

LAO PEOPLE'S DEMOCRATIC REPUBLIC
PAKLAY HYDROPOWER PROJECT
Feasibility Study Report

FINAL
(Chapter 2 - 4)



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March, 2017

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2 Hydrology

2.1 Catchment Overview

Lantsang-Mekong is an international river geographically located between $8^{\circ}\sim 34^{\circ}$ in northern latitude and $94^{\circ}\sim 110^{\circ}$ in east longitude. In China, it is named as Lantsang which originates from Guozongmucha Mountain (altitude: 5,514 m) in Zhaqing Township, Zadoi County, Yushu Tibetan Autonomous Prefecture, Qinghai Province. Its headstream area belongs to Tanggula Mountains and the headstream is also named as Zha'aqu River; thus, it begins to be called as Lantsang after it arrives at Qamdo, Tibet. It flows to the south and leaves China near Nanlahe River outlet in Yunnan Province. After leaving China, it is named as Mekong River which flows through Myanmar, Thailand, Laos, Cambodia and Vietnam and into the South China Sea to the south of Ho Chi Minh City, Vietnam.

The main stream of Lantsang-Mekong is about 4,880 km in full length, being the longest river in Southeast Asia region, among which 2,130 km is within China (excl. the 30km boundary river). Its mean annual runoff at the Mekong River outlet is about 475×10^9 m³, and its basin area upstream from the outlet is about 795,000 km², among which about 202,000 km² is within Laos, accounting for 25%, and the areas within Thailand, China and Cambodia all exceed one fifth, accounting for 23%, 21% and 20% respectively, while those in Vietnam and Myanmar only accounts for 8% and 3% respectively.

The main stream of Mekong River is 2,720 km in full length. The upstream section to Vientiane is generally called as the upper reach, section from Vientiane to Pakse as the middle reach, section from Pakse to Phnom Penh as the lower reach and downstream section from Phnom Penh as the delta reach. One part of the upper reach is the boundary river between Myanmar and Laos, which is about 234 km long, and one part of the middle reach is the boundary river between Thailand and Laos, which is about 976 km long. Mekong River is about 502 km long within Cambodia and about 230 km long within Vietnam.

Mekong River is the largest river within Laos where the river section is about 777 km

in length. It flows throughout Laos in south-north direction. The section in the north of Vientiane is the upper reach of Mekong River, with many rock patches on the riverbed, while the section in the south of Vientiane is becoming wider gradually. There are over 20 tributaries in length more than 200 km within Laos, among which the main tributaries upstream from Pak Lay are Nam Tha River, Nam Ou River, Nam Suang River, Nam Khan River, etc. Refer to Fig. 2.1-1 for water system distribution of Mekong River.

The Paklay HPP is located on the middle reaches of Mekong River in Laos, with Sayaburi HPP at its upstream, and Sanakham HPP at its downstream. Two damsites are compared for the Paklay HPP. The upper damsite is located 1829 km away from the estuary of Mekong River, with a controlled drainage area of about 278,400 km², and is about 31 km upstream of the Pak Lay County seat. The lower damsite is about 11 km away from the upper damsite, with a controlled drainage area of 280,500 km². Refer to Fig. 2.1-1 for the location of the damsites.

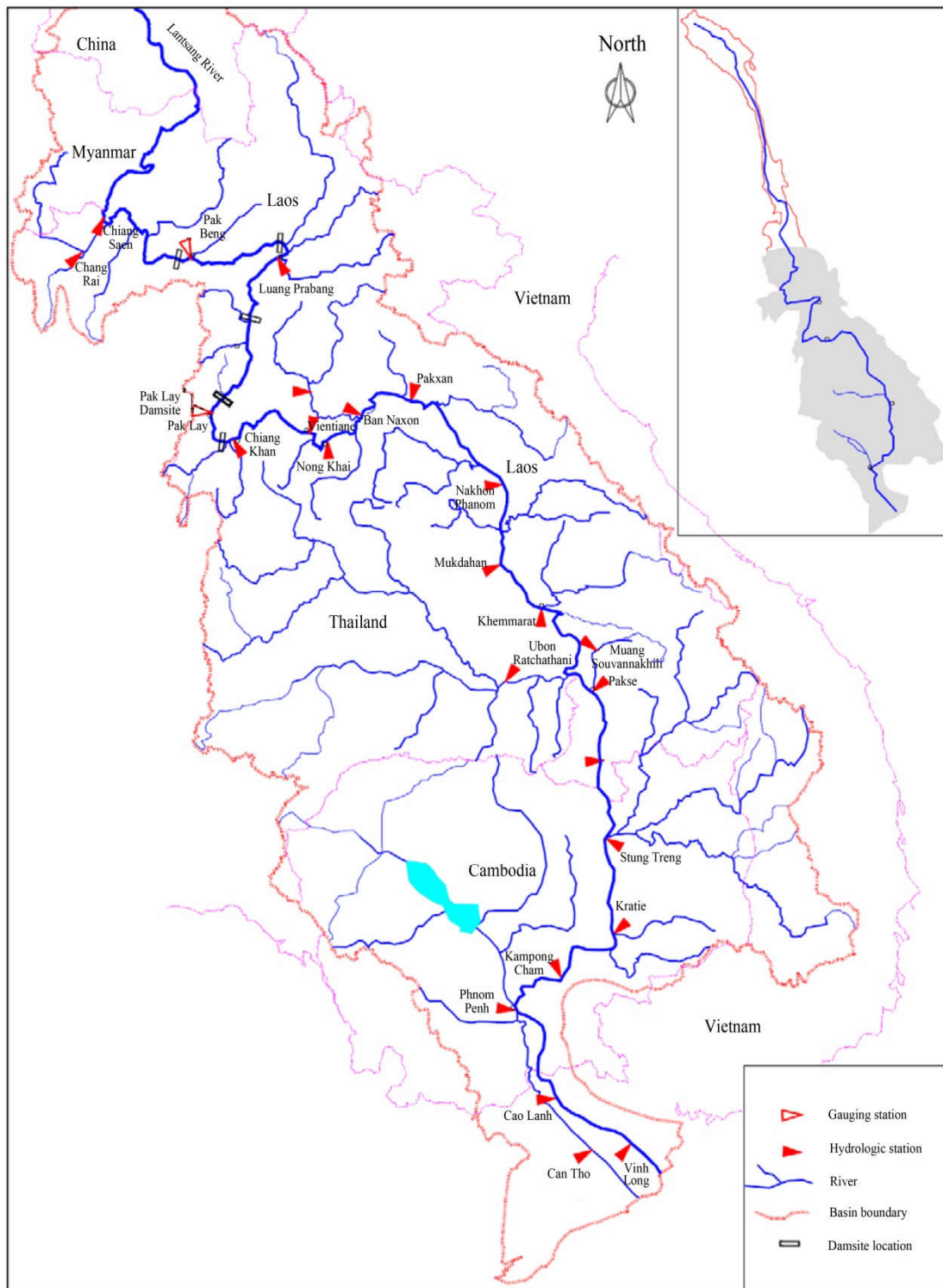


Fig. 2.1-1 Mekong River System and Distribution of Hydrometric Stations

Laos has a tropical monsoon climate with a relatively high temperature. There are two seasons throughout the year – the dry season and rainy season. The rainy season is from May to October with an average air temperature of 24.2°C and abundant rainfall due to the southwest monsoon. The dry season is from November to April of the next year with an average air temperature of 27.3°C, and due to the dry and cool northeast monsoon, there is nearly no rainfall and droughts are frequent in the plain area. The annual average temperature of Laos is about 25°C; the hottest month falls in April with a monthly average temperature of 29°C, while the coolest month falls in December with a monthly average temperature of 24°C, and the minimum temperature is 18°C. The temperature difference between the north and south of Laos is small, e.g., the annual average temperature of Luang Prabang City in the north and Pakse City in the south is 25°C and 28.4°C respectively.

Pak Lay Cascade Hydropower Station is located above the main stream of Mekong River, about 31km upstream from Pak Lay County of Sayaboury (Xaignabouli) Province. It is a Cascade IV station in Planning Report on Runoff-type Development of Main Stream of Mekong River prepared by Mekong River Commission in 1994. The control catchment area at the damsite is about 278,400 km², which is 1,829 km away from the Mekong River outlet. According to the results of statistic data (1969~2014) from the meteorological station (about 326 m in elevation) in Sayaboury Province where Paklay HPP is located, the mean annual temperature is 25.3°C; the hottest month is April with an extreme maximum temperature of 40.5°C; from December to February of the next year, the temperature in mountainous areas is the lowest with an extreme minimum temperature of 1.3°C. The mean annual precipitation is 1,369.7 mm; the number of mean annual precipitation days is 124d; and the precipitation from April to October accounts for 92% of the annual precipitation. Data on wind velocity are unavailable at the damsite; thus, estimated temporarily according to the 13 largest wind velocities (for reference) in the capital of Sayaboury Province, the mean annual maximum wind velocity is 16m/s, the velocity for wind of 50-year return period is 31m/s, and the measured maximum velocity is 25m/s. Refer to Table 2.1-1 for statistical results of mean monthly meteorological factors from the

meteorological station in the capital of Sayabuary Province.

Table 2.1-1 Statistical Results of Mean monthly Meteorological Factors from Meteorological Station in Capital of Sayabuary Province

Item	1	2	3	4	5	6	7	8	9	10	11	12	<i>Year</i>
Average temperature (°C)	20.9	22.9	25.5	27.6	27.9	27.9	27.3	27.0	26.9	25.7	23.3	20.8	25.3
Extreme maximum temperature (°C)	34.5	37.0	39.5	40.5	39.7	37.0	38.5	35.7	35.0	36.7	34.5	34.6	40.5
Extreme minimum temperature (°C)	1.3	7.0	7.0	13.5	19.0	18.0	15.6	20.8	17.8	11.2	7.0	2.5	1.3
Relative humidity (%)	72	68	67	70	76	78	81	82	81	78	76	74	75
Evaporation (mm, Pich evaporation pan)	60.0	78.4	104.6	88.2	62.3	57.8	51.3	42.6	44.2	48.9	49.4	50.4	737.9
Maximum wind velocity (m/s)	NW/9	W/20	NW20	NE/25	NW/20	WNW/20	W/15	SW/15	N/18	NNE/10	NE/8	N/10	NE/25

Note: The data series is 1969-2014.

2.2 Hydrometric Station and Basic Data

The earliest hydrologic observation on the main stream of Mekong River can be traced back to 1890s when hydrologic record data was already available in the capital of Laos – Vientiane. Hydrologic observation and record data on the reach within Luang Prabang City was later available from 1913. In 1957, Vietnam, Laos, Cambodia and Thailand took part in and established Mekong Basin Research & Coordination Commission which along with their own Mekong River commissions started relatively comprehensive meteorological, hydraulic and other preliminary work on the Mekong River Basin. Since 1963, the Mekong River Commission started to undertake a lot of engineering planning and feasibility researches.

As per current understanding of situation, there are mainly set with, from the upper reach to the lower reach, Chiang Saen, Luang Prabang, Chiang Khan, Vientiane, Nong Khai, Nakhon Phanom, Mukdahan, Pakse and other hydrologic stations as well as Ban pakkhone, Pak Lay and other gauging stations above the main stream of Mekong River. Refer to Fig. 2.1-1 for distribution of main hydrometric stations above the main stream of Mekong River.

Paklay HPP (upper dams site) is located between Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station and is about 31 km away from Pak Lay Gauging

Station. Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station are key hydrometric stations within the Mekong River Basin, and Pak Lay Gauging Station is a major survey station; therefore, the above-mentioned three stations shall be taken as major basis stations for the hydrological analyses and calculations for Paklay HPP in this phase.

2.2.1 Luang Prabang Hydrologic Station

Luang Prabang Hydrologic Station is located in the river reach within the capital of Luang Prabang Province, about 181 km upstream away from the damsite of Paklay HPP , northern latitude 19°53.5' and east longitude 102°8.2'. It is a key control station of the Mekong River Basin with a control catchment area of 268,000 km² and is 2,010 km away from the Mekong River outlet. The main observation data include water level and flow, and some sediment data are available for some years. The basic cross section of the survey station is located nearby riverside stone step downstream from Luang Prabang Royal Palace, and the cross section for current surveying by hydrological surveying boat is located 100 m downstream from basic gauge cross-section.

The earliest water level record of the station was made in 1913; later then, water level records for some years were incomplete (e.g. 1927, 1945-1947 and 1952-1954); years with relatively complete water level records are 1914-1918, 1920-1923, 1925-1926, 1928-1944, 1948-1951 and 1955-1973. The water gauge is of vertical type and tilting type. The water level observation is conducted twice during dry season, and observation times are increased during flood season. The automatic water level recorder has been used since the beginning of the 1990s.

The flow records are available from January 1950 with a maximum measured flow of 25,200 m³/s (on September 2, 1966). The flow discharge observation is mainly tested by a cup-type current meter, and the multi-thread multipoint flow test on cross section of survey boat is adopted to calculate water flow. According to the recent information, the flow discharge observation is conducted approximately twice during dry season, and observation times are increased during flood season. Flow discharge observation times are 32, 40, and 23 separately in 2009, 2010, and 2011.

The curve of the stage discharge relation of the Luang Prabang Hydrologic Station has been flat with some changes among years. From the analysis of the corresponding relation between day-to-day water level and day-to-day flow in recent years, stage-discharge relations since 2005 have a relatively larger relation than stage-discharge relations in and before 2004, and the single stage-discharge relations before 2005 are almost familiar.

2.2.2 Chiang Khan Hydrologic Station

Chiang Khan Hydrologic Station is located in Chiang Khan County Seat of Thailand, about 112 km downstream from Pak Lay Damsite, northern latitude $17^{\circ}53.8'$ and east longitude $101^{\circ}40.1'$. It is a key control station on Mekong River Basin, with a control catchment area of $292,000 \text{ km}^2$, and is 1,717 km away from the Mekong River outlet. The main observation data include water level and flow, and some sediment data are available for some years. The basic cross section of the survey station is located nearby the police camp 500 m downstream from the customhouse, and the cross section for current surveying by hydrological surveying boat is located about 500 m downstream from basic gauge cross-section.

The station started to observe water level from July 1964. The water gauge is of vertical type, and water level is observed here in more times. The maximum water level measured is 18.22 m (assumed datum, on September 4, 1966).

The station began flow test from December 1966, with a maximum measured flow of $24,400 \text{ m}^3/\text{s}$ (on August 15, 2008). The flow data mainly measured by current meters are made by hydrological surveying boats. The flow observation is conducted less during dry season, and observation times are increased during flood season. Flow discharge observation times are 47, 41 and 35 separately in 2009, 2010, and 2011. Flow discharge observation times are 17 and 21 separately in 2014 and 2015.

The curve of the stage discharge relation of the Chiang Khan Hydrologic Station has been flat with some changes among years. When the water level is high (if the water level is at about 15.3 m, the corresponding flow is about $20000 \text{ m}^3/\text{s}$), the corresponding flow

range is about $\pm 10\%$. From the analysis of the corresponding relation between day-to-day water level and day-to-day flow in recent years, stage-discharge relation each year basically changes within a band width and is basically stable.

2.2.3 Pak Lay Gauging Station

Pak Lay Gauging Station is located on upstream side of Pak Lay County Seat and right bank of Mekong River, being a major control station of Mekong River Basin. It is about 1.4 km downstream from Pak Lay Wharf, about 1,800 km away from the Mekong River outlet and about 29 km upstream from the upper damsite of Paklay HPP . The river reach under test is smooth and straight, and the basic water gauge is of vertical type and tilting type. Based on relevant data, the earliest water level records was made in 1913; later then, observation records for some years were incomplete or even unavailable. The maximum water level measured in 2008 is 15.12m (assumed datum, on August 14, 2008).

2.2.4 Gauging Station in Dam Area

According to requirements in design outline and demands of engineering design, Hydrochina Zhongnan constructed 4 gauging stations along the river reach in the dam area in December 2007, i.e. gauging station at upper damsite, main channel gauging station at lower damsite, right channel gauging station at lower damsite and automatic-record gauging station under dam. Through these stations, water level data of over one year were collected and flood data in August 2008 were observed. The observation data from the gauging station at upper damsite were recorded till March 2009.

According to the project development and evaluation requirements, temporary flow observation and sampling for analyzing the sediment particle grading were carried out in the reach of the upper damsite in September 2015. The manual observation gauging station was built at the river reach of the upper damsite in the middle of March, 2016. A gauging station was built at the river reach of the upper damsite to carry out the water level observation of damsite, flow observation, and sampling of suspended sediment in June, 2016.

2.2.5 Other Hydrometric Stations

Vientiane Hydrologic Station is constructed in the capital of Laos – Vientiane, about 249 km downstream from the Paklay HPP Damsite. It is a major control station of Mekong River Basin with a control catchment area of 299,000 km², 4 km downstream from Vientiane and 1,580 km away from the Mekong River outlet. Water level and flow data are observed by the station with a long data series and with a maximum flow measured of 26,000 m³/s (on September 4, 1966).

Nong Khai Hydrologic Station is set in Nong Khai County Seat within Thailand, about 279 km downstream from the Pak Lay Damsite. It is a key control station of Mekong River Basin with a control catchment area of 302,000 km² and is aimed to observe data on water level, flow and sediment.

2.2.6 Preliminary Analysis on Compilation Results

The main basis stations for hydrological analyses and calculations of Paklay HPP are the upstream Luang Prabang Hydrologic Station, downstream Chiang Khan Hydrologic Station and Pak Lay Gauging Station. It is known that the Paklay gauging station is of manual observation with automatic recording, and the observation frequency is twice a day. The Luang Prabang and Chiang Khan hydrological stations have both manually and automatically recorded water levels water level, and flow measurement is done mainly by boat velocity meter. According to preliminary analyses on collected data, the daily water level fluctuation of the three stations are basically consistent, with good correspondence. Comparing the monthly average flows of the two hydrological stations, the water unbalance occurred in some months. In the dry periods of some years, the monthly average flow in Chiang Khan hydrological station was less than that in Luang Prabang hydrological station for some consecutive months (the preliminary statistics indicates that the occurrence of unbalanced periodic flow is around 5.7%). The water unbalance mainly occurred before 1998 and since then it only occurred in 2010. The water balance results from Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station are relatively favorable through preliminary comparison and analysis on annual runoff data

from Luang Prabang, Chiang Khan and Vientiane Hydrologic Stations.

According to preliminary analyses on collected data since 2005, stage discharge relations adopted and compiled by the Luang Prabang station have relatively less adjustments compared with stage discharge relations adopted and compiled in previous years.

With the consideration of some real limitations for survey and material collection at the stage, the flow measurement scheme and data compilation method of the two hydrological stations are not well known to us, and the measured flow and water level data can hardly be collected, which makes it hard to comprehensively analyze and adjust the basic data of the two hydrological stations. Furthermore, the data of the two hydrological stations have been assembled into the compilation conducted and printed by the Mekong River Commission. The compiled results have already been applied to study on the analysis of the Mekong River Basin water resource, and other analyses. The preliminary analysis on the available information indicates that the compilation results of the two hydrological stations are basically reliable, and their accuracy can basically meet the project design requirements. Therefore, at this stage, the results in the assembled annual book and data collected from the Mekong River Commission and Lao Meteorological Department are directly adopted in the analysis and calculation..

2.3 Runoff

2.3.1 Runoff Series of Basis Station

According to the geographical location of Paklay HPP and situations of upstream and downstream hydrologic hydrometric stations, the control catchment area of Pak Lay Damsite (278,400 km²) accounts for 95.34% of that (292,000 km²) of downstream Chiang Khan Hydrologic Station, being 1039 times as the control catchment area (268,000 km²) of Luang Prabang Hydrologic Station with a relatively small sectional area; therefore, the runoff results from Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station are adopted as bases for damsite runoff calculations.

From the collected materials to be supplemented, data at the Luang Prabang

Hydrologic Station in 1960~2005 are extended to data in 1960~2015, and thus the corresponding mean annual flow over the years is 3820 m³/s and the process of the mean annual flow is shown in Fig.2.3.1-1; data at the Chiang Khan Hydrologic Station in 1967~2005 are extended to data in 1967~2015, the corresponding mean annual flow over the years is 4240 m³/s and the process of the mean annual flow is shown in Fig.2.3.1-2.

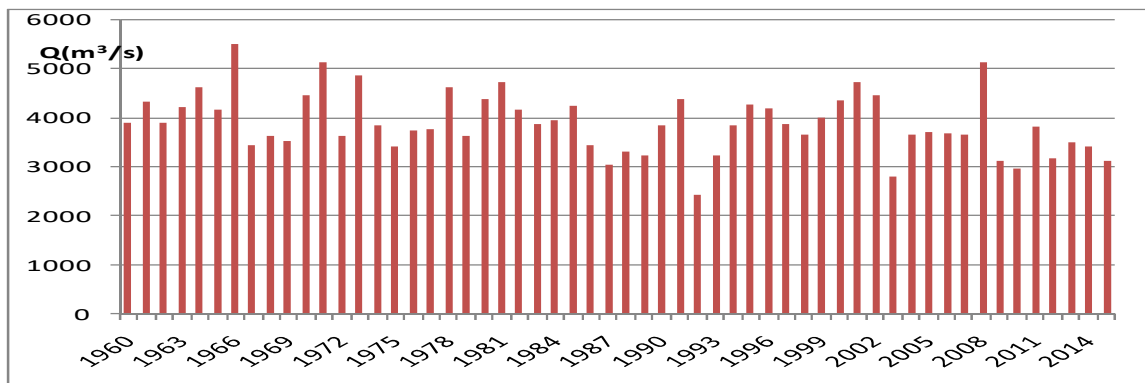


Fig. 2.3.1-1 Column of Mean Annual Flow at Luang Prabang Hydrologic Station

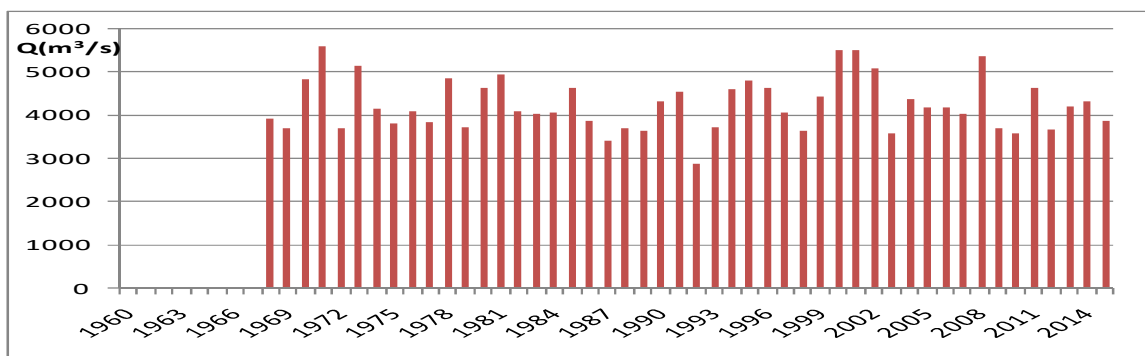


Fig 2.3.1-2 Column of Mean Annual Flow at Chiang Khan Hydrologic Station

2.3.2 Runoff Series and Characteristics at Damsite

In accordance with analyses on collected data and in consideration of measurement accuracy of hydrologic stations, sectional precipitation distribution and other reasons, the mean annual flow at the upper damsites over the years is separately 4050 m³/s and 4040 m³/s according to the corrective calculation of the area ratio via the runoff data of upstream Luang Prabang Hydrologic Station and downstream Chiang Khan Hydrologic Station at the stage. The mean annual flow over the years is 4060 m³/s at the damsite via

interpolation algorithm. The calculated results differ slightly. The monthly runoff data of upstream Luang Prabang Hydrologic Station and downstream Chiang Khan Hydrologic Station over the years are adopted for calculations of natural runoff at the damsite via interpolation algorithm. The formula is shown below:

$$Q_B = Q_L + (Q_Q - Q_L) \times (F_B - F_L) / (F_Q - F_L)$$

Wherein: Q_B , Q_L and Q_Q refer to the monthly average flow at the damsite, Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station respectively;

F_B , F_L and F_Q refer to the control catchment area of the damsite, Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station respectively.

According to Chinese specification requirements and design demands, an upper and lower damsites are proposed preliminarily at this stage, with an area between the two damsites of 2,100 km². The monthly average flow at the upper damsite in April 1967~2015 is calculated as per the formula above. The monthly average flow at the upper damsite in 1960~March 1967 is derived and calculated through correction of monthly average flow of Luang Prabang Hydrologic Station as per area ratio.

The monthly mean annual flow of the upper damsite is 4060 m³/s and the corresponding annual runoff is 128 billion m³ based on the statistics of monthly average flow in 56 years from 1960 to 2015. Refer to Table 2.3-1 for mean monthly flow at the upper damsite. Mean Annual Flow at Upper Damsite is shown in Fig.2.3.2-1.

Table 2.3-1 Mean monthly Flow at Upper Damsite unit:m³/s

Month	January	February	March	April	May	June	July	August	September	October	November	December	Year
Q	1740	1310	1120	1150	1690	3210	6610	10250	9280	5880	3810	2440	4060
%	3.59	2.70	2.31	2.37	3.49	6.62	13.63	21.14	19.14	12.13	7.86	5.03	100

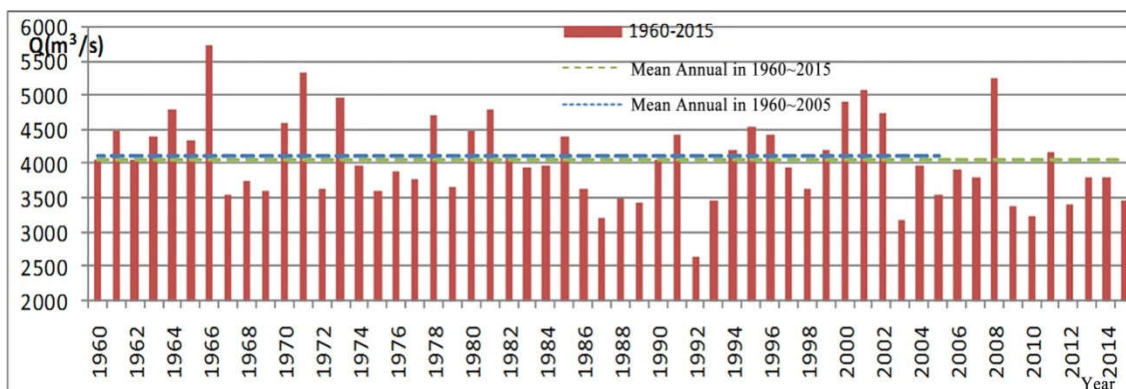


Fig. 2.3.2-1 Column of Mean Annual Flow at Upper Damsite

Through analyses on the calculated monthly average flow data at the upper damsite over the years, the ratio between the maximum monthly average flow and minimum monthly average flow of each year is 3.62~17.2. The maximum monthly average flow is 17,400 m³/s (August 1971), being 27.5 times as the minimum monthly average flow (633 m³/s, March 2004), while the maximum annual average flow is 5,720 m³/s (1966), being 2.17 times as the minimum annual average flow (2,630 m³/s, 1992). Through analyses on the statistical results of mean monthly flow over the years, the maximum monthly average flow accounts for 21.14% of the mean annual flow, while the minimum monthly average flow only accounts for 2.31%. The total flow in July to October accounts for 66.03% of the mean annual flow over the years, while that in January to May and in December (6 months in total) accounts for 19.49% of the mean annual flow. Therefore, the annual variance of runoff within the damsite reach is relatively large, while the inter-annual variance is relatively small.

2.3.3 Analysis on Reasonability of Runoff Results at Damsite

The Pak Lay Damsite is located between Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station. The runoff series of these two hydrologic stations are over 30 years and are all compiled and printed by Mekong River Commission; thus, it is suitable to use the runoff data from these two hydrologic stations in linear interpolation algorithm to calculate the runoff data at the Damsite, and the basic data taken as bases are reliable with the accuracy meeting design requirements in this phase.

According to comparison and analysis on runoff results of upstream and downstream hydrometric stations and each cascade, the runoff at the damsite is basically in coordination with the runoff results of upstream & downstream hydrometric stations and each cascade and basically conforms to the characteristic of rainfall reduction between Luang Prabang and Chiang Khan within such area. Thus, the runoff results calculated for Pak Lay Damsite in this phase is basically reasonable. Refer to Table 2.3-2 for the runoff characteristics at upstream and downstream hydrometric stations, and refer to Table 2.3-3 for the runoff characteristics at upstream and downstream cascade hydropower stations.

Table 2.3-2 Runoff Characteristics at Upstream and Downstream Hydrometric Stations

Name of station	Area (km ²)	Series	Annual average flow	Runoff modulus (L/(s×km ²))
Chiang Saen	189000	1962~2005	2678	14.17
Luang Prabang	268000	1960~2005	3945	14.72
		1960~2015	3880	14.48
Chiang Khan	292000	1968~2005	4253	14.57
		1968~2015	4240	14.52

Table 2.3-3 Runoff Characteristics at Upstream and Downstream Cascade Hydropower Stations

Damsite	Area (km ²)	Series	Annual average flow	Runoff modulus (L/(s×km ²))
Xayaburi	272000	1960~2005	3977	14.62
Pak Lay	278400	1960~2005	4110	14.76
		1960~2015	4060	14.58
Sanakham	290100	1923.4~2004.5	4410	15.2

2.3.4 Design Runoff at Damsite

The runoff series at Pak Lay Damsite in 1960~2015 is analyzed, and is 56-year long, including two longer dry periods of 1986~1993 and 2009~2015, wet periods of 1960~1966 and 1999~2002 as well as wet years alternating with dry years in other time periods with alternate wet, normal and dry seasons. As per analyses on the accumulative annual average flow hydrograph of the damsite, the accumulative average flow of about 30 years trends to

be stable. Refer to Fig. 2.3.4-1 for the residual mass curve and cumulative mean hydrograph of annual runoff series at Pak Lay Damsite.

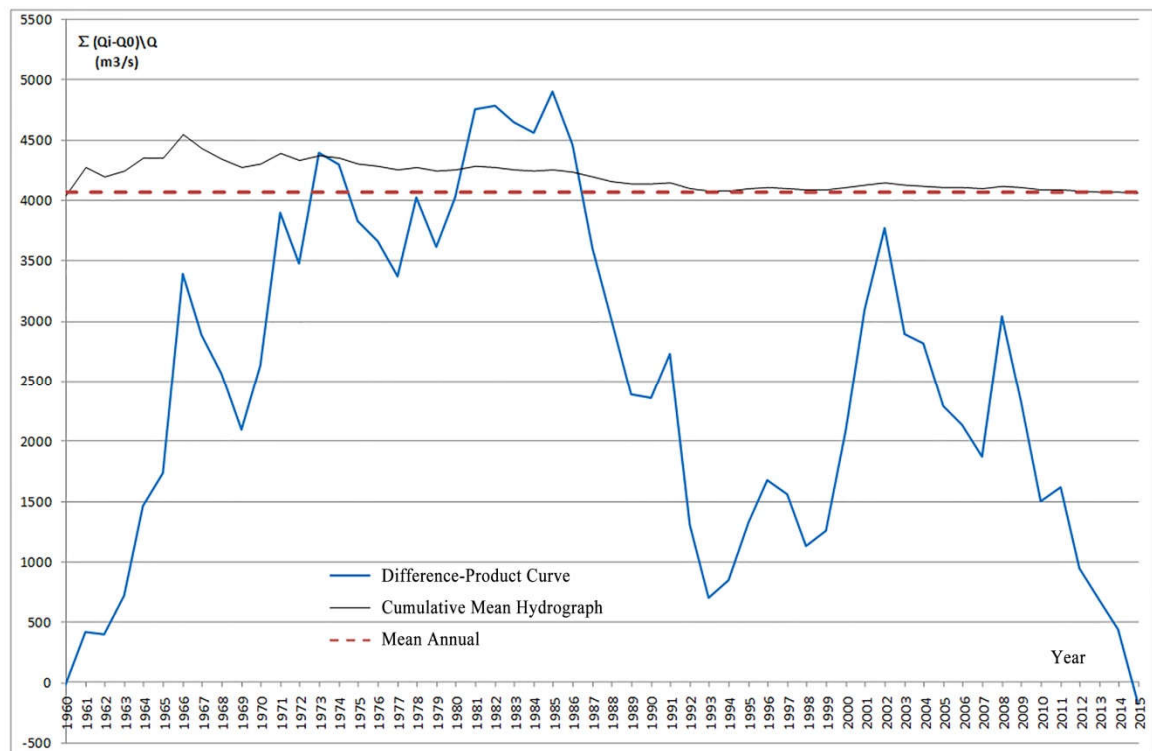


Fig. 2.3.4-1 Residual Mass Curve and Cumulative Mean Hydrograph of Annual Runoff Series at Pak Lay Damsite

According to the calculated annual average flow at the upper dams site over the years of 1960~2005, P-III type frequency curve is adopted, and statistical parameters are adjusted and determined as per the curve fitting method. Refer to Fig. 2.3.4-2 for the frequency curve of annual average flow at the dams site, and refer to Table 2.3-4 for the design results.

Table 2.3-4 Design Results for Annual Average Flow at Upper Damsite flow unit: m^3/s

Statistical parameters			P(%)								
Mean value	Cv	Cs/Sv	2	5	10	20	25	50	75	90	95
4060	0.155	2.5	5480	5160	4890	4570	4460	4020	3620	3280	3100

2.3.5 Daily Runoff at Damsite in Design Representative Year

As per design demands, the mean daily flow of 5 representative years is calculated

in this phase. The annual average flow frequencies of the 5 representative years are 10%, 25%, 50%, 75% and 90%, and the data from downstream Chiang Khan Hydrologic Station are adopted for these representative years. According to the principle that the experience frequency of annual average flow at Chiang Khan Hydrologic Station is close to the design frequency, principle of uneven annual runoff distribution and other basic principles, the daily average flow data from Chiang Khan Hydrologic Station over the 5 representative years are selected, and the mean daily flow of the representative years is processed as per the ratio between design annual flow and annual flow of representative years; thus, the mean daily flow data of the damsite in the 5 representative years are obtained. See Tables 2.3-5(a), 2.3-5(b), 2.3-5(c), 2.3-5(d) and 2.3-5(e).

Table 2.3-5(a) Daily Average Flows of Representative Year p=10%

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov..	Dec..
1	2060	1450	1340	1120	1590	3370	6350	11500	9080	8090	4620	2600
2	2010	1450	1400	1130	1680	3760	6630	10400	10200	8080	4660	2550
3	1980	1460	1450	1150	1740	3900	6770	9640	12400	7490	4610	2520
4	1940	1460	1500	1170	1810	3860	6850	9070	14200	6740	4550	2520
5	1910	1470	1590	1190	1910	3860	6970	8480	15500	6510	4790	2540
6	1890	1530	1720	1210	1980	3920	6940	8160	17500	6530	4840	2580
7	1890	1650	1780	1250	2010	3830	6580	8130	18500	6760	4550	2600
8	1900	1730	1680	1260	2020	3670	6390	8880	19000	7060	4170	2570
9	1900	1670	1530	1220	2020	3660	6320	10200	19800	7340	3940	2530
10	1850	1570	1430	1180	2090	3720	6530	11100	17600	7560	3800	2500
11	1800	1480	1360	1150	2220	3760	7790	11400	15900	7480	3710	2430
12	1780	1440	1330	1150	2430	3660	9760	11200	14600	7050	3570	2350
13	1750	1410	1300	1180	2750	3390	11600	10800	14300	6590	3450	2290
14	1730	1370	1280	1220	2960	3350	13000	10200	14300	6280	3420	2280
15	1740	1350	1270	1280	3020	3540	12900	9580	13700	5750	3370	2280
16	1740	1340	1260	1350	2980	3660	12200	9260	13000	5240	3280	2240
17	1710	1320	1250	1400	2980	3950	12100	8980	12200	4900	3220	2180
18	1680	1300	1240	1430	3000	4760	12000	8670	11800	4750	3180	2140
19	1650	1300	1230	1440	3050	6150	12200	8840	11500	4750	3120	2110
20	1620	1290	1220	1460	3370	7670	12600	9230	10900	4690	3080	2100
21	1600	1280	1210	1470	4490	8520	12900	9460	10200	4510	3080	2080
22	1570	1280	1200	1460	5300	8630	13100	9760	9580	4410	3060	2050
23	1560	1290	1180	1450	5520	8290	13300	9840	9220	4450	3000	2010
24	1540	1310	1160	1440	5830	7700	14000	9680	9160	4670	2900	1990
25	1530	1310	1150	1440	5750	7180	14400	9820	9070	4780	2840	1960
26	1530	1290	1140	1430	5250	6860	14600	10100	8900	4970	2800	1930
27	1530	1270	1130	1430	4700	6570	14900	10100	8670	4830	2760	1940
28	1550	1270	1130	1470	4210	6290	14900	9460	8570	4640	2700	1980
29	1550	1280	1120	1490	3660	6030	14300	8910	8470	4510	2630	2000
30	1510		1120	1510	3290	6010	13500	8680	8130	4470	2600	1960
31	1470		1120		3190		12600	8750		4520		1920

Table 2.3-5(b) Daily Average Flows of Representative Year p=25%

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov..	Dec..
1	1680	1190	931	834	873	1840	6130	11400	13500	8220	5220	2720
2	1650	1180	915	840	907	1750	6890	11000	14200	8350	4920	2670
3	1640	1160	900	843	938	1700	7110	10800	14800	8390	4750	2630
4	1620	1150	884	851	1010	1880	6620	10300	15400	8500	4550	2580
5	1600	1130	877	866	1100	2200	6770	9590	16800	8690	4370	2510
6	1580	1120	873	904	1100	2230	6580	9020	16700	8780	4280	2470
7	1560	1110	869	934	1050	2180	5880	8880	16600	8670	4170	2430
8	1550	1100	863	938	1000	2150	5140	9100	16600	8830	4100	2390
9	1530	1080	857	923	985	2090	4550	8980	15300	8760	4000	2340
10	1520	1070	851	923	994	1980	4200	8610	14200	8610	3930	2310
11	1510	1050	849	919	1000	1920	4010	8690	13500	8830	3840	2270
12	1490	1040	860	911	1010	2090	3990	9080	13200	9510	3770	2260
13	1470	1040	869	907	1030	2360	4280	8900	12900	9370	3650	2240
14	1460	1030	877	892	1070	2450	4660	8630	12600	9060	3480	2220
15	1450	1020	869	884	1090	2490	4680	8630	12600	8690	3420	2240
16	1430	1010	866	869	1100	2740	4660	8690	12900	7980	3340	2280
17	1420	1010	877	863	1120	3130	5610	8720	13100	7180	3260	2370
18	1410	1000	869	857	1140	3420	6280	8870	14300	6710	3210	2400
19	1390	994	857	860	1150	3460	7110	9620	13300	6490	3160	2380
20	1370	985	849	863	1110	3800	7420	10200	12100	6460	3100	2330
21	1350	985	840	869	1100	4830	7410	11500	10800	6400	3040	2260
22	1330	975	834	888	1180	5520	8370	13100	9850	6390	2980	2210
23	1310	975	828	900	1810	5410	8170	14100	9120	6220	2930	2150
24	1290	985	820	919	1710	5040	9850	14400	8590	5960	2890	2100
25	1280	985	814	938	1510	5050	11000	16000	8350	5700	2840	2050
26	1270	985	811	946	1420	5410	11800	16800	8220	5440	2800	2020
27	1260	975	805	938	1410	5540	12100	16800	7950	5270	2770	2000
28	1250	962	805	911	2040	5760	13100	16400	7790	5040	2760	1990
29	1240	946	811	900	2290	6080	13000	15600	7870	5430	2740	1980
30	1220		820	892	2040	6260	12800	14900	8050	5920	2730	1950
31	1200		831		1910		12100	14000		5690		1920

Table 2.3-5(c) Daily Average Flows of Representative Year p=50%

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov..	Dec..
1	1770	1230	1010	813	856	4490	7300	15700	7000	6690	4710	2560
2	1740	1220	1030	811	860	4860	7530	15500	6640	6580	4890	2520
3	1720	1220	1050	808	871	5470	6840	14800	6490	6550	4940	2490
4	1710	1200	1040	808	890	6330	6220	13800	7060	6510	4770	2460
5	1690	1190	1020	816	905	6490	7110	12900	7030	6440	4510	2430
6	1680	1160	1000	822	924	6350	8270	11800	7110	6530	4250	2410
7	1660	1160	972	833	944	6320	9630	10700	7110	6730	4110	2380
8	1650	1140	954	845	982	6690	9720	10100	7010	6890	3940	2370
9	1630	1140	931	868	1010	6960	9150	9720	7130	7240	3830	2340
10	1600	1130	935	875	1060	6430	8270	9260	7090	7350	3870	2330
11	1590	1110	944	864	1180	5730	7480	8680	6890	7150	3940	2330
12	1560	1080	954	853	1260	5250	7010	8320	6730	6960	3880	2330
13	1530	1070	972	841	1230	4900	6690	8050	6680	7300	3870	2330
14	1510	1050	991	833	1180	4670	6640	7820	6710	7620	3860	2250
15	1500	1030	1010	827	1090	4710	6960	7550	6680	7480	3870	2200
16	1480	1020	1030	819	1070	4810	7050	7210	6730	7180	3860	2140
17	1470	1010	1050	808	1080	4880	6640	7010	6670	6820	3660	2100
18	1460	1010	1060	791	1090	4810	6470	6860	6680	6440	3450	2070
19	1440	991	1050	782	1270	4760	6540	6720	6430	6040	3250	2030
20	1420	972	1020	780	1420	4850	7010	6490	6250	5730	3130	2000
21	1400	963	1000	777	1630	4550	7840	6200	6380	5500	3020	1980
22	1380	935	991	774	2230	4590	8590	5940	6830	5350	2940	1960
23	1360	931	972	771	3310	4800	9910	5640	7000	5220	2890	1940
24	1350	935	954	791	3800	5100	10800	5380	7110	5060	2830	1920
25	1330	935	935	841	3500	5430	11400	5240	7390	5000	2780	1910
26	1310	954	916	883	3130	6060	12200	5170	7270	5140	2720	1880
27	1290	972	894	890	2870	7150	12400	5570	7180	5240	2670	1860
28	1280	991	875	879	2760	7290	12600	6500	6920	4920	2650	1860
29	1270		853	868	2820	6970	13100	6660	6860	4650	2610	1850
30	1260		839	856	3180	6780	13100	6780	6840	4440	2580	1850
31	1240		827		3800		14500	7160		4510		1820

Table 2.3-5(d) Daily Average Flows of Representative Year p=75%

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov..	Dec..
1	2300	1650	1240	968	1370	2400	4000	13100	6650	4820	4830	2580
2	2280	1640	1230	959	1450	2410	3600	12600	6270	4590	4510	2540
3	2250	1740	1220	950	1500	2210	3230	12100	6130	4490	4190	2500
4	2200	1610	1200	940	1540	2120	2970	11800	6000	4530	3970	2460
5	2170	1590	1190	940	1580	2200	2740	11400	6060	4490	3800	2440
6	2160	1570	1180	940	1640	2280	2580	10500	6340	4470	3680	2410
7	2150	1560	1180	940	1610	2300	2440	9780	6750	4420	3570	2390
8	2130	1540	1170	940	1600	2260	2340	9340	7380	4340	3500	2360
9	2120	1520	1170	936	1570	2170	2360	8740	7910	4250	3420	2340
10	2100	1520	1180	940	1720	2090	2600	8350	8420	4250	3380	2320
11	2070	1500	1170	950	2170	1980	3020	7910	8090	4640	3350	2290
12	2040	1500	1180	959	2580	1900	4630	7440	8170	5550	3250	2260
13	2010	1490	1180	968	2660	1900	5270	7090	8110	6530	3220	2220
14	1990	1470	1170	978	2630	1960	4950	6600	7940	9090	3210	2200
15	1970	1450	1150	978	2670	2210	4640	6410	7570	10700	3300	2170
16	1960	1450	1140	978	2650	2870	4800	6480	7410	9400	3610	2140
17	1950	1430	1120	978	2570	2910	4370	6590	7150	10800	3980	2140
18	1920	1410	1100	997	2450	2830	4450	6690	6960	9500	3980	2160
19	1920	1390	1090	997	2230	3000	4260	6390	7070	8170	3790	2160
20	1900	1370	1070	997	2090	3080	4320	6600	7390	7200	3610	2140
21	1870	1350	1060	997	1970	3310	4550	6810	7000	6530	3410	2110
22	1840	1340	1050	997	1830	3630	5440	6510	6820	6000	3210	2070
23	1820	1330	1040	997	1810	3830	6590	6160	6820	5630	3070	2050
24	1810	1320	1030	1020	1920	3950	8000	6060	7090	5440	2980	2010
25	1790	1290	1020	1080	2200	4340	9680	6010	7100	6790	2900	1980
26	1790	1280	1010	1110	2520	4760	10500	6480	6650	5930	2820	1950
27	1770	1260	1010	1160	2750	4680	10900	7980	6060	5350	2760	1920
28	1750	1250	1010	1220	2980	4640	11800	7950	5630	4880	2700	1900
29	1730		997	1300	3200	4590	12000	7700	5310	4750	2660	1880
30	1700		987	1350	3070	4450	12600	7380	4960	4930	2620	1860
31	1670		978		2900		13100	7070		5050		1840

Table 2.3-5(e) Daily Average Flows of Representative Year p=90%

Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov..	Dec..
1	1650	1360	733	730	1260	1430	2650	6510	11200	7890	4840	2240
2	1570	1320	727	709	1310	1600	2670	6290	10500	7890	4910	2200
3	1470	1280	719	750	1320	1800	2850	6430	9490	7790	4850	2160
4	1440	1270	733	796	1340	1840	3020	7160	8800	7420	4680	2160
5	1410	1260	747	836	1280	1750	3060	7590	8090	6960	4310	2200
6	1380	1240	744	847	1200	1830	3060	7270	7710	6700	4000	2200
7	1380	1210	747	847	1160	2020	2980	7700	7140	6170	3920	2210
8	1360	1180	747	859	1140	2180	2950	7740	6650	5670	3890	2350
9	1350	1140	754	886	1110	2510	2940	7370	6270	5350	3730	2160
10	1330	1090	754	890	1080	2470	2790	7360	6080	5190	3560	2160
11	1320	1050	771	886	1040	2680	2650	7220	5980	5030	3420	2150
12	1310	1010	782	878	1030	2660	2900	7260	6350	4890	3350	2070
13	1300	997	779	870	1030	2560	3240	7730	6740	4930	3100	1980
14	1340	960	779	870	1050	2380	3360	7730	7270	5230	3150	1950
15	1340	901	779	878	1110	2210	3420	7650	7770	6020	3250	1960
16	1280	863	793	890	1150	2030	3270	7820	9330	6440	3010	1970
17	1280	855	844	893	1160	1910	3110	7490	9870	6260	2980	2040
18	1330	833	863	901	1140	1780	3150	7480	10300	5970	2980	2180
19	1400	818	840	924	1120	1570	3450	8460	10500	5870	2970	2350
20	1430	804	829	956	1150	1650	3830	9230	9890	6080	2920	2480
21	1400	796	825	964	1200	1570	4740	8880	9490	5920	2870	2420
22	1480	789	829	944	1240	1650	5010	9590	8930	5560	2840	2280
23	1500	782	818	932	1220	1760	4820	9630	8440	5080	2800	2070
24	1540	782	807	952	1170	1820	4940	9300	8190	4870	2690	1880
25	1610	771	818	968	1150	1890	5440	8760	8090	4940	2630	1800
26	1630	758	825	984	1120	2100	6020	8490	7800	5010	2590	1790
27	1590	754	800	1010	1120	2320	6920	8280	7590	5240	2540	1760
28	1510	744	768	1030	1140	2540	8080	8160	7940	5230	2480	1730
29	1490		761	1120	1200	2660	8140	8580	7830	5060	2400	1720
30	1460		768	1180	1260	2690	7670	10600	7830	4990	2300	1700
31	1410		758		1260		7120	11500		4830		1700

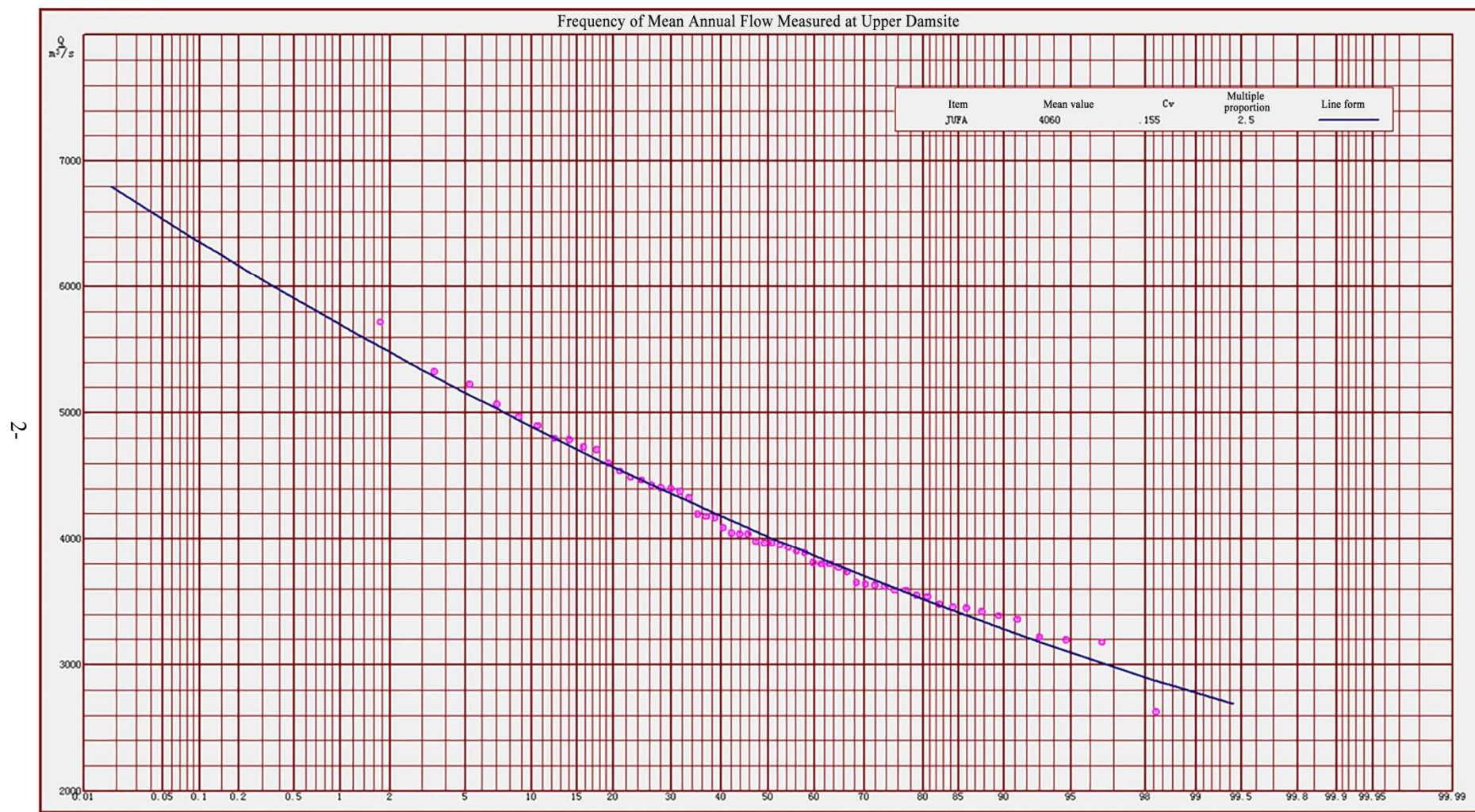


Fig. 2.3.4-2 Mean Annual Flow-Frequency Curve at Upper Damsite

2.3.6 Design Results of Monthly Average Flow at Damsite

According to design demands, the statistical parameters are adjusted and determined by use of the curve fitting method and the design results of monthly average flow at the upper dams site are analyzed and calculated based on the monthly mean flow series in 1960~2015 at the upper dams site, in accordance with the calculated monthly average flow at the upper dams site as well as the experience frequency calculation formula and P-III type theoretical frequency curve specified in Chinese codes. Compared with the calculation results of former series in 1960~2005, the relative variation of monthly frequency design value being 2%~85% shift within -3.99%~8.28%. Number, whose variation is within $\pm 3\%$, accounts for 68% of the total number. After the period of monthly mean flow series is extended to 1960~2015, different frequency design values in each month are shown in Table 2.3-6.

Table 2.3-6 Design Results of Monthly Average Flow at Upper Damsite Unit: m^3/s

Month	P(%)						
	2	5	10	20	50	75	85
January	2590	2380	2210	2010	1690	1490	1390
February	1890	1760	1640	1510	1290	1130	1060
March	1550	1450	1360	1260	1090	960	898
April	1570	1470	1380	1290	1120	994	933
May	3020	2660	2380	2080	1600	1310	1190
June	5800	5130	4590	3990	3050	2460	2200
July	12100	10700	9530	8270	6260	5010	4470
August	17000	15300	13900	12400	9940	8320	7570
September	15200	13600	12400	11000	8900	7580	7010
October	8440	7810	7290	6710	5750	5110	4820
November	6700	5880	5240	4560	3570	3030	2820
December	3950	3530	3190	2840	2320	2030	1920

2.3.7 Runoff at Dam Site Influenced by Upstream Cascade

From the collected materials in the present, the monthly runoff influenced in the upstream cascade

during 1960~2005 subtracts the natural monthly runoff, and runoff influenced by the adjustment of Nuozhadu hydroelectric station and Xiaowan hydroelectric station in 1960~2005 can be calculated. Besides, from the monthly runoff at the Pak Lay Upper Damsite on natural conditions, results of the monthly runoff at the Pak Lay upper Damsite influenced by Xiaowan Hydropower Station and Nuozhadu Hydropower Station in 1960-2005. Refer to Table 2.3-7 for mean monthly flow.

Table 2.3-7 Mean Monthly Flow at Upper Damsite

Unit: m³/s

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Natural Q	1730	1300	1070	1090	1640	3290	6830	10400	9460	5980	3880	2440	4110
Influenced Q	2550	2220	2030	2000	2090	3050	5320	8480	8440	5770	4040	3020	4110
Difference value	820	920	960	910	450	-240	-1510	-1920	-1020	-210	160	580	0

Note: The series ranges from 1960 to 2005.

2.3.8 Analysis of Impact of Climate Change on Runoff

Regions where the Mekong River flows through are of sub-tropical monsoon climate and tropical monsoon climate as well as are mountainous. The overall rainfall is rich and the river flow is big. Due to the mountainous terrain, the terrain plays an important influence on the rainfall distribution.

As the climate change is a kind of natural phenomenon, the impacts of the climate change in regions where the Mekong River flows through on the hydrological situation lie in that, temporal and spatial distribution of rainfall is more uneven, channeled runoff varies greatly, and the climate change can easily make it drier or cause the occurrence of flood in local regions. For example, the drought hit the Mekong River Basin from September 2009 to March 2010. The mean rainfall of the upstream Lantsang Basin is only 37 mm during the corresponding period and is 65% less than that during the corresponding period in ordinary years. Its inflow is over 50% less than that during the corresponding period in ordinary years, hitting a record all-time low during the corresponding period over the years.

According to related research results for predication of the climatic change in Mekong River Basin, based on the time of the 1980s, the air temperature in Mekong River Basin

will rise to a degree in the future 20 or more years, and variation range is great and lasts for a long time in the northern area; the mean annual precipitation will increase by 4%, and its distribution is extremely uneven. For the predication of river inflow, the runoff in the future 20 or more years will 15% higher than the mean annual runoff in 1960~2000 reference period, the maximum runoff will be 18% higher and the minimum runoff will be 3% lower. Some researches indicated that the inter-annual evolution of channeled runoff differs greatly. The period of 9~10 years of runoff during worst dry season exists stably for a long time, and its stability strengthens with the decrease of latitude, indicating that the solar activity obviously influences the channeled runoff of Mekong River during worst dry season.

From the research results above, the characteristics of runoff change will correspondingly influence the runoff of the Project. From analysis for variation trend of the difference product curve of runoff series at the damsite and the moving average line for 10 years, the difference product curve of runoff series at damsite and the moving average line will probably change upward, and the runoff will probably enter into the step-by-step rising stage influenced by the increased precipitation in the future.

2.4 Flood

2.4.1 Characteristics of Storm Flood

As the largest river in Southeast Asia region, Lantsang-Mekong flows through 26° in latitude and 16° in longitude. Due to the large north-south span and terrain effects, the climate characteristics of upper reach and lower reach within the basin are obviously different, and the factor, size and other aspects of storm and flood are also largely different.

According to relevant statistical data, the precipitation within the river basin generally trends to diminish from the lower reach to the upper reach due to effects of latitude and southwest monsoon. In the process of going north, the humid air brought by the southwest monsoon reduces due to rainfall along the process, resulting in the diminishing trend of rainfall along the process. The annual precipitation is less than 1,000 mm in the upper reach of Lantsang and about 1,500 mm in the lower reach, while the annual average precipitation of lower Mekong River Basin is more than 1,500 mm. Because orographic

rains are generated in some regions due to orographic influences, the annual precipitation in such regions is large, such as Bolaven Plateau, Cammon Plateau and Tran Ninh Plateau regions, among which the annual precipitation in Paksong of Bolaven Plateau is up to 3,987 mm.

In the Mekong River Basin within Laos, Vientiane, Phonsavan, Pakxan, area to the south of Se Bang Hieng River in the south and upstream area of Nam Ou River in the north are areas with relatively frequent rainstorms. According to relevant statistical data, Chang Rai Precipitation Station within Thailand is with a mean annual precipitation of 1,730 mm, maximum mean monthly precipitation of 390 mm (August) and maximum monthly precipitation over years up to 600 mm. In the Sayabuary Meteorological Station upstream from Pak Lay Damsite, the maximum mean monthly precipitation is 233.7 mm (August), and the precipitation from May to September is 1,107.9 mm; rainstorms mainly appear in May~September.

The flood in Mekong River Basin is caused by torrential rain. The flood and torrential rain appear almost in the same period of the year. Due to differences in the precipitation characteristics between Lantsang River Basin and Mekong River Basin, the flood correspondence between these two basins is relatively poor.

Through analyses on collected hydrological data of Mekong River Basin, the flood period of river reaches near to Pak Lay Damsite generally is June~October, and the maximum annual peak discharge mainly occurs in July~September. Through analyses on maximum annual flow data of Chiang Khan Hydrologic Station over the years, the maximum annual flood falls in August and September with probability of 60% and 38% respectively; therefore, the maximum annual flood in the river reaches near to Pak Lay Damsite mainly falls in August and September.

Since the measured data from hydrologic stations upstream and downstream from Pak Lay Damsite became available, the maximum flood fell in September 1966. In such year, the maximum peak discharge at Luang Prabang Hydrologic Station is 25,200 m³/s; there is no measured flow data from Chiang Khan Hydrologic Station with a measured maximum

water level of 18.12 m; the maximum peak discharge of Vientiane Hydrologic Station is 26,000 m³/s. During the flood period in 2008, Chiang Khan Hydrologic Station is with a measured maximum water level of 16.80 m and corresponding flow of 25,560 m³/s, while Pak Lay Gauging Station is with a maximum water level of 15.12 m.

The characteristics of flood near Pak Lay Damsite are: large flood volume, relatively small floor peak and relatively fat process shape. According to the statistical data from Chiang Khan Hydrologic Station, the maximum flood volume for 1d accounts for about 34% of the maximum flood volume for 3d, the maximum flood volume for 3d accounts for about 64% of the maximum flood volume for 7d, the maximum flood volume for 7d accounts for about 71%~77% of the maximum flood volume for 15d, the measured annual average maximum peak discharge is 16,000 m³/s, and the maximum peak discharge is about 26,000 m³/s.

2.4.2 Design Flood at Basis Station

2.4.2.1 Chiang Khan Hydrologic Station

Chiang Khan Hydrologic Station is 112 km downstream from the damsite, and the area between the both accounts for 4.9% of the control area of the damsite. According to the collected data in hydrologic year books of Mekong River, and by use of the maximum peak discharge (basically, maximum daily average flow) at Chiang Khan Hydrologic Station over the years since 1967, statistical calculations are made on the maximum flood volumes of 1d, 3d, 5d, 7d, 15d and 30d over the years to determine the measured annual maximum flood peak and flood volume series of such station.

In 1966, a great flood happened in Mekong River Basin, and there is no measured flow data from Chiang Khan Hydrologic Station in 1966; in accordance with the maximum water level measured by the station in such year and stage discharge relations in 1967, 1969, 1970 and 1971, the maximum flow in 1966 is preliminarily calculated in this phase, and in reference to the maximum peak discharges of 1966 from the upstream Luang Prabang Hydrologic Station and the downstream Vientiane Hydrologic Station, the maximum flood volume of 1966 calculated and adopted in this phase is 26,000 m³/s. The

maximum flood volumes of 1d, 3d, 5d, 7d, 15d and 30d in 1966 are deduced and calculated as per the peak discharge measured by the Station and the relations between flood volumes in each period.

There are no available historical flood survey data from Chiang Khan Hydrologic Station. According to relevant requirements in Chinese hydropower design specifications, the historical flood data of the Station are analyzed based on the upstream and downstream flood data while calculating the design flood of the Station.

In the upper reach of Mekong River, the water channel between Vientiane Hydrologic Station and Luang Prabang Hydrologic Station is about 426 km long, and the area between the both is about 31,000 km² (among which, the area between Chiang Khan Station and Vientiane Station is about 24,000 km²), accounting for 10.4% of the control catchment area of Vientiane Hydrologic Station, being 11.8% of the control catchment area of Luang Prabang Hydrologic Station. According to the collected and known flood data, the flood at Vientiane Hydrologic Station in September 1966 is the largest flood since 1913, which is with a peak discharge of 26,000 m³/s; the peak discharge of the flood in 1929 is 25,300 m³/s; the flow at Vientiane Station is 21,200 m³/s corresponding to the flood in Lantsang River Basin in 1924; analyzed by Mekong River Commission in September 2008, the flood peak discharge in August of such year is 23,500 m³/s. A great flood also fell in 1942, 1970, 1971, 2002 and other years.

At Luang Prabang Hydrologic Station, the flood in 1966 is the largest flood since 1950 when measured flow data are available, which is with a peak discharge of 25,200 m³/s (daily average flow, the daily average flow in two days before and after it is 23,500 m³/s and 24800 m³/s respectively); the peak discharge in August 2008 is 23,100 m³/s (analyzed by Mekong River Commission in September, 2008); other floods before 1950 are not known.

At Chiang Khan Hydrologic Station, the peak discharge of 1966 is deduced as about 26,000 m³/s as per the measured water level and stage discharge relation as well as upstream and downstream flood data of such year; the peak discharge of 2008 provided by

the Mekong River Commission is 25,560 m³/s; floods before 1966 are not known.

Through preliminary analyses and judgments on the aforesaid data, the flood in 1966 is the first largest flood at Vientiane Station in Mekong River Basin since 1913. The peak discharge at Chiang Khan Hydrologic Station and that at Vientiane Hydrologic Station are different through comparison, which indicates that the flood source has certain effects on the peak discharges at the both stations. In consideration of the lack of historical data, the historical flood recurrence interval of such river reach is calculated from 1913 which is mentioned by Vientiane Station in the hydrologic year books. The floods in 1966 and 2008 are considered to be historical floods for Chiang Khan Hydrologic Station; however, the flood at Vientiane Station in 1929 reaches 25,300 m³/s, which is of same magnitude basically as that in 1966, while the peak discharges at both Chiang Khan Hydrologic Station and Vientiane Station are different through comparison, and it is hard to deduce whether the flood in 1929 is larger than that in 1966 or not in the flood analyses for Chiang Khan Hydrologic Station; thus, the flood in 1966 is deemed as the second largest flood and that in 2008 is deemed as the third largest flood for analyses and calculations during the ranking analysis of historical floods for Chiang Khan Hydrologic Station in this phase.

According to the ranking scheme of historical floods and the historical peak discharge data determined above as well as the measured flood series of 50 years from 1966 to 2015, the statistical parameters are adjusted and determined as per two different schemes (frequency analysis and calculation as per measured series; frequency analysis and calculation in consideration of historical floods) according to the experience frequency calculation formula and P-III theoretical frequency curve specified in Chinese specifications in this phase. Through analyses on frequency curve fitting drawing, changes in statistical parameters obtained as per two frequency analysis & calculation methods only have small effects on the frequency curve fitting results of the maximum annual flood peak and volume series at Chiang Khan Hydrologic Station; therefore, the analyzed and calculated design results for the maximum annual flood peak and volume at Chiang Khan Hydrologic Station are shown in Table 2.4-1 through analyses and comparisons in this

phase. Refer to Fig. 2.4-1(a) and Fig. 2.4-1 (b) for the drawing of frequency curve fitting results of the maximum annual peak discharges obtained as per the two frequency analysis methods.

The correlation among the actual measurement series of 1967~2015 is relatively favorable with a correlation coefficient of 0.988 through analyses on the maximum annual peak discharge at Chiang Khan Hydrologic Station and the 3d flood volume correlation diagram (Fig. 2.4-2). The design peak discharge and design 3d flood volume correlation points are close to the correlation line of actual measurement series, which indicates that the design values of peak discharge and 3d flood volume meet the actual flood situation and peak volume value in case of great flood. Therefore, the design flood results for the Station are reasonable basically. After the period of monthly mean flow series is extended to 1960~2015, the average annual value of measured maximum annual peak discharge and flood volume in each period decrease to a degree than those before the extension with parameters being basically the same at Chiang Khan Hydrologic Station. The corresponding design values for each frequency also decrease to a degree (see Table 2.4-1), the 1d flood volume, 3d flood volume, and design peak discharge decrease less than 4%.

Table 2.4-1 Frequency Calculation Results of Maximum Annual Flood Peak & Volume at
Chiang Khan Hydrologic Station $Q_m: m^3/s; W: 10^8 m^3$

Item	Statistical parameters			P(%)											
		Mean value	Cv	Cs/Cv	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
Previous FS	Qm	16800	0.24	3.5	39300	37800	35700	34100	32500	30300	28600	26800	24200	22200	19900
	W1d	14.2	0.24	3.5	33.3	32	30.2	28.9	27.5	25.6	24.1	22.6	20.5	18.8	16.8
	W3d	41.5	0.24	3.5	97.2	93.4	88.3	84.3	80.3	74.8	70.6	66.1	59.9	54.8	49.2
	W7d	91.8	0.24	3.5	215	207	195	187	178	166	156	146	132	121	109
Present FS	Qm	16200	0.25	3.5	39200	37600	35500	33800	32200	29900	28100	26300	23700	21600	19300
	W1d	13.7	0.24	3.5	32.1	30.8	29.1	27.8	26.5	24.7	23.3	21.8	19.8	18.1	16.3
	W3d	40.1	0.24	3.5	93.9	90.3	85.3	81.5	77.6	72.3	68.2	63.9	57.9	53	47.6
	W7d	88.1	0.24	3.5	206	198	187	179	171	159	150	140	127	116	105

2.4.2.2 Luang Prabang Hydrologic Station

The Luang Prabang Hydrologic Station is 181 km upstream from the damsite, accounting for 96.3% of the control catchment area of the damsite. The measured maximum annual flood peak series of the station is determined in accordance with the collected hydrologic year book data of Mekong River and supplemented materials as well as by use of the maximum peak discharge at Luang Prabang Hydrologic Station over the years since 1960.

Because the measured flow data series is the data obtained since 1960, analyses on historical flood data are added while calculating the design flood for the station according to relevant requirements in Chinese hydropower design specifications. The historical flood data adopted for Luang Prabang Hydrologic Station are the same as those adopted for Chiang Khan Hydrological Station in years, so as the ranking analysis.

According to the determined historical flood peak discharge data as well as the measured maximum annual flow series of 56 years from 1960 to 2015 at Luang Prabang Hydrologic Station, the statistical parameters are adjusted and determined as per two different schemes (frequency analysis and calculation as per measured series; frequency analysis and calculation in consideration of historical floods) according to the experience frequency calculation formula and P-III theoretical frequency curve specified in Chinese specifications in this phase. Through the analyses on the frequency curve fitting drawing, the changes in statistical parameters obtained as per the two frequency analysis and calculation schemes only have small effects on the frequency curve fitting results of the maximum annual flood peak series at Luang Prabang Hydrologic Station. Through analyses and comparison in this phase, refer to Table 2.4-2 for the analyzed and calculated design results of the maximum annual flow at Luang Prabang Hydrologic Station and refer to Fig. 2.4-3 (a) and Fig. 2.4-3 (b) for the frequency curve fitting result drawings of maximum annual flow obtained as per two frequency analysis schemes. After the period of monthly mean flow series is extended to 1960~2015, the average annual value of measured maximum annual flood peak discharge for the station decreases to a degree than it before

the extension. Cv is adjusted from 0.24 to 0.25, the corresponding frequency design values (see Table 2.4-2) decreases less than 2.4% before the extension.

Table 2.4-2 Frequency Calculation Results of Maximum Annual flow at Luang Prabang

Hydrologic Station unit: m³/s

Item		Statistical parameters			P(%)										
		Mean value	Cv	Cs/C _v	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
Qm	Previous FS	15800	0.24	3.5	37000	35600	33600	32100	30600	28500	26900	25200	22800	20900	18700
	Present FS	15300	0.25	3.5	37000	35500	33500	31900	30400	28200	26500	24800	22400	20400	18300

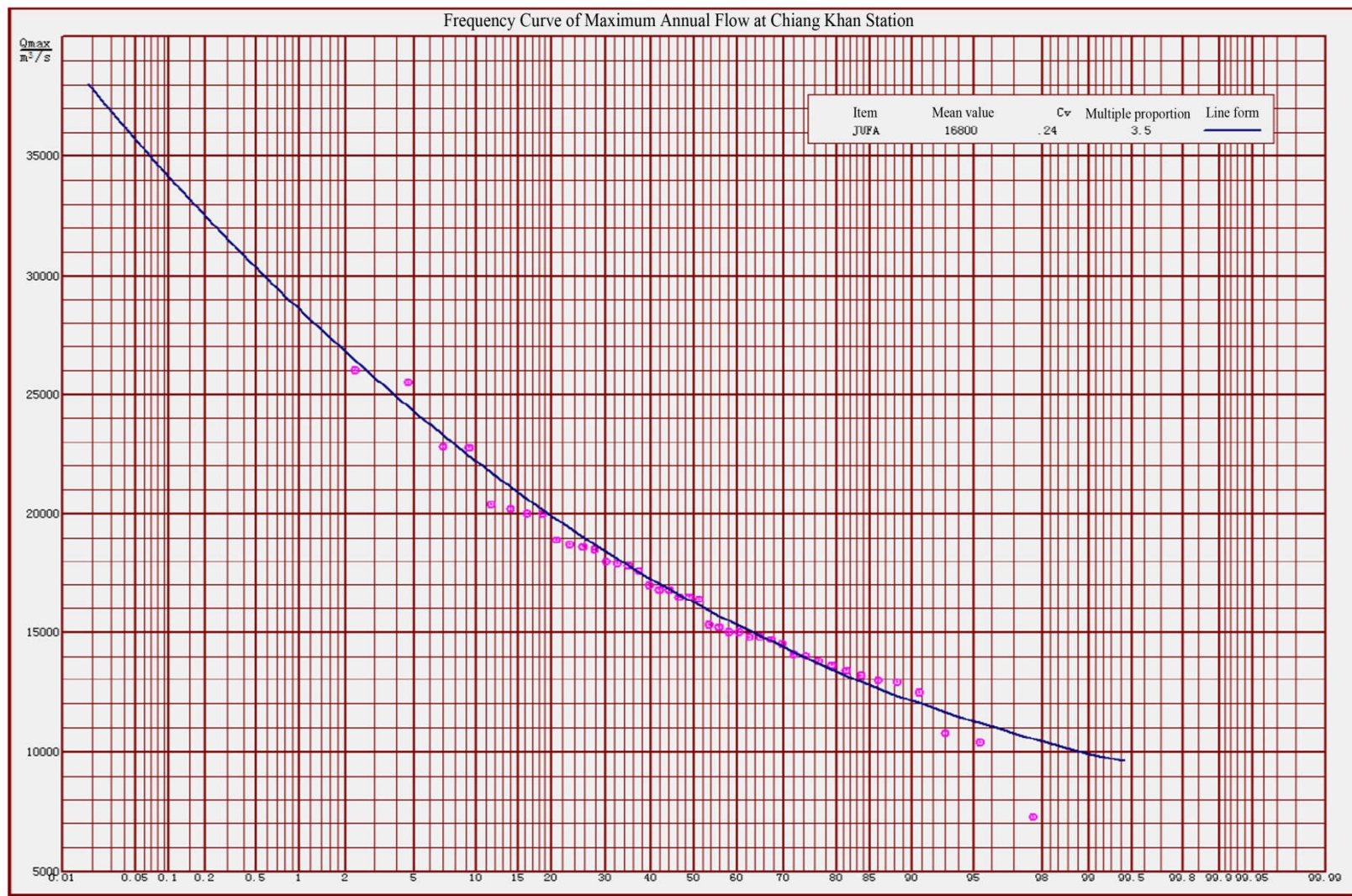


Fig. 2.4-1(a) Frequency Curve of Maximum Annual Flow at Chiang Khan Hydrologic Station (calculated as per measured series)

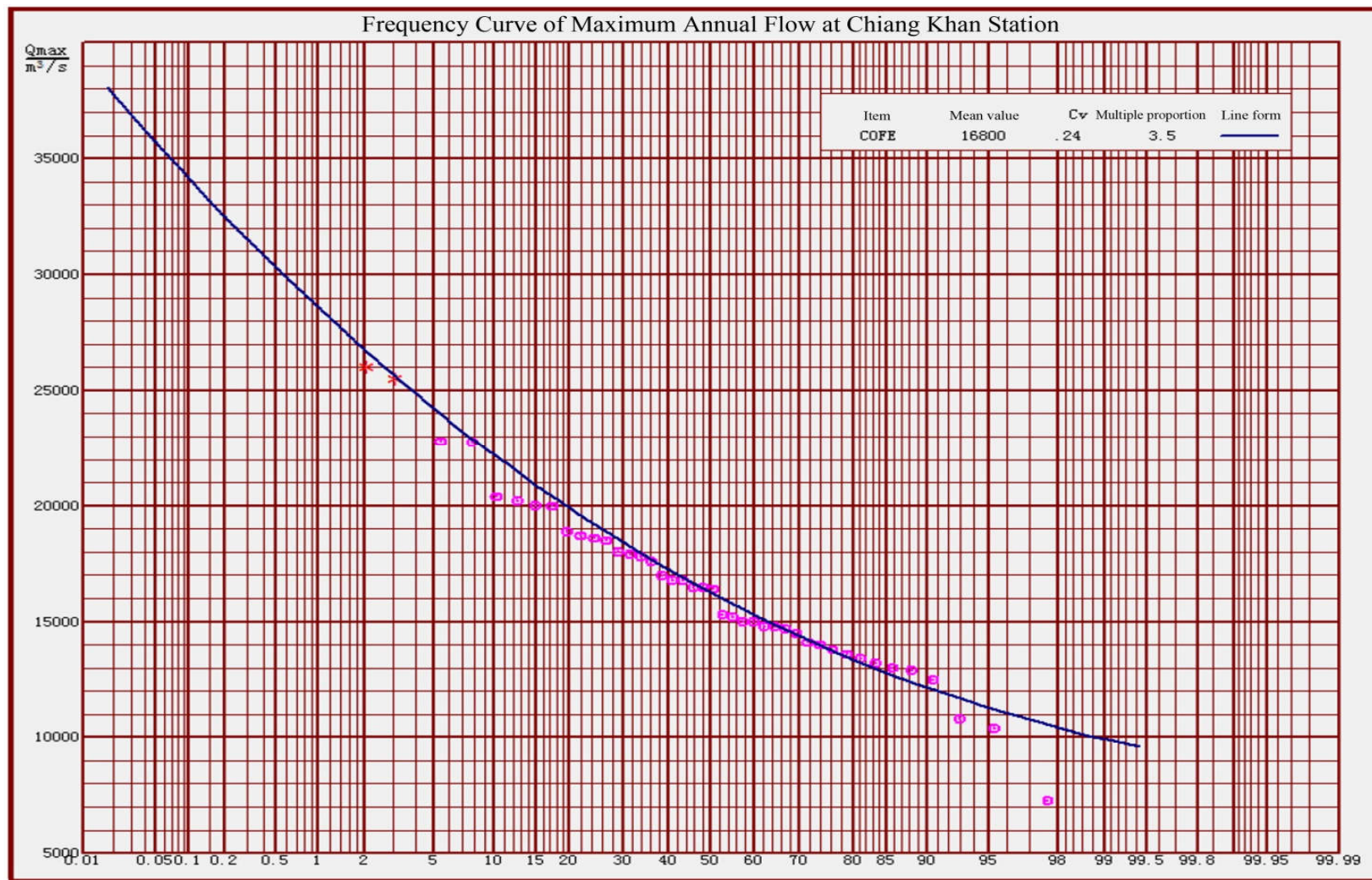


Fig. 2.4-1(b) Frequency Curve of Maximum Annual Flow at Chiang Khan Hydrologic Station (calculated in consideration of historical floods)

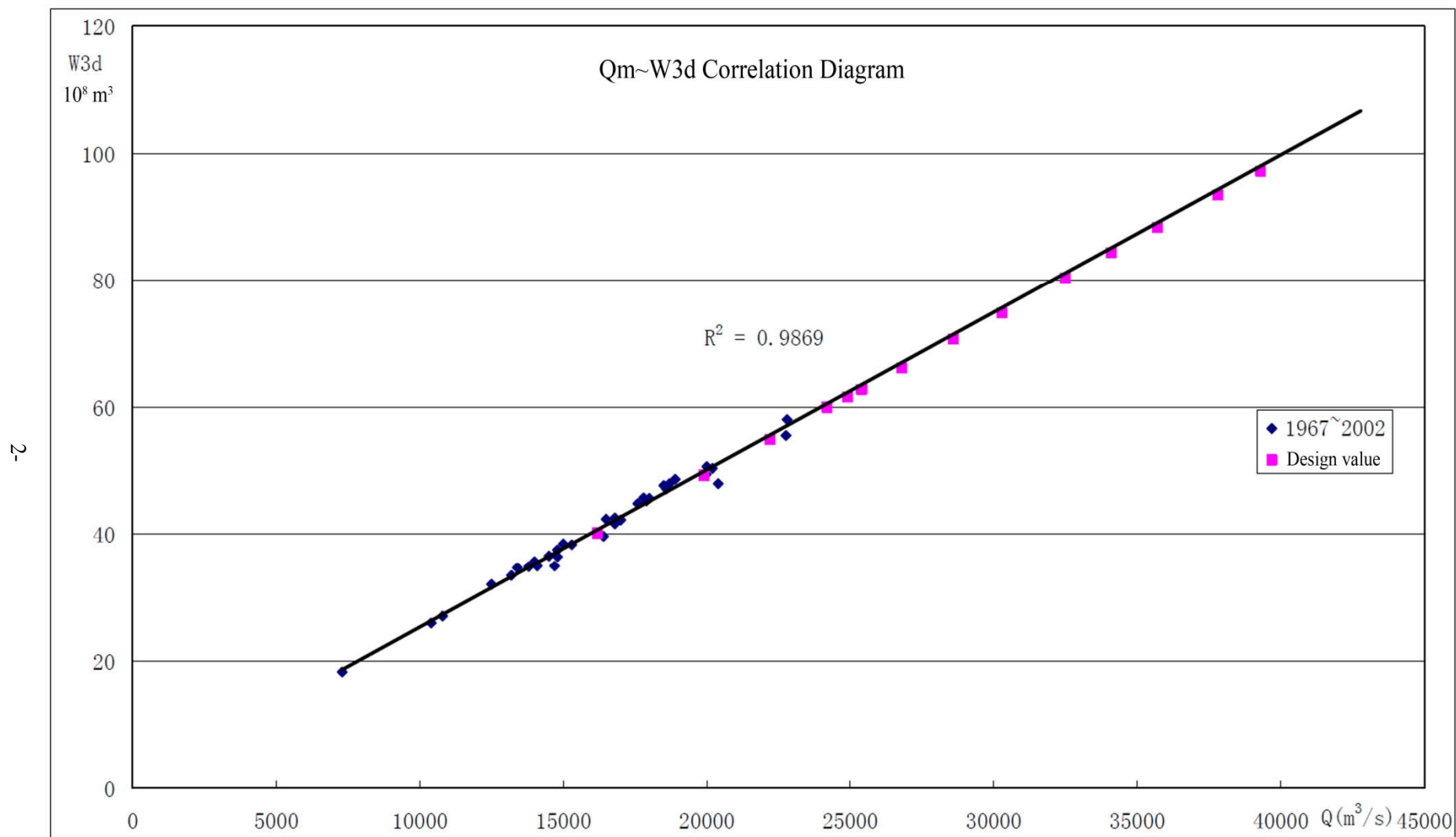


Fig. 2.4-2 Diagram of Correlation between Maximum Annual Flow and 3d Flood Volume at Chiang Khan Hydrologic

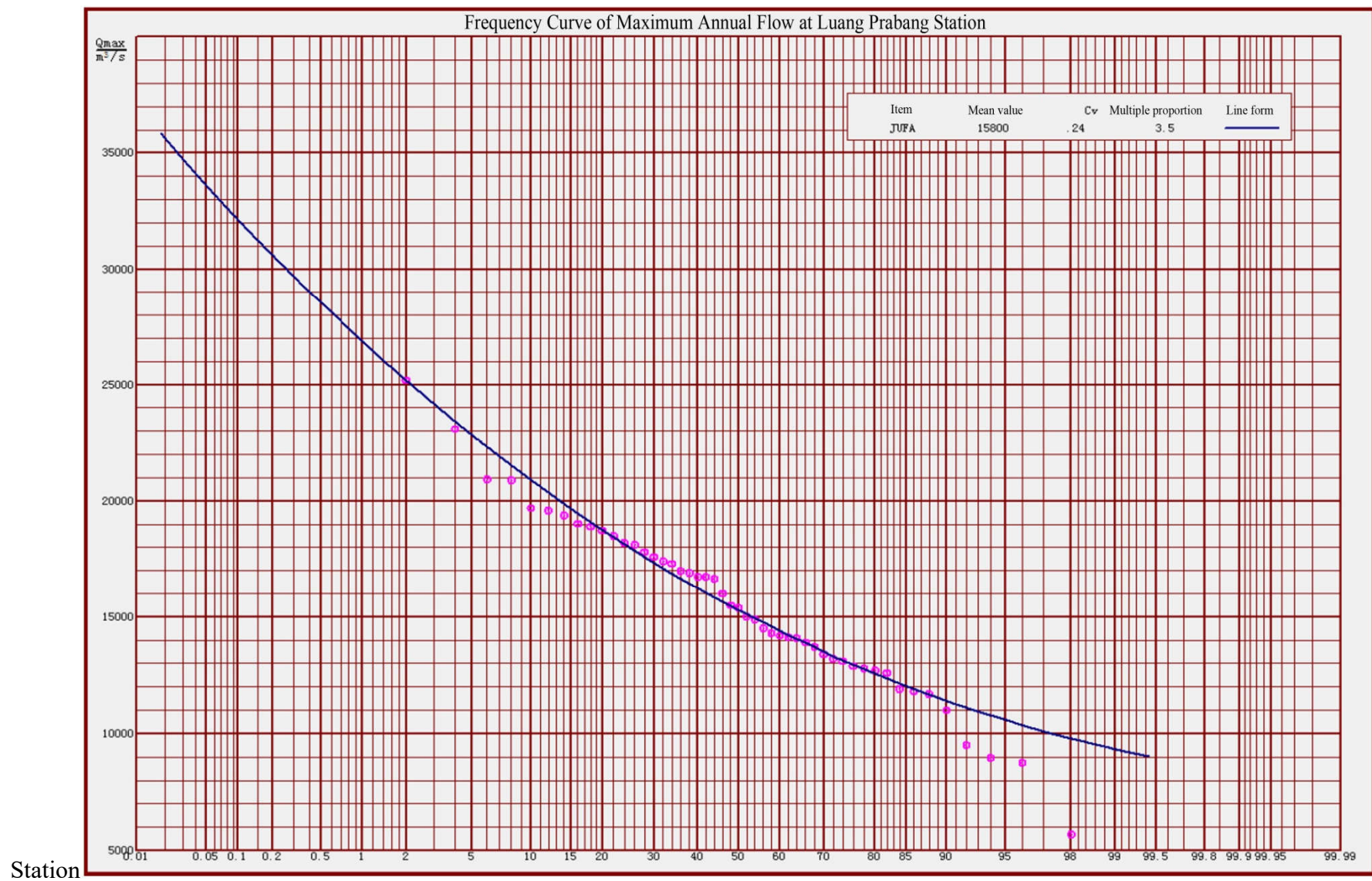


Fig. 2.4-3(a) Frequency Curve of Maximum Annual Flow at Luang Prabang Hydrologic Station (calculated as per measured)



series)
 Fig. 2.4-3(b) Frequency Curve of Maximum Annual Flow at Luang Prabang Hydrologic Station (calculated in consideration of historical floods)

2.4.3 Design Flood at Damsite

Pak Lay Damsite is 181 km downstream from Luang Prabang Hydrologic Station and is 112 km upstream from Chiang Khan Hydrologic Station, with an interval area of 10,400 km² and 13,600 km² respectively. The design flood for the damsite is calculated in two methods in this phase, i.e., calculation based on the design flood results of Chiang Khan Hydrologic Station as per n power of area ratio, and calculation based on the design flood results of Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station via areal interpolation algorithm. Because the upper damsite of Paklay HPP is only 11 km away from its lower damsite and the interval area only accounts for 0.75% of the control area of the damsite, same design flood results are adopted for the both damsites.

Refer to Table 2.4-3 for the damsite design flood results deduced as per the design flood results of Chiang Khan Hydrologic Station and the area ratio of catchment between the damsite and Chiang Khan Hydrologic Station. The index n of area ratio after the extension is calculated as 0.67~0.69 as per the measured maximum corresponding flood peak at Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station over the years. It differs slightly from 0.7 being recommended as the adopted value of former calculation.

Table 2.4-3 Comparison for Frequency Calculation Results of Maximum Annual Flood at the Damsite Qm: m³/s; W: 10⁸ m³

Item		P(%)										
		0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
Previous FS	Qm	38200	36800	34700	33200	31600	29500	27800	26100	23500	21600	19300
	W1d	32.4	31.1	29.4	28.1	26.7	24.9	23.4	22	19.9	18.3	16.3
	W3d	94.5	90.8	85.9	82	78.1	72.7	68.6	64.3	58.2	53.3	47.8
	W7d	209	201	190	182	173	161	152	142	128	118	106
Present FSy	Qm	38100	36600	34500	32900	31300	29100	27300	25600	23000	21000	18800
	W1d	31.2	29.9	28.3	27	25.8	24	22.7	21.2	19.3	17.6	15.8
	W3d	91.3	87.8	82.9	79.2	75.4	70.3	66.3	62.1	56.3	51.5	46.3
	W7d	200	193	182	174	166	155	146	136	123	113	102

Refer to Table 2.4-4 for the design peak discharge results for the damsite, which are calculated with interpolation algorithm as per area based on the re-checked design flood

results of Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station after the extended series. Table 2.4-4 Frequency Calculation Results of Maximum Annual Flood of the Damsite $Q_m: m^3/s$

Item	P(%)										
	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
Q_m	38100	36600	34500	32900	31300	29100	27300	25600	23100	21000	18800

Through analyses on the data in Table 2.4-3 and Table 2.4-4, the design peak discharge results calculated as per the two methods for the Pak Lay Damsite are basically consistent. Refer to Table 2.4-5 for the comparison between the calculation results above and the design flood results for the hydrologic stations, which are analyzed and calculated through upstream & downstream works and by Mekong River Commission. Through analyses on the data in the tables, the design peak discharge calculated for Luang Prabang Hydrologic Station is larger than the data in *Annual Mekong Flood Report 2006* published by Mekong River Commission and in the feasibility study report of upstream Pakbeng Project, smaller than the results in the basin planning scheme prepared by Mekong River Commission in 1994 and data in the feasibility study report of upstream Sayabouly Project. The design peak discharge calculated for Chiang Khan Hydrologic Station in this phase is larger than that in *Annual Mekong Flood Report 2006* published by Mekong River Commission and is basically similar to the design results for Chiang Khan Hydrologic Station in the feasibility study report of upstream Sayabouly Project.

During the calculation of design peak discharge results for Luang Prabang Hydrologic Station and Chiang Khan Hydrologic Station in this phase, two different schemes are compared for adjustment and determination of statistical parameters according to requirements in Chinese specifications, and the slight adjustment of curve fitting parameters has a relatively small effect on the design flood results for the two stations. The flood in 1966 is the first largest flood measured in the Vientiane reach of Mekong River since 1913, and the flood recurrence interval is uncertain at Chiang Khan Hydrologic Station. In addition, the Mekong River Basin is also affected by tropical storm from the Western Pacific and typhoon in some years, so rainstorms in individual years are extremely heavy. In consideration of the analyses above, the design flood results

calculated in this phase for the river reaches basically meet the rainstorm flood characteristics in the basin.

Refer to Table 2.4-6 for the comparison between the calculated results in this phase and calculated results of feasibility study for upstream & downstream works. The design flood result of the Project basically coordinates with upstream cascade design peak discharge, and the modulus of flood peak is basically consistent with rainstorm characteristics in the region.

Refer to Table 2.4-6 for the comparison between the calculation results of Pak Lay Damsite in this phase and the optimization results of design peak discharge in the Mekong Mainstream Planning 2009. The design peak discharge values for design flood of 10000-year return period and 2000-year return period calculated in the phase are 1.8% and 0.6% lower than those in the optimization design of Mainstream Planning, and other frequency design values are almost the same. In accordance with the integrated consideration and requirements of the Cascade Project in the Mekong Mainstream as well as the advice and suggestions on consultation and evaluation of Paklay HPP. The design peak discharge of the Pak Lay Damsite in the phase adopts the optimization design results of mainstream, and it is shown in Table 2.4-7.

2.4.4 Design Flood Hygrograph at the Damsite

According to collected hydrological data, flood years with relatively large peak discharge are 1966, 1971, 2000, 2008, etc. Because of the lack of flood process data in 1966 and 1971, the first three floods are basically similar to each other in shape through analyses and comparison on their daily process data. Therefore, the maximum flood process at Chiang Khan Hydrologic Station in September 2000 and August 2008 is selected as the typical flood process in this phase, and the hygrograph of design flood at the damsite is calculated as per the amplification method based on the flood peak, flood volume within each period and frequency, which is shown in Fig. 2.4-3.

Table 2.4-5 Comparison on Design Peak Discharge Results Between Hydrologic Stations

Upstream and Downstream from Damsite Q: m³/s

Station	Recurrence Interval	Planning Report 1994 by Mekong River Commission	Hydrologic Review 2005 by Mekong River Commission	Flood Report 2006 by Mekong River Commission	Feasibility Study Report of Sayabouly Project	Feasibility Study Report of Pakbeng Project	Present Calculation
Luang Prabang Hydrologic Station	10000-year						37000
	2000-year					30900	33500
	1000-year	32850			36501	29600	31900
	200-year					26500	28200
	100-year	27100		23500	28688	25100	26500
	50-year			22000	26324	23700	24800
	20-year			20200	23169	21600	22400
	10-year	21200		19500	20731	19900	20400
Chiang Khan Hydrologic Station	10000-year						39200
	2000-year						35500
	1000-year				36336		33800
	200-year						29900
	100-year			24500	28930		28100
	50-year			23000	26689		26300
	20-year			21500	23698		23700
	10-year			20000	21687		21600
Vientiane Hydrologic Station	2000-year						
	1000-year	34100			37979		
	200-year		27000				
	100-year	29000	25500	26000	30255		
	50-year		24100	24000	27917		
	20-year		22000	22500	24798		
	10-year	23750	20000	21000	22388		

Table 2.4-6 Comparison on Design Peak Discharge Results between Upstream and

Downstream Project Damsites

Station	Recurrence Interval	Feasibility Study		Mekong Mainstream		Remarks
		Q(m ³ /s)	M(m ³ /s/k)	Q(m ³ /s)	M(m ³ /s/km ²)	
Pakbeng Damsite	2000-year	30200	0.1385	26400	0.1211	2011-year
	1000-year	28700	0.1317	24000	0.1101	
	200-year	24800	0.1138	20500	0.0940	
	100-year	23100	0.1060	19000	0.0872	
	50-year	21400	0.0982	17500	0.0803	
	20-year	18900	0.0867	15500	0.0711	
	10-year	17000	0.0780	14000	0.0642	
Sayabouly Damsite	10000-year			38500	0.1415	
	2000-year	37080	0.1363	34200	0.1257	
	1000-year			32800	0.1206	
	200-year	29150	0.1072	28300	0.1040	
	100-year	26740	0.0983	26500	0.0974	
	50-year	23540	0.0865	24500	0.0901	
	20-year	21060	0.0774	21800	0.0801	
	10-year	37080	0.1363	19800	0.0728	
Pak Lay Damsite	10000-year	38100	0.1358	38800	0.1383	
	2000-year	34500	0.1230	34700	0.1237	
	1000-year	32900	0.1173	33000	0.1176	
	200-year	29100	0.1037	29000	0.1034	
	100-year	27300	0.0973	27200	0.0970	
	50-year	25600	0.0913	25500	0.0909	
	20-year	23000	0.0820	23000	0.0820	
	10-year	21000	0.0749	21100	0.0752	
Sanakham Damsite	10000-year	37300		38800	0.1329	
	2000-year	34400	0.1175	34700	0.1188	
	1000-year	33100	0.1130	33000	0.1130	
	200-year	29900	0.1024	29000	0.0993	
	100-year	28400	0.0973	27200	0.0932	
	50-year	25000	0.0856	25500	0.0873	
	20-year	22900	0.0784	23000	0.0788	
	10-year	21300	0.0726	21100	0.0723	

Table 2.4-7 Results of Maximum Annual Peak Discharge at the Damsite (recommended)

Qm:m³/s

Item	P(%)										
	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
Qm	38800	37000	34700	33000	31200	29000	27200	25500	23000	21100	19000

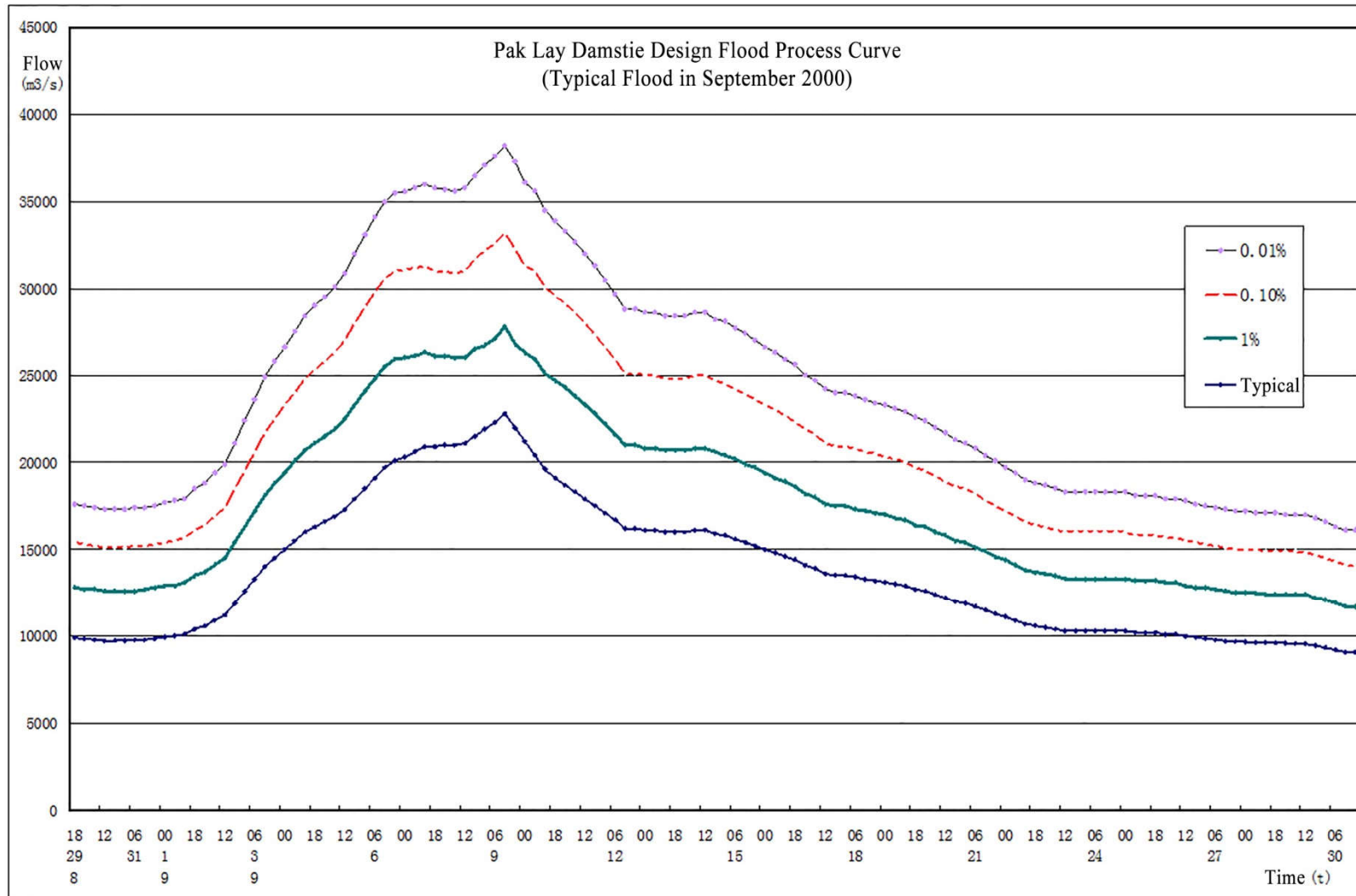


Fig. 2.4-3 Damstie Design Flood Hydrograph Curve (typical flood in September 2000)

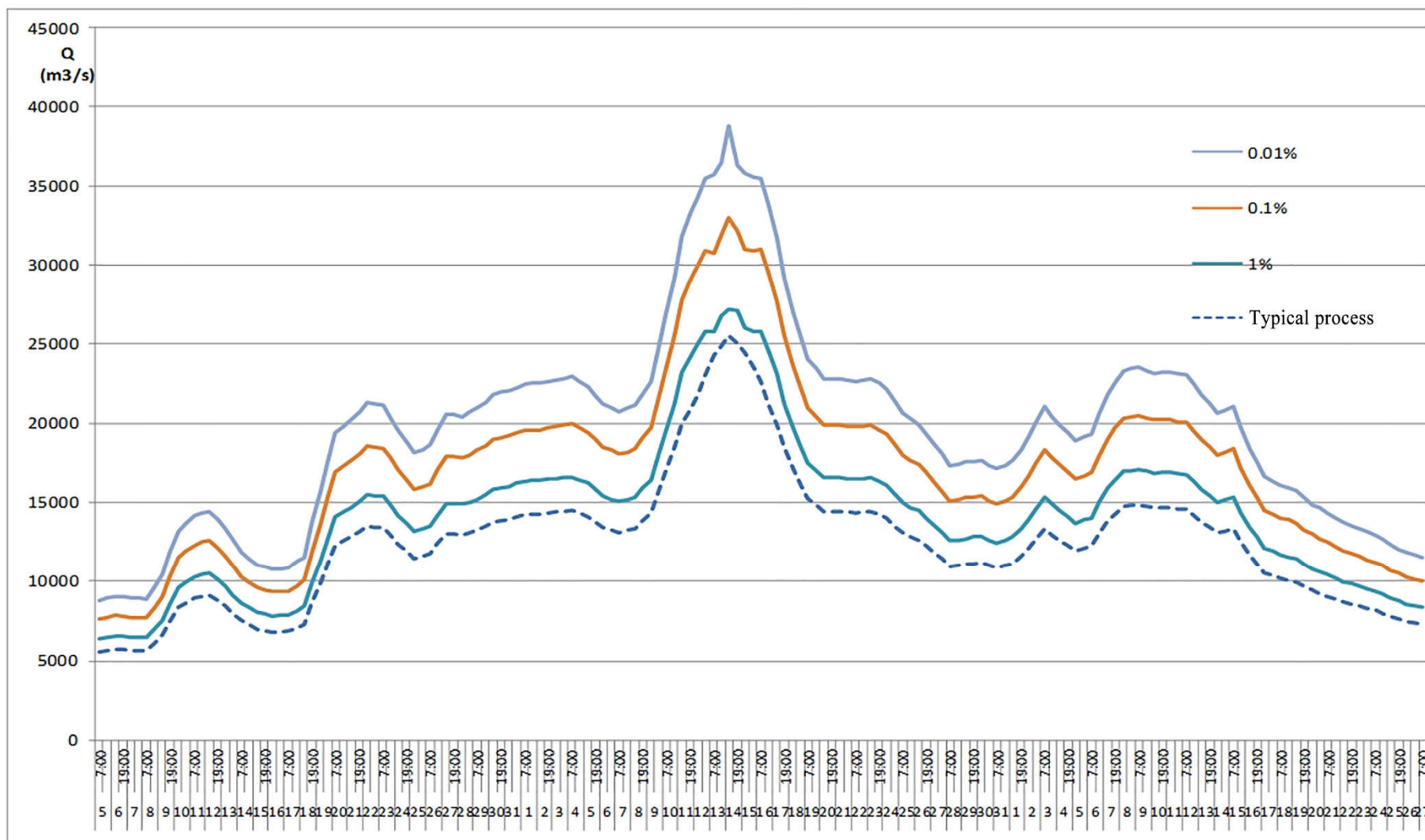


Fig. 2.4-3 Damstie Design Flood Hydrograph Curve (typical flood in September 2008)

2.4.5 Design Flood during Construction Period

According to the situation of measured flood data at hydrologic stations upstream and downstream reaches from the damsite, the design flood for each time period at the damsite in this phase is directly analyzed and calculated based on the flood data measured in each time period at the downstream Chiang Khan Hydrologic Station. The period of the series is 1967~2015.

According to design demands, the maximum flow series for periods of November~April of the next year, November~May of the next year, December~April of the next year, December~May of the next year, January~May and November~December are analyzed and calculated on frequency as per Chinese design codes for hydropower projects. The flood characteristics and measured data of each month and time period are considered during the frequency curve fitting and parameter adjustment, and the design results of each time period are determined in this phase as per the basic principle of “enlarging scope”, which are shown in Table 2.4-6.

Table 2.4-6 Analysis and Calculation Results of Maximum Flow Frequency in Each

Time Period Unit: m³/s

Period	P(%)			
	2	5	10	20
January	4010	3480	3080	2670
February	2650	2340	2100	1850
March	2560	2190	1910	1620
April	2680	2340	2070	1780
May	6930	5710	4770	3810
November	11000	9330	8090	6840
December	6600	5520	4710	3920
November~April of the next year	11100	9410	8160	6900
November~May of the next year	11100	9430	8170	6910
December~April of the next year	7000	5790	4900	4020
December~May of the next year	7600	6290	5320	4370

2.5 Stage-Discharge Relation

2.5.1 Reexamination on Comprehensive Stage-Discharge Relation at Chiang Khan Hydrologic Station

In consideration of the collected data, based on the original design and analysis results, the electronic document data of 1999~2004, wet year data of 2008 from Chiang Khan Hydrologic Station, and daily stage-discharge materials of 2005~2015 for Chiang Khan Hydrologic Station are preliminarily analyzed in accordance with the collected materials being supplemented in the phase to understand the change of stage-discharge relation. The recently annual stage-discharge relation of the station based on preliminary analysis is shown in Fig. 2.5-1.

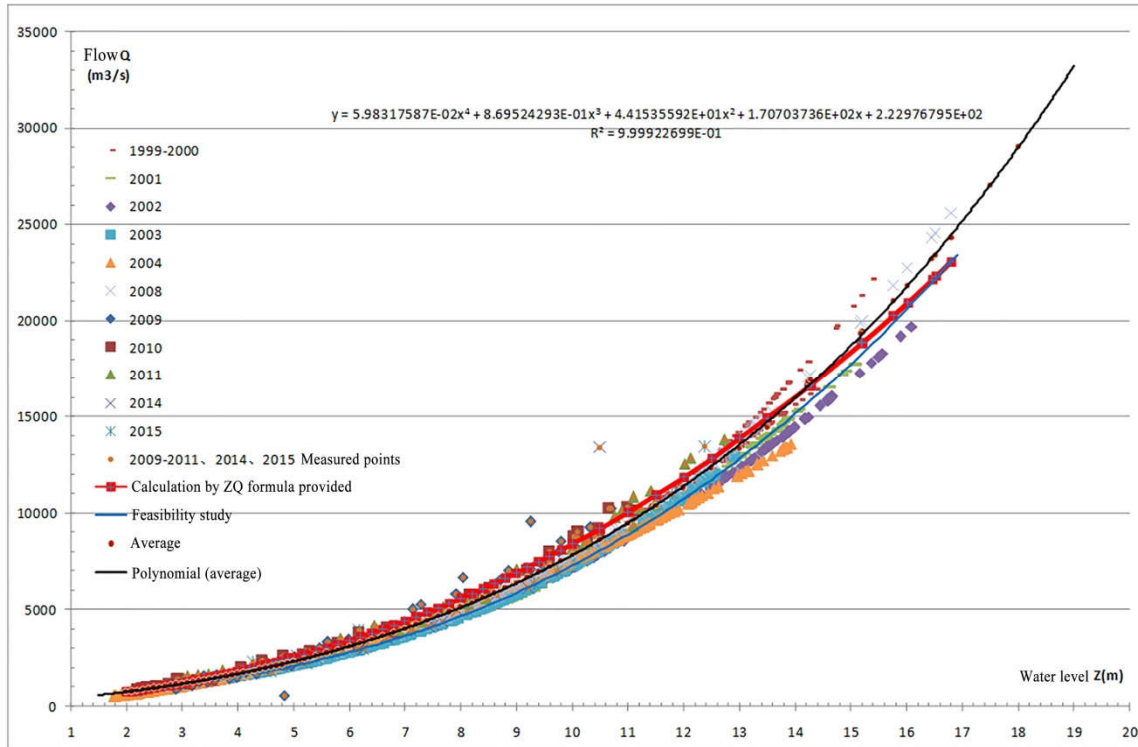


Fig. 2.5-1 Recently Annual Stage-Discharge Relation of Chiang Khan Hydrologic Station based on Preliminary Analysis

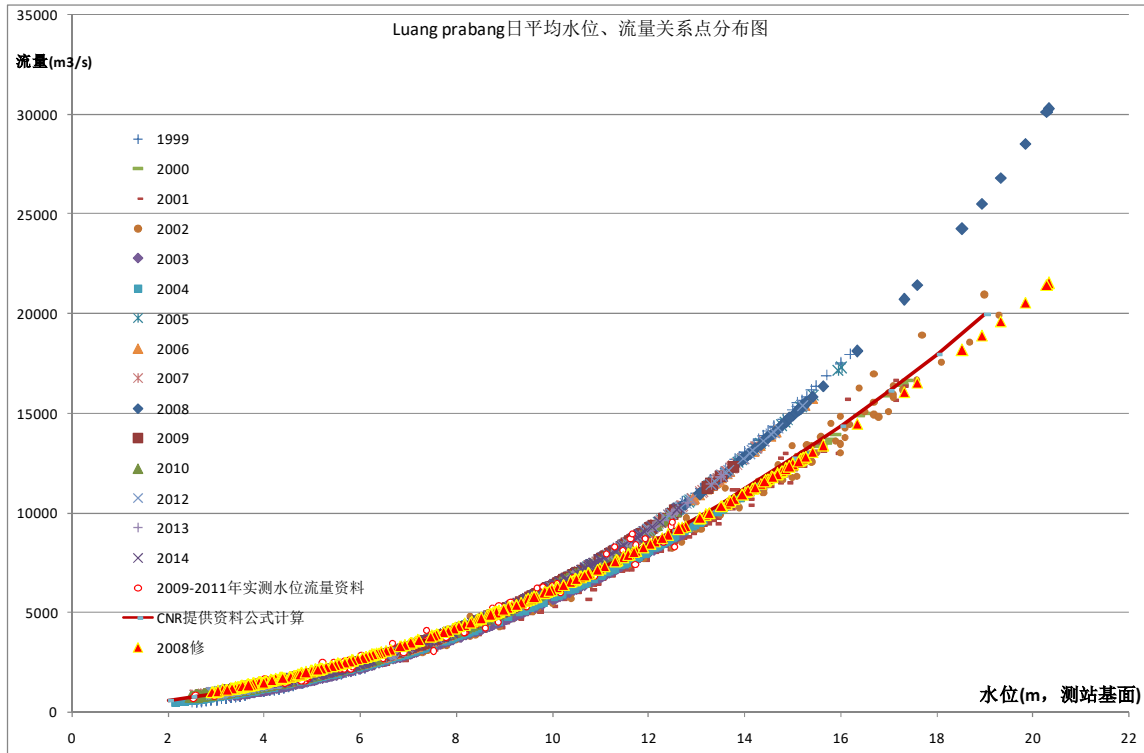
From the preliminary analysis, the annual stage-discharge relation of Chiang Khan Hydrologic Station is basically stable, and its compilation results are reliable. The comprehensive stage-discharge relation of the station determined through analysis basically represents stage-discharge change within the measured water level variation, meeting the design requirements of the Project.

2.5.2 Comprehensive Stage-Discharge Relation at Luang Prabang Hydrologic Station

In accordance with collected materials of the station, annual stage-discharge data of 1999~2014 at Luang Prabang Hydrologic Station is drawn in Fig. 2.5-2. From analyses of annual stage-discharge points, the curve of the stage-discharge relation of has been flat with some adjustments of changes among each year. The stage-discharge relation is basically distributed in a ribbon shape before 2005 without great changes among the years. The stage-discharge relations has been basically the same since 2005, the stage-discharge relation at middle and lower water levels is basically close to the former

relation, but it differs slightly from the former relation at high level. According to the observation and materials compilation from Hydro Meteorology Department of Laos in time of materials collection, the comprehensive stage-discharge relation of the station is sorted and analyzed based on the recent materials collected in the phase as reference for the analysis of the stage-discharge relation of the Project.

Fig. 2.5-2 Recently Annual Stage-Discharge Relation of Luang Prabang Hydrologic Station



2.5.3 Calculation of Stage-Discharge Relation for Pak Lay Gauging Station

According to the water level data collected from Pak Lay Gauging Station and Chiang Khan Hydrologic Station in corresponding periods in 1999~2015, the water level correlation of the both stations is established. The water level correlation of the both stations is determined via segmentation fitting method. Because the distance between the both stations is only 83 km with a relatively small interval area which is less than 3.8% of the control area of Chiang Khan Hydrologic Station, the stage discharge relation at Pak Lay Gauging Station is directly calculated in this phase based on the water level correlation

of the both stations and the comprehensive stage discharge relation at Chiang Khan Hydrologic Station.

2.5.4 Calculation on Stage-Discharge Relation at Damsite

Chiang Khan Hydrologic Station is 112 km downstream from the damsite, and the area between the both accounts for 4.9% of the control area of the damsite. The Luang Prabang Hydrologic Station is 181 km upstream from the damsite, and the control area accounts for 96.3% of the control catchment area of the damsite.

At the river reach of the dam site, a manual gauging station was established in Mid March 2016, and a hydrological station was established in June 2016 to measure the water level and flow at the dam site. Up to now, the water level observation has been done for 6 months, and 39 flow measurements have been obtained, which have been used to preliminarily check the derived stage-discharge relation. For the hydrographs at the dam site and Chiang Khan Hydrological Station from March to September, 2016, see Fig. 2.5-3.

According to the water level data of Pak Lay upper damsite observed from January 2008 to March 2009 as well as collected water level data of Chiang Kha Station and Luang Prabang Station, the water level correlation of the upper damsite gauging station, Chiang Khan Station, and Luang Prabang Station (see Fig. 2.5-4) has been established. The water level data observed at the dam site from March to September of 2016 and corresponding water level data collected from Chiang Khan hydrological station are used to preliminary check and analyze the proposed stage-discharge relation (see the hydrographs in Fig.2.5-4). As shown from Fig.2.5-4, the co-related points of the dam site and Chiang Khan hydrological station are basically located on both sides of the correlation curves and distribute in strip form, which indicates that the proposed water level correlation between the dam site and Chiang Khan hydrological station are basically suitable.



Fig.2.5-3 Hydrographs of dam site and Chiang Khan hydrological station from March to September 2016

The stage-discharge relation at the upper dam site has been derived based on the water level correlation proposed based on the analysis of water level data from Jan. 2008 to March 2009 and the synthetical stage-discharge relations of Chiang Khan and Luang Prabang hydrological stations.

In comparison between the above stage-discharge relation of upper damsite and the relation calculated in the former feasibility study, the relation lines of both calculations are basically the same in terms of the trend. The relation points calculated in this phase are distributed on both sides of the former stage-discharge relation (see Fig. 2.5-4). Comparing the stage discharge points measured by flow meter at the river reach of the dam site in September 2015 and July to September of 2016 with the stage discharge points measured by ADCP from July to September of 2016, the stage-discharge relation of upper

damsite calculated in the former feasibility study is basically proper.

From the present materials, and in consideration of design requirements of the Project, it is recommended to adopt the stage-discharge relation of upper damsite calculated in the former feasibility as the stage-discharge change within the measured water level variation. See the solid line in Fig. 2.5-5.

As for the stage-discharge change outside the measured water level variation, in accordance with the design requirements and materials, the low-head cross section is extended along the trend line based on the low-level points, while the high-head cross section for the upper damsite is extended with the stage discharge velocity relation curve method and based on the stage discharge relation trend, measured profile $Q \sim A \sqrt{D}$, and so on. Then, the stage discharge relation at the upper damsite is determined through comprehensive comparison. For the stage-discharge relation results of the upper dam site in this phase, see Table 2.5-1. For the stage-discharge relation of the upper dam site in this phase, see Fig.2.5-5.

As the water level observation and flow measurement at the damsite is still ongoing. The stage and discharge data measured at the river reach of the dam site and used in this report have not been analyzed and processed, which are of preliminary analysis nature and can not be the basis for precise analysis. After the one hydrological year of stage and discharge measurement at the river reach of the dam site is completed, the measured data will be processed and analyzed, and the processed results will be used to verify the stage-discharge relation of the dam site.

Due to lack of measured stage and discharge data at the river reach of the dam site, it is suggested that the hydrometrical work be continued to further collect the measured stage and discharge data at the river reach of the dam site after the hydrometric work contract expires .

~~Refer to Table 2.5-1 for the stage-discharge relation result of the upper damsite in this phase. The stage-discharge relation diagram for the upper damsite is shown in the solid line in Fig. 2.5-4.~~

Table 2.5-1 Stage-Discharge Relation at Pak Lay Upper Damsite

Water level at upper damsite	m	214.87	215.27	215.67	216.07	216.5	217	217.5	218
Flow	m ³ /s	685	772	853	950	1060	1200	1340	1500
Water level at upper damsite	m	218.5	219	219.5	220	220.5	221	221.5	222
Flow	m ³ /s	1680	1870	2100	2360	2650	2980	3350	3760
Water level at upper damsite	m	222.5	223	223.5	224	224.5	225	225.5	226
Flow	m ³ /s	4230	4760	5350	5990	6680	7420	8220	9070
Water level at upper damsite	m	226.5	227	227.5	228	228.5	229	229.5	230
Flow	m ³ /s	9960	10900	11900	12900	14000	15200	16400	17600
Water level at upper damsite	m	230.5	231	231.5	232	232.5	233	233.5	234
Flow	m ³ /s	18900	20200	21600	23000	24500	26000	27600	29200
Water level at upper damsite	m	234.5	235	235.5	236	236.5	237	237.5	238
Flow	m ³ /s	30800	32600	34300	36200	38000	40000	42000	44000

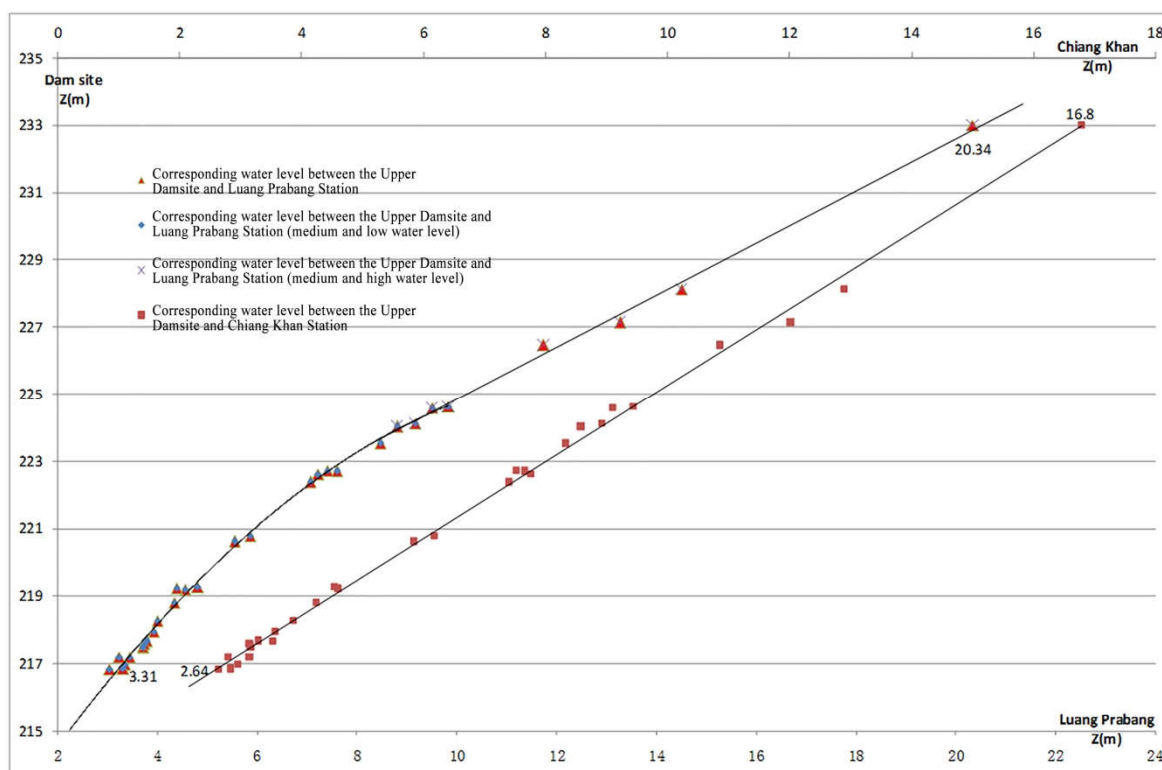


Fig. 2.5-4 Water Level Correlation among the Upper Damsite, Chiang Khan Station, and Luang Prabang Station

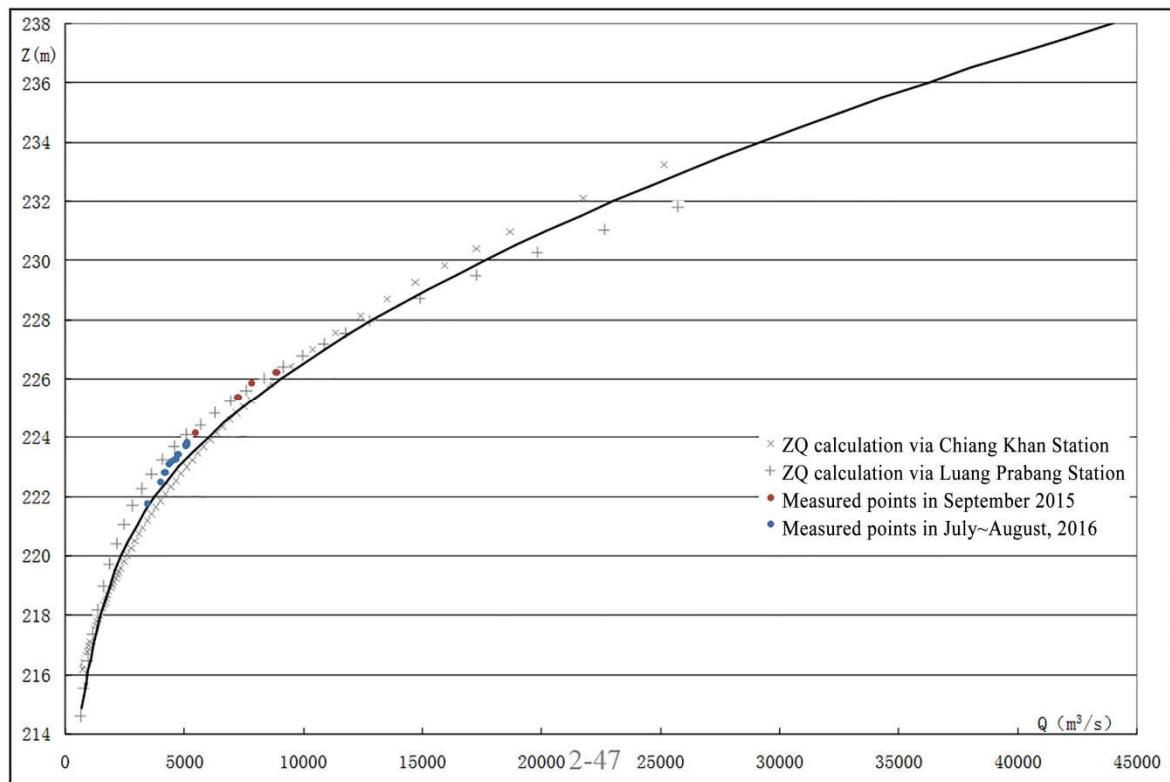


Fig. 2.5-5 Stage-Discharge Relation at Pak Lay Upper Damsite

2.6 Sediment

There is no measured sediment data at Pak Lay Damsite. The characteristic values of sediment at the damsite are calculated as per the sediment data measured at Chiang Khan Hydrologic Station about 112km downstream from the damsite. The suspended sediment series of 56 years from 1960 to 2015 is adopted for sediment derivation.

2.6.1 Sediment at Chiang Khan Hydrologic Station

Some daily average sediment concentration data (monthly average sediment concentration is unavailable) are available at Chiang Khan Hydrologic Station in April 1967 ~ March 1968 and April 1969 and March 1977. A total of 189 sediment measurements at Chiang Khan Hydrologic Station measured in 2009~2015 are collected and supplemented in the phase.

When the calculation of former feasibility study is performed, the relations between daily average discharge and daily average sediment concentration or between daily average discharge and daily average sediment discharge are analyzed, and the correlation between daily average discharge and daily average sediment discharge is established (see Fig. 2.6.1-1) in accordance with some daily sediment concentration data in April 1967 ~ March 1968 and April 1969 and March 1977. With this, calculate the monthly average sediment discharge and monthly average sediment concentration in corresponding years, and establish the correlation between monthly average flow and sediment concentration. See the lateral line in the middle upper place of Fig. 2.6.1-2.

Collected flow and sediment concentration materials being supplemented in a total of 189 measurements at Chiang Khan Hydrologic Station in 2009~2015 are analyzed and calculated, new relations between flow and sediment discharge or between flow and sediment concentration are established, and the average relation line between flow and sediment discharge is analyzed in the phase. For relation line (lower side line) about distribution of flow and sediment discharge relation points and analyses of relation line, see Fig. 2.6.1-2.

From comparison of relation points and relation line in the Fig. 2.6.1-2, the measured flow-sediment discharge relation points in the phase are distributed below those in the

former feasibility study, and the relation line is lower than the former relation line. That is to say, the sediment discharge in the phase is lower than that in the former calculation. From the preliminary analysis of present owned materials and known situations, the differences mainly relate to underlying surface conditions in the basin, sediment measurement devices, measurement scheme, and many other factors. In consideration of materials in 1967~1977 as basis for the former feasibility study calculation as well as the improvement of present measurement devices and technologies, it is recommended to adopt the flow-sediment discharge relation and results of the station analyzed and calculated from the flow and sediment concentration materials in a total of 189 measurements at Chiang Khan Hydrologic Station in 2009~2015 as the basis for damsite sediment to be ascertained.

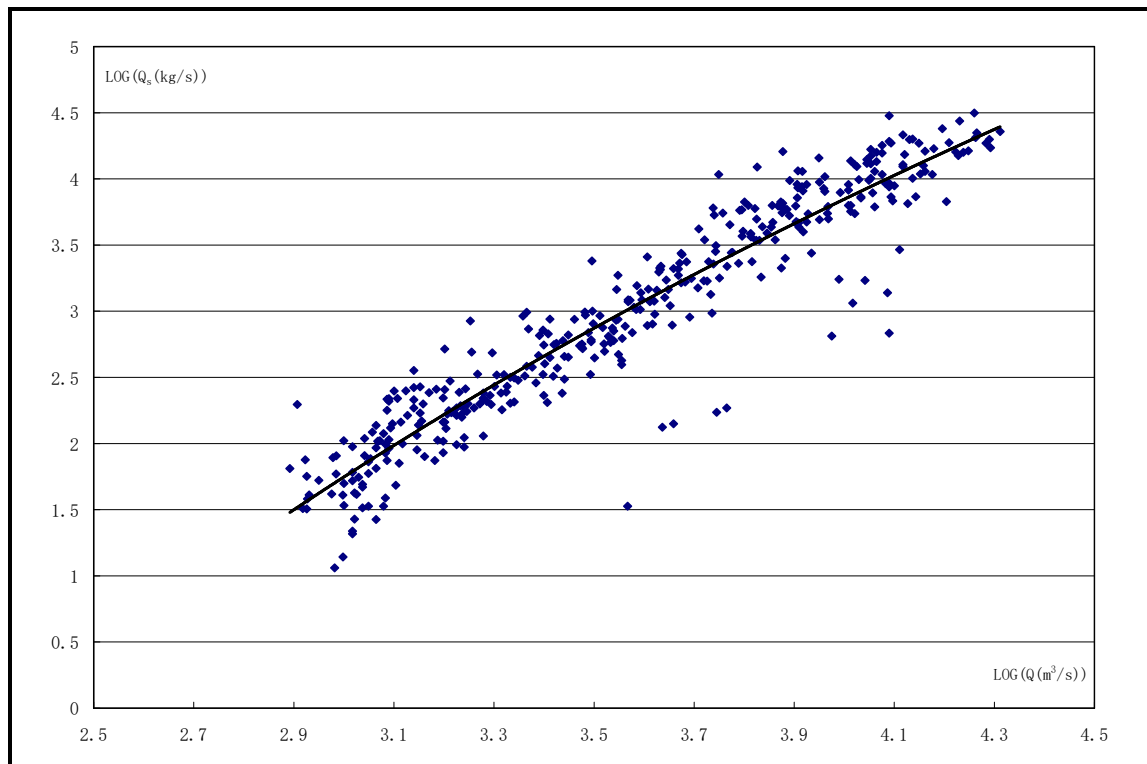


Fig. 2.6.1-1 Correlation between Daily Average Flow and Daily Average Sediment Discharge at Chiang Khan Hydrologic Station in 1967~1977

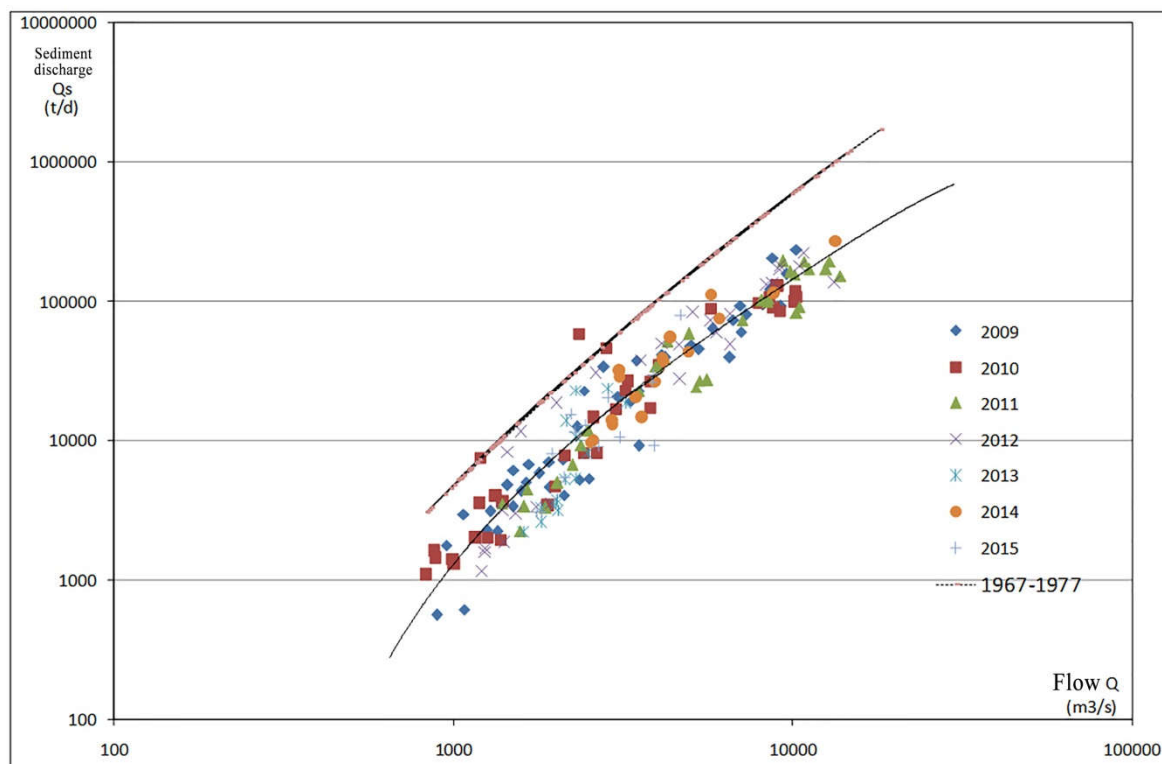


Fig. 2.6.1-2 Correlation for Measured Flow and Sediment Discharge of Chiang Khan Hydrologic Station

2.6.2 Calculation of Damsite Sediment

No sediment measurement material exists for the reach of the upper damsite. The monthly average sediment discharge of the damsite in the feasibility study period is calculated by use of the monthly average sediment concentration at Chiang Khan Hydrologic Station in April 1967 ~ March 1968 and April 1969 ~ March 1977 as well as the monthly average flow of corresponding years at the upper damsite, and the correlation between the monthly average flow and monthly average sediment discharge at the damsite is established (refer to Fig. 2.6.2-1); by use of the monthly average flow and monthly average sediment discharge at the damsite, the monthly average sediment discharge over the years, the monthly average sediment concentration and sediment runoff at the upper damsite are calculated. The corresponding mean annual sediment concentration of suspended sediment is 509 g/m^3 at the upper damsite and the maximum annual sediment runoff is $13 \times 10^7 \text{ t}$. Refer to Table 2.6-1 for characteristic values of sediment.

Table 2.6-1 Mean monthly Suspended Sediment Runoff at Upper Damsite Unit: 10000 t

Month		1	2	3	4	5	6	7	8	9	10	11	12	Year
Sedi ment	Previous FS	57	27	18.6	18.6	53.3	236	1020	2190	1780	760	321	122	6600
Runof f	Present FS	21	9	7	7	20	74	254	499	412	206	99	44	1650
%		1.26	0.56	0.42	0.42	1.22	4.46	15.36	30.21	24.97	12.50	5.97	2.64	100

The monthly mean sediment discharge in 2009~2015 at the upper damsite is ascertained, and the monthly mean flow-sediment discharge relation is established (see Fig.2.6.2-2), the monthly sediment discharge over the years at the damsite, sediment runoff, and statistical characteristic values over the years are calculated in accordance with the flow-sediment discharge relation and results of the station analyzed and calculated from the flow and sediment concentration materials in a total of 189 measurements at Chiang Khan Hydrologic Station in 2009~2015, and by use of the monthly mean sediment concentration in 2009~2015. As the monthly mean sediment runoff over the years at the upper damsite calculated in the phase is shown in Table 2.6.1, the mean annual sediment runoff for many years is 16,500,000 t, the mean sediment concentration for many years is 0.129 kg/m³, and the maximum annual sediment runoff is 30,350,000 t.

The sediment materials of Chiang Khan Hydrologic Station in 1967~1977 were adopted for the calculation of the damsite sediment in the former feasibility study period, while the sediment materials of Chiang Khan Hydrologic Station in 2009~2015 collected from Mekong River Commission (Phnom Penh, Cambodia) are adopted in the phase. The data in the phase might be closer to the sediment data in the Chiang Khan reach of Mekong River, and the present observation technologies and devices might be more advanced than those in the 1960s~1970s. As a result, it is recommended in this phase to adopt the damsite sediment results analyzed and calculated from the collected materials in 2009~2015.

At present, the suspended sediment is being measured at the river reach of the dam site. The average suspended sediment content has been measured over 20 times in the section, and sediment content of individual sample has been measured over 30 times at the fixed plumb line. The measured max. suspended sediment content is 4.33 kg/m³ at the measuring point, and 4.04 kg/m³ at the measuring plumb line, and 3.77 kg/m³ at the

measuring section. Based on the measured suspended sediment data, see Fig.2.6.2-3 and Fig.2.6.2-5 for the variation of suspended sediment in different water depth.

As the sampling and analysis of suspended sediment is ongoing and the measured data has not been analyzed or processed, the measured water and sediment relation at the river reach of the dam site cannot be obtained at this phase. After the sediment measurement at the river reach of the dam site is fully completed and the data is processed and analyzed, the processed results will be used to compare and verify the suspended sediment results in this feasibility study report.

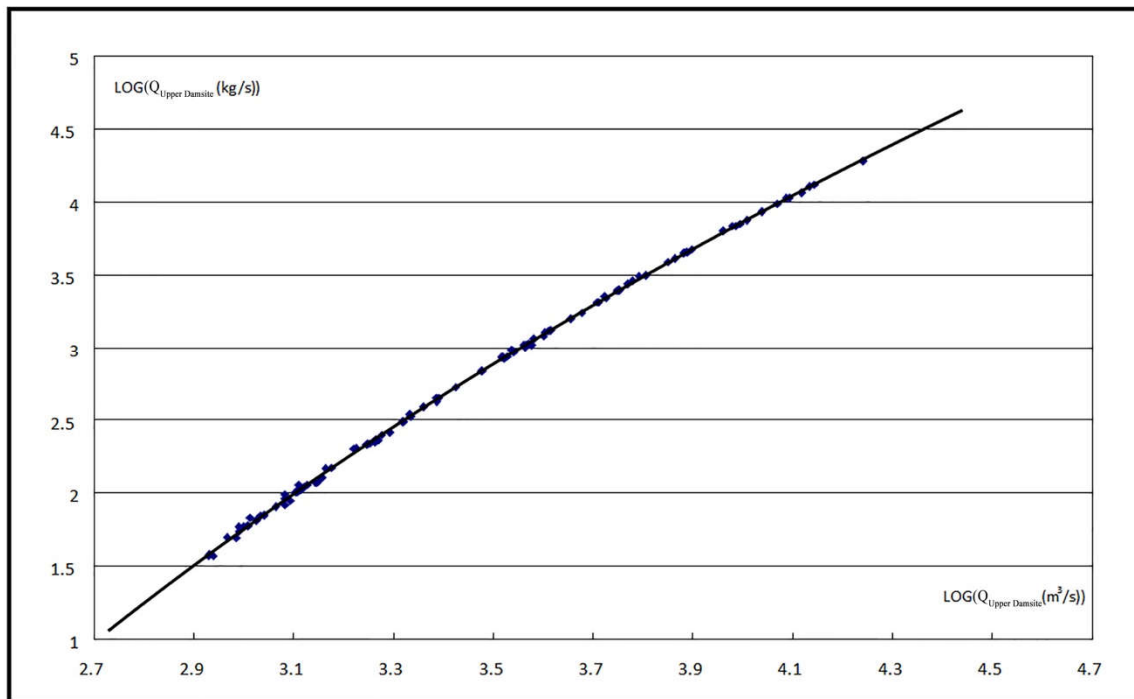


Fig. 2.6.2-1 Correlation between Monthly Average Flow and Monthly Average Sediment Discharge at Upper Damsite in 1967~1977

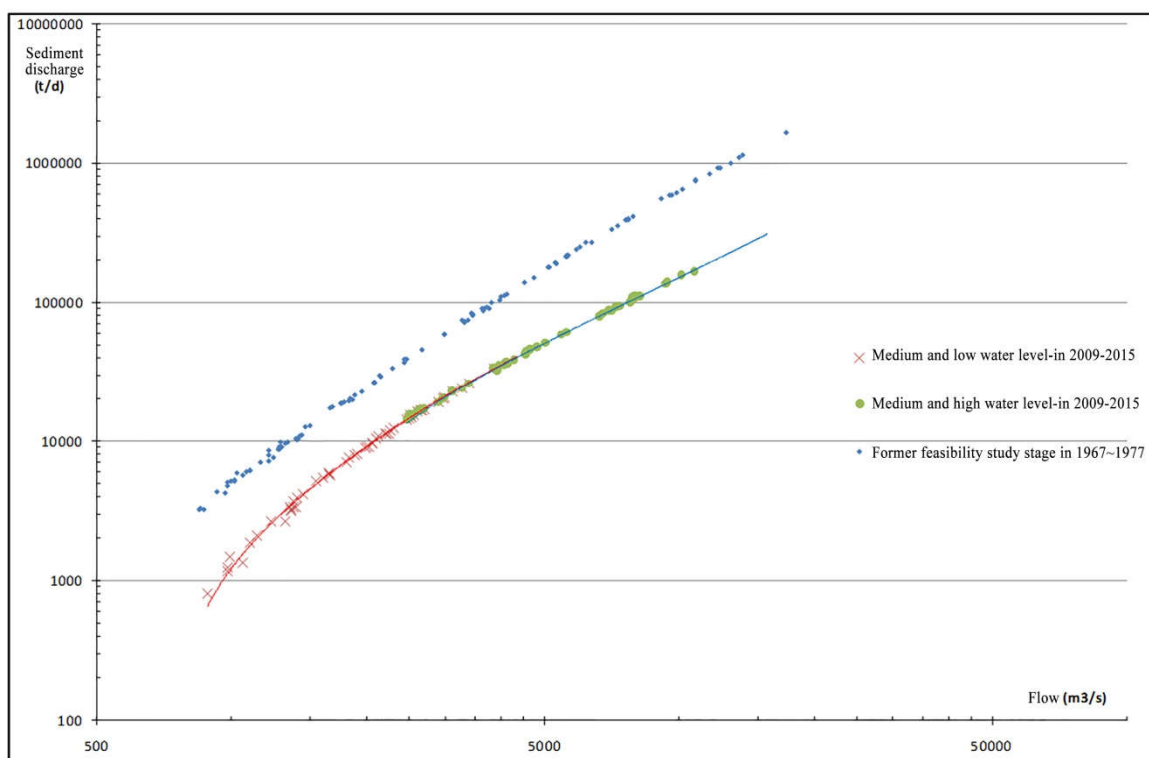


Fig. 2.6.2-2 Correlation between Monthly Average Flow and Monthly Average Sediment Discharge at Upper Damsite in 2009~2015

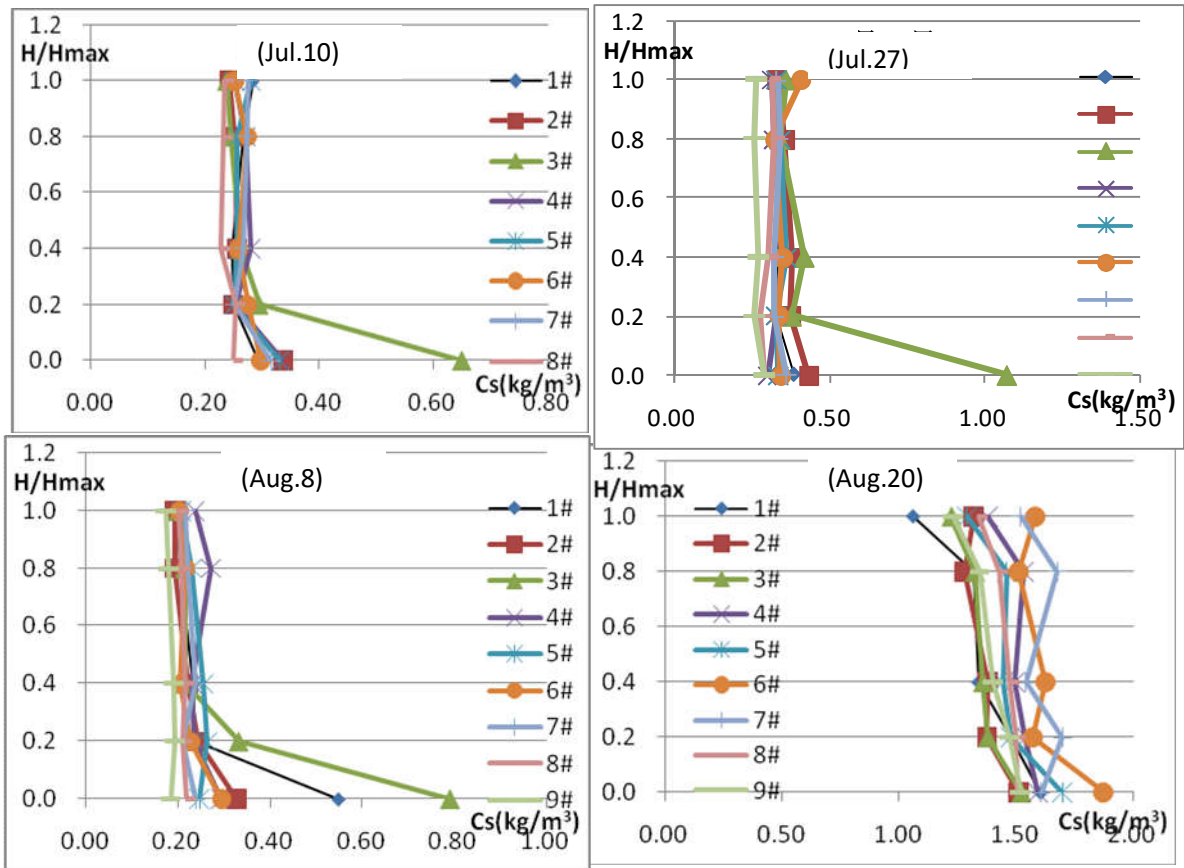


Fig.2.6.2-3 Relation between Measured Suspended Sediment Content and Relative Water Depth of the Plumb Lines at Damsite Hydrological Station Section

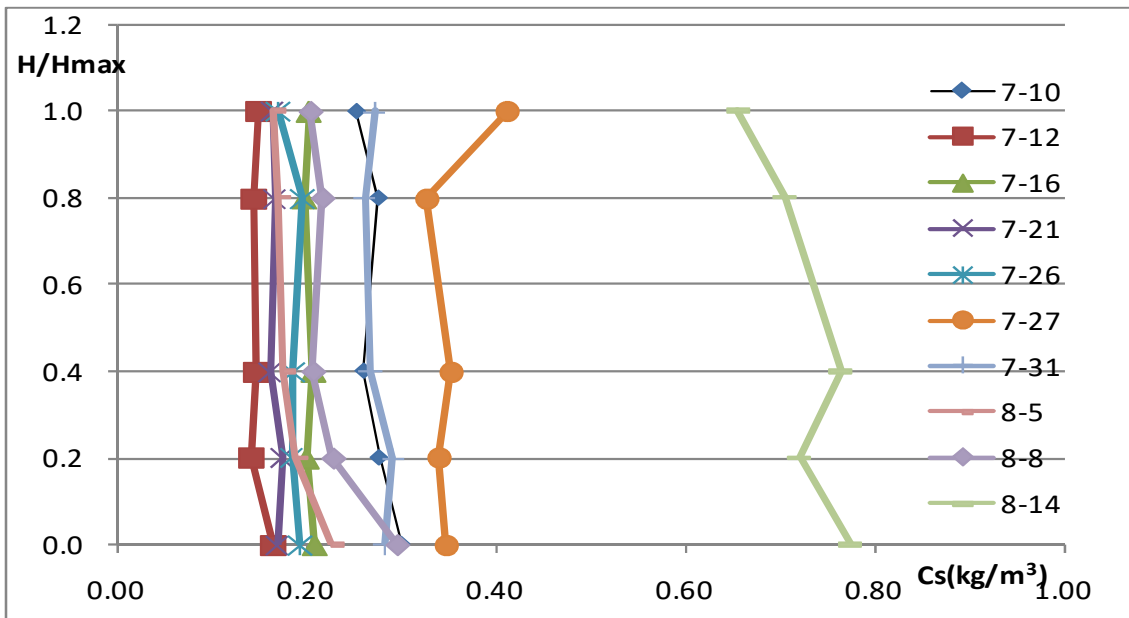


Fig.2.6.2-4 Relation between Measured Suspended Sediment Content and Relative Water Depth of the Plumb Line No.6 at Damsite Hydrological Station Section

2.6.3 Sediment Particle Grading

2.6.3.1 Sediment Grading of the Damsite Reach

In accordance with the advice and requirements on sediments proposed by the preliminary evaluation of CNR in August~September, 2015, our designers were designated to measure sediments and flow on site. A total of 4-time sampling for the full-section suspended sediment at the damsite reach and 2-time sampling for desilting on bank are carried out for the site works. The sampling of full-section suspended sediment adopts the multi-thread multipoint flow method. A vertical line for measuring sediments is arranged every 50 m on the section of flow test. Sediments along each vertical line are sampled at relative depths 0, 0.2, 0.6, 0.8, and 1.0. The arithmetic method is adopted for the calculation of the mean sediment concentration along the vertical line, and the flow weighting method is adopted for the calculation of silt discharge on the cross section. The particle size measurement method and the pipette transferring method are adopted to analyze the suspended sediment particles by use of the full-section mixed sand samples. The particle grading curve of six sand samples analyzed in this phase is shown in Fig. 2.6.3-1 (the yellow solid line).

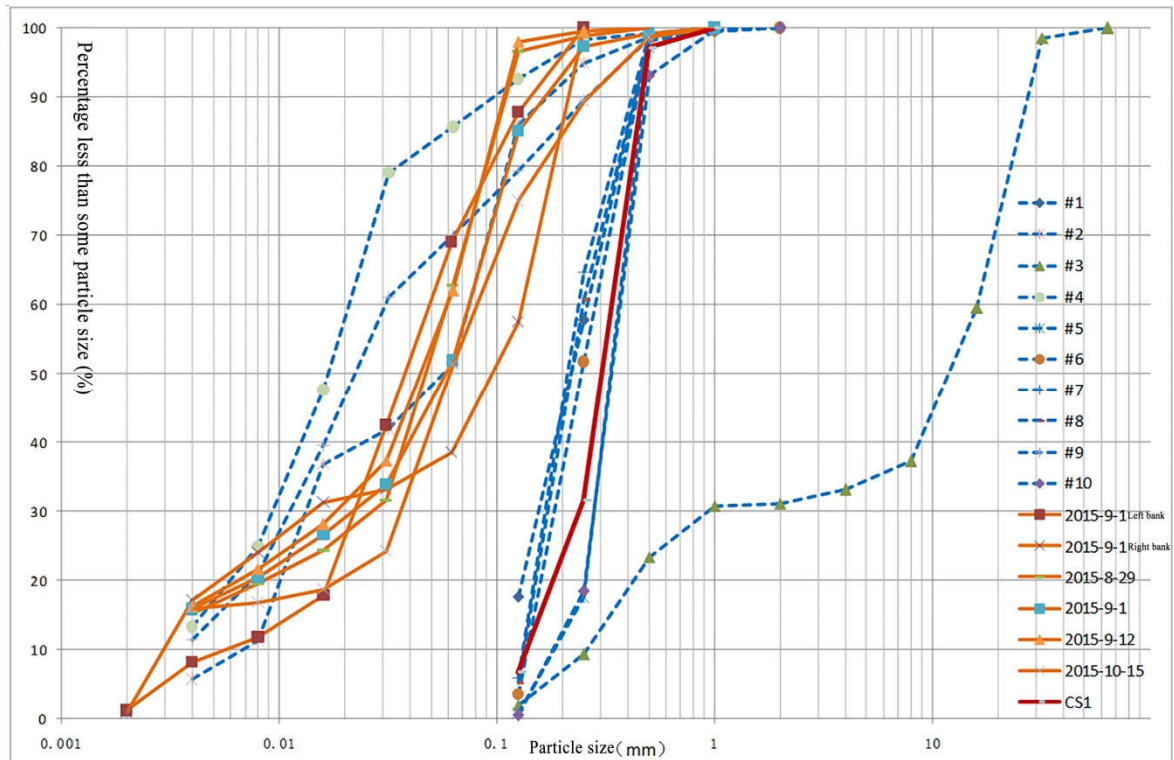


Fig. 2.6.3-1 Suspended Sediment Particle Grading at the Damsite Reach

One new survey was carried out in the site reach according to the evaluation schedule of the Project in January, 2016. A total of 10 sand samples were collected in the sandbank on the upstream side of the damsite jointly accompanied by CNR specialists in the survey. The result for analyses on particles grading of 10 sand samples is shown in Fig. 2.6.3-1 (the blue dotted line, #1~#10).

In accordance with the evaluation advice and requirements in March, 2016, our designers were re-designated to sample sediments on site islets and banks in the reach of reservoir to understand the sediment particle grading difference and the change along the river in different reaches. Sampling on the marginal bank of damsite reach is also executed, and the result of sediment particle grading on the marginal bank of damsite reach is shown in Fig. 2.6.3-1 (the red thick line, CS1).

2.6.3.2 Sediment Grading of the Reservoir Reach

In accordance with the advice and requirements on the evaluation of the feasibility study report, our designers were designated to sample sediments on site islets and banks in March, 2016. Sediments are sampled on 7 sections (no. CS1~CS7) from the damsite of the

Project to the tail area of the reservoir. One sampling point (CS1) is positioned near the dam site, and other six sampling points (CS2~CS7) are distributed in an almost equal and even distance from bottom to top in the reservoir above the dam site in accordance with the distribution of bed materials in the river course. The position coordinate of sampling points is shown in Table 2.6.3-1 and the section arrangement for sampling of bed materials is shown in Table 2.6.3-2.

The pit testing method is adopted for sampling of bed materials on 7 sections (no. CS1~CS7), and positions without man-made sabotage and special accumulation form are adopted as positions for sampling. Three layers underneath the surface sediment samples in each test pit are exposed and sampled. The plane size and layered depth of the sampling pit meet the regulations of river's bed load sediments and bed materials measurement.

Table 2.6.3-1 Result for Position Coordinates of Bed Materials Sampling Points

S/N	Cross Section No.	B	L	Sampling Date	Remarks
1	CS1	18 °24'36"	101 °36'01"	2016-3-12	Right marginal bank
2	CS2	18 °28'47"	101 °42'16"	2016-3-12	Left marginal bank
3	CS3	18 °33'14"	101 °45'06"	2016-3-13	Islet in a river on the left bank
4	CS4	18 °39'52"	101 °47'55"	2016-3-13	Tail of islet in a river
5	CS5	18 °48'19"	101 °50'49"	2016-3-14	Right side of islet in a river
6	CS6	18 °54'50"	101 °47'42"	2016-3-14	Left marginal bank
7	CS7	19 °02'20"	101 °47'59"	2016-3-15	Right marginal bank

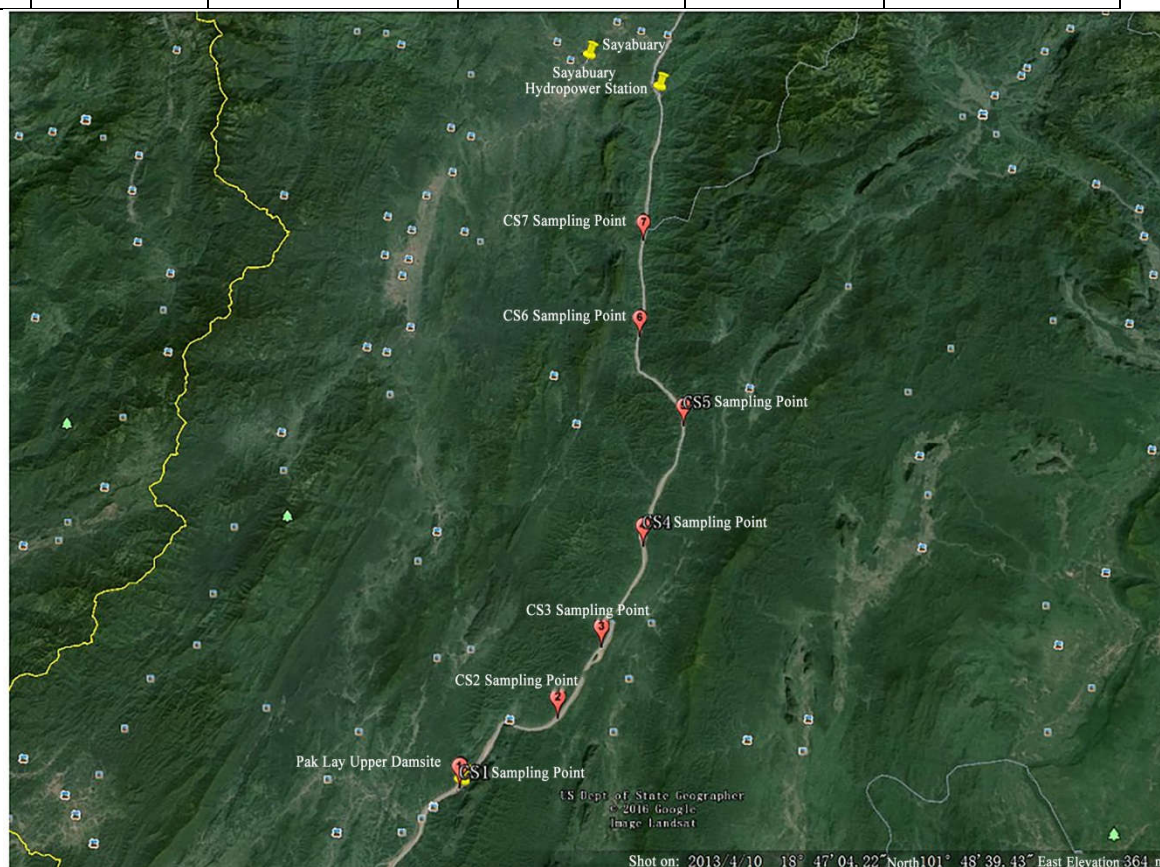


Fig. 2.6.3-2 Sampling Position of Sediment Particle Grading in the Reservoir Reach

Particle grading analysis is carried out via the sieving method in accordance with sediment sampling on 7 cross sections. The results are shown in Table 2.6.3-2 and Fig. 2.6.3-3 (the red line). Besides, the sampling of bed materials is analyzed in the reservoir reach of the Project, when the sediment research is carried out in the Mekong River main stream by CNR. The result of sediment particle grading analysis is shown in Fig. 2.6.3-3 (the green line).

Fig. 2.6.3-2 Result of Sediment Particle Grading on the Cross Section of the Reservoir

Cross Section No.	Weight Percentage of Sediment less than the following Particle Size (%)											D _{cp} (mm)	D ₅₀ (mm)	D _{max} (mm)
	140 (mm)	64 (mm)	32 (mm)	16 (mm)	8 (mm)	4 (mm)	2 (mm)	1 (mm)	0.5 (mm)	0.25 (mm)	0.125 (mm)			
CS1								100.00	97.14	31.55	6.74	0.31	0.33	1
CS2		100.00	97.34	81.61	71.88	66.28	58.20	55.64	41.45	25.67	4.62	6.91	0.78	52
CS3		100.00	98.69	93.40	91.11	90.36	90.36	89.93	89.28	46.71	3.72	2.42	0.27	41
CS4	100.00	99.42	94.65	76.64	63.80	56.75	52.29	51.82	37.20	7.05	0.99	4.67	0.95	140
CS5							100.00	99.67	97.67	40.86	2.33	0.30	0.29	2
CS6							100.00	99.69	97.51	41.75	6.85	0.29	0.28	2
CS7							100.00	99.52	65.95	4.52	0.24	0.49	0.47	2

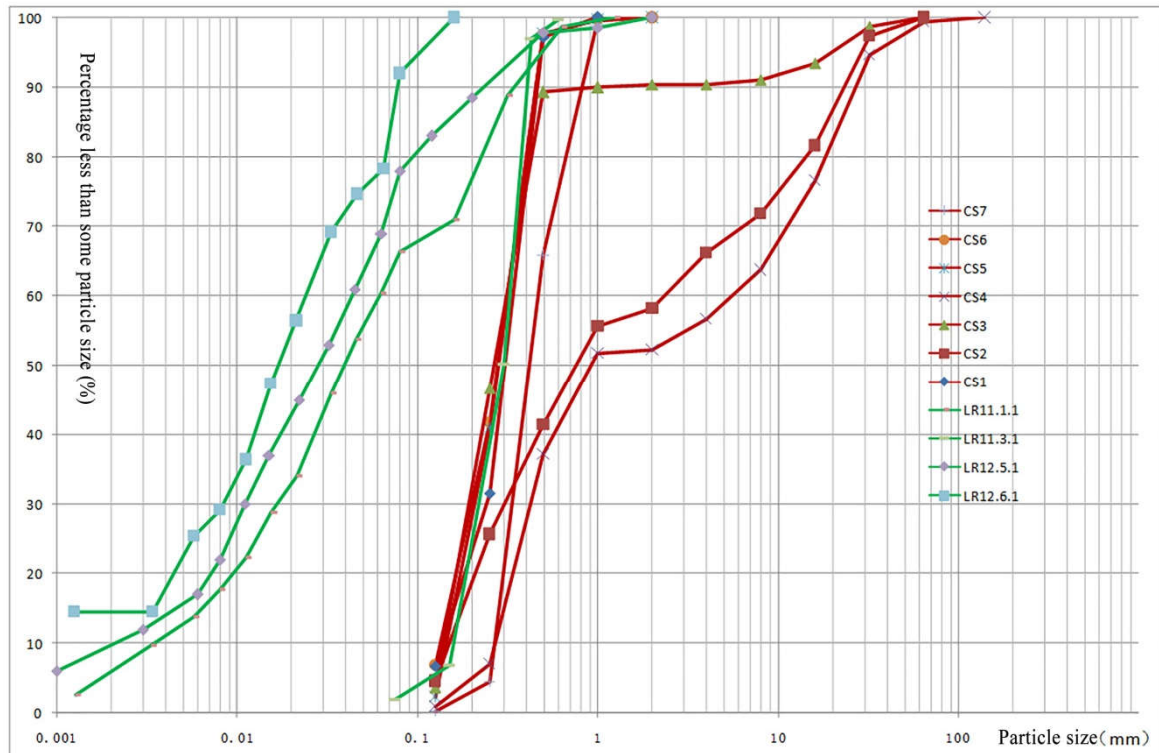


Fig. 2.6.3-3 Result for Particle Grading Analysis of Sediment Sampling in the Reservoir Reach

2.6.3.3 Comparison of Sediment Particle Grading

A preliminary comparative analysis is conducted between the result of sediment sampling analysis in the damsite and reservoir reach and the result of sediment grading in the reach of the Project provided by CNR. The comparison of sediment particle grading is shown in Fig. 2.6.3-4 and Fig. 2.6.3-5. From the particle grading curves in Fig. 2.6.3-4 and Fig. 2.6.3-5, the particle grading distribution of sediments in different periods and different reach positions for the reach of the Project is basically close. There is obvious zonal distribution between fine particles and coarse particles, indicating that the sediment particle grading in the reach of the Project changes slightly.

From the analysis on average particle grading of fine sediments (see Fig. 2.6.3-5, the red thick line) in the phase, the average particle grading curves separately analyzed in the phase and by CNR (see Fig. 2.6.3-5, black line in the middle) are almost the same. The distribution of curves, whose particle size is larger than 0.06 mm, is almost the same. From the curves whose particle size is smaller than 0.06 mm, the analysis result differs slightly

from the average particle grading curve analyzed by CNR.

In consideration of the undergoing sediment measurement in the damsite reach and non-compiled particle grading analysis; given that CNR has carried out the specialized analysis research in Mekong River about 850 km from the upstream and downstream of the Project, therefore it is recommended to adopt the analysis result by CNR in Table 2.6.3-3 for the average sediment particle grading curve and its variation range in the damsite and reservoir reach for the moment.

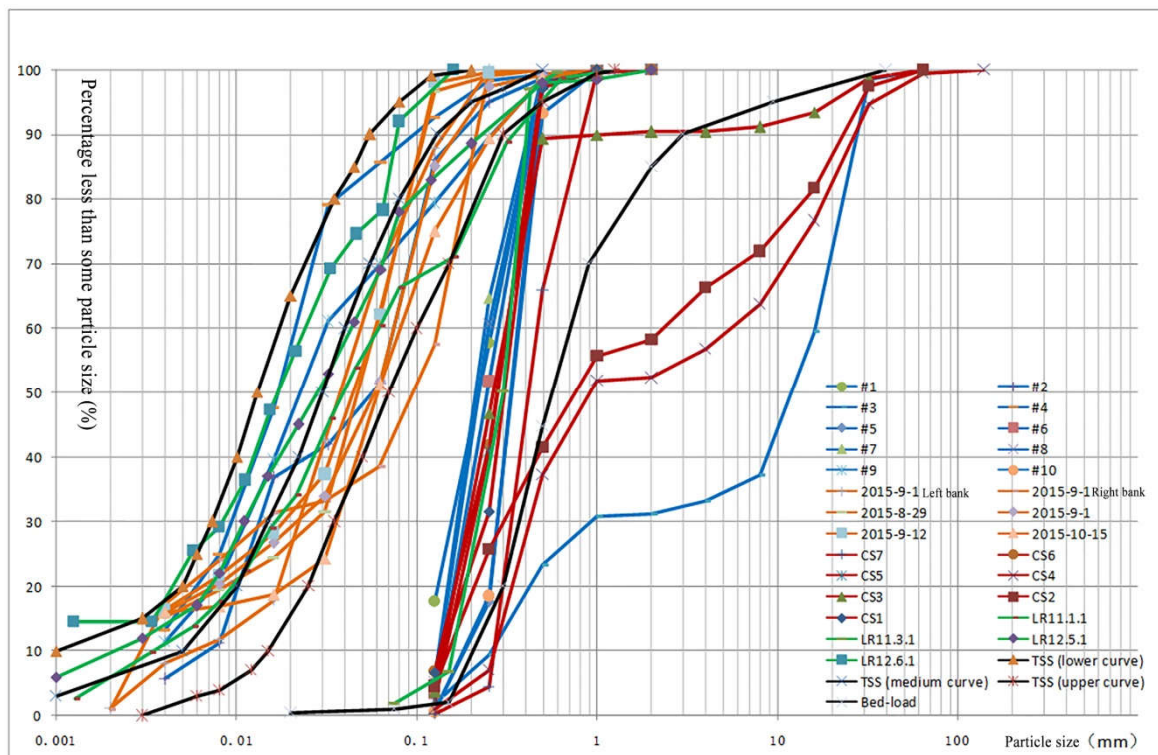


Fig. 2.6.3-4 Comparison of Sediment Sampling Analysis Result in the Damsite and Reservoir Reach

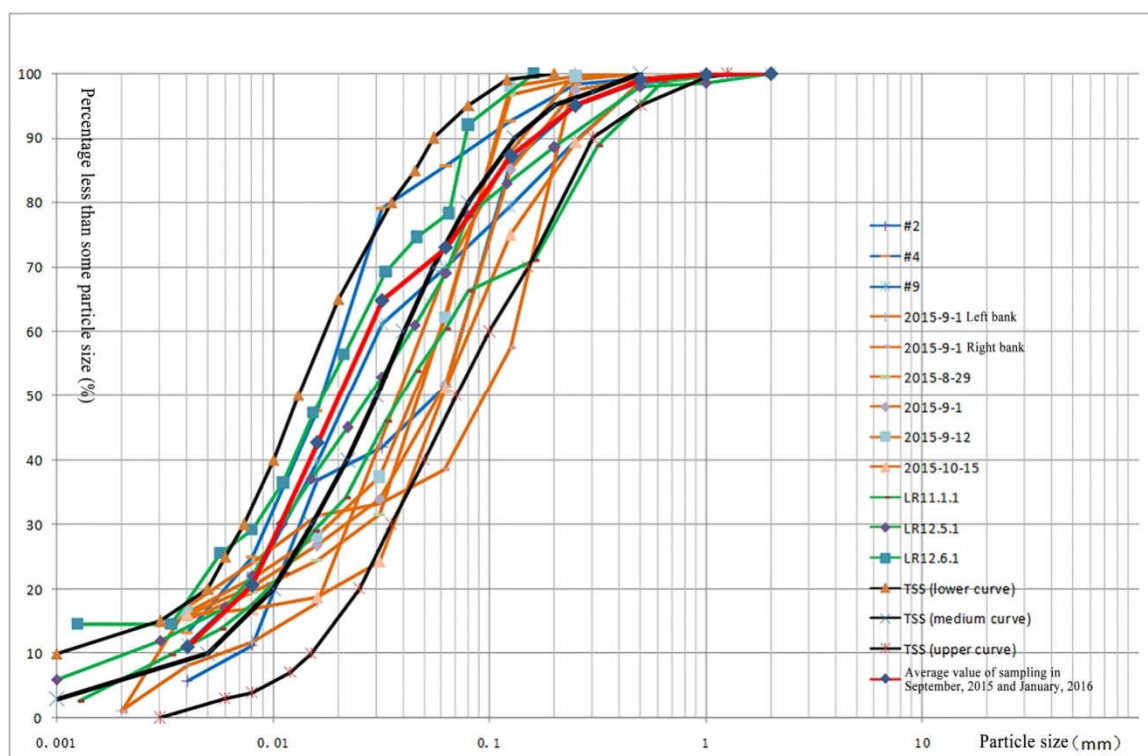


Fig. 2.6.3-5 Comparison of Sediment Sampling Analysis Result in the Damsite and Reservoir Reach(fine particle part)

Table 2.6.3-3 Result of Average Sediment Particle Grading in the Damsite and Reservoir Reach (recommended)

TSS (lower curve)	d(mm)	0.200	0.120	0.080	0.055	0.045	0.035	0.020	0.013	0.010	0.007	0.006	0.005	0.003	0.001	
	%	100	99	95	90	85	80	65	50	40	30	25	20	15	10	
TSS (medium curve)	d(mm)	0.500	0.300	0.200	0.130	0.080	0.055	0.040	0.030	0.022	0.015	0.010	0.005	0.001		
	%	100	97	95	90	80	70	60	50	40	30	20	10	3		
TSS (upper curve)	d(mm)	1.250	1.000	0.500	0.300	0.150	0.100	0.070	0.050	0.035	0.025	0.015	0.012	0.008	0.006	0.003
	%	100	99	95	90	70	60	50	40	30	20	10	7	4	3	0

2.6.4 Monitoring Planning of Sediments for the Project

2.6.4.1 Monitoring Purpose

Upon its completion, due to the increased depth in the reservoir reach upstream from the dams site, the flow velocity decreases to a degree during the non-flood discharge period, and some of the river's suspended sediments will deposit in the reservoir during the non-flood discharge period, thus occupying parts of storage capacity. The former channel form will change to a degree, and then the operation of hydropower station will be

influenced. Sedimentation number, sedimentation position in the reservoir, erosion and deformation of downstream channel caused by the discharged clear water flow, and others will influence the safe operation of the reservoir and the change of downstream channel. As a result, it is necessary to carry out the planning for sediments monitoring, for the monitoring can conduct the reservoir dispatching, guarantee the safe operation, and decrease the influence on the downstream channel. The main task includes:

- a) Monitoring the water and sediment entering and getting out from the reservoir;
- b) Get familiar with loss of storage capacity and its process to serve the reasonable dispatching of the reservoir;
- c) Estimating the influence of sedimentation in the reservoir on the hydropower station, providing basis for the dispatching and operation of the reservoir during flood season;
- d) Monitoring the scouring of clear water in the downstream from the hydropower station.

2.6.4.2 Monitoring Items and Requirements

- a) Test of inflow and outflow sediments of the reservoir

Sediments entering the reservoir mainly are from sediments discharged from the upstream cascade hydropower station. A control cross-section for monitoring at the downstream from the upstream cascade hydropower station is set to test water level, discharged flow, sediment concentration, and others on the cross-section as well as to understand and master the situation of sediments entering the reservoir. The control cross-section should coordinate uniformly with the monitoring cross-section of sediments getting out from the reservoir set at the upstream cascade hydropower station. The monitoring contents on the control cross-section are almost the same to those on the monitoring cross-section.

Certain test works of water level, flow, and sediments for the monitoring of sediments getting out from the reservoir, are mainly carried out on the control cross-section for monitoring set at the dam downstream so as to understand and master the flow and sediments situations of the hydropower station. The control cross-section of the dam

downstream in the Project should coordinate uniformly with the control cross-section for monitoring sediments in the tail area of the reservoir set at the downstream cascade hydropower station, and the monitoring contents on both cross-sections are almost the same.

b) Measurement on monitoring cross-section of sediments in the reservoir

The normal water level is 240 m in the reservoir of the hydropower station, and the length of return water is about 109.9 km in the reservoir of the main stream. Nine monitoring cross-sections are preliminarily selected in the reservoir of the main stream with their average spacing of about 12 km in accordance with variation profiles of channel vertical sections in the reservoir and reaches obviously influenced by sedimentation. As no relatively big tributary and no important objects of protection from flood exist in the reservoir, the sediment monitoring is conducted to the reaches of main streams. It is required to label fixed cross-section signs and bury piles of cross-section base points on each cross-section for monitoring sediments.

One section survey of the monitoring cross-section for sediments in the reservoir is conducted separately at the initial construction stage and at the later construction stage, while one section survey for the whole cross-section in the reservoir is conducted before the reservoir storage; one section survey will be conducted each year or every several years after the operation of reservoir storage in accordance with the sediment inflow from the river so as to understand and master the sedimentation in the reservoir. Related conditions should be known timely and determination whether all cross-sections in the reservoir should be surveyed is made through analysis after occurrence of major flood, so as to understand and master the influences of major flood on the reservoir and channel.

c) Water level observation in the reservoir

Two~three water level observation stations are established in the main stream of the reservoir, and the range of water level observation is defined according to the variation of reservoir water level. The water level observation is conducted once each day during dry season and twice and four times each day during flood season.

d) Analyses of sedimentation sampling in the reservoir and particle grading

Sedimentary bed materials are sampled on islets and banks of reservoir sedimentation. Bed materials sampling is conducted and composition of sediments' particles is analyzed in the reservoir, while the cross-section survey is being conducted.

2.6.5.3 Analysis and Arrangement of Observation Materials

Materials for each observation should be timely arranged and analyzed:

- a) Analyses on sedimentation elevation of each monitoring cross-section below the dam and in the reservoir.
- b) Arrangement for results of monitoring cross-section survey in the reservoir, and analyses on influences of sediment volume in the reservoir on storage capacity.
- c) Analyses on sampling of monitoring sections, flow, and sediment concentration out of the reservoir.
- d) Arrangement of water level observation materials at each water level station below the dam and in the reservoir.

The relation between reservoir operation mode and sediment movement in the reservoir is preliminarily analyzed in accordance with the process of water and sediments entering and getting out from the reservoir and the sedimentation in the reservoir each year after materials for each observation are arranged and comprehensively analyzed. Annual monitoring analysis report and suggestions are proposed to solve adverse effects of sedimentation on the Project.

2.7 Hydrological Telemetry and Forecast System

Upon its completion, the hydrological telemetry and forecast system (the System for short) of Paklay HPP will have such functions as real-time collecting, water and rainfall information transferring and alerting, analyses for statistics, compilation, query of entering the reservoir, and water regime forecasting. The construction of the System will play an important role in the hydropower station, the construction safety, flood control dispatching, and economic operation of the upstream and downstream hydropower station.

2.7.1 Necessity of the System Construction

It is an automatic system to provide service for the project's flood control, benefiting, and optimized dispatching and to collect, transfer, and process hydrologic parameter,

meteorological parameter, flood situation parameter, project parameter, and other parameters in the basin or monitoring area real-timely via telemetering, communication, computer and network, and other advanced technologies.

Necessity for the construction of the System mainly shows in following aspects:

a) Necessity for the construction, operation, and management security control of the hydropower station

Paklay HPP is located in the second reach of Mekong River---Chiang Saen-Vientiane Reach. Mountains cover most of the reach. As the special terrain conditions make the construction more difficult and the construction organization relation more complicated, there is a higher requirement and heavier responsibility of the hydrological telemetry and forecast during construction period. The few hydrologic stations at the hydropower damsite and basins above the damsite cannot meet the requirement of the hydrological telemetry and forecast for the hydropower station during construction period and construction requirement of the Project. Besides, compared with the manual measuring and forecast system, the hydrological telemetry and forecast system can automatically collect, transfer, and process information. The System has many remarkable advantages such as rapid information transferring, short calculation time, and high operational reliability. Being an important non-engineering measure to ensure safety of the hydropower engineering in the high water season and to enhance economic performance, it has been widely applied in construction and operation of hydraulic and hydroelectric projects inbound and outbound, and has obtained good economic benefits and social benefits.

Next, Paklay HPP is a kind of run-off-river hydropower station with low water head and large flow. The submerge area is widely distributed in the reservoir, and return water is very long in the reservoir, and many very sensitive international problems are involved. The establishment of the hydrological telemetry and forecast system of Paklay HPP can achieve the flood prediction. Based on the flood prediction, the System provides decision-making foundation for flood control dispatching, thus promoting the flood control capacity of Paklay HPP, decreasing losses of inundation upstream, and ensuring the safe operation of the station and reservoir.

Moreover, its establishment will decrease the management workload of the station and the operational costs, for the System can make operation of the station effectively less-attended or non-attended, and can be conducive to storage, filing, search, and use of data. It is one of the basic goals for the station to achieve modernization management.

b) Necessity for optimal dispatching of flood control during operation period

Paklay HPP belongs to the Cascade IV development of the Mekong River main stream. With the development of hydropower stations at different grades in succession, Paklay HPP can provide services for flood control safety of projects downstream during construction period and flood control of completed products downstream during operation period by full use of each built cascade, and can maximize the comprehensive benefits of cascades by use of cascade optimal dispatching. However, reliable, timely, and comprehensive water regime information and accurate water regime forecasting are basis for cascade flood control dispatching and optimal dispatching, and are preconditions for cascade dispatching.

c) Necessity for water resources management of multifunctional hydropower station

The development of Paklay HPP should simultaneously be given consideration to navigation, fish migration, irrigation, power generation, and other comprehensive utilization tasks. When dispatching of the reservoir is being carried out, it is required that the reservoir should remain at a certain high water level for one thing, the water level cannot be lowered acutely in time of draining floodwater for another. Based on the correct master of water regime, the dispatching is required to be very accurate so as to avoid influencing stability of the bank and safety of the dam and its surroundings as well as avoid destroying the ecological environment along the river. Upon its completion, the System can rapidly and correctly collect, transfer, and process water and rainfall information in the basin, and timely make correct flood prediction and buy time for pre-discharge of the reservoir. Therefore, the System is conducive to optimal dispatching of the comprehensively used reservoir.

In conclusion, the establishment of the System is one of important measures to ensure safety of project construction and operation, distribute water resources scientifically and reasonably, and promote economic benefits of the project, is one of the basic goals for the station to achieve modernization management; is an necessity to achieve the optimal dispatching and maximize the comprehensive benefits of the hydropower project in the basin; is an necessity to reach the comprehensive use task of the hydropower station, ensure safety of the station, and protect the surrounding ecological environment, etc.

2.7.2 Scope of the System

Located above the main stream of Mekong River, about 31 km upstream from Pak Lay County of Sayaboury (Xaignabouli) Province, Pak Lay Cascade Hydropower Station

is a Cascade IV station in *Planning Report on Runoff-type Development of Main Stream of Mekong River* prepared by Mekong River Commission in 1994. Paklay HPP is about 70 km from Cascade III Sayabuary Hydropower Station (It has been currently constructed, and is scheduled to be completed in 2019. It owns the daily regulating capacity.), the sectional basin area is about 6400 km², and the sectional flood travel time is about 7~14 h, the foreseeable period for water regime forecasting can basically meet requirements of hydropower station construction and flood control dispatching of the reservoir; the damsite of Paklay HPP is about 181 km from the upstream Luang Prabang Hydrologic Station, the sectional basin area is about 10,400 km², the sectional flood travel time is about 18~36 h, and the foreseeable period for water regime forecasting can basically meet requirements of hydropower station construction and flood control dispatching of the reservoir.

As a result, according to the analyses of flood travel time and the requirements of the foreseeable period for water regime forecasting in construction and operation of Pak Lay Cascade Hydropower Station above, the measuring and forecast scope of the System is the section between Luang Prabang Hydrologic Station and the damsite of Paklay HPP, with a measuring and forecast area of about 10,400 km².

2.7.3 Layout of Telemetry Station Network

2.7.3.1 Existing Stations

Located 19°53.5' of northern latitude and 102°8.2' of east longitude, Luang Prabang Hydrologic Station is within the measuring and forecast scope of the System now. It is a key control station of the Mekong River Basin with a control catchment area of 268,000 km² and is 2,010 km away from the Mekong River outlet. The main observation data include water level and flow. And some sediment data are available for some years.

2.7.3.2 Station Network Layout

a) Scheme 1 for station network layout

The System has established 1 center station and 12 new various telemetry stations. The 12 telemetry stations include 4 hydrologic stations, 1 water level station, and 7 precipitation stations. The 4 hydrologic stations are Luang Prabang, Sayabuary, BamKeo, and Pak Lay Dam Downstream Hydrologic Stations separately, and the 7 precipitation stations are located above Pak Lay Dam Upstream Water Level Station and in the basin.

b) Scheme 2 for station network layout

The System has established 1 center station and 11 new various telemetry stations. The 12 telemetry stations include 3 hydrologic stations, 1 water level station, and 7

precipitation stations. The 3 hydrologic stations are Sayabuary, BamKeo, and Pak Lay Dam Downstream Hydrologic Stations separately, and the 7 precipitation stations are located above Pak Lay Dam Upstream Water Level Station and in the basin. Next, the information of Upstream Luang Prabang Hydrologic Station is transferred into the System, and Luang Prabang Hydrologic Station acts as the upland water control station in the basin for the measuring and forecast.

c) Scheme 3 for station network layout

The System has established 1 center station and 4 new various telemetry stations. The 4 telemetry stations include 3 hydrologic stations and 1 water level station. The 3 hydrologic stations are Sayabuary, BamKeo, and Pak Lay Dam Downstream Hydrologic Stations separately, and the water level station is Pak Lay Dam Upstream Water Level Station. Next, the information of Upstream Luang Prabang Hydrologic Station, information and its dispatching information of hydrological telemetry and forecast system of Sayabuary Hydropower Station are transferred into the System. Furthermore, precipitation information in the measuring and forecast basin of the System can be obtained at <http://disc.sci.gsfc.nasa.gov/services>.

From the schemes for station network layout above, all measuring stations are stations automatically established by the System in Scheme 1, where information is stable and safe, but construction cost is very high; information of Luang Prabang Hydrologic Station is transferred into the System and is shared in Scheme 2, which decreases the project investment and workload of the System to a degree, but is required to coordinate with the affiliated unit of Luang Prabang Hydrologic Station over information sharing; information of Luang Prabang Hydrologic Station, information and its dispatching information of hydrological telemetry and forecast system of Sayabuary Hydropower Station are transferred into the System and are shared in Scheme 3, which not only enriches water regime information in the measuring and forecast scope of the System, but also raises the accuracy of the flood prediction scheme for Paklay HPP 's damsite to a degree. However, the information above is required to be coordinated with respective affiliated units to be shared, and the coordination even involves the Lao Government. As a result, it is very difficult to share the information above. Besides, precipitation information in the basin is obtained in other ways, and obtaining the information requires 24 h uninterrupted network and power supply, continuously updated network data, information decoding and receiving software, and others with none being dispensable. As a result, the limited conditions are

very heavy. Therefore, there is relatively less the project construction investment and workload due to fewer stations automatically established by the System in Scheme 3, but the stability and accuracy of information are limited to external conditions to a great degree, thus influencing the accuracy for decision making of flood control, irrigation, and others in the Hydropower Station.

Through the comprehensive consideration, Scheme 1 is temporarily recommended for the design, and all the following contents are designed as per Scheme 1.

The radar water gage is adopted as the water level monitoring facility for various stations above, the tipping-bucket rain gauge is adopted as the precipitation monitoring facility, and the tour-measuring method is adopted for the measurement of flow at hydrologic stations. See Fig.2.7-1 for Station Network of Hydrological Telemetry and Forecast System of Paklay HPP.

2.7.4 Water Regime Forecasting Scheme

According to runoff in the Mekong River Basin, precipitation and flood characteristics and basin development, in comprehensive consideration of development and operation requirements of cascade hydropower stations in the Mekong River Basin as well as station network layout in the basin, the water regime forecasting of the System should adopt the scheme integrating river system forecasting and sectional precipitation runoff forecasting. The detailed scheme is structured as follow:

a) The scheme of forecast cross-section coupling precipitation runoff forecasting is structured by regarding Luang Prabang Hydrologic Station as the upland water control station and by combination of sectional precipitation runoff forecasting between Luang Prabang Hydrologic Station and the damsite of Paklay HPP . The main data used in the scheme are the discharges (derived from the stage-discharge relations of corresponding stations) and rainfalls of the four hydrological stations as well as the rainfalls of seven rainfall stations on the river reach from Luang Prabang hydrological station to the dam site. The scheme has a long forecast lead time, but its forecasting accuracy is subject to the possible adjustment and storage of Sayabuary Hydropower Station.

b) The scheme of forecast cross-section coupling precipitation runoff forecasting is structured by regarding Sayabuary Hydrologic Station as the upland water control station and by combination of sectional precipitation runoff forecasting between Sayabuary Hydrologic Station and the damsite of Paklay HPP . The main data used in the scheme are the discharges (derived from the stage-discharge relations of corresponding stations) of the

three hydrological stations as well as the rainfalls of four rainfall stations on the river reach from Xayaburi hydrological station to the dam site. The scheme has shorter forecast lead time than the scheme a), but it should have a higher forecasting accuracy. Therefore, it can act as the key forecasting scheme at routine work.

The real-time forecasting information should be modified in combination with the latest water regime information of key control hydrologic station within the measuring and forecast scope so as to improve the forecasting accuracy; estimated precipitation and flood forecasting can be conducted for the precipitation (forecast results) within the foreseeable period in the scheme in accordance with the precipitation forecast results of the professional meteorological department.

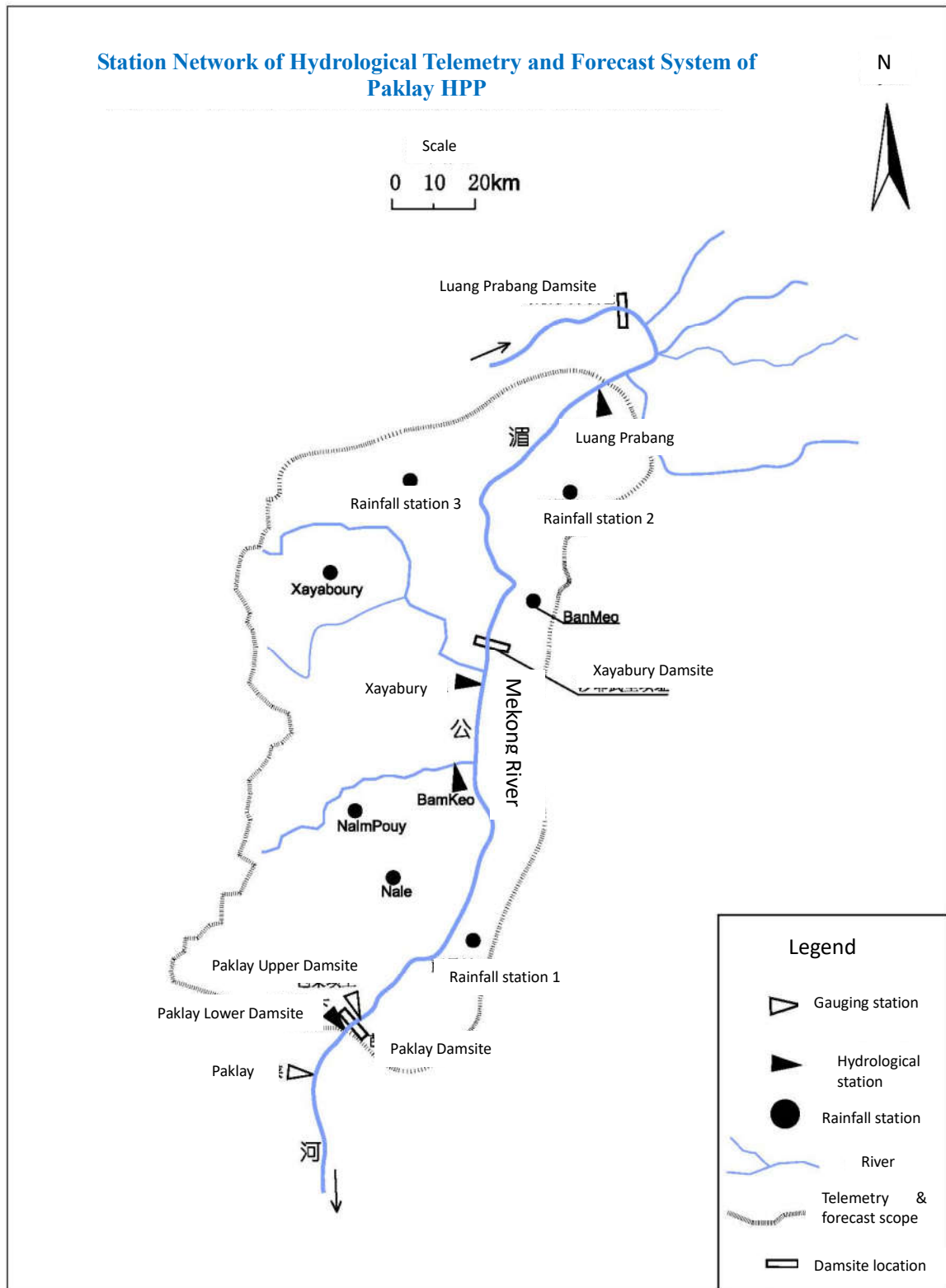


Fig.2.7-1 Station Network of Hydrological Telemetry and Forecast System of Paklay HPP

2.7.5 Information Collection and Transfer System

The information collection and transfer system mainly undertakes real-time collection and transfer of water and rainfall information in the measuring and forecast basin, and it is the most important part of the hydrological telemetry and forecast system. The telemetry station realizes the real-time collection of the water and rainfall information, and the remote terminal unit (RTU) will process the collected water and rainfall information. When the processed water and rainfall information meets the required sending conditions, the system will timely transfer it to the center station in a corresponding channel communication manner in accordance with the required transfer mechanism. The information will be stored in database after the communication server at the center station makes necessary procession of received information.

In consideration of influences from the local terrain, economic conditions, and other unpredictable elements, the hydrological telemetry and forecast system of Paklay HPP adopts Beidou Satellite/GSM (GPRS) communication method, among which the communication method of Beidou Satellite/GSM (GPRS) main and backup channels is adopted at important measuring stations (hydrologic station, water level station), and the Beidou Satellite single channel communication method is adopted at the precipitation station.

The System adopts the self-reporting working mechanism.

Measuring and forecast stations adopt the power supply method of solar energy floating charge.

2.7.6 Central Station

Being the pivot for receiving and processing data of the hydrological telemetry and forecast system, the central station mainly consists of computer network system, database system, data receiving and processing system, business application system, and information release system. It mainly has following functions: receiving and processing of telemetry information, alarming and data statistical analysis, inquiry of report forms and information, real-time flood prediction, and other functions.

It is decorated according to requirements of the machine room with the area range of 30~50m². It adopts the AC power method and is equipped with back-up power sources.

2.7.7 Hydrological Telemetry and Forecast System During Construction Period

In order to make full use of the investment, avoid the repeated construction as well as keep the continuity of basic hydrological data simultaneously, the water regimen hydrological telemetry and forecast system during construction period is designed and constructed with the full consideration of water regimen automatic measuring and forecast characteristics and in combination of water regimen automatic measuring and forecast characteristics during operation period.

The measuring and forecast station network of the hydrological telemetry and forecast system of Paklay HPP during construction period is the same with it during operation period. In consideration of flood control in construction, temporary water level stations of manual observation are established at upstream cofferdam, downstream cofferdam, and other important flood control points in the construction area to monitor flood stage during flood season and ensure safety of plants, dams and other facilities in construction during high water season. Water level stations of manual observation can be removed upon its completion.

2.7.8 Cost Estimation

The cost of the system establishment and water regime service fees during the construction period have been listed into the total project cost, and the annual cost during operation period will be put into the operation cost of the Paklay HPP.