annual maximum monthly inflow to Dong Nai No.3 dam is shown in Table C6.1. As seen in those Figure and Table, it is foreseen that the annual monthly maximum outflow of the Dong Nai No.4 reservoir would be reduced, especially in the draught years to a considerable extent, when flowing from the Don Nai No.4 power station, because of the regulation effects of the Dong Nai No.3 and No.4 reservoirs.

Considering the natural inflow from the tributaries in a river section between the Dong Nai No.4 power station and Cat tien National Park, on the other hand, it appears that the reduction of the wet season flow would not become a significant environmental issue to be caused by the Project unless the Dong Nai No.3 reservoir with excessively large storage capacity is built. This is seen from Figure C6.2 which shows the monthly hydrographs of the Dong Nai River at Cat Tien National Park, revealing that the flood peak reduction is not so significant. Table C6.2 shows annual ratios of maximum monthly discharge of the Dong Nai at the Cat Tien National park under the condition with the Project to that under the without condition.

C6.2 Conceivable Countermeasures

As mentioned above, the peak power operation of the Dong Nai No.4 power operation might lead the occurrence of the adverse effects on ecosystem of the downstream reach. In the downstream reach of the Dong Nai No.4 power station to existing Tri An dam, river water of the Dong Nai is hardly utilized for the purpose of irrigation and municipal water supply at a significant level according to the field reconnaissance conducted during the field investigation. Therefore, it is judged that any large-scale countermeasures would not be need to be taken to cope with the environmental change in the downstream reach. Nevertheless, the present feasibility study recommends to contemplate the Dong Nai No.4 power plants to be operated keeping a minimum plant factor of 33.3 % with three units. In this way, it can be guaranteed that the tailwater from the Dong Nai No.4 power station is released for 16 hours a day even in the driest period. Consequently, it is anticipated that the adverse effects on the downstream reach would be minimized.

C6.3 Hydrological Phenomenon in Cat Tien National Park

In the Bau Sau wetland of Cat Tien National Park (CTNP), daily water level observation was continued since July 1999 at three (3) water level gauging stations (WLGS) where staff gauges were installed during the field investigation. Location of these three WLGS is shown in Figure C6.3. Besides, the leveling survey was conducted during the 3rd field investigation by intrusting it to the PECC2 in order to relate the elevations of stage heights of staff gauges at those WLGS.

Figure C6.4 shows the mean daily water levels at those WLGS between June and November 1999. As seen in the Figure, the water level in Bau Sau wetland becomes lower than that at the Junction WLGS located near the confluence of the Dong Nai mainstream and Dak Lua stream five times during the observation period. However, it appears that the rapid drawdown of water level of the Bau Sau wetland that was observed in early July 1999 is doubtful unless the inland water of Bau Sau wetland was drained to the Dong Nai mainstream through any artificial drainage structures. From the water level records, it was assessed that the reverse flow in the Dak Lua stream (water of the Dak Lua stream flows in a direction from Bau Sau wetland to the Dong Nai mainstream through the Dak Lua stream for most periods of the year) in ealy August 1999. After August 28, high stage heights of more than 134 m at the Bau Sau WLGS lasted between July 31 and August 10, 1999.

With regard to the large scale flood which hit the Bau Sau wetland in July to August 1999, it was reported by local people in the field reconnaissance conducted in September 1999 that the plain land spreading along the Dak Lua stream was completely inundated to roof of existing houses therein. It is roughly estimated that a flood equivalent to 20-year return period would occur both in the Dong Nai mainstream and the Bau Sau wetland. In the event of large-scale flooding in the Bau Sau wetland, the water level of the Dong Nai mainstream also became very high so that water levels exceeded the highest stage heights of staff gauges at the Dal Lua and Junction water level gauging stations. Consequently, the water level observation could be continued only at the Bau Sau water level gauging station for the period from the end of July to the middle of July 1999.

Judging from the hydrological phenomenon observed during the field investigation, the reverse flow in the Dak Lua stream tends to take place when a stage height at the Junction WLGS exceeds 131 m in a rising portion of flood hydrograph on the Dong Nai mainstream. Figure C6.3 also depicts mean daily water levels at the downstream Ta Lai SGS for the corresponding period. As a matter course, the flood hydrograph at Ta Lai SGS exhibits a synchronized pattern with that at SGS at the junction of Dak Lua stream and Dong Nai mainstream. On the basis of the water level records observed at both SGSs, it was found out that the stage height at SGS at the Junction corresponds to that of about 111.75 m at Ta Lai SGS.

The annual frequency of occurrence of the reverse flow in the Dal Lua stream was estimated based on the water level records at Ta Lai SGS between 1979 and 1995 by counting the number of days when the water level exceeds 117.5m. As a result of the examination, the yearly average number of days of occurrence of the reverse flow was estimated at about at 10 days as shown in Table C6.3. The result of the examination on occurrence of the reverse flow was endorsed by the information obtained from the local inhabitants. On the basis of the information collected during the field reconnaissance as well as the results of the examination mentioned above, besides, It is assessed that the outstanding reverse flow would have taken place so far when a large-scale flood occurred over the whole Dong Nai River basin.

Appendix C

Tables

Table C2.1 Daily Rainfall Observed at Dak Plao Rainfall Sation, Newly Installed during the Field Investigation

Location : Dak Plao
Year : 1999

(Unit : mm/day)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	---	---	---	---	---	---	6.5	3.0	106	10.5	4.5	2.0
2	---	---	---	---	---	---	1.5	6.0	25.5	1.5	5.5	0.5
3	---	---	---	---	---	---	4.0	50.5		0.5		
4	---	---	---	---	---	---		4.0	0.5	1.5	10.0	0.5
5	---	---	---	---	---	---		13.5	10.5	19.0	9.5	10.0
6	---	---	---	---	---	---		12.5	7.5		0.5	
7	---	---	---	---	---	---	9.0	12.5	1.5	36.0	20.5	
8	---	---	---	---	---	---		8.0	0.5	1.5	10.0	
9	---	---	---	---	---	---	5.5	0.5	28.0	0.5	3.0	
10	---	---	---	---	---	---	5.5	1.5	4.5	62.5	3.0	4.0
11	---	---	---	---	---	---	13.5	5.0	1.0	20.5		1.0
12	---	---	---	---	---	---	27.0	2.0	7.0	14.0		0.5
13	---	---	---	---	---	---			2.5	8.5		
14	---	---	---	---	---	---	4.5		4.5	15.0	2.0	
15	---	---	---	---	---	---	1.5	37.0	5.5	11.0		
16	---	---	---	---	---	5.5					10.0	
17	---	---	---	---	---	3.5	1.5	1.5		10.0		44.5
18	---	---	---	---	---	4.0	1.0	4.5		10.0		---
19	---	---	---	---	---	9.0	-	7.0		5.0		---
20	---	---	---	---	---		1.5	32.5			1.5	---
21	---	---	---	---	---		-	0.5	0.5	2.5	13.0	---
22	---	---	---	---	---		8.5	2.5	4.0	5.5	-	---
23	---	---	---	---	---		7.0	2.5	6.5	26.0	14.0	---
24	---	---	---	---	---		55.5	9.5	16.5	3.5	15.5	---
25	---	---	---	---	---	1.5	41.5	6.5	0.5	0.5	12.5	---
26	---	---	---	---	---	11.5	2.0	1.5	9.5	9.0		---
27	---	---	---	---	---	7.5	59.0	0.5	0.5	2.0		---
28	---	---	---	---	---	30.5	21.5		16.0	1.5		---
29	---	---	---	---	---	75.0	62.5	18.0	8.5	10.5		---
30	---	---	---	---	---	1.0	22.0		0.5	23.0		---
31	---	---	---	---	---		11.0	1.5		1.0		---
Total	---	---	---	---	---	149.0	373.0	244.5	268.0	312.5	135.0	---
Max.	---	---	---	---	---	75.0	62.5	50.5	106.0	62.5	20.5	---
Min.	---	---	---	---	---	1.0	1.0	0.5	0.5	0.5	0.5	---

Note : "---" means that no records are available.

Table C2.2 Mean Daily Stage Water Level Observed at New Straemflow Gauging Sation Installed near Dong Nai No.3 Dam Site

Location : Dong Nai No.3 Dam Site
C.A. : 2,441 km^2
Year : 1999

(Unit : m)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	---	---	---	---	---	---	497.2	497.2	497	496.5	496.8	496.3
2	---	---	---	---	---	---	496.8	497.1	497.3	496.5	496.6	496.4
3	---	---	---	---	---	---	496.6	497.1	497.4	496.4	496.7	498.0
4	---	---	---	---	---	---	496.6	497.6	497.4	496.4	496.8	497.1
5	---	---	---	---	---	---	496.5	497.5	497.3	496.4	497.1	496.9
6	---	---	---	---	---	---	496.6	497.4	497.1	496.5	498.2	496.8
7	---	---	---	---	---	---	496.7	497.3	497.0	496.8	497.4	496.7
8	---	---	---	---	---	---	496.6	497.2	496.9	497.0	496.9	496.7
9	---	---	---	---	---	---	496.3	497.1	496.8	497.0	496.8	496.4
10	---	---	---	---	---	---	496.4	496.9	496.7	496.9	496.7	496.5
11	---	---	---	---	---	---	496.3	496.8	496.8	496.8	496.8	496.4
12	---	---	---	---	---	---	496.4	496.7	496.9	496.7	496.7	496.8
13	---	---	---	---	---	---	496.7	496.7	496.9	496.6	496.8	496.6
14	---	---	---	---	---	---	496.5	496.6	496.8	496.6	496.9	496.6
15	---	---	---	---	---	---	496.4	496.5	496.7	496.6	496.7	496.6
16	---	---	---	---	---	496.9	496.2	496.5	496.6	497.0	496.6	496.6
17	---	---	---	---	---	496.8	496.1	496.6	496.9	496.9	496.6	496.4
18	---	---	---	---	---	496.7	496.2	496.9	496.7	496.8	496.6	496.5
19	---	---	---	---	---	496.5	496.2	496.9	496.4	497.2	496.6	496.4
20	---	---	---	---	---	496.6	496.3	497.0	496.4	497.5	496.4	496.2
21	---	---	---	---	---	496.6	496.2	497.3	496.4	496.8	496.3	496.1
22	---	---	---	---	---	496.4	496.4	497.2	496.3	496.7	496.6	496.2
23	---	---	---	---	---	496.3	496.3	497.2	496.3	496.7	496.9	496.1
24	---	---	---	---	---	496.2	496.3	497.5	496.4	497.6	496.5	496.1
25	---	---	---	---	---	496.3	497.1	497.1	496.5	498.4	496.3	496.0
26	---	---	---	---	---	496.4	497.4	497.0	496.6	497.6	496.3	496.0
27	---	---	---	---	---	496.8	497.1	496.9	496.6	497.2	496.3	496.0
28	---	---	---	---	---	496.8	497.3	496.8	496.7	497.0	496.2	496.0
29	---	---	---	---	---	496.7	497.3	496.7	496.6	496.9	496.5	495.9
30	---	---	---	---	---	497.3	497.3	497.0	---	497.0	496.2	496.0
31	---	---	---	---	---		497.3	496.9		496.9		495.9
Mean	---	---	---	---	---	496.6	480.6	481.0	480.2	480.9	496.7	480.4
Max	---	---	---	---	---	497.3	497.4	497.6	497.4	498.6	498.4	498.1
Min	---	---	---	---	---	496.2	496.1	496.5	496.3	496.4	496.2	495.9

Note : "---" means that no records are available.

Table C2.3 Results of Suspended Load Analysis for Water Samples Taken at New Streamflow Gauging Station near Dong Nai No.3 Dam Site

No.	Number of Sample	Date of Sampling	Analyses of Sample	Dry Weight of Suspended Load Contained (g/l)	Density of Suspended Load (g/cm³)	Particle Distribution Curve of Suspended Load : P (%) < 0.005
1	PS 662	8/18/99	10/4/99	0.23		
2	PS 663	8/18/99	10/4/99	0.14		
3	PS 664	8/18/99	10/4/99	0.10		
4	PS 665	8/18/99	10/4/99	0.10		
5	PS 666	8/18/99	10/4/99	0.16		
6	PS 667	8/18/99	10/4/99	0.18		
7	PS 668	8/21/99	10/5/99	0.40	2.69	100
8	PS 669	8/21/99	10/5/99	0.36	2.70	100
9	PS 670	8/21/99	10/5/99	0.39		
10	PS 671	8/21/99	10/5/99	0.38		
11	PS 672	8/21/99	10/5/99	0.39		
12	PS 673	8/21/99	10/5/99	0.36		
13	PS 674	8/25/99	10/6/99	0.26		
14	PS 675	8/25/99	10/6/99	0.27		
15	PS 676	8/25/99	10/6/99	0.31		
16	PS 677	8/25/99	10/6/99	0.27		
17	PS 678	8/25/99	10/6/99	0.28		
18	PS 679	8/25/99	10/6/99	0.29		
19	PS 680	8/27/99	10/7/99	0.16		
20	PS 681	8/27/99	10/7/99	0.17		
21	PS 682	8/27/99	10/7/99	0.19		
22	PS 683	8/27/99	10/7/99	0.17		
23	PS 684	8/27/99	10/7/99	0.18		
24	PS 685	8/27/99	10/7/99	0.17		
25	PS 686	8/31/99	10/8/99	0.33		
26	PS 687	8/31/99	10/8/99	0.34		
27	PS 688	8/31/99	10/8/99	0.29		
28	PS 689	8/31/99	10/8/99	0.36		
29	PS 690	8/31/99	10/8/99	0.30		
30	PS 691	8/31/99	10/8/99	0.34		

Table C2.4 Annual Rainfall in the Dong Nai River Basin

Unit = mm

Year	Da Lat	Dong Duong	Tan My	Lien Khuong	Dai Ninh	Di Linh	Bao Loc	Ta Pao	Da Te	Phuoc Long	Ta Lai
1950	-	-	-	1,813	-	-	2,456	-	-	-	-
1951	-	-	-	1,768	-	-	2,769	-	-	-	-
1952	3,923	-	-	1,782	-	-	3,072	-	-	-	-
1953	1,362	-	-	1,769	-	-	2,884	-	-	-	-
1954	2,130	-	-	1,730	-	-	2,318	-	-	-	-
1955	1,911	-	-	1,634	-	-	2,473	-	-	-	-
1956	1,962	-	-	1,433	-	-	2,599	-	-	-	-
1957	1,704	-	-	1,261	-	-	2,537	-	-	-	-
1958	1,459	-	-	991	-	-	2,350	-	-	-	-
1959	1,609	-	-	1,451	-	-	2,354	-	-	-	-
1960	1,951	-	-	1,833	-	-	2,577	-	-	-	-
1961	1,829	-	-	1,547	-	-	3,115	-	-	2,710	-
1962	2,142	-	-	1,645	-	-	2,299	-	-	2,821	-
1963	1,691	-	-	1,282	-	-	1,718	-	-	3,090	-
1964	2,108	-	-	1,967	-	-	2,466	-	-	2,761	-
1965	1,607	-	-	1,278	-	-	2,599	-	-	-	-
1966	-	-	-	1,857	-	-	2,590	-	-	-	-
1967	-	-	-	1,862	-	-	2,965	-	-	-	-
1968	1,678	-	-	1,401	-	1,745	2,657	-	-	-	-
1969	1,499	-	-	1,589	-	1,433	2,784	-	-	-	-
1970	2,120	-	-	1,813	-	1,885	2,986	-	-	-	-
1971	-	-	-	1,662	-	-	2,181	-	-	-	-
1972	1,648	-	-	1,643	-	-	3,347	-	-	-	-
1973	-	1,903	-	1,708	-	-	-	-	-	-	-
1974	-	1,500	-	1,591	-	-	2,603	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	2,490	2,031	-	-	-
1977	1,493	-	-	1,058	-	-	2,326	-	-	-	-
1978	1,551	-	1,023	1,505	1,265	2,029	3,132	2,437	-	2,570	-
1979	1,968	-	963	1,806	1,541	2,318	3,071	2,815	2,219	2,802	2,632
1980	1,980	-	1,304	1,838	-	2,062	3,191	2,406	-	2,461	2,806
1981	1,332	-	1,209	1,662	1,249	1,652	2,814	2,455	5,199	2,288	2,594
1982	1,776	-	736	1,296	1,439	1,683	3,025	2,395	3,414	2,192	2,964
1983	1,751	-	965	2,085	-	2,131	2,752	2,609	2,893	2,083	2,912
1984	1,701	1,423	1,137	1,651	1,753	-	2,316	2,753	3,437	2,484	2,784
1985	1,864	1,377	928	1,304	1,278	-	2,717	2,294	2,503	2,548	-
1986	2,033	1,459	1,243	1,522	1,494	-	3,189	3,008	2,927	2,960	3,403
1987	1,622	-	943	1,510	1,254	1,004	2,449	1,983	2,715	2,572	2,561
1988	1,799	-	890	1,468	1,125	-	2,195	2,065	-	2,125	2,418
1989	2,015	-	1,004	1,958	1,597	-	2,579	2,940	2,608	2,645	2,699
1990	1,936	-	1,010	1,496	1,817	1,561	2,811	2,256	2,821	2,858	2,871
1991	1,714	-	842	1,450	-	-	2,401	2,383	2,585	2,265	2,667
1992	1,665	-	756	1,339	1,154	-	2,477	2,081	-	2,600	2,589
1993	1,773	-	-	1,530	1,512	1,227	2,708	2,261	2,451	2,346	3,000
1994	1,589	-	912	1,463	1,343	-	-	2,770	-	3,199	3,038
1995	1,941	-	1,185	1,672	1,417	-	2,592	2,180	-	2,906	2,335
1996	1,830	-	1,903	1,850	1,518	-	2,421	1,972	-	3,206	2,719
1997	1,899	-	1,209	1,649	1,460	1,469	3,383	2,261	-	2,927	2,599
1998	1,998	-	2,010	1,818	1,458	-	2,472	2,460	-	2,296	2,659
Mean	1,839	1,532	1,109	1,601	1,426	1,708	2,657	2,401	2,981	2,629	2,750

Table C2.5 Estimated Monthly Evaporation at Dong Nai No.3 Reservoir

(Unit : mm/month)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
123	132	137	102	78	64	60	56	53	62	91	113	1,071

Table C3.1 Observed Mean Monthly Discharges at Ta Lai SGS (C.A. = 8,850 km^2)

Unit : m^3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1979	56.66	37.08	32.65	37.99	92.13	340.39	910.46	1059.51	530.93	717.73	359.73	155.17	364.01
1980	76.14	48.96	35.25	37.34	88.48	280.70	364.33	521.91	951.83	773.72	543.60	208.94	327.75
1981	101.72	71.54	38.49	39.45	82.90	410.15	356.89	923.77	698.57	736.39	415.36	210.49	342.14
1982	92.38	52.73	47.27	75.87	76.41	175.01	526.88	590.41	1075.05	546.32	330.47	165.01	313.85
1983	84.77	47.03	34.40	30.30	46.64	175.68	319.64	714.22	515.69	972.77	440.94	163.23	297.54
1984	85.99	46.80	33.48	49.96	117.82	263.75	293.44	1163.47	911.54	778.44	282.87	152.40	349.66
1985	71.60	44.90	39.60	69.20	155.00	346.00	368.00	497.00	626.00	680.00	325.00	185.00	285.28
1986	85.10	52.40	39.20	38.90	113.00	176.00	347.00	1140.00	859.00	808.00	404.00	203.00	357.80
1987	93.60	52.50	37.40	33.80	44.90	181.00	476.00	741.00	830.00	649.00	362.00	166.00	307.18
1988	82.50	52.30	37.60	47.10	64.40	202.00	277.00	335.00	444.00	718.00	411.00	137.00	234.53
1989	72.70	42.00	49.40	61.60	152.00	253.00	529.00	625.00	787.00	640.00	256.00	111.00	299.88
1990	65.50	41.80	43.20	39.80	49.50	459.00	422.00	893.00	1030.00	650.00	503.00	177.00	365.56
1991	86.70	52.60	37.40	41.30	64.00	120.00	476.00	794.00	1080.00	849.00	299.00	114.00	336.26
1992	72.10	43.10	26.90	58.20	79.50	361.00	401.00	891.00	895.00	638.00	301.00	128.00	325.24
1993	75.90	49.20	46.60	48.80	88.10	160.00	357.00	660.00	728.00	877.00	347.00	260.00	310.12
1994	94.50	63.80	51.90	61.90	155.40	235.90	720.50	824.90	1261.00	744.60	279.30	150.90	388.91
1995	78.70	49.60	40.60	40.50	71.00	120.00	342.00	458.00	1000.00	817.00	276.00	134.00	286.75
1996	74.49	52.98	38.10	79.13	199.43	331.27	384.81	610.19	924.87	900.13	698.20	312.00	384.25
1997	113.55	101.53	61.86	96.02	150.32	223.13	715.10	1080.35	794.50	644.87	320.97	130.88	371.74
1998	69.65	48.34	31.76	36.51	107.15	126.35	203.94	252.35	624.40	710.03	710.13	506.97	286.61
Mean	81.71	52.56	40.15	51.18	99.90	247.02	439.55	738.75	828.37	742.55	393.28	188.55	326.75

Table C3.2 Observed Mean Monthly Discharges at Ta Pao SGS (C.A. = 2,000 km^2)

Unit : m^3/sec

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1979	22.60	13.40	9.90	11.60	30.70	88.60	280.00	304.00	135.00	227.00	106.00	42.20	106.90
1980	23.30	14.40	8.40	7.40	24.60	85.70	89.20	123.00	237.00	218.00	125.00	54.40	84.26
1981	29.90	22.10	9.60	9.40	17.50	127.00	69.10	208.00	129.00	137.00	73.50	35.90	72.61
1982	20.70	12.70	14.30	26.10	22.80	43.40	141.00	129.00	289.00	151.00	82.10	40.10	81.26
1983	22.90	12.30	10.50	5.90	10.60	42.70	73.10	153.00	98.00	237.00	104.00	43.30	68.29
1984	25.30	12.20	7.30	8.70	20.20	61.40	86.00	437.00	206.00	142.00	62.50	44.10	93.25
1985	24.10	14.60	10.80	22.20	51.90	118.00	99.90	123.00	129.00	160.00	80.70	54.00	74.36
1986	25.90	15.70	11.00	10.40	53.90	62.30	117.00	293.00	232.00	191.00	133.00	66.90	101.62
1987	30.60	17.60	11.40	9.50	8.00	39.80	138.00	163.00	188.00	138.00	91.90	50.40	74.22
1988	30.60	18.80	12.10	11.90	15.90	57.40	53.80	60.20	86.90	153.00	102.00	32.30	52.97
1989	13.20	7.50	10.40	13.20	48.40	69.30	165.00	154.00	189.00	153.00	56.30	25.40	75.88
1990	13.80	8.50	8.80	7.10	9.30	100.00	74.50	200.00	240.00	150.00	102.00	39.50	79.68
1991	18.30	11.28	7.75	9.46	16.56	24.42	139.41	221.73	240.43	142.44	54.29	25.88	76.46
1992	15.42	9.09	6.46	10.20	13.25	71.95	80.54	196.36	153.40	126.44	56.23	25.41	63.93
1993	13.95	8.60	9.05	8.57	16.73	33.07	63.67	121.59	107.20	179.51	67.23	47.61	56.82
1994	21.24	12.92	10.16	12.37	28.64	36.63	193.37	220.08	307.77	177.01	76.20	37.50	95.01
1995	18.47	9.96	7.68	7.39	9.12	17.38	81.72	98.41	216.10	194.83	58.31	35.63	63.22
1996	18.68	12.38	7.47	24.27	36.92	39.34	53.82	118.99	225.82	192.00	130.70	54.34	76.44
1997	23.65	20.40	12.70	24.99	43.44	59.77	157.78	294.61	159.57	137.07	78.64	33.61	87.81
Mean	21.72	13.39	9.78	12.67	25.18	62.01	113.52	190.47	187.85	168.75	86.35	41.50	78.16

Table 3.3 Estimated Mean Monthly Discharges at Dai Ninh Dam Sites
(Effective C.A. = 1,158 km^2)

(Unit : m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1979	9.70	6.46	5.95	9.41	11.99	21.14	26.62	27.16	25.65	38.30	64.02	25.70	22.73
1980	11.75	8.22	5.30	5.60	18.41	46.31	18.47	34.54	35.88	60.61	53.20	24.97	26.95
1981	13.07	10.57	5.87	5.72	12.88	17.60	16.80	17.38	27.71	59.20	81.10	73.41	28.54
1982	16.44	10.31	11.46	16.87	19.68	26.80	15.93	12.51	33.38	24.87	21.73	13.38	18.61
1983	9.09	6.58	5.71	6.49	11.45	18.36	21.38	46.41	51.13	89.13	36.74	21.46	27.15
1984	12.98	9.13	6.09	9.51	23.66	25.37	37.87	24.07	29.65	59.72	35.02	28.75	25.24
1985	13.01	9.51	6.71	21.91	24.69	13.36	19.92	11.98	21.48	52.61	29.78	29.84	21.33
1986	12.34	8.89	6.77	5.31	6.00	10.45	15.28	19.28	37.92	55.21	37.27	54.22	22.52
1987	14.77	9.69	7.87	8.44	12.38	13.96	12.22	18.38	33.48	23.40	44.49	19.44	18.20
1988	11.14	8.29	5.91	7.63	6.67	10.67	33.34	18.23	53.21	46.11	84.86	20.58	25.50
1989	15.15	8.91	10.32	12.81	28.87	35.05	39.91	21.97	35.94	40.58	25.27	13.25	24.09
1990	8.48	5.92	6.20	14.19	12.31	32.12	21.01	29.03	34.26	35.79	73.20	24.90	24.79
1991	12.22	8.29	7.13	7.49	8.27	7.42	9.83	9.30	37.35	43.17	16.03	9.94	14.73
1992	7.06	4.95	4.03	20.35	26.88	50.34	30.30	26.79	18.30	58.87	39.13	18.00	25.46
1993	11.36	7.80	8.95	7.42	11.40	27.37	19.09	12.11	26.21	72.09	46.06	92.39	28.71
1994	20.75	11.98	8.85	9.11	28.23	25.24	23.25	15.47	31.46	38.16	26.19	22.77	21.86
1995	9.58	6.28	4.90	6.00	10.36	22.83	31.47	35.81	41.09	53.07	25.08	37.52	23.81
Mean	12.29	8.34	6.94	10.25	16.13	23.79	23.10	22.38	33.77	50.05	43.48	31.21	23.54

Table C3.4 Estimated Mean Monthly Discharges at Dong Nai No.3 Dam Site (C.A. = 2,441 km²)

(Unit : m³/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1979	13.03	8.53	7.51	8.74	21.19	78.29	209.41	243.69	122.11	165.08	82.74	35.69	83.72
1980	17.51	11.26	8.11	8.59	20.35	64.56	83.80	120.04	218.92	177.96	125.03	48.06	75.56
1981	23.39	16.45	8.85	9.07	19.07	94.34	82.08	212.47	160.67	169.37	95.53	48.41	78.69
1982	21.25	12.13	10.87	17.45	17.57	40.25	121.18	135.79	247.26	125.65	76.01	37.95	72.18
1983	19.50	10.82	7.91	6.97	10.73	40.41	73.52	164.27	118.61	223.74	101.42	37.54	68.43
1984	19.78	10.76	7.70	11.49	27.10	60.66	67.49	267.60	209.65	179.04	65.06	35.05	80.61
1985	16.47	10.33	9.11	15.92	35.65	79.58	84.64	114.31	143.98	156.40	74.75	42.55	65.61
1986	19.57	12.05	9.02	8.95	25.99	40.48	79.81	262.20	197.57	185.84	92.92	46.69	82.29
1987	21.53	12.08	8.60	7.77	10.33	41.63	109.48	170.43	190.90	149.27	83.26	38.18	70.65
1988	18.98	12.03	8.65	10.83	14.81	46.46	63.71	77.05	102.12	165.14	94.53	31.51	54.06
1989	16.72	9.66	11.36	14.17	34.96	58.19	121.67	143.75	181.01	147.20	58.88	25.53	68.97
1990	15.07	9.61	9.94	9.15	11.39	105.57	97.06	205.39	236.90	149.50	115.69	40.71	84.08
1991	19.94	12.10	8.60	9.50	14.72	27.60	109.48	182.62	248.40	195.27	68.77	26.22	77.34
1992	16.58	9.91	6.19	13.39	18.29	83.03	92.23	204.93	205.85	146.74	69.23	29.44	74.98
1993	17.46	11.32	10.72	11.22	20.26	36.80	82.11	151.80	167.44	201.71	79.81	59.80	71.33
1994	21.74	14.67	11.94	14.24	35.74	54.26	165.72	189.73	290.03	171.26	64.24	34.71	89.45
1995	18.10	11.41	9.34	9.32	16.33	27.60	78.66	105.34	230.00	187.91	63.48	30.82	65.95
1996	17.13	12.19	8.76	18.20	45.87	76.19	88.51	140.34	212.72	207.03	160.59	71.76	88.59
1997	26.12	23.35	14.23	22.08	34.57	51.32	164.47	248.48	182.74	148.32	73.82	30.10	85.50
1998	16.02	11.12	7.30	8.40	24.64	29.06	46.91	58.04	143.61	163.31	163.33	116.60	65.92
Mean	18.79	12.09	9.24	11.77	22.98	56.81	101.10	169.91	190.52	170.79	90.45	43.37	75.20

Table C3. 5 Estimated Mean Monthly Discharges at Dong Nai No.4 Dam Site (C.A. = 149 km²)

(Unit : m³/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
1979	1.13	0.74	0.65	0.76	1.84	6.81	18.21	21.19	10.62	14.35	7.19	3.10	7.28
1980	1.52	0.98	0.71	0.75	1.77	5.61	7.29	10.44	19.04	15.47	10.87	4.18	6.57
1981	2.03	1.43	0.77	0.79	1.66	8.20	7.14	18.48	13.97	14.73	8.31	4.21	6.84
1982	1.85	1.05	0.95	1.52	1.53	3.50	10.54	11.81	21.50	10.93	6.61	3.30	6.28
1983	1.70	0.94	0.69	0.61	0.93	3.51	6.39	14.28	10.31	19.46	8.82	3.26	5.95
1984	1.72	0.94	0.67	1.00	2.36	5.27	5.87	23.27	18.23	15.57	5.66	3.05	7.01
1985	1.43	0.90	0.79	1.38	3.10	6.92	7.36	9.94	12.52	13.60	6.50	3.70	5.71
1986	1.70	1.05	0.78	0.78	2.26	3.52	6.94	22.80	17.18	16.16	8.08	4.06	7.16
1987	1.87	1.05	0.75	0.68	0.90	3.62	9.52	14.82	16.60	12.98	7.24	3.32	6.14
1988	1.65	1.05	0.75	0.94	1.29	4.04	5.54	6.70	8.88	14.36	8.22	2.74	4.70
1989	1.45	0.84	0.99	1.23	3.04	5.06	10.58	12.50	15.74	12.80	5.12	2.22	6.00
1990	1.31	0.84	0.86	0.80	0.99	9.18	8.44	17.86	20.60	13.00	10.06	3.54	7.31
1991	1.73	1.05	0.75	0.83	1.28	2.40	9.52	15.88	21.60	16.98	5.98	2.23	6.73
1992	1.44	0.86	0.54	1.16	1.59	7.22	8.02	17.82	17.90	12.76	6.02	2.56	6.52
1993	1.52	0.98	0.93	0.98	1.76	3.20	7.14	13.20	14.56	17.54	6.94	5.20	6.20
1994	1.89	1.28	1.04	1.24	3.11	4.72	14.41	16.50	25.22	14.89	5.59	3.02	7.78
1995	1.57	0.99	0.81	0.81	1.42	2.40	6.84	9.16	20.00	16.34	5.52	2.68	5.74
1996	1.49	1.06	0.76	1.58	3.99	6.63	7.70	12.20	18.50	18.00	13.96	6.24	7.70
1997	2.27	2.03	1.24	1.92	3.01	4.46	14.30	21.61	15.89	12.90	6.42	2.62	7.43
1998	1.39	0.97	0.64	0.73	2.14	2.53	4.08	5.05	12.49	14.20	14.20	10.14	5.73
Mean	1.63	1.05	0.80	1.02	2.00	4.94	8.79	14.78	16.57	14.85	7.87	3.77	6.54

Table C3.6 Results of Discharge Measurements at New Streamflow Gauging Station near Dong Nai No.3 Dam Site

No	Date of Measurement	Stage Height : H (m)	Discharge : Q (m3/sec)
1	7-12-99	496.12	117.37
2	7-24-99	496.24	104.16
3	7-25-99	497.16	290.20
4	7-26-99	497.36	343.70
5	8-13-99	496.70	183.56
6	8-14-99	496.59	157.56
7	8-15-99	496.50	139.80
8	8-16-99	496.55	143.71
9	8-17-99	496.55	139.40
10	8-18-99	496.83	206.39
11	8-21-99	497.20	296.20
12	8-25-99	497.14	284.71
13	8-28-99	496.79	187.96
14	8-31-99	496.95	237.47
15	9-03-99	497.33	333.54
16	9-06-99	497.11	282.57
17	9-09-99	496.82	222.96
18	9-12-99	496.84	213.30
19	9-15-99	496.72	187.62
20	9-18-99	496.46	139.26
21	9-21-99	496.34	112.96
22	9-25-99	496.47	139.35
23	9-28-99	496.64	163.70
24	10-3-99	496.43	134.42
25	10-8-99	496.85	213.76
26	10-13-99	496.43	145.67
27	10-21-99	496.86	215.70
28	11-2-99	496.61	166.42
29	11-7-99	497.33	323.06
30	11-13-99	496.75	186.87
31	11-20-99	496.37	124.77
32	11-24-99	496.45	127.77
33	11-27-99	496.31	102.59
34	12-3-99	497.99	462.43
35	12-10-99	496.53	148.06
36	12-16-99	496.63	164.30
37	12-21-99	496.08	78.74
38	12-27-99	496.02	74.08
39	12-31-99	495.95	61.39

Note: The above table shows the results of the discharge measurement performed by EVN, which were provided to the JICA Study Team until January 2000.

Table C3.7 Observed Mean Daily Discahrges at New Straemflow Gauging Sation Installed near the Dong Nai No.3 Dam Site

Location : Dong Nai No.3 Dam Site
C.A. : 2,441 km2
Year : 1999

(Unit : m3/sec)

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	---	---	---	---	---	---	300.46	294.91	255.94	150.71	202.29	114.58
2	---	---	---	---	---	---	213.31	275.70	326.93	150.71	173.32	140.17
3	---	---	---	---	---	---	161.76	286.37	339.73	138.47	179.29	469.95
4	---	---	---	---	---	---	173.32	395.23	350.41	136.78	213.31	271.43
5	---	---	---	---	---	---	143.63	369.62	322.66	140.17	282.10	243.63
6	---	---	---	---	---	---	165.56	341.87	282.10	158.02	506.23	211.08
7	---	---	---	---	---	---	191.62	318.39	246.07	206.66	337.60	183.35
8	---	---	---	---	---	---	175.30	297.04	231.69	250.97	241.22	185.39
9	---	---	---	---	---	---	122.19	271.43	213.31	248.51	213.31	135.10
10	---	---	---	---	---	---	125.33	238.81	199.70	229.34	197.98	148.92
11	---	---	---	---	---	---	119.10	211.08	211.08	202.29	200.13	133.43
12	---	---	---	---	---	---	130.15	197.98	236.42	195.85	197.98	220.10
13	---	---	---	---	---	---	191.62	185.39	222.39	163.65	200.13	173.32
14	---	---	---	---	---	---	158.02	163.65	206.66	171.36	234.05	165.56
15	---	---	---	---	---	---	128.53	150.71	187.46	175.30	197.98	177.29
16	---	---	---	---	---	222.39	103.15	156.17	169.41	246.07	175.30	175.30
17	---	---	---	---	---	213.31	91.38	161.76	227.01	227.01	159.88	131.78
18	---	---	---	---	---	184.57	104.53	224.69	183.35	204.47	177.29	147.14
19	---	---	---	---	---	154.34	103.15	234.05	138.47	303.45	163.65	128.53
20	---	---	---	---	---	165.56	123.75	255.94	133.43	365.35	126.92	100.44
21	---	---	---	---	---	173.32	103.15	322.66	126.92	208.86	120.64	95.18
22	---	---	---	---	---	135.10	136.78	290.64	120.64	187.46	165.56	97.78
23	---	---	---	---	---	119.10	120.64	297.04	116.07	195.85	224.69	90.14
24	---	---	---	---	---	108.75	110.19	358.95	130.15	380.29	150.71	88.92
25	---	---	---	---	---	111.64	286.37	275.70	158.02	566.00	120.64	78.56
26	---	---	---	---	---	125.33	336.53	258.62	171.36	378.16	111.64	78.56
27	---	---	---	---	---	215.56	275.70	234.05	163.65	307.72	113.10	80.76
28	---	---	---	---	---	215.56	311.99	208.86	187.46	246.07	103.15	76.41
29	---	---	---	---	---	191.62	311.99	193.73	167.48	236.42	141.89	72.29
30	---	---	---	---	---	331.20	331.20	260.75	---	248.51	105.92	75.36
31	---	---	---	---	---		320.52	224.69		224.69		69.35
Mean	---	---	---	---	---	177.82	182.93	256.66	207.79	233.71	191.26	147.09
Max.	---	---	---	---	---	331.20	336.53	395.23	350.41	566.00	506.23	469.95
Min.	---	---	---	---	---	108.75	91.38	150.71	116.07	136.78	103.15	69.35

Note : "---" means that no records are available.

Table C4.1 Annual Maximum Peak Discharges at Dai Ninh Streamflow Gauging Station (C.A.= 1,158 km²)

No.	Annual Maximum Mean Daily Discharge (m^3/sec)	Date of Occurrence	Annual Maximum Peak Discharge (m^3/sec)
1	186.2	Dec. 4, 1981	263.8
2	6.2	Sep. 11, 1982	34.8
3	-	-	-
4	161.1	Oct. 13, 1984	203.1
5	177.9	Oct. 12, 1985	229.3
6	191.0	Sep. 29, 1986	224.8
7	282.0	Sep. 17, 1987	304.5
8	649.0	Nov. 8, 1988	838.6
9	193.0	Oct. 1, 1989	205.3
10	390.0	Nov. 13, 1990	472.5
11	191.0	Sep. 14, 1991	213.0
12	344.0	Oct. 27, 1992	409.7
13	382.0	Oct. 9, 1993	924.6
14	191.0	Oct. 29, 1994	227.0
15	315.0	Oct. 9, 1995	350.2

Data Source : Basic Design Report on Dai Ninh Hydropower Project, July 1997

Table C4.2 Annual Maximum Peak Discharges at Ta Lai Streamflow Gauging Station (C.A.= 8,850 km²)

No.	Annual Maximum Mean Daily Discharge (m^3/sec)	Date of Occurrence	Annual Maximum Peak Discharge (m^3/sec)
1	1,421.	Aug. 7, 1979	1,421.
2	1,255.	Aug. 30, 1980	1,255.
3	1,435.	Aug. 17, 1981	1,470.
4	1,808.	Sep. 7, 1982	1,862.
5	1,120.	Oct. 17, 1983	1,386.
6	1,576.	Aug. 21, 1884	1,599.
7	1,040.	Oct. 4, 1985	1,040.
8	1,580.	Aug. 15, 1986	1,580.
9	2,920.	Aug. 22, 1987	3,260.
10	1,430.	Oct. 9, 1988	1,510.
11	1,180.	Sep. 9, 1989	1,260.
12	1,620.	Sep. 5, 1990	1,660.
13	1,460.	Aug. 23, 1991	1,510.
14	1,520.	Aug. 22, 1992	1,630.
15	1,210.	Oct. 10, 1993	1,250.
16	1,750.	Sep. 6, 1994	1,800.
17	1,340.	Sep. 21, 1995	1,360.

Table C4.3 Results of Flood Frequency Analysis for Annual Maximum Peak Discharges at Dai Ninh and Ta Lai SGSs

(1) Dai Ninh Streamflow Gauging Station (C.A. = 1,158 km^2)

Return Period (yr)	Probability (%)	Probable Flood (m3/sec)		
		Iwai	Peason-III	Gumbel
2-Year	0.5000	324	293	342
5-Year	0.2000	568	477	605
10-Year	0.1000	824	656	779
20-Year	0.0500	1,157	882	946
50-Year	0.0200	1,740	1,274	1,162
100-Year	0.0100	2,310	1,662	1,324
200-Year	0.0050	3,010	2,152	1,486
300-Year	0.0033	3,489	2,495	1,580
500-Year	0.0020	4,174	2,997	1,699

Note
Number of Samples : 13

(2) Ta Lai Streamflow Gauging Station (C.A. = 8,850 km^2)

Return Period (yr)	Probability (%)	Probable Flood (m3/sec)		
		Iwai	Peason-III	Gumbel
2-Year	0.5000	1,530	1,427	1,512
5-Year	0.2000	1,914	1,793	2,020
10-Year	0.1000	2,194	2,120	2,357
20-Year	0.0500	2,480	2,495	2,680
50-Year	0.0200	2,874	3,078	3,098
100-Year	0.0100	3,189	3,597	3,412
200-Year	0.0050	3,520	4,195	3,724
300-Year	0.0033	3,722	4,586	3,906
500-Year	0.0020	3,985	5,126	4,136

Note
Number of Samples : 13

Table C4.4 Annual Maximum Basin Average Daily Rainfall for the Project Catchment

No	Year	Date of Occurrence	Annual Maximum Basin Average Daily Rainfall (mm)
1	1950	Jul. 4	83.0
2	1951	Mar. 18	69.1
3	1952	Oct. 20	260.5
4	1953	Sep. 20	47.0
5	1954	Aug. 28	50.5
6	1955	Oct. 30	62.5
7	1956	Oct. 5	47.2
8	1957	Sep. 17	53.6
9	1958	Aug. 20	65.3
10	1959	Jul. 22	63.7
11	1960	Oct. 1	63.6
12	1961	Jun. 25	58.8
13	1962	Jul. 30	58.8
14	1963	Sep. 29	53.9
15	1964	Dec. 11	113.2
16	1965	Sep. 17	42.9
17	1966	Sep. 18	69.9
18	1967	Sep. 29	94.9
19	1968	Oct. 20	52.0
20	1969	Jul. 19	57.7
21	1970	Oct. 28	54.2
22	1971	Sep. 19	76.9
23	1972	Sep. 4	49.7
24	1974	Sep. 28	82.7
25	1977	Sep. 25	66.7
26	1978	Oct. 7	69.5
27	1979	Nov. 18	97.3
28	1980	Oct. 2	60.0
29	1981	Oct. 14	55.3
30	1982	Mar. 25	65.5
31	1983	Oct. 17	62.2
32	1984	Aug. 30	34.5
33	1985	Sep. 18	54.1
34	1986	Oct. 1	82.9
35	1987	Sep. 16	65.3
36	1988	Nov. 7	47.5
37	1989	May 20	47.4
38	1990	Jun. 16	62.5
39	1991	Apr. 5	68.0
40	1992	Jun. 26	34.6
41	1993	Oct. 28	34.0
42	1994	Jun. 28	51.2
43	1995	Oct. 7	47.7
44	1996	May 16	54.9
45	1997	Sep. 14	39.1

Table C4.5 Annual Maximum Daily Rainfalls at Da Lat and Lien Khuong

(1) Da Lat Rainfall Gauging Station

No	Date			Rainfall
	Year	Month	Day	(mm)
1	1929	Sep.	16	60.0
2	1952	Oct.	20	375.0
3	1953	Sep.	28	40.1
4	1954	Sep.	26	63.7
5	1955	Sep.	30	80.0
6	1956	Oct.	15	89.5
7	1957	May	5	84.3
8	1958	Sep.	3	103.3
9	1959	Jun.	28	66.9
10	1960	Oct.	1	90.0
11	1961	Jul.	22	104.2
12	1962	Jul.	30	96.0
13	1963	Aug.	29	67.3
14	1964	Dec.	11	141.2
15	1965	Sep.	18	52.9
16	1968	Oct.	20	108.5
17	1969	Aug.	28	67.0
18	1970	Oct.	28	91.0
19	1972	Oct.	15	63.5
20	1976	Aug.	21	59.7
21	1977	Sep.	25	89.4
22	1978	Oct.	7	66.4
23	1979	Nov.	18	101.4
24	1980	Aug.	18	80.1
25	1981	Oct.	14	60.0
26	1982	Mar.	25	67.9
27	1983	Oct.	17	72.5
28	1984	Jul.	23	74.1
29	1985	Oct.	1	77.8
30	1986	Oct.	1	186.5
31	1987	Oct.	3	68.2
32	1988	Apr.	20	89.0
33	1989	Sep.	29	74.3
34	1990	Jun.	16	71.3
35	1991	Oct.	10	97.7
36	1992	Apr.	13	72.6
37	1993	Dec.	10	76.7
38	1994	Oct.	1	78.8
39	1995	Apr.	1	66.9
40	1996	May	16	61.3
41	1997	Apr.	11	69.7

(2) Lien Khuong Rainfall Gauging Station

No	Date			Rainfall
	Year	Month	Day	(mm)
1	1950	Jul.	4	95.7
2	1951	Mar.	18	76.7
3	1952	Oct.	20	184.7
4	1953	Sep.	20	80.0
5	1954	Sep.	30	69.2
6	1955	Aug.	22	74.4
7	1956	May	1	84.6
8	1957	Sep.	17	62.1
9	1958	Feb.	9	54.4
10	1959	Jul.	22	72.6
11	1960	Feb.	26	90.0
12	1961	Oct.	3	67.1
13	1962	May	21	86.1
14	1963	Sep.	29	67.4
15	1964	Dec.	11	121.3
16	1965	Mar.	27	49.6
17	1966	Sep.	18	77.0
18	1967	Sep.	29	109.4
19	1968	Mar.	27	80.5
20	1969	Jul.	19	107.1
21	1970	Jul.	26	87.2
22	1971	Sep.	19	81.5
23	1972	Sep.	10	77.3
24	1973	Sep.	19	89.4
25	1974	Sep.	28	110.0
26	1977	Jun.	15	101.6
27	1978	May	17	124.0
28	1979	Nov.	18	136.0
29	1980	Oct.	2	89.4
30	1981	Oct.	10	105.8
31	1982	Mar.	25	84.4
32	1983	Oct.	17	86.4
33	1984	Apr.	17	99.4
34	1985	Sep.	18	76.0
35	1986	Dec.	2	56.4
36	1987	Oct.	3	80.5
37	1988	Sep.	28	83.6
38	1989	May	18	98.3
39	1990	Sep.	26	114.2
40	1991	Apr.	5	96.1
41	1992	Jun.	26	57.7
42	1993	Dec.	9	92.2
43	1994	May	25	67.8
44	1995	Jul.	8	72.8
45	1996	Apr.	5	95.6
46	1997	Sep.	14	93.8

Table C4.6 Relation between Point Rainfall at Da Lat and Basin Average Rainfall

No	Date			(a) Point Rainfall at Da Lat (mm)	(b) Basin Average Rainfall (mm)	Ratio (b) / (a)
	Year	Month	Day			
1	1929	Sep.	16	60.0	48.0	0.800
2	1952	Oct.	20	375.0	260.5	0.695
3	1953	Sep.	28	40.1	14.7	0.367
4	1954	Sep.	26	63.7	25.6	0.402
5	1955	Sep.	30	80.0	62.5	0.781
6	1956	Oct.	15	89.5	34.9	0.390
7	1957	May	5	84.3	46.5	0.552
8	1958	Sep.	3	103.3	37.2	0.360
9	1959	Jun.	28	66.9	28.0	0.419
10	1960	Oct.	1	90.0	63.6	0.707
11	1961	Jul.	22	104.2	39.1	0.375
12	1962	Jul.	30	96.0	58.8	0.613
13	1963	Aug.	29	67.3	34.1	0.506
14	1964	Dec.	11	141.2	113.2	0.801
15	1965	Sep.	18	52.9	20.8	0.393
16	1968	Oct.	20	108.5	52.0	0.479
17	1969	Aug.	28	67.0	23.4	0.349
18	1970	Oct.	28	91.0	54.2	0.596
19	1972	Oct.	15	63.5	29.6	0.467
20	1976	Aug.	21	59.7	46.2	0.774
21	1977	Sep.	25	89.4	42.1	0.471
22	1978	Oct.	7	66.4	69.5	1.047
23	1979	Nov.	18	101.4	97.3	0.959
24	1980	Aug.	18	80.1	52.3	0.653
25	1981	Oct.	14	60.0	55.3	0.922
26	1982	Mar.	25	67.9	65.5	0.965
27	1983	Oct.	17	72.5	62.2	0.858
28	1984	Jul.	23	74.1	21.6	0.292
29	1985	Oct.	1	77.8	28.1	0.361
30	1986	Oct.	1	186.5	79.5	0.426
31	1987	Oct.	3	68.2	49.8	0.730
32	1988	Apr.	20	89.0	44.2	0.497
33	1989	Sep.	29	74.3	35.5	0.478
34	1990	Jun.	16	71.3	62.5	0.876
35	1991	Oct.	10	97.7	47.9	0.491
36	1992	Apr.	13	72.6	31.8	0.438
37	1993	Dec.	10	76.7	27.6	0.360
38	1994	Oct.	1	78.8	36.4	0.462
39	1995	Apr.	1	66.9	27.5	0.412
40	1996	May	16	61.3	54.9	0.896
41	1997	Apr.	11	69.7	27.9	0.401
					Max.	1.047
					Min.	0.292

Table C4.7 Runoff Coefficients for Major Floods at Ta Lai SGS

Year	Volume (mm)			Runoff Coefficient
	Rainfall	Runoff	Loss	
1979	1,151	573	578	0.50
1982	1,870	865	1005	0.46
1984	1,489	832	657	0.56
1986	1,062	489	573	0.46
1987	369	235	134	0.64
1990	1,308	681	627	0.52
1991	1,508	876	632	0.58
1993	1,581	753	828	0.48
			Average	0.52
			Max.	0.64
			Min.	0.46

Table C4.8 Parameters of Storage Function Model

Basin

No	Name	Area (km²)	K	P	Tl (hr)	Er	Upper El. (El.m)	Lower El. (El.m)	dH (m)	Length (km)	Average Slope (1/I)
1	Da Nhim	775	103.08	0.70	2.41	0.70	2,062	1,028	1,034	63	164
2	Dai Ninh	1,158	88.76	0.78	2.65	0.70	1,600	833	767	68	270
3	Dong Nai No.3	2,441	92.30	0.76	7.34	0.70	1,800	481	1,319	168	237
4	Dong Nai No.6	2,677	83.49	0.82	6.73	0.70	910	125	785	155	331
5	Ta Lai	2,574	73.73	0.70	3.50	0.70	1,442	105	1,337	86	501

Channel (Manning's Coefficient of 0.040)

No	Name	Length (km)	K	P	Tl (hr)	Fi	Upper El. (El.m)	Lower El. (El.m)	dH (m)	Width (m)	Average Slope (1/I)
a	Dai Ninh	61	315.1	0.600	1.02	1.00	1,028	833	195	70	508
b	Dong Nai No.3	87	457.4	0.600	1.18	1.00	833	481	352	80	339
c	Dong Nai No.6	114	686.5	0.600	1.82	1.00	481	125	356	90	467
d	Ta Lai	71	955.8	0.600	3.68	1.00	125	105	20	100	4,920

(Remarks) K, P : Constants for storage Function
Er : Effective rainfall coefficient
Fi : Inflow rate of channel
Tl : Lag time (hr)

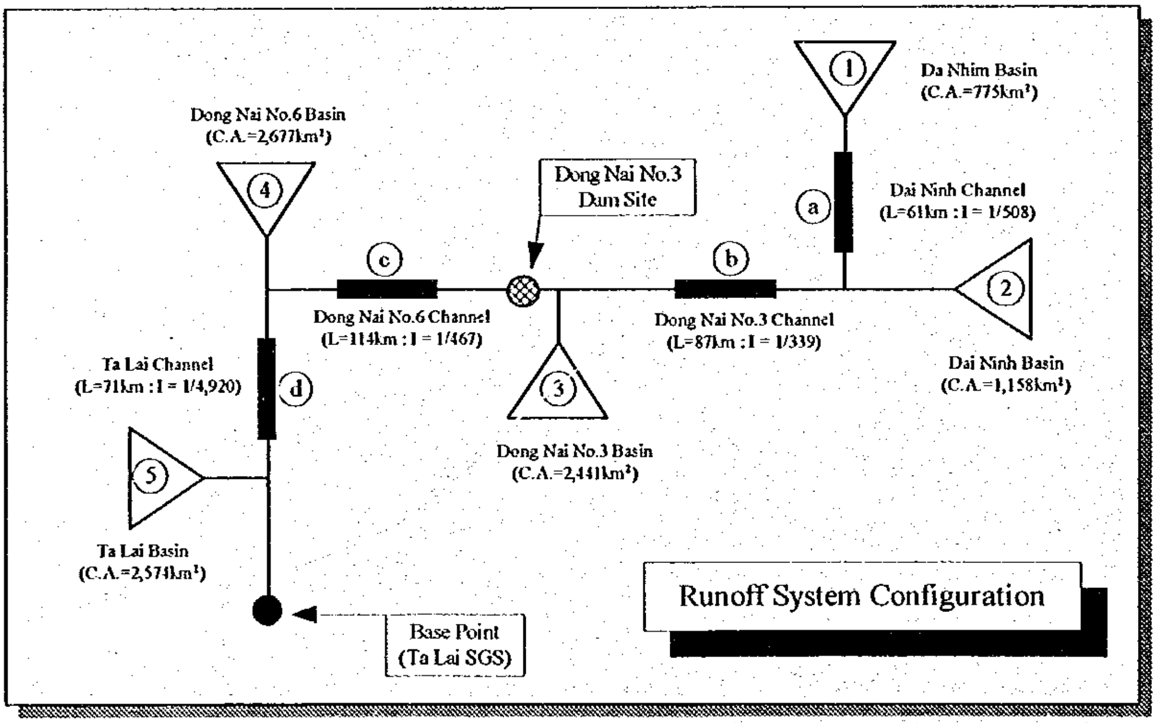

Table C5.1 Suspended Sediment Load Concentrations at Ta Lai SGS

Date			Daily Discharge	Sediment Consentration
Year	Month	Day	(m^3/sec)	(g/m^3)
1985	Jul.	13	424.0	50.0
		26	301.0	69.8
	Aug.	10	587.0	61.0
		15	614.0	75.1
		26	712.0	138.2
		29	647.0	38.3
	Sep.	4	415.0	52.4
		6	566.0	41.9
		10	810.0	63.5
		15	673.0	62.1
		20	770.0	81.3
		22	665.0	90.7
	Oct.	3	912.0	157.9
		4	1060.0	215.1
		6	961.0	137.4
		7	844.0	69.7
		11	703.0	62.6
		14	788.0	51.9
		18	614.0	50.7
		25	545.0	41.8
		29	466.0	40.3
	Nov.	3	381.0	23.5
		15	326.0	25.3
		21	280.0	11.5
		25	241.0	6.8
	Dec.	3	202.0	0.7
		6	244.0	5.9
		9	216.0	4.6
1986	Jan.	6	100.0	24.1
		13	90.2	28.2
		25	70.4	15.8
	Feb.	7	57.3	6.1
		16	52.4	5.4
	Mar.	3	42.6	4.2
		13	34.2	5.6
		28	40.0	4.4
	Apr.	10	32.0	13.1
		14	51.3	7.2
	May	1	28.0	6.2
		3	26.0	6.8
		18	133.0	19.5
		19	289.0	54.0
	Jun.	1	115.0	16.0
		19	249.0	24.3
		24	399.0	78.7
	Jul.	12	322.0	34.8
		16	438.0	74.7
	Aug.	5	606.0	146.9
		6	733.0	119.2
		7	1230.0	294.3
		9	1320.0	165.2
		10	1450.0	156.8
		11	1560.0	103.2
		28	1070.0	26.5
	Sep.	1	846.0	21.0
		5	906.0	90.6
	Oct.	22	662.0	53.0
		30	529.0	68.2
	Nov.	9	359.0	18.7
		19	655.0	166.4
	Dec.	28	148.0	9.7
1987	Jan.	1	119.0	3.1
		9	104.0	4.2
		23	78.5	5.5
	Feb.	4	64.7	11.1
		16	49.1	8.1
	Apr.	27	22.3	3.6
	May	21	72.8	68.7
	Jun.	16	227.0	55.9
		18	324.0	59.0
		19	427.0	98.6
		21	452.0	95.1
		24	200.0	35.4
		26	148.0	30.6
		29	287.0	44.9
	Jul.	2	391.0	83.6
		5	527.0	110.1
		14	1400.0	771.4
		15	995.0	182.9
		16	697.0	104.3
		17	600.0	91.3
		19	664.0	99.4
		23	552.0	73.9
		24	470.0	70.4
		30	357.0	62.7
	Aug.	16	760.0	207.9
		20	486.0	106.6
		21	1170.0	906.0
		21	1930.0	1233.2
		25	1230.0	203.3
		26	1050.0	135.2
		27	974.0	98.5
		29	890.0	17.3
	Sep.	16	864.0	75.1
		18	1330.0	254.1
	Oct.	7	827.0	34.5
		26	512.0	28.3
	Nov.	14	431.0	39.9
	Dec.	3	261.0	5.9
		31	111.0	0.6
1988	Jan.	1	111.0	0.2
		13	89.4	0.1
		21	68.8	0.4
		30	59.8	0.2
	Mar.	3	43.8	2.5
		13	37.6	1.4
		16	36.3	1.7
		18	35.0	1.6
		21	34.2	1.7
		28	31.4	1.9
	Apr.	26	63.8	1.1
	May	15	77.0	4.5
	Jun.	4	107.0	9.3
		6	271.0	96.3
		6	300.0	182.0
		9	206.0	79.1
		10	161.0	12.5
		17	342.0	37.1
		24	180.0	207.6
	Jul.	13	235.0	38.7
		16	432.0	104.4
		21	382.0	41.1
	Aug.	1	590	84.4
		2	553	49.4
		5	501	9.0
	Sep.	13	273	57.5
		23	788	209.4
		24	712	129.1
		29	908	134.4
	Oct.	8	1120	48.5
		10	1230	64.0
		11	1020	27.0
		12	879	29.7
		21	670	39.0
	Nov.	9	831	278.0
	Dec.	13	143	3.4
		31	90	1.2
1989	Jan.	1	92.2	1.8
		15	71.8	2.1
		31	60.9	1.2
	Feb.	18	39.9	1.2
		26	33.3	0.9
	Mar.	14	27.4	1.0
	Apr.	2	50.5	8.9
		21	72.8	10.3
	May	8	112.0	23.0
		21	195.0	21.3
		22	328.0	53.7
		25	252.0	73.8
	Jun.	20	138.0	30.0
		24	348.0	74.1
		27	493.0	95.9
	Jul.	10	692.0	100.3
		12	546.0	80.2
		13	449.0	59.5
		22	934.0	106.4
		24	846.0	35.9
	Sep.	8	1150.0	126.1
		9	1110.0	99.1
		10	978.0	81.1
		11	895.0	79.6
		18	798.0	71.3
	Oct.	31	373.0	26.8
	Nov.	11	291.0	13.2
		13	269.0	4.4
		21	202.0	1.9
		27	164.0	1.4
	Dec.	2	147.0	8.7
		8	123.0	8.0
		12	116.0	5.2
		15	108.0	5.0
		19	101.0	5.6
1990	Jan.	1	80.9	3.3
		5	77.0	4.9
		19	62.1	2.2
		22	60.4	1.1
	Feb.	12	42.7	8.4
		16	39.6	10.8
	Mar.	12	53.0	7.9
		21	31.1	8.6
	Apr.	3	36.9	7.2
		14	22.5	10.9
	May	1	34.7	4.4
		26	104.0	5.3
	Jun.	7	170.0	16.4
		8	146.0	16.6
		12	231.0	18.4
		14	343.0	25.6
	Jul.	10	283.0	16.3
		21	459.0	49.7
	Aug.	9	566.0	25.4
		15	660.0	35.5
		17	1300.0	68.8
		21	1070.0	36.5
		26	1380.0	41.4
		29	1520.0	61.9
	Sep.	16	837.0	28.9
	Oct.	2	886.0	94.7
		6	782	74.9
		19	623	101.3
		26	489	85.7
		30	435	75.4
	Nov.	3	372	41.4
		28	314	25.8
	Dec.	2	257	21.6
		12	197	12.7

Table C5.2 Annual Sediment Transport at Ta Lai SGS (C.A. = 8,850 km^2)

Year	Suspended Load (m^3/year)	Bed Load * (m^3/year)	Total Sediment Transport (m^3/year)	Total Sediment Transport (mm/year)
1979	1,767,848	353,570	2,121,417	0.240
1980	1,338,554	267,711	1,606,264	0.181
1981	1,433,717	286,743	1,720,460	0.194
1982	1,307,618	261,524	1,569,142	0.177
1983	1,214,224	242,845	1,457,069	0.165
1984	1,763,784	352,757	2,116,540	0.239
1985	878,369	175,674	1,054,042	0.119
1986	1,771,191	354,238	2,125,429	0.240
1987	1,373,066	274,613	1,647,679	0.186
1988	680,571	136,114	816,685	0.092
1989	1,062,977	212,595	1,275,573	0.144
1990	1,804,779	360,956	2,165,735	0.245
1991	1,641,415	328,283	1,969,698	0.223
1992	1,456,726	291,345	1,748,071	0.198
1993	1,173,385	234,677	1,408,062	0.159
1994	2,004,847	400,969	2,405,817	0.272
1995	1,232,109	246,422	1,478,531	0.167
Average	1,406,187	281,237	1,687,424	0.191

* Note : Bed Load was calculated as 20 % of Suspended Load.

Table C6.1 Peak Flow Reduction Rate in Downstream of Reach of Dong Nai No.4 Power Station

Year	Maximum Monthly Discharge (m^3/sec)		Reduction Rate
	Monthly Inflow to the Dong Nai No.3 Reservoir	Monthly Outflow from the Dong Nai No.4 Power Station	
1979	243.7	178.0	27.0%
1980	218.9	133.9	38.8%
1981	212.5	177.3	16.6%
1982	247.3	126.8	48.7%
1983	223.7	85.9	61.6%
1984	267.6	193.3	27.8%
1985	156.4	80.1	48.8%
1986	262.2	179.4	31.6%
1987	190.9	102.1	46.5%
1988	165.1	80.8	51.1%
1989	181.0	82.3	54.5%
1990	236.9	110.8	53.2%
1991	248.4	204.8	17.6%
1992	205.9	154.8	24.8%
1993	201.7	84.0	58.4%
1994	290.0	272.4	6.1%
1995	230.0	82.9	64.0%
1996	212.7	172.6	18.9%
1997	248.5	197.4	20.6%
1998	163.3	80.7	50.6%

Note : Monthly outflows shown above were estimated for the selected plan in this Feasibility Study

Table C6.2 Peak Flow Reduction Rate at Cat Tien National Park After Completion of the Project (at Junction of Dak Lua Stream and Dong Nai River)

Year	Maximum Monthly Discharge (m^3/sec)		Reduction Rate
	Monthly Discharge at the Junction on the condition without the Project	Monthly Discharge at the Junction on the condition with the Project	
1979	587.6	461.7	21.4%
1980	527.9	375.6	28.9%
1981	512.4	401.6	21.6%
1982	596.3	415.5	30.3%
1983	539.5	382.2	29.2%
1984	645.3	437.9	32.1%
1985	377.2	287.3	23.8%
1986	632.3	429.8	32.0%
1987	460.3	335.9	27.0%
1988	398.2	299.5	24.8%
1989	436.5	322.0	26.2%
1990	571.3	400.9	29.8%
1991	599.0	463.4	22.6%
1992	496.4	357.0	28.1%
1993	486.4	351.2	27.8%
1994	699.4	656.5	6.1%
1995	554.6	387.4	30.1%
1996	513.0	441.9	13.9%
1997	599.2	461.2	23.0%
1998	393.9	297.0	24.6%

Note : Monthly discharges with the Project shown above were estimated for the selected plan in this Feasibility Study

Table 6.3 Estimated Yearly Frequency of Occurrence of Reverse Flow of Dak Lua Stream in CTNP in Each Year

Year	Estimated Yearly Occurrence of Reverse Flow in Dak Lua Stream of CTNP	
	Number of Occurrence (times)	Yearly Total Duration (number of days)
1979	7	12
1980	6	8
1981	9	13
1982	5	13
1983	5	7
1984	6	10
1985	7	11
1986	6	10
1987	8	10
1988	6	10
1989	7	11
1990	8	13
1991	7	12
1992	6	10
1993	6	7
1994	6	9
1995	5	8
Average	6	10

Appendix C

Figures

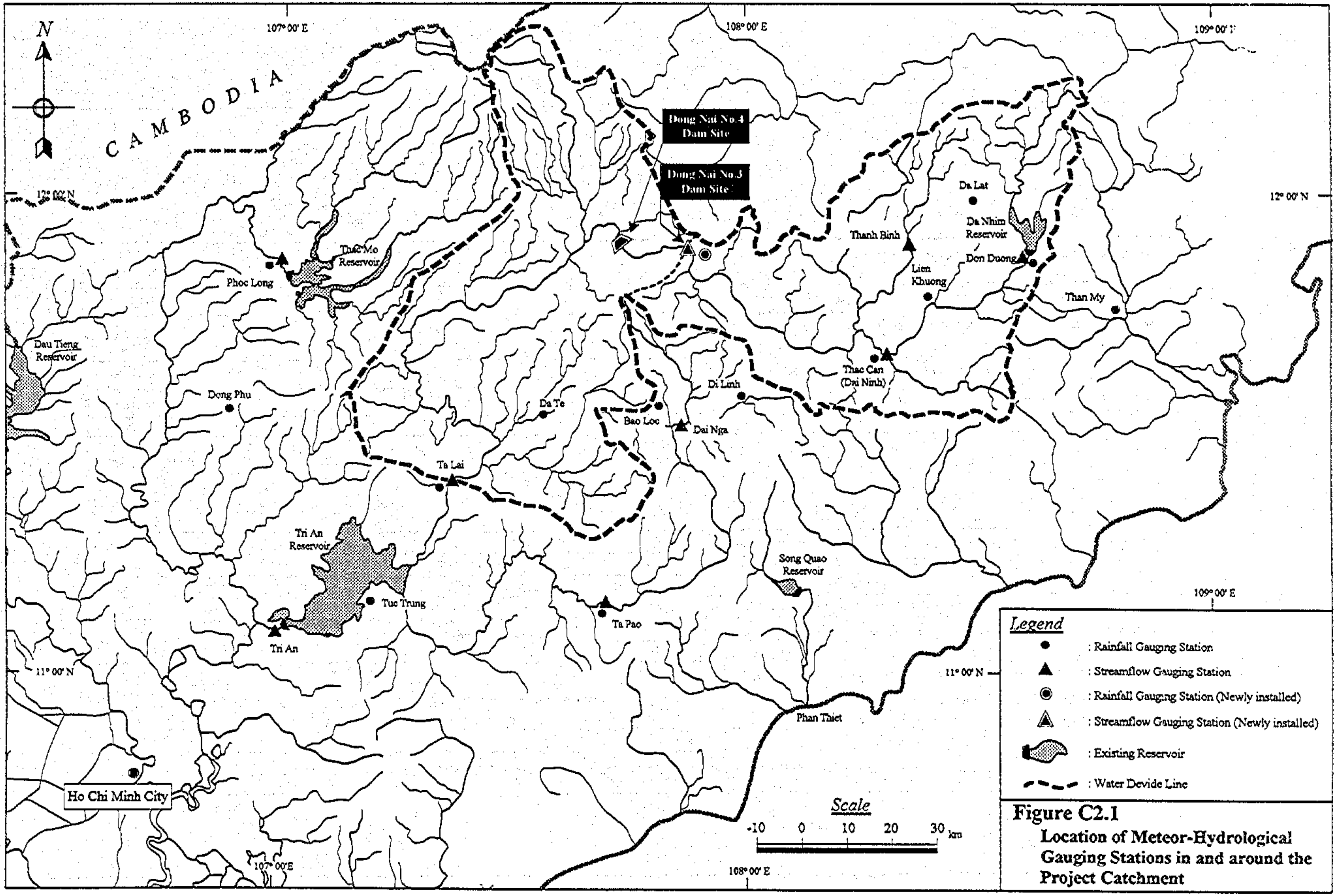

Figure C2.1
Location of Meteor-Hydrological Gauging Stations in and around the Project Catchment

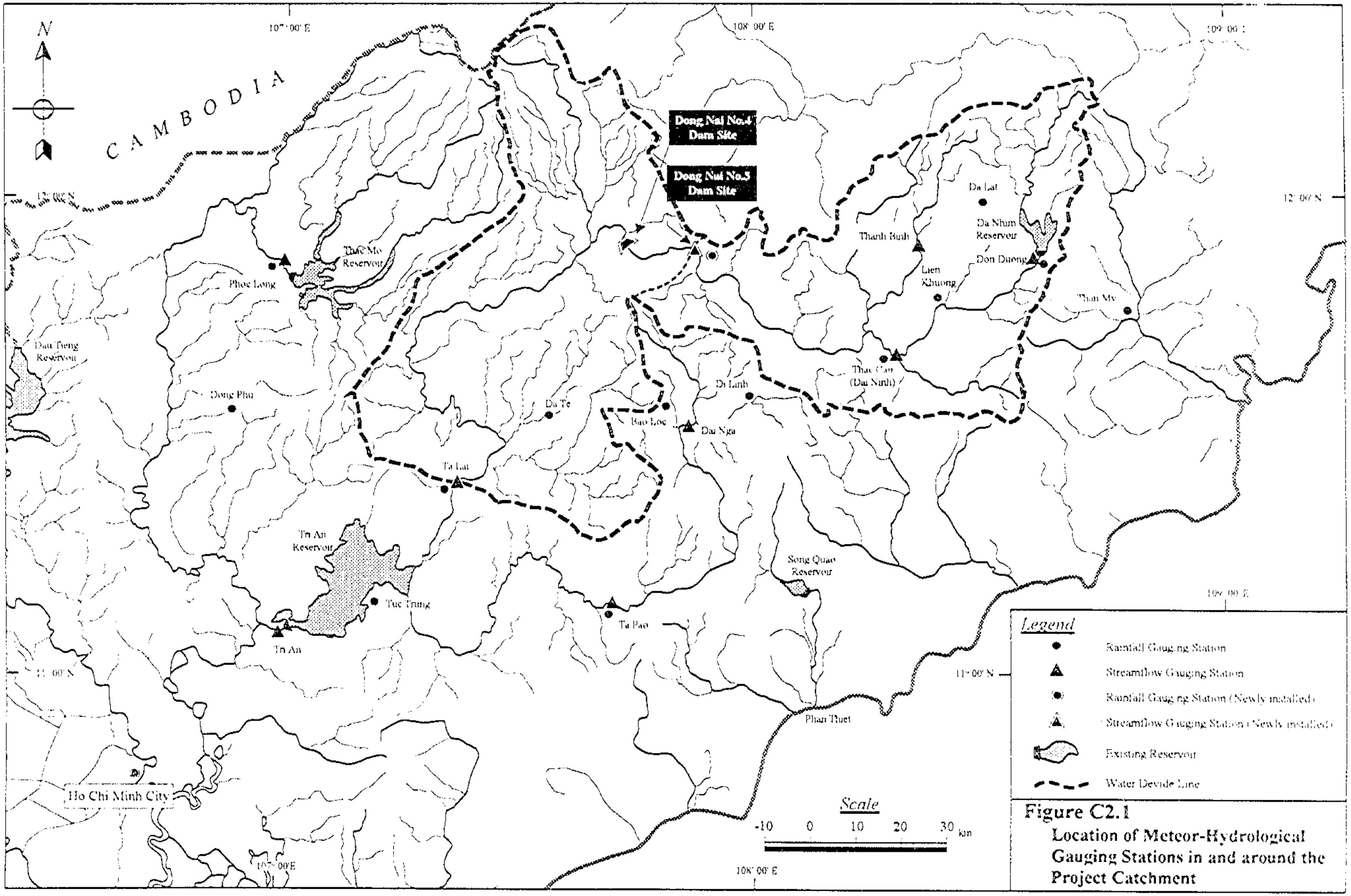

Figure C2.1
Location of Meteor-Hydrological Gauging Stations in and around the Project Catchment

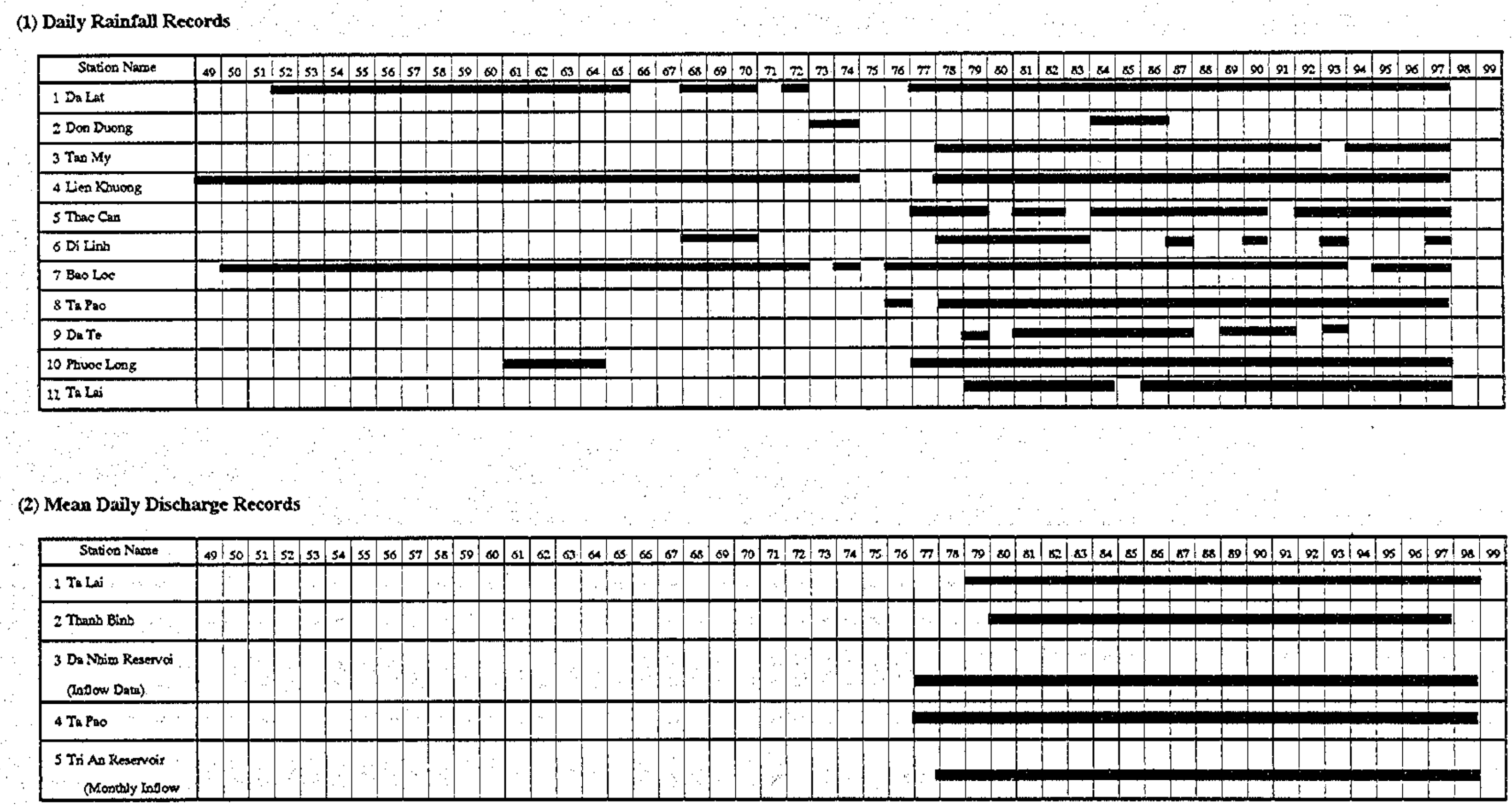

Figure C2.2 Available Period of Meteo-Hydrological Records Related to the Project

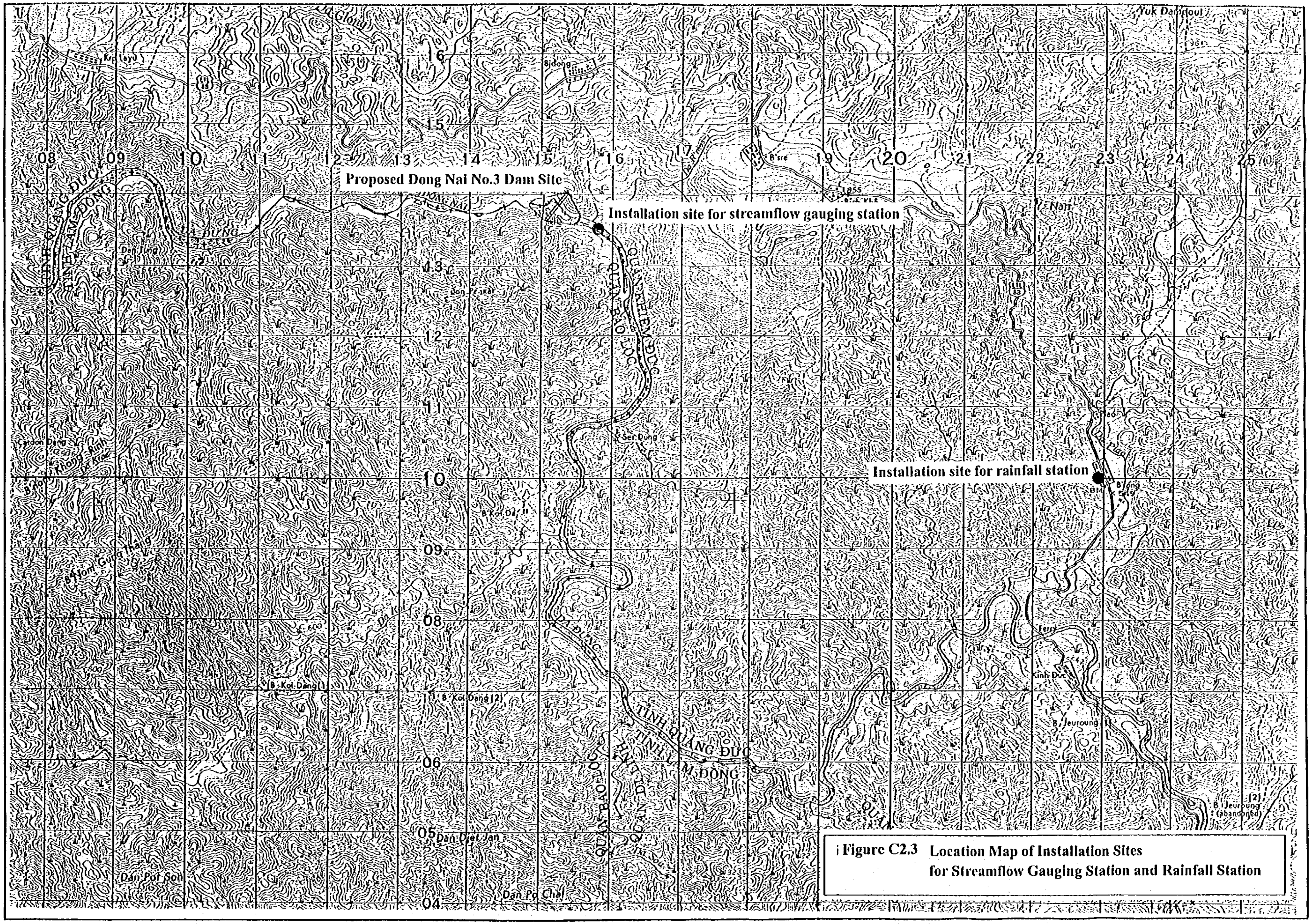

Figure C2.3 Location Map of Installation Sites for Streamflow Gauging Station and Rainfall Station

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