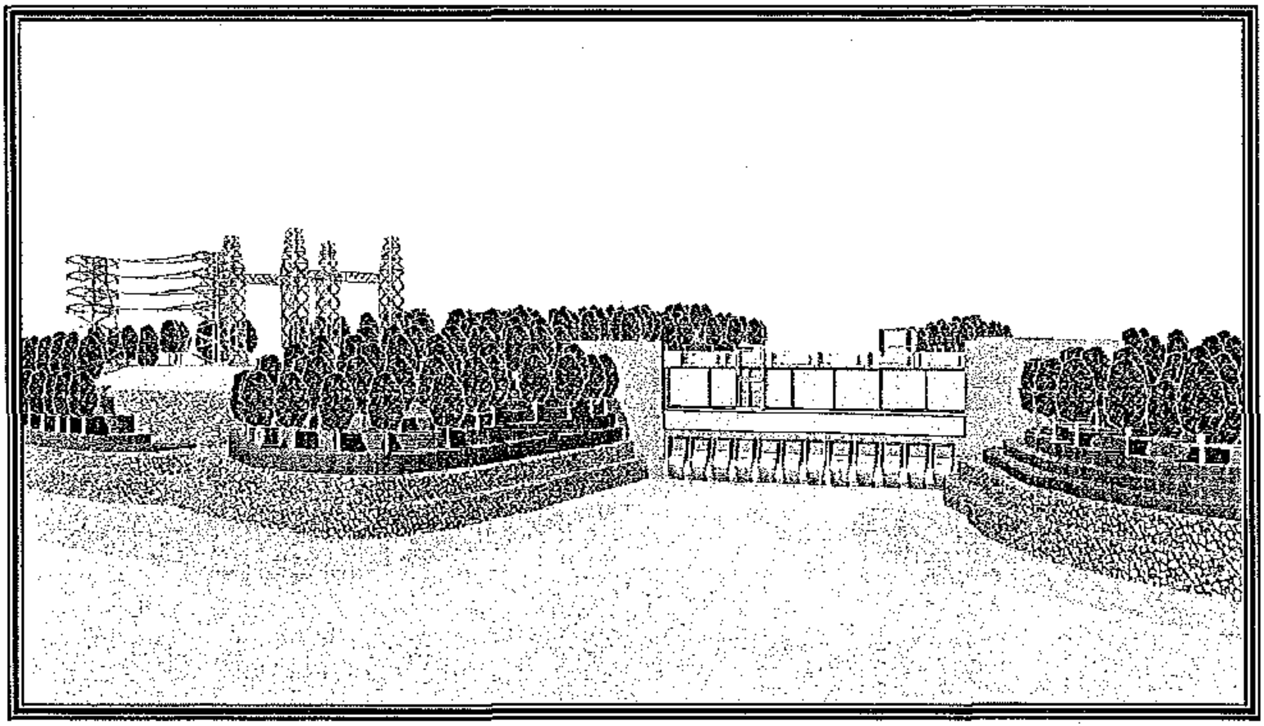
MFCB MEGA FIRST CORPORATION BERHAD

Don Sahong Hydroelectric Project
Lao PDR

Feasibility Study Report

Volume 1 – Report



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DON SAHONG HYDRO-ELECTRIC PROJECT

FEASIBILITY STUDY REPORT

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[1] Figures marked with this symbol • are bound in Volume 3 in A3 size, but are also included in this Volume 1 as A4 sheets at the positions indicated

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Abbreviations and Acronyms

AAM	AAM (Thailand) Co. Ltd.
AC	Alternating Current
APW	Australian Power and Water Pty. Ltd.
ASA	ASA Power Engineering Company Limited
BOP	Balance of Plant
BOT	Build, Operate, Transfer
CA	Concession Agreement
CFRD	Concrete Faced Rockfill Dam
CLO	Community Liaison Officer
CMPE	Centre for Malariology, Parasitology and Epidemiology
CNR	Compagnie Nationale du Rh6ne
DC	Direct Current
DCRC	District Compensation and Resettlement Committee
DEM	Digital Elevation Model
DSHEP	Don Sahong Hydro-Electric Project
E & M	Electrical & Mechanical
EdC	Electricite du Cambodia
EDL	Electricity du Lao
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPCC	Engineering, Procurement & Construction Contractor
EVN	Electricity of Vietnam
FOB	Free on Board
GFL	Great Fault Line
FS	Feasibility Study
GoL	Government of Laos
GPS	Global Positioning System
GWh	GigaWattHour(s)
HC	Health Centre
HSE	Health, Safety and Environment
IPP	Independent Power Producer
IRR	Internal Rate of Return
ITN	Insecticide Tested Net
IUCN	International Union for Conservation of Nature
km	kilometre
kV	kilovolt
LNMC	Lao National Mekong Committee .
Mb	Megabyte
MDA	Mass Drug Administration
MDF	Mixed Deciduous Forest
MEM	Ministry of Energy and Mines

MFCB	Mega First Corporation Berhad
MOAF	Ministry of Agriculture and Forests
MoU	Memorandum of Understanding
MRC	Mekong River Commission
MSL	Mean Sea Level
MVA	Mega Volt Ampere
MW	Megawatt
NGD	National Geographic Department
NPV	Net Present Value
0 & M	Operations & Maintenance
PDA	Project Development Agreement
PDR	People's Democratic Republic
PESC	Provincial Environmental and Social Committee
PESMU	Project Environmental and Social Management Unit
PHO	Provincial Health Office
PPA	Power Purchase Agreement
PSDP	Power System Development Plan
RAP	Resettlement Action Plan
RMB	Renminbi
SAP	Social Action Plan
SCADA	Supervisory Control and Data Acquisition
SPT	Standard Penetration Test
STEA	Science Technology and Environment Agency
UXO	Unexploded Ordnance
VCGRC	Village Consultative and Grievance Redress Committee
VHV	Village Health Volunteer
WG	Water Gauge
WREA	Water Resource and Environment Agency
WWF	World Wildlife Fund

FEASIBILITY STUDY REPORT

EXECUTIVE SUMMARY

E.I. The Project

A Memorandum of Understanding (MoU) was signed between the Government of Laos (GoL) and Mega First Corporation Berhad (MFCB) on 23 March 2006 which gave MFCB exclusive rights to investigate the technical, environmental and economic feasibility of the Don Sahong Hydroelectric Project (DSHEP or "the Project"). Figure E.l shows the general location of the Project.

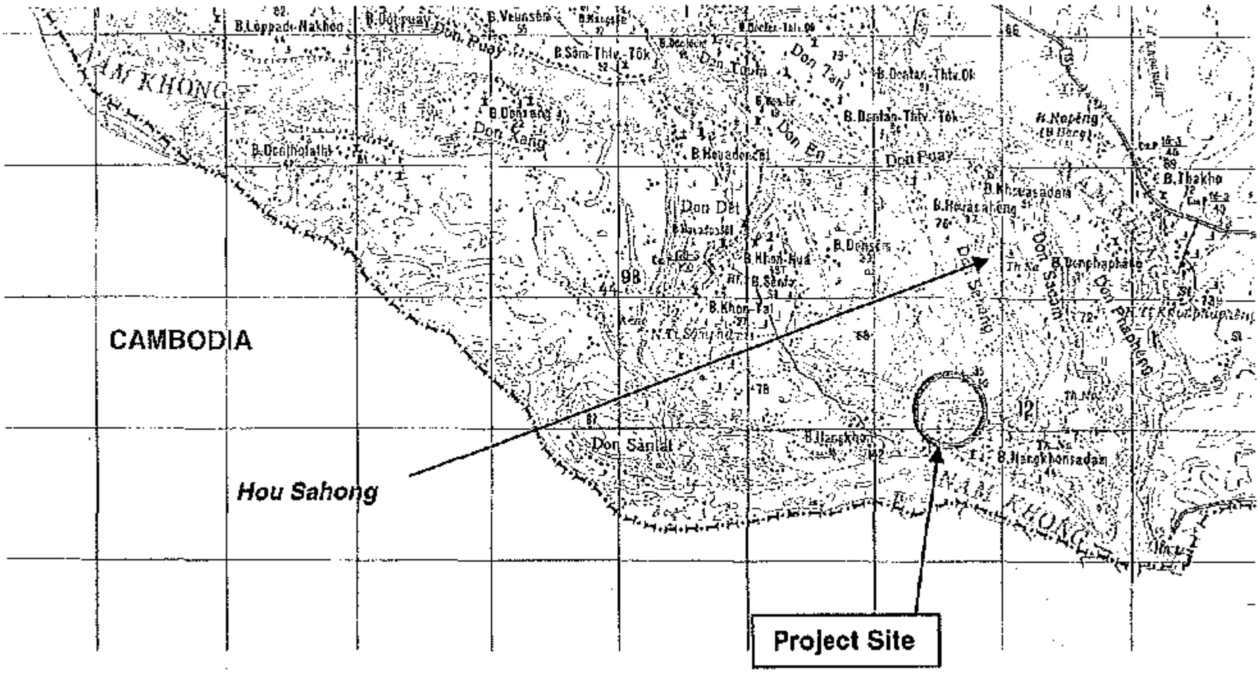


Figure E.1 - Location of Don Sahong Hydro Electric Power Project

The MoU stipulates that the Feasibility Report and the Environmental Impact Assessment are to be presented to GoL within 18 months. Upon acceptance and approval of these reports, the Project Development Agreement (PDA) would be negotiated and executed. This would enable the developer to undertake further activities to develop the Project and to negotiate and execute Power Purchase Agreement(s) (PPA) for the export of energy to Thailand and/or Cambodia, leading ultimately to the signing of a Concession Agreement (CA) and the construction and subsequent operation of the power station for a period of 30 years on a build, operate and transfer (BOT) basis. The GoL would also be a shareholder in the Project development.

To carry out the Feasibility Study and the EIA Studies for the Project, the following site surveys, investigations and data collection were carried out:

a. Establishment of a first order control network in the project area, topographical survey and production of 1:1,000 and 1:5,000 scale maps of the area

b. Geotechnical investigation, including site mapping, refraction seismic traversing, diamond drilling of foundations, test pitting, materials investigation and laboratory testing of samples.

c. Stream gauging over a period of nine months to determine basic relationships between flows at Pakse, at Thakho and in the Hou Sahong, using also historic data from staff gauge records from stations in the area.

d. Collection of 82 years of flow records at the Pakse gauging station and other hydrology-related data available for the Project area.

e. Socioeconomic surveys of the six villages directly affected by the construction of the project,

f. Survey of tourism (tour operators, boat operators and guesthouses).

g. Field surveys and data collection relating to fisheries, birdlife and vegetation.

The Environmental Impact Assessment (EIA) for the Project is in the accompanying EIA Report.

E.2. Water Availability and Energy Production

Reliable records of daily flow dating back to 1924 are available for the gauging station at Pakse, 150 km upstream of the Don Sahong site. There are no long-term records for stations closer to the site, but there is little increase in catchment area between Pakse and the site and comparison with records at Stung Treng, 50 km downstream, in Cambodia, indicate that it is slightly conservative in adopting the Pakse flows as the discharges in the Mekong through the channels in the Project location.

The numerous water flow channels through the complex of islands range from the Phapheng Falls to unnamed channels that carry flow only during the high flow period- Hou Sahong and the adjacent Hou Sadam are the only two channels that do not include substantial waterfalls but instead rapids are present along the length of these two channels which have water flow throughout the year.

Stream gauging carried out during this study, together with staff gauge records from sites established in the area since the mid 1990s indicate that at low flows during the dry season, as much as 90% of the flow measured at Pakse is earned over the Phapheng Falls. During the wet season with high flows this drops off to about 25%, as a substantial portion of the total flow is carried over the Khone (Liphi) Falls at the western side of the river, the Samphamit Falls south and west of Don Det and through the channels between Don Khone and Don Sahong.

It is necessary to excavate the channel bed deeper and deeper in the intake portion of the Hou Sahong to optimise water flow for power generation as the power station capacity is increased. The natural bed level is EL 70.5m and the maximum depth of excavation proposed is about 7 metres and the excavation will extend for approximately 2 km downstream from the Hou Sahong entrance. It is also proposed that the bed of the Hou Sahong channel be excavated for a depth of about 1 metre from the power station tailrace to as far as the exit of the Hou Sahong into the Mekong main stream

The topographical survey and review of the hydrographic records, together with studies undertaken during the feasibility indicate that the upstream water level in the Mekong River at the entrance to the Hou Sahong will vary according to river flow from RL 72 (dry season) to RL 74.5 (wet season) and that corresponding natural river levels downstream of the power station are RL 50 (dry season) and RL 58 (wet season). Hence in this project during the dry season when flow is minimum, the head available is much higher than the head available during the wet season when the flow is maximum.

The amount of water available for generation during the dry season depends on the minimum amount of water that is allowed to pass over the Phapheng Falls for purposes of visual effect and other channels for fish migration purposes, referred to as the "environmental flow". In the energy modelling a range of environmental flows has been studied, with a value of 1,000 m /sec, which is about the minimum flow measured at Pakse, being selected as an appropriate discharge.

Based on the head available, the power station will discharge between 1,600 and 2,400 m /sec, depending on the installed capacity chosen. Therefore, during the low flow period when the discharge at Thakho is less than 3,400 m^3/sec, approximately 40 % of the time (based on the 82 years of record), the power station output and flow will be reduced to maintain the "environmental flow". For the rest of the year the power station will be able to operate at full capacity as there is more than enough water available.

Figure E.2 shows the variation in annual average energy production for a range of installed generation capacities and environmental flow of 1,000 m^3/sec. Also shown is the intake channel excavation elevation affecting the annual energy generation for the range of installed capacities.

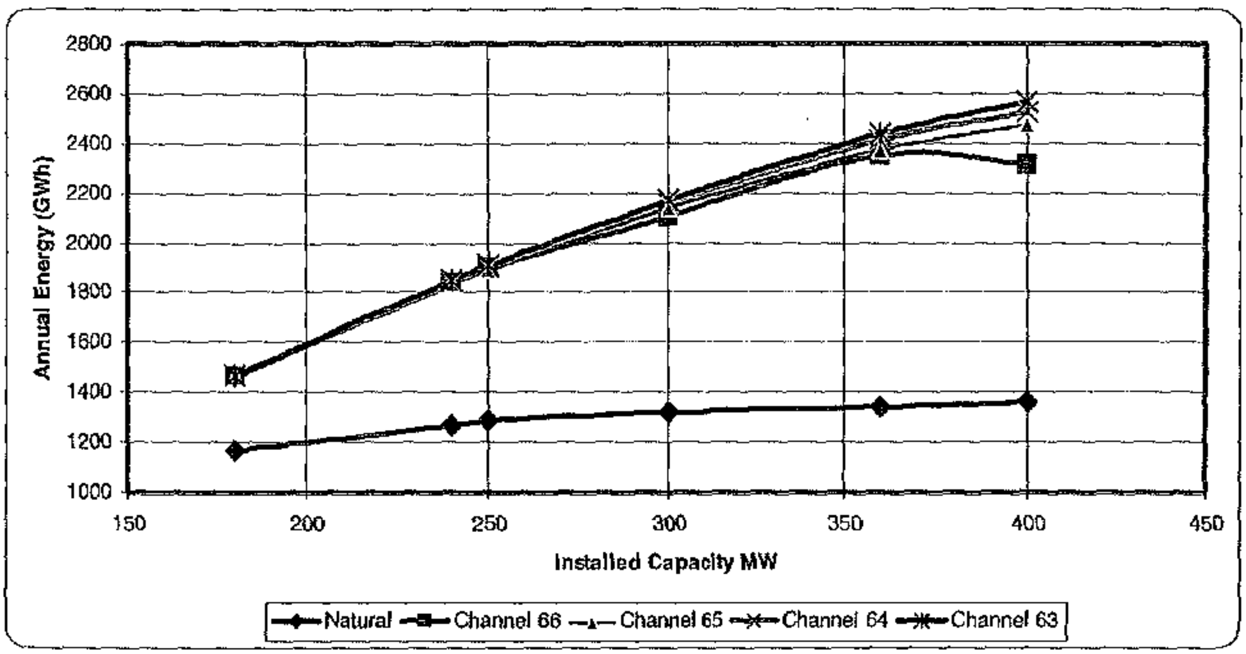


Figure E.2 - Annual Energy Production for various installed capacities

E.3. Geology of the site

The geological mapping and the limited subsurface investigations have indicated that the power station and reservoir area lies on hard volcanic rock. Foundations for the power station are sound, fresh rock with little weathering and there is little concern for seepage around the structures. No significant seismic event has been recorded close to the site.

The excavation of the power station and the deepening of the inlet to the Hou Sahong will provide more than enough suitable material for coarse aggregate and for construction of the retaining embankments on either bank of the Hou Sahong channel. Sand and aggregate for concrete can be sourced by dredging from the Mekong itself or recovered from deposits that are common on the islands upstream from the project area.

E.4. The Proposed Development

The layout envisaged is for a concrete box-like structure to be constructed about 150 metres upstream from the exit of the Hou Sahong. This structure, to be excavated about 15 m below the existing channel floor will extend to both banks and will contain bulb-type hydro turbine generators and associated control and protection equipment in a semi-outdoor arrangement. Three-phase transformers will be located on the downstream side of the powerhouse, with cables taking the high voltage power to the substation adjacent to the right of the powerhouse. From the substation a 230 kV double circuit transmission line will run north across Don Sahong and Don Tan before reaching the mainland in the vicinity of Ban Nakasang and continuing to Ban Hat substation and then on to Ubon and Stung Treng.

The general level of Don Sahong and Don Sadam falls to the south, and it is necessary to construct rockfill embankments on both islands to contain the water within the Hou Sahong.

E.5. Export of Energy

The existing demand in the Laos southern grid is very small and is presently catered for by Xeset and Selabam Power Stations, with import as necessary from EGAT via Ubon, Thailand. The plan, as per the MoU, is to export all or most of the power generated to EGAT and /or EdC, Cambodia. The proposed route to the EGAT system would be via a 230 kV double circuit transmission line, initially to run parallel and adjacent to the existing EdL 115 kV transmission line from Ban Hat to Pakse and then on to Ubon. Exports to EdC would be through the proposed 115 kV line from Ban Hat to Stung Treng. The Cambodian power grid is not large enough at the moment to take a major portion of the output from the Project. Hence, for the puipose of this Feasibility Study, 90% of the energy is sold to EGAT and 10% is sold to EdC.

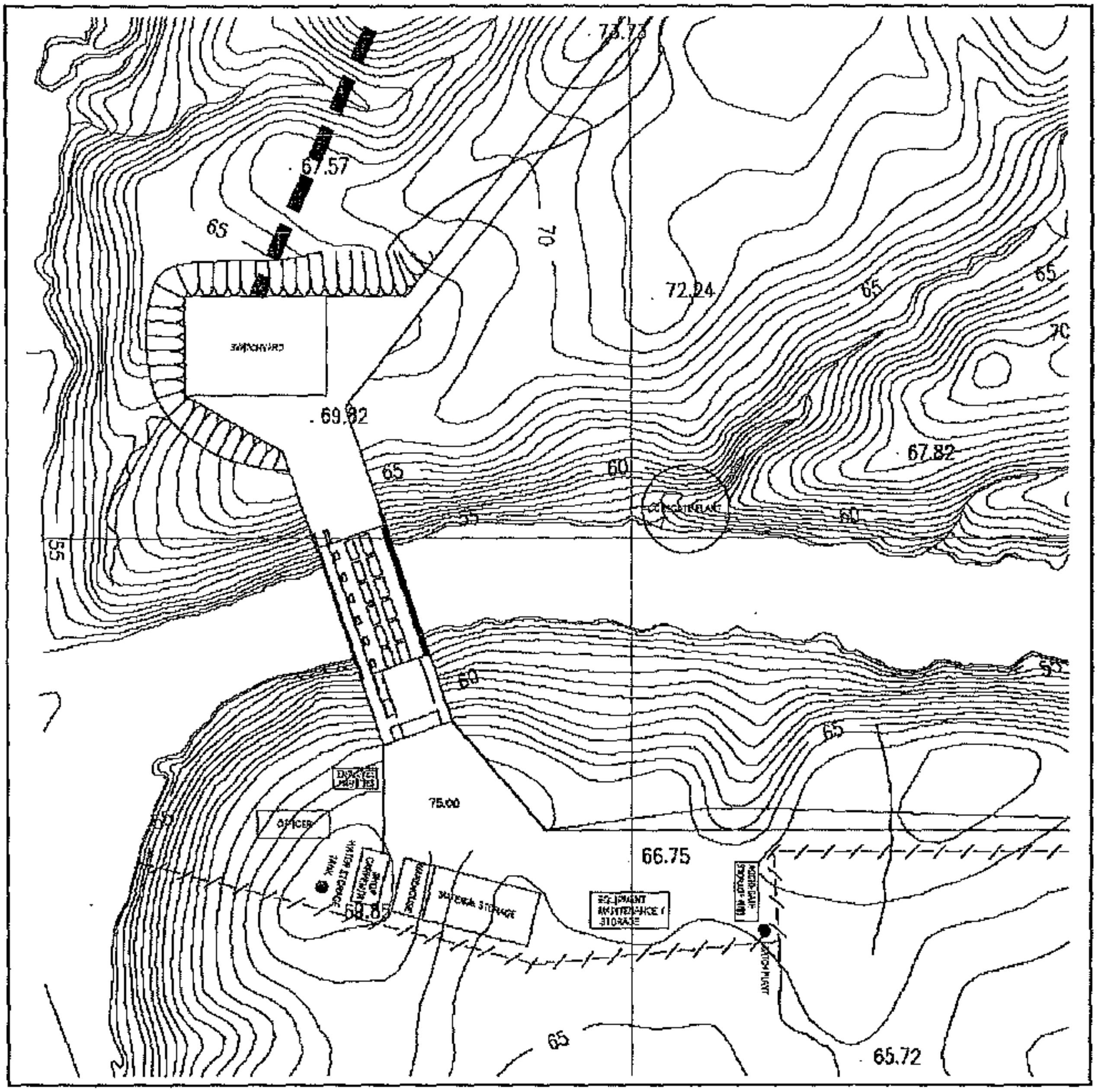


Figure E.3 – Layout of Power Plant

E.6. Construction costs and schedule

Preliminary designs were prepared for all major features of the project and cost estimates prepared from quantities derived from those designs. Budget costs were requested for plant and equipment from experienced manufacturers in Europe and China. Project cost estimates for three installed capacities, 240 MW, 300 MW, and 360 MW, are given in Table E.l, together with the average annual generation estimates.

Table E.1 - Project Cost Estimates (millions of US$)

Station capacity	**(6 x 40 MW) 240 MW**	**(5 x 60 MW) 300 MW**	**(6 x 60 MW) 360**
Development Costs	US$ 20.0	**US$** 20.0	US$ 20.0
Power Station Construction	US$ 352.4	**US$401.1**	US$ 453.2
Transmission Line to EGAT	US$ 70.5	**US$** 70.5	US$ 70.5
Environmental Costs	US$28.1	**US$ 28.1**	US$ 28.1
Project Capital Cost	**US$471.0**	**US$519.7**	**US$571.8**
Interest During Construction [1]	**US$** 82.9	US$91.9	**US$101.5**
TOTAL PROJECT COST	**US$ 553.9**	**US$611.6**	**US$ 673.3**
Annual Average Energy	**1838.1 GWh**	**2140.4 GWh**	**2375.0 GWh**

Note: 1 - IDC based on borrowing finance at 9.5% interest, a 75:25 debt:equity ratio and a four-year construction period.

Construction of the major features of the project is quite conventional and straightforward, however, some difficulties foreseen are the transport of materials and equipment to the project sites on Don Sahong and Don Sadam. One proposed site for the construction base camp facility is on the mainland immediately north of the Khone Phapheng Golf Resort. The base camp would include offices, workshops, material stockpiles, warehouses and staff accommodation. Barges would ferry the workforce, materials and equipment to a landing on Don Sadam, east of Ban Houa Sadam and an access road would be built to the power station site. There will be further offices, workshops, crushing and concrete batching equipment at the power station site. The channel between the mainland and Don Sadam needs to be deepened to ensure safe use of the barges under all conditions of flow. Other proposals for the base camp are east of Highway 13 (with an access road to the river and barge loading point) and at Veunkham. The EPC contractor needs to cany out his own studies to select the site that best suits his construction methodology.

The project execution / construction is expected to take four years and if the financial close is achieved by the end of 2008, the power plant would be in full commercial operation in the first quarter of 2013.

E.7. Economic and Financial Evaluation

Based on a 30-year BOT concession period, project costs, energy generation and range of tariffs, the project is found economically viable for a range of installed capacities. The sensitivity of a range of project parameter variations, including increased project costs, extended construction period, interest rates , etc were also studied and the project is found to be economically viable.

Based on the economic returns on the Project, it was found that the optimum installed capacity is between 300 and 400 MW. Savings in the project costs or increases in the tariff rate will push the optimum installed capacity higher and the reverse applies for increased project cost and lower tariff rates.

For the three installed capacities and Project Costs shown in Table E.l, the Financial Model runs using a tariff of US$ 0.0625/kWh gave Project IRRs of 14 %, 14.8 % and 14.9 % for the 240 MW, 300 MW and 360 MW stations respectively.

E.8. Conclusion

The project is economically viable and, as discussed in the accompanying Environmental Impact Assessment, mitigating measures proposed will minimize social and environmental impacts.

Construction of the project meets the aims of the Government of Laos to promote the export of electrical energy to neighbouring countries so as to expedite economic growth in order to alleviate poverty and achieve its social development goals and is in accordance with the aim of the Mekong River Commission's Hydropower Development Strategy,

> *The efficient and socio-economically and environmentally appropriate generation and distribution of hydropower in the riparian countries, in a cooperative and well co-ordinated way is promoted;*

its immediate object that

> *Hydropower resources of the Mekong mainstream and its tributaries are developed according to true least-cost planning, fully considering environmental and social impacts;*

and its basic vision that

> *The increasing demand for affordable electric energy in the MRC member countries is met with minimal negative impacts on the environment and local people, thereby promoting economic growth for the countries' mutual benefit,*

SECTION 1

INTRODUCTION

1.1 Background

Mega First Corporation Berhad (MFCB) has signed a Memorandum of Understanding (MoU) with the Government of the Lao People's Democratic Republic (GOL) on 23 March 2006 regarding the development of the Don Sahong Hydroelectric Project (DSHEP or "the Project").

The Project involves a power station proposed to be built on the Hou Sahong branch of the Mekong River in Champassak Province, immediately north of the border with Cambodia.

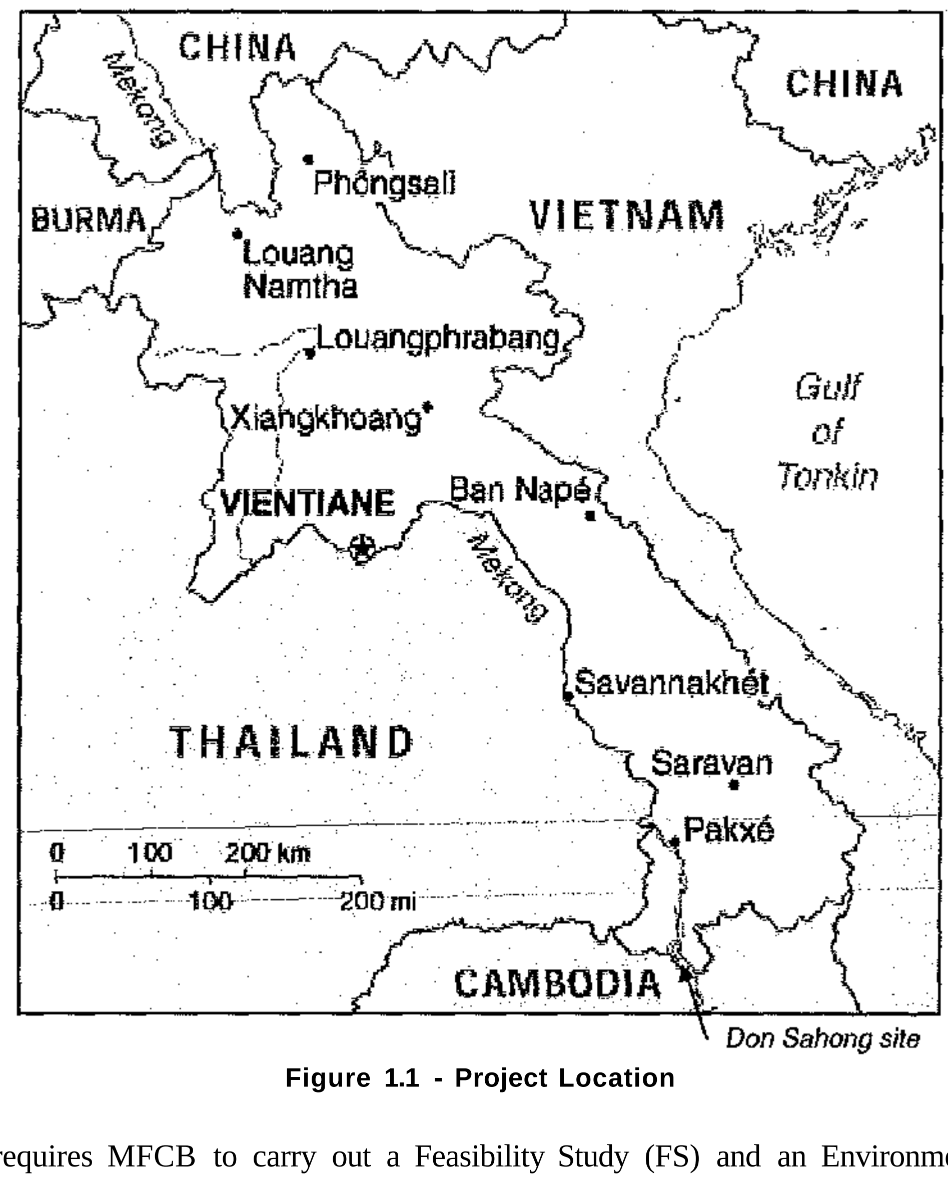
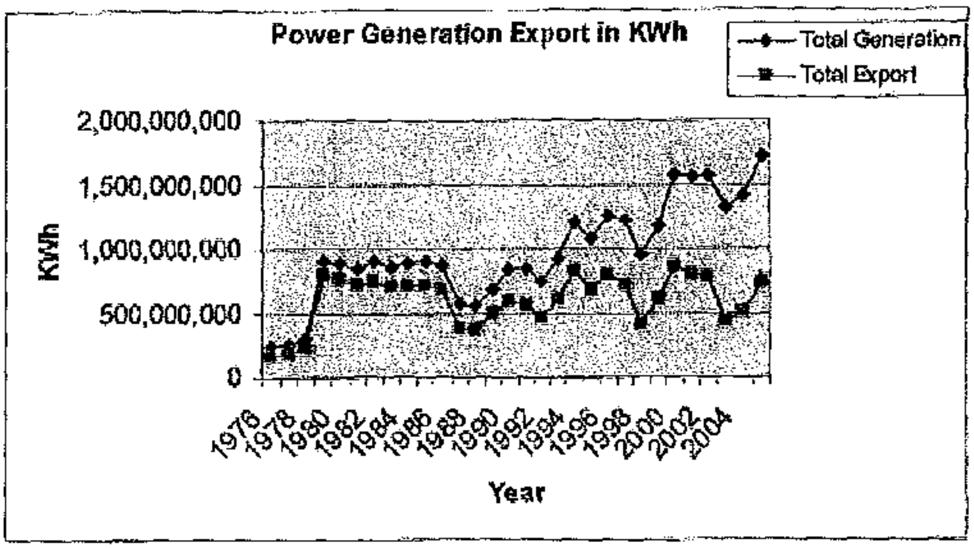


Figure 1.1 - Project Location

The MoU requires MFCB to carry out a Feasibility Study (FS) and an Environmental Impact Assessment (EIA) and submit the associated reports within 18 months.

1.2 Electricity Export

The private development of the country's hydropower resources for export earnings is a major policy of the Lao PDR government. Export earnings can help develop the country. 1,715 GWh was generated in year 2005 of which 728 GWh was exported, earning about US$21.5 million.



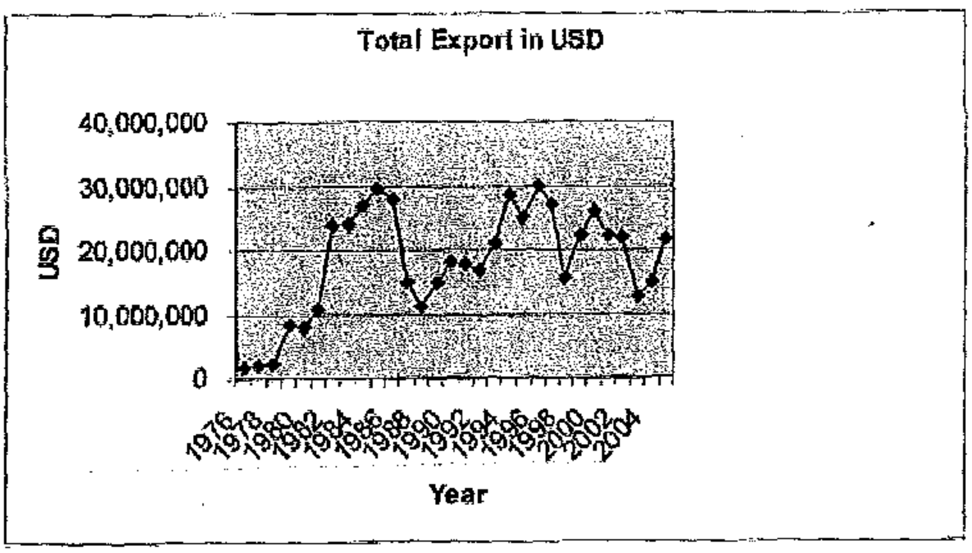


Figure 1,2 - Historical Energy Exports
(Source: www.poweringprogress.com)

In August 2004 there were two operating Independent Power Plants (IPPs) (Houay Ho and Theun Hinboun), five concession agreements (including the Hongsa Lignite Development), three Project Development Agreements (PDA) and 19 MoUs in place, although several of the latter were classified as inactive.

Since then three of the concession agreements have advanced with PPAs signed for Nam Theun 2, Nam Ngum 3 and Xe Kaman 3 with construction underway at all sites. Theun Hinboun expansion is being studied at feasibility level.

Currently there are ten hydropower projects in operation with a total capacity of 670 MW, less than *2%* of the country's estimated hydropower potential. Only two of these were specifically constructed for export, four are small (less than 5 MW total capacity) to supply domestic demand and the other four (owned and operated by EdL) export surplus generation to EGAT.

In addition, there are:

- four stations (2,029 MW) under construction;
- five projects with Concession Agreements and PPAs under negotiation;
- one project with a signed Heads of Agreement;
- one Project Development Agreement under negotiation;
- two turnkey contracts signed; and
- 27 Memorandums of Understanding signed, with studies in various stages of completion.

Both Electricity Generating Authority of Thailand (EGAT) and Electricity of Vietnam (EVN) are eager to import power and energy from Laos and Don Sahong is well placed to fulfil this requirement and also export to Cambodia which badly needs reliable electricity supply in the north of the country.

1.3 Don Sahong Hydroelectric Project Development

The Don Sahong Hydroelectric Project was first identified in a report "Mekong Mainstream Run-of-River Hydropower Projects" prepared by Compagnie Nationale du Rh6ne (CNR) in association with Acres International for the Mekong Secretariat in 1994. This study considered twelve projects and Don Sahong was ranked as a "First Category Project" with major positives being that it. displaced no population, flooded no land and had an IRR of 14.6%.

CNR/Acres designated the project to have an installed capacity of 240 MW which produced an average of 1,640 GWh/year and indicated that there was no negative impact if large storages were subsequently built upstream.

This study was a desk study *"based on existing information from ongoing data collection, mapping and resource inventory activities of the Mekong Secretariat, and included review of previous studies and existing reports".* There were no new investigation, mapping or data collection and there was no site visit.

In their description of the Project, CNR/Acres said that *"the greatest part of the river flow would continue over the falls in the natural channels, including the well-known Phapheng waterfall."*

In February 2001, the "Power Sector Strategy Study", draft final report of Electrowatt-Ekono and Hagler Bailey for ADB, briefly mentioned development in the Phapheng Falls area and said that diversion of a larger proportion of flow through a power station would not affect the visual appearance of the falls.

The definitive study of power development in Laos is the Maunsell/Lahmeyer International *"Power System Development Plan for Lao PDR"* (August 2004). This considers three developments of similar size in the area - Don Sahong; Phapheng Falls or Thakho, a tunnel arrangement around the falls; and Tad Samphamit, around the Khone Falls, further to the west. These options, which are mutually exclusive, would develop around 20 m of head with installed capacities in the region of 50 MW. This study was also very much a desk study, with no field visit to assess the sites in detail. The assessment of attractiveness of each option uses an in-house developed computer program, EVALS.

This FS Report addresses the technical and economic viability of implementing the Don Sahong Hydroelectric Project while a separate EIA Report addresses the environmental and social issues. (See Section 2.)

1.4 Location

The Don Sahong Hydroelectric Project is located on the Mekong River in the south-western corner of the Lao PDR directly north of the international border with Cambodia. (See Figure 1.1). By road it is 150 km south of Pakse, the provincial capital of Champasak Province and it is wholly within the Khong District.

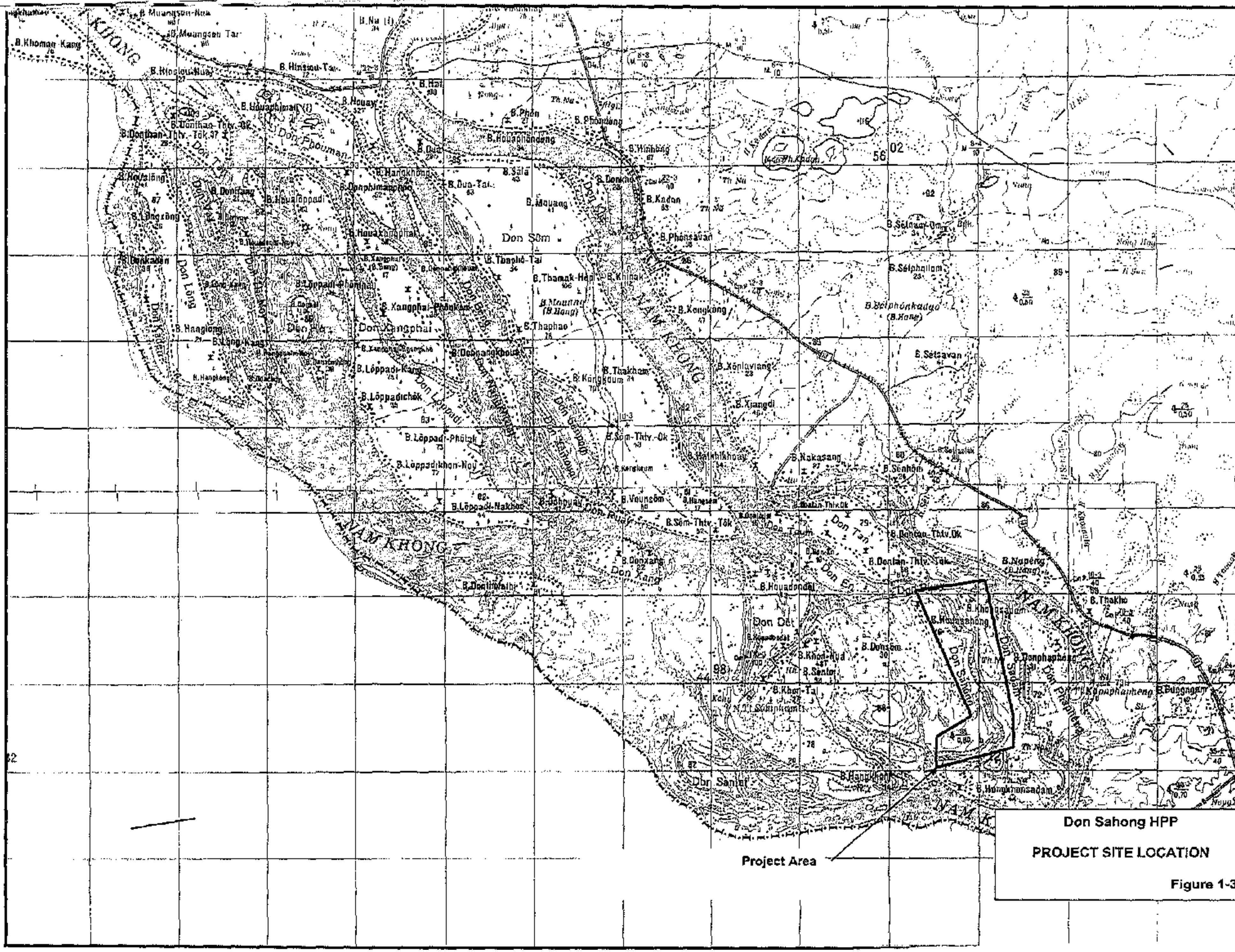
The site is in the Siphandone (Four Thousand Islands) complex of islands covering an area of about 60 sq. km. of the Mekong, which have been formed in ancient geologic times by a sequence of predominantly volcanic (andesitic) lithologies with some interbedded sedimentary sequences. The whole series has been folded and thermally metamorphosed and then subsequently eroded to form a planar land surface. In this area, the Mekong has eroded numerous channels. There are two major water falls - Khone Phapheng on the eastern bank and the Lippi or Samphamit Falls further west, as well as numerous channels and cascades, most of which flow only in the high flow period and are mainly dry in the low flow period. This area where the falls and rapids occur is known as the Great Fault Line (GFL).

The Project is located on the Hou Sahong, which is only one of the many parallel channels in the location of the GFL. (See Figures 1-3 and 1-4). A photomosaic of the whole area is shown on Figure 1-5.

1.5 Access - General

The Project site is adjacent to Highway 13, the main highway south from Vientiane through Thakhek, Savankhet and Pakse to the Cambodian border. The highway continues south into Cambodia to Steung Treng (40 km) and eventually to Phnom Penh.

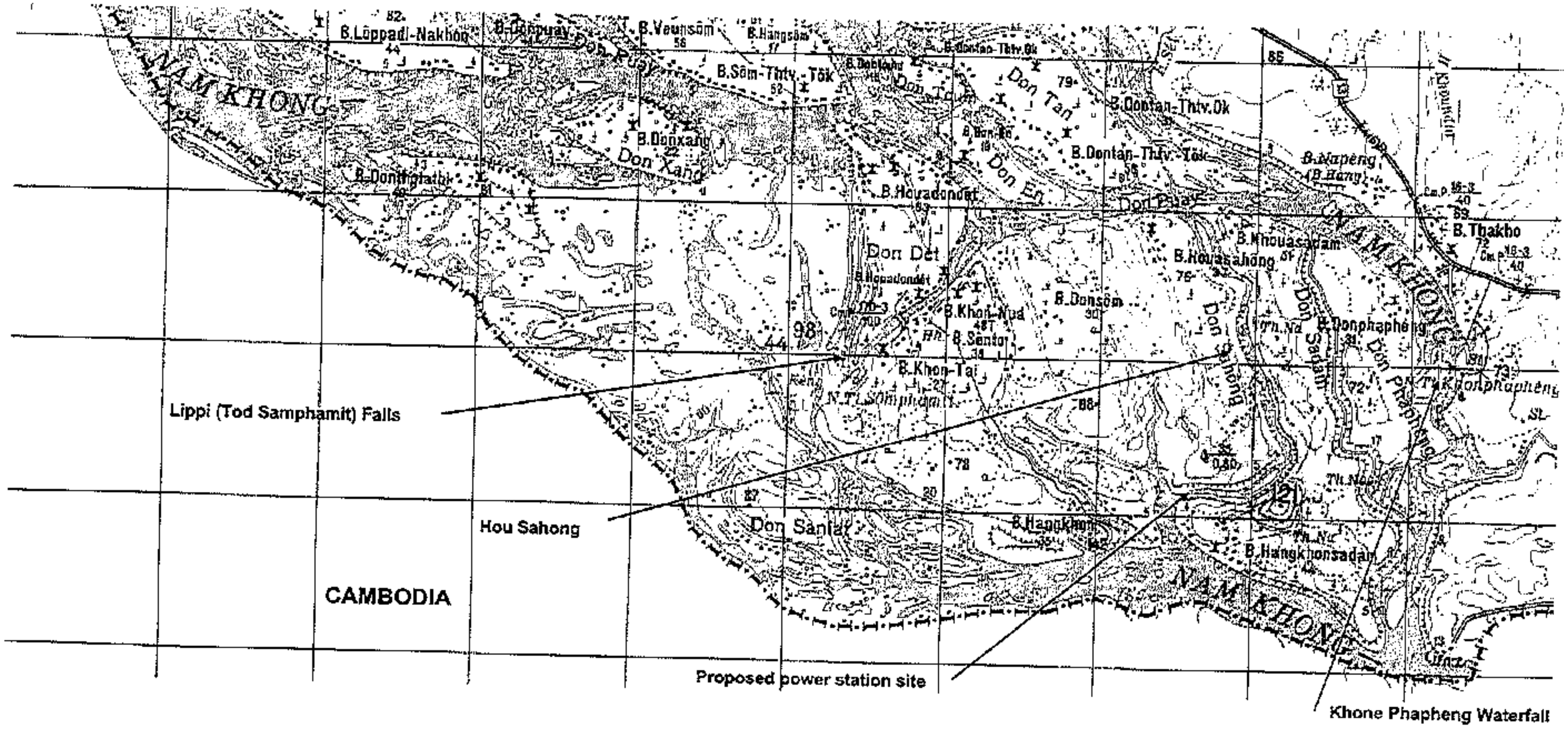
From Ubon Ratchathani, in Thailand, a highway runs 100 km to the Lao border at Chong Mek/Vang Tao and extends 45 km to Pakse (Highway 10), crossing the Mekong on the Lao Nippon Bridge. This prestressed concrete bridge, completed in 2000, is 7 m between kerbs. It is anticipated that all equipment and materials would be taken to the site from Thailand over this route.



Don Sahong HPP

PROJECT SITE LOCATION

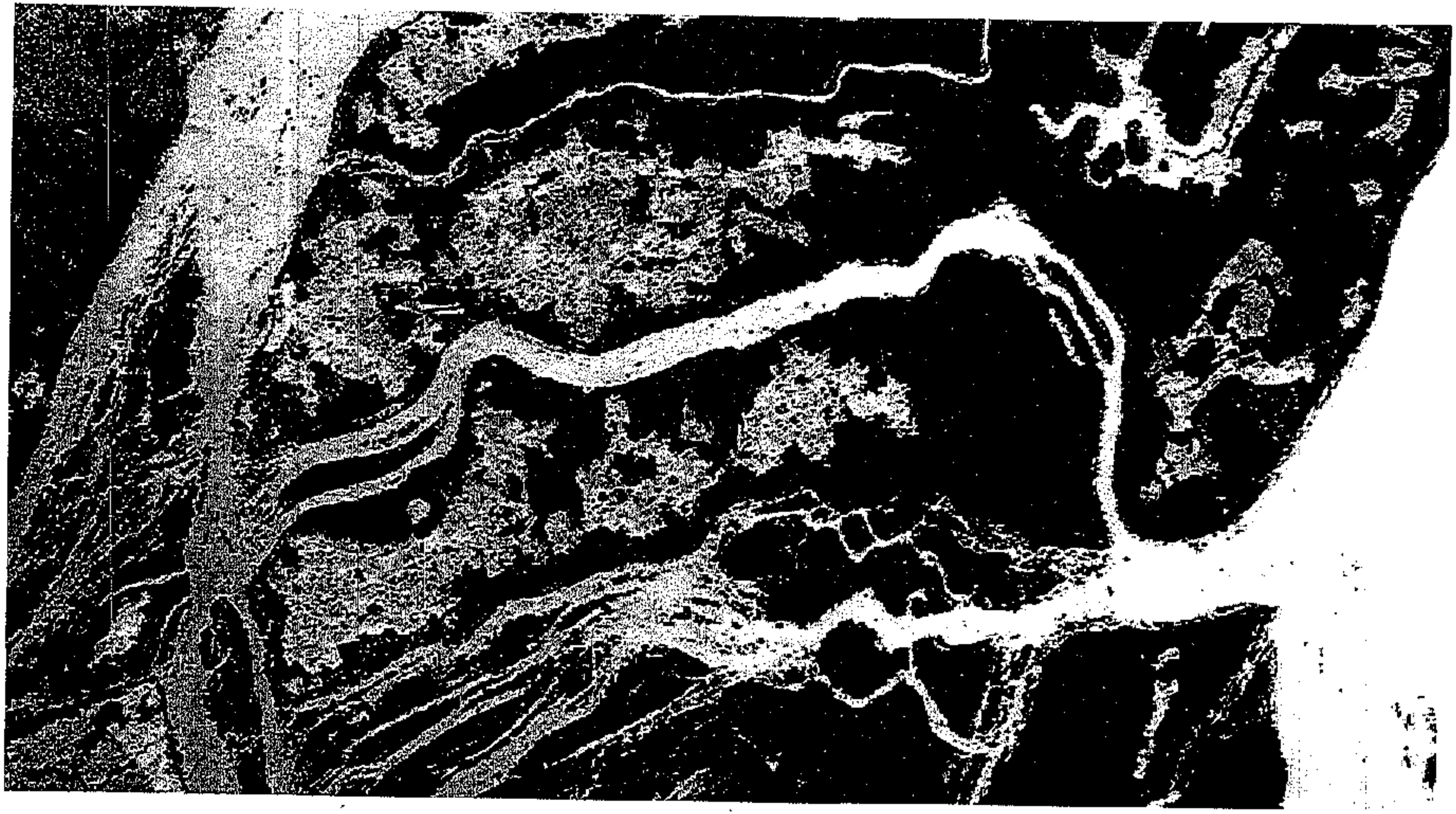
Figure 1-3



Don Sahong HEP

PROJECT AREA

Figure 1.4



N

This photomosaic based on aerial photography flown on
4 December 1993, so recent developments not shown
Pakse flow on 1 and 2 December was 4,100 m^3/s and on 3 December 4,140 m^3/s

DON SAHONG HEP

HOU SAHONG

FIGURE 1.5

1.6 Road Access from Pakse

Highway 13 south from Pakse to the Cambodian border at Veungkham (160 km) was reconstructed in 2001 and has a 7 m double flush seal pavement on a 9 m carriageway. The numerous bridges on the highway are designed to AASHTO HS-24 +25%.

1.7 Access by River

An alternative route for materials and heavy equipment could be by barge up river from Phnom Penh port or 724 km from the mouth of the Mekong. The river may not be navigable in all seasons and would have to be investigated more fully. During the French colonial period, river transport was significant, with vessels coming to Ban Hang Khone, where their cargo was off-loaded and carried by railway to Ban Don Det where it was reloaded onto smaller vessels for carriage upstream to Vientiane, Luang Prabang and beyond. Although this transhipment ceased decades ago, markers defining the channel approaches to the wharf at Ban Hang Khone still exist.

The Mekong River Commission published its "Navigation Strategy" in August 2003 and this indicates that vessels of 5,000 DWT can navigate to Phnom Penh in high flow conditions (3,000 DWT is limit at low water), but that the carrying capacity drops off sharply upstream and between Stung Treng and the project area the Mekong is navigable only for 70 DWT vessels in the high flow and 15 DWT vessels at low water. However, special purpose air cushion vessels (Hovercraft) may be able to carry larger loads.

Above the falls, the Navigation Strategy indicates 50 DWT vessels can navigate between Khinak (12 km upstream of Thakho) in the high flow and 20 DWT in the low flow season. Vessels can approach no closer to the falls than Ban Don Det (the upper terminus for the colonial French railway) as the river is very dangerous across the top of the Great Fault Line

1.8 Access to the Project site

The Project site lies between two islands, Don Sadam and Don Sahong, in the Mekong River and present access is by long-tail canoes from Veungkham or Ban Hangkhon (downstream) and Thakho, Ban Napeng or Ban Houadondet (upstream).

Construction access to the site itself is not straightforward and involves crossing the Mekong River by boat or barge as there are no bridges to the islands. Two crossing sites have been identified:

- upstream of the falls, from immediately north of Khone Phapheng Resort to Ban Houa Sadam

- downstream of the falls from Veunkham to either the power station site near Ban Hang Sadam or the southern end of Don Sadam.

In either case there will need to be excavation of rock from the river bed to provide a deep enough and safe enough passage for barges at all times during the year.

A further option is to construct a bridge to the south-east corner of Don Sadam from the vicinity of Veunkham. This would only be for light traffic and heavier loads would have to be barged.

1.9 Access by Air

The nearest airport to the site is at Pakse. This airstrip is capable only of handling smaller prop-jet aircraft and is serviced on a daily basis from Vientiane, with flights continuing to Phnom Penh and Siem Reap in Cambodia.

A twice weekly flight from Bangkok commenced in April 2007.

Larger jet aircraft service Ubon Ratchathani in Thailand, with road service to Pakse (Section 1.5).

SECTION 2

IMPACT ON ENVIRONMENT

A comprehensive Environmental Impact Assessment Report has been prepared in conjunction with this Feasibility Study Report and this section summarises the findings of that report.

2.1 Legal Policies and Relevant Environmental Guidelines

The construction and operation of the project will be undertaken in accordance with the relevant laws and regulations of the Lao PDR applicable to hydroelectric developments. The main legislation relates to Decrees and Regulations relating to Environmental Protection (1999 & 2001); Power Sector EI A and Environmental Management Plans (EMP) (2001 and 2002) and Compensation and Resettlement (2005). These legislations provide for approvals by the Science Technology and Environment Agency (STEA)[1] and MEM-DoE. Proposed hydropower projects are required to submit an EIA report including sections on biodiversity management, dam safety, mitigation and restoration of the environment and the establishment of an Environmental Protection Fund.

These legislations for hydropower projects require project sponsors to prepare an EIA Report in accordance with the Regulation for Implementing Environmental Assessment for Electricity Projects in Lao PDR (2001). This includes aspects such as Environmental Management Monitoring Plans, public involvement of stakeholders, submission of and approval of EIA and EMP by STEA including comments from MEM-DoE, other GOL ministries and agencies, stakeholders and provincial and local administrations, issuance of an Environmental Certificate by STEA and monitoring of EMP by STEA and MEM-DoE throughout project life.

Recent laws, policies, regulations and guidelines compiled for the Prime Minister's Office and STEA in 2005 have been complied with by the promoters of DSHEP including the preparation of a Social Action Plans ("SAP") and Resettlement Action Plan ("RAP") and liaison with the relevant line ministries. The SAP and RAP are presented in Appendices B and C, respectively of the Environmental Impact Assessment Report.

Two other relevant documents have been considered during preparation of the EIA Report. The first is the Mekong River Commission's (MRC) Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin. One requirement of the Agreement is that all member countries be advised of projects that will affect them and, for some projects, all member countries must approve its development. Literal interpretation of the Agreement indicates that for DSHEP, approval is not necessary but member countries only need to be advised of the project.

The second is the proposal to ratify the Ramsar Convention and nominate the Siphandone Wetland for inclusion in the Ramsar *"List of Wetlands of International Importance",* The Ramsar Convention is a United Nations International Treaty and has been signed by Thailand, Cambodia and Vietnam, the other Lower Mekong Basin countries. Nomination of the Siphandone Wetland would not preclude development of the DSHEP, but would require discussion and concurrence with other bodies, principally the Ministry of Agriculture and Forests and its advisors.

[1] In July 2007, in a reorganisation of GOL ministries and responsibilities, STEA was subsumed into a new department, Water Resources and Environment Agency (WREA)

2.2 Streamflow

The construction of the Project will have no impact on the total flow in the Mekong River downstream of the Great Fault Line because the power station will operate to use the available flow. Flow through most of the 18 channels which cross the Great Fault Line will not be changed during all seasons, with the major impact being on the channels at the eastern side of the river.

Flow will be higher through Hou Xang Peuk, west of Don Sahong, as the channel will be modified to facilitate passage of migrating fish, replicating the present conditions in the Hou Sahong. Flow in the channel between Ban Hang Khone and Ban Hang Sadam, which is the union of Hou Xang Peuk and Hou Sahong, will be increased throughout the year.

Flow over the Khone Phapheng Falls will be correspondingly reduced. During the high flow season (May to November) this will be barely noticeable as the water diverted for power generation is only a small proportion of the existing total flow. During the low flow season (December to April) water diverted into the Hou Sahong for power generation will be limited to ensure that there is no detraction to the visual appearance of the falls.

2.3 Borrow and Disposal Areas and Construction Sites

There will be no need to establish quarries on the islands or mainland as sufficient good quality rock is available for coarse concrete aggregate and for embankment fill (the impermeable membrane will be a concrete face slab) from the excavations required for the powerhouse and the deepening of the Hou Sahong entrance. There will be a disposal requirement for more than a million cubic metres of surplus rock from these excavations and it is proposed that it be dumped on low-lying non-agricultural areas. Sand and fine gravel for concrete aggregate and filters will be dredged from the Mekong River at upstream locations where large deposits are known to exist.

A major temporary construction facility will be located on the mainland and will include offices, accommodation, workshops, storage and holding areas so that only personnel and immediate requirements need to be transhipped to the project site. Both this facility and the site facilities will be removed at the end of construction and the areas rehabilitated, with the exception of housing required for the power station operation and maintenance staff.

2.4 Communities and Cultural Aspects

The DSHEP on Hou Sahong and its impacts will cover an extensive area in the centre of Don Sadam and Don Sahong and a household survey was conducted to gather basic information on the project and surrounding areas. A Resettlement Action Plan (RAP) has been prepared (there is a need to relocate the Hang Sahong hamlet (10 households) and other households in the Hang Sadam area) as well as a Social Action Plan (SAP) which focuses on Don Sadam and Don Sahong, as the most seriously impacted areas and contains suggestions for mitigating actions for the future public involvement program to be undertaken by the DSHEP.

2.4.1 Household Survey

A Household Survey was conducted covering four island communities and two on the mainland which are in the DSHEP area. The Household Survey covered the full range of socio-economic data, group discussions, gender analysis and vulnerable groups. The important points used in formulating the RAP and the SAP include:

- Regionally, some 134 villages, population of 72,922 people and a predominant Lao Loum culture with small rice paddy holdings for sustenance and fishing for protein consumption and as cash income
- Non-registered landholdings on Don Sadam and Don Sahong with the two islands having a total of 628 ha for tax purposes
- Limited local facilities and infrastructure with boats presently providing the means of access to the islands
- Some 117 families out of 662 families sampled including approximately 20% of the families classified as below self-sufficiency
- Estimated two island population of 149 families of which 30 families or 12% classify themselves as being insufficient and 21 families as female-headed households
- Very limited infrastructure and vehicles except for boats on the islands and poor communications and education facilities with 482 primary students but only 44 secondary level students
- Limited sanitation with only 21% of households having access to a toilet, of which 18% are pour/ flush toilet types all using the Mekong River as a supply source
- Some 80% of persons classify themselves as farmers because of their land ownership and rice cultivation are critical although fishing is seen as a source of cash income along with livestock raising.
- Cash incomes and expenditure vary considerably but fishing which accounts for 70% of earnings and 74% of participating households excluding business and sale of forest product income
- The average annual expenditure per household is 8,800,000 Kip or USD 880 and is for medicine (1), rice for subsistence (2) and transportation (3): accounting for some 35% and another 40% of household income is expended on items such as clothes (4), house construction (5), education (6), meat (7) fish (8) and energy (9).

2.4.2 Resettlement Action Plan

The RAP is based on maps, the Household Survey, inventorying of the affected communities and discussions with locally affected groups and is a guideline for the GOL and the DSHEP proponent for implementing compensation and resettlement for the project and is based on policy, principles of resettlement, entitlement to compensation, livelihood restoration, monitoring and evaluation including institutional and management arrangements of required resettlement.

The DSHEP will acquire land for project construction with the total area of 268.9 ha, including works areas (30.1 ha), mainland barge landing site (1.2 ha), project pondage area on Hou Sahong (172.6 ha) and transmission line (65.6 ha). Recent ground surveys indicate that 4 villages, namely Don Sahong (Houa Sahong and Hang Sahong hamlets), Houa Sadam, Hang Sadam and Thakho would be affected and that 14 households *(66* persons) from 3 villages need to be relocated.

Table 2.1 - Affected Houses, Residential Lands, and Persons by Village/Hamlet

Name of Village	Affected Houses	Residential Areas (ha)	Affected Persons
1. Don Sahong (Hang Sahong)	**10**	**1.5**	**46**
2. Hang Sadam	**2**	**0.3**	**10**
3. Thakho	**2**	**0.3**	**10**
Total	**14**	**2.1**	**66**

Source: GroundSurvey by El A Study Team, January/February 2007

A socio-economic profile of these communities and people shows that among the 10 affected households in Ban Hang Sahong only 6 have any agricultural land and people are poor and disadvantaged. Fishing is the main source of non-agricultural cash income. Perceptions of the DSHEP among the local community include general agreement with the GOL plans for the DSHEP, a need to have electricity at their village, recognition that DSHEP would create loss of village agricultural lands and if relocation is required, preference for cash compensation and resettlement within Don Sadam island

The basic entitlements of affected persons are indicated in Table 2.1 and DSHEP will formulate a Resettlement Policy on this basis.

Consultation with the main affected community, Ban Hang Sahong, accepted relocation within the Don Sahong Island approximately 1.5 km north from their existing hamlet. Each of the two households at Hang Sadam and mainland Thakho villages would be relocated within their main community areas, including a planned proposal by the District administration for Thakho on Highway 13. Specific development for the proposed Hang Sahong resettlement site would include:

- 10 house plots of 0.075 ha each (25m x 30m)
- Village main road (4m x 800m)
- Pump for a gravity fed water system
- Electricity supply
- Village market.

The most important issue of rehabilitation and livelihood restoration is recovery of the income loss of resettlers and ensuring that affected vulnerable groups such as landless families are given priority for income generation. Fishing is the main source of income of all affected households in Hang Sahong and 4 households have no agricultural land. It is assumed that the relocatees can fish at Hou Xang Peuk or other Mekong River channels and supplementation of household incomes for 3 years and employment with DSHEP during construction will be available.

Table 2.2 Basic Entitlement Matrix for RAP for DSHEP

TYPE OF LOSS	ENTITLED PERSONS	COMPENSATION POLICY	IMPLEMENTATION ISSUES
Dwellings	Registered taxpayer or occupant identified during survey	Full replacement cost so as to enable affected persons to have a dwelling of at least similar size and standard	Stakeholder consensus on replacement value assessment
Residential land	Registered taxpayer or occupant identified during survey	Replacement land if relocating to other site or compensation in cash at replacement cost for household who can move back onto existing site	Stakeholder consensus on suitability of replacement land and/or compensation
Expense of residential relocation	Registered taxpayer or occupant identified during survey	Lump sum payment sufficient to cover all relocation cost as agreed with the affected persons	Stakeholder plus Resettlement Committee consensus on definitions and rates used
Rice storage	Owner identified during survey	Lump sum payment sufficient to cover all relocation cost as agreed with the affected persons	Assessment of suitability of relocation site
Retail shops	Owner identified during survey	Lump sum payment sufficient to cover alf relocation cost as agreed with the affected persons	Review of shops recorded during the survey
Agricultural land	Owner or person with usage rights identified during survey	Compensation in cash at full replacement cost	Consensus among stakeholders on valuation assessment and methods
Crops and trees	Owner or person with customary usage rights	Full replacement cost of anticipated harvest at market value	Consensus among stakeholders on valuation assessment and methods
Fish traps	Owner identified during survey	Compensation in cash at full replacement cost	Consensus among stakeholders on valuation assessment and methods
Common property resources	Community losing the resources	Restoration of affected community buildings and structures to at least previous condition	Consensus among Village Committee members on resources and rates used
Temporary impact during construction	Owner or person with usage rights identified during survey	Care by contractors to avoid damaging properties; where damage do occur, the contractor would be required to pay compensation; and damaged property would be restored immediately to its former condition on completion of project	Consensus among stakeholders and Village Committee

The following committees would need to be set up by DSHEP management for the assessing, implementation and arrangements for the compensation and resettlement action plan. This would include development of policies for the construction, and supervision of programs such as the BMP, RAP and SAP and running of the following 4 committees as outlined in Section 6.1.7 of the EIA Report:

- Provincial Environmental and Social Committee (PESC)
- District Compensation and Resettlement Committee (DCRC)
- Village Consultative and Grievance Redress Committees (VCGRC)
- Project Environmental and Social Management Unit (PESMU).

The operation of the Grievance Redress Committee is essential to the success of the DSHEP and will to be set up to include representatives from each village as these are remote and inexperienced island communities. This committee will address any and all problems and is a forum for expressing villager's comments and feedbacks to DCRC and the DSHEP's Manager and indirectly to GOL. Any local village or affected parties that are dissatisfied may address matters such as project compensation and Resettlement Action Plan performances and all complaints by project affected persons are registered officially with this committee and it is obliged to raise these issues at higher levels.

DSHEP internal and external monitoring systems will be set up to provide feedback on the effectiveness and progress of implementation of various EMP, RAP and SAP programs and would need to involve groups such as PESC and DCRC in external supervision and PESMU and other appropriate monitoring consultants.

One year after finishing implementation of the RAP, a specific evaluation will be conducted by an independent body to determine compliance with and achievement of RAP and SAP objectives. A similar post-evaluation of the EMP is also a legal obligation of the DSHEP project owner.

2.4.3 Island Communities' Public Involvement, Plans and Programs

The present villages on the islands of Don Sadam and Don Sahong do not have any plans for development other than those operating under the Village Committees. The DSHEP is going to be a major development for them. These villages also have rights to resources within the DSHEP area which would be directly affected. The developers of DSHEP would have to liaise and consult with these communities and it is recommended that it do so through a committee involving all three communities, without reference to the District and Provincial Governor's offices.

The exact make-up of this committee is uncertain but it is suggested that the Village Consultative and Grievance Redress Committee (VCGRC) would be the most appropriate body. It would play the dual roles of overseeing the RAP for Ban Hang Sahong hamlet and day to day liaison and decision-making relating to all actions on Don Sadam and Don Sahong with the DSHEP managers. District and provincial authorities could be consulted on an "as needed basis," It is recognised that this arrangement has risks but if it is supervised by representatives of the three communities it should operate satisfactorily. This committee would report to the Provincial Environmental and Social Committee (PESC) proposed under the RAP. This is suggested as the best alternative given the low status of local development and the fact that all project decisions would affect all local communities.

A mechanism for discussion is needed for ongoing public information about the Project, its immediate and near-future needs and effects on local communities. It is also self-evident that the DSHEP project would require a Community Liaison Officer (CLO), or as many as are needed. The setting up of regular company and community discussion meetings targeted towards "effects on individual communities and company needs" are required. These would be arranged and paid for by the developers of DSHEP , including the building of a meeting hall in Ban Hang Sadam.

2.4.4 Social Action Plan (SAP)

The Social Action Plan (SAP) has been prepared as a guideline for the GOL and the DSHEP's management and is targeted to improve the social welfare of the general project area as well as mitigating the project's main long-term negative impacts. Six villages, namely Thakho, Veunkham, Hang Khone, Hang Sadam, Houa Sadam and Houa Sahong, are located in proximity to the DSHEP project and are likely to be affected to some degree by project development, For all local communities and people the effects of DSHEP would be different and to varying degrees, but in the main can be classified as

- Group I - The households having to be relocated as per the RAP outlined above and including an estimated 14 households from 3 villages
- Group II - The other remaining households of the directly impacted villages, namely Ban Hua Sahong, Ban Hang Sadam and Ban Hua Sadam
- Group III: The households living on the mainland, namely Veunkham hamlet (part of Ban Bung Ngam), Ban Thakho and Ban Hang Khone on southern part of Khone Island.

The local perceptions of DSHEP are varied but overwhelmingly include reduced fish abundance, loss of fishing assets due to flooding and access to fishing opportunities. This will affect all villages to some degree. Some villagers are also worried about the negative social impacts (e.g. problems with prostitutes and STD) and other social disruptions to their way of life. However, there is a general willingness to have the dam constructed without knowing all the impacts on them directly, as obtained through household, group and village level interviews. Household level interviews show that many villagers are afraid the DSHEP will not be realized.

Community preferences for livelihood improvement are to have suitable amount of land for agriculture with appropriate extension support plus necessary public facilities for education, healthcare, market areas and a secure water supply. The natural resources and the rich biodiversity of the area including fish stocks and natural attractions create an environment that sustains human life and produces a basic quality of life. Therefore, any investment projects such as DSHEP while aiming at generating financial benefits should also yield additional social benefits and not degrade the social and economic livelihood of the villagers. This is basic GOL policy.

All six villages are impacted from the proposed DSHEP development but the three island villages from Don Sahong and Don Sadam are the main focus of regional development measures including;

- Livelihood training and awareness raising, including programs for gender, agricultural, health, education and other local groups
- Construction of additional infrastructure, including electricity supply, schools, health facilities, water supply and local markets
- Support for livelihood and economic development, including agricultural extension, tree plantations, sanitation and micro-credit schemes.

As for implementation of the RAP, formation and operation of local committees would be the key agencies in the implementation and arrangement for DSHEP's environmental and social works included in its SAP. The composition of the committees is essentially the same as those outlined in Section 6.1 of the EIA Report and indicated above. Similarly, the operation of the VCGRC would play a key role in addressing any land use disputes and inequities in development perceived by various local populations.

The program for the implementation of the SAP would of necessity be longer, with the program starting later and extending for 3 years and including similar monitoring groups and activities for DSHEP and other parties as indicated for the RAP.

2.4.5 Public Involvement Program for Project

The requirement for public meetings is outlined in the MEM and STEA guidelines for both Environmental Impact Assessments and for the Resettlement Plans. The DSHEP has accepted this and has held two Stakeholder's Meetings to date. These meetings were arranged through the offices of the Social and Environmental Management Division of the MEM's Department of Electricity (DoE) and the Champassak Province DoE and included:

- 1^{sl} Meeting- Pakse and Muang Khong - 25 & 26 October, 2006 with representatives of Provincial and District authorities and over 25 participants attended both meetings
- 2nd Meeting - Ban Hang Sadam - 30 January 2007 - included representatives from Provincial and District authorities, local Sub-district and Village officials and representative of organizations and over 110 participants attended this meeting.

There is a STEA requirement in the environmental guidelines that the Draft EIA should be available to the public for review and it is the intent of the DSHEP proponent to hold this meeting in Vientiane. Issues raised would be answered at that meeting and addressed in the Final EIA Report.

2.4.6 Integration with Provincial and District Programs

The plans and proposals of the Champassak Province and Muang Khong District for the immediate Project area have not been fully canvassed or documented. The proposal for projects suggested in the SAP would need to be integrated with the District authorities, including education and agricultural bodies. Similarly, further discussions on the extent and locations of projects would require further consultation with relevant village authorities. Likewise all fisheries programs outlined as mitigation measures would require liaison with both the provincial and national Departments of Fisheries.

The declaration of the Siphandone Wetland as a Ramsar site would generate a number of issues for the IUCN or other organizations involved in planning for the resource management of the area, particularly for fisheries sustainability.

It is indicated that the Khong District development plans include a new village along Highway 13 South to be located in the vicinity of Khone Phapheng Resort to resettle the villagers from Ban Napeng. A village plan has been drawn-up, lots have been allocated but the timing of development is dependent on funding. Confirmation of these plans are required as they may affect the selection of a main campsite. Planning and integration of the proposed DSHEP works and proposed mitigating programs require liaison and coordination with the provincial and district authorities and DSHEP intends to do this during the detailed design stage of the Project.

2.4.7 Public Health Survey

A public health survey was executed by the Centre for Malariology, Parasitology and Epidemiology (CMPE) and is included as Section 4.4 in the EIA Report and Appendix D, in detail. All the main diseases such as malaria, dengue fever, STD and HIV Aids and helminth infections are reviewed on a provincial and district level. The organization and operations of the Champassak Provincial Health Office (PHO) and the Khong District Health Office (DHO) are outlined and focus on curative medicine and prevention and health promotion.

The Khong District hospital has 25 beds and 6 Health Centres (HC) with a total of 22 beds and a total staff of 76 persons including 6 medical doctors and some 52 public health staff at Health Centres (HC)such as Ban Khone Hang being one of these. At the three local villages in the DSHEP area there are Village Health Volunteers (VHV) and most of these have limited training. An overview of health indicates that malaria (5[!]) and dengue fever (7[1]) are among the frequently treated at provincial, district and local health facilities. The other main points include:

- Malaria is the most common arbo-virus, it fluctuates from year to year, is earned by *Plasmodium falciparnum* mosquito (over 98% of cases) and is much more common in newly cleared areas to the north
- Dengue fever is carried by the *Aedes aegypti* mosquito and associated with stagnant pools of water
- STD and HIV Aids infection rates are low in the region but people are wary of these diseases
- The whole area bordering the Mekong River is endemic for *Schistosoma mekongi* and *Opistorchis viverrini:* two helminth infections with the former dependent on transmission to humans by small snails in the Mekong River and the second on the eating of infected uncooked Cyprinid fishes, a tradition in the DSHEP area and both diseases are under control by treatment of infected parties and communities with drugs.

The DSHEP area has not been included in previous areas in which stool samples were undertaken by the various medical teams doing the studies, so the communities of Don Sadam and Don Sahong, were sampled. All patients were examined by doctors and treatment was administered for both intestinal parasites and *S. mekongi*, using Praziquental and other minor ailments treated. The three villages in the EIA survey all had similar socio-economic backgrounds including agricultural pursuits and fishing activities. Similarly their history of public health including 3 recent rounds of Mass Drug Administration (MDA), programs of Insecticide Treated Nets (ITN) and the presence of local Village Health Volunteers (VHV).

There is no significant difference between the three communities in terms of the prevalence of helminth infections and more importantly, these rates are acceptable except for *Opisthorchis viverrini* or Liver Fluke infections. In general the health standards of these three communities are good given that they use the Mekong River as their main water source. The latrine situation in all villages is poor varying at around 20% of families having some facility but this can be rectified by an intensive supply and fit program.

2.4.8 Unexploded Ordnance

DSHEP study team engaged Gerbera Demering, a UXO Consultant to assess the situation in respect of Khong District:

- Khong District is the lowest UXO contaminated area in Champassak Province
- There are no reported incidence of UXO in Khong District or the project area nor are B 52 bombing raids reported on the area
- The nearest affected areas are in Cambodia straight south of Ban Han Khone and high intensity area is near Kampong Sralau,opposite Don Tan.

The report concludes that there is "no need for specialized surface or sub-surface UXO clearance before starting earth works in the DSHEP area" but to better ensure safety a technical survey of the actual construction works areas should be undertaken.

2.4.9 Regional Tourism

Due to its unique and impressive waterfalls, extensive wetland areas, natural diversity, fishing activities and historical sites dating back to colonial times the area is a major attraction of Champassak Province. In recent years using access via the Chong Mek/Vung Tao border crossing and the Pakse Bridge, Thai tourists come to visit the area in large numbers on day-trips by vans and tourist coaches. Also, in the past 5 years, the area has become a destination for western backpackers for simple life, authentic local livelihoods, nature and the traces of the colonial period. Don Det and Don Khone have accommodation and are recommended destinations for backpackers' holidays. Most tourism occurs from December through April.

In 2006, a total of 113,684 tourists visited Champassak Province, an increase from 63,963 in 2004 and 99,044 in 2005. Recent data from the Thai immigration authority shows that the number of visitors from Ubon Ratchatani to Southern Laos is currently more than 140,000 and has increased by about 12% from 2005 to 2006. Approximately 70% of the total visitors from Thailand visited Khon Phapheng Waterfalls as the main attraction.

2.5 Biological Resources

2.5.1 Fishery

The most significant of the biological resources is the fishery (more than 1,300 species identified in the Mekong River) and the significance of Hou Sahong as a major fish migration channel. While it is difficult to state the exact migration patterns of fish in Hou Sahong based on actual data/obser vati ons:

- At least nine (9) species of medium to small sized Cyprinids are dry season upstream migrants plus a large migration of lunar dependent *Henichorychits spp.* significant to the upstream fishery throughout the Siphandone Wetland
- Another 35 species of larger catfish and cyprinids migrate upstream and made up of *Pangasidae, Bagridae, Siluridae* and *Sisoridae* species use this channel along with others in the wet season, which yield most of the catch in traps
- Several species of *Cyprinidae* migrate downstream as waters rise from June to December.

These migrations are illustrated on Figure 2.1.

Fishing in all sections of the Mekong River and inter-island channels takes place using a vast range of fishing equipment and methods during every month of every year but intensify markedly in the periods of fish migration, especially in Hou Sadam, Hou Sahong and Hou Xang Peuk. Most of the families resident on the islands of the Siphandone region are involved in fishing to some extent, using a variety of methods and equipment, and construction of the DSHEP with no mitigation measures would adversely affect fishing.

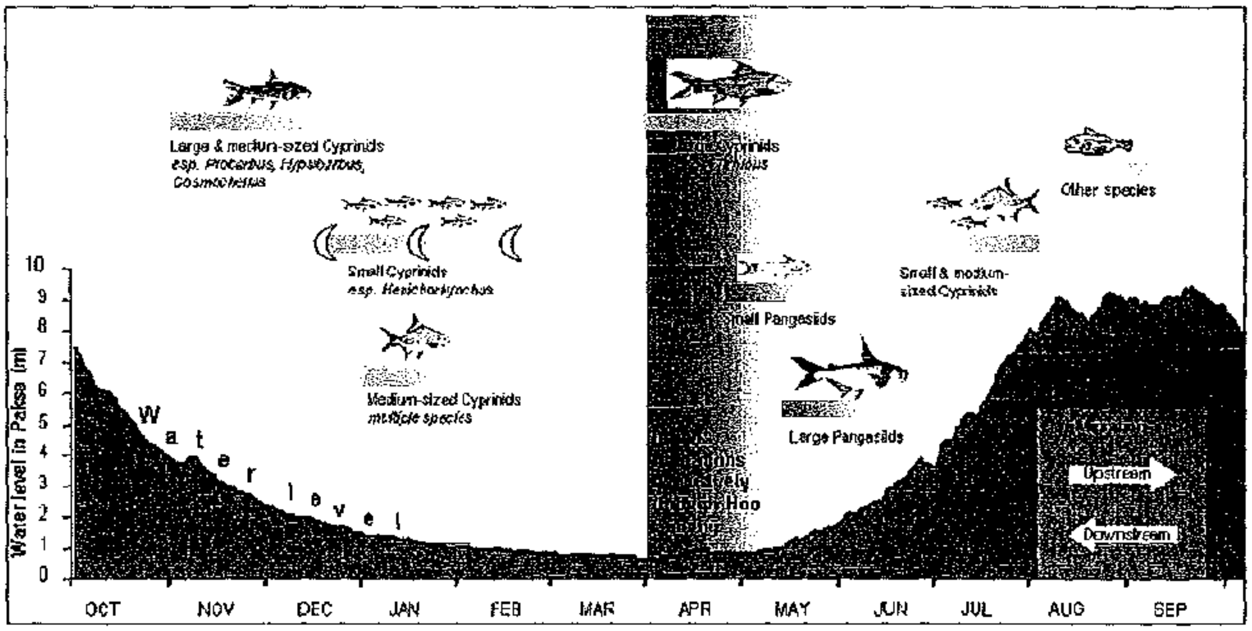


Figure 2.1 - Fish Migration Patterns at Great Fault Line (after Baran 2007)

One of the prime uncertainties about fish migration in the complex of channels, islands, waterfalls and cascades is whether or not fish migrate in only one channel. It is understood that upstream migrating fish arrive at the falls and, after recuperation, attempt to navigate in any of the 18 channels where they are attracted by the flow conditions. If that channel proves to be impassable, they try another channel.

During the low flow season the Hou Sahong is the main route for upstream migration as it is wider, has a more regular gradient, without major falls, and carries more water.

Hou Sadam is narrower and shallower than Hou Sahong, (historically reported to cease flow over certain rapids) and its exit is some six (6) km from Hou Sahong.

The Hou Xang Peuk and associated channels are larger than Hou Sahong, with the main channel followed from the Hou Sahong confluence to east of Don Xsom to the entrance in the Mekong River mainstream near the southeast corner of Don Det. It is a major route for downstream migration but is limited for upstream migration in the low flow season by several falls which block larger fish. This channel has more fish traps than Hou Sahong.

2,5.2 Mitigation Measures for Fisheries

Blocking of the Hou Sahong will cause significant impact on the fisheries and it is proposed to create alternative routes for migration by modifying the Hou Sadam and Hou Xang Peuk.

The Hou Xang Peuk is the most feasible alternative to Hou Sahong but will require streamlining to eliminate a number of steep drops and to ensure a viable flow throughout the year. The required channel improvements will be confirmed by topographic survey and hydraulic engineering design with input from experienced fisheries biologists to ensure that the resultant channels will replicate the conditions in the Hou Sahong. This will be initiated immediately.

In addition, the Hou Sadam entrance will be excavated and channel improvements undertaken to improve its ability to carry fish in the low flow season, particularly at the downstream end where the stream is overgrown with vegetation.

Fishing controls on these 2 channels, located on either side of the Hou Sahong will be required as fish migration patterns are uncertain. Only limited knowledge of fish caught during the wet season trapping is available primarily on these areas by Baird. There are the precedents of "Fish Conservation Zones" (FCZ) to protect the dolphin pool below Ban Hang Khone/Ban Hang Sadam and others in the Siphandone area of the Mekong River complex. The proposed control programs for the Hou Sadam and Hou Xang Peuk will have to be supervised by the District Fisheries Department staff.

The inclusion offish lifts was examined, but the effectiveness offish lifts in tropical rivers such as the Mekong, with its multitude of fish species and migration patterns is unproven. In fact, few have worked effectively and none had to deal with the volume and variety of species involved at the Great Fault Line. The improvements to the Hou Sadam and Hou Xang Peuk will be more effective for fish migration, so no fish lift facility is included in the powerhouse.

2.5.3 Irrawaddy Dolphins

There is a small population of Irrawaddy Dolphins *{Orcaella brevirostris)* resident in pools in the Mekong River immediately below Don Rhone. This population has been in decline for some time and local advice is that it may now be as small as seven individuals, which is hardly self sustaining. Unless the group joins up with the group resident at Kratie it will eventually cease to exist.

Care will be taken during the construction to ensure that no harm will come to the dolphins.

2.5.4 Terrestrial Ecology

The terrestrial ecology was assessed in terms of remaining vegetation, forestry and land systems. According to forest cover maps, the field reconnaissance survey and villagers' interviews, many areas of Don Sahong and Don Sadam have been disturbed already by use of forests near villages and along Hou Sahong for use as firewood and making of fish traps, conversion of forest land into agricultural land and residual areas. Mixed Deciduous Forests (MDF) occurring on the upper slope of Don Sadam. Many of the big trees have been removed by local residents for timber for housing construction and only small diameter regenerated trees remain.

The effects of the DSHEP pondage and associated works are:

- Some 25.7% of the land systems of the two islands are affected including over 32% of their forests and between 5.0% and 22.4% of their agricultural lands, with the effects greater on Don Sahong
- The quantity affected increases to 33.2% directly affected if the two islands and water body of Hou Sahong are included (total island ecosystem).
- A total of 290.7 ha are affected out of a total of 876.5 ha.

The wildlife and birdlife of the islands and Hou Sahong were inventoried and the status of these resources in the DSHEP is indicated to be poor, largely through isolation and predation on the island environments. Of concern to the DSHEP would be the presence in Hou Sahong of any Smooth-coated otters, a protected species, and possibly small mammals, amphibians and reptiles.

A total of 48 species of bird occurring in the general DSHEP project area but none of the bird species for the Don Sadam and Don Sahong are listed as Endangered Species of Category I of Regulation No. 360, which is a Department of Forestry Regulation on Species Listed for Conservation Purposes in Lao PDR. However, some are indicated for the transmission line corridor and the exact effects on these species are to be confirmed when data are available. There is no data on numbers and these species relate mainly to birds that are hunted by local populations.

2.5.5 Proposed Siphandone Wetlands Ramsar Site

While DSHEP occupies a small area, it is located in a major zone for conservation and protection of endangered species, being in the southern part of a currently proposed Ramsar site, the Siphandone Wetlands. . This proposal has been ongoing for several years and is being proposed by the GOL Department of Foreign Affairs and would be administered by the Ministry of Agriculture and Forests (MOAF). This proposed Ramsar site has considerable momentum within the Laos government framework. Currently STEA, the Lao National Mekong Committee (LNMC), the MRC and IUCN are all active advisors to the relevant Lao authorities.

This Siphandone Wetland proposal is about conservation and sustainable resource management for a 400 km^2 area which is upstream of a similar area, already declared on the Cambodian border and embracing the Mekong River. It includes all of the Mekong River below Khong Island, its numerous channels and a 1 km wide buffer zone on the banks of the Mekong River including a 40,000 ha central zone. The DSHEP is integrally involved as it affects one of the year round migration routes for fish migration around Khone Phapheng Falls. However, declaration of the area as a RAMSAR site would not necessarily preclude development of the DSHEP.

Both the IUCN and WWF are actively involved in resource management in Laos and are promoting the declaration of the Siphandone Wetlands as a Ramsar site. IUCN intends to inventory the Siphandone Wetland once it is declared. This is a step towards preparing a development plan for the area and would involve consultation with the local communities on Don Sahong and Don Sadam. Of particular interest for the Siphandone Wetlands would be the role of fishing management in the long-term development plans for the area. The role of DSHEP and its implications to fisheries in this location is self-evident. IUCN has a "vision" for the future whereby the established Stung Treng Ramsar site and the proposed Siphandone Ramsar site would merge, leading to a trans-boundary Ramsar site - one of only a few worldwide.

2.6 CONCLUSIONS AND RECOMMENDATIONS

2.6,1 Conclusions

A comprehensive study has been undertaken on the social and environmental issues associated with the project, as required by the various regulations of the Science Technology and Environmental Agency (STEA) and Ministry of Energy and Mines (MEM). The social and environmental impact of this project compared with other current or potential hydro project of similar capacity in Lao PDR is very small in terms of:

- minimal inundation of land.
- minimal storage - Run of River.
- minimum displacement of people.

- no damming across whole river but only on one small channel in the river
- minimal impact on Flora & Fauna

The impact of the project on for Mekong River fisheries is a complex issue. The project site area in the Mekong river is called "Siphandone" meaning four thousand islands. There are very many water channels in the river one of which is Hou Sahong, a major route for fish migration. When DSHEP is constructed on the Hou Sahong, fish migration in this water channel will be cease. As part of the mitigation measures, over and above the other existing channels, excavation works will be carried out on two channels to improve the passages for fish migration.

The GOL, its various fisheries department at the national, provincial and district levels, the Mekong River Commission and the associated Lao National Mekong Committee will be involved with the DSHEP development to minimise any effect on the fish migration. The social and environmental impact of DSHEP and its mitigation measures are detailed in the EIA Report.

2.6.2 Recommendations

Notwithstanding the possible impacts as detailed above and in the EIA Report, the implementation of the DSHEP would be of considerable economic benefit to the Lao PDR and would provide improved infrastructure and stimulation for growth in the Champassak Province.

Numerous suggestions and recommendations in the EIA Report are proposed to enhance the benefits of implementing DSHEP, including:

- Additional studies during detailed design to determine more exactly the minimum environmental flows of the Mekong River to safeguard the flows over Khone Phapheng and the flows in streams between Hou Sahong and the Phapheng Falls
- Budgets for and implementation of recommended mitigating actions for the fisheries component
- The Resettlement Action Plan (RAP) for relocating communities such as Ban Hang Sahong hamlet and others affected by DSHEP
- The Social Action Plan (SAP) as revised in consultation with GOL, including Khong District authorities and representatives of affected villages

The social action plan is recommended that will improve infrastructure (water supply, sanitation, education, health facilities and electric power) in the six affected villages. Further, electrification will be extended to a number of other islands, including Don Det and Don Khone, which will enhance their tourist potential, as well as improving the living conditions for the residents.

SECTION 3

HYDROLOGY AND HYDRAULICS

3.1 General

The Mekong River is the largest river in South east Asia, rising in the Tibetan Plateau of south west China (where it is known as the Lanchang) and flowing through Myanmar, Thailand, Laos, Cambodia and Vietnam to the South China Sea, some 4,800 km from its source.

Reliable records have been kept on the river for many years and are now coordinated by the Mekong River Commission (MRC), presently headquartered in Vientiane.

3.2 Mekong River at Pakse (013901)

This is the longest operating river gauge close to the project area. Data available for the period 1 April 1924 to the 31 December 2006 was obtained from the Hydrology section of the Mekong River Commission in Vientiane. The catchment area at Pakse is 545,000 km .

A plot of the daily flow duration curve of the data is shown on Figure 3.1 with an expanded r for low flows on Figure 3.2. The highest daily flow was 57,800 m^3/s and the lowest wa,^ m^3/s. The Mekong River has a distinct seasonal flow pattern with flood flows tcU^e^JJl between June and December. A summary of the monthly flows is included on Table *Wttf£'&"*

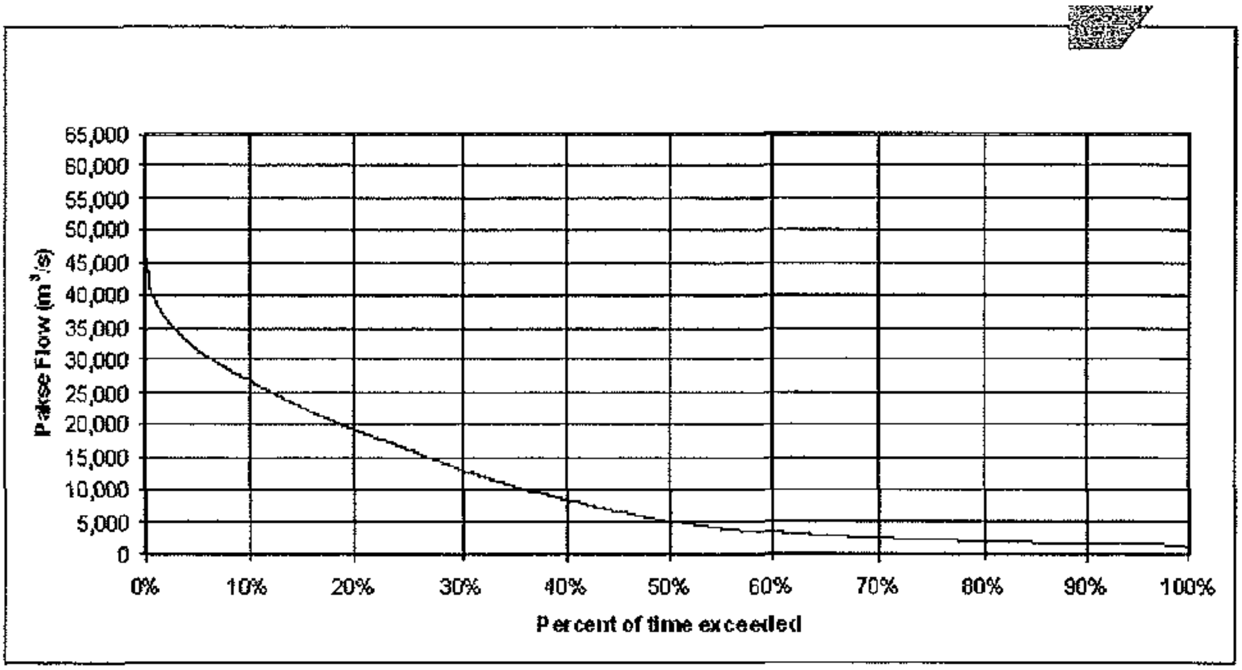


Figure 3-1 - Pakse Flow Duration Curve

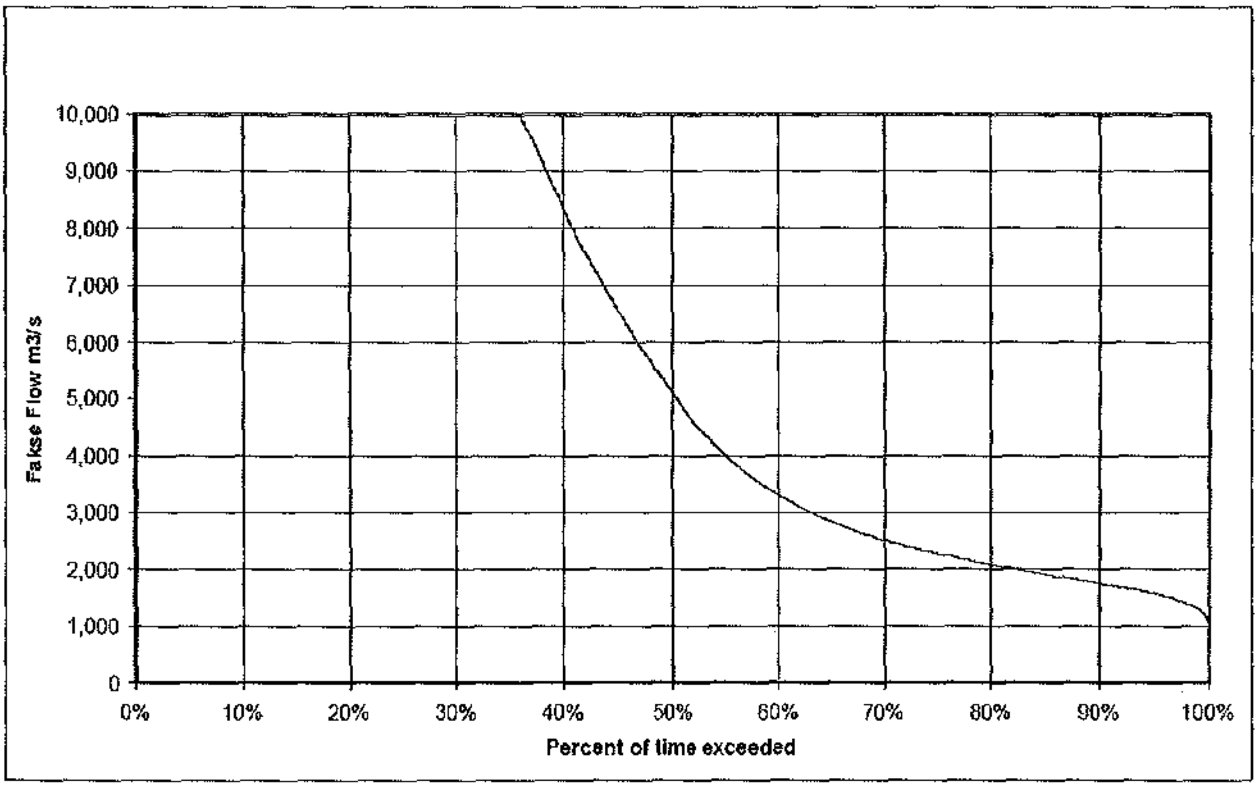


Figure 3-2 – Pakse Low Flow Duration Curve

This is the station with the longest record in the project vicinity and has been adopted as a reference for daily water flows available for the project.

3.3 Mekong River at Stung Treng (014501)

This station is located in Cambodia, 50 km downstream from the project area, with a catchment area of 635,000 km^2, and has data available for the period 1950-1970 and 1990- 2004. Data for the period 1999 - 2002 was available from the MRC on CD and was used for the initial appraisal of flow data availability for the project site.

A comparison of daily flows at Pakse and Stung Treng has been plotted on Figure 3-3. This shows that flows at Stung Treng are generally larger than those at Pakse.

A comparison of the monthly flows at Pakse with those at Stung Treng shows that on the Average the flows at Stung Treng are 40 percent greater than those at Pakse. As the project is more critically affected by dry season flows than by wet season flows this comparison is presented on a monthly basis on Figure 3-4. It can be seen that while the average flows at Stung Treng are greater than those at Pakse, they are similar during critical dry sequences.

As a result it is recommended that Pakse daily flows are used for the energy estimates and not increased to allow for the slightly larger catchment (553,000 km^2) to the project site.

Table 3-1 Average monthly flow (m^3/s) at Pakse 1924-2006

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1924				1714	2127	7855	19408	41088	27246	14316	9956	4703	14306
1925	2829	2136	1773	1747	2446	7515	19811	23370	32271	13713	6392	3862	9862
1926	2690	2222	1788	1693	1591	4838	13879	30461	24607	19380	9993	5671	9960
1927	3417	2273	2002	1991	3009	10507	18065	32134	21303	22625	9226	4877	11038
1928	3026	2206	1972	2141	3354	11487	21669	25190	23656	14570	6725	3741	10009
1929	2515	1902	1634	1657	2296	8189	21404	35844	33849	19556	7300	4447	11785
1930	2882	2099	1783	1870	3265	8359	19233	29275	25478	19961	7606	4450	10588
1931	2866	2015	1686	1754	2224	4245	9236	22209	24566	16627	5888	3175	8079
1932	2206	1677	1477	1496	1817	5159	16196	20520	25352	20629	8991	4846	9227
1933	2353	1512	1163	1098	1313	4566	14609	26261	21302	15233	8868	3872	8565
1934	2400	1881	1523	1263	1894	3787	16092	29303	31303	21476	9005	4513	10429
1935	2807	1910	1547	1381	2182	7803	16949	26794	23981	22233	15366	6262	10826
1936	2987	2294	1836	1815	2698	8502	20303	25506	28178	10937	4721	3100	9430
1937	2283	1660	1530	1248	2930	8724	21764	36278	39976	18261	8290	5253	12413
1938	3431	2573	2143	2492	3861	13131	21088	27956	27000	21962	9414	5135	11742
1939	3305	2604	2267	2281	3808	12705	19413	32948	30456	18270	7581	4820	11763
1940	2991	2225	1940	1798	2654	8849	18269	27481	30532	11592	5633	3673	9624
1941	2915	2363	1970	1754	2594	10795	17394	28984	28131	21130	11222	5073	11247
1942	3023	2279	1935	1905	3713	10742	24023	32746	25972	15726	8254	4042	11264
1943	2950	2195	2041	2353	2565	10863	18945	26966	31093	18609	6902	3991	10838
1944	2972	2334	1847	1609	2911	7372	16039	28362	22045	16439	10454	5408	9851
1945	3369	2440	2037	1918	3632	11723	20626	25096	32268	14589	7645	4803	10887
1946	3195	2186	1766	1649	3450	11079	17347	27393	35583	20168	9505	4922	11565
1947	3267	2536	1877	1776	4574	8565	24362	28728	33094	17328	7440	4121	11532
1948	2925	2278	1830	1842	3788	8861	17744	29554	36437	19731	10260	5281	11734
1949	3154	2545	1954	2072	3471	5370	12977	28646	34103	23536	10601	4907	11161
1950	3109	2452	1860	1606	2328	8668	20213	29015	26646	23587	13754	5868	11655
1951	3241	2514	1710	1591	2706	13134	19088	30703	28406	18055	10416	5107	11440
1952	2660	1706	1544	1470	2314	6039	16903	31881	35198	21030	10339	3590	11253
1953	1755	1616	1377	1370	4316	11618	16958	23324	24465	14123	8779	4316	9544
1954	2405	1594	1276	1435	2675	7658	9529	19048	30981	19881	8914	4026	9146
1955	2426	1805	1464	1787	2150	6278	15866	20701	22614	11687	7703	4426	8280
1956	2557	1924	1435	1342	3868	10491	15661	33342	31717	13451	6851	3602	10544
1957	2544	1998	1612	1661	2134	7762	19077	18445	23573	17687	7819	3160	9000
1958	2123	1786	1480	1256	1627	6714	14158	19652	29877	13848	6753	3554	8596
1959	2003	1648	1513	1446	1888	5139	10391	21632	30783	17929	8985	3947	8973
1960	2504	1906	1505	1107	1313	5004	10198	30058	28203	18758	7821	3835	9379
1961	2371	1850	1559	1704	2607	13344	17448	25845	38530	27423	8908	4071	12185
1962	2908	2203	1772	1549	2836	10867	18239	26819	25027	17442	7376	3156	10067
1963	2220	1743	1418	1282	1476	9065	18499	31977	25310	14108	11007	5149	10326
1964	2841	2154	1813	1795	3287	8776	17090	20861	29140	22477	9748	4922	10432
1965	2950	2325	1899	1710	2137	15514	19790	21839	21387	11309	10152	4671	9672
1966	4350	3098	2038	1652	4142	9872	19275	30807	40031	15616	7727	4669	11981
1967	3383	2567	2096	1704	2505	6789	10388	18365	24190	17266	5835	4046	8293
1968	2565	2103	1746	1557	3284	6081	11634	19955	26040	12185	7068	3559	8159
1969	2370	1841	1488	1362	1646	10062	21200	28658	19680	10433	6339	3198	9078
1970	2190	1723	1393	1568	3035	9821	22661	32635	32153	14195	6522	4972	11134
1971	3138	2217	1781	1600	2082	8827	27645	30965	26870	14345	7186	4009	10957
1972	2956	2330	1870	1988	2197	6875	14230	34271	21223	14113	8192	5860	9717
1973	3245	2288	1911	1751	2879	7099	15861	22055	32207	15864	7570	4832	9833
1974	2950	2318	1831	2105	2936	8978	11249	29071	28173	12621	7193	4059	9492
1975	2977	2333	1777	1696	2627	10464	16439	27526	31023	17568	9221	4051	10683
1976	2731	2370	1994	2042	3280	7221	12867	27690	18057	16542	10085	4658	9163
1977	2645	1946	1978	2196	2420	3210	10427	17016	23733	11683	6800	3673	7336
1978	3135	2250	1901	1795	3122	10600	20203	42477	32340	22945	7971	3919	12803
1979	2911	2385	1990	1945	4066	11449	17332	25330	23493	13726	5365	3456	9500
1980	2479	1950	1741	1745	2648	7693	16042	23342	34647	18026	9459	4431	10363
1981	3030	2426	2145	2125	3883	17551	27171	32523	23507	15558	8677	5489	12075
1982	3561	2765	2201	2319	2645	6111	12286	23284	26027	21110	8125	4370	9611
1983	3020	2336	2208	2071	2395	5391	9611	19874	23633	17219	11023	5517	8724
1984	3494	2462	1877	1674	3305	8158	19548	32023	26960	14719	8183	4082	10577
1985	2908	2245	2008	1828	2666	11753	15861	27445	26873	13999	7964	5298	10113
1986	3023	2358	1937	1747	4752	11619	16037	23426	21140	11206	6729	3763	9018
1987	2521	2135	1859	1685	1918	4414	10806	21029	22263	13416	6394	4046	7742
1988	2641	1889	1665	1607	3444	7513	9557	22813	16327	12045	5722	3142	7389
1989	2061	1667	1482	1513	2642	8690	12358	23158	19307	15971	7562	3684	8386

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1990	2680	2294	2425	2091	2898	13719	19984	24058	24637	16419	8239	4211	10350
1991	2802	2039	1748	1827	2159	5821	16916	30206	27700	16565	8809	4091	10112
1992	2887	2236	1910	1762	2014	5262	12076	20006	17513	10544	5961	3119	7128
1993	2324	1731	1575	1449	2451	5822	17959	21619	21793	9996	5783	3147	8014
1994	2265	2030	1648	2006	2441	12851	23242	29991	28239	14984	5338	3983	10808
1995	2819	2089	1868	1650	2586	7004	16014	28826	29962	15751	7708	4266	10094
1996	2813	2218	2041	2154	3583	5730	12887	27095	30453	19705	10927	5459	10446
1997	2898	2282	1919	2402	2677	3397	20953	32941	26737	14856	5541	3312	10062
1998	2557	1975	1707	1881	2636	4811	15019	16150	20111	7400	4510	2921	6835
1999	1982	1734	1502	1778	4907	12556	15425	23823	26175	15073	10416	4646	10039
2000	2880	2399	2349	2427	7202	15348	28706	27451	36393	15178	7561	4099	12692
2001	2784	2333	2347	2224	3296	12401	23648	34333	32495	15278	10914	4881	12301
2002	3396	2683	2232	2045	3943	12540	27543	34653	31565	16346	8194	5145	12593
2003	3876	2860	2422	2396	2643	6538	11537	19896	27397	11395	4458	2705	8199
2004	2191	2000	1640	1840	3175	8797	15060	28823	32697	12324	5032	3388	9764
2005	2509	2117	1983	2296	2460	5919	18220	34646	30598	17488	7065	3997	10838
2006	2662	2228	2003	1871	2764	5325	17023	27868	19508	21022	7388	3224	9476
Ave	2805	2156	1815	1781	2870	8648	17215	27137	27536	16435	8136	4286	10156
Max	4350	3098	2425	2492	7202	17551	28706	42477	40031	27423	15366	6262	14306
Min	1755	1512	1163	1098	1313	3210	9236	16150	16327	7400	4458	2705	6835
Median	2854	2211	1834	1754	2666	8502	17090	27481	27000	15971	7821	4110	10103

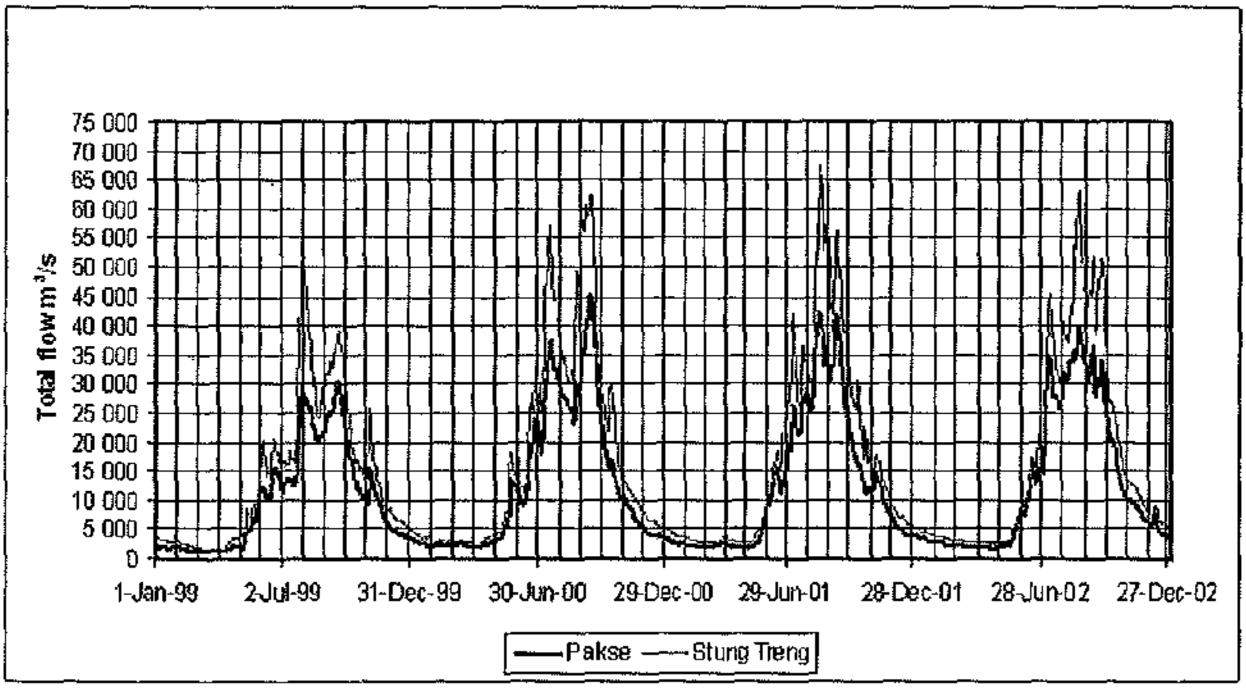


Figure 3-3 - Comparison of Pakse and Stung Treng Flows

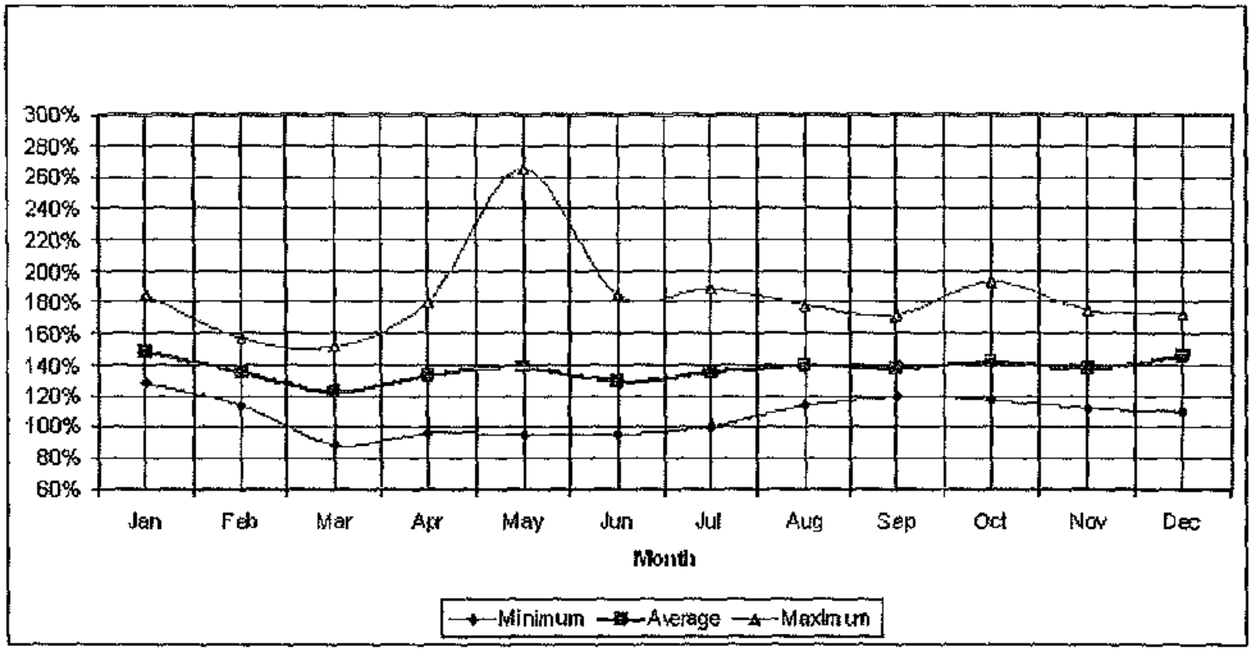


Figure 3-4 Monthly Comparison of Stung Treng as percentage of Pakse Flows

3.4 Gauging Stations in Project Area

Daily read staff gauges have been set up in the project area from the mid-1990s to record water levels relevant to the project. These stations have been listed in Table 3-2 and are shown on Figure 3-5. The gauges are supposed to be read twice daily, but rating curves are not yet available for these sites so it is not possible to use these stations to estimate flows in the river.

Table 3-2 River Gauging Stations in Project Area 1998-2006

No.	Station Code	Identified by Surveyor	Station Name	UTME (m)	UTMN (m)
1	014303	WG01	Thakho	606275	1544726
2	014306	WG03	Hou Sahong Theung (upstream)	603891	1544419
3	014304	WG04	Veunkham	606761	1539651
4	014308	WG05	Don Sadam	603937	1540800
5	014307	WG06	Hou Sahong Leum (downstream)	603614	1541710
6	014305	WG07	Khonetai	599860	1544088

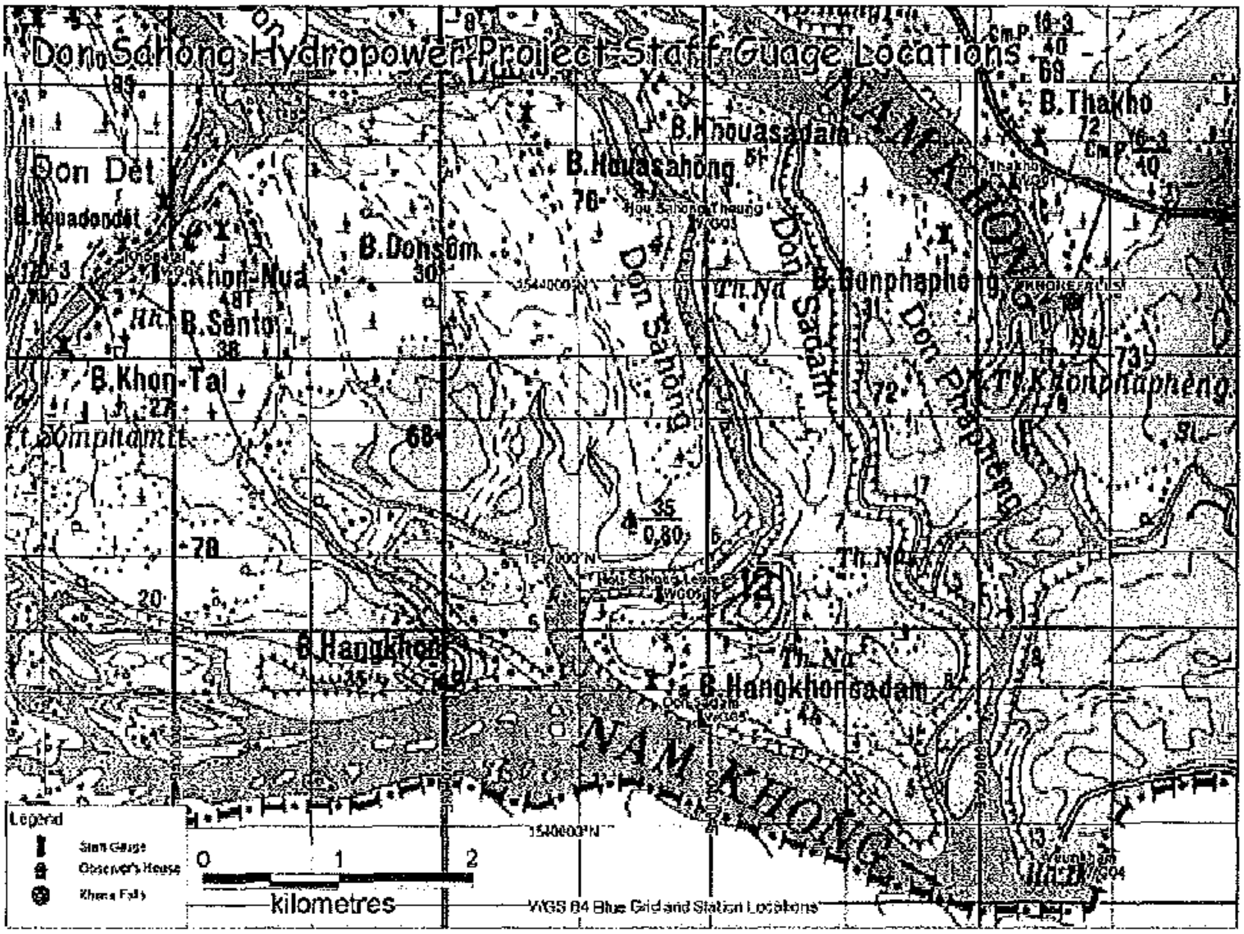


Figure 3-5 – Location of Staff Gauge Stations in Project Area

Gauge readings for the period 1 June 2005 to 31 October 2006 were downloaded from the Waterway Unit Office in Pakse, while records from January 1998 to 31 December 2005 were purchased from the Waterways Department Head Office in Vientiane. These daily water levels have been particularly relevant in the assessment of the relationships between water levels in the project area and Pakse flows (Sections 3.6 and 3.7). However, there is doubt as to the reliability of the readings. While the readings cover only a short period compared with the 80 years of record at Pakse, they do encompass the record high flow season (2002) and a low flow season (2003-2004) so the relationships derived in Sections 3.6 and 3.7 can be considered as representative of the conditions.

The consultant's hydrographer inspected all six staff gauge water level stations and the condition of the gauge boards checked. The gauge readers were interviewed and a photographic record was made of any data contained in the observers' note books. Notes on the inspections and photographs of the stations are presented in Appendix A.

3.5 Stream Gauging

The Siphandone Area is comprised of numerous channels, some of which, the Khonephapheng and Lippi Falls and the Hou Sahong flow year round, while others carry flow only during periods of high Mekong flow. To estimate the water available to generate energy through the Hou Sahong Power Station it was necessary to get as accurate an estimate as possible of the percentage of flow that is carried by the Khonephapheng Falls, particularly in the low flow season when the power station will need as much water as possible for generation. It is not so important during the high flow season when there is ample water.

While it would have been ideal to establish automatic recording level gauges on more of the channels than are presently served by daily read staff gauges and to have a gauging team gauging all the major channels through out the year, in the short time period available it was feasible only to do some gauging on the channels of immediate interest - the Mekong mainstream above Khonephapheng Falls (at the Thakho staff gauge), the Hou Sahong (above the Hou Sahong Leum staff gauge) and on the Hou Sadam.

A contract was awarded to Asa Power Engineering Co Ltd of Vientiane to carry out this gauging. Unfortunately, the timing of the award was not good and the initial gaugings in mid-July were taken with the Mekong rising rapidly. These gaugings were not well done and the results were unsatisfactory. The current meter was also damaged during this exercise.

The flows were considered unsafe to attempt further gaugings until December, when Thakho and Hou Sahong were gauged. Again, due to an error in technique, the results were unsatisfactory. The work from January onwards was considered satisfactory and the discharges are summarised in Table 3-3.

Table 3-3 - Results of Stream Gauging

Date	Pakse Discharge		Calculated Disharge[3] at		
	Discharge (m^3/s)	Date	Thakho	Hou Sahong	Hou Sadam[5]
19 July 2006	15,800			898[1] 6.72[4]	
21/22 July 2006	16,000		3,735[1] 5.10		
14/15 Dec 2006 [2]	3,250			**138[1]** 4.48	
6/7 Jan 2007	2,500		1,860 3.56		
30 Jan 2007	2,000	4 Feb 2007			6
31 Jan 2007	«	u		79 4.02	
1 Feb 2007	a	»	1,580 3.41		
17 Feb 2007	1,952	18 Feb 2007		42 3.84	
6 Mar 2007	1,835	6 Mar 2007		60 3.93	
22 Mar 2007	1,622	21 Mar 2007			3
23 Mar 2007	1,578	22 Mar 2007	1,444 3.25		
24 March 2007	1,622	23 Mar 2007		40 3.65	
23 April 2007	1,593 1,773 1,866	20 Apr 2007 21 Apr 2007 22 Apr 2007	1,790 3.39		

Notes:
1. Unreliable
2. From 14 December, discharges are average of 3 gaugings.
3. Calculated discharge (m^3/s)and reading at adjacent staff gauge in metres
4. At this day the staff gauge **at** Ban Hang Sadam read 5.00 m
5. No staff gauge in Hou Sadam

From this small sample it is difficult to make an accurate evaluation of the proportion of total flow that discharges at Khonephapheng Falls except in the low flow season when the only other channels of significance are Hou Sahong and the Lippi Falls (mostly via the Hou Don Det channel). In the high flow season, however, major flows occur down the right bank channel (adjacent to Cambodia) and in the maze of channels between Don Sahong and Don Khone.

The gaugings indicate that the percentage of the Pakse discharge that passes over the Phapheng Falls is as high as 90% in low flow periods and less than 25% in the high flow period.

3.6 Main River Hydraulics

3.6.1 Existing

Site inspection made it clear that there is a considerable river gradient from the entrance to the distributary channel Hou Don Det (approximately 3.5 km upstream of the entrance to Hou Sahong) to some distance (at least 1 km) downstream of Hou Sahong. It was considered important to obtain levels along that reach during the early 2007 dry season as a quantitative guide to the lowest river level determining the flows into the Hou Sahong.

The survey of the water levels along the main river from about 350 m upstream of the tip of Don Det to Thakho was carried out on 27 January 2007. Figure 3-6 shows the location of the spot levels on a satellite image of the area. These levels were taken over an eight hour period and give a good idea of the general slope of the water surface profile. While the quantum of flow would not change significantly over the period, there are inaccuracies due to wave action, particularly in the reach downstream from point WL13 where the water surface is far from smooth. From the spot levels obtained, the profiles shown in Figure 3-7 were obtained. This figure was constructed using distances along the river thread line. This 'thread line' is also an approximation as levels were taken on both banks of the Mekong, up to 5 hours apart.

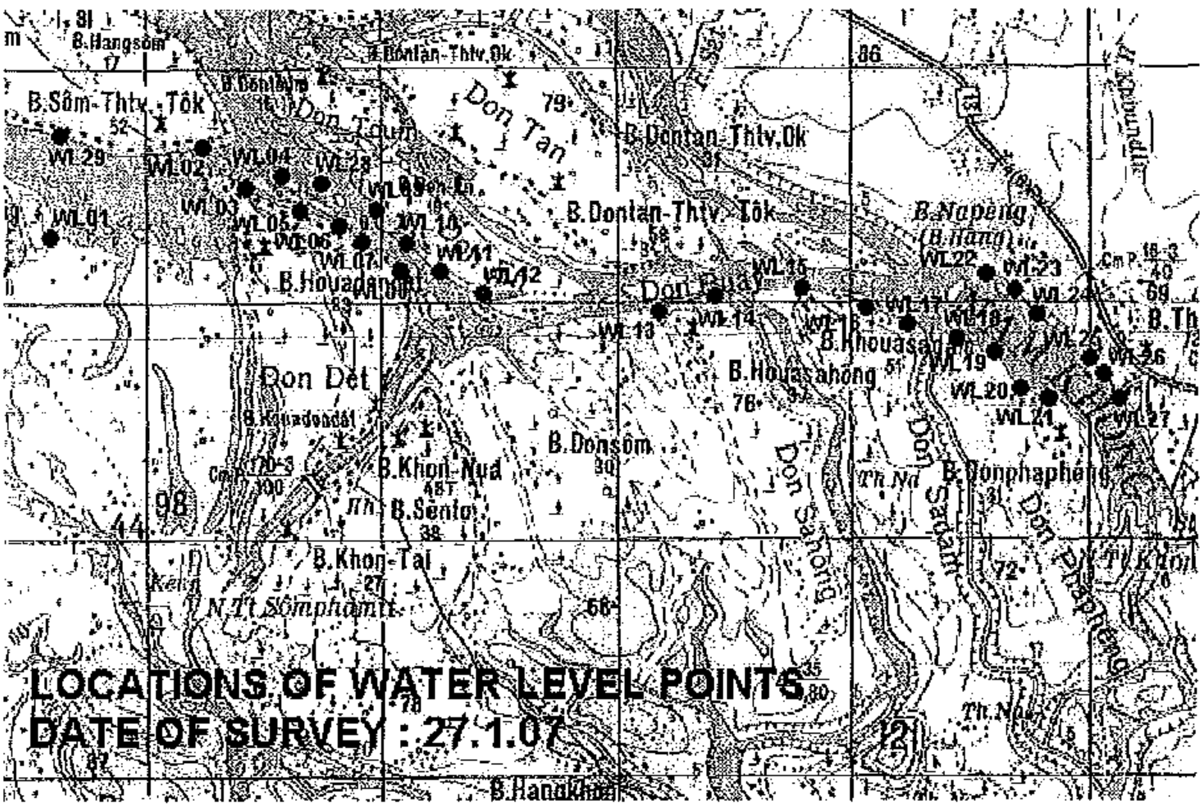


Figure 3-6 Location of Water Levels in Mekong River, 27 January 2007

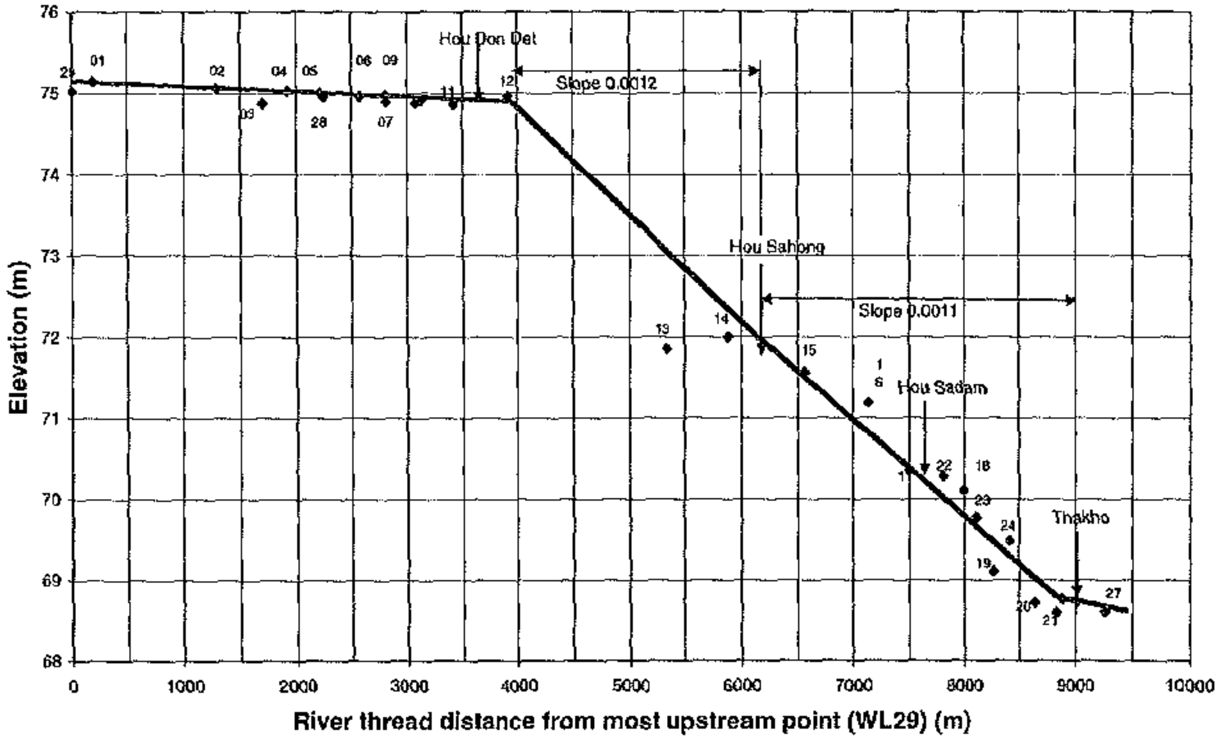


Figure 3-7 Water surface profile past the entrance to the Hou Sahong

Using previous water level measurements at WG7 (about 1.3 km downstream of the entrance to Hou Don Det, and therefore measuring water levels considerably below the levels at the entrance to the channel), WG1 (Thakho), WG5 (Hou Sadam) and WG6 (Hou Sahong (for discharges at Pakse from 1,500 m7s to 45,000 m /s)), the data were assessed to derive an overall picture of the water level correlations.

Using the observed water level at Thakho (RL 68.6), the plot of Thakho water levels plotted against Pakse discharge indicated that the river discharge at Pakse at the time of the survey was approximately 2,000 m^3/s. Plotting the observed levels at the entry to Hou Don Det and Hou Sahong, indicated that the level at the entry to Hou Don Det is about 1.25 m higher than the Khonetai (WG7) level). The field inspection 18 January indicated that a drop of this magnitude could be expected.

Eyeing in a curve through the historic water data for entry to Hou Don Det and Hou Sahong provided a reasonably strong indication that at a Pakse discharge of 25,000 m^3/s (for instance), the level at the two entry locations would be RL 77.2 and RL 73.9, respectively.

This further indicated that the lowest low-season level at the entry to the Hou Sahong is slightly over RL 71.0 and in the flood season up to about RL 74.5 or a little higher. Figure 3-8 shows the water levels during 2006 for Pakse, Thakho, Ban Hang Sadam and Veunkham (in that descending order). This figure (for one year only) tends to support the assessment of the high-season water level at Hou Sahong (about 3.2 m higher than Thakho, Figure 3-7), as the high season level at Thakho is RL 71.8. The low-season level at Thakho in 2006 was RL 69.6 and so based on Figure 3-7 it would appear that the lowest level at the entrance to Hou Sahong would have been approximately RL 72.8 - considerably higher than the level in 2007.

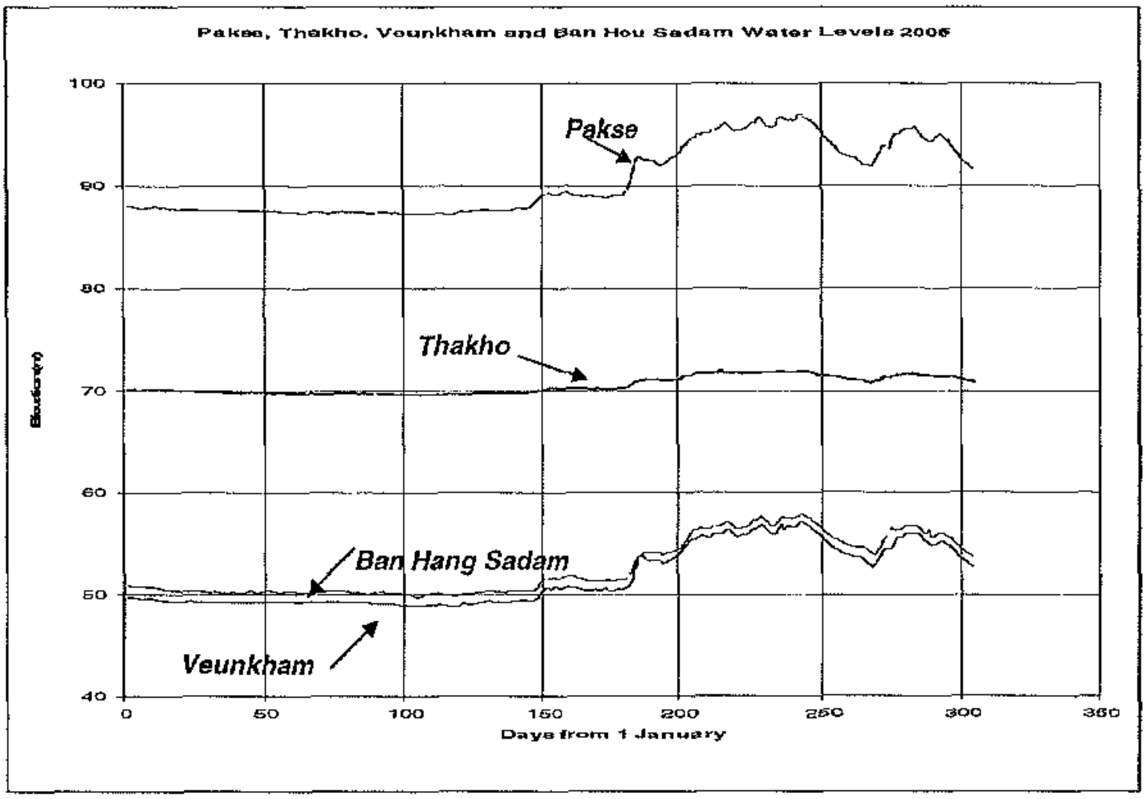


Figure 3-8 2006 Water Levels at Pakse, Thakho, Ban Hang Sadam and Veunkham

Figure 3-8 2006 Water Levels at Pakse, Thakho, Ban Hang Sadam and Veunkham

The plots in Figure 3-7 indicate that the river gradient upstream of Hou Don Det is 0.00014. At that point it enters a steeper reach whose slope is generally 0.0012 to a location about 550 m upstream of Thakho.

Figure 3.9 is a correlation plot of the 2006 water level data for Pakse and Thakho, with the January and February data omitted due to a trend that differed markedly from the remainder of the data. The figure suggests inconsistencies at the low end as explained below.

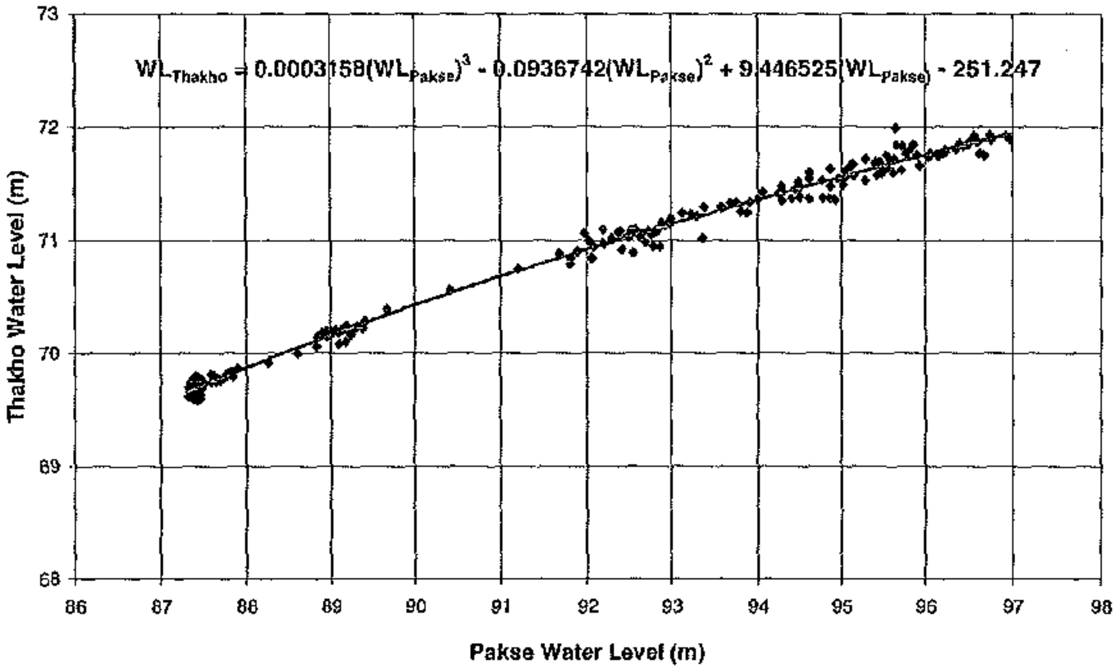


Figure 3-9 Water Level Correlation, Pakse to Thakho (March-October 2006 data)

3.6.2 Effect of increased discharges into Hou Sahong

The proposal for a power station in the Hou Sahong requires a major increase in the low season discharges down the Hou Sahong over what occur naturally, variously considered to be 1,500 m^3/s or more. The existing channel with a water level at the entrance at RL 74.5, say (a high season level) would have the potential to discharge around 2,000 m^3/s (the numerical model results are discussed later). Whether or not the Hou Sahong actually carries that discharge depends to some extent on the entrance geometry and flow conditions, including the momentum of high velocity flows in the main river past the entrance.

In the low season with a water level at the entrance to Hou Sahong of RL 71.0, say, the existing channel might have a discharge of 250 m^3/s or even less. Clearly, therefore, it would be necessary to introduce appreciable changes to the entrance geometry (including lowering of the channel bed over hundreds of metres) to achieve the major increases in discharge in the Hou Sahong.

At the time that the main river is at RL 71.0 at the entrance *to* Hou Sahong, the level at Thakho would, on the basis of the slope data presented earlier, be about RL 68. The correlation between Thakho and Pakse gauge elevations (Figure 3-9) extends from a Thakho level of RL 69.7 only.

The gauge zero at Pakse is reported to be RL 86.4925, and the discharge rating for the station used by IWD and MRC is given by Equation 3-1:

$$Discharge_{Pakse} = 715.17\ (GH_{Pakse} + 1.035)^{1.552} \qquad (3\text{-}1;$$

Use of the equation shown on Figure 3-9, for a Pakse level of RL 86.4925 would suggest a Thakho level of RL 69.37, and Equation 3-1 for a zero gauge height corresponds to a discharge at Pakse of 754 m /s. When these values are compared with the information contained in the plots of Thakho levels against Pakse discharge, it is seen that Thakho levels do drop to RL 68 and the discharge at Pakse is then approximately 1,500 m^3/s. Accordingly, attempts to determine a main river discharge corresponding to a level at Thakho of RL 68.0 has some uncertainty on the basis of available data.

It could be that the main river discharge is around 1,500 m^3/s, or it could be significantly lower. If it is as high as 1,500 m/s (for RL 71 at the entrance to Hou Sahong), clearly diversion of a discharge of a similar magnitude into Hou Sahong would

- Account for virtually all of the main river discharge
- Reduce the discharge over Phapheng Falls to a very low value
- With the lowering of the river level downstream of the entrance to Hou Sahong, the water level will not be at RL 71 anymore, but less by an amount that would require detailed modelling to make a reliable estimate, and
- With the lowering, the accomplishment of the intended diversion discharge would likely require more excavation in Hou Sahong than at first thought and the flow momentum past the entrance would also mitigate against satisfactory diversion, unless there was a physical means of turning the water into the channel.

3.7 Environmental Flows

As the Don Sahong power station will be extracting water from the Mekong that otherwise would be discharged over the Khonephapheng Falls, an estimate is required as to the minimum environmental flow that can be passed over the falls.

The project is located in an environmentally sensitive area.. Flows must bypass the project for several reasons:

- to maintain the flow over the Phapheng Falls for tourist impact
- to allow fish migration along the river

The following photos were taken in May 2006 when the Pakse flow was approximately 3000 m^3/s. Photo 3.1 shows the Phapheng Falls with a flow of approximately 2000 m^3/s. Photo 3.2 shows the corresponding flow down Hua Sahong passing a fish trap with a flow of approximately 1000m^3/s ungauged.

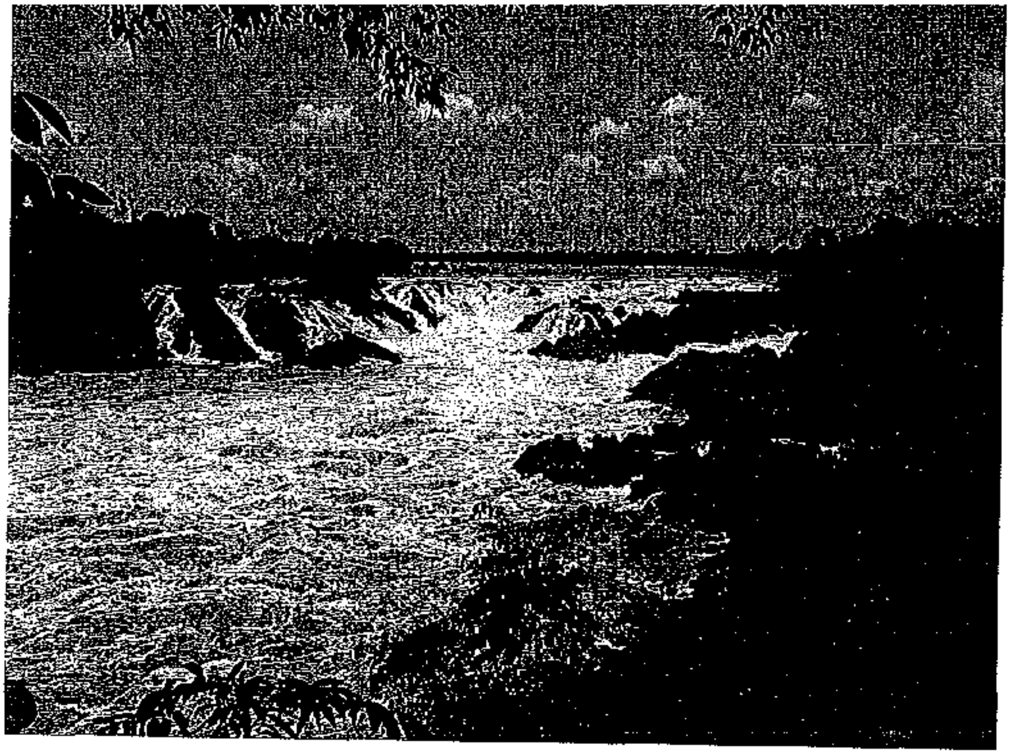


Photo 3.1 Flow over Phapheng Falls - 26 May 2006 (Pakse flow 3000 m^3/s)

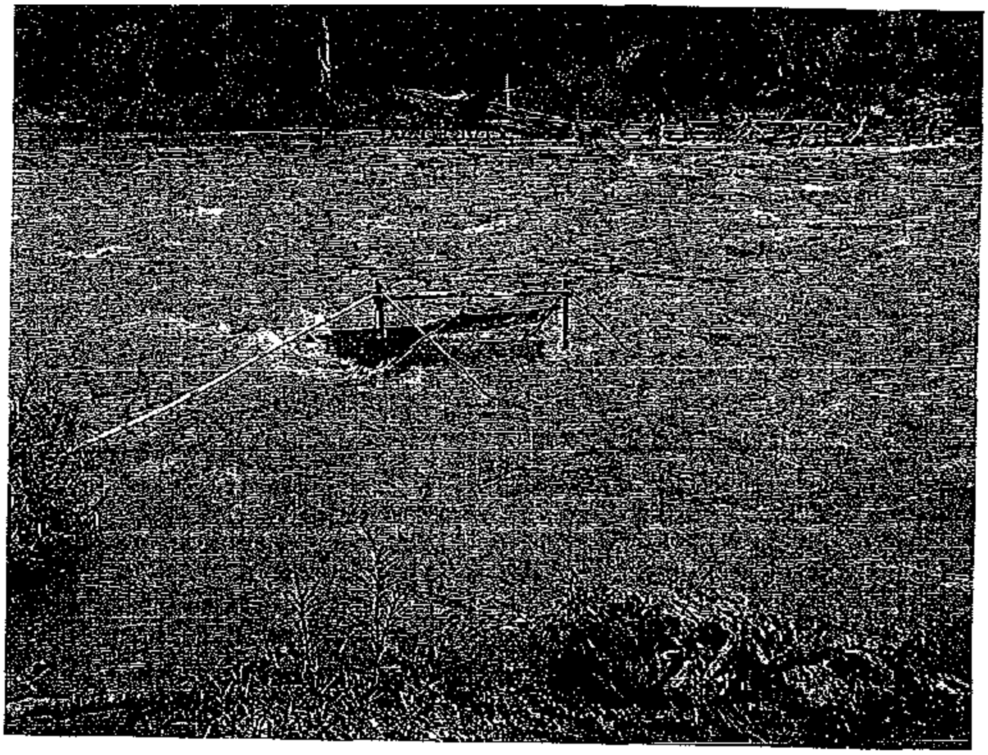


Photo 3.2 Flow down Hua Sahong in May 2006

A number of options for total Environmental flow were considered for the purpose of quantifying their impact on energy potential.

The energy modelling described in Section 11 of this report examined the impacts on the Don Sahong Energy potential of two approaches to environmental flows.

The first suggested in the earlier Acres study was that the station flow could be up to 25% of the Pakse flows limited by the station capacity.

The second approach is that there is some fixed minimum flow which is required for Environmental purposes including:

- Losses in the Mekong River between Pakse and the Project Site
- Flows over the Phapheng Falls
- Fish Migration
- Low flows through other branches of the cascade which bypass the station unless separate control structures are installed

The assumption is that this flow has first priority and must be satisfied. Any incremental flow can pass through the station up to the operating limit of the station. Environmental flows over the range 800 m^3/s to 1400 m^3/s were examined to give a better understanding of this effect.

3.8 Headwater Variation

The gauge readings obtained from Waterways Department in Vientiane and Pakse were converted to water levels by adding the gauge zero level to the readings for the Khone Tai and Thakho stations then plotting these levels against the corresponding Pakse discharge as shown on Figure 3-9. This plot also shows the values calculated using the following formulae developed for the model:

Formula 1 - Khone tai

$$Level = -21 * 10^{-10} * flow^2 + 0.00016 * flow + 74.0$$

Formula 2- Thakho

$$Level = -25 * 10^{-10} * flow^2 + 0.00018 * flow + 68.5$$

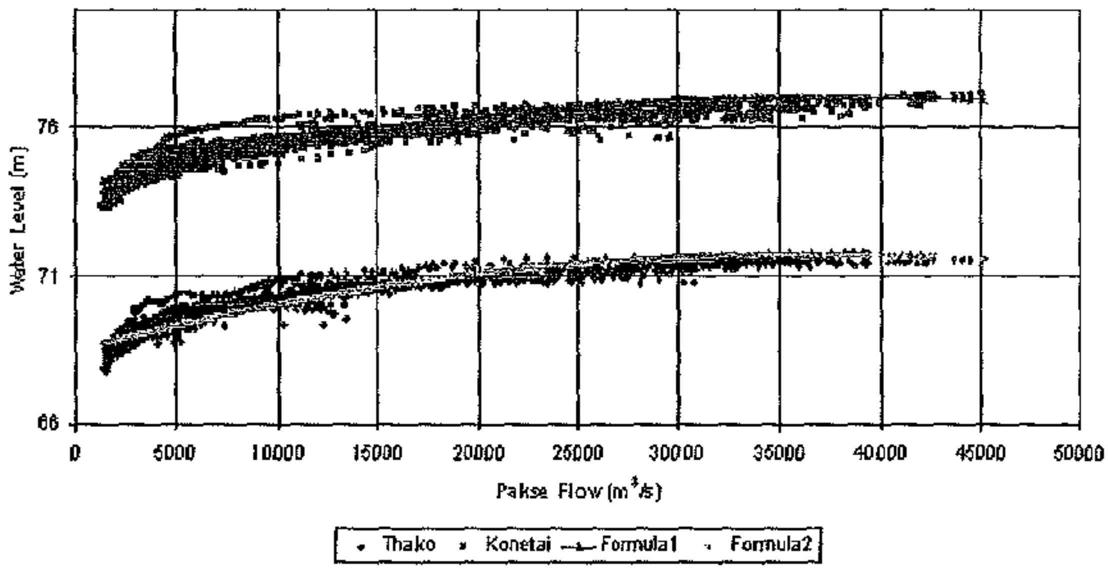


Figure 3-10 - Comparison of Khonetai and Thakho Water Levels

However, Khone Tai is 3,900 m upstream of the entrance to Hou Sahong and Thakho is 3,800 m downstream and the Mekong falls quite steeply in between, so a survey of the water surface was undertaken to establish a relationship between the recorded water levels and the Hou Sahong entrance and this is discussed in Section 3.6.

3.9 Tailwater Variation

A similar approach was followed to estimate the Mekong water level downstream from the proposed power station using records from Don.Sadam (WG05) and Hou Sahong Leum (WG06). A plot of these levels against the Pakse Flows is shown on Figure 3-11.

In this case there was a sharper dropoff in levels at low flows so a composite curve was used for Hua Sadam:

Formula 1 - Sadam for Pakse flows greater than 4000 m^3/s

$$Level = -30 * 10^{-10} * flow * +.00038 * flow + 48.6$$

Formula 2 - Sadam for Pakse flows less than 4000 m^3/s

$$Level = 29,9 * flow^{0.63} - 0.4$$

The formula used for Hua Sahong was:

Formula 3 - Sahong

$$Leveh = -31 * 1O^{-10} * flow^2 + .00037 * flow + 50,0$$

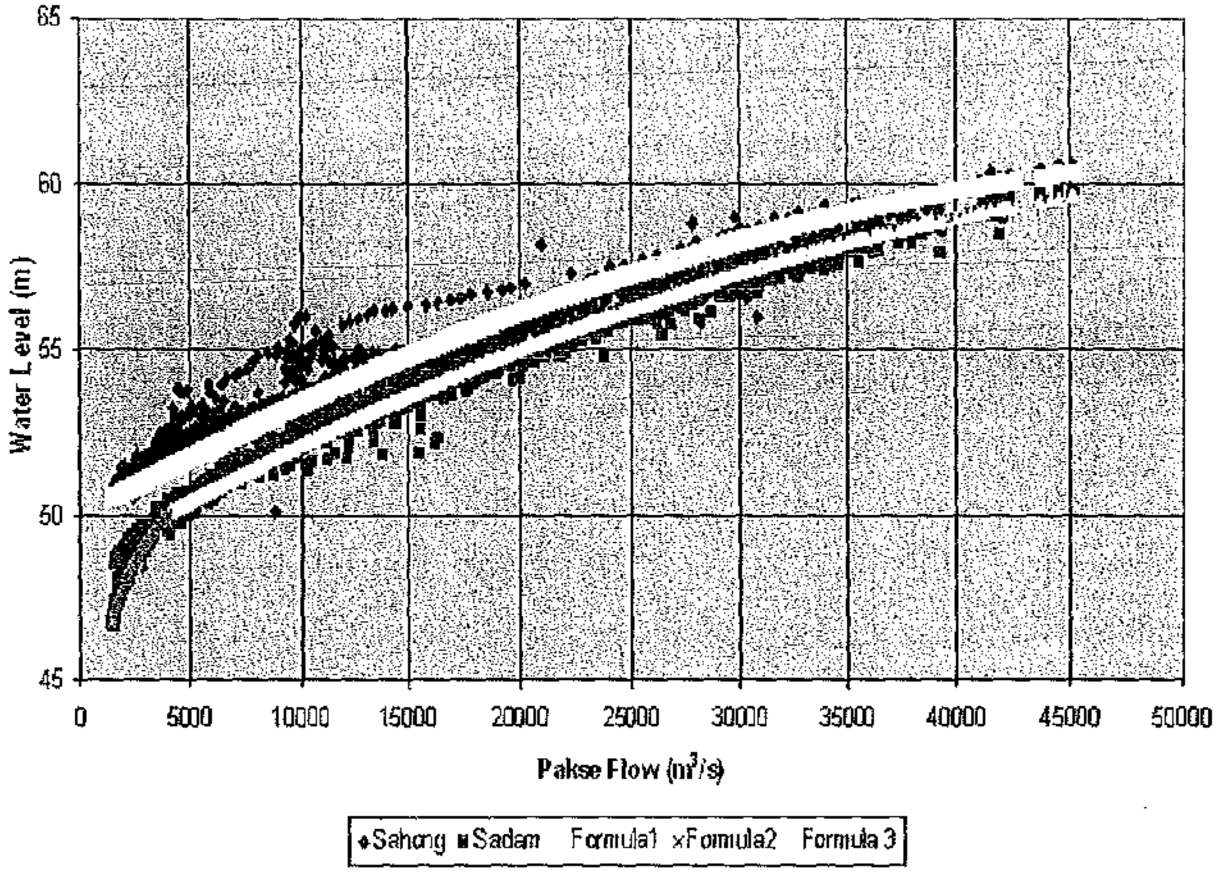


Figure 3-11 - Comparison of Don Sadam and Hou Sahong Leum Water Levels

The scatter in the Hou Sahong plots occurred in 2003 and was possibly caused by errors in the re-location of some of the gauge boards. The consultant's hydrographer inspected this site and commented that it might be unreliable.

3.10 Capacity of the Hou Sahong Channel

For the analysis of the hydraulics of the Hou Sahong, some 55 cross sections of the channel were surveyed from "UD1L" more than 400 m long at the upstream entrance of the channel to "DC16L" at the downstream end. The surveys, at 100 m spacing in the upstream reach and at 50 m spacing for the lower 800 m, included the left and right channels around the two islands in the river.

Inspection of the river shows it to be hydraulically rough. A typical view of the river is shown in Photo 3-3.

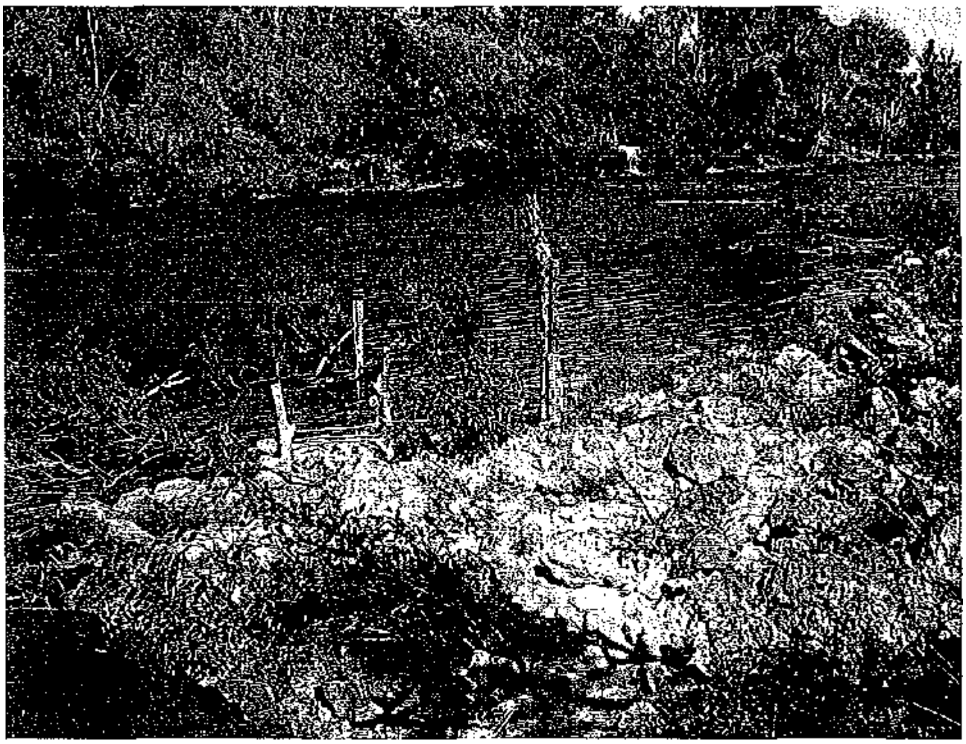


Photo 3-3 View of Hou Sahong at WG6 (Hou Sahong Leum)

Downstream of Hou Sahong, the river is much wider over a length of approximately 600 m before it enters the 600 m to 700 m wide Mekong southern arm. The WG5 gauge is on the left bank of this wide arm, Some bathymetric survey was made for an area downstream of the most downstream Hou Sahong section (DC16L).

The analysis of discharges required the establishment of a downstream rating as a boundary condition for the numerical model. Available information included the historic levels at WG5 and WG6 versus the Mekong River discharge at Pakse. Figure 3-11 shows the data. What are of interest are the data for the low discharges. Clearly, when the Pakse discharge is lower than 3,000 m /s the level in the southern arm of the Mekong (WG5) lowers much more than the Hou Sahong (WG6). It is believed that this is a reflection of the lowering of the discharges from the upper reaches of the Mekong across the wide expanse to the west of Hou Don Det.

As the main river discharge drops even more (around 1,500 m^3/s at Pakse), it is likely that the discharge over Liphi Falls is also markedly lower.

The plots of the WG5 levels (about 500 m downstream of the waterway into which the Hou Sahong flows) and the WG6 levels (about 600 m upstream of the mouth of Hou Sahong) provide the very limited data on levels to be used as "tailwater control" for the Hou Sahong flows. The other gauge at Veunkham (WG4) is about 3 km or more downstream of WG5.

The levels plot (Figure 3-11) indicates that at a Pakse discharge of 4000 m^3/s, the levels are as follows:

WG5	("Sadam")	RL50.0
WG6	("Sahong")	RL51.9

The downstream end of the numerical model was arbitrarily set at approximately 500 m downstream of the mouth of the Hou Sahong (Section DC16L). Site inspection seemed to show that the drop in water level from WG6 to the mouth of Hou Sahong would be appreciably more than from the mouth to WG5, and so it is likely that the model tailwater level would be closer to the WG5 level than the WG6 level.

Clearly, the southern arm of the Mekong has a much lower proportion of the total Mekong discharge than does the flow over Phapheng Falls. This means that, while under normal conditions in the low season the discharge in the southern Mekong might drop to 500 m^3/s or lower, and have water levels as low at RL 48, the introduction of appreciable discharges in the Hou Sahong with the hydropower project, will mean that the water levels (as model tailwater) will not then be around RL 48, but back to around RL 50.

On the basis of this discussion, for the purposes of the HECRAS modelling a rating curve for the downstream end of the model was coarsely estimated as follows:

Low-flow season: use downstream water level of RL 50

High-flow season: use RL 56 (this was based on site observations that indicated flood debris approximately 6 m above the river level in January 2007).

3.11 The HECRAS Model

3.11.1 Model description and set-up

The HECRAS model is a water surface profile model that utilises the cross section data (described above), an inflow boundary condition consisting in the present exercise of a number of steady (constant) discharges, and outflow boundary condition consisting of a water level-discharge rating, and selection of channel roughness coefficients. In the present study the roughnesses are expressed as Manning n values and were set on the basis of judgment made during the site inspection.

The n values used were generally 0.04 for the bed of the channel and 0.08 for the bank areas. The downstream end of the model is at chainage 421.7 m, cross section DC16L (the most downstream from the survey in Hou Sahong) is at chainage 1,000 m, and the upstream end of the model is at a chainage of 6,260.98 m.

While the model provided an analysis of the water surface profiles down the Hou Sahong, some uncertainties arose in relation to the ability of sufficient flow to physically enter the Hou Sahong. In order to model the overall behaviour of the flow at the entrance, it would be necessary to include a significant portion of the main river as it flows past the Hou Sahong. This is regarded as a refinement of what has been accomplished so far in the numerical modelling - but a necessary part of any future detailed design.

3.11.2 Existing Hou Sahong Hydraulics

Figure 3-12 presents water surface profiles for a range of discharges in the Hou Sahong for the existing cross sections. The profiles shown are for the water surface (hydraulic grade line) for discharges of 250 m^3/s, 500 m^3/s, 1,000 m^3/s, 1,500 m^3/s, and 2,000 m^3/s. The energy grade line for the 2,000 m^3/s discharge is also shown. The velocities in the channel reach as high as 4 m/s, and for most of the channel they are above 3 m/s. As cross sections did not extend to sufficient elevation at the banks on some of the cross sections, the model extended the section as vertical "walls" to contain the flow. This is not considered to affect the results in any significant way.

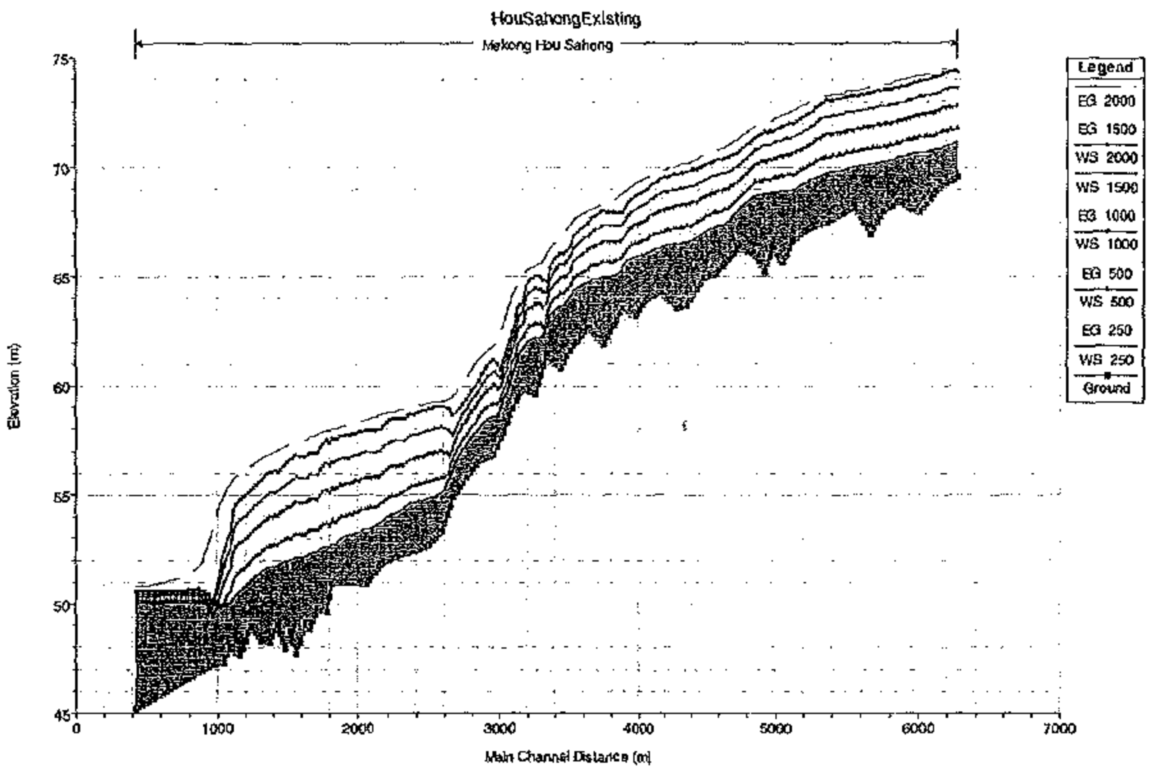


Figure 3-12 Hou Sahong water surface profiles for existing channel

3.11.3 Excavation at Upstream End

Figure 3-12 shows that for a discharge of 1,500 m /s the water level at the upstream end is RL 73.7. Given the need to discharge flows well in excess of 1,000 m^3/s during the low seasons, when the main river water levels are as low as RL 71.0 - the sections at the upstream end of Hou Sahong were modified to simulate excavation to open up the entrance. The excavation was simulated as a horizontal bed at three different levels: RL 67, RL 66, and RL 65.

Figure 3-13 shows the water levels for the same discharges as previously for the RL 67 case. Figure 3-14 shows the results for RL 65.

It will be seen that for a discharge of 1,500 m^3/s the water level at the upstream end was RL 72.6 for the excavation to RL 67, and RL 71.2 for the excavation to RL 65. In the latter case the bed excavation would extend about 1,800 m from the upstream end of Hou Sahong. For all the cases presented in these figures the downstream rating table used was as shown in Table 3-4.

Table 3-4 Tailwater Rating for HECRAS Modelling - Case 1

Discharge (m^3/s)	150	500	1,000	2,000	3,000
TW level (RL)	50.0	50.2	50.4	50.6	50.8

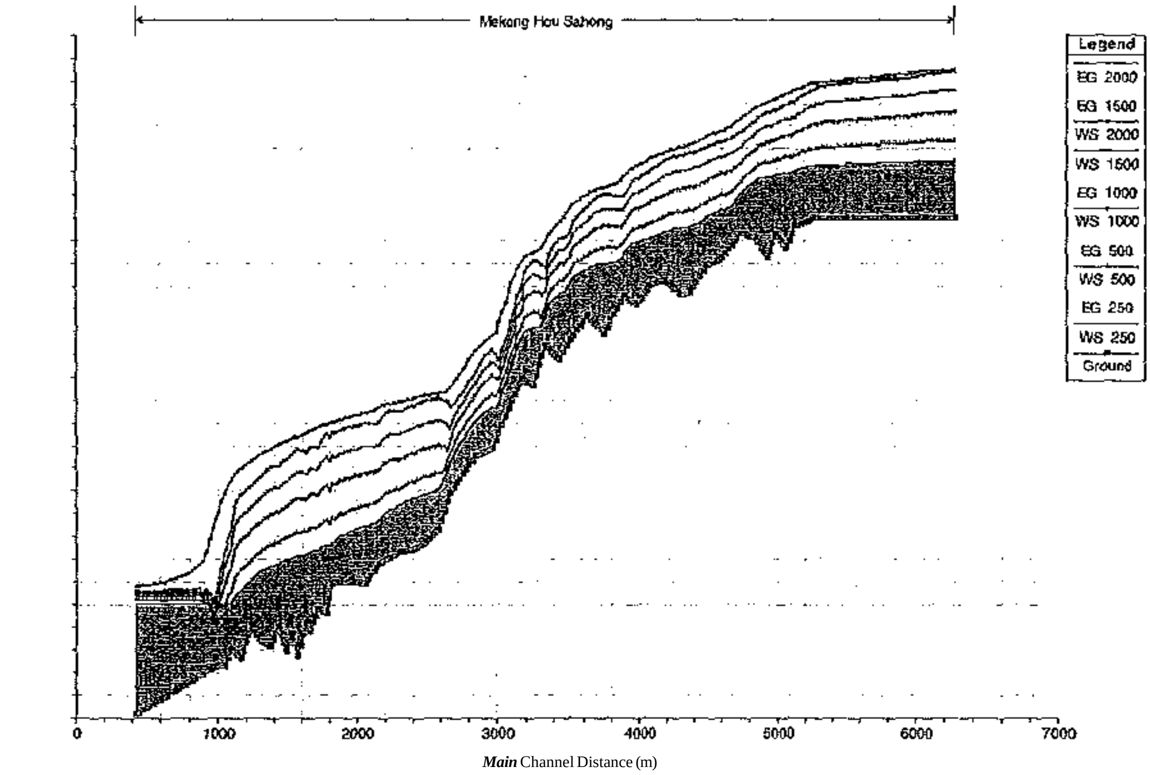


Figure 3-13 Water surface profiles for excavation to RL 67 at upstream end

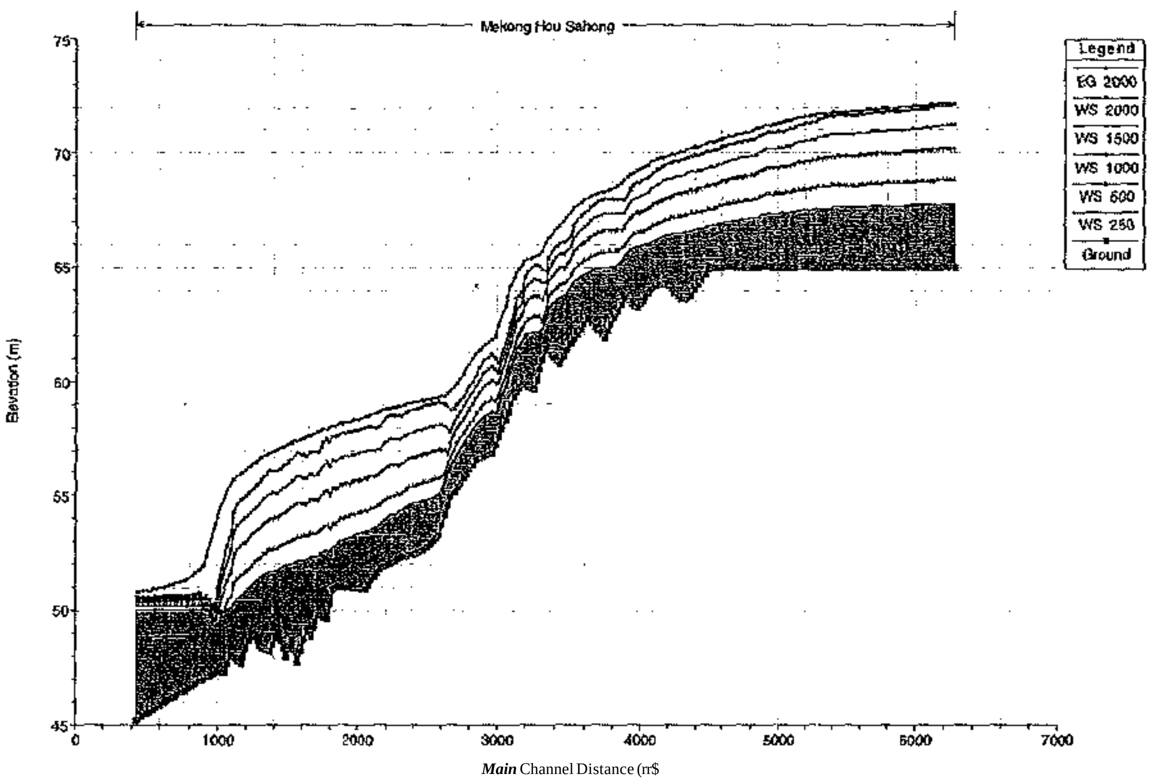


Figure 3-14 Water surface profiles for excavation to RL 65 at upstream end

In order to assess the effect, if any, of having higher tailwater rating at the downstream end, the am shown Figure 3-14 was re-run with the rating table shown in Table 3-5. This Case 2 rating was designed to reflect the higher river levels downstream due to the large inflows into the southern arm of the Mekong from Hou Sahong.

Table 3-5 Tailwater rating reflecting the effect of discharge through Hou Sahong - Case 2

Discharge (m^3/s)	150	500	1,000	2,000	3,000
TW level (RL)	50.0	50.7	51.5	52.5	53.5

Figure 3-15 shows the effect of the higher tailwater rating. It may be seen, in fact, that the effect is negligible. At chainage 1,000 m (*CS* DC16L) the water level and energy level is virtually identical with the levels shown in Figure 3-14.

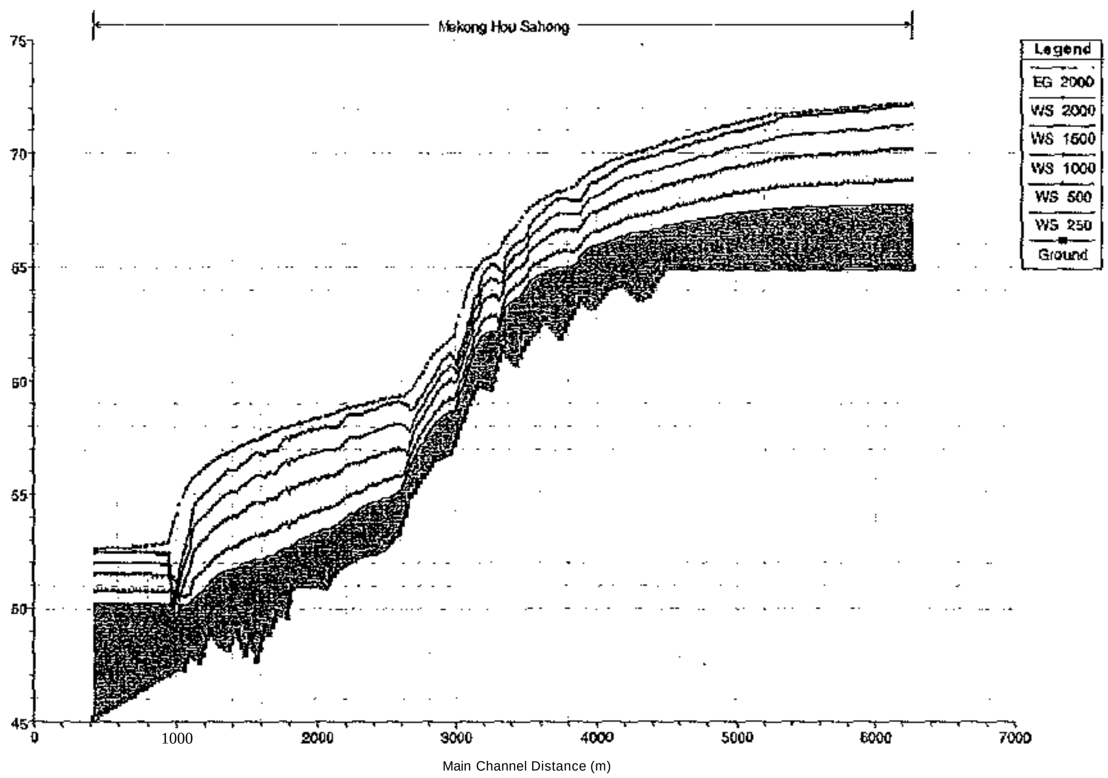


Figure 3-15 Water surface profiles for excavation to RL 65 at upstream end - with higher tailwater rating (Table 3-5)

3.11.4 Excavation at Downstream End

The proposed location of the dam and power station is near cross section DC13L (158.9 m upstream of DC16L). The model was run with the existing conditions (as shown in the above figures) and also with a simulation of excavation of the bed downstream of the dam.

At the location of the dam, the computed water levels were as shown in Table 3-6. The table shows the water levels for a range of discharges up to 2,000 m^3/s, for the existing bed profile and for the profile lowered to RL 47 and RL 48. In effect, this would mean that the bed for a cross section distance of approximately 60 m would be excavated to the selected level.

Table 3-6 Water Levels at CS DC13L (dam location)

Discharge (m^3/s)	Bed Condition from CS DC13L Downstream		
	Existing Bed	Bed Levei at RL 47	Bed Level at RL 48
250	50.67	50.29	50.44
500	51.52	50.91	51.20
1,000	52.85	51.88	52.51
1,500	53.91	52.93	53.62
2,000	54.82	53.91	54.58

It can be seen that for a discharge of 1,500 m^3/s, for example, lowering the bed to RL 48 would lower the water level by 0.29 m, and to RL 47 by 0.98 m. Other considerations would determine whether there was sufficient advantage to be gained by carrying out excavation of this nature.

3,11.5 Backwater curve on reservoir

The above modelling was carried out on the natural channel. Further modelling was carried out with the dam/power station in place to determine the backwater effect due to channel constraints.

Figures 3-16 to 3-19 show the backwater profile for various power station discharges for a common headpond level of RL 70 at the power station.

Table 3.7 indicates the headloss between the Mekong River at the channel entrance and the power station for various discharges.

Table 3-7 Headloss in Channel, with Invert lowered to RL 66

Head loss in metres for power station discharge of			
1500 m^3/s	2000 m^3/s	2500 m^3/s	3000 m^3/s
2.1	**2.9**	**3.6**	**4.1**

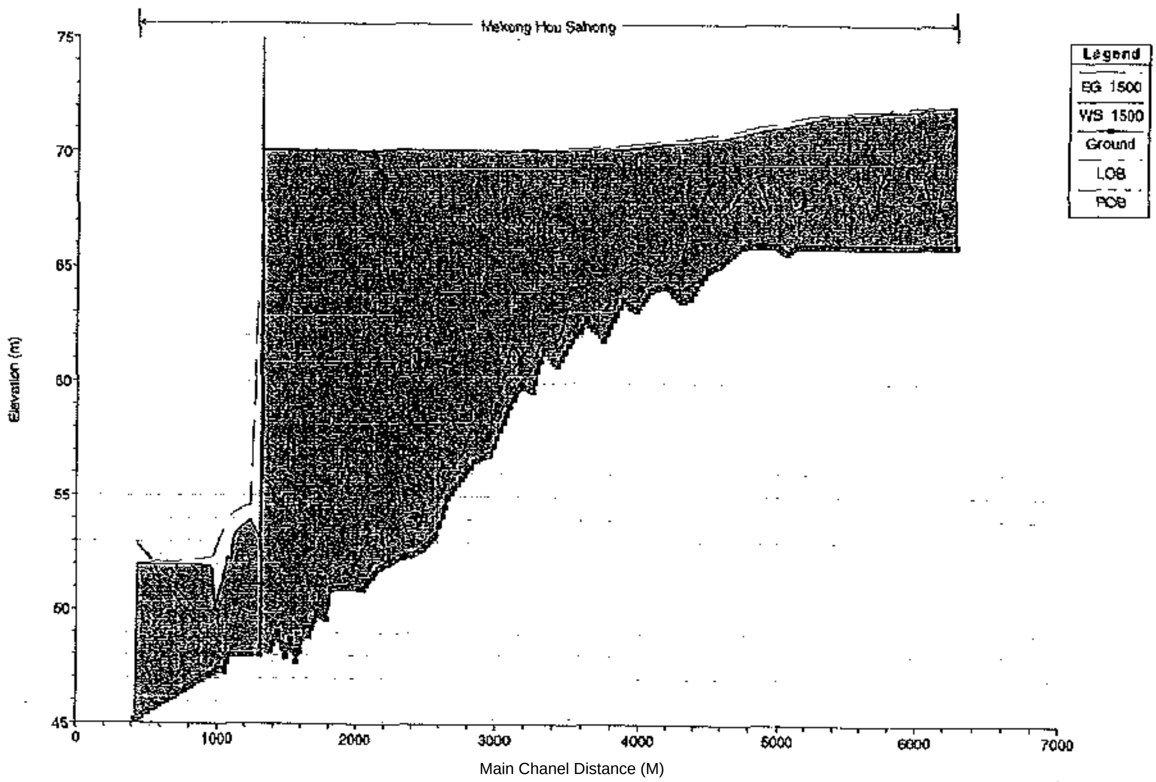


Figure 3-16 Water surface profiles (backwater) for discharge of 1500 m^3/s

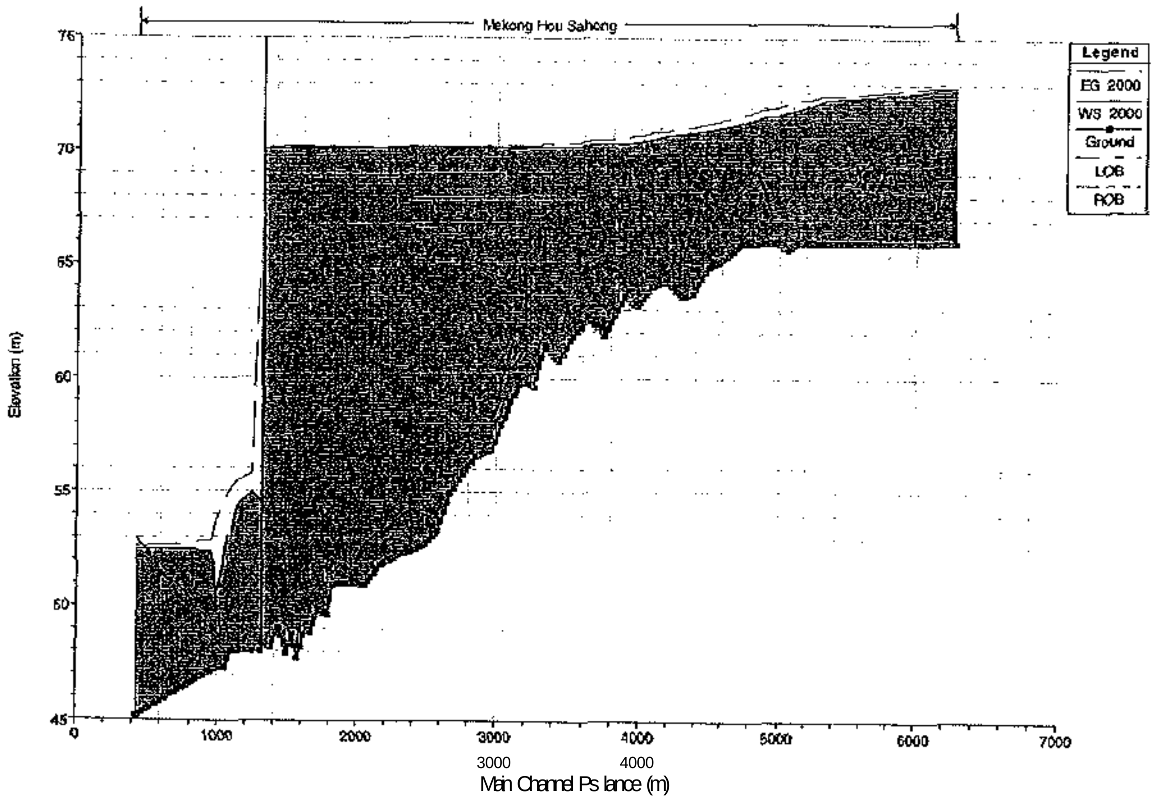


Figure 3-17 Water surface profiles (backwater) for discharge of 2000 m^3/s

Figure 3-18 Water surface profiles (backwater) for discharge of 2500 m^3/s

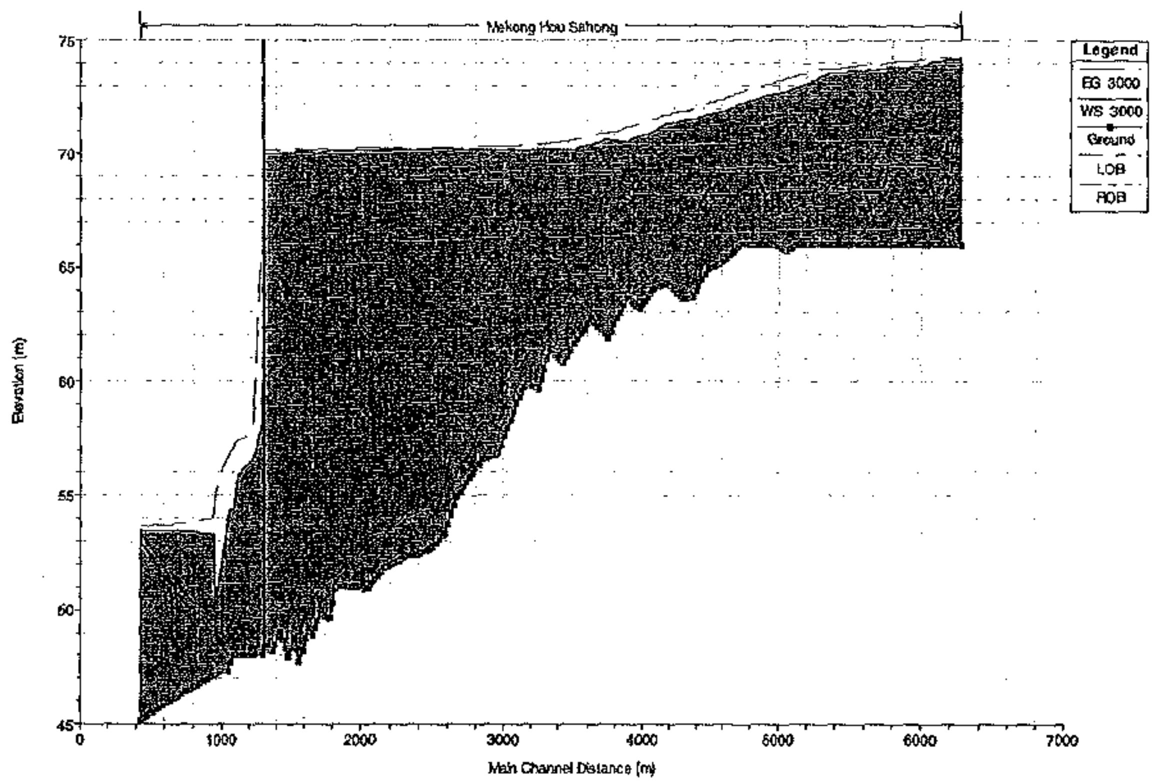


Figure 3-19 Water surface profiles (backwater) for discharge of 3000 m^3/s

SECTION 4

TOPOGRAPHICAL SURVEY

4.1 General

Topographic survey data is sparse. The area is covered by the standard Service Geographique d'Etat 1:100,000 map series. The project site is on the sheet D-48-80 Ban Thakho; with adjacent sheets D-48-68 Khong (to the north), D-48-69 Ban Napakiap (north-east) and D-48-81 Ban Bungnam (east) having some relevant information. Unfortunately, the maps show no information beyond the border into Cambodia. The available maps are variously 1986, 1987 editions, originally prepared in 1982 and 1983 from aerial photography flown in 1981. These maps use the Vientiane horizontal datum and a Vietnamese, South China Sea, vertical datum.

The area is also covered by 1:50,000 mapping - Sheet 61361, Ban Nakasang. This series was drawn in 1965 by the US Army Map Service, but updated in 1995/1996 by the Vietnam Scientific Technical Institute of Land Administration and the Lao National Geographic Department. This map shows all features in Cambodia, west of the Mekong River. The datum used are India 1960 (horizontal) and Ha Tien (vertical)

There is also a 1:20,000 map, 1-108. This map is one of a series prepared jointly by the Royal Thai Survey Department and the Lao National Geographic department for the Lao Ministry of Communication, Transport, Post ands Construction covering the Mekong River. The maps were prepared in 1993/1994 based on aerial photography from 1991/1992. Neither horizontal nor vertical datum is quoted, other than "UTM Zone 48, Everest Spheroid". This sheet is the most southerly of the series, covering the Mekong River from km 722 to km 724, and there is no detail south of Ban Hang Sadam.

There is some more recent aerial photography of the area, held by the National Geographic Service. There are four runs in an east to west direction across the islands flown by Kevron Pty Ltd of Perth, Australia on 4 December 1993 at 1:15,000 photoscale. There is another series flown in a SW-NE direction on the left bank of the Mekong in December 1994, but these do not cover any of the project area. Both these series were flown on behalf of a developer who was interested in developing an international resort complex around Phapheng Falls and Don Sadam.

4.2 SURVEY UNDERTAKEN FOR THE PROJECT

4.2.1 General

The survey, covering topographic coverage at 1:1,000 and 1:5,000 scale, cross-sections of the Hou Sahong, underwater survey of the area downstream of the Hou Sahong and miscellaneous tasks was carried out from October 2006 to February 2007 by AAM (Thailand) Co Ltd, in association with Vientiane Geomatic Services.

4.2.2 Control Survey

Control survey was extended into the project area initially by differential GPS and transfer of level datum using closed high accuracy differential level survey from the Lao National Geodetic survey station at Khong Island (56880), 22 km north-west of the project area. However, independent checks indicated that the published orthometric level for this station was incorrect and subsequently a differential GPS survey was carried out using the Lao National Geodetic survey station at Paksone (3351), 136 km north of the site, and base control points DS03 and DS10 using multiple long occupation (overnight) data acquisition sessions. These confirmed that the published orthometric level for Khong Island was incorrect.

Sixty-nine control points were established and surveyed for the Don Sahong Hydropower Project using a selection/combination of high accuracy, geodetic standard differential GPS measurements (for control points WG04, DS06, DS07, DS17 and DS18), rigorous closed loop total station traversing, and closed loop differential leveling. To reinforce the accuracy, integrity and homogeneity of the network of new permanent survey control monuments, the differential GPS survey component was carried out with up to 6 differential GPS receivers measuring simultaneously in any one occupation session at any given time/day. There was sufficient overlap of measurement to introduce the required redundancy and quality control checks into the field survey control network.

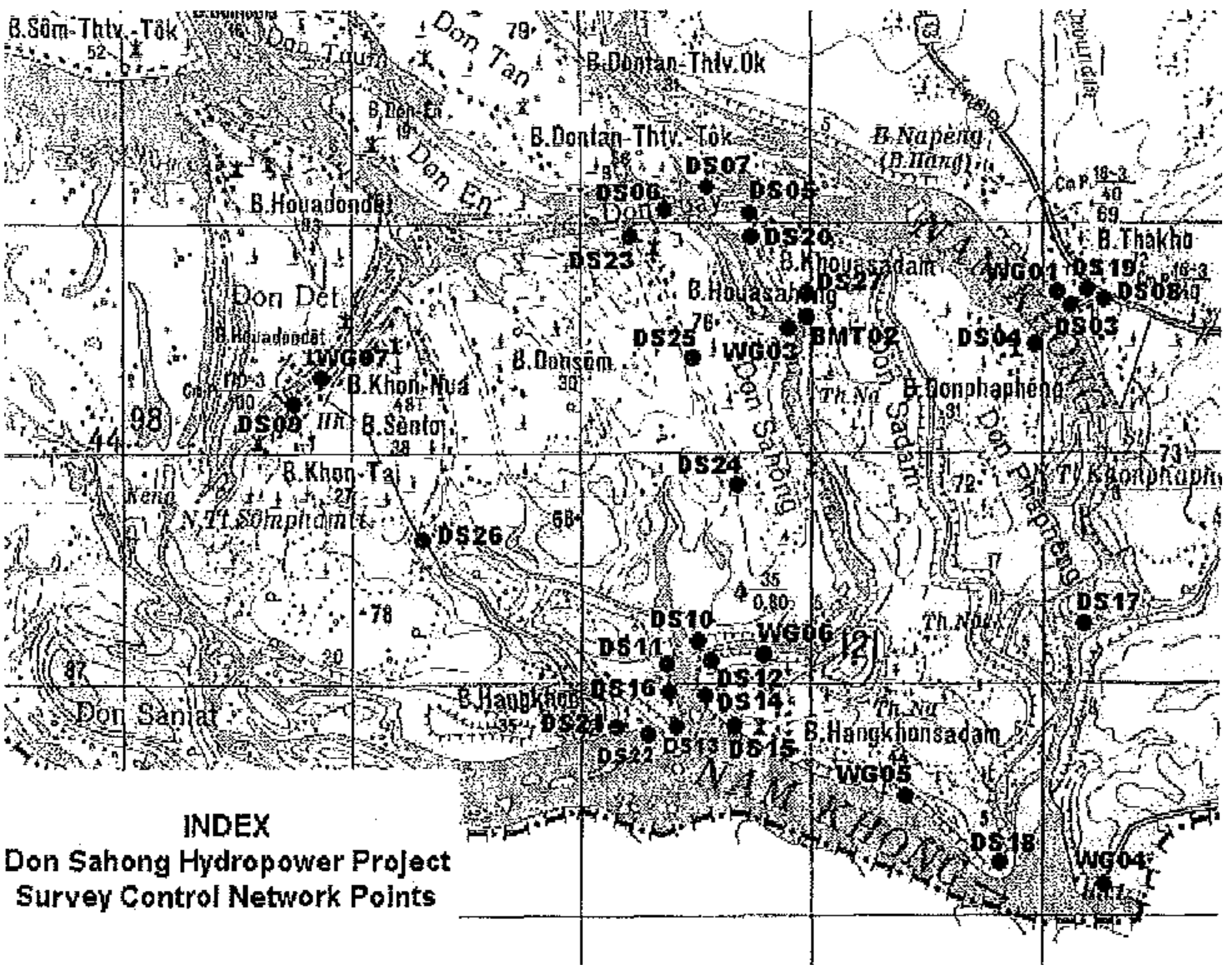


Figure 4,1 - Location of Control Points in Project Area

Of these 69 control points, 33 are regarded as permanent (Figure 4.1 and Table 4.1) and are marked, typically with steel pins in a concrete base (Figure 4.2).

There are a number of grid datums in use in Laos and the more common ones have been adopted for the Don Sahong Project, ie WGS84-UTM (Zone 48 N) for position and Hon Dau for the level datum.

Table 4.1 - List of Permanent Control Points

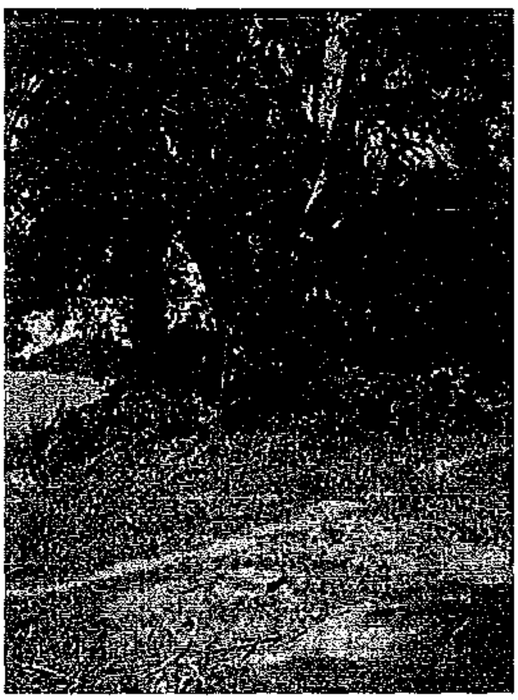
Point	Easting WGS84-UTM (Z48N)	Northing WGS84-UTM (Z48N)	Level Hon Dau (MSL)	Remarks
56880	591993.931	1561037.845	*Orthometac level supplied by NGD incorrect (not used)*	NGD Geodetic Point Khong Island - coordinates correct
3351	631854.031	1678515.803	1279.833	NGD Geodetic Pt. Paksone (base station used for differential GPS transfer of level datum)
WG01	606275.547	1544726.196	72.109	ASA Power BM near WG01 used as ground mark & surveyed independently by AAM / VGS
WG03	603890.515	1544419.229	76.429	Water gauge monument / BM
WG04	606760.841	1539651.480	62.093	Water gauge monument / BM
WG05	603936.559	1540800.218	57.924	Water gauge monument / BM
WG06	603613.990	1541709.572	53.805	Water gauge monument / BM
WG07	599860.237	1544087.631	76.776	Water gauge monument/ BM
BMT1			74.84	BM in Ban Thakho near road T junction (level only)
DS01	590920.016	1558057.208	85.038	Out of main project area
DS02	591279.100	1557894.158	86.472	Out of main project area
DS03	606330.645	1544628.364	71.759	Main Project Base Control Point at Ban Thakho
DS04	605971.504	1544362.342	71.099	Control Point
DS05	603619.855	1545518.935	73.399	Control Point
DS06	602791.214	1545539.587	74.283	Control Point
DS07	603296.661	1545680.277	74.166	Control Point
DS08	606673.763	1544685.562	75.204	Control Point
DS09	599528.242	1543834.667	80.146	Control Point
DS10	603131.968	1541752.004	56.798	Main Project Base Control Point at Ban Hangdonsahong
DS11	602761.444	1541540.064	58.519	Control Point
DS12	603200.209	1541619.637	60.774	Control Point
DS13	602867.790	1541051.815	57.615	Control Point
DS14	603281.246	1541189.047	57.151	Control Point
DS15	603169.236	1541365.637	54.155	Control Point
DS16	602814.696	1541274.890	57.428	Control Point
DS17	606448.999	1541905.873	55.014	Control Point
DS18	605750.801	1539743.748	57.519	Control Point
DS19	606519.267	1544743.216	74.842	Control Point
DS20	603628.066	1545456.548	75.184	Control Point
DS21	602386.470	1541038.255	61.107	Control Point
DS22	602632.025	1540845.180	52.724	Control Point
DS23	602441.111	1545164.721	76.756	Control Point
DS24	603640.339	1542975.434	73.221	Control Point
DS25	603144.154	1543982.302	75.178	Control Point
DS26	600563.212	1542690.997	71.729	Control Point
DS27	604238.039	1544482.975	76.268	Control Point

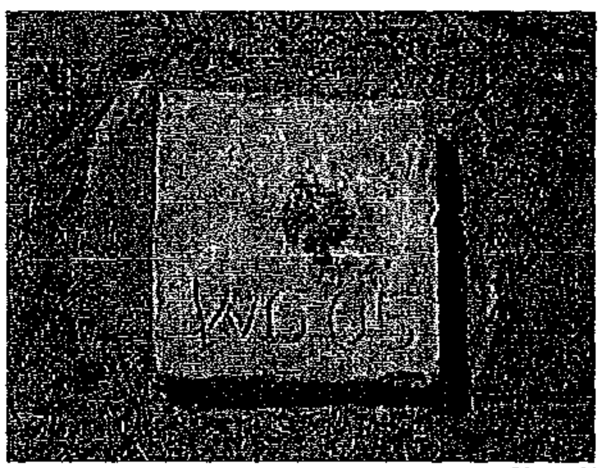
WG05

THAILAND

AAM (Thailand) Co., Ltd. in affiliation with Vientiane GEOMATIC Services	Survey Control Station Description WGS 84 Grid (Zone 48N) (all dimensions in metres)	Date of Issue : February 2007
Project : Don Sahong Hydropower Project Client : Mega First Corporation Berhad		
Station : WG05	Type of Mark : Steel Rod in Concrete Monument	Date of Survey : November 2006
Level Datum Hon Dau (Vietnam MSL) : NGD Geodetic Survey Control Monument First Order Geodetic Station 3351 (Paksone)		
Coordinates (WGS 84 Grid) : East : 603936.559 North : 1540800.218	Elevation : 57.924 Vertical Datum : Hon Dau	Method of Survey : Differential GPS Differential Leveling

Photographs :





Close Up

Figure 4.2 - Typical Control Point Record

4.2.3 Topographic Mapping

The lower section of the Hou Sahong, approximately 800 metres upstream from the exit and for 100 metres from either bank, is mapped at a scale of 1:1,000, with 0.5 metre contour interval and the mapping component of the work was carried out by a combination of field survey methods, which included differential GPS, total station, and differential level survey.

The full length of the Hou Sahong and the adjacent areas of Don Sahong and Don Sadam below approximately RL 80 were mapped by photogrammetric means and presented at a scale of 1:5,000 with 1 m contour interval. The 1:15000 scale (nominal) scale colour aerial photography flown over the project area in 1993 was used for the digital photogrammetry.

A conservatively dense pattern of field survey (photo control) points, was surveyed and used as control for the digital aerial triangulation and block adjustment process prior to the digital photogramrnetric mapping.

The tasks and processes for the digital photogrammetric mapping included :

- Acquisition of sufficient existing aerial photography at a nominal contact scale of 1:15,000 to cover the Don Sahong Hydropower Project area.
- Selection of precise photo control image points in the field using the 1:15,000 scale aerial photography for identification and documentation.
- Survey of the precise photo control image points for the photogrammetric control using a selection of high accuracy differential GPS, differential level, and total station survey techniques.
- Carry out high resolution metric scanning of the (1:15,000 scale) aerial photography negative frames.
- Using a modern state-of-the-art soft copy digital photogrammetric hardware and software system, carry out digital aerial triangulation and block adjustment of the aerial photogrammetric stereoscopic models, *(see Note at end of this section)*
- Using a modern state-of-the-art soft copy digital photogrammetric hardware and software system[1], carry out digital photogrammetric mapping of digital elevation model (DEM) data of the project area for mapping at scale 1:5000 with 1 metre contours.
- Generation of final digital mapping data and contours at the required interval of 1 metre.

[1] Due to the legal requirement of the Government of Lao PDR that aerial photography shall not be taken out of Lao PDR, the digital photogrammetry was carried out within the premises of the National Geographic Department {NGD), using AAM's (compatible) digital photogrammetric system.

4.2.4 Underwater Mapping

Cross-sections were surveyed of the Hou Sahong at approximate 100 metre spacing commencing from the entrance of the channel as far as Don Kiew, the island approximately 800 metres from the lower end of the channel. Four of the proposed sections above the island were not surveyed because the rapids in that area made work in the river unsafe. From the island down to the end of the channel there were 16 sections at approximately 50 metre intervals. The location of the sections is shown on Figure 4.3. There are 57 cross-sections in all, 41 in the upstream section and 16 in the downstream reach,

The area downstream of Hou Sahong, the waterway between Don Sadam (to the east) and Don Khone (to the west) was also surveyed to establish bed levels.

High accuracy total station survey equipment with automatic in-field data recorders, was utilised to carry out the survey of cross sections of Hou Sahong, and the survey of river bed levels at the southern part of Hou Sahong. On selected occasions, the total station measurements were supplemented by direct sounding line measurements (for depth of water).

4.2.5 Miscellaneous Survey

Additional survey included:

- levelling of all staff gauges at the recording stations in the project area to confirm water levels
- pick up of geological investigation features (drill holes etc)
- water surface profiles from above Don Det to Thakho (discussed in Section 3.6)
- pick up of rock outcrops on wither side of the Hou Sahong in the vicinity of the power station site
- location of navigation markers downstream of Ban Hang Khone.

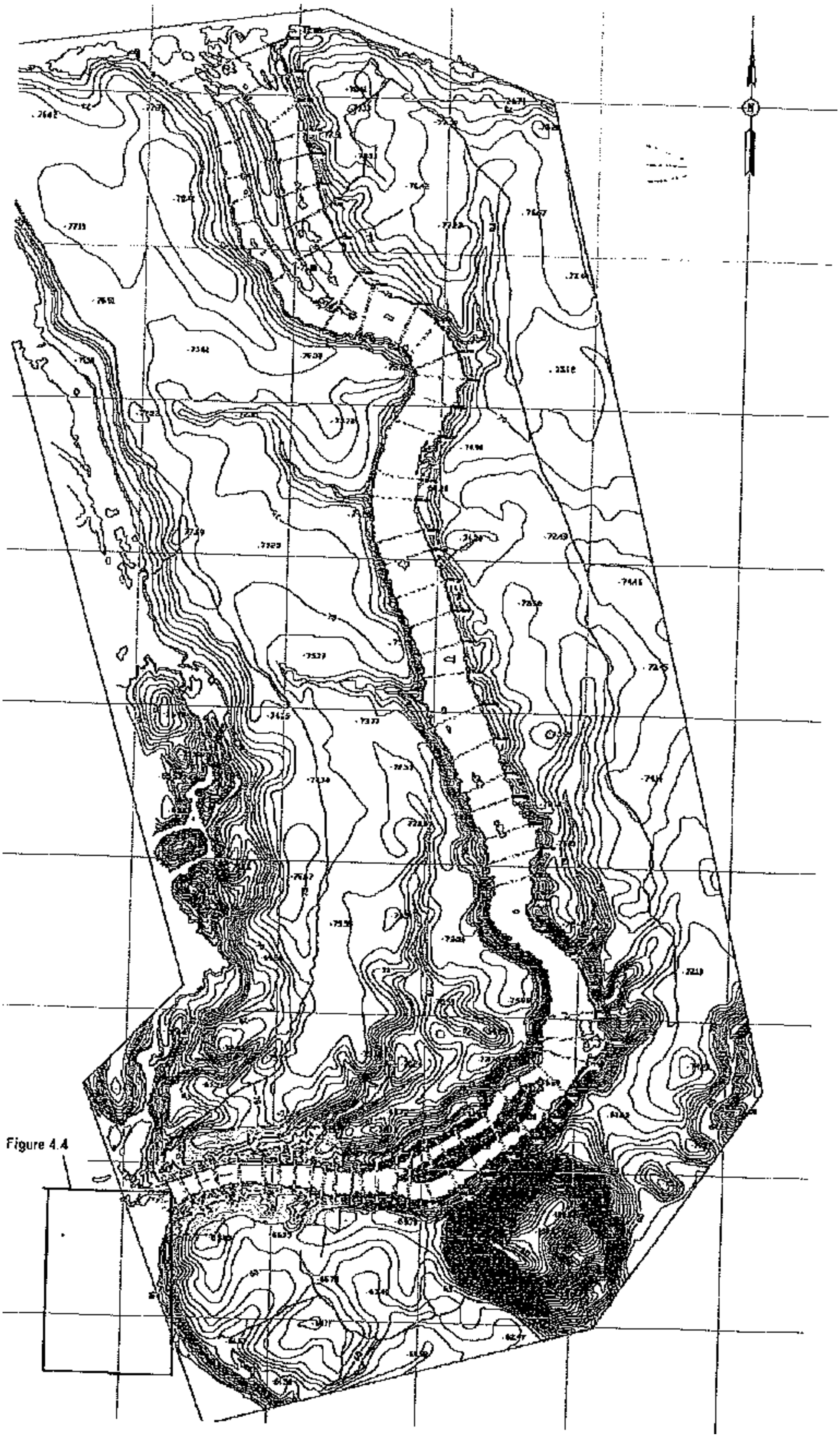


Figure 4.3 - Location of Hou Sahong Channel Cross-sections

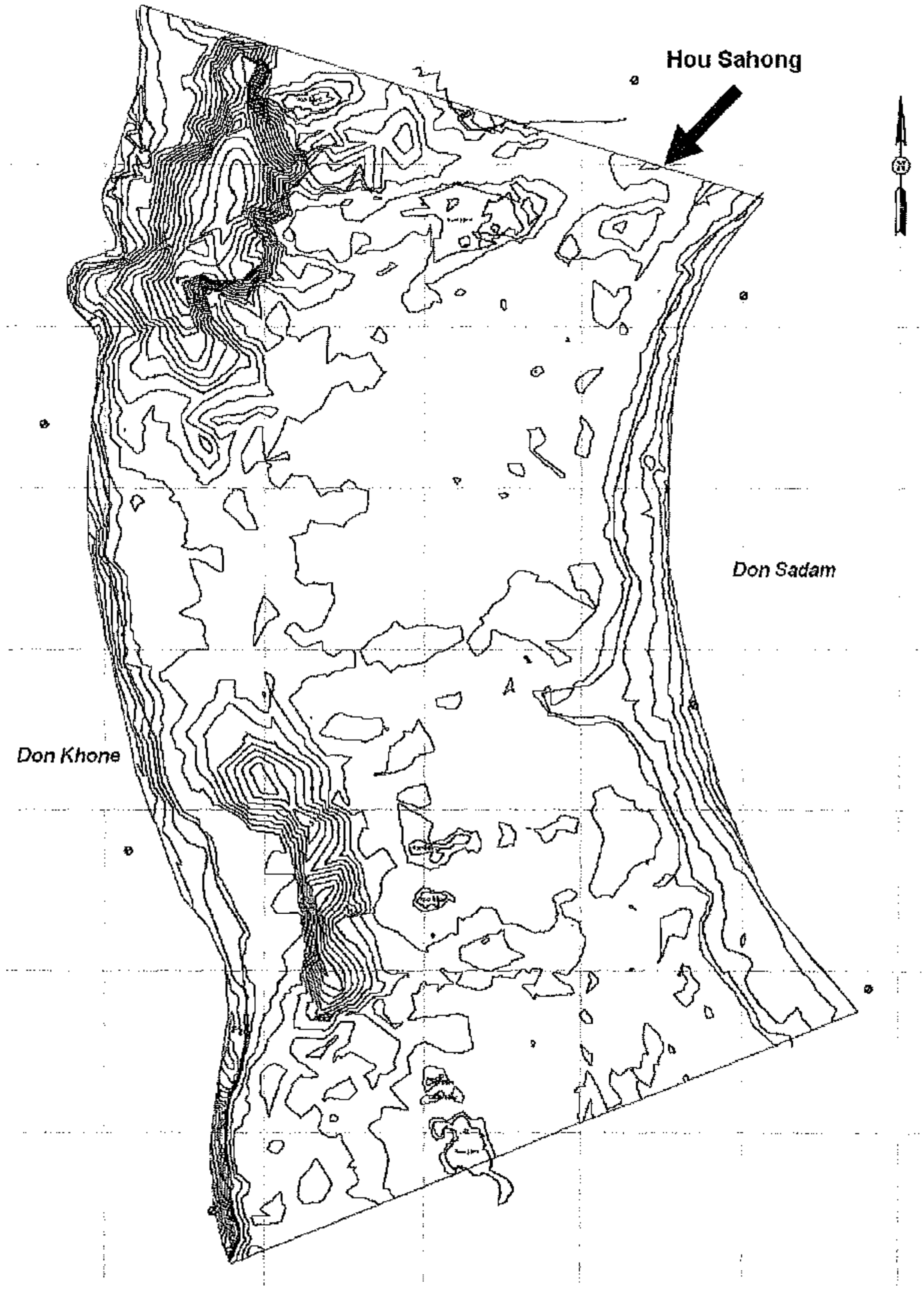


Figure 4.4 - Underwater Survey Downstream of Hou Sahong

SECTION 5

GEOLOGY

5.1 General

Initial inspection of the downstream end of the Hou Sahong channel suggested three potential dam sites located between an elongate island at the last bend in the channel and the confluence of the channel with a main branch of the Mekong River. At an early stage, the most upstream of the three sites was deleted from consideration as unsuitable. Attention was then concentrated on the remaining two sites. A geotechnical investigation of the project had been awarded in October 2006 to ASA Power Engineering Co. Ltd, of Vientiane. Drilling under this contract commenced on site on 11 November 2006.

The investigation comprised the drilling of eight boreholes: one at the upstream entrance of the channel and the remainder at the potential dam sites near the downstream end. Two of these boreholes were inclined beneath the stream, to intersect the span of lithologies forming the bed of the stream. In combination with the boreholes, seismic traverses were made along each bank, together with cross traverses, to define rock depths and investigate the possible presence of former infilled channels of the drainage system. The locations of the dam site boreholes and the seismic lines are shown on Figure 5-1.

Test pits were excavated on the left bank, four on lowermost slopes of the nearby hill. Laboratory testing of samples of soil and rock was undertaken on the basis that the main water retaining structure would probably comprise a concrete "box", housing the turbines, with extended saddle embankments along either bank. All work was undertaken at the specific direction of the consultant's geologist, while technical supervision of the field work was provided by ASA representatives. Full details of the investigation, together with borehole logs and seismic traverses, are set out in the geological report on the site by ASA (Appendix B).

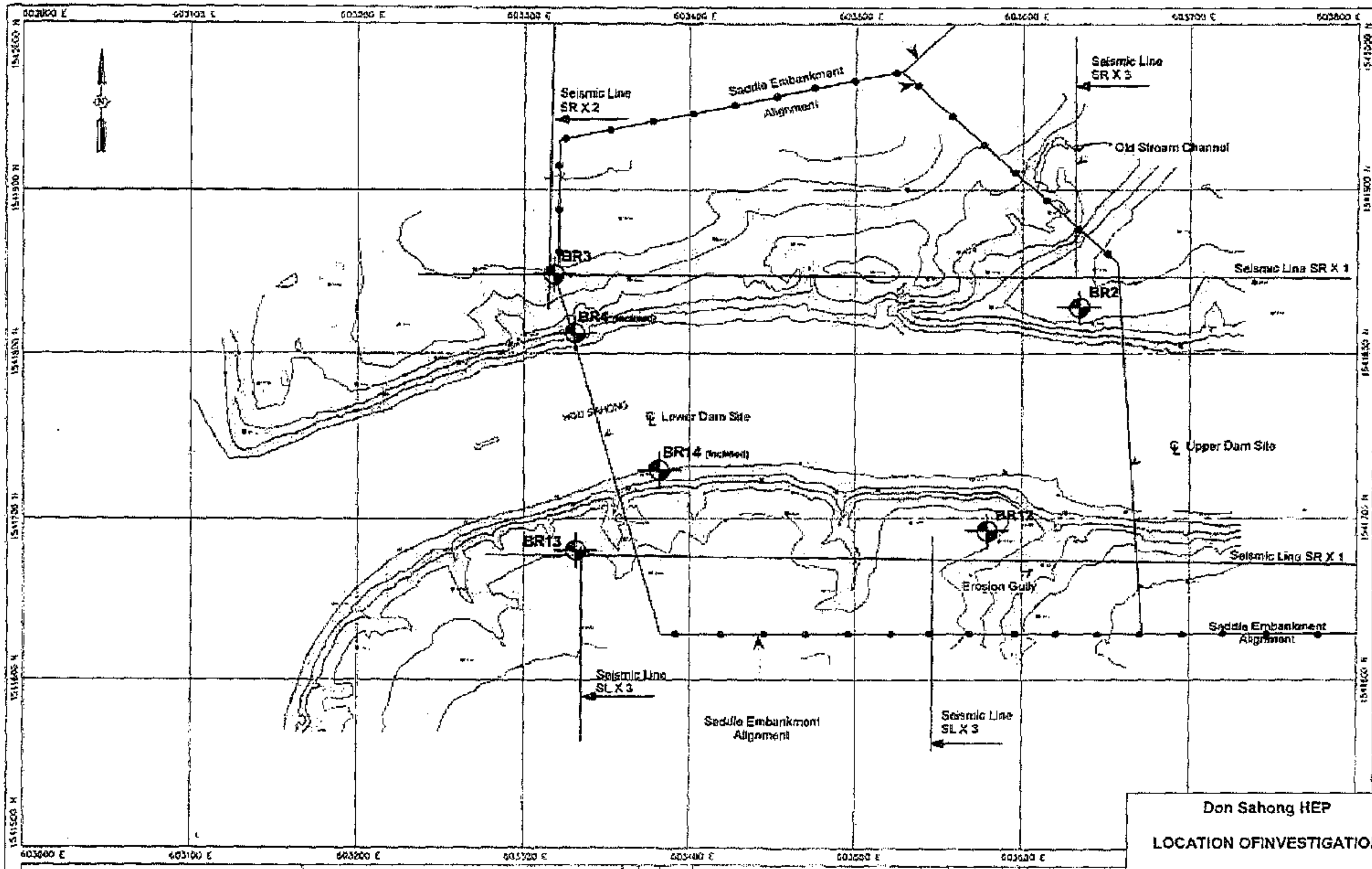
The present report adds some geotechnical interpretations and recommendations on the site conditions pertinent to the proposed project.

5.2 GEOLOGY

5.2.1 Geomorphology

The Mekong runs as a well defined river in a wide flood plain until it approaches southern Laos. Just to the north of the project area, the river bifurcates and then develops into what might be described as a braided stream topography; this continues to the Cambodian border. The situation differs from a true braided character, however, in that much of the sheet flow in the wet season takes place across planar rock surfaces rather than in alluvial soils. The flow is essentially perpendicular to the strike of the rocks and hence a large sequence of lithologies is crossed in this zone. In the dry season, the flow is confined to several defined channels which are often subject to abrupt changes in direction where weaker beds or where shear zones are encountered. Features of this type are well illustrated on air photos covering the region.

The effect of lithology on stream directions is also demonstrated to a lesser degree in the lower reaches of the Hou Sahong. The final bend in the stream has been dictated by a change in strike of



Don Sahong HEP

LOCATION OFINVESTIGATION

Figure 5-1

the rocks, and the stream then flows along an interbedded series of weaker sedimentary rocks that are sandwiched between more massive metavolcanics rock types forming either bank.

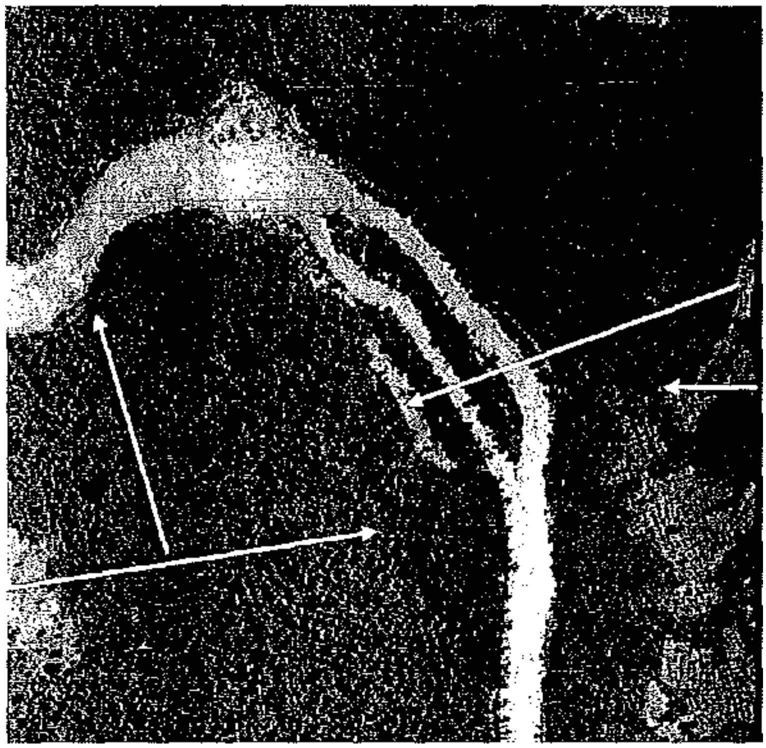
What gives this whole zone its unique character is that the natural land surface, even when composed of bare rock, is strikingly planar. Moreover, the natural surface slopes very gently to the south, at much the same gradient as the river channels. This characteristic is well exposed at the falls near Simpheng, to the west of the project site, (Photo 5-1). It is apparent that the original location of this waterfall was at some distance downstream, probably where the river encountered a weaker rock band. The river has since gradually eroded its way upstream in the form of a small gorge, still maintaining the gradient of the ambient land surface on either bank. It is considered that the extensive planar rock surfaces forming this type of topography can only have been shaped by marine erosion at some fairly recent stage in the geological past. This would also probably account for the fact that residual soil development above the rock is sporadic.

Photograph 5-1 - Waterfall near Simpheng, showing river gradient parallel to the planar rock surface of the bank

A second facet of this unusual geomorphology is that normal valley profiles have not yet developed. As the ground surfaces tend to parallel the river gradients, there is typically no significant rise in the land away from the river channels, except for the occasional isolated small hill. The relevance of this to the project is that bank heights do not increase greatly as one proceeds down channels such as the Hou Sahong.

A third feature of the lower course of the Hou Sahong is the presence of former erosion channels on either bank. These can be either dry or infilled and are taken as evidence of earlier stream paths, which have been abandoned as the Hou Sahong has down-cut its bed to its present level. A major deep channel on the right bank emerges just downstream of Borehole BR 2. This channel undergoes periodic flows in the wet season, indicating that it is connected - albeit at a high level - with the Hou Sahong at about half way along its course. A second former channel on the right bank truncates the last bend of the Hou Sahong. This is partially infilled (Photograph 5-2).

On the left bank, what appears to be a former channel on the air photos, now infilled, turns sharply south on the downstream side of the small hill and winds down to the Mekong, hugging the slightly elevated land on its eastern side. The results of the seismic work suggest that the rock level in this channel is at a somewhat higher level than in the two channels of the right bank.



Photograph 5-2 - Aerial photograph showing infilled channels

Obviously, former channels of any kind have the potential to affect the integrity of the proposed reservoir and this matter is discussed further in a later section.

Two major islands are present in the Hon Sahong: one near the upstream entrance and one at the last bend, downstream. Inspection of these reveals that, although alluvial pockets are present, the islands are basically formed of bedrock, often with a small residual profile developed. This would indicate that the islands have been in place for some considerable time.

The river bed near the lower dam site is around an elevation of RL 47-48, which level generally continues to the southern end of Don Khone. At times of high flows, the channel level rises to around RL 60 elevation at this location. Topographic surveys along both banks of the lower Hou Sahong have recorded general elevations around RL 65.

5.2.2 Site Geology, General

Early geological maps at 1:1,000,000 scale provide a general picture of the geological conditions, with folded Mesozoic rocks typically striking east-west. More recent geological records are available for southern Laos. While the maps do not extend as far south as the project area, they also indicate an east-west trend in the geological sequences. Extrapolation from these records, together with field observations, confirms the regional trend.

The swathe of land between the Phapheng Waterfall, to the east, and the waterfall near Sipheng, to the west, comprises suites of conformable Triassic Age rocks ranging from generally massive metavolcanics (rhyolites) to thinly bedded sedimentary rocks (shales, siltstones, sandstones and some limestones). The massive rhyolites tend to dominate the project area although the sedimentary series occur along the left bank of the Hou Sahong at the proposed dam sites and are also expected to outcrop in the river bed itself. The general strike of the rocks is east-west, with some minor variations, while the dip is consistently to the south at around 30 - 50°. It is possible that this geological structuring represents one limb of a large truncated anticline. Folding to form this structure has produced shearing (flexural slip) between the various lithologies, typically manifest as slickensiding in the argillaceous and calcareous components. The shales, in particular, represent continuous planes of weakness in the rock mass although the geometry of the beds does not make their presence a problem of major concern for the proposed dam structure. This matter is addressed again in the following section.

At the upstream entrance to the Hou Sahong channel, a wide bar of massive rhyolite is interpreted from the air photos. This again strikes east-west across the entrance and dips to the south. Drilling has confirmed its massive and hard nature. Further zones of hard rock are indicated along the length of the channel by the presence of rapids and intermittent rock outcrops in the waterway. Further detailed information of the rock types is available from the borehole logs given in the ASA Geological Report.

5.3 GEOTECHNICAL INVESTIGATION

In addition to the survey component, investigation of the project site comprised the following activities:

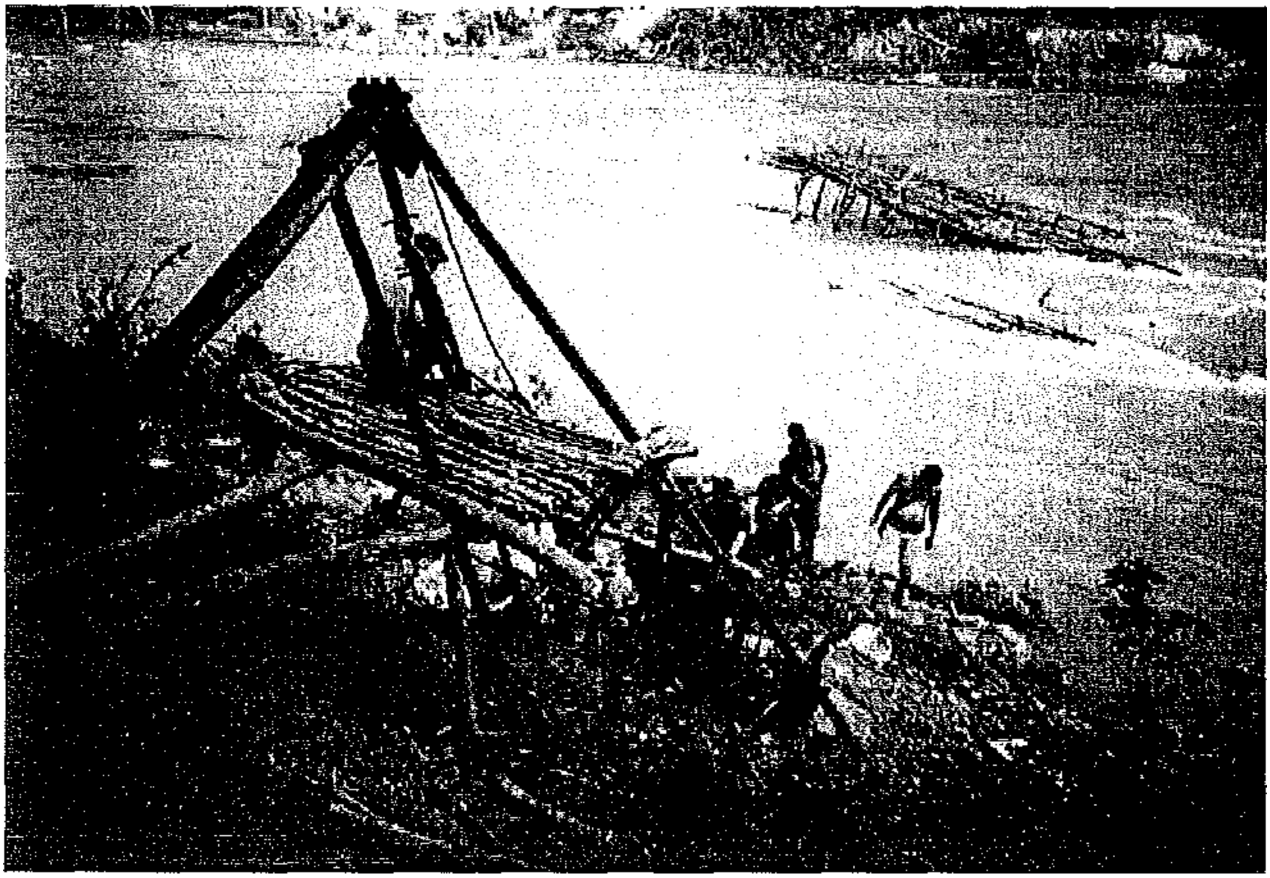
- Geological and geomorphological traverses
- Drilling, both vertical and inclined boreholes
- Seismic traverses of both banks
- Test pit excavations
- Laboratory testing of both soil and rock samples

All aspects of the site work were directed by the consultant's geologist and undertaken by ASA Power Engineering, using drilling and seismic sub-contractors. The drilling work was carried out under full time supervision, initially by a drilling engineer and later by a geologist. Local labour was utilised for the trial pit excavations and the laboratory testing was carried out at Khon Kaen University in Thailand. Each of these aspects is treated in turn below and should be read in conjunction with the above mentioned geological report.

5.3.1 Drilling

Four boreholes were drilled at two sites selected as potential dam sites. The positions are shown on Figure 5-1. Boreholes from the top of the banks were vertical and typically encountered variable amounts of alluvial or residual soils overlying extremely weathered rock. The alluvial cover varied but, except associated with infilled erosion features, weathered rock was generally met at shallow depths and by 5 m depth was showing signs of gradation to hard, massive rocks. Massive rhyolite formed the right bank and massive sandstones, with interbedded rhyolites, formed the left. The boreholes drilled from positions at the top of the bank were taken to depths of 25 m.

Two inclined (45°) boreholes were drilled from the lower banks of the Hou Sahong at the downstream dam site: BR 4 on the right bank, taken to 60 m; BL13, on the left bank, taken to 100 m. Because of the moderate dip of the strata to the south, BL 13 was inclined almost at right angles to the bedding and thus traversed the full sequence of the rocks that can be expected to outcrop in the bed of the river. Sedimentary lithologies predominated with limestone occurring as a thin seam near the left bank and as a more substantial stratum on the northern side (right bank) of the stream. A borehole profile across the channel, at the lower dam site, is given in Figure 5-2.



Photograph 5-3 ~ Inclined Borehole BL14, left bank, near lower dam site axis.

A third possible dam site was originally contemplated towards the upstream end of the lower reach of the Hou Sahong and was drilled at the outset of site work. The borehole, BR1, was positioned on the right bank and encountered broken limestone with solution effects, overlying a thin conglomerate band. Both these materials can be seen to outcrop on the stream bank not far from the borehole location. The units dip gently to the west and overlie the Triassic bedrock unconformably. It is considered that they probably represent some more recent lake-bed sediments. This dam site was rejected partly on the results of this borehole.

Near the upstream entrance to the Hou Sahong, Borehole BL 15 was drilled to 50 m depth on the left bank to check on the nature of the rock forming the entrance bar. Massive rhyolites were found to be present to the full depth of drilling.

Records of the boreholes, including the results of insitu permeability and other tests, are given in the above mentioned geological report.

5.3.2 Seismic Traverses

Seismic traverses were set out by the consultant's geologist as shown on Figure 5-1. The configuration was designed to check the depths to rock along the tops of either bank and also to check on the possible presence of buried channels behind the banks. In general, the seismic interpretations indicate relatively uniform conditions along both banks, although features such as narrow gullies are unlikely to be picked up by this type of geophysical work. Detailed descriptions of the work are given under the appropriate section in the geological report and the results have been utilised where relevant in this report.

5.3.3 Test Pits

Four test pits were excavated by hand methods along the lower slopes of the small hill, upstream on the left bank, and one on the left bank, near Borehole BL12. The dry condition of the ground made excavation conditions extremely hard and limited the depths to which the pits could practicably be excavated. Samples were taken for laboratory testing to determine the suitability of the colluvial/residual soils as fill. However, a more useful survey of the overburden materials in the site area would require the use of mechanical excavators.

5.3.4 Laboratory Testing

Rock and soil samples were taken from drill holes, test pits, bulk rock and sand samples. A schedule of laboratory testing was provided to the Geotechnical Contractor, the testing to be undertaken at a specified laboratory in Thailand. The full test results are contained in the ASA Report and comments on the results are given in Section 5.6

5.4 GEOTECHNICAL DISCUSSION

5.4.1 Power Station Site Comparison

Two potential power station sites along the lowermost reach of the Hou Sahong were investigated at this feasibility stage:

- The more upstream site would preferably be aligned through BR2 on the right bank, crossing the left bank upstream of a major gully, perhaps 100m to the east of Borehole BL12.
- The downstream site is aligned through BR3 and BR4 on the right bank, and between BL13 and BL14 on the left.

Similar geological and topographical conditions are present at both sites and thus there is little to choose between them on this basis. The upstream site would have the advantage of a slightly shorter saddle embankment, at least on the left bank. However, the downstream site would have the advantage of a shorter river bed excavation below the structure, together with other advantages, discussed below. It is considered at this preliminary stage that the advantages of the lower dam site would outweigh the benefit of the shorter saddle embankment(s) for the more upstream site. Some of these comparative factors are discussed in the following subsections.

5.4.2 Structure Foundations

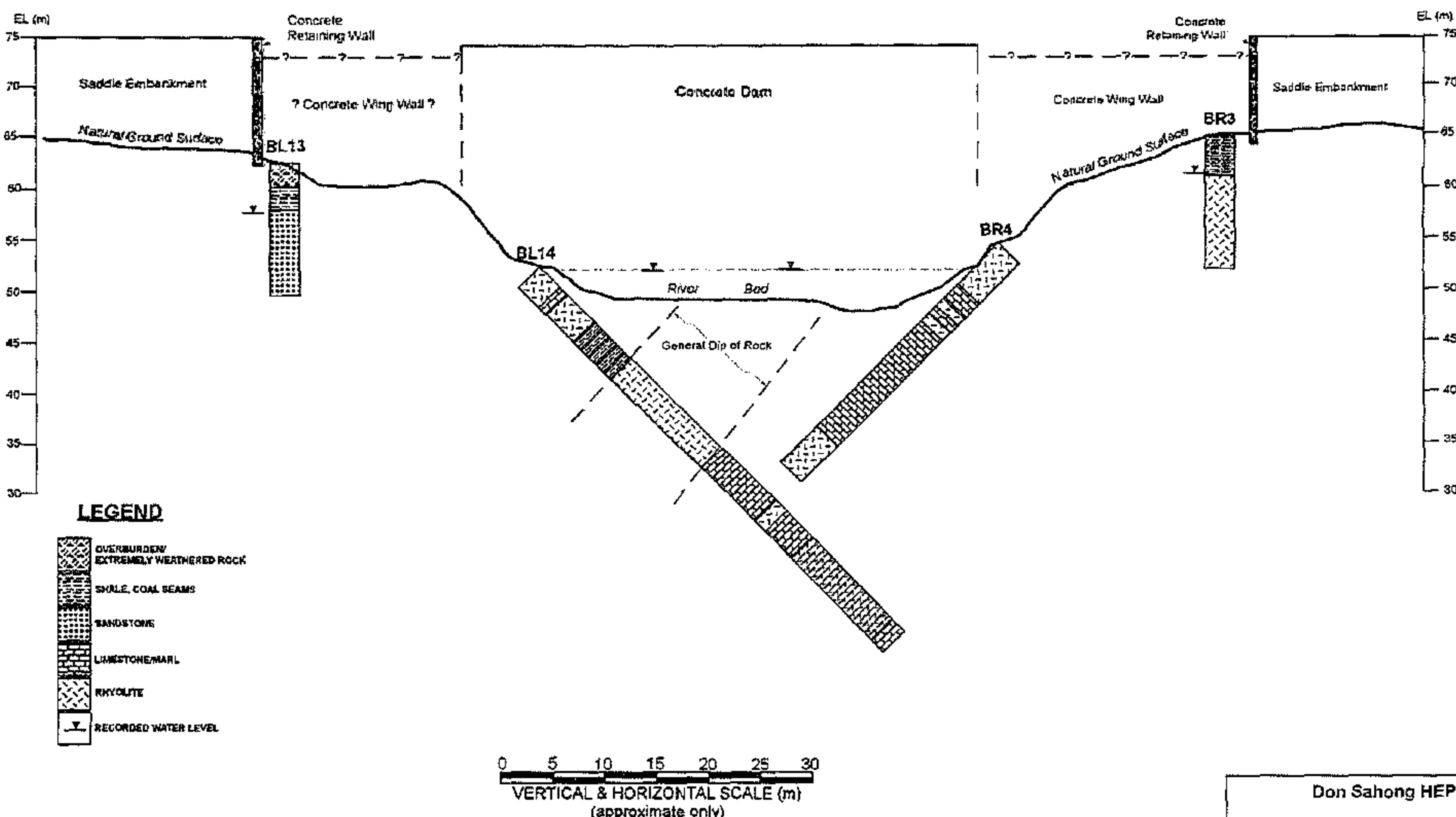
In the following discussion, attention will be predominantly confined to the lower site, although much of what follows would be applicable to either site. It is understood that a monolithic concrete power station structure is envisaged, housing the turbines and generators. The length of the structure could be of the order of 70m and a crest level of around RL 75 elevation is understood to be favoured.

The foundation rocks across the bed of the stream are detailed by the findings of the inclined borehole BR14, illustrated in the section Figure 5-2. The foundation rocks comprise a sedimentary sequence over almost the full width of the stream bed. On the left bank, sandstones and rhyolites predominate, but shale partings are common near river level (Photo 5-4). The shale members are frequently slickensided as a result of the folding of the rocks. A thin limestone bed is indicated to outcrop at river bed level on the left bank, while a substantial section of limestone should be present on the right hand side of the stream bed. Massive rhyolites then form the base of the right bank and this rock type extends beneath the right bank for some distance. All the rocks encountered during drilling were extremely hard, when fresh, with the exception of one stratum of impure limestone, or marl, which could be rated as no more than moderately hard.

The rock formation, dipping as it does at some 45 - 55° to the south, should provide a more than adequate modulus for the foundation of a dam of the size envisaged. There may be some problem, however, with regard to the presence of sub-horizontal jointing in the rock mass. This form of jointing was noted in outcrops along the left bank and is illustrated in Photo 5-5. The jointing is planar, suggesting a joint strength of no more that f = 30°. Where such jointing extends over some metres, it is could well form wedges of lower strength with the slickensided shale partings. Such a situation could conceivably pose a localised stability problem for the dam structure and the geometry of the discontinuities should be identified when the foundation area is opened out and can be inspected in detail. The problem could be overcome by selective excavation or by general anchorage. It is understood that the structure might require cable anchorages in any event, to counter uplift pressures. Such anchors, if inclined slightly upstream, could be designed to cope with any sliding stability concerns.

Because the Hou Sahong, along this lowermost reach, appears to be relatively youthful, significant karst development in the limestone is not anticipated. Preferential erosion along weaker rock members might nonetheless have occurred but, again, this is not expected to cause any major foundation problems.

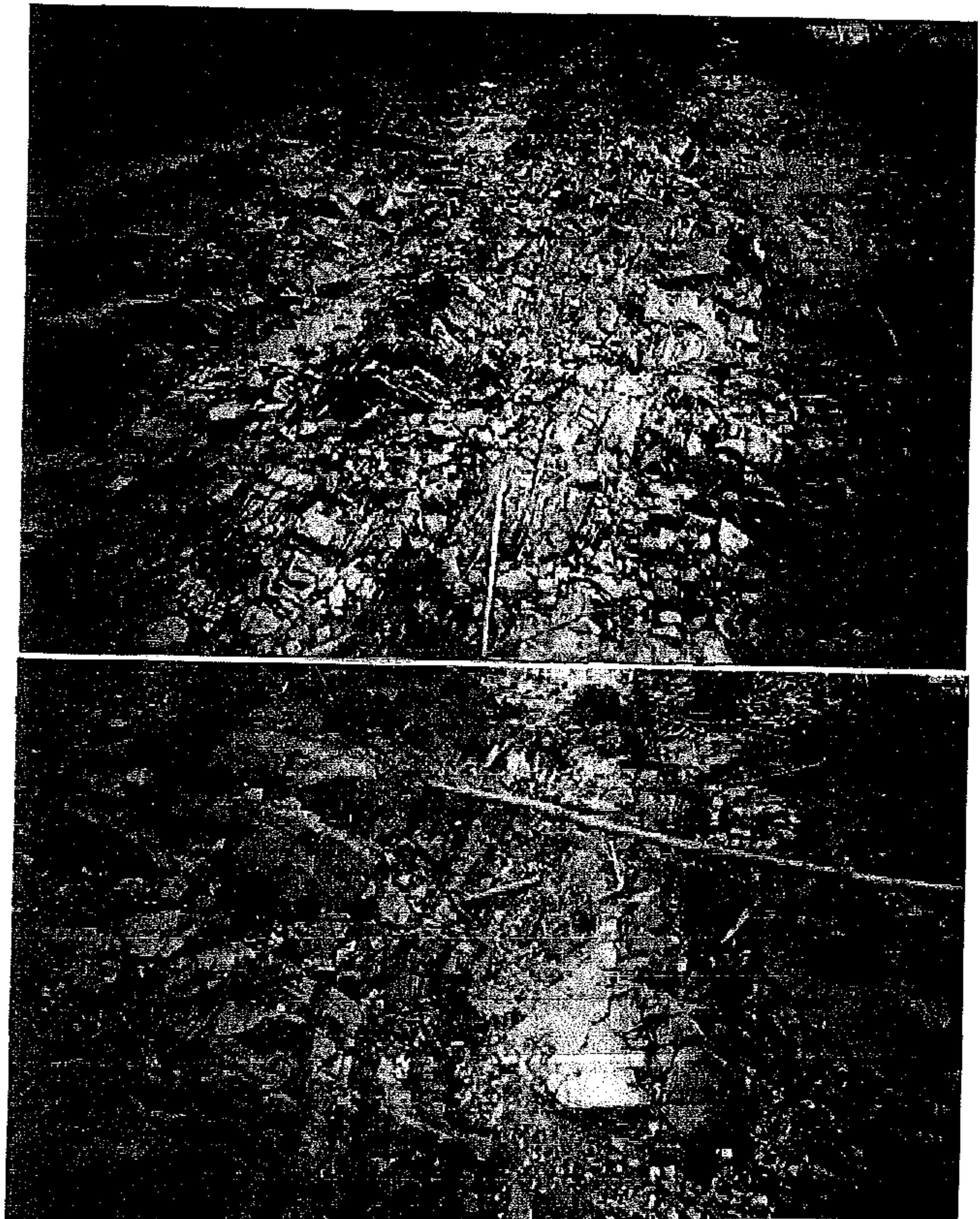
On the right bank, the moderately steep dip of the rocks to the south is likely to produce bedding planes that daylight on steeply excavated abutment slopes. This geometry could cause minor slope stability problems, and would need to be assessed for its potential effects on the sliding stability of the right abutment of the structure. Again, any such problem should be amenable to solution by the use of anchors.



Don Sahong HEP

DOWNSTREAM SITE
BOREHOLE PROFILES

Figure 5-2



Photograph 5-4 - Thinly bedded Strata, left bank. Lower Hou Sahong

Photograph 5-5 Subhorizontal Bedding in the Massive Rhyolite

5.4,3 Saddle Embankment Requirements

The ground level at the potential abutments of both sites seldom exceeds RL 65 elevation. Little increase in elevation occurs away from the stream course, except sporadically on the right bank. In addition, there is only a gradual increase in the elevation of the banks in the upstream direction and elevations of RL 75 tend to occur only in the uppermost reach of the channel. Thus, any dam site on the lower Hou Sahong will require extensive saddle embankments if it is to take full advantage of the head available for power generation. The saddle embankments will also need to be of sufficient height to avoid any possibility of being overtopped, since overtopping would almost certainly cause embankment failure and loss of power generation.

For the purposes of discussion, a working water supply level of RL 74.5 m elevation is assumed, with some freeboard available for the saddle embankments. Whatever the decision, a crest level of the order of RL 75 elevation would appear appropriate for the full lengths of the saddle embankments. Allowing for a general foundation excavation depth of around 1.5 m for the saddle embankments, it is obvious that embankment heights of around 12 m could well be required for considerable distances upstream of the dam. For instance, on the left bank, there would be little change in the embankment dimensions between the dam site to the small hill upstream, a distance of almost one kilometre. Reduction in embankment height would be possible as the natural land surface(s) rise upstream. On the left bank, the most practical embankment location would follow the course of the Hou Sahong. On the right bank, the saddle embankment alignment need not follow the channel, as on the left, but could take advantage of slightly higher ground just to the north, truncating the large bend in the process.

It has already been mentioned that, for the downstream dam site, the saddle embankment on the left bank would be several hundred metres longer than for the upstream site. However, this same upstream dam site would require additional construction to seal off the deep channel that emerges just downstream of Borehole BR2. As mentioned earlier, this channel connects with the upper reaches of the Hou Sahong in the wet season and thus represents a bypass around the dam. By contrast, the lower dam site could incorporate this deep channel within its reservoir and, by so doing, also incorporate the potential quarry site represented by the knoll of massive rhyolite proved in Borehole BR2.

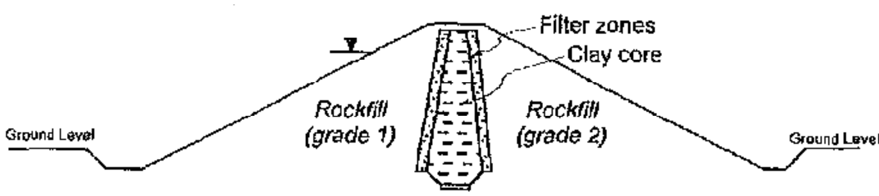
It is not possible to provide precise alignments for the saddle embankments at this stage, as there appears to be some conflict between the elevations obtained by the land survey and the elevations obtained from the photogrammetric work, at least for some pockets of thicker and/or mature vegetation. A final decision on the alignment and the length of the saddle embankments will require further specific traverses. At this preliminary stage, however, it would appear that embankments to 12 m height would be likely for at least 1 km upstream of the dam, on either bank. Thereafter, heights would gradually reduce and an average of some 5m height could be assumed for at least another 2 km distance. For a rockfill embankments, with l(v) : 1.5 (h) slopes, something of the order of a million cubic metres of rockfill would be required for the higher embankments of both banks, with perhaps half this volume for the lower embankment sections, upstream. Quantities would increase for an earth core dam and for some type of composite dam.

5.4.4 Saddle Embankment Design

The quantities of materials required for the saddle embankments will place some constraints on design. For instance, the only major source of clay fill in the area is considered to be the residual profile on the slopes of the small hill on the left bank, just upstream of the dam site. However, quantities are likely to be restricted in this environment. On the other hand, quantities of rockfill should be plentiful, both from the excavation at the upstream entrance to the Hou Sahong and also from other potential quarry sites within the reservoir area, on the right bank. Some options for the embankment design are given in Figure 5-3. The preferred options are summarised as follows.

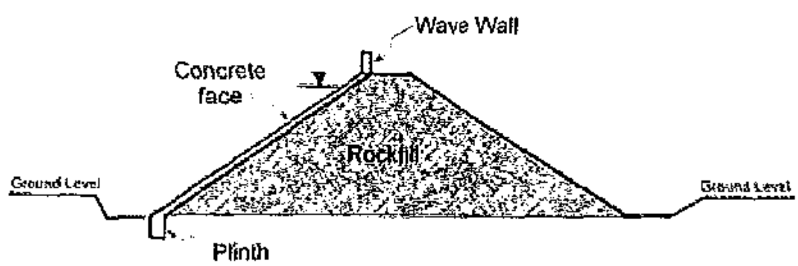
- A rockfill dam with a clay core might be feasible, but further exploration would be required to prove the availability of adequate quantities of suitable clay fill. Investigation of potential borrow areas would require the use of a mechanical excavator. A clay core would need at least two filter zones. Local sands should prove suitable as a fine filter but, again, quantities could be limited if the sand deposits are required for concrete production. Coarser filters would need to be manufactured as there is little gravely material available in the environment and much of this tends angular. A rockfill with clay core would require a reasonably high degree of skill and close supervision. It is not seen as a favourable choice.

- Because of the estimated quantities of rockfill available in the site area, some form of rockfill embankment would appear to be most appropriate. The water retaining capacity for a rockfill embankment could be provided either by a concrete face or by a central concrete membrane. Both could be extended up above the embankment crest to form a wave wall. The concrete face option would probably require a greater degree of skilled



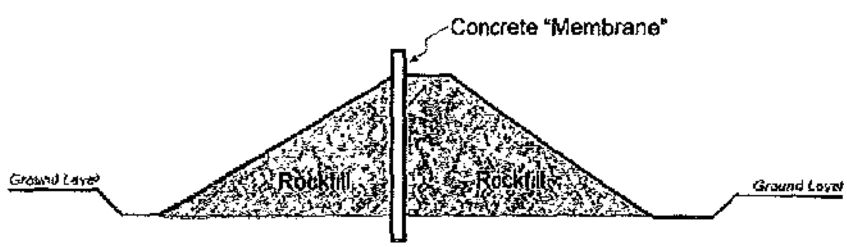
a) EARTH/ROCKFILL EMBANKMENT

b) HOMOGENEOUS EMBANKMENT



Plinth

c) CRF EMBANKMENT



d) CONCRETE MEMBRANE EMBANKMENT

Don Sahong HEP

EMBANKMENT OPTIONS

Figure 5-3

labour for construction than a concrete membrane, which can be raised progressively ahead of rockfill placement. While inflexible concrete cores are not typically favoured for large embankment dams, the anticipated settlements for well compacted rockfill, to the envisaged saddle dam heights, should not raise serious problems. A concrete core should also be more easily connected to the main concrete structure than a concrete facing, since the latter might be more susceptible to disruption at the junction with the main concrete structure.

- An L-shaped concrete retaining wall, as a continuance of the concrete membrane, might also be worth considering as embankment heights reduce upstream. Backfill by rockfill, behind the wall, would ensure stability.

5.4.5 Coffer Dams

An upstream coffer dam is envisaged at the entrance to the Hou Sahong. This would be constructed in the dry season, possibly as a low concrete wall to minimise interference with the proposed excavations of the 70 m wide rock bar at the entrance.

The downstream cofferdam will need to taken to an elevation of in excess of RL 58, which could mean a height approaching 12 m. The dam will also need to be located as far downstream as practicable, to mitigate space restrictions for construction of the main dam. The location will, however, be dependent on rock conditions downstream. From surface indications, it would appear that rock levels in the stream bed fall away rapidly near the stream confluence. Some soundings could be useful prior to a decision on the location of this coffer dam.

5.4.6 Reservoir integrity

Mention has been made of former channels of the Hou Sahong, which have the potential *to* by-pass the major structure in the river. On the right bank, the major channel that emerges just downstream of Borehole BR 2 is believed to have a connection with the Hou Sahong about half way upstream to the entrance. This would need to be sealed by a saddle embankment if the upper dam site is chosen. Infilled channels also exist and in such cases, it would be prudent *to* excavate out the alluvial silts/sands infilling the channels, before constructing a saddle embankment. Alternatively, some form of slurry trench could be considered. The major problem associated with a slurry trench is the fact that the alluvial infilling beneath an embankment is likely to settle, particularly if subject to earthquake loadings, and the stiff slurry trench could cause consequent disruption of the embankment.

5.5 EARTHQUAKE HAZARDS

Reference to the record catalogue of the United States Geological Survey, Earthquake Hazards Program (http.7neic.usgs.gov.neis) shows the project area to be seismically quiet. Since the commencement of detailed records, in the last thirty five years, only two earthquakes have been registered, both of low magnitude (M 2 - 3), both occurring to the north of Pakse. This, of course, is no complete guarantee that the seismically quiet condition will persist for the lifetime of the project. Attention to quality control in concrete and rockfill emplacement would be prudent as a safeguard against possible future seismic events.

5.6 MATERIALS

5.6.1 Clay Borrow

Test pits were excavated on the lowermost slopes of the small hill, upstream of the dam site on the left bank. Being the dry season, the subsurface materials were very hard and hand excavation was typically halted at superficial depths. The laboratory testing of the materials recovered indicate that the residual profiles here are generally of low plasticity and are dispersive in nature. If such materials were to be used as an impervious barrier for the saddle embankments, careful attention to placement water control contents and to achieving a good binding between layers would be essential. In the absence of such measures, piping through such materials is a common hazard and it would need only one instance, in the several kilometres of embankments to subvert the viability of the project's operation. Furthermore, the quantities of available clay borrow appear limited, again militating against their value for long embankments.

The above comments do not necessarily apply to the red residual clay on the left bank, at the upstream dam site (TP1), but this material is even more restricted in quantities.

5.6.2 Alluvial Sands

Sporadic pockets of alluvial sands occur along most of the channels of the Mekong. In the dam site area, these are of fine, uniform grading, with a mica content of perhaps 5%. The broad sand deposits at the upstream end of Khong are coarser in grain size, rounded, and reasonably well graded, with a mica content of 2 - 3%. Sands of this environment should be suitable for exploitation for concrete, although quantities are unknown at this stage. The river alluvium in the area of the dam site is predominantly coarse silt.

5.6.3 Rockfill

Large volumes of rock excavation are anticipated for the project. That for the entrance of the Hou Sahong should be composed largely of hard quartzite. Potential quarry sites were identified on both banks of the Hou Sahong, at the upstream end of the first major bend above the dam site. The isolated ridge on the right bank, drilled by Borehole BR 2, would also provide a source of hard rock, within the reservoir area - should the lower dam site be chosen.

Excavation of the channel downstream of the dam will generally encounter more bedded rock strata, as shown in Photo 5-2. This is likely to comprise smaller rock fragments that elsewhere, but these would be quite appropriate for the outside zone of any rockfill (saddle) embankment.

5.6.4 Coarse Aggregates

Two major lithologies are identified as possible sources of aggregate in the project area: Massive (silicified) andesite and quartzite. Both rock types are hard to extremely hard in the hand specimen.

Samples RR1 and RL1 were taken from the possible quarry sites at the upstream end of the major bend above the dam sites; Sample R2 from the enhance area to the Hou Sahong, and the remainder from the two investigated dam sites.

Unconfined compression tests made on core samples here are prone to be influenced by the unfavourably inclined foliation/bedding in the samples and it is suggested that the upper unconfined strengths of around 500 kg/sq.cm would be more representative of the nature of either rock type. Los Angeles Abrasion tests show some 10 - 15% loss for the rock types.

No alkali reactivity tests are available. The petrographic analysis indicate both rock types are high in silica content, in the form of small quartz clasts in a matrix of micro-crystal line quartz. The recognisable crystalline characteristics of the matrix is a positive feature, but it would be worth seeking the advice of a concrete expert to confirm this or not, with regard to the possible long term behaviour of this fine grained quartz material

SECTION 6

PROPOSED PROJECT LAYOUT

6.1 Head Pond

The project area is constrained within the Hou Sahong channel of the Mekong River. Construction of a power station structure across the channel near its exit and just upstream of the village of Ban Hang Sahong on the right bank will cause the channel to fill with water to the level of the Mekong River at the channel entrance to provide the necessary head pond for the Project.

It has been estimated that the head pond level will not exceed RL 74.5, so the power station structure will have a crest level of RL 75. As there are areas on both'Don Sahong (right bank) and Don Sadam (left bank) where the landform is at less than RL 75, embankments will be necessary to prevent unnecessary inundation of land, loss of agricultural land and possible flow out of the head pond.

6.2 Location of Power House

Several locations were considered for the powerhouse in the lower reach of the Hou Sahong, ranging from just downstream of the final bend (as proposed by Maunsell-Lahmeyer) and as far downstream as topography would allow (as suggested by Acres). Initial drilling at the upstream site indicated unsuitable geological conditions, with possible leakage through old river channels on the inside of the channel bend and less than favourable rock in the foundations. In addition, the further downstream the powerhouse is located, the higher the available head on the turbines as the Hou Sahong is still quite steep in the lower reach.

Accordingly, a location about 150 m upstream of the junction with the Hou Xang Peuk has been selected for the powerhouse.

Figure 6-1 indicates the general arrangement of the project.

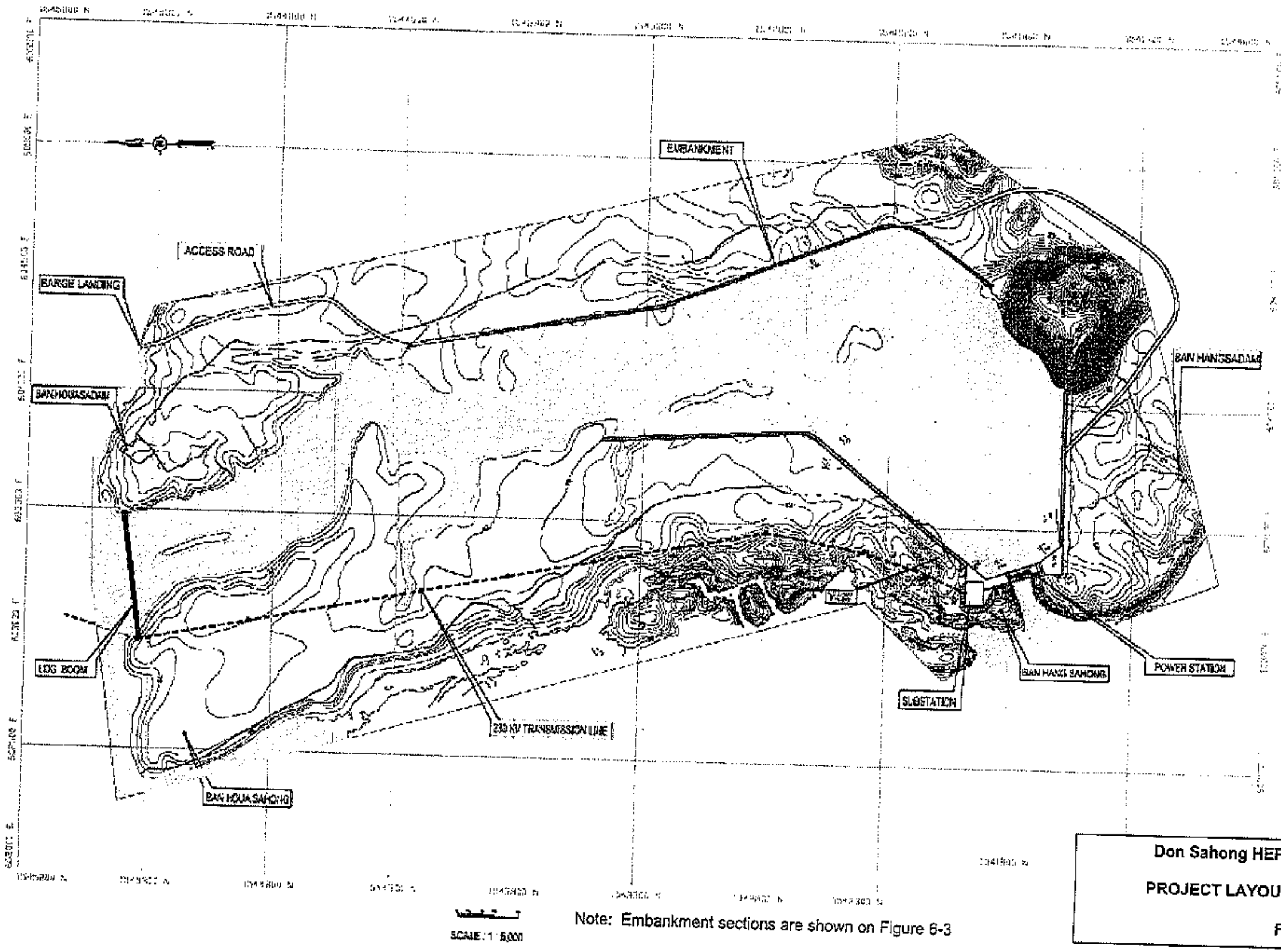
6.3 Access

Figure 6-2, at a larger scale, shows the power station and adjacent areas. Access to the power station will be by road from a landing area east of the village of Ban Houa Sadam, which will use the retaining embankments as a right-of-way wherever practical. The power station support facilities - unloading and assembly bay, workshop, offices, etc - will be at the eastern end of the station. Controlled access will be available across the power station deck to give access between Don Sadam and Don Sahong for the local villagers.

6.4 Embankments

Figure 6-3 indicates the cross-sections of the water retaining structures adjacent to the power station and on the retaining embankments.

As the water level behind the powerhouse is controlled by the levels in the Mekong River at the entrance to the Hou Sahong, the level for the top of the embankment wave wall is selected to ensure that there will be no spill, even with wind generated waves. Model tests during the design phase will ascertain whether there is a need for an emergency floodway to cope with any wave surges due to load rejection of the turbines, an extreme event. If such a floodway is required it will

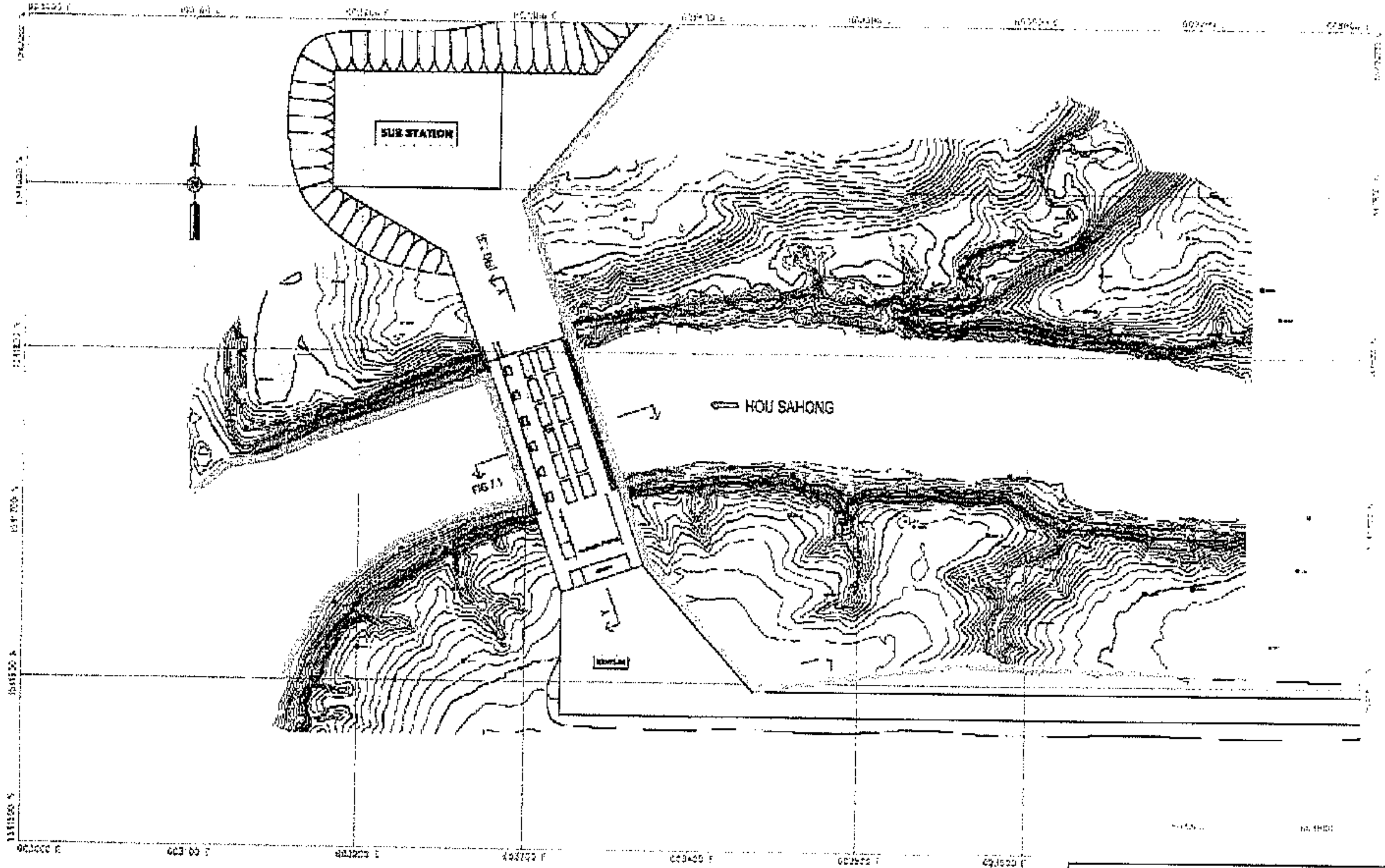


Note: Embankment sections are shown on Figure 6-3

Don Sahong HEP

PROJECT LAYOUT

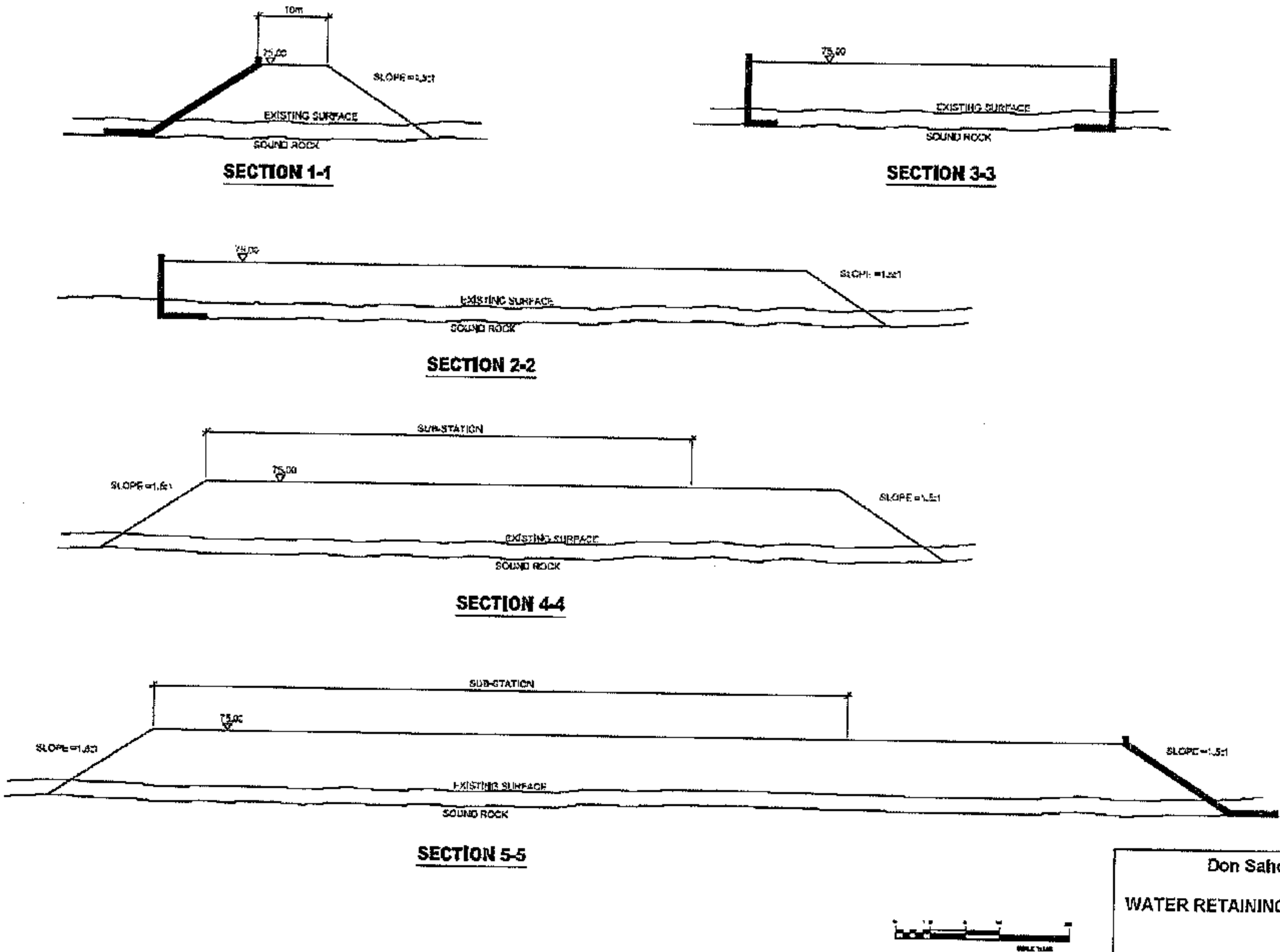
Figure 6-1



Don Sahong HEP

TYPICAL POWER STATION ARRANGEMENT (6 x 40 MW)

Figure 6-2



Don Sahong HEP

WATER RETAINING EMBANKMENTS

Figure 6-3

be facilitated by a lower section of the wave wall over a short section to the west of the powerhouse, discharging into the Hou Xang Peuk through a concrete lined channel

6.5 Power Evacuation

Power will be evacuated from the station via a 230kV switching station located at the western end of the station and a double circuit 230 kV transmission line will run generally north across Don Sahong and cross onto Don Tan and thence to the mainland south-east of Ban Nakasang and thence to the existing Ban Hat substation.

6.6 Construction Facilities

It is assumed that the contractor will erect his construction facilities on both banks of the channel. A buffer zone will be established between these facilities and Ban Hang Sadam on the left bank some distance from the site, but Ban Hang Sahong is too close to the site and the inhabitants will have to be shifted to a new location.

6.7 Navigation Facilities

The inclusion of a facility to pass vessels through the powerhouse structure was considered. In the Acres 1994 report, locks were included in all mainstream projects, except Don Sahong, with the comment that *"At Rhone Falls practical navigation could not be established past the falls with the addition of facilities only at the power development project"*. This is because considerable work would be necessary to improve the river between the top of Hou Sahong and Don Det or Khinak, the most downstream navigable parts of the Mekong in Laos. Even now they are only navigable for 50 DWT vessels in high flow and 20 DWT vessels at low flow periods[1], which is far short of the 5,000 tonne barges that locks were considered for the other projects upstream and downstream of the Great Fault Line,

At some time in the future, if passing of vessels through the GFL is seriously considered, a facility could be constructed in the western arm of the river to avoid the dangerous conditions between Don Det and Thakho.

[1] Mekong River Commission MRC Navigation Strategy, August 2003

SECTION 7

POWER STATION

7.1 Site

The power station is located at the lower end of the Hou Sahong channel (Figures 6.1 and 6.2), to take advantage of the maximum head available with minimum excavation of the river bed downstream. Three potential sites were considered from just below the bend in the channel and the end of the island to a site about 150 m from the end of the channel, limited by the falling topography.

Geological investigation (Section 5) indicated that the most downstream site was preferable and the layouts were developed on this basis.

The channel is quite narrow, approximately 90 m betsveen the banks, and this limits the available options as excavating into the banks on either side will require significant quantities of rock.

7.2 Layout

For the purpose of this report and the estimating of costs, a manned power station layout is considered. While a number of alternative unit sizes and total station capacity have been considered the following discussion, based on a 6-unit station with bulb units, is common to all alternatives.

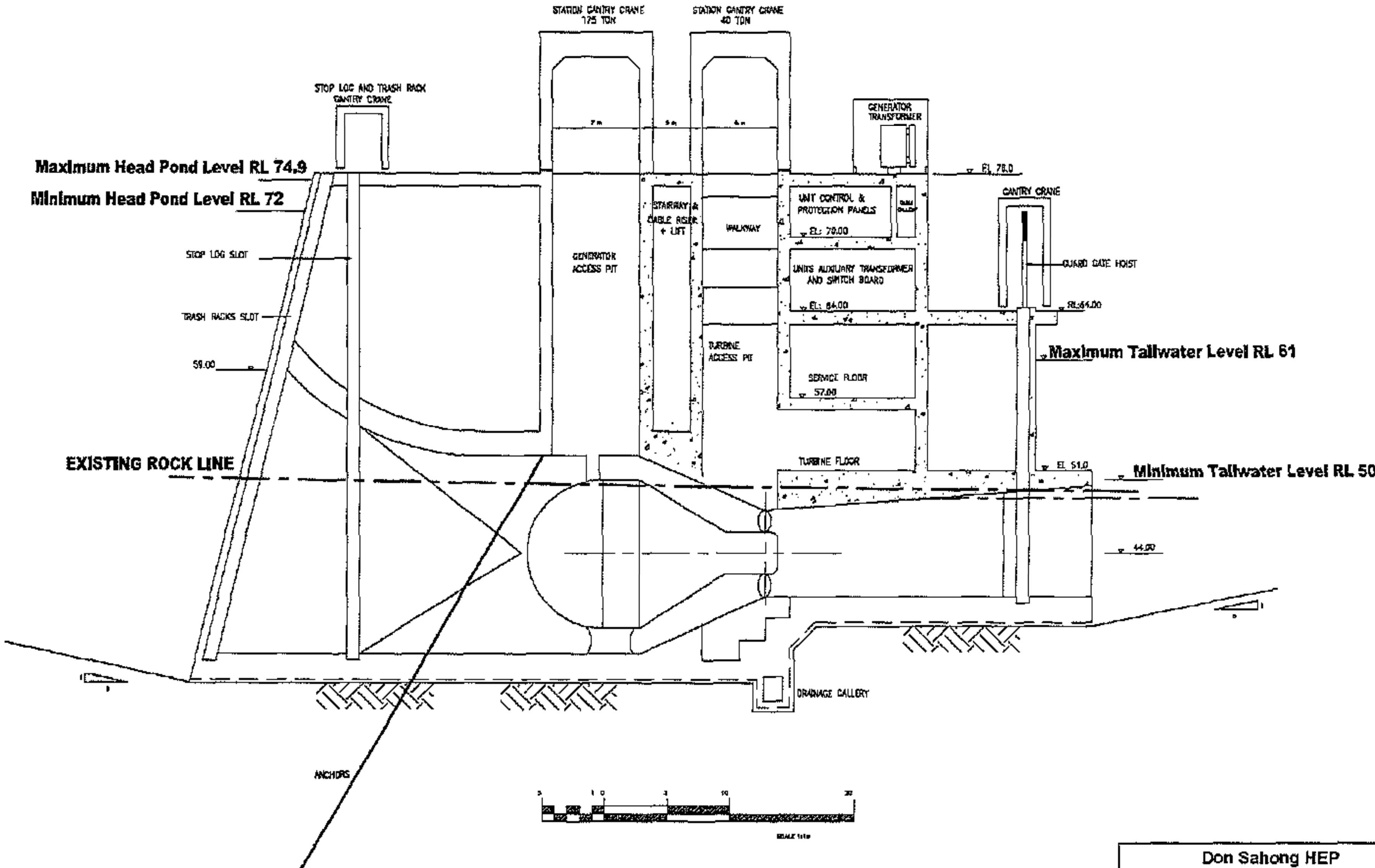
The power station layout is a semi outdoor arrangement comprising machine bays in the river channel, with an assembly/unloading bay at the left (eastern end). Each machine bay is independent with relevant services rooms and a three-phase main transformer located on the top deck. The control room and other general services are located under the assembly bay with offices and workshop at ground level. (Figures 7.1 to 7.5)

The main floor level has been set at RL 75 m to be clear of the anticipated maximum flood levels. The Mekong has been gauged for more than 80 years and there is confidence in the flood level assessment.

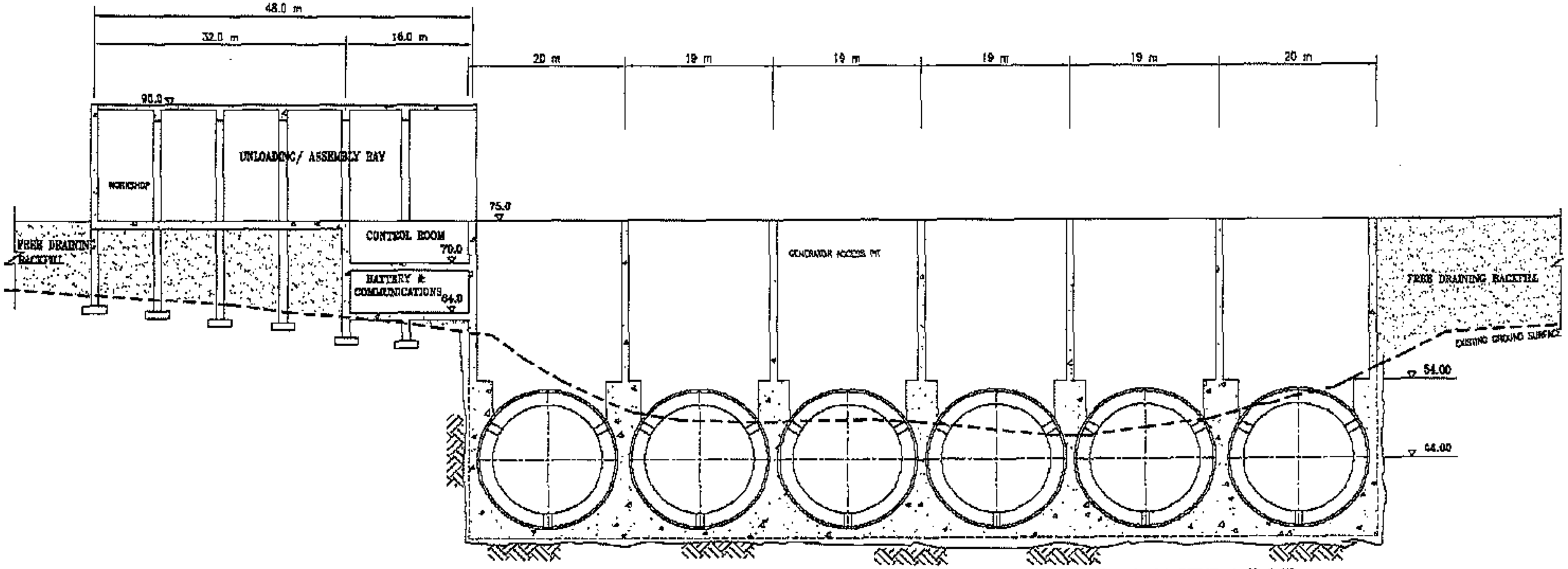
7.3 Machine Bays

Each machine bay is an independent unit, separated from the adjacent unit with expansion and contraction units. Within each unit the generator and turbine pits are sealed so that any major failure that releases water from either a generator or a turbine is restricted to that unit and does not flood the whole station.

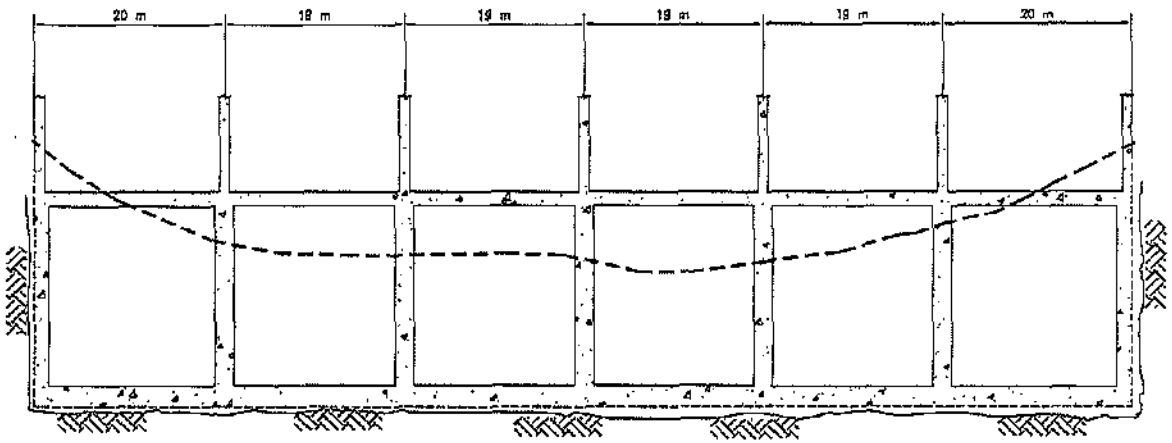
As well as the log boom provided at the entrance to the Hou Sahong from the Mekong to exclude floating debris, at the upstream end each unit trashracks provide protection against debris passing into the turbine water passages. They are designed with a water passage between the bars sufficient to allow a maximum water velocity through the trashracks of 1 m/sec. A trashrake will be provided to clean accumulated debris from the racks.



Don Sahong HEP
6 x 60 MW POWER STATION
CROSS SECTION
Figure 7-1

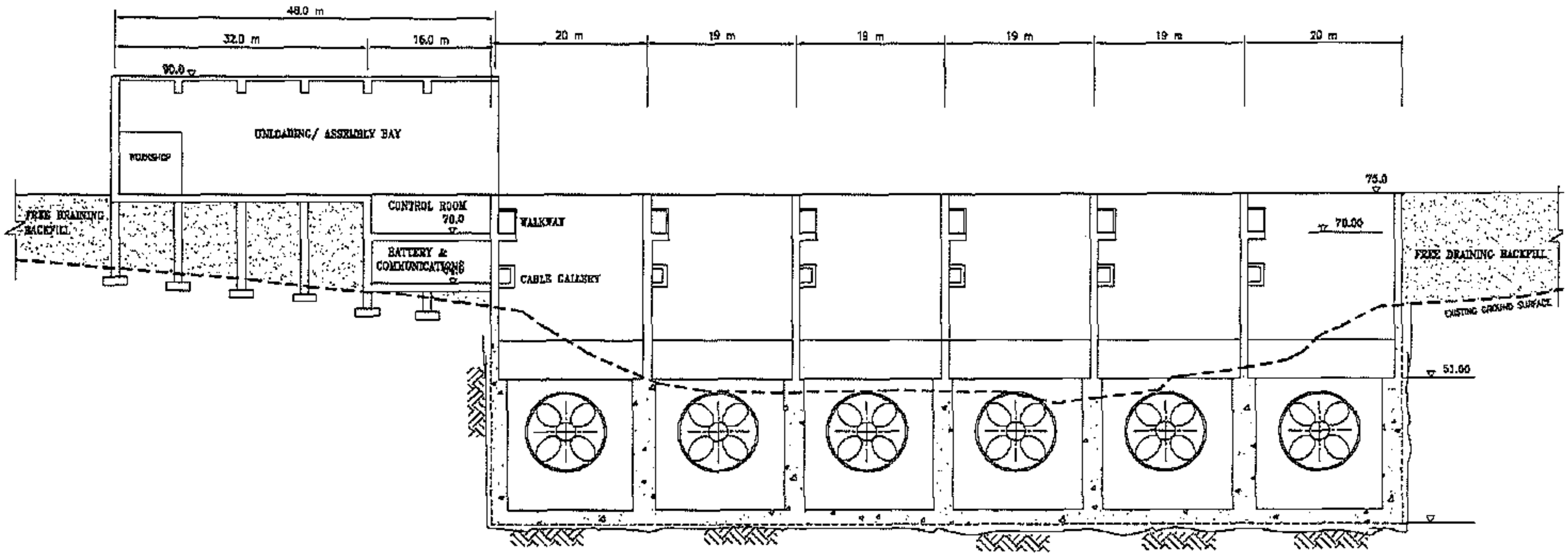


LONG SECTION THROUGH GENERATOR

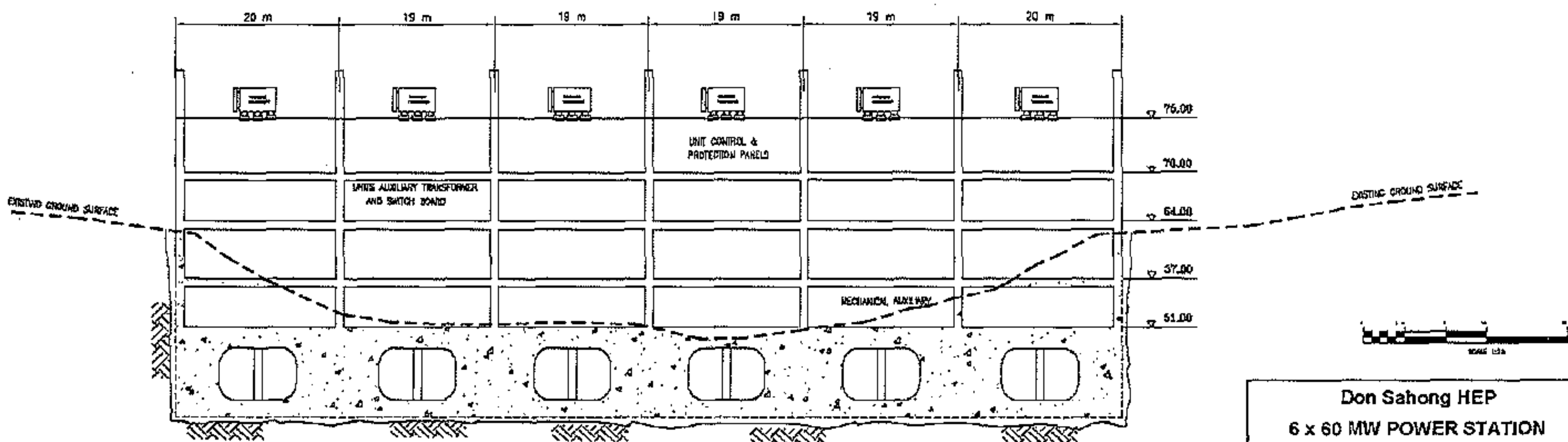


LONG SECTION THROUGH INTAKE

Don Sahong HEP
6 x 60 MW POWER STATION
UPSTREAM LONG SECTIONS
Figure 7-2



LONG SECTION THROUGH TURBINE



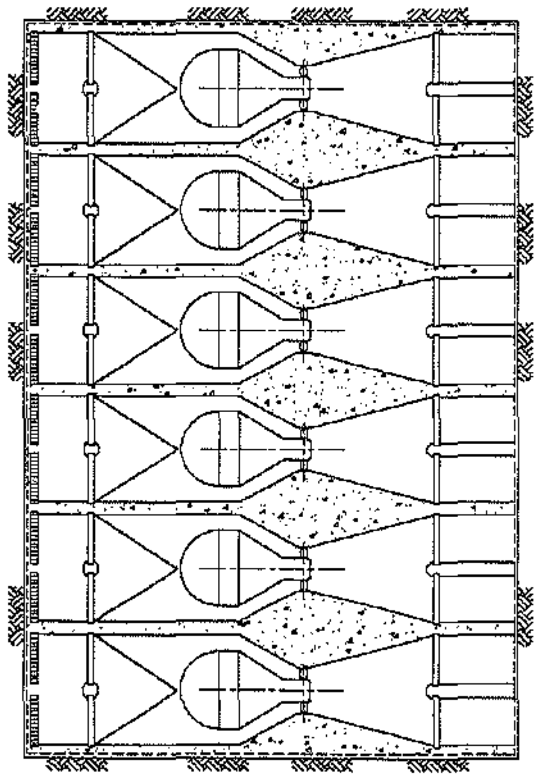
LONG SECTION THROUGH DRAFT TUBE

Don Sahong HEP

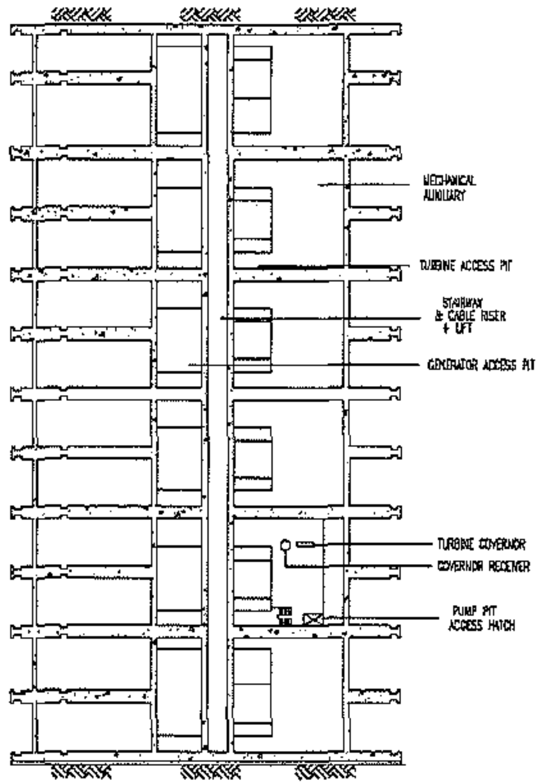
6 x 60 MW POWER STATION

DOWNSTREAM LONG SECTIONS

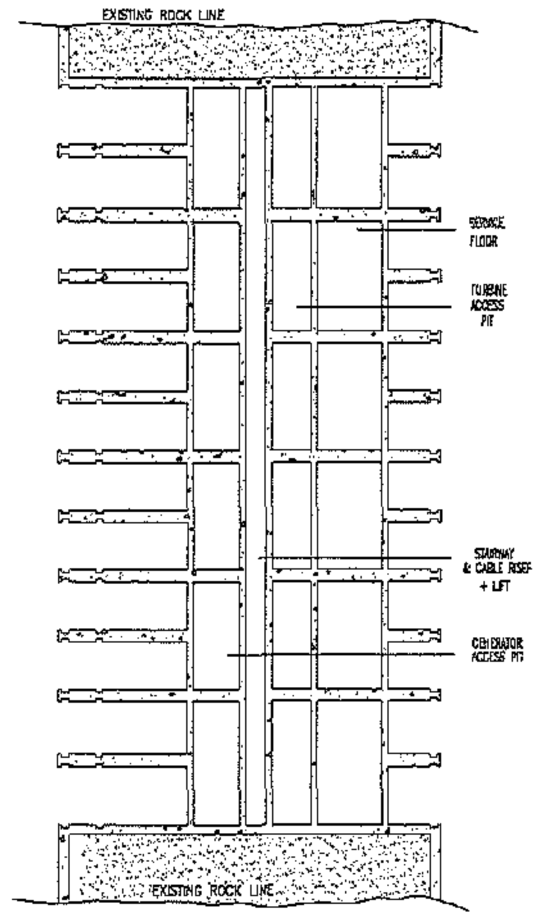
Figure 7-3



PLAN AT TURBINE CENTRE LINE

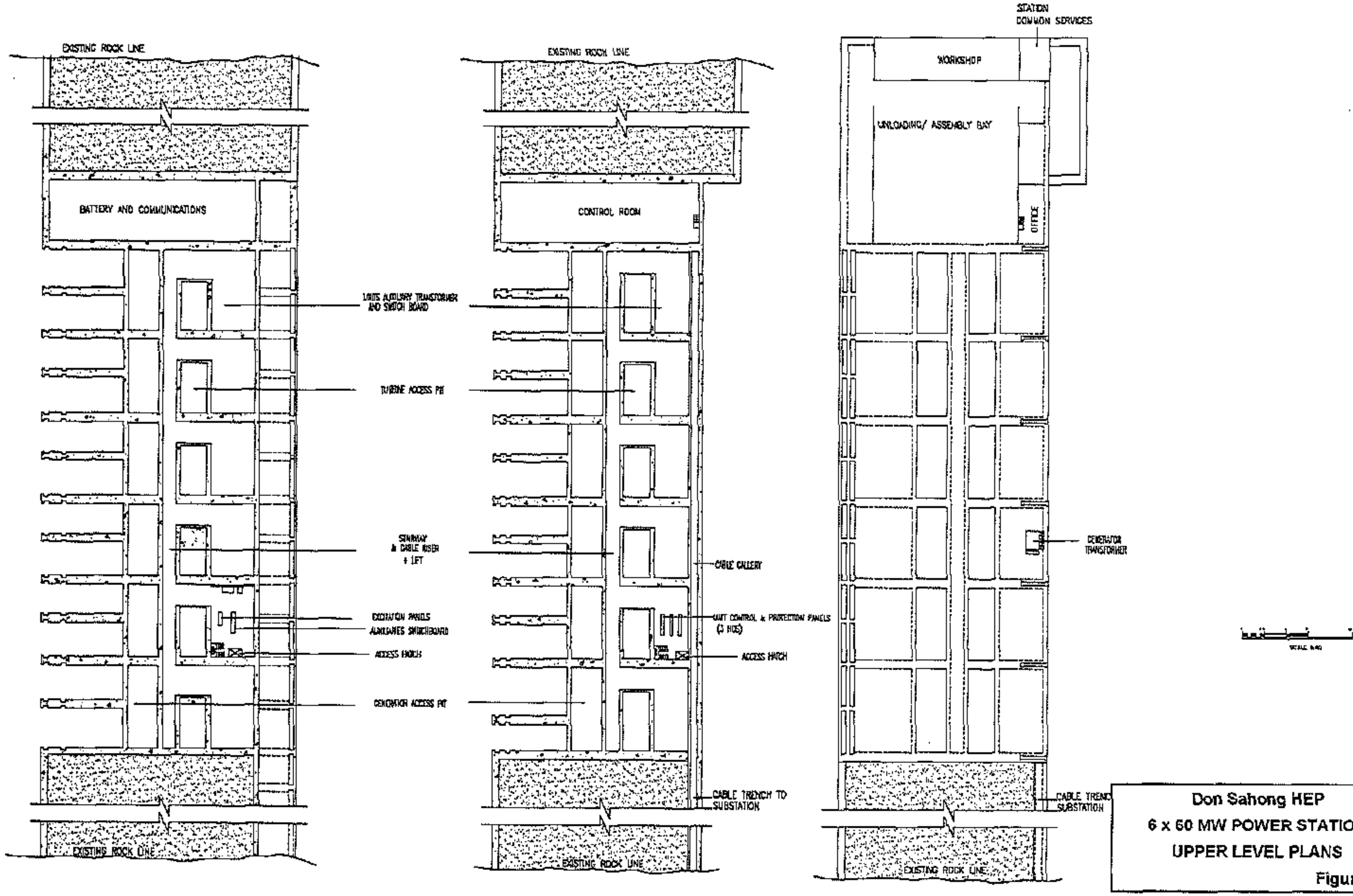


PLAN AT TURBINE FLOOR



PLAN AT SERVICE FLOOR

Don Sahong HEP
6 x 60 MW POWER STATION
LOWER LEVEL PLANS
Figure 7-4



PLAN AT RL 64.00

PLAN AT RL 70.00

PLAN AT RL 75.00

Don Sahong HEP

6 x 60 MW POWER STATION

UPPER LEVEL PLANS

Figure 7-5

Downstream of the trashracks provision is made for stoploges (bulkhead gates) that can be lowered into still water to isolate the generator and turbine for maintenance. Only two sets of stoplogs will be provided as it is not envisaged that more than two units will be under maintenance, planned or otherwise, at any one time. However, some temporary measure may be necessary to waterproof the station during erection of the equipment if it is decided to commence operation before all units are installed and commissioned. A rail-mounted gantry crane will command the stoplogs and also the trashracks, which will need to be removed from time to time for repainting or other maintenance.

Two rail-mounted gantry cranes are proposed, each of which will traverse the length of the station into the Assembly/Unloading Bay at the east end of the station. One crane will cover the generator pit and the other the turbine pit. The option of a single gantry covering both pits was considered, but rejected for two reasons:

- Two cranes allows for flexibility of working on a generator and a turbine simultaneously, and

- A single gantry would have to span at least 16 m and would have been more expensive than the two crane option.

Between the generator and turbine pits there is a full depth access gallery, nanning the length of the station. This will contain stairs, cable and pipe runs and other services. Watertight doors will give access to the generator and turbine pits and enclosed corridors will connect across the turbine pit to the services block downstream of the turbine pit.

Hatch covers at main floor level will give weather protection to the pits.

The services block, downstream of the turbine pit contains, at various levels, cable and pipe runs, auxiliary electrical and mechanical equipment, switchgear etc, with the station power transformers at main floor level.

The guard gates for the bulb turbine are located at the downstream side of the power station, at the draft tube exit. A twin gate in each unit is selected because they are smaller in size and operate under a lesser head than if located at the upstream of the units. Guard gates are designed to close into flow - the maximum possible flow likely in the event of failure of guide vanes of conduit downstream from the gate. Closure is normally by gravity triggered by an overspeed detection device on the generator, releasing a latch on the gate. Hoisting into the open position is by hydraulic cylinders.

Guard gates also serve as isolation for maintenance purposes.

Sedimentation is not expected to be a problem as sediment laden water will be carried past the Hou Sahong in the Mekong mainstream during the high flow season when the sediment load is highest. Further, as the power station will be operating continuously there will not be a general; reduction in stream velocity which would cause sediment to precipitate. The bulb units, with their large clearances, will permit sediment to pass through without damage to the units. Any accumulated sediment can be sluiced through by opening one or more of the turbine passages with the turbine blades feathered and the units braked.

The machine bay structure consists of reinforced concrete external and internal walls and machine foundations of mass concrete, reinforced concrete and steel. The walls and floors are of sufficient capacity and stiffness to support the static and dynamic loads of the turbine, generator and associated machinery.

The machine bay structure is, in effect, a large tank and is subject to considerable uplift (flotation) and overturning forces. Uplift is highest during the high flow period, when the headwater and tailwater both rise, while overturning forces are greatest at low flow period when the tailwater is at its minimum. The self weight of the structure is not sufficient to resist these forces and anchors will be required to mobilise the weight of the rock foundation to stabilise the structure. Another option is to increase the self weight by adding more concrete between the trashrack and the generator pit and above the draft tubes, downstream of the services block. The detailed design will examine the most cost effective manner of providing structural stability.

A drainage gallery traverses the station beneath the lowest point of the turbine pit. Any leakage or washing down water will gravitate to a pump sump at the eastern end of the station from which submersible pumps will remove the waste water to the tailrace. Two station oil traps will be provided to prevent oil contamination downstream of the station. The dewatering pumps' AC supplies and controls are located above the station waterproof level.

The machine bays will be excavated about 15 m into the rock foundations and, as can be seen from Figures 7.2 and 7.3, extend into the existing channel banks. As mentioned in Section 7.2, the narrow channel will limit the generation capacity of the power station. Table 7.1 indicates the length of the station for various unit capacities.

Table 7.1 - Machine Bay Length (m)

Station capacity	180	240	240	250	300	300	320	360	400
Configuration	6x30	6X40	4x60	5x50	6x50	5x60	8x40	6x60	8x50
Bulb units	86	98	74	87	104	92	130	110	138
Kaplan Units		146	118	137	164	147	194	176	218

The increased length of the station with larger capacities is reflected in the civil cost estimates.

7.4 Unloading/Assembly Bay

The assembly bay, located at the eastern end of the power station, serves as a general working area during construction of the station and for subsequent maintenance activities. Road access is provided by large doors on the northern side. The generator and turbine gantry crane rails will extend into the building to collect or deliver the large components.

A workshop will be provided at the eastern end of the Assembly/Unloading Bay. Since the station is in a remote area, the workshops have been sized to allow for most types of mechanical and electrical maintenance work to be done at the station. The mechanical workshop is intended to contain a range of machine tools, including lathes, a milling machine, shaper, drill presses, grinders, etc. It is also suitable for welding purposes, although this work can be done in the assembly bay as well. The electrical workshop is intended to contain electrical testing and repair equipment and a storage area for small electrical components.

The control room area is located beneath the assembly bay. It comprises the station control room, office and records room, lunch room and toilets. Below the control room area are the battery room, DC distribution room (which contains the battery chargers and DC distribution boards), communications and protection room and air conditioning equipment. The air supply to the control room and the communications and protection room, which contains delicate electrical equipment, and the office and store are suitably air-conditioned to provide an appropriate environment with controlled temperature and humidity.

Further offices, visitor control facilities are provided in a single story building on the south side of the assembly bay. This building also contains general amenities (mess, showers and toilets) sized to cater for a reasonable number of people that may be working in the station at times of major maintenance work.

The station services transformers, 380 V switchgear and AC boards which are located in rooms near the electrical workshop for easy access. The 22 kV switchgear, for local supply, is to be indoor switchgear located in a building within the 230 kV switchyard.

The ventilation plant room is located for ease of ducting the air around the station and is well clear of the electrical control equipment in the control room area to ensure that the plant's noise and vibration do not interfere with the station's control equipment.

A single station emergency diesel generator set will be housed in an annex on the eastern end of the assembly bay. This location is close to the AC boards and prevents noise and fumes from the diesel engine causing adverse effects in any other part of the station.

7.5 Station Services

A station fire fighting tank (not shown on the drawings) is located above the power station at sufficient elevation to provide adequate water pressure in the station.

The station is provided with a compressed air system with outlets at various locations for workshop tools and general services.

A water treatment plant will provide domestic water to the power station and to the security and visitors' reception block.

SECTION 8

GENERATION EQUIPMENT

8.1 Selection of Unit Type

Figure 8.1 indicates the general duty of the various types of lai'ge hydropower turbines. The Don Sahong units (22 m to 14 m head, unit sizes from 30 to 60 MW) fall within the overlapping Kaplan and Bulb turbine zones. The zone limits are approximate and are being stretched as technology improves. Bulb turbines as large as 63.5 MW at 14.8 m rated head, 58.5 MW @ 13.8 m head and 58 MW @ 15.2 m head have been manufactured. These are all physically larger than the largest option envisaged for Don Sahong - 60 MW at a rated head of 17 m.

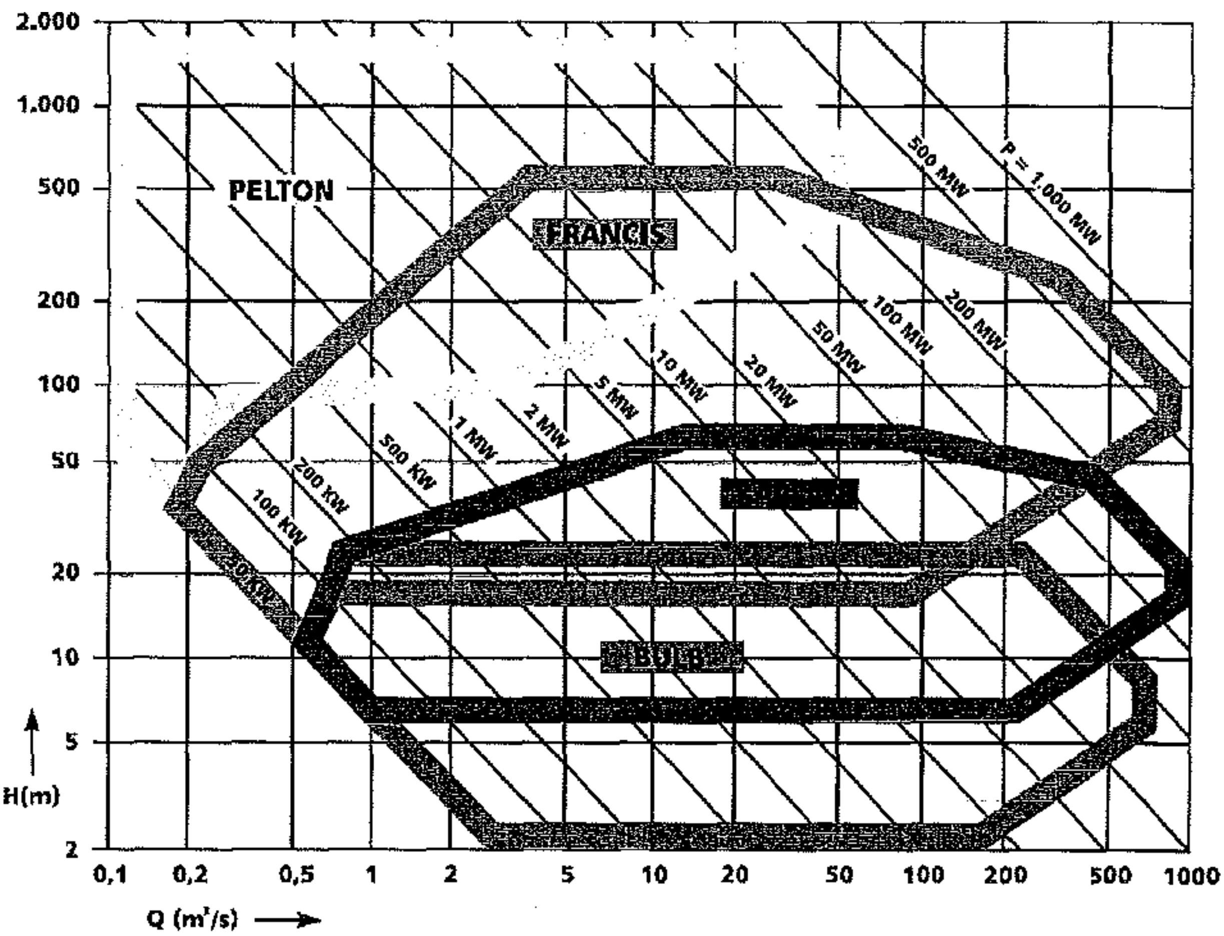


Figure 8.1 - Turbine selection chart

In concept, the Kaplan and bulb turbines are similar with adjustable blades on the runner hub and adjustable guide vanes ("double regulated") which result in a very flat efficiency curve across the range of head and flow. Each type, though, has its advantages and disadvantages.

- For a remote area, the Kaplan can be delivered in smaller components and assembled at site; typically the bulb comes in three large, heavy packages. Conversely, the bulb, while more difficult to transport, has advantages in that these large components are manufactured and assembled in factories under better conditions than are experienced in the field.

- The bulb units have considerably less civil cost as the Kaplan has a larger footprint and a deeper excavation. The latter requires either more concrete or additional anchors, typically prestressed, to mobilise foundation rock: to counterbalance the corresponding higher uplift (flotation) and overturning (stability) forces on the station. This is a significant item in the restricted width of the Hou Sahong channel.

- Turbine costs for the Kaplan unit are higher, but are compensated by lower generator costs.

- Construction time is less for a bulb station. The embedded components can be provided for installation as the civil works proceed and the turbine and generator components installed when the civil works are essentially complete. For the Kaplan units, the draft tubes are installed by the station main cranes (or by suitably large mobile cranes) and then the area is handed back to the civil contractor for embedment; the spiral case is then installed and the process of embedment repeated, with the generator support and housing following. Only then can the generator installation commence. It is estimated that, for a multiple unit station such as Don Sahong, the construction time would be one year longer for the Kaplan option.

- Energy production is less for the Kaplan because of the additional head losses inherent in the hydraulic system.

Concept drawings for a 6 by 40 MW station were prepared for both Bulb and Kaplan units (Figures 8.2 and 8.3) and cost comparisons made for the total of six unit bays (Table 8.1).

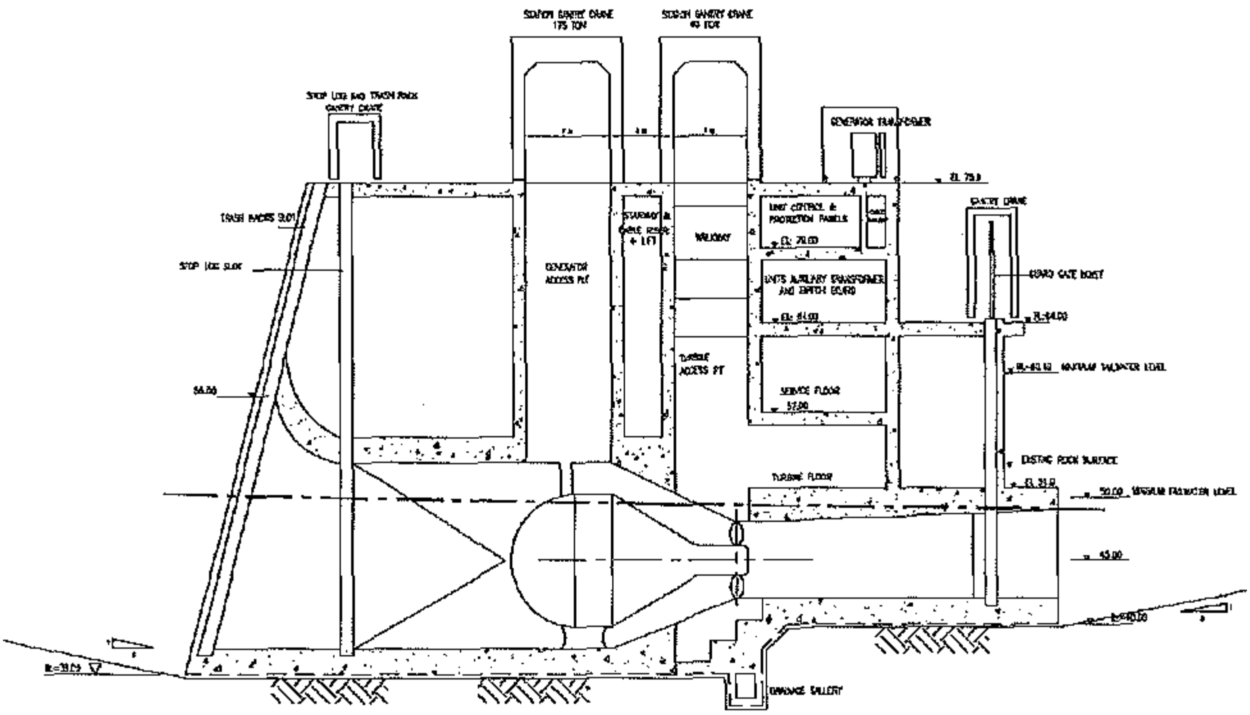


Figure 8.2 - Cross-section of 40 MW Bulb unit

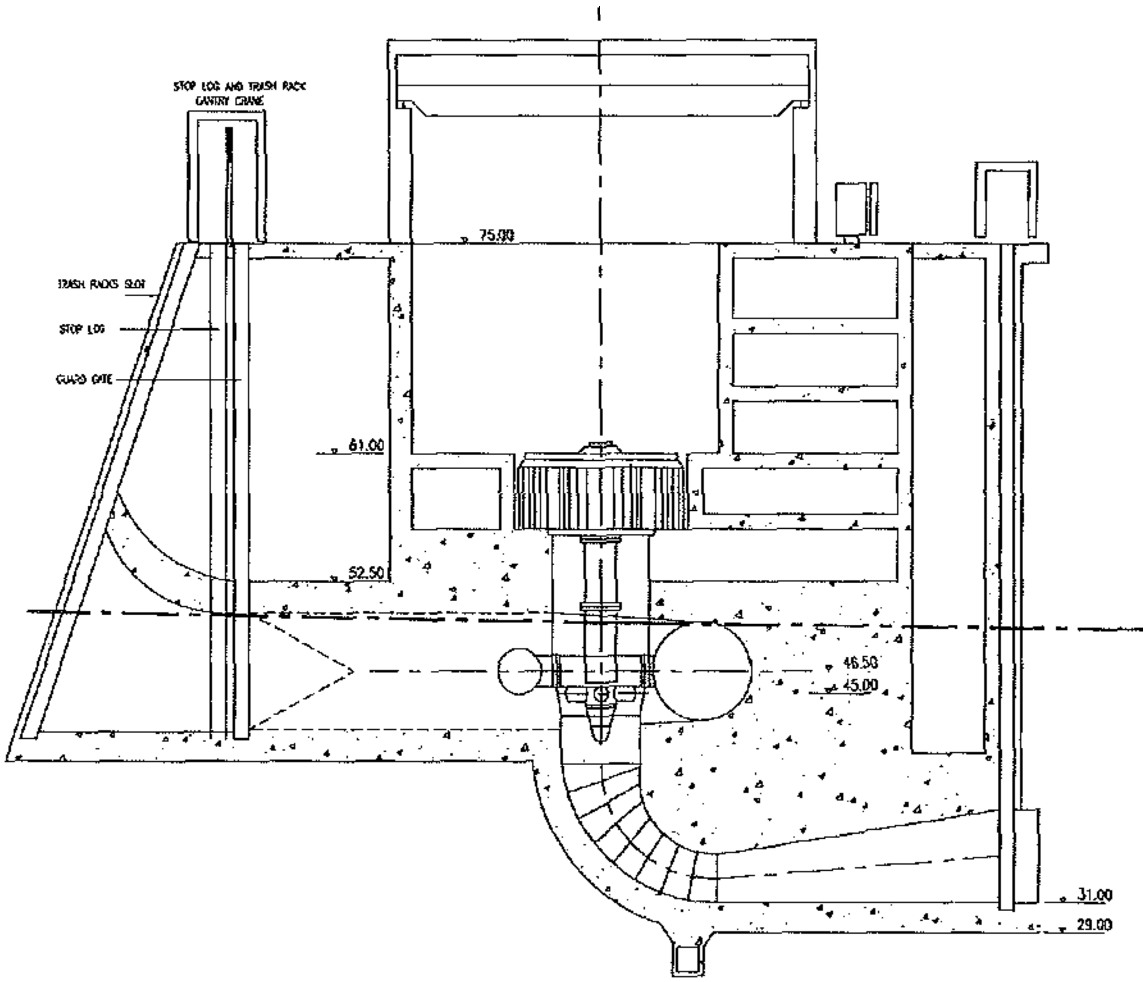


Figure 8.3 - Cross-section of Kaplan Unit

Table 8.1 - Cost estimates for bulb and Kaplan units
(millions of USS)

Item	Bulb	Kaplan
Excavation	**2.7**	**7.8**
Concrete	**5.6**	**9.7**
Superstructure	**0.0**	**1.8**
Cranes	**1.7**	**1.2**
Trashracks, gates, hoists	**5.8**	**6.1**
Turbine	**85.1**	**97.9**
Generator	**61.8**	52.8
BOP	**42.6**	42.6
TOTAL	**205.4**	**219.8**

Thus the estimated additional cost for using Kaplan-type turbines in a 6 by 40 MW installation is estimated at US$ 14.4 million.

The energy model has indicated that for a 240 MW station, with 1,000 cumec environmental flow and improved entry conditions, the bulb unit option has an average energy generation of 1838,1 GWh/annum, while the Kaplan option has an average energy generation of 1765.6 GWh/annum, a reduction of 72.5 GWh/annum or 4%.

For stations with a larger capacity or larger units the cost difference is significantly higher because the station extends further into the banks on either side, and excavation quantities and costs increase disproportionately.

Because of the increased construction cost and reduced energy capacity, the use of bulb units is recommended.

8.2 Other turbine options

While the bulb or Kaplan units have a flat efficiency curve over their normal operating range because of the adjustments to blade angle and guide vanes, a less expensive option is a propeller turbine which has a similar geometry to the other mixed flow units, but has fixed blades on the turbine runner. This results in a loss of efficiency as head varies from the design rated conditions.

However, because of the circumstances at Don Sahong, where there are periods during the high flow season when the head is low, but varied within a narrow band, this loss of efficiency would not result in excessive energy loss. For example a 40 MW turbine rated at 14 m head and operating in a range of 18 m to 11 metres would generate an average of 250.0 GWh/a compared with the 271.4 GWh/a produced by a conventional bulb unit. This generation would occur in the months June to December with occasional bursts of operation in other months when abnormal inflows permit.

While the cost of the mechanical plant would be less by reason of the simpler control systems, this is partially counterbalanced by an increase in physical size because of the lower rated head and consequent increased turbine and civil costs.

A number of alternative arrangements of bulb plus propeller and Kaplan plus propeller units were modelled and it is recommended that during the design phase, these options be further studied.

8.3 Mechanical auxiliaries

Turbine controls are located in the turbine floor, immediately downstream of the turbine and comprise the governor cubicle and an air/oil receiver which provides the energy required to power up the guide vane servomotors and also the blade servomotor. Control of the blades is done using an interlock with the guide vanes. When the guide vanes move, the blade angles are adjusted to maintain the optimum relationship to sustain efficiency. During emergency shutdown, the blades are also moved to their most inefficient position to minimise overspeed, whilst getting the guide vanes closed as slowly as possible to minimise overpressures.

The governor oil pumps are inside the governor cubicle, as is the main distributor valve and the PLC cam which controls the blade/guide vane relationship.

8.4 Generator

8.4.1 Generator options

For the generators, conventional synchronous equipment has been assumed.

A further alternative is considered for use with propeller turbines, if selected. This is use of asynchronous (induction) generators. This type of generator is commonly used in micro hydro and wind turbine plant in sizes up to 10 MW. This type of generator could not operate alone in the Don Sahong situation because of inherent problems of voltage regulation and inrush current on start up, but could possibly be used in parallel with synchronous generators of similar capacity.

It is estimated that these generators could be up to 10% cheaper capital cost than the conventional synchronous generators. Control and protection systems would be more complex and expensive. There may be, however, restrictions imposed by EGAT or EDC when they carry out detailed system stability studies for the transmission component of the project.

Also, if one or more of the synchronous generators was off line for routine maintenance or unplanned outages, the asynchronous generator would be unable to operate.

Because of the uncertainty of acceptance by the consumer utilities, without detailed system studies, the use of asynchronous generators can not be recommended at this stage, but should be evaluated further during detailed design.

8.4.2 Generator equipment

Each generator is rated for continuous operation at 50 Hz for a power factor range of 0.85 leading to 0.85 lagging. The inertia of the generator and turbine combination will be designed to limit the speed rise of the machine to a maximum of 160% under fault conditions. The rated voltage of the generator will be selected by its manufacturer; however, it is likely to be in the range 14 to 18 kV.

The generator will be supplied complete with automatic voltage regulation, controls, metering, protection, alarms, closed-circuit cooling water system for the stator and oil systems, braking and jacking systems, lifting equipment and all auxiliaries.

Each generator will be fitted with a unit transformer and an excitation transformer. The specification will allow for the generator star point (neutral) to be either unearthed or earthed through a high impedance, depending on the generator manufacturer's recommended electrical protection design and subject to approval by the Engineer/Client. The generator stator earth fault protection scheme is selected on its ability to limit the stator fault current and prevent damage to the windings.

Generator controls will be PLC/PC based and designed so that the sets can be controlled in any one of the following ways; manual control with control of individual devices with appropriate interlocks; local automatic control utilising automatic control sequences within the PLC/PC controls, or remotely controlled from a designated system control centre. Control in this case is likely to be via an optical fibre link through one of the transmission line earth wires, with a power line carrier as a backup communication system.

Consideration will be given to the provision of a power system stabiliser in the controls during the detail design phase.

8.5 Balance of Plant

The Balance of Plant includes the main transformers, generator switchgear, the unit LV & HV connections, station AC & DC supplies and communications.

The main transformers would be located on the top level above each unit (Section 9) and be continuously rated to transfer the generator output to the 230 kV HV transmission network. As the generators are expected to operate at full load for extended periods, the transformers will be water-cooled to keep their full load losses to a minimum.

On the generator side of the main transformer the generator switchgear would be limited to one surge diverter to protect the generator from any voltage spikes and one earthing switch to ground the LV connections during maintenance access to generator. All other switchgear associated with operation and control of the generator (generator circuit breaker, isolator and HV earthing switch) would be located within the 230 kV transmission switchyard.

For unit capacities up to 40 MW the LV connections from the generator to the main transformer would be by cable, while for capacities greater than 40 MW phase isolated aluminium busbar (solid busbar) would need to be considered due to the higher generator currents involved. In all cases the HV connections between the main transformers and the 230kV transmission switchyard will be via HV cables.

Provision shall be provided to take the station AC supplies from one of the operating units. To cover emergency situations when no other supplies are available a Diesel generator will be provided for black start operation and to supply essential station services, communications, emergency lighting, battery chargers, drainage pumps, etc

The station DC supplies will comprise chargers and batteries and DC switch boards for distributing DC supplies for the control and protection of the units and the station communications systems. The batteries shall have sufficient capacity to supply normal DC loads for a period of up 8 hours.

SECTION 9

SWITCHYARD AND TRANSMISSION

9.1 Existing Transmission Grid in Champasak Province

Champasak and the other southern provinces are connected by a basic 115 kV grid (Figure 9-1). There are two main sources of energy to the southern provinces:

- from Xe Set 1 Power Station, 73 km north-east of Pakse, via a single circuit 115 kV transmission line to JiangXai switching station and thence to BangYo substation

- from Thailand (Srinigard Power Station) via a single circuit 115 kV transmission line to the BangYo substation in the south of Pakse City (this line is also used to export excess energy from Xeset 1).

There is also a 22 kV line bringing energy 34 km from the small (5 MW) Selebam Power Station to BangYo substation. This line is planned to be upgraded to 115 kV. From BangYo Substation eight 22 kV feeders supply Pakse City.

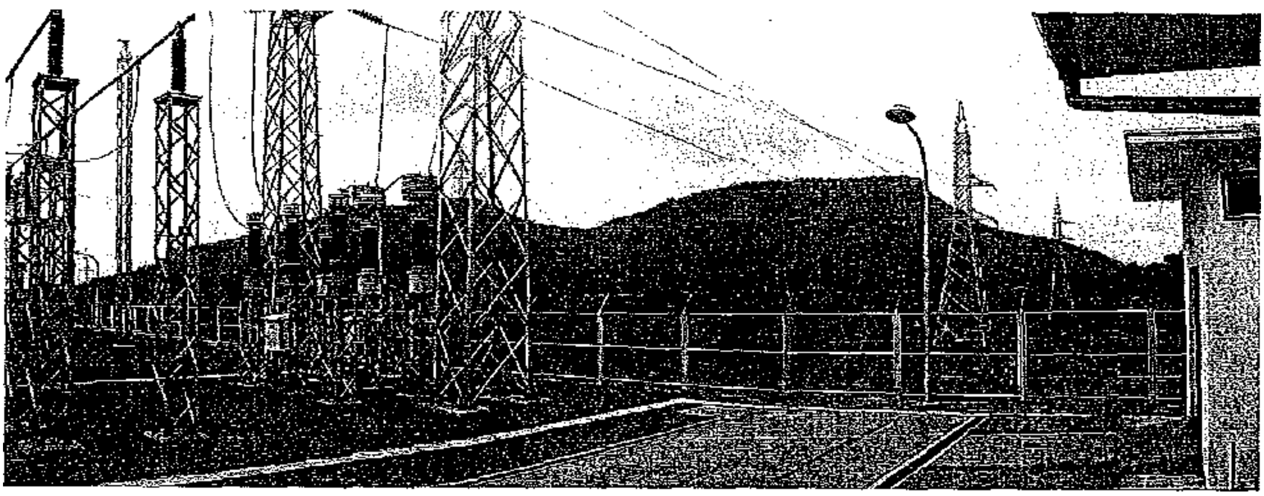


Photo 9-1 - JiangXai Switching Station, with incoming line from Xeset 1 on right

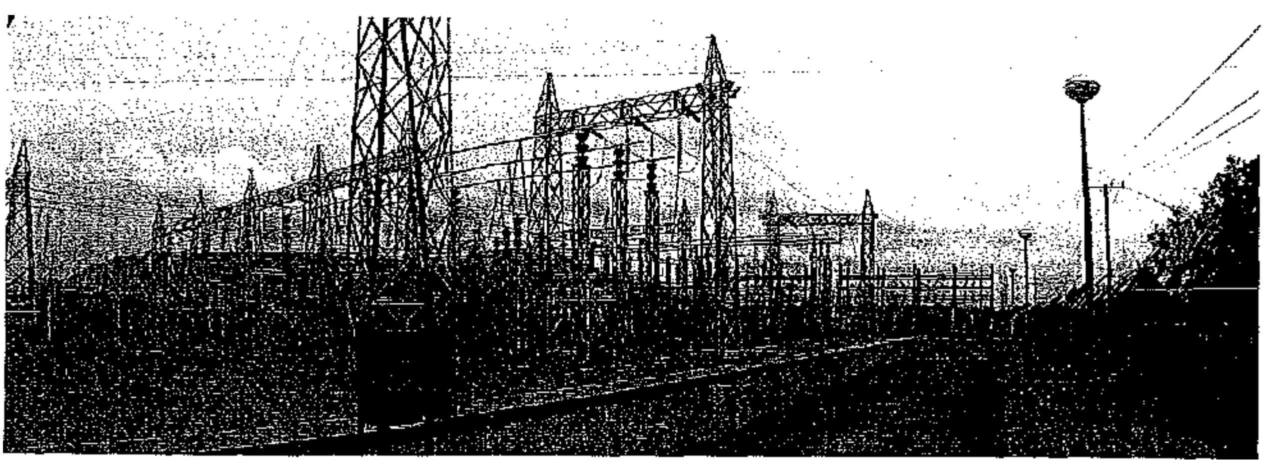


Photo 9-2 - BangYo Substation

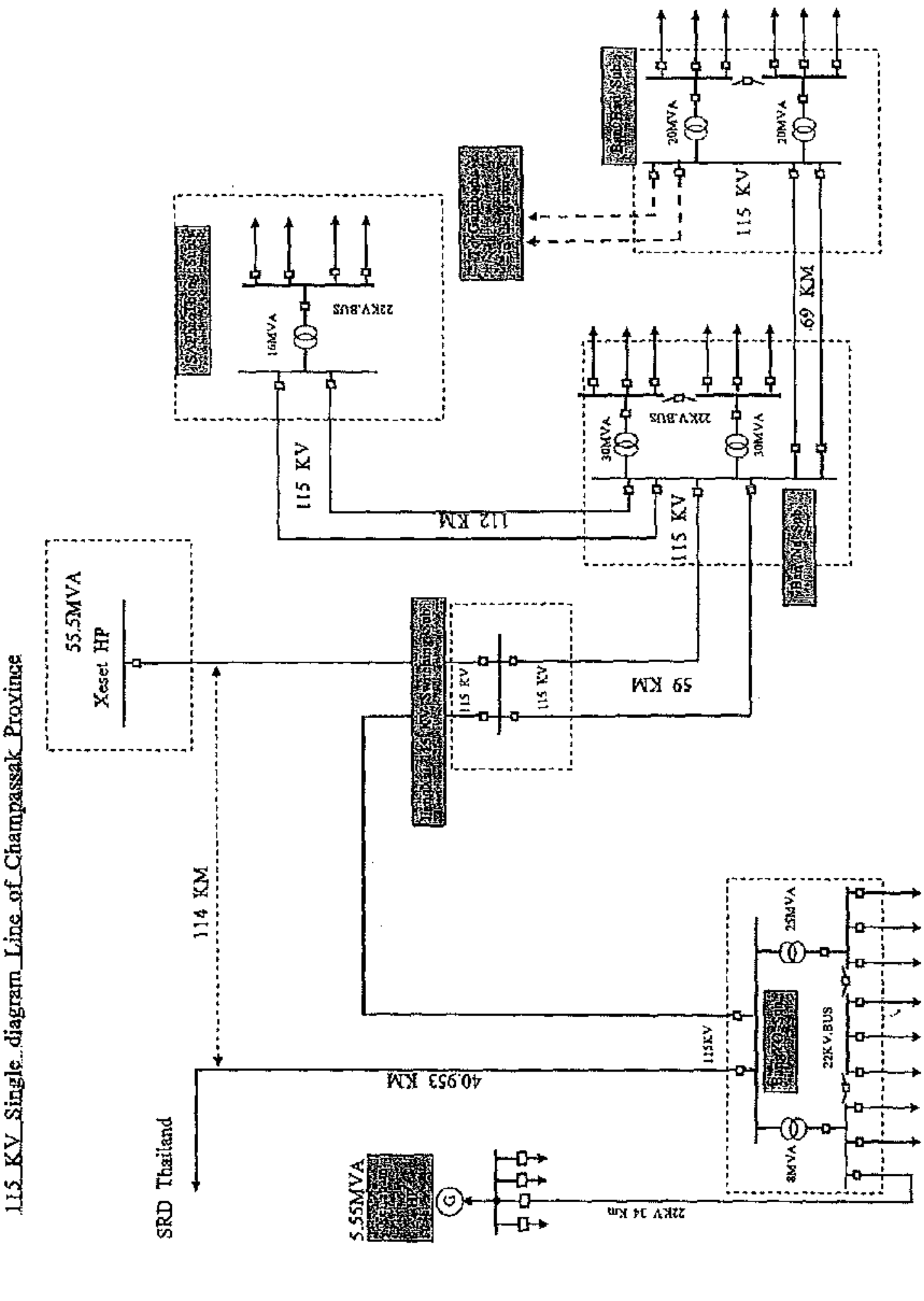


Figure 9-1 - Single Line Diagram of Southern Province 115 kV transmission grid

From JiangXai switching station a double circuit 115 kV line then runs south to Ban Na substation, on Highway 13, 60 km south of Pakse. From Ban Na, one double circuit line runs east to Attapeu, while a second double circuit line runs south to Ban Hat Substation, on Highway 13, 20 km north of the Cambodian border, where the line terminates and 22 kV distribution network serves the local area, including Khong Island, via a long span across the Mekong River left branch,

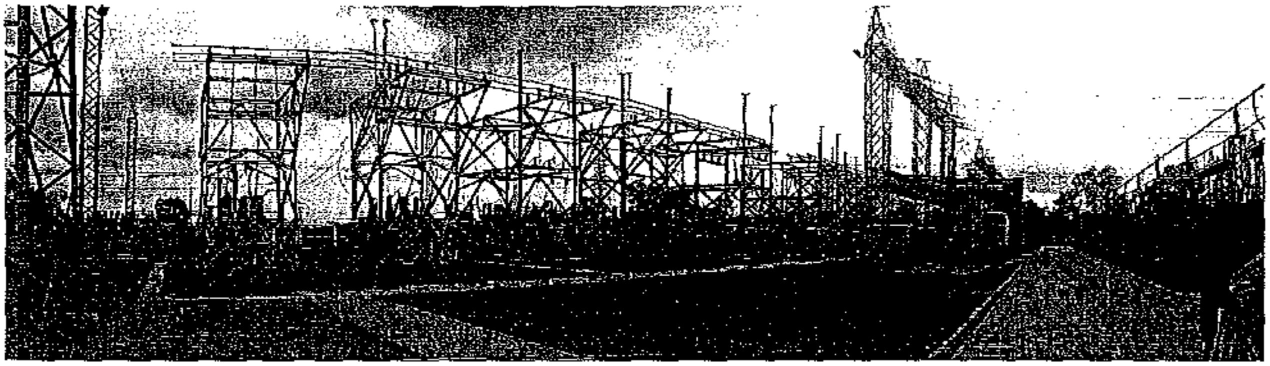


Photo 9-3 - Ban Na Substation

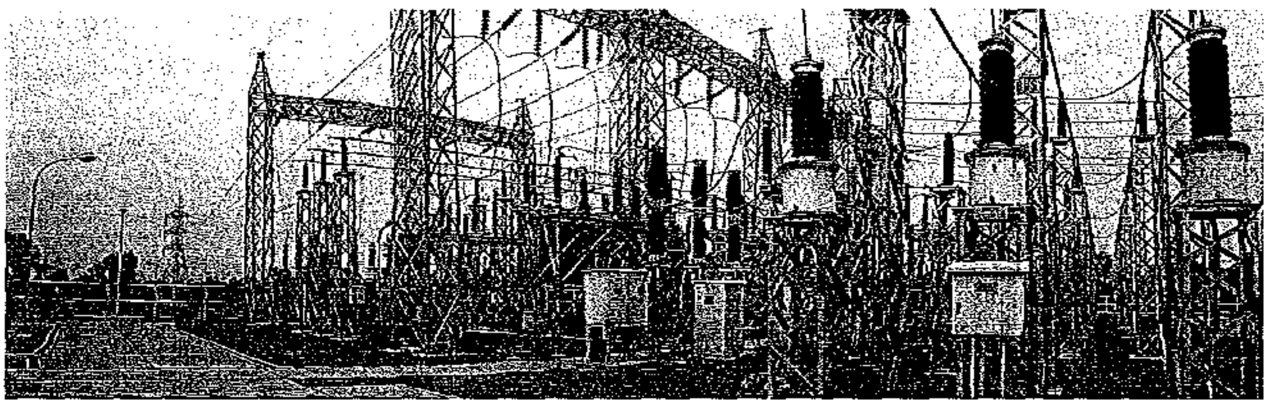


Photo 9-4 - Ban Hat Substation

Photo 9-5 - Double circuit transmission line between JiangXai and Ban Na

All the 115 kV transmission lines are strung with ACSR conductor of 240 cm^2.

Following a World Bank-funded consultancy, the Bank has, in June 2007, made a grant to GOL, together with a similar grant to the Royal Government of Cambodia, to fund construction of the extension of the 115 kV line from Ban Hat to Stung Treng. The line should be operational by 2013. The World Bank grant will also fund construction of a 115 kV Hne from Xeset 1 power station to Saravan.

Not shown on the single line diagram is a 230 kV double circuit transmission line that runs east to west across the province from Houay Ho Power Station to EGAT's Ubon substation. This line is owned and operated by the Hoauy Ho Power Company to export energy from the 150 MW Houay Ho Power Station. The Xeset 2 Power Station, presently under construction, will tap into this transmission line through new switching station near Paksong.

Other proposed transmission enhancements include a 500 kV substation at Ban Soke to collect energy from a number of planned hydropower stations in the Xe Kong and Xe Kaman catchments in Attapeu Province, and a 500 kV transmission line to Ubon 3 substation in Thailand. Figure 9-2 shows the southern portion of the EdL Long-Term Power Development Plan (October 2006) with existing and planned transmission enhancements. Don Sahong Project is not shown on this map.

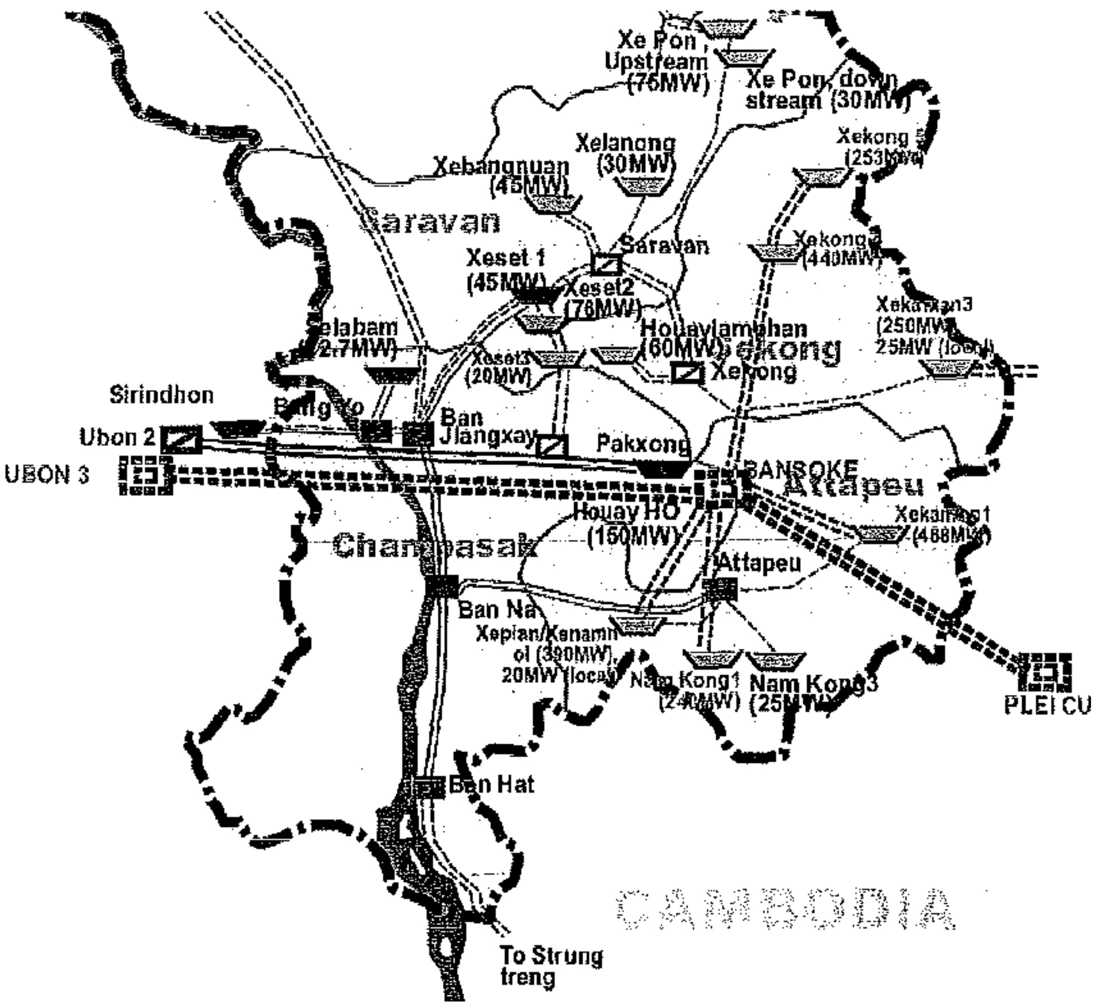


Figure 9-2 - EdL Long-term Development Plan for Southern Laos

9.2 Options for Exporting Power from Don Sahong Project

Table 9-1 shows the seven power export options considered, together with brief notes on the advantages and disadvantages of each one.

Option One provides a relatively simple and ideal technical solution because it only involves negotiating a power purchase agreement with one customer and it utilizes 230 kV which can accommodate the full 240 MW station capacity. However it is expensive because the transmission distance is approximately two hundred and fifty kilometres.

Option Two provides another 230 kV arrangement which has the advantage of costing significantly less than option one. However by the time the Don Sahong power station could be commissioned the Houay Ho transmission line will not have sufficient capacity to accommodate 240MW. It has a rating of 340 MW and is currently exporting 150 MW. In 2009 it will have to accommodate an additional 76 MW from the Xeset 2 power station. This leaves 126 MW which would have to be sold to Cambodia or Vietnam.

Option Three is a very simple option which provides unconstrained opportunities to negotiate contracts with either or both EGAT (Thailand) and EDC (Cambodia). However, *it* is totally dependent upon the future construction of the 500 kV Ubon 3 to Bansoke and Pleiku transmission line, which is currently at feasibility study stage. There isn't any 500 kV system within Lao at present so presumably it will require very rigorous financial and technical evaluation in order to justify moving to this higher voltage level. Consequently option three is totally dependant upon a decision being made to construct the Ubon 3 to Bansoke line. If it does proceed, its commissioning date would determine the earliest commissioning date for Don Sahong power station.

Option Four has a capacity constraint, because the existing 115 kV Ban Hat to Ban Jiangxay transmission line has a firm rating of only 90 MVA (80 MW maximum) which limits the export to Thailand. Accordingly this option requires an additional customer for the remaining 160 MW or the upgrading of the existing connection in order to remove the capacity constraint. If two customers were supplied then satisfactory long term contracts with similar commencement dates and preferably contract periods would need to be negotiated with both customers. This could be difficult if the two customers (countries) have different energy requirements. It isn't possible to prepare a reasonable cost estimate for this option until discussions have been held with the potential customers because their transmission line and substation design requirements will be determined by their energy needs..

Option Five is a medium cost and technically straightforward solution. Its cost could be reduced if EDC build the section of the transmission line within Cambodia. However, there is no indication that EDC has a requirement in the near future for 240 MW at Steung Treng. EDC may be interested because their transmission development plan does provide for a double circuit link to Siam Reap and 230 kV transmission line to Kratie and on to Kampong Cham and Phnom Penh as well as an incoming supply from EVN and potential hydropower stations in Stung Treng and Ratanakiri Provinces.

Table 9.1 - Power Export Options

Route	Advantages	
To Thailand:		
1 Construct a 230 kV line from DSHEP northto Pakse, generally following the route of the existing 11 5 kV line and then westtoUbon, following the existing 230 kVline from HouayHo.	Dedicated line	Length (250
2 Constructs 230 kV line from DSHEP northto Pakse, generally following the route of the existing 115 kV line and connect to HouayHo 230 kVline via a simple switching station	Lower construction cost	Possible lim li ne, as it n o Xeset 2 pow
3 Construct a 230 kVline from DSHEP northto Pakse, generally following the route of the existing 11 5 kV line and connect to the proposed 500 kV line from BansoketoUbon3 via a simple switch in q station	Lower construction cost (but not aslowas2)	Unknown da Ubon 3
4 Transmit at 115 kV along existing line to Jiang Xai (East of Pakse) and then conned to Houay Ho 230 kVorBansoke500kV(asin2 and 3)	Very lowcapital cost (DSHEP to Ban Hat- 20 km) Would help EdL stabilise their Jiang Xai-Ban Na-Ban Hat line	Existing 115 capacity, so
To Cambodia:		
5 Construct a 230 k V line direct to Steung Treng	Medium construction cost, verylowif EdC build line within Cambodia	EdC doesn medium term Their transm show230k 230 kV sc s supply from
To Thailand and Cambocia		
6 Construct 115 kVline DSHEP to Ban Hat and transmit to Thailand as in 4 and Cambodia as in 5 (but **at 115** kV)	Low construction cost Existing line Ban Hat-Jiang Xai has sufficient capacity, defending requirements Newline Ban Hat- Steung Treng could be desiqnedto suit the load	N egotiatin g each m ay h Duplicate m
To Vietnam		
7 Construct 230 kVline to proposed Bansoke Substation	Could also be attemate route for option 3	Long distan

Option Six has the same capacity constraint as option four because the existing Ban Hat to Ban Jiangxay 115 kV transmission line limits the future export to Cambodia to 80 MW and so this option would require either the upgrading of this connection or another customer to take 160 MW. If two customers were supplied then satisfactory long term contracts with similar commencement dates and preferably similar contract periods would need to be negotiated with both customers. This could be difficult if the two customers (countries) have different requirements. As construction of the Ban Hat -Stung Treng 115 kV line has now been funded by World Bank and Cambodia has only a small demand in the foreseeable future, there is no need for the project to construct a transmission line to Stung Treng. It isn't possible to prepare reasonable cost estimates for this option until discussions have been held with the potential customers because their transmission line and substation design requirements will be determined by their energy needs.

Option Seven is the least attractive as it involves a long distance over rough terrain. However, approaches have been made on behalf of the Xepian-Xenamnoi project whereby the line would only be built as far as their project and they would build to the line to Ban Soke. The basis of this approach is that a minimum of 1,000 MW of supply capacity is needed before the Ban Soke to Ubon or Ban Soke to Pleiku (in Vietnam) would be justified.

9.3 Power Station Substation Options - (6 x 40 MW Power Plant)

The design of the transmission system and the substation is based on a transmission voltage of 230 kV with a double circuit transmission line connection.

The following are two practical design options for the power station substation:

- A land-based substation located on the western bank adjacent to the power station.
- A 230 kV switchyard located on the western bank adjacent to the power station and the transformers located on the top of the power station.

a Land-based substation

The first option requires an area of 100 metres by 65 metres and has three 100 MVA, 3-phase transformers which are connected to the units via a MV busbar (at generator voltage) arrangement utilizing SF6 switchgear. The generating units are connected to the substation by cables installed in a large cable duct which runs from the eastern end of the substation building to the western end of the power station machine area. The transport weight of the 100MVA transformers is 95 tonnes and their installed weight is 115 tonnes each. This option provides the following supply security features:

- In the unlikely event of a transformer failure, the station output is only reduced by a third of its total capacity.
- Supply to the station transformer can be maintained when any section of the MV system is withdrawn from service.

Alternatively the three transformers could be replaced with a single 300MVA unit. This would reduce the space required but in the unlikely event of a transformer failure all generation is lost. Generator transformers tend to be very reliable because they are never subjected to overload, however in the unlikely event of a fault, repairs can take a considerable time and so the risk of losing all generation for such a time makes the three transformer arrangement preferable. Also transporting a 300MVA unit to this site could be more difficult than transporting three fighter and smaller 100MVA units.

b Transformers on Power Station

The second option requires an area of 100 metres by 68 metres for the switchyard and a reasonable amount of space clear on the deck of the station for other activities and equipment. In this option all 230 kV switchgear and associated equipment are located in the substation and are connected by cables to the six 50 MVA generator transformers each positioned on the top deck of the power station above their respective machines. The control room is located within the power station. The transport weight of the 50 MVA transformers is 48 tonnes and their installed weight is 60 tonnes each. In the event of a transformer failure, the station output is only reduced by one sixth of its total capacity. The single line diagram is shown in Figure 9-3 and the switching station layout on Figure 9-4.

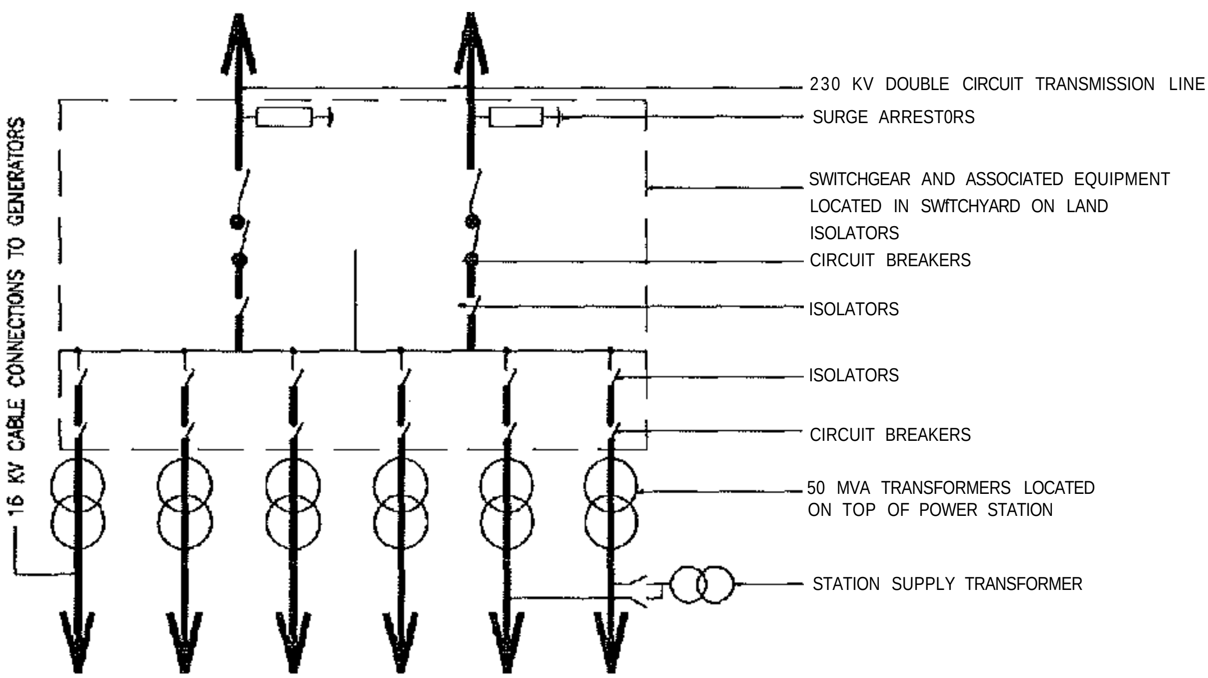


Figure 9-3 - Single line diagram for transformer connection to transmission line

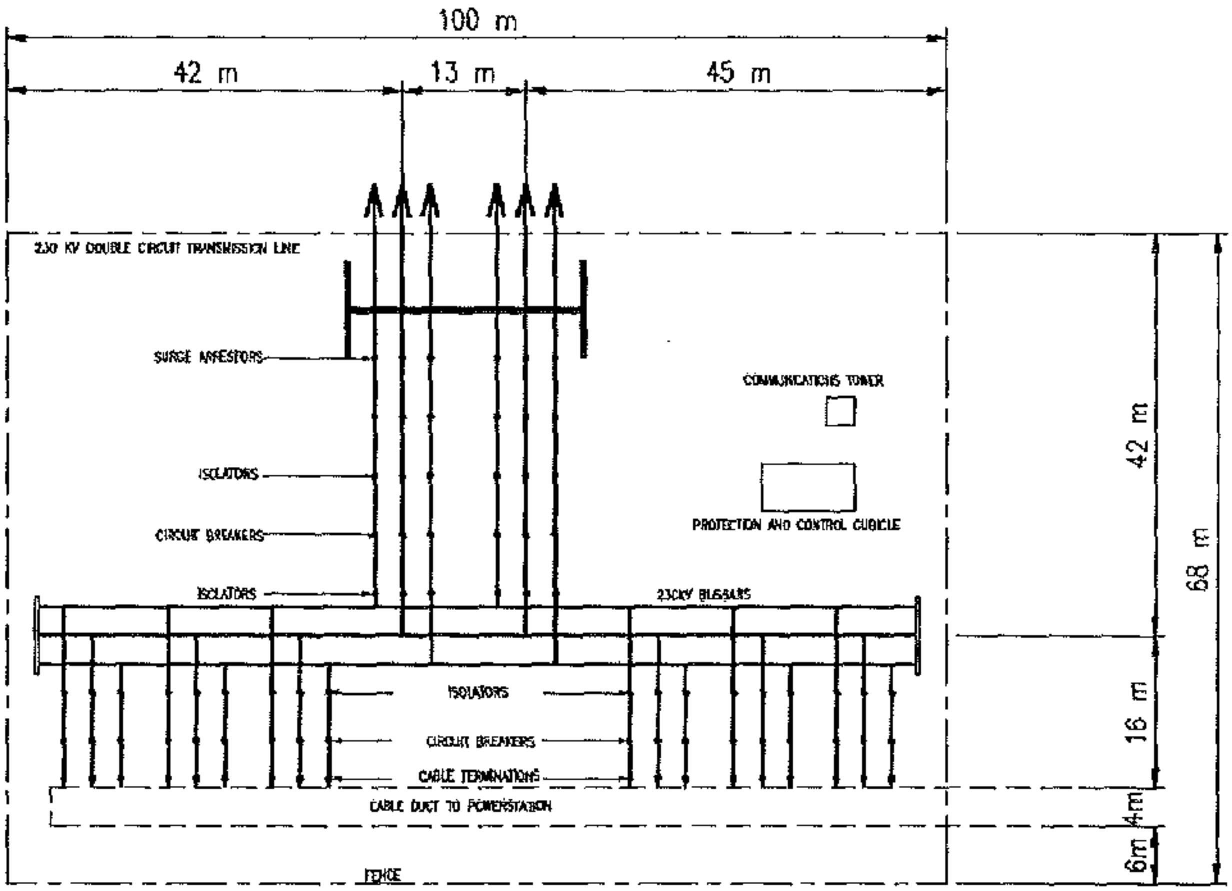


Figure 9-4 - Substation layout

The transformer on the power station option was selected because of the higher security of supply. There is no significant difference in costs between the alternatives.

9.4 Transmission Connection to Ban Hat Substation

The route and connection arrangements for the transmission line are the same for both the substation design options. It is double circuit conventional lattice tower design identical to the recently commissioned 230 kV lines in the Lao PDR.

The transmission line will exit the power station substation (or in the case of option two, the switchyard) on Don Sahong Island and follow a north westerly direction to the northern end of the island and then cross the Mekong River to Don Tan Island. It will then continue in a north westerly direction until it crosses the Mekong River again to the mainland near Ban Nakasang and on to Ban Hat substation, the present terminal substation on the 115 kV line from Pakse.

In the case of export options one, two, and three the line will then go direct to Ban Na substation and then onto Pakse following the route of the existing 115kv transmission line. In export option five the line would go from Ban Nakasang in a southerly direction to Stung Treng in Cambodia.

9.5 METERING

It is not appropriate to determine the metering energy metering requirements until one of the export options is selected and the consumers demand and energy requirements are determined. Also the capital cost of the metering equipment is relatively insignificant and its location is immaterial at this stage.

9.6 REGULATORY ARRANGEMENTS

The following two documents cover the technical regulatory requirements for the design, construction and operation of transmission assets within Lao:

- Lao Electric Power Technical Standards 2004
- Draft Grid Code

The first document specifies the minimum design criteria for both overhead and underground cable transmission systems together with installation requirements, protection against lightning and trees, protection of communication systems against interference from induction, etc. Its provisions are consistent with contemporary practice of well developed western countries.

The draft grid code is expected to be formally adopted in the near future. It specifies:

- The performance standards required of the grid owner, system operator and all users.
- The criteria and requirements for the planning and development of the transmission system,
- The design and construction criteria, procedure and requirements for users connection to the grid.
- The procedures and requirements for the operation of the grid.

The requirements of this document on the owner of transmission assets appear quite realistic; however, a more thorough review of the final formalized will be required.

9.7 ENVIRONMENTAL REQUIREMENTS

The environmental and social impact requirements are covered in the official government document, *Environmental Management Standard for Electricity Projects.* It primarily focuses on the social impact of electricity projects and covers the following five major areas:

- Environmental Screening
- Social Impact Assessment
- Resettlement
- Environmental Guideline for Socio-Economic and Culture
- Responsibilities

9.8 WAYLEAVES

Procurement of the necessary wayleaves for the transmission line is expected to be a relatively straight forward process because private individuals do not have title to the land on which they live or conduct commercial or farming activities.

The terrain to be traversed is flat and generally unoccupied and undeveloped with the exception of a few rice growers who could still continue farming under the transmission line. Accordingly there would be very few if any relocation or compensation issues.

9.9 CONSTRUCTION

Construction of the transmission line on the mainland should be relatively straightforward because the terrain is very flat and there is good road access in the near vicinity for the entire length of the route. All tree and vegetation removal could be handled economically with mechanical plant.

Construction of the substation and the section of the transmission line on the island will be more difficult due to the need to transport some large and heavy components to the site. However the transformers, which are the heaviest items, are nonetheless lighter than some of the power station components.

SECTION 10

CONTAINMENT EMBANKMENTS

10.1. General

Based on the information obtained from the various river level gauges, the maxinuim river level at the entry to Hou Sahong is RL 74.00 and this will be the level of ponded water. Accordingly, the crest level of the main dam has been set at RL 75.0

However the topography on both Don Sadam and Don Sahong is such that the land in much of the downstream area is below this level. Accordingly, "Containment Embankments" will be required to confine flow to the Power Station and prevent spillage to adjacent catchments.

Three embankments will be required as shown on Figure 5.3. For convenience they have been designated as follows:

(i) Right Bank Containment Dam

This dam will connect to the right-hand end of the Power Station and extend for approximately 1,820 m to merge into the RL 75 contour. The height will vary from a maximum of 8 m and for most of its length will be less than 3 m high.

(ii) Left Bank Containment Dam

This dam will connect to the left-hand end of the Power Station and extend for approximately 720 m to merge with the RL 75 contour of the prominent hill feature on the left bank. The height will vary from a maximum of 12 m to less than 3 m.

(iii) Left Bank Saddle Dam.

This saddle dam will extend from the northern side of the hill feature and extend for approximately 2,730 m to merge with the RL 75 contour. The height will vary from a maximum of 7 m and for most of its length will be less than 4 m high.

10.2. Embankment Design

As stated in Section 5, availability of suitable construction materials will impose constraint on embankment design. The following designs have been considered:

(a) Rockfill dam with clay core.
(b) Rockfill dam with an upstream concrete face slab (concrete face rockfill or CFRF)
(c) Rockfill dam with central concrete membrane
(d) L-shaped concrete retaining wall, possibly with rockfill embankment to enhance stability.

Alternative (b) is the preferred design due to ease of constmction and the plentiful supply of rockfill from required excavation. The embankment section, with crest width of 10 m and upstream and downstream slopes of 1.5:1 is shown on Figure 10-1. As the embankment height decrease, the section will change to the fourth alternative, the L-shaped wall.

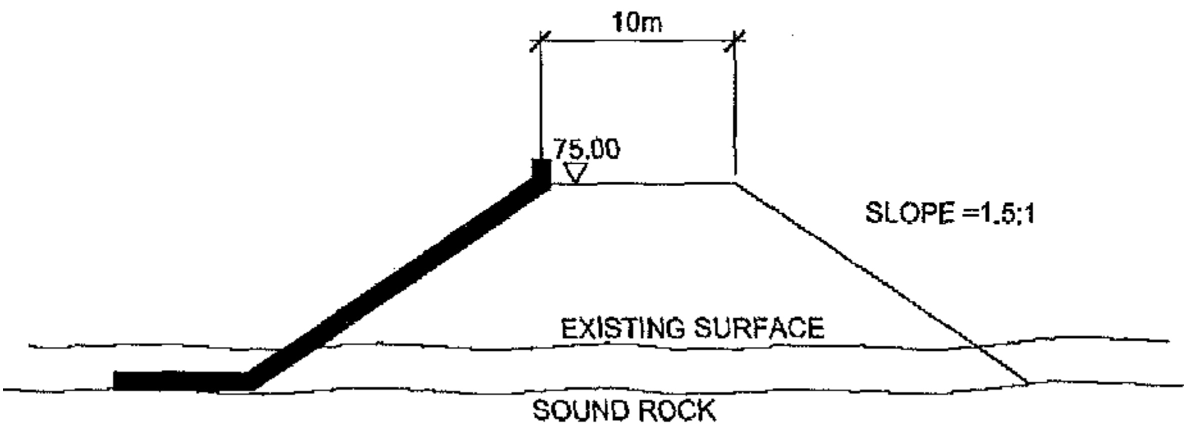


Figure 10-1 - Embankment Cross-section

10.3. Permanent Access Road

The permanent access will be aligned to utilize the crest of the Left Bank Saddle Dam and the Left Bank Containment Dam.

10.4. Gully Crossings

The Left Bank Containment Dam and Right Bank Saddle Dam will cross existing gullies. To avoid ponding of rainfall run-off, it is proposed to backfill the area of these gullies upstream of the embankments and to suitable grade the surface of the backfill to merge with adjacent contours. Backfill material will be obtained from the soil and weathered material stripped from embankment foundations.

This backfilling will also create level ground where local villagers may get land to replace land alienated by the project.

SECTION 11

ENERGY STUDIES

11.1. Introduction

The objectives of the energy studies were to:

- Identify factors controlling the head and flow available for energy production.
- Quantify the impact of different environmental flow scenarios on the energy potential from the project.
- Identify the impact of different combinations of unit size and station capacity in the power potential of the project.

This energy study used a daily simulation model to assess the energy potential under a range of operating scenarios to identify the key aspects affecting the energy potential of the proposed Don Sahong Hydropower project in Lao PDR.

The key findings of this study are that

- The Don Sahong site is suitable for a run-of-river hydropower project.
- The energy output from the project shows a pronounced seasonal variability following the low flow and flood seasonal variations of flow in the Mekong River.
- The existing Hou Sahong River channel restricts the flow available for energy production. This can be resolved by excavating a channel at the entrance to Hou Sahong to increase the volume of water that can be diverted from the Mekong River. The entrance channel should be excavated to at least EL 66 m. Additional excavation increases the energy potential. The tailwater channel between the power station and the main Mekong River should be excavated to improve flows and increase the net head available for energy generation.
- An allocation of water to maintain environmental flows over the Phapheng Falls and to provide for fish migration is required. The minimum daily dry season flow at Pakse in the period of the study was 1060 m^3/s. Environmental flows in the range 800 m^3/s to 1400 m^3/s were examined. Environmental flows in excess of 1000 m^3/s result in the station being unable to operate during some periods in the low flow period.
- The power station structure and the head pond retaining embankments must be designed to withstand a water level of at least EL 75 m if a control structure at the entry to Hou Sahong is to be avoided. A higher level would increase the factor of safety against overtopping in extreme floods. A lower level embankment is possible,

but any reduction below EL 73 m reduces the annual energy potential.

- Power station capacities of between 180 and 360 MW are possible at Don Sahong. Larger power stations up to 400 MW are possible with significant widening of the downstream reaches of Hou Sahong. Unit sizes in the range 30MW to 60 MW can operate with satisfactory efficiencies over the full operating range expected at the site provided adjustable blade turbines are used. These could be either bulb or Kaplan units, although the limited width of the channel restricts the use of Kaplan units.

  An alternative arrangement for the larger stations greater than 300 MW would be to provide adjustable blade units capable of passing the dry season flow and fixed blade propeller units to pass some of the wet season flows

  The capacity of the power station will reduce whenever the available turbine head drops below the design head. This will occur in the flood season when the tailwater level rises significantly at high Mekong River flows.

  There is no advantage in increasing the design head beyond 17 m because most of the energy is generated at lower heads in the wet season.

- Climate change is not expected to have a significant impact on annual energy potential because flood season flows will remain significantly greater than the power station flow requirements. A reduction in dry season flows will be offset by the construction of new storage hydro projects on Nam Theun and Nam Ngum. These projects will regulate wet season flows for release in the following dry season improving the potential energy production from Don Sahong. Any increase in dry season Irrigation from the Mekong or its tributaries will reduce the water available for power generation from Don Sahong

  While the results tables show the results of all simulations carried out for this study, it has been necessary when commenting on these results to pick a typical case for comparison. This case was a 300 MW station with an environmental flow of 1000 m^3/s and a design head of 17 m. The selection of this case does not mean that it will prove to be the most economic size or that it will be the finally recommended scheme for detailed design

11.2. Energy Model

A customised spreadsheet was set up to model the Don Sahong Project. This allows a flexible examination of the project without constraints imposed by the modelling software. Nevertheless, the model is eventually constrained by the computer and the version of Excel being used. The model is currently around 100 Mb in size. The model uses daily flow data over the period 1924 to 2006 giving a representative sample of flows for the energy evaluation.

The model has been based on run-of-river models used over the past 10 years and does not consider the impact of changes in storage. This is appropriate for Don Sahong where the maximum storage available represents less than 1/2 hour full load generation for a 300 MW installed capacity during the dry season.

The model evolved during the study to take advantage of additional data as they became available and to allow the impact of specific issues to be studied more closely. Versions A and B of the model were used for the Appraisal study in May-June 2006 while versions C to N were used for this feasibility study.

The key features of each version are listed below.

- **Version A** This used four years of data, an average turbine efficiency and an environmental flow defined as a percentage of Pakse Flows
- **Version B** A constant environmental flow was added
- **Version C** A unit efficiency table was added varying efficiency with unit flow and turbine head. Tailwater levels were based on Veun Kham
- **Version D** Data was extended to 1926 to 2005 and tailwater levels were based on Hou Sahong gauge
- **Version E** Tailwater estimates were extended to include Hou Sadam as well as Hou Sahong, Headwater levels were derived from Khone Tai and Thakho gauges
- **Version F** The model was extended to allow unit overload when head exceeded rated head. This was not used because surplus water only existed when heads were less than rated head
- **Version G** Hou Sahong Headlosses were adjusted based on the preliminary results from HECRAS hydraulic modelling and varying with discharge
- **Version H** Data was extended to include 1924 to 2006 and summary spreadsheet was prepared based on new Pivot Tables
- **Version I** Not produced to avoid confusion between I and 1
- **Version J** Efficiency table extended downwards to 50% rated head and 10% rated flow
- **Version K** Peak generation introduced and tailwater rating improved based on river level and flow in tailrace.
- **Version L** Hou Sahong headlosses modified based on entrance velocity allowing channel excavation to be included
- **Version M** Secondary Propeller units added to powerstation Pivot tables modified to include secondary powerstation Frequency duration curves added to model for key variables
- **Version N** Power station relocated further downstream reducing tailwater levels slightly
- **Version O** Not produced to avoid confusion between O and 0
- **Version P** Thakho estimated flows added to model with option of flows in Thakho-Sahong section of cascade being used to limit environmental flows and station flows

11.3. Results of the Modelling

It is not practicable to include all the results from the model in this report. A typical complete output and a series of summary tables are included in Appendix D. The summary spreadsheet was limited to the monthly energy values and the key parameters which were saved during the modelling carried out for this report.

Tables D.IA and D.IB in Appendix D show typical results from the model. In this case the simulations were for 6x60 MW bulb units and 3x50 MW bulb units with 3x50 MW propeller units respectively with an improved river channel and a maximum pond level of 75m.

Tables D.2 and D.3 consider the impact of installed capacity and environmental flows on annual energy potential for the existing river channel in Hou Sahong and the improved channel respectively for a range of rated heads.

Tables D.4 to D.7 consider the impact of different dam crest levels on the energy potential from a. 240 MW power station for a range of environmental flows and rated heads.

Table D.8 summarises the impact on annual energy potential of operating the power station as a peak load station instead of on a continuous basis. These results should be derated to allow for the drawdown of the pondage when inflows are low. Unfortunately the present daily model is unable to quantify the degree of energy reduction because the degree of reservoir drawdown is a function of inflow, storage availability and the number of hours of peaking generation desired..

Table D.9 considers the impact of lowering the entrance channel elevation on the energy potential of a 400 MW power station generating peaking power output These results should be derated to allow for the drawdown of the pondage when inflows are low..

Table D.10 examines the implications of reducing the total flow at Pakse by 10% such as might occur with climate change in the future.

Table D.ll examines the effect of substituting vertical axis Kaplan units for the horizontal Bulb units in the main station.

Table D. 12 examines the energy implications of a station combining double regulated bulb turbines with lower head propeller turbines for supplementary wet season generating capacity.

Table D.13 examines the energy implications of basing energy estimates on Thakho/Sahong flows rather than the full Mekong flows at Pakse. Neither this nor the previous cases specifically allows for inflows between Pakse and the project site since these have not been measured-
Table D.14 shows the impact of channel excavation level on the energy potential from a station with 1000 m^3/s environmental flow operated to generate base load energy for a range of station capacities

11.4. Comments on the Results from the Energy Model

11.4.1. Reliability of Supply

The value of a hydropower station to an electrical power network is closely linked to the reliability of supply as well as the characteristics of the grid, A run-of-river project such as Don Sahong is unable to call on stored water to regulate wet season surplus flows into the following dry season to improve the reliability of supply.

Factors affecting the reliability of supply at Don Sahong include the following:

- Availability of head for generation

- Availability of water for generation
- Availability of plant for generation

The turbine head is governed mostly by the seasonal flows in the Mekong River. The head is greatest in the dry season when the tailwater level is lowest and reduces as the flood season approaches. Figure 11.1 shows the variability of the monthly average turbine head over the period of the analysis. The head also varies with the flow down Hou Sahong which makes it sensitive to environmental flows and station installed capacity. On a daily basis the range is greater than shown on the plot with a range between 12.11 m and 23.4 m for the 300 MW case.

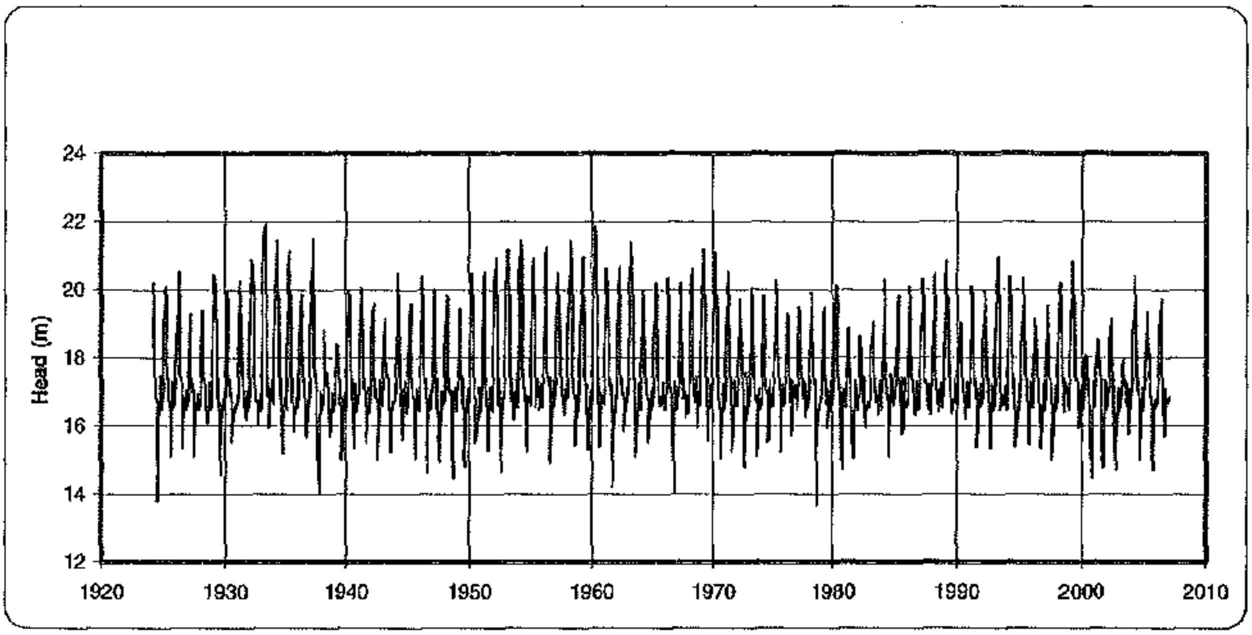


Figure 11.1 Variation of Monthly Average Turbine Head at Don Sahong

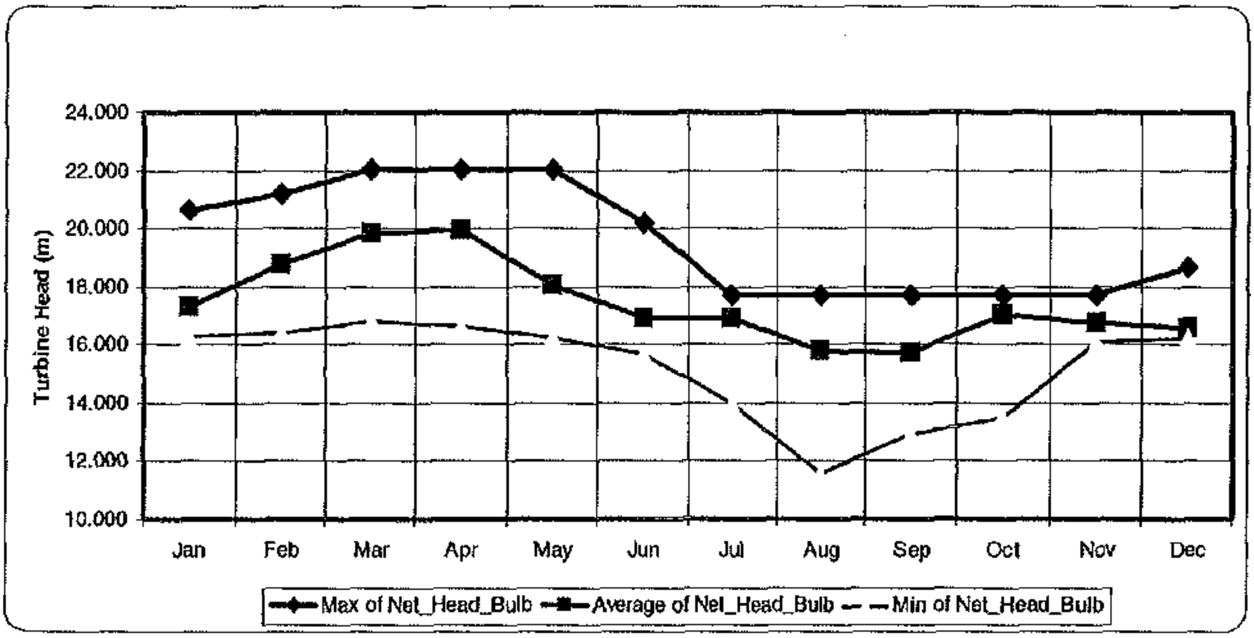


Figure 11.2 Monthly Pattern of Turbine Head at Don Sahong

Water availability is limited by the flow in the Mekong River and the environmental flow allocation. The minimum daily Pakse flow in the period of study is 1060 m /s, while 1580 m^3/s is exceeded 95% of time and 1780 m^3/s for 90% of time. Environmental flow allocations greater than this will result in no flow available for power generation on that day. The highest daily flow was 57,800 m^3/s which is much greater than anything being considered for the power facility. The seasonal variability of flows through the power station and water available from the Mekong River are shown on Figure 11.3. This graph highlights the seasonal variation in turbine flow assuming 1000 m^3/s environmental flows. Note, however, that the maximum water available curve reflects the flow at Pakse and, as discussed in Sections 3.5 and 3.6, the flow at Thakho is only a fraction of the Pakse flow, a large fraction in the low flow season, but a significantly lower fraction in the high flow period when the bulk of the Mekong flow discharges down the western (Cambodian) side of the river.

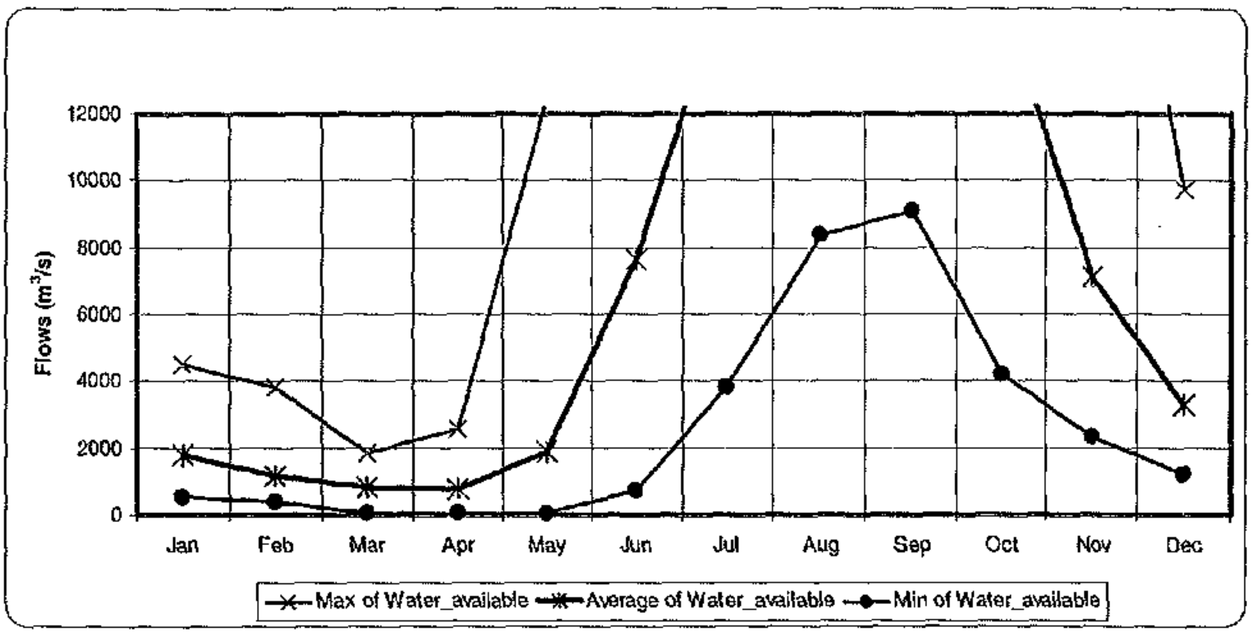


Figure 11.3 Monthly Pattern of Water Available at Don Sahong

Another factor limiting the water available for power generation is the capacity of the entrance channel into Hou Sahong. This will vary depending on the depth and width of the entrance channel excavation.

Plant availability depends on the water and head available remaining within the limits of operation of the selected turbines. Plant can also be out of service for either scheduled or unscheduled maintenance. The more units installed, the less the impact of having a unit out of service. It is expected that scheduled maintenance would be carried out in the low flow season when the remaining units can pass the available flow without loss of energy.

An acceptable level of reliability for a run-of-river power station is usually taken to be about 90% to 95% of the time depending on the reserve power available in the power system. Dry season energy shortfalls must be made up by alternative energy sources such as thermal or other storage based hydropower plant.

An alternative indication of the reliability of energy production can be seen from Tables 11.1 and 11.2 and Figures 11.4 and 11.5 which show the seasonal variation of energy production from a 300 MW power station with an environmental flow of 1000 m^3/s. It is clear from these plots that there is a wide variation from year to year. The annual variability is best seen from Figure 11.6 which shows the annual energy potential for the same power station over the 1924-2006 analysis.

Table 11.1 - Monthly Energy Capability for 300 MW Installed Capacity (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Average	185.6	129.5	105.9	97.8	163.0	,205.7	218,0	204.0	197.0	219.3	207.5	206.2	2140.2
Maximum	207.4	185.3	171.3	169.8	212.6	214.9	222.1	222.1	214.9	222.1	216.6	211.0	2349.8
Minimum	100.3	63.4	23.0	13.3	42.7	183.0	200.8	164.2	165.9	203.2	200.9	184.3	1769.6
Median	195.4	136,6	109.4	96.9	172.3	207.5	219.4	204.6	198.6	220.3	207.5	207.0	2169.9
95% Exceedance	140.7	80.2	58.3	36.2	83.9	189.8	211.2	186.5	175.9	212.9	202.2	199.3	1913.6
90% Exceedance	151.4	88.1	66.2	50.3	116.7	197.2	213.3	189.5	182.0	215.2	202.8	201.1	1933.8

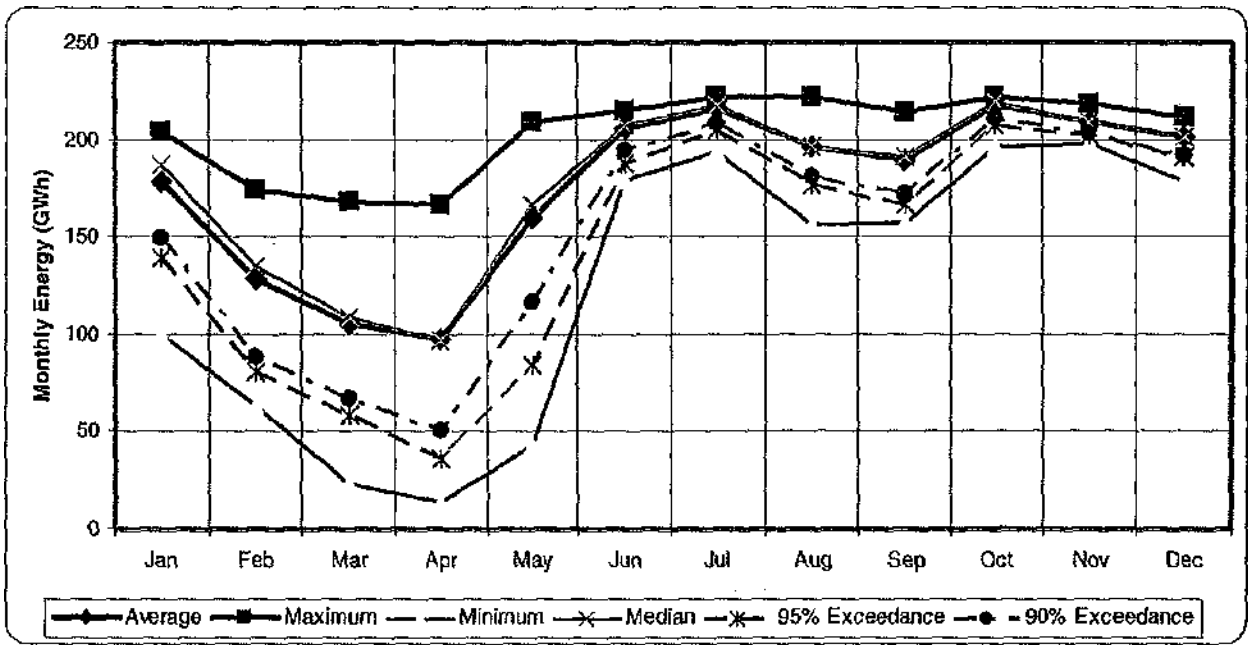


Figure 11.4 Seasonal Variability of Energy Potential - 300 MW Capacity

Table 11.2 • Seasonal Variation in Head, Water Availability and Generation Capacity (300 MW)

	Unit	Jan	Feb	Mar	**Apr**	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Maximum Net Head	m	20.7	21.2	22.0	22.0	22.0	20.3	18.2	18.2	18.2	18.2	18.2	18.9	22.0
Average Net Head	m	17.5	18.9	19.9	20.0	18.3	17.6	17.4	16.0	16.0	17.5	17.7	17.1	17.8
Minimum Net Head	m	16.6	16.6	16.7	16.6	16.6	15.9	14.1	11.8	13.1	13.6	16.3	16.6	11.8
Maximum Water available	m^3/s	1987	1987	1850	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987
Average Water available	m7s	1671	1153	815	780	1428	1960	1987	1987	1987	1987	1987	1964	1647
Minimum Water available	m^3/s	550	370	60	60	60	720	1987	1987	1987	1987	1987	1192	60
Maximum 24„hour Capacity	MW	282	281	276	278	300	300	300	300	300	300	300	300	300.0
Average 24_hour Capacity	MW	250	192	143	137	220	287	295	276	275	296	290	279	245.5
Minimum 24Jiour Capacity	MW	101	69.7	11.3	11.3	11.3	131	232	163	203	219	278	201	11.3

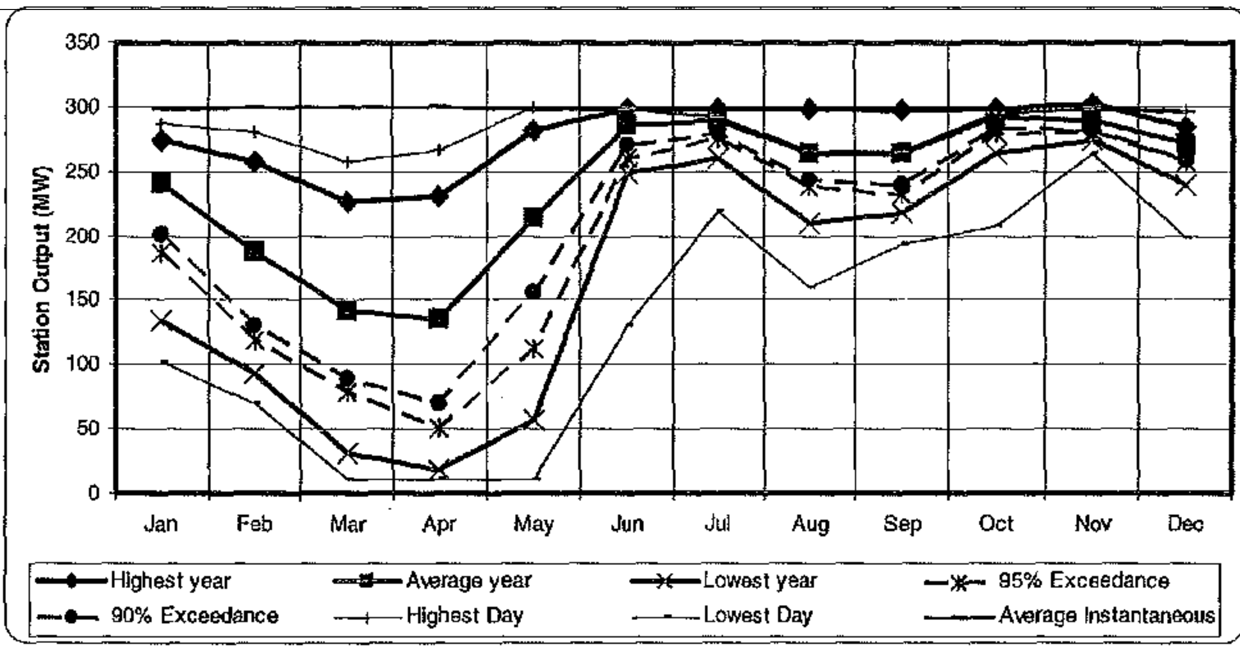


Figure 11.5 Seasonal Variability of Station Capacity - 300 MW

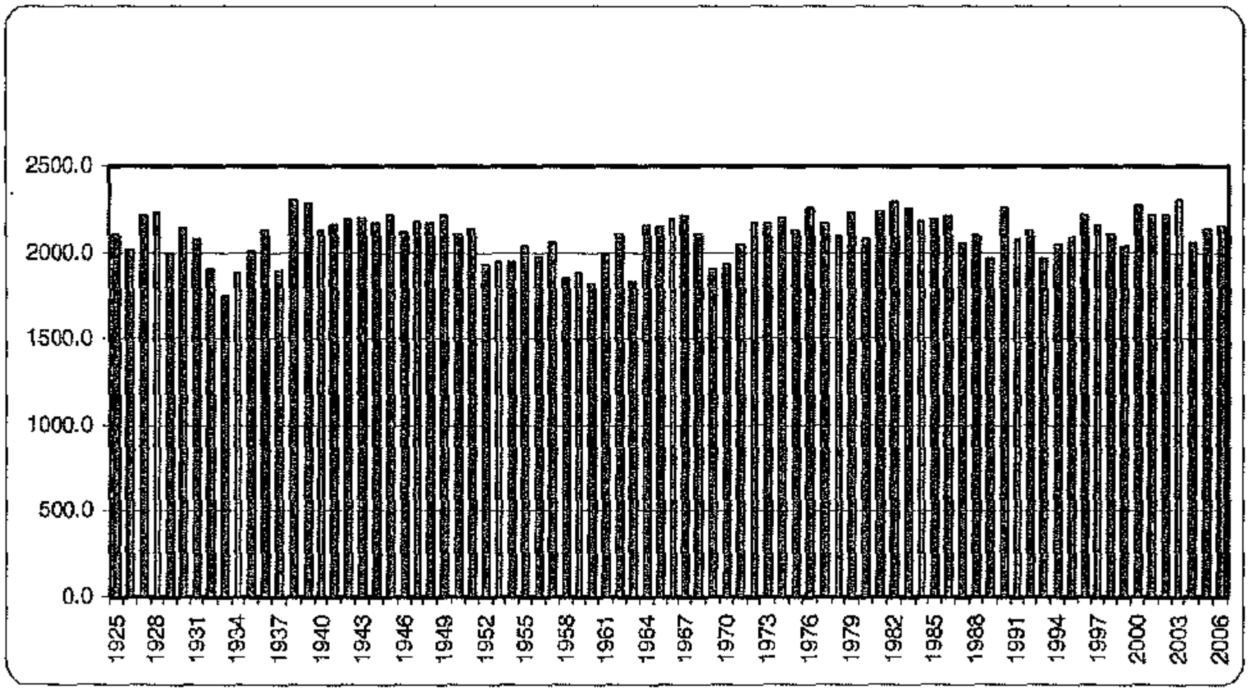


Figure 11.6 Annual Variability of Energy Potential - 300 MW Station

11.4.2. Effect of Installed Capacity

It can be seen from Tables D.2 to D.10 that an increase in installed capacity results in better use of flood season water and a corresponding increase in energy as shown in Figure 11.7. Larger units have no impact on dry year performance in the dry season, but may produce a slight improvement in wet years.

Figure 11.8 shows the seasonal effect on energy potential for different station capacities assuming the environmental flow is 1000 m^3/s. The small increment for the 400 MW station is brought about by high headlosses in the entrance channel to Hua Sahong. The energy output from this case can be improved by increasing the channel excavation as shown on Table D.8.

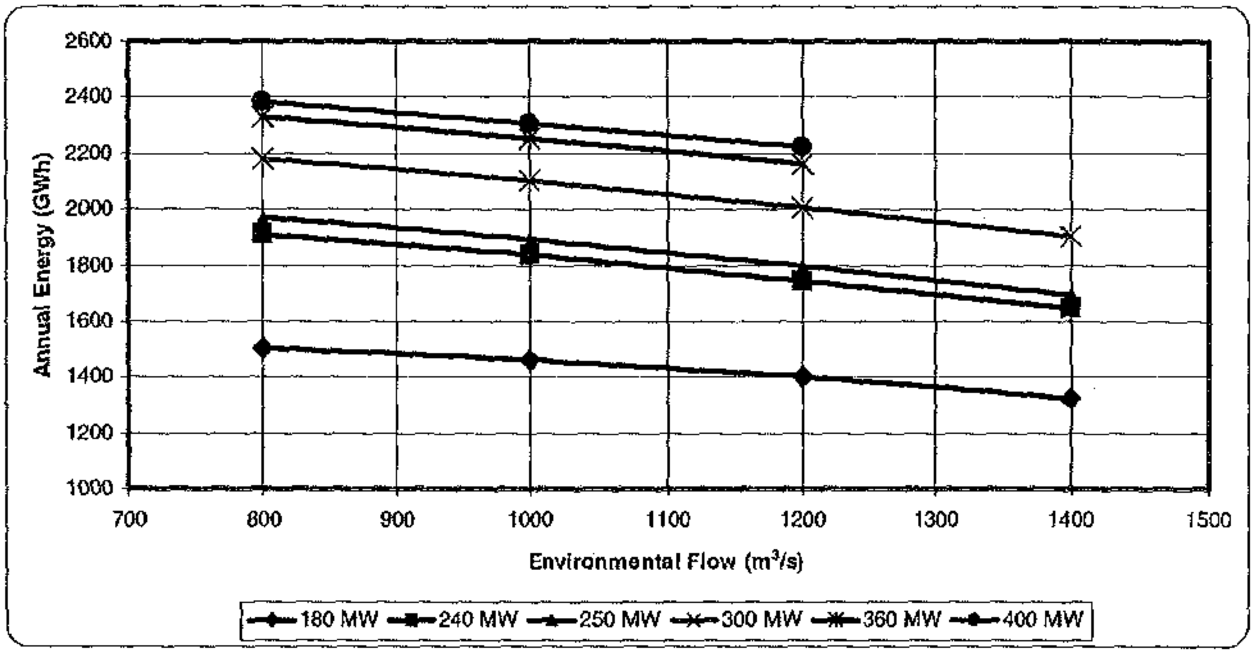


Figure 11.7 Impact of Installed Capacity and Environmental Flow on Annual Energy Potential

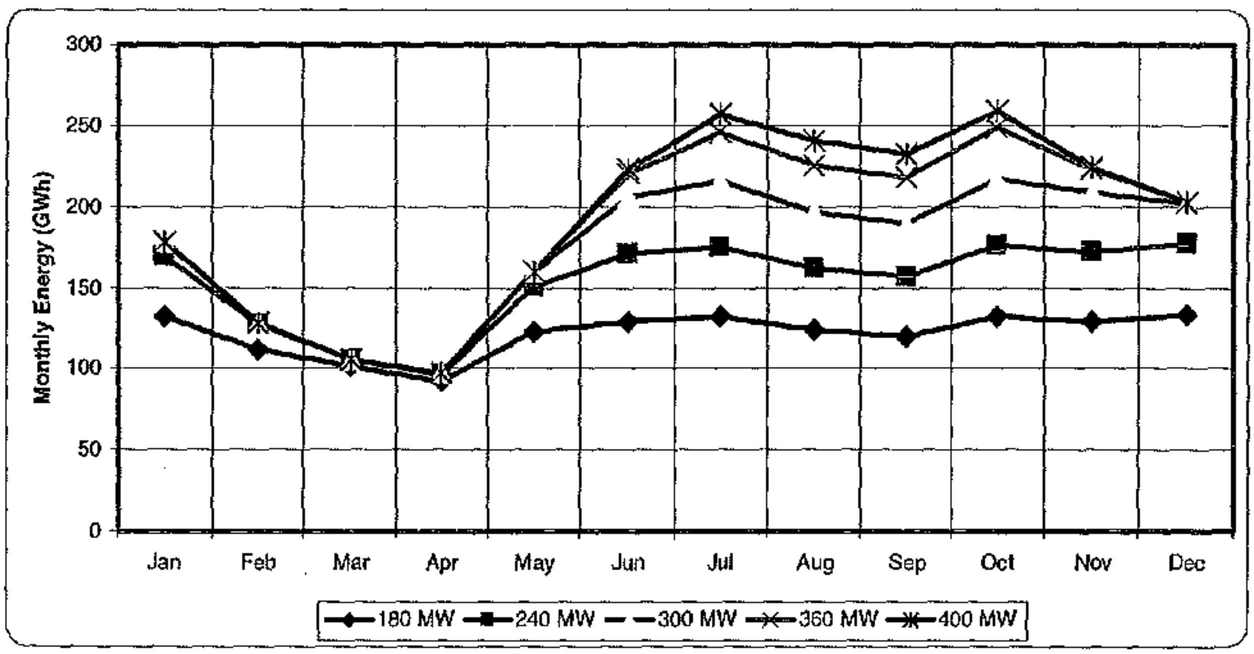


Figure 11.8 Impact of Installed Capacity on Seasonal Energy Potential

11.4.3. Environmental Flows

Figure 11.7 also shows the impact of changing environmental flows over the range 800 m^3/s to 1400 m^3/s. The reduction of energy occurs in the dry season when the environmental flow is a greater proportion of the total Mekong River Flow.

Another case considered for the environmental flow to be 25% of the flows at Pakse as originally suggested by Acres. This had better dry season performance, but resulted in less annual energy than the cases guaranteeing a minimum environmental flow,

The main advantage of providing a constant environmental flow is simplicity of operation.

An automated gauge can be established downstream of Hou Sahong, for example near the existing Thakho Gauge, and the level telemetred to the powerstation operating centre. Loading on the station can then be automatically adjusted to achieve the required water level corresponding with the environmental flow required.

The alternative of using a fixed percentage of the Mekong River flow, as used by Acres, for example at Pakse, would be that it introduces the need to compute flows at a suitable representative point, calculate the appropriate proportion of the flow and select the appropriate machine output corresponding with this flow. This process is less suitable for automation. Unless the reference point is close to the station, any inflows between the automated gauge and the entrance to Hou Sahong would be ignored.

11.4.4. Effect of Channel Improvements

Tables D.2 and D.3 summarise the results with the natural river channel with those with improved entry and exit channels as described in the hydraulics section of this report. The natural channel suffers from two issues:

- Firstly the constrained channel results in increased head losses giving a lower headpond level and a higher tailwater level. The channel improvements are less significant in the dry season because the high tailwater level in the main river eventually drowns out the downstream control on flow
- Secondly, an important impact of the existing entrance to Hou Sahong is that the flow is constrained by the water level in Mekong River as shown in Figure 3.12. Figure 11.9 compares the energy potential for a 300 MW station with the existing river channel with that from a 300 MW station with an improved river channel. Figure 11.10 shows the seasonal pattern for average and minimum energy production for these two cases.

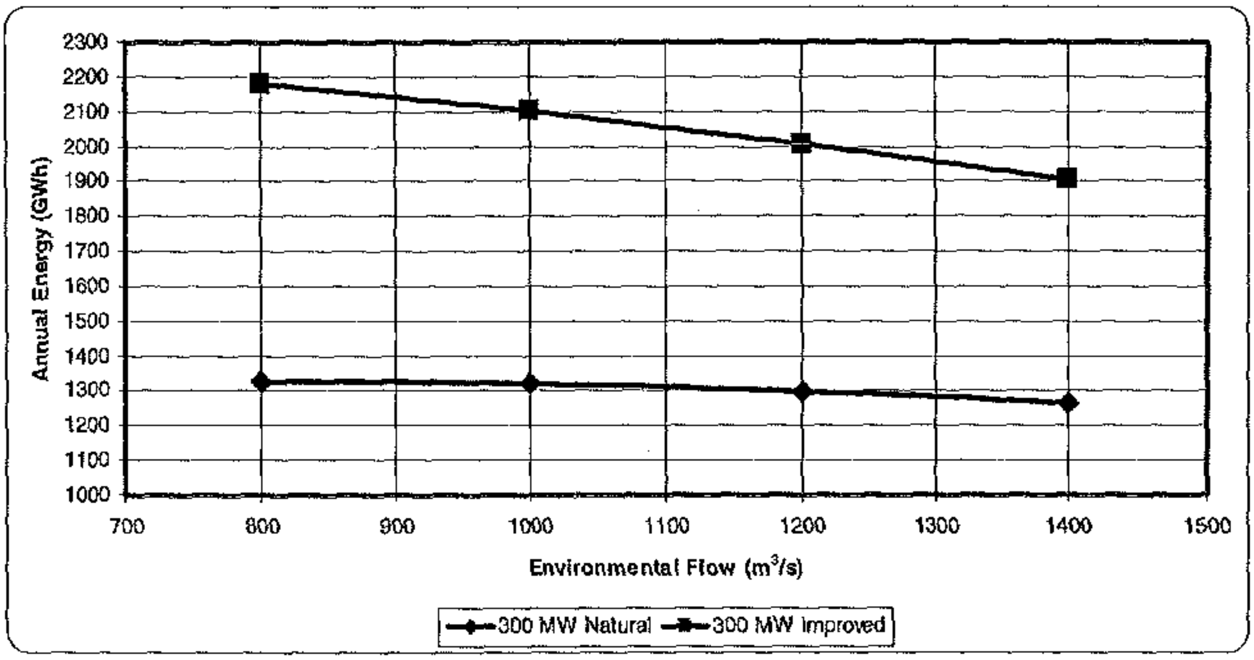


Figure 11.9 Impact of Channel Improvements on Annual Average Energy Potential

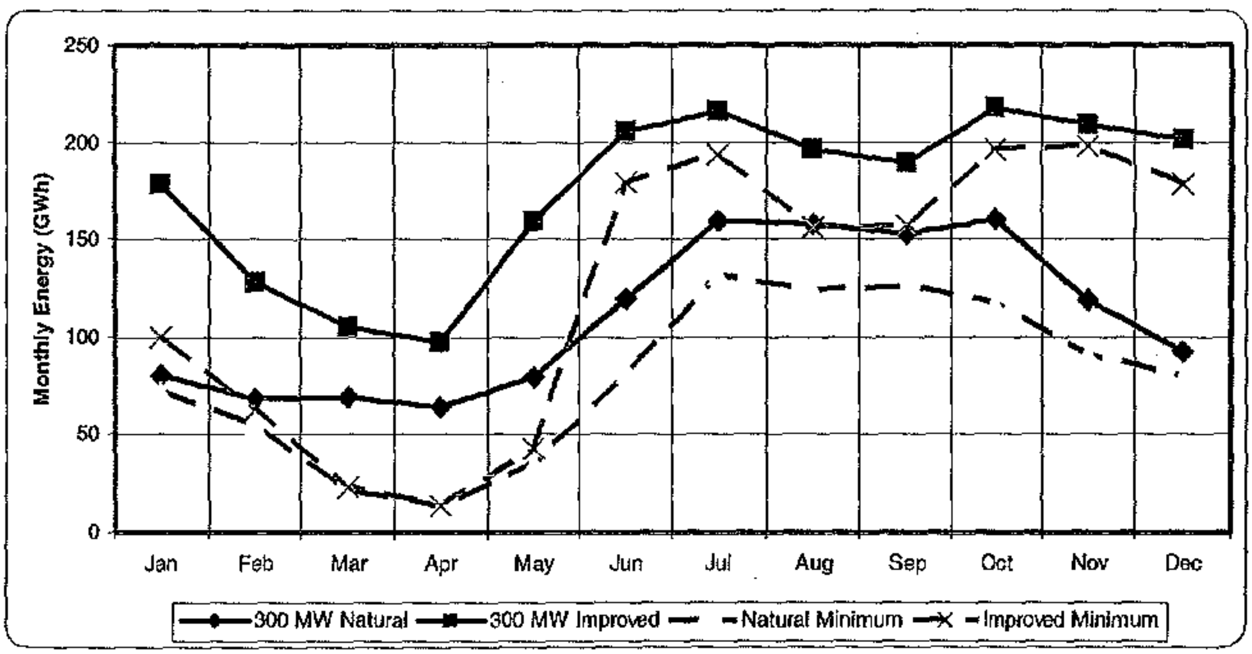


Figure 11.10 Impact of Channel Improvements on Seasonal Energy Potential

11.4.5. Head for Rating Unit

Changing the rated head has two areas of influence. The lower the rated head, the higher the discharge and unit physical size needed to generate the same nominal output. This makes the machine less affected by reduced head in the flood season.

A change in rated head moves the unit into a different part of the efficiency curve for the same operating conditions.. A higher rated head has the effect of improving dry season efficiency when head is often above the rated value and water is a critical resource. However, this introduces the risk that the minimum head in the flood season will be outside the operating range for the turbines and the station will be forced to close down. A lower rated head improves performance at low heads when water is abundant and reduces the risk of head being less than the minimum head acceptable to the turbine.

Characteristically the rated head is chosen either to match the median head or some sort of weighted average head including the energy produced at each level.

Figure 11.11 shows the effect on annual energy production of changing the rated head for a 300 MW station

This chart shows there is no advantage in increasing the rated head above the average head which is 17.4m. There is a slight advantage in reducing the design head to 16m., but no advantage in reducing it still further. Note, however, that this addresses only total average energy production and does not take into consideration the additional plant and civil costs involved in achieving the increase in energy.

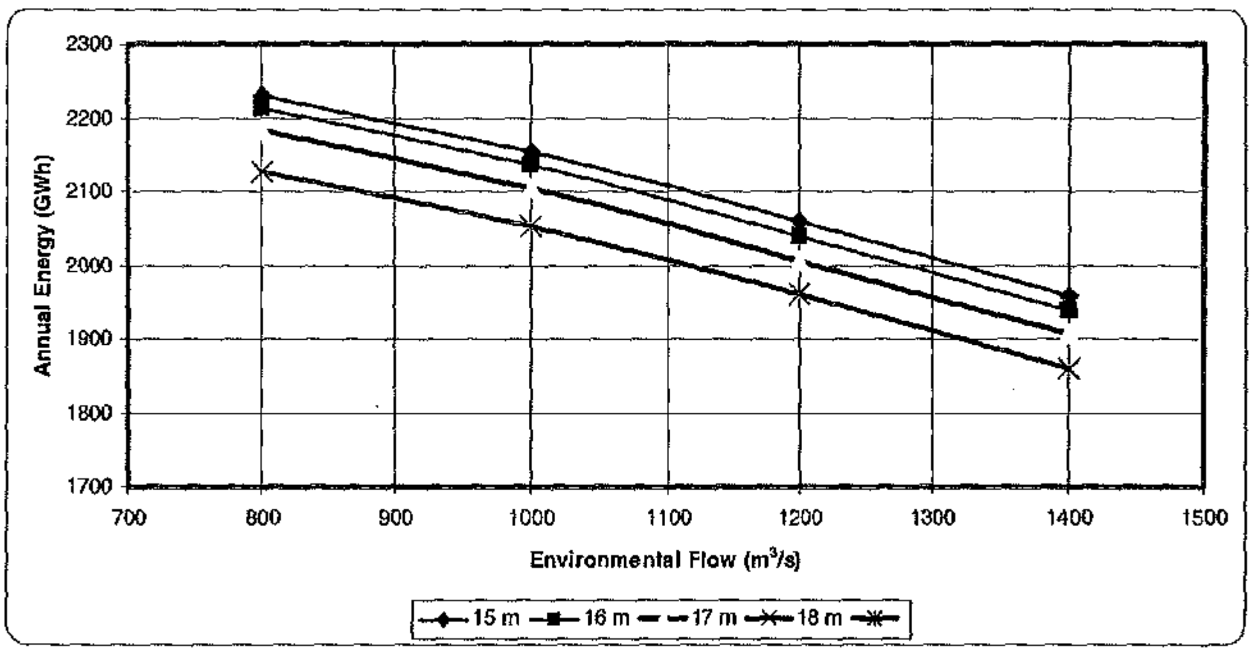


Figure 11.11 Impact of Rated Head on Annual Energy Potential - 300 MW Station

11.4.6. Impact of Dam Height

The main advantage of setting the structural crest of the dam to give a maximum pond level of 75m is that it avoids any requirements for control gates on Hou Sahong or for a need for a spillway since this level is higher than any recorded Mekong river water level.

There may be an advantage in reducing the water level to save construction costs and reduce the impact of the project on nearby villages. The effect of changing the maximum level of the upstream pondage is shown on Figure 11.12.

This figure shows that there are significant energy penalties from lowering the FSL below 72m. Additionally there are considerable cost penalties associated with providing gates at the Hou Sahong entrance that may not compensate for the lower and Jess expensive embankments.

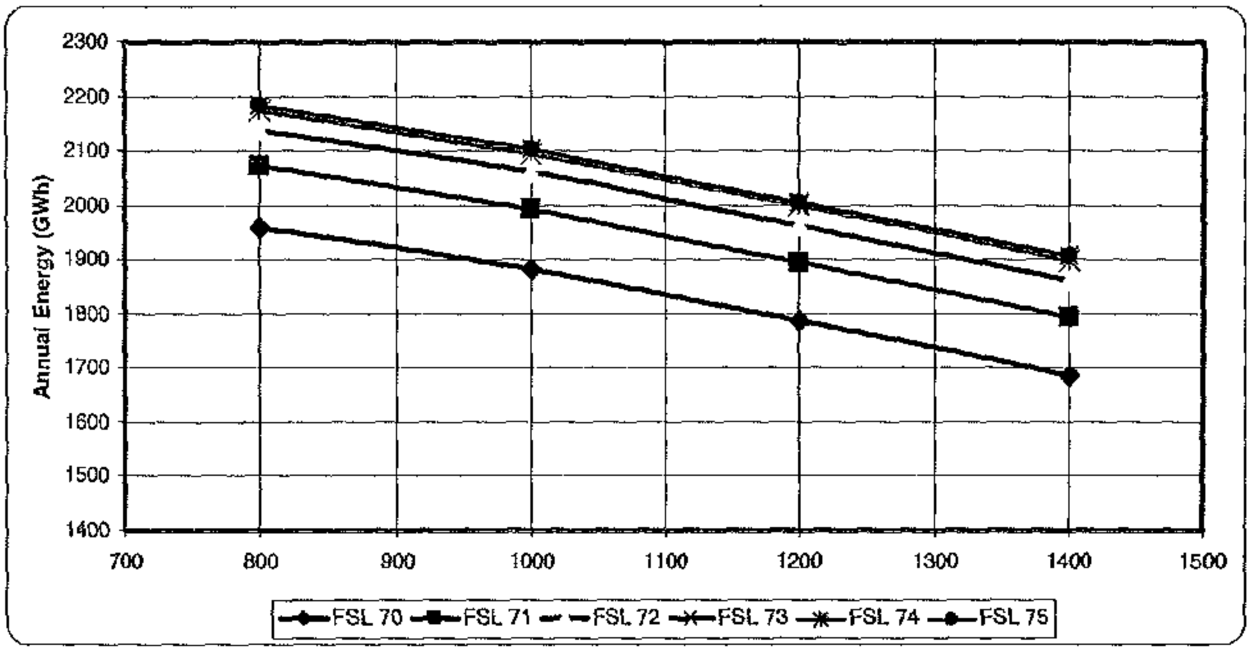


Figure 11.12 Impact of Lower Embankment levels on Annual Average Energy Potential

11.4.7. Peak Load Operation

DSHEP is a run-of-the-river Project with special characteristics in that a substantial portion of water during periods of low flow in the main Mekong River will bypass the power plant for environmental purposes. The head pond level will be low during this period but the net head across the hydro turbines will be higher. However, as indicated in Table 11,2, in the low flow periods of March, April and May the 24-hour generating capacity can be as low as 11.3 MW in an exceptionally dry year.

The possibility of operating the plant in a peaking mode by drawing down head pond level was examined and the following conclusions were drawn:

(a) In the low flow periods of March, April and May even on an average year the normal head pond level, if drawn down by 2 m, will allow only an increased generation of 30 MW over a 4-hour peak period.

(b) Any draw down of head pond level for peaking purposes at any time will result in a lower annual energy production in any year.

(c) The head pond capacity and the variable nature of the water levels upstream and downstream render DSHEP unsuitable for any form of peak load operation.

11.4.8. Future Changes

While it is not possible to quantify the impact of Climate Change on the energy potential of Don Sahong Power Facility, a sensitivity case was examined in which the inflow sequence was reduced by 10%. The results were summarised in Table D.10.

Figure 11. 13 compares the annual energy potential for a 300 MW power station with 1000 m/s environmental flows. Figure 11.14 shows the seasonal distribution of energy production from a 300 MW Power Station with 1000 m^3/s environmental flows.

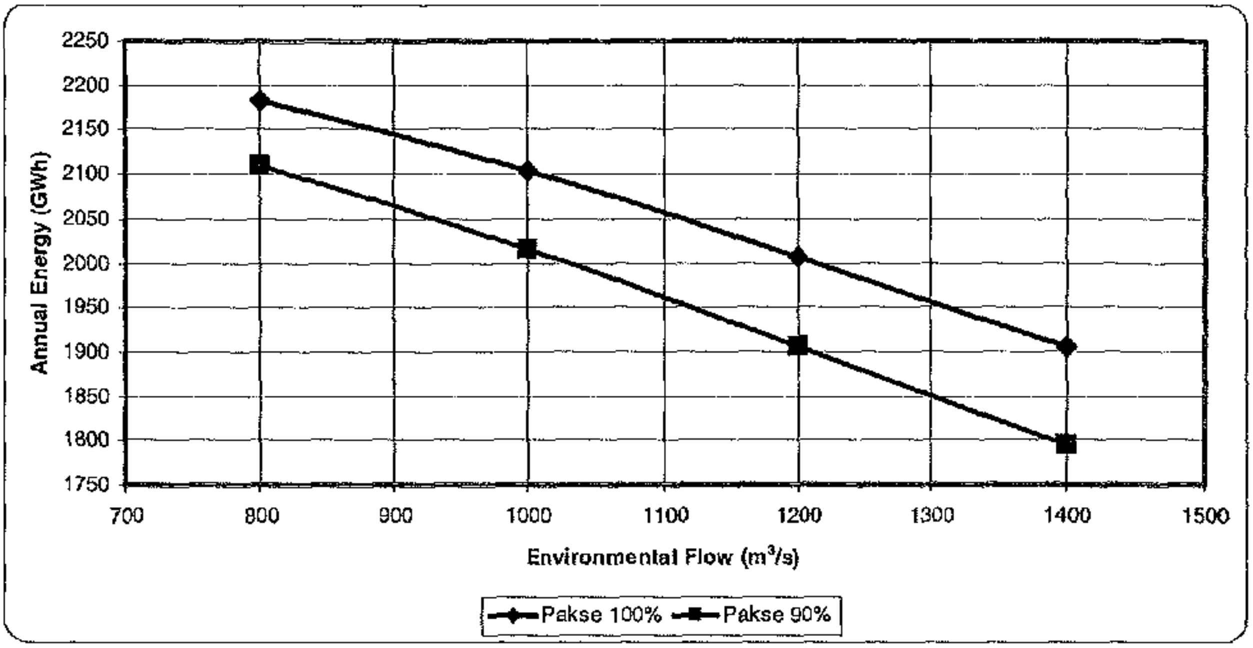


Figure 11. 13 Effect of 10% Reduction of Inflows on Annual Energy Potential of 300 MW Station

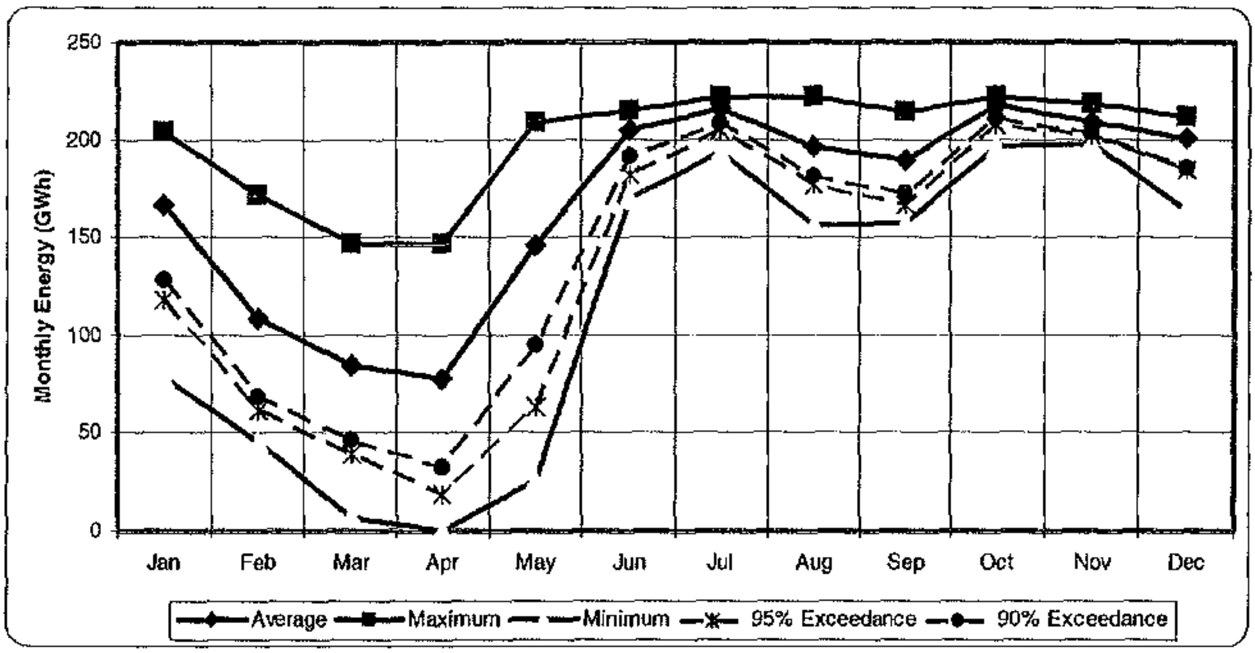


Figure 11.14 Seasonal Variation of Energy Production for 300 MW Power Station with 10% Reduced Inflows

The construction of new storage power projects on the Nam Theun and Nam Ngum in Laos and on the Mekong (Lancang) mainstream in China in the future will serve to regulate some of the wet season flows into the following dry season. Study of flows in recent years indicates that the Chinese projects such as Xiaowan, Manwan and Dachaoshan are already changing long-term distribution patterns. This will improve the dry season performance of Don Sahong, but it is not possible to quantify the changes in water and energy potential.

11.4.9. Impact of Kaplan Turbines on Energy Potential

The bulb turbines modelled in this analysis were chosen because the straight flow pattern around the unit minimises headlosses. Since the turbine runner of a bulb turbine is virtually identical with that of a Kaplan Turbine the results for a horizontal axis Kaplan unit should be similar.

A vertical axis Kaplan unit is more conventional but introduces draft tube and inlet spiral losses to the unit. The design of a Kaplan unit will minimse the losses, but it is expected that a headloss penalty of 25% of the velocity head will be imposed on a vertical axis Kaplan when compared with the corresponding bulb unit as shown in Table D.l 1. Figure 11.15 shows the results for a 300 MW station.

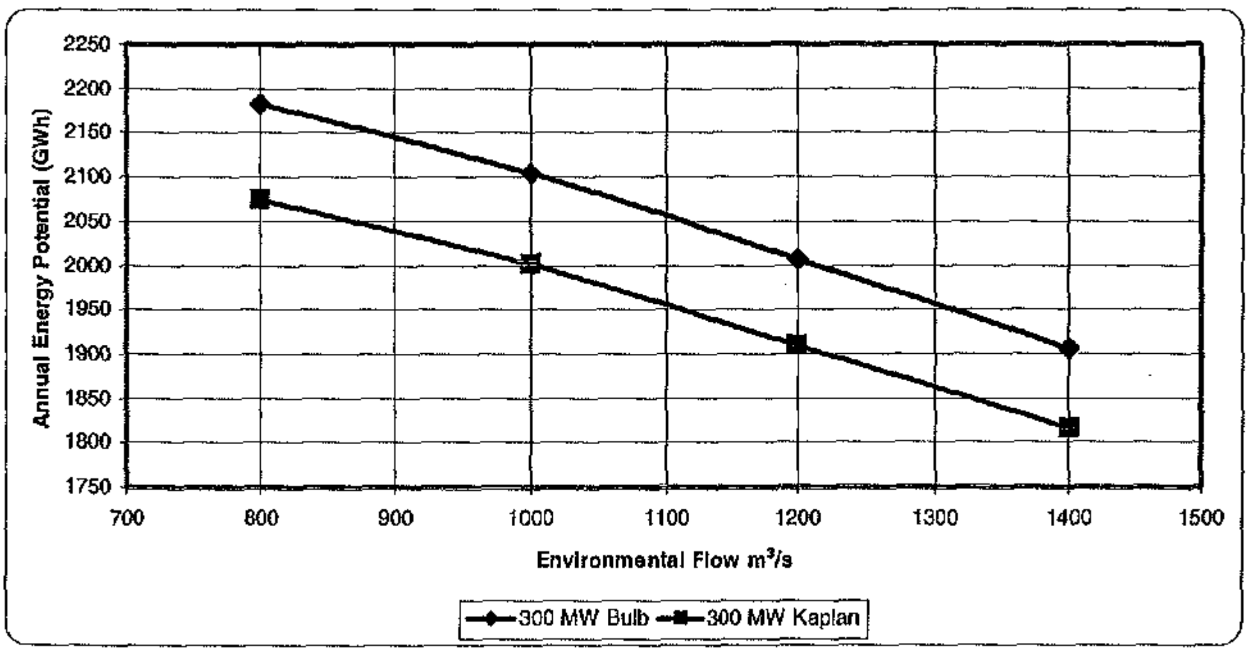


Figure 11,15 Comparison of Energy Potential from Bulb and Kaplan units in 300 MW Power Station

11.4.10. Impact of Propeller and Bulb Turbines on Energy Potential

Variable pitch turbines, (either Bulb or Kaplan), have an advantage of high efficiency over a wide range of unit flows and head which make them suitable for operation in both the dry season and the flood season at Don Sahong Power Station. They have the disadvantage of cost and maintenance issues when compared with the simplicity of a fixed blade or 'Propeller' turbine.. There are potential savings in cost if bulb units are installed for the low flows in the dry season and Propeller units used for additional wet season capacity. Tables D.12 and D.13 show the energy potential for a number of combinations of main bulb units and secondary propeller units.. The efficiency of a propeller turbine drops off significantly below 50% rated flow or 70% rated head, In order to remain within these limits of operation, the Propeller turbine was rated for a 2 m lower head than the main units. This results in a larger turbine for the same output than is the case for the equivalent bulb unit. This increase in size offset the lower efficiency giving similar performance for the power station as a whole as would be the case for bulb units alone.

11.4.11. Impact of Thakho Flows on Energy Potential

Table D.14 shows the annual energy potential if the station operation is based on estimated flows in the Thakho/Sahong arm of the cascade. The initial gauging being carried out as part of this project indicates that the natural flow at Thakho will vary between about 90% of Pakse flows in the dry season to about 25% of the Pakse flows during floods. There is insufficient data available for this to be a reliable estimate, but it was included as part of the sensitivity analyses for the project.

These results are not directly comparable with the previous cases because part of the environmental flow passes down other arms of the cascade. This effect has been allowed for to some extent by carrying out the analyses with smaller environmental flows representing the Thakho arm of the river only.

Similarly it is not known to what extent channel improvements in the Hon Sahong entrance will change the future distribution of flows between the Thakho/Sahong reach of the cascade and the other branches of the cascade. Any improvement in the flows towards Thakho/Sahong will reduce the differences between these two cases.

Nevertheless the upper limit of the impact has been shown in Figure 11.16 with the environmental flows used for Thakho were 500, 750, 1000, and 1250 m^3/s plotted at the locations 800, 1000, 1200, and 1400 m^3/s

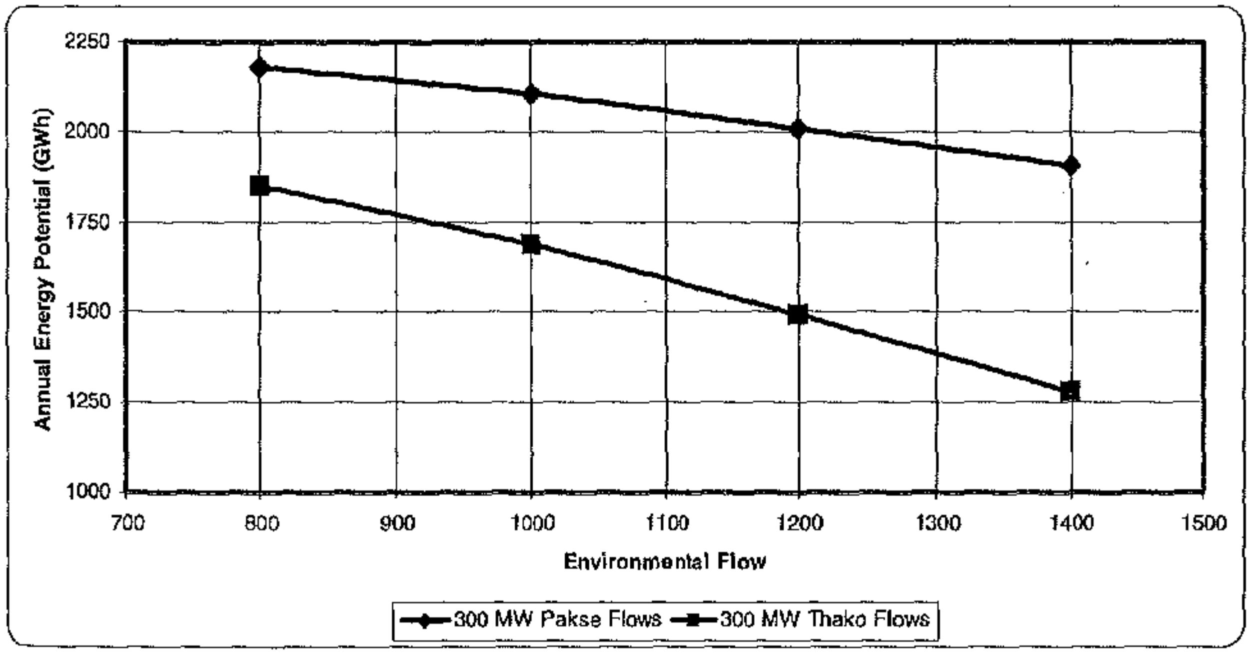


Figure 11.16 Comparison of Energy Potential Based on Pakse Flows and Thakho Estimated Flows in 300 MW Power Station

11.4.12. Effect of Channel Improvement on Base Load Energy Potential

Table D.15 shows the effect of different excavation levels on annual energy potential for a range of station capacities assuming 1000m^3/s environmental flows and Pakse inflows.

These values have been plotted on Figure 11.17. This emphasises the importance of lowering the rockbar controlling flows into Hou Sahong and the limited response to excavation below level 65 metres.

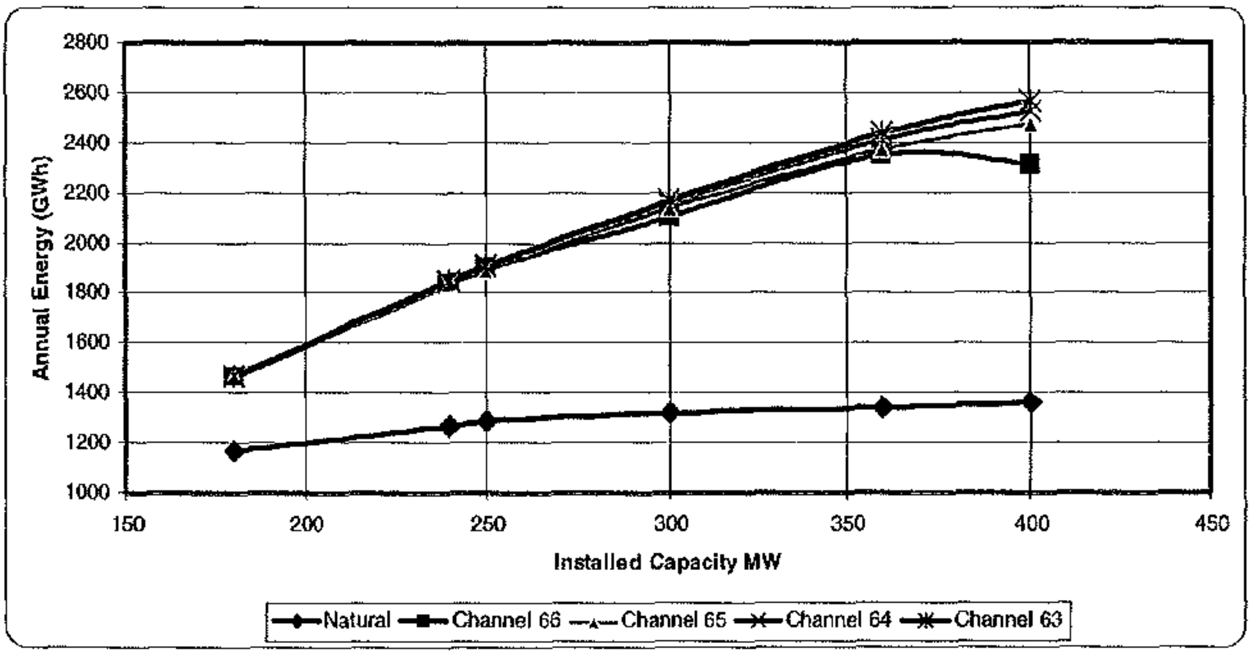


Figure 11.17 Impact of Different Degrees of Improvement to Hou Sahong Channel Entrance

SECTION 12

CONSTRUCTION PLAN AND SCHEDULE

12.1 Contract Arrangements, Resources and Hours of Work

12.1.1 Introduction

These notes describe the proposed contractual an-angements to be adopted following the signing of a Concession Agreement and an associated Power Purchase Agreement.

12.1.2 Project Company

Prior to the signing of the agreements related to the Project, the Project Developer, will have been required to establish a Project Company vested with the necessary powers and authority to arrange and authorize all ongoing activities associated with the Project. The Company will be headed by a suitably qualified person to whom will be delegated the role and responsibilities of Company (or Owner's) Representative.

The first task of this Company will be to appoint an appropriate consulting organization to act as the Owner's Engineer/Supervising Consultant for the Project.

On an ongoing basis, the Company will

(a) handle all financial matters, including loans and payments,
(b) liaise with the Government of Lao PDR and their agencies,
(c) liaise with the Power Purchaser, and
(d) handle all matters related to land resumption, re-settlement and compensation of local inhabitants displaced or affected by the Project.

12.1.3 Owner's Engineer

The Owner's Engineer will have responsibility for the following tasks:

- Preliminary Design and Documentation for an EPC (Engineering, Procurement and Construction) Contract.
- Tendering process leading to the appointment of the EPC Contractor.
- Organisation of Preliminary Works by Local Contract.
- Supervision of all Project Works.

(a) Preliminary Design

The Owner's Engineer will develop the project concept and layout as shown in the Feasibility Report to provide a preliminary design to form the basis for the preparation of

(i) an "Expression of Interest" document, and
(ii) tender documents for an EPC Contract.

The documentation will include a Detailed Design Brief setting out the requirements for the Project including the requirements of the Government and the conditions of the Approved EIA that the EPC Contractor will be required to comply with.

(b) Tender Process For EPC Contractor

Prior to the formal tendering process, it is envisaged that, through appropriate advertising, expressions of interest will have been obtained from companies with the necessary financial capability and technical expertise to design and construct the Project.

From an analysis and review of the expressions of interest received, detailed and costed submissions will then be called from a selected short-list of prospective EPC Contractors.

The successful EPC Contractor will then be selected and appointed following a tender review and negotiation process.

(c) Preliminary Works By Local Contractors

During the course of the EPC Contract tendering process, the Owner's Engineer will arrange for local contracts for the execution of various preliminary works for eventual handover to the EPC Contractor. The intention of this is to use periods of low river flows during the period of the tendering process to reduce the period required for the successful EPC Contractor to mobilize and commence construction activities.

The works envisaged include the following:

- Procurement of a suitable motorized barge for transport of employees, equipment and materials from the mainland to Don Sadam.
- Construction of barge landing facilities at the Mainland Complex and on Don Sadam.
- Excavation of the river bed adjacent to the barge landing facilities ensures suitable water depth for safe barge operation.
- Initial development of the Mainland Complex to provide basic facilities. The facilities envisaged include the following:

  (i) clearing and initial site earthworks,
  (ii) initial roadworks,
  (iii) initial stormwater drainage,
  (iv) initial water supply and treatment,
  (v) initial sewerage works,
  (vi) initial power supply, and
  (vii) housing and accommodation, including office accommodation, for the advance parties of employees of the Company, Owner's Engineer and the EPC Contractor.

- Construction of access roads on Don Sadam and Don Sahong to provide access to

  (i) suitable quarry sites for rockfill for cofferdam construction and
  (ii) the cofferdams.

- Quarry development and stockpiling of rockfill

- Provision of a power supply to the site, initially for construction use, eventually for use for power station services.

(d) Ongoing Tasks

The ongoing role of the Owner's Engineer will include the following:

(i) Review and approval of detailed designs submitted by the EPC Contractor.
(ii) Supervision of civil construction and E&M installation works.
(iii) Witnessing and certification of testing and commissioning activities.

12.1.4 EPC Contractor

The EPC Contractor will be responsible for the following:

(a) Detailed Design of Permanent Works

(i) Civil works,
(ii) Generating Units,
(iii) Transformers and Switchgear,
(iv) Transmission Line
(v) Hydraulic gates, trashracks and hatch covers.

(b) Design and provision of construction facilities
(c) Construction of civil works, including removal of cofferdams
(d) Fabrication, delivery, installation, testing and commissioning of all E&M equipment
(e) Construction of transmission line
(f) At end of project construction, removal of redundant construction facilities and the rehabilitation of sites.

12.2 Timing

Timing for various phases of construction is dictated by the flow in the Mekong River with the most critical activity being the diversion of the flow in Hou Sahong which can only be achieved in the annual four-month period of low river flows. Failure to achieve diversion will inevitably result in a 12-month delay to Power Station construction. Accordingly, construction planning has envisaged the performance of preliminary works by local contracts during the tendering period for the main EPC Contract as mentioned previously.

12.3 Climate

The climate in the project area is characterized by a pronounced wet season from May to October. However, the rain generally falls in relatively short, heavy storms and is not expected to severely disrupt most construction activities although daily planning will be required for operations such as slip-forming of embankment face slabs.

The related factor of variation in river flow is a critical constraint on the timing of various activities as discussed elsewhere.

12.4 Construction Methods

12.4.1 General

The project layout is quite simple - it involves a powerhouse constructed across the downstream end of Hou Sahong combined with two containment embankments and a saddle dam.

For most of the project features, "standard" construction techniques can be adopted. In the following sections, feasible construction methods have been described however as it is intended that the project be implemented by an Engineer, Procure and Construction (EPC) Contract, final methods may be varied by the selected Contractor. The construction sequence is shown graphically on Figure 12-1 (Sheets 1 of 2 and 2 of 2).

12.4.2 River Diversion Works

12.4.2.1 Introduction

For construction within the stream bed, the flow in Hou Sahong has to be diverted. Because of the high seasonal flows in the Hou Sahong, diversion through the site would not be possible and the only viable option will be to divert the Hou Sahong flows into the other channels of the Mekong River by a cofferdam at the upstream.

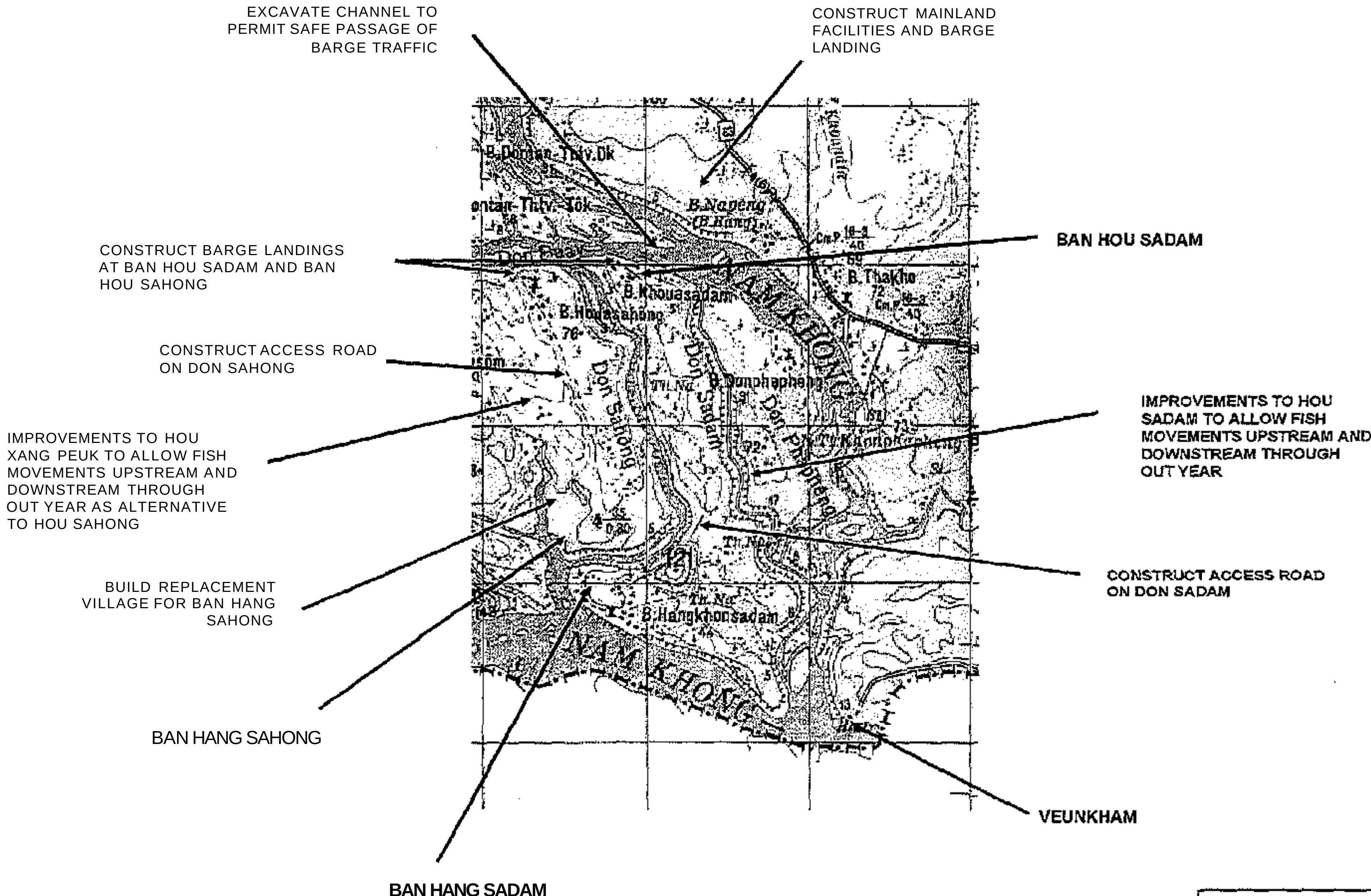
Similarly, inflow from downstream needs to be prevented and hence a downstream cofferdam will also be required.

Finally, as there will be significant runoff from the island catchments between the two main cofferdams during the wet season, a secondary upstream cofferdam will be required.

12.4.2.2 Upstream Cofferdam

The upstream cofferdam will need to be constructed to RL 75 m to match the high-flow season water level.

From inspection of the contours at the upstream end of Hou Sahong, the suggested location for the cofferdam is immediately upstream of the mid-stream island which would allow the dam to be constructed normal to the valley walls.

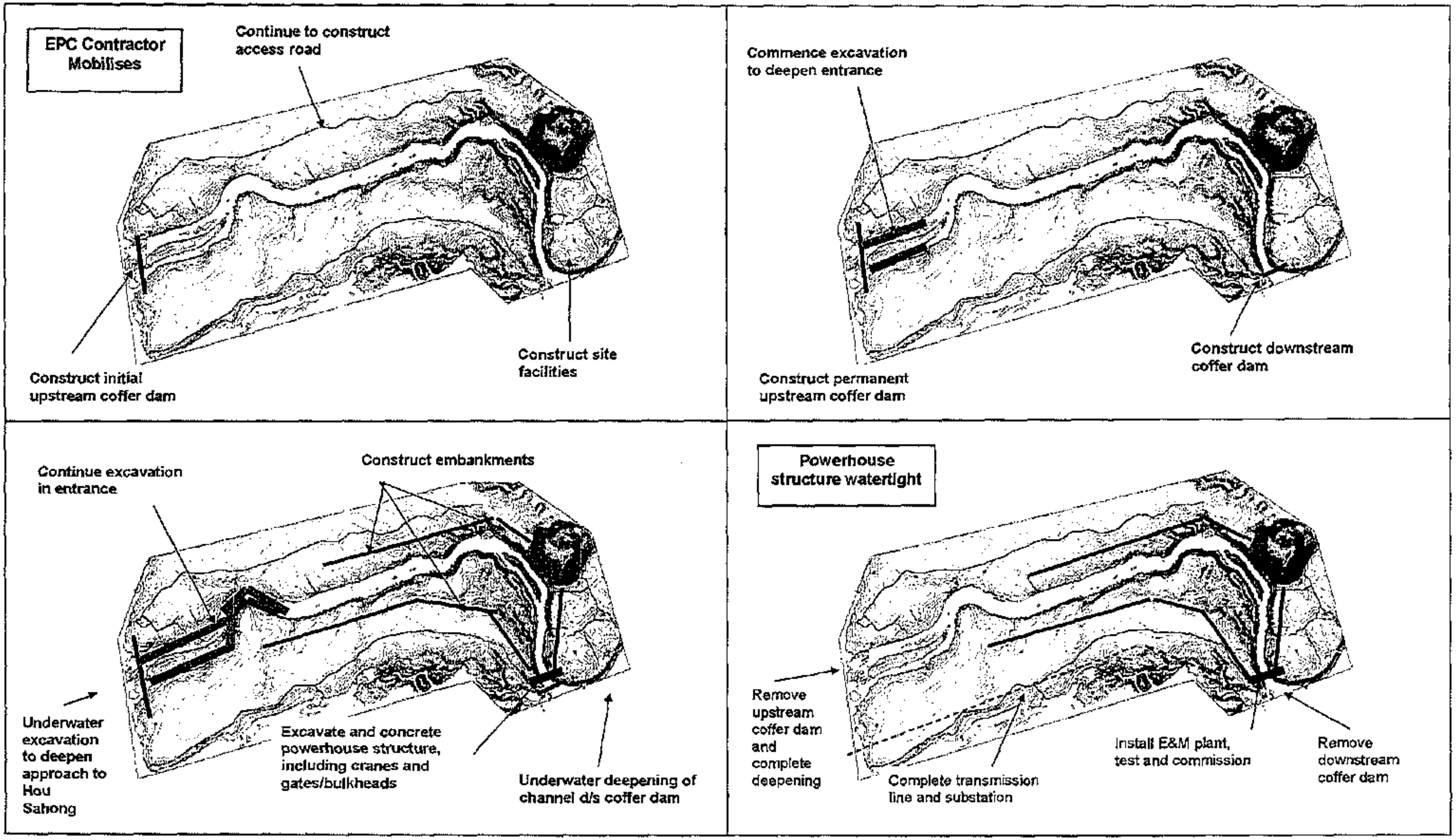


PRE EPC AWARD ACTMTES

Don Sahong HEP

CONSTRUCTION SEQUENCE

Figure 12-1 – Sheet 1



Don Sahong HEP

CONSTRUCTION SEQUENCE

Figure 12-1 Sheet 2

Photo 12.1 – View across Hou Sahong above Upstream Coffer Damsite
(River flows right to left)

To enable this dam to be constructed, a smaller cofferdam will be required at the entry to Hou Sahong. This dam will be constructed by progressively dumping rockfill from the abutments to form an embankment to RL 72 m (approximately) and then providing waterproofing by placing sandbags to RL 71.5 m (approximately) against the upstream face of the embankment.

Cofferdam construction is a critical activity, and initial diversion is required in as short a time as possible to allow adequate construction time for the remaining cofferdams during the low-flow period. Embankment construction on both abutments is considered necessary and hence the need for temporary barge landing facilities on Don Sahong.

Once the flow into Hou Sahong has been stopped, construction of the main cofferdam can proceed (as well as the downstream cofferdam).

Construction will involve stripping the foundation area to sound rock and then placement of rockfill. Water proofing of the dam can be achieved by the placement of sandbags or layers of filter cloth and a clay material.

12.4.2.3 Downstream Cofferdam

The downstream cofferdam can be located within the river channel and downstream of the required excavation for the tailwater channel.

To protect the Power Station site, the dam will need to be constructed to RL 61 m. As the lowest river bed level in the vicinity is RL 48, the dam will have a maximum height of 13 metres.

During the low-flow period, the water level drops to RL 50 m, so an initial low level embankment can be constructed and water-proofed with sand bags to allow dewatering and stripping of the foundations for the main rockfill embankment.

Construction of the cofferdam within the river bed area cannot be commenced until the stream flow has been diverted by the initial upstream cofferdam. However, preparatory works and some construction of abutments sections could proceed before this situation is achieved in view of the limited period available for river diversion activities.

This cofferdam can be incorporated into the site access road system.

12.4.2.4 Secondary Upstream Cofferdam

A secondary upstream cofferdam will be required immediately upstream of foundation excavation for the approach channel to the Powerhouse to intercept the rain-fall runoff from the island catchments on both sides of Hou Sahong as well as any seepage through the main upstream cofferdam.

A relatively low rockfill embankment, water-proofed with sandbags, should be adequate and a sump and dewatering pump system will be required to transfer the intercepted water around construction works and discharged into the main stream downstream.

This cofferdam can also be incorporated into the site access road system.

12.4.3 Power Station - Civil Works

12.4.3.1 Excavation

Foundation excavation for the Power Station, including the upstream approach channel and the tailwater channel, can commence as soon as Hou Sahong has been successfully diverted and the area between the cofferdams dewatered.

The river bed level in this area is approximately RL 50 m and the required excavation level is RL 36 m for the main structure and RL 40 m for the draft tubes. As the excavation extends over a relatively large area, the excavation can proceed in several areas simultaneously with the development of a series of benches 4 to 5 m high for drilling and blasting of the rock and access ramps for hauling excavated material.

Within the area of the structure, the sides of the excavation, and especially the right side, will be pinned before vertically pre-splitting and supported as required to minimize overbreak.

For the upstream approach channel and tailwater channel, the need for concrete lining is not envisaged however the left side batter will be presplit to a slope of 0.25 to 1 while the right side batter will be laid back to a slope of 1 to 1, parallel to the dip of the strata.

It is envisaged that most of the excavated material will be used for embankment construction and ideally hauled direct to one of the embankments. However, some of the material will be screened over a grizzly to separate smaller sized material for processing into concrete aggregate and filter material for embankments.

12.4.3.2 Anchorage to Foundation Rock

In view of the potential of the Power Station structure to buoyancy, the structure is required to be anchored to the foundation rock. Anchorage may be in the form of anchor bars grouted into the foundation rock and embedded in the base slab of the structure, stressed rock anchors or a combination of both.

Grouted anchor bars need to be installed before placement of the base slab while stressed rock anchors require prior concrete placement and the embedment of a suitable bearing pad against which the rock anchor can be stressed.

12.4.3.3 Concrete works

The major concrete works for the Power Station structure are as follows:

Below General Access Level:

- Foundation slab.
- Conduits, partly formed partly steel-lined, to convey flows to the turbine runner.
- Drainage Gallery.
- Upstream buttress walls incorporating trashrack and stoplog slots.
- Vertical longitudinal and lateral walls to provide generator and turbine access pits.
- Trashrack and stoplog handling deck extending the full length of the structure.
- Draft tube structure to convey flows from the turbine to the tailwater channel and incorporating slots for draft-tube gates.
- A multi-level building extending the full length of the structure for locating ancillary equipment and incorporating the downstream wall of the Station.
- Draft-tube gate handling deck extending the full length of the structure and supported on buttress walls.
- Control room located at the left end of the structure.

Above General Access Level (RL 75 m)

- An unloading and assembly area incorporating a mechanical workshop and office facilities.

Two tower cranes will be installed to provide coverage of the whole area of the structure to enable work to proceed simultaneously in different areas. Access roads will be provided both upstream and downstream to transport materials to the cranes. Mobile cranes will also be used to assist when required to minimize disruption to key tasks such as concrete placement.

The features that will control the sequence of construction are the waterway conduits conveying generating flows.

Each conduit starts at the upstream trashracks with a rectangular section. The upper surface is curved for stream lining of flow and at the stoplog location the section has been reduced to a square section. After this the conduits are transitioned to a circular section which is maintained along the upstream section of the bulb unit before it tapered in a conical shape to a short cylindrical section surrounding the turbine runner. Downstream of the turbine runners, the conduit expands in diameter and transitions to a single rectangular section before being separated into two conduits by a central pier before exiting to the tailwater channel.

Sections of the conduits will be steel-lined. The remainder will be formed in concrete. Two sets of special forms for curved and transitioned surfaces will be shop-fabricated and re-used in successive adjacent conduits.

The steel liners for the steel-lined sections will be supplied by the generating set supplier. The sequence and details for installation of the steel liners and anchorage devices for the generating sets will be dependent on the final detailed design of the supplier and established after due consultation.

Above the conduits, construction consists of expanses of vertical walls and suspended slab which lend themselves to the use of modular "gang forms" complete with secure walkways.

Construction will commence with the two end units and proceed simultaneously towards the centre. This will allow for earlier commencement of abutment works including the Unloading/Assembly Bay and the sections of the Containment Embankments adjoining the Power Station structure.

Concrete construction works will need to be progressed to meet target dates established in conjunction with the generating set supplier, the main targets being as follows:

- Completion of structure to allow for (a) installation and (b) operation of the Power Station Gantry Cranes.
- Power Station Water-tight, i.e.trashracks, stoplogs, draft tube gates and ancillary equipment installed and commissioned.

12.4.3.4 Architectural Works

Architectural works will be earned as access becomes available and will be coordinated with the installation of station services and the various electrical and mechanical systems.

12.4.4 Generating Units

To minimise the amount of site assembly required, the generating units will be delivered in the maximum size components which transport logistics (weight and size) will allow. At this stage it is envisaged that there would be three principal components to be delivered for each unit. These components in order of weight would be the generator rotor, generator stator and the turbine drive shaft and runner hub. While installation of the principal components will be relatively straight forward it is estimated that a time period of 3 months would be required for completion of the bulb unit housing and installation and connection of the power and control cables before the same work could be started on the next unit. This time period would result in a 3 month gap between the commencement of testing and commissioning of the units

12.4.5 Transformers

To minimise transport weights the main transformers will be delivered to site empty of oil and without any external fittings, eg coolers, cable boxes, header tanks etc. To prevent any chance of moisture penetrating the windings during transport the transformer tanks will be filled and slightly pressurised with dry nitrogen. Once the transformer bays are ready the transformers will be skidded into place and the external fittings fitted prior to filling with oil. Note the LV and HV connections to the transformers and their subsequent testing and commission will be dependent on the commissioning of the associated generating units and the transmission switchyard.

12.4.6 Station Cranes

The provision and installation of the four separate gantry cranes will be critical to the works required for power station water tight milestone and for the schedule for assembly of the generating units. Consequently installation of the cranes should commence as soon as access is available for their assembly. The principal item for the interface with the civil contractor is the provision of the crane rail holding down bolt, for embedment in the concrete deck.

12.4.7 Containment Embankments

As explained previously, a containment embankment is required on each bank of Hou Sahong to close off the river valley to provide the anticipated operating levels during periods of high river flows. In addition, a saddle dam is required to prevent overflow along a section of land below RL 75 on the left-hand side of the Hou Sahong.

It is proposed to align the permanent access road along the crests of the left bank embankments.

The main quantities associated with each of these embankments are summarized in Tablel2-l.

Table 12-1. Embankment Quantities

Embankment	Length	Volume of Rockfill	Maximum Height
	m	m	m
Right Bank Containment Dam	1,820	70,000	8
Left Bank Containment Dam	720	124,000	12
Left Bank Saddle Dam	2,730	135,000	7

With the length of each embankment, work can proceed at different sections along the lengths simultaneously with the following operations:

- Stripping of foundation
- Trimming of excavation to provide suitable profile
- Excavation for plinth
- Concrete placement of plinth
- Placement of embankment rockfill
- Placement, compaction and protection of downstream filter zone
- Fixing of face slab reinforcement, side forms and water-stop
- Slip-forming of face slab
- Construction of wave wall
- Placement and compaction of roadway surfacing.

Early attention will be given to the sections where the embankments traverse existing erosion gullies (one each for the containment embankments and two along the left bank saddle dam) to establish the level and profile of foundation rock as input for plinth design.

Top soil and weathered material stripped from the foundations will be stockpiled and used later for the backfilling of the sections of the gullies uphill of the embankments to prevent ponding of rainfall runoff and for landscaping in the vicinity of the Power Station.

The majority of rockfill for the embankments will come direct from the required excavation for the Power Station with the remaining quantity being obtained from the channel deepening of the upstream end of Hou Sahong. Accordingly planning of resources allocation will endeavour to allow rock to be placed direct into embankments to minimize the need for rehandling.

Construction completion of the containment dams and saddle dam will be required by the time that the situation of "Power Station Water-tight" has been achieved and thereby allow for the removal of the main upstream cofferdam and completion of channel deepening.

12.4,8 River Channel Excavation

As explained elsewhere, to ensure adequate flow for generation during the low-flow period (March to May), the stream bed level at the entry to Hou Sahong will be excavated to RL 66. This will require excavation of rock gradually decreasing from a depth of 6 m at the entry to zero at a distance of approximately 1.2 km where the existing stream bed level is RL 66.

The excavation will be carried out in the following stages:

Stage 1 (Estimated volume of 1,600,000 cu. m.)

This stage extends downstream from the main upstream cofferdam and can proceed after completion of the dam.

Stage 2 (Estimated volume of 300,000 cu. m)

This stage involves excavation in the area between the main cofferdam and the initial cofferdam. This work will need to be planned for a period of low-flow when the initial upstream cofferdam can be rehabilitated to provide protection.

Stage 3 (Estimated volume of 60,000 cu. m.)

Stage 3 will involve the excavation of the section of the river occupied by the main cofferdam. Work will need to be planned for a period of low flow and after the Power Station has reached "water-tight" stage, i.e. structure completed and stoplogs installed, and the main cofferdam no longer required and can be removed. The initial upstream cofferdam will also need to be restored once more to provide protection for this work.

Stage 4 (Estimated volume of 30,000 cu. m.)

Stage 4 will involve the removal of the initial upstream cofferdam and excavation of the under-lying rock to provide a transition from RL 60 at a grade 1 in 5 into the main stream of the Mekong River,

This will involve under-water excavation utilizing the same equipment used earlier for excavation of navigation channels.

Approximately 250,000 cubic metres of the excavated material will be required to supplement material obtained from the required excavation for the Power Station structure for construction of the Containment Dams and Saddle Dam. Some can be used for rip-rap protection and streamlining of the entry into Hou Sahong. The remainder will need to be hauled to selected disposal areas.

Downstream of the power station and for approximately 800 m until the Hou Sahong channel merges with the broader Mekong River approximately 70,000 cubic metres of rock is to be excavated to reduce the headloss through the station and increase energy. The bathymetric survey indicates that the average depth of excavation will be in the order of one metre. This area is downstream of the downstream coffer dam and will have to be carried out underwater. Precautions will be needed to ensure that there is no impact on the colony of Irrawaddy dolphins that lives in the Mekong mainstream.

Geologic investigation indicates that the bulk of the excavation in both upstream and downstream areas will be of hard rhyolite.

12.5 Temporary Works

12.5.1 Site Access

12.5,1.1 Access from Mainland

As the project is located on/between the islands of Don Sadam and Don Sahong, access to the site requires access across the main eastern channel of the Mekong River. The most convenient form of access would be a bridge. However, either a large suspended span would be needed or the problem of constructing mid-stream piers for a multi-span structure would have to be overcome. It would appear that the cost of this structure and the time needed to construct it makes the option impractical, but the EPC contractor might opt for this alternative.

The use of barges, a traditional form of transport for the Mekong River will require a landing facility on the northern end of Don Sadam, however a secondary landing site will be required in the early stages for transporting equipment and materials to Don Sahong for construction of upstream cofferdams. As there are turbulent flow conditions at the western end of the entry to Hou Sahong, the barge landing site will need to be on the western side of the island even though this will require longer barge trips to avoid the turbulent conditions.

A bridge for light traffic and use of barges for heavy loads is an option. The arrangement adopted will be dependent on the EPC Contractor's construction methodology and strategies.

12.5.1.2 Access on Islands

Figure 6-1 depicts the layout of the Project, In addition to the main access road from the barge landing site on the western side of Don Sadam to the Power Station site, construction access roads and haul roads will be required to the following:

(i) both sides of the upstream cofferdam,

(ii) along the Right Bank Containment Embankment, the Left Bank Containment Embankment and the Right Bank Saddle Dam,

(iii) the upstream river channel for haulage of excavated material from the channel deepening.

The initial section of the main access road and the section around the prominent hill feature between the Right Bank Embankments will become part of the permanent access road. After embankment completion, the permanent access road will be re-routed along these embankments.

All cofferdams can be incoiporated into the access road/ haul road network.

12.5.2 Barge Transportation Facilities

(a) Barge

A relatively large motorized barge will be required.

Depending on the final selection of type, size and source of generating unit, a capacity of around 120 tonnes is envisaged.

For flexibility, additional smaller vessels will also be required for the conveyance of employees and lighter vehicles.

Early procurement of a barge has been identified as part of the measures to facilitate preliminary works for expediting river diversion activities.

(b) Loading/Unloading Ramps

Loading/unloading ramps will be required at the Mainland Complex and on Don Sadam. The ramps will be designed with a concrete slab to allow vehicles transporting large/heavy loads to safely drive onto the barge for all river flow levels. Batters of ramp excavations will be protected from damage from stream flows.

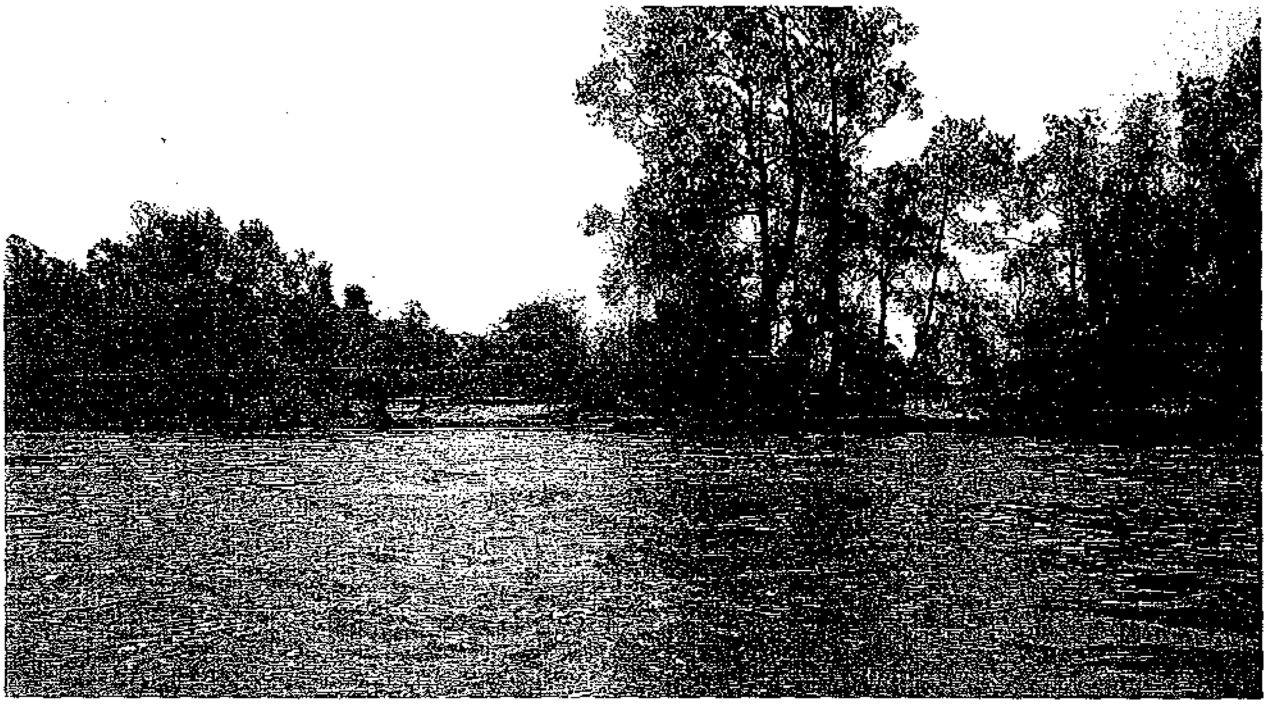


Photo 12-2 Probable Landing Site on Don Sadam, from the Mekong River

(c) Navigation Channel

For the safe transit of barges across the river, the need for a navigation channel has been identified, A channel 30m wide and 2m deep will need to be "dredged".

A pontoon with hydraulically-operated retractable legs and fitted with drilling units, air compressors, diesel generator and a hydraulic pumping system will be used to provided a secure platform for under-water drilling and for an excavator for side-casting blasted rock from the channel.

The channel will be identified by securely embedded navigation markers. Markers will be fitted with lights powered from batteries and solar-power battery re-charging units.

12.5.3 Aggregate and Concrete Supply

(a) **Concrete** Aggregates

Both coarse and fine aggregates for concrete are available from river deposits developed in a number of areas relatively close to the project site.

However, the locally available material will need to be augmented with crushed materials to provide the larger particle sizes necessary for the mass concrete in the lower parts of the Power Station.

Also, tests on the available fine aggregate indicate that blending with crusher fines may be necessary to provide a better graded material for the production of workable, durable concrete.

(b) Concrete Production

Concrete production will be required in the initial stages for Project Village construction, construction facilities including the barge loading/unloading ramps. Mobile batching units combined with concrete mixer trucks can be used to produce this concrete.

For the permanent works, concrete is required for the Power Station structure and for the face slabs of the containment embankments and saddle dam.

A concrete batching and mixing plant will be established within the construction facility complex adjacent to the Power Station site. For Power Station construction, mixed concrete will generally be transported to the site in kibbles for handling by tower cranes. Concrete pumps may also be considered to provide increased flexibility and simultaneous placement in different areas of the structure.

For concrete face slab construction, centrally mixed concrete can be transported in concrete mixer tracks and placed using a combination of chutes and conveyors.

(c) Filter Material for Embankments

Suitable excavated material will be processed to provide filter material for the upstream face of containment embankments and saddle dams. A grizzly for initial processing and a relatively simple crushing and screening plant will be required.

12.5.4 Works Area and Site Offices

Works areas and site offices will be divided between the Mainland Complex and the site.

(a) Site Facilities

At the site, facilities will be located in an area developed on the left bank of Hou Sahong adjacent to the Power Station. The following facilities will be required:

- Site Offices
- Employee Amenities, e.g. crib huts, toilets, first aid.
- Material Storage, e.g. construction timber, reinforcing steel, etc.
- Compressor House
- Carpentry shop for timber preparation and fabrication of simple formwork items.
- Construction Plant parking and maintenance
- Fuel Storage
- Explosive Magazine.
- Concrete Batching Plant, including cement storage and aggregate stockpiles
- Aggregate Processing Plant

Storage facilities will be sized to provide sufficient materials for short term use with material stocks replenished as required from bulk storage facilities located within the Mainland Complex.

The site will be fenced for the safety of local residents. Figure 12.2 suggests a possible layout of facilities.

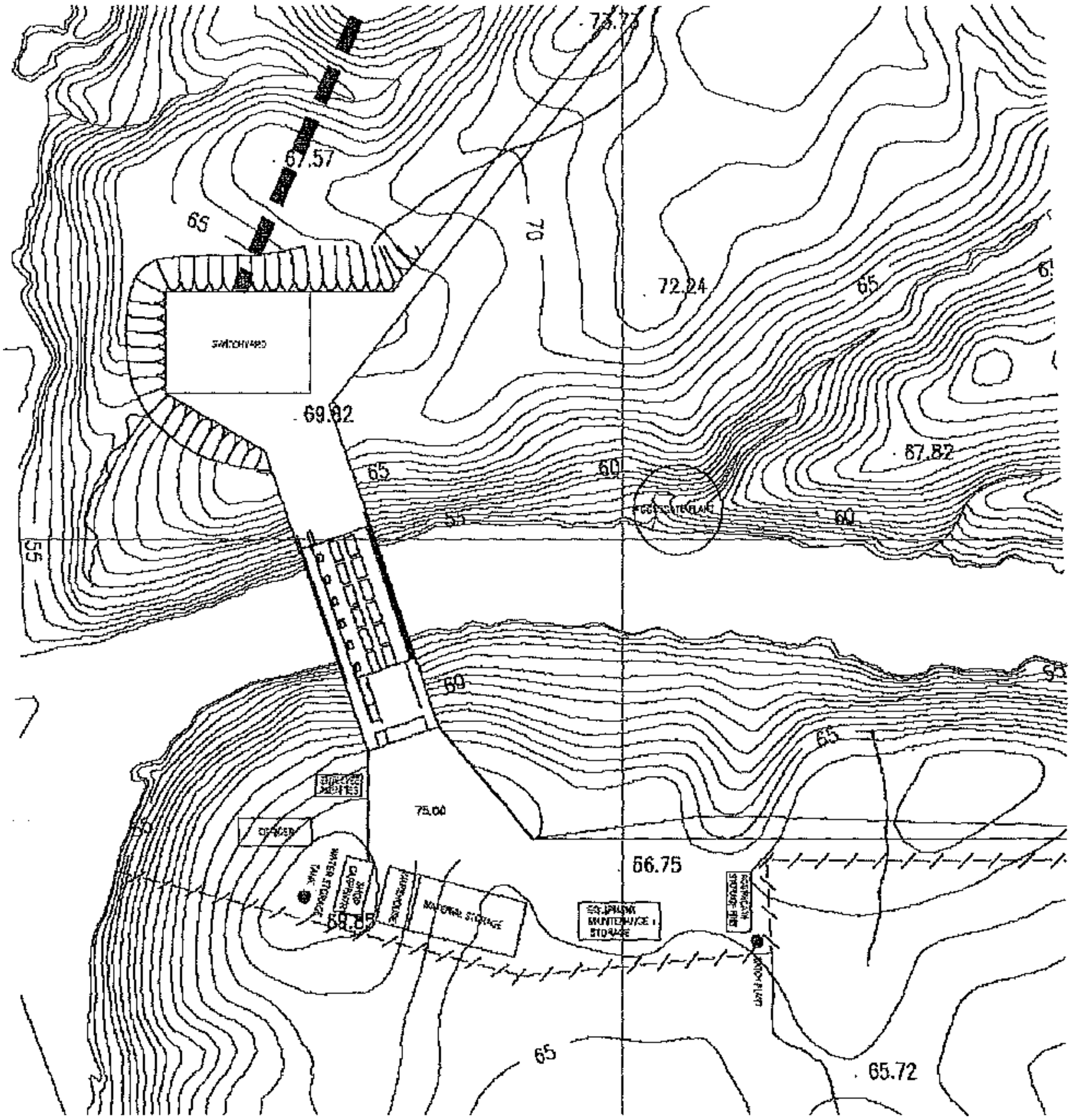


Figure 12-2 Layout of Facilities at Site

(b) Mainland Complex

Three sites have been identified as suitable for the establishment of the Mainland Complex: (Figure 12.3)

- Immediately north of the Khone Phapheng Resort complex, between the Mekong River and Main Road 13 (preferred option)

East of Main Road 13 and opposite the preferred site, with road access to the river and the barge landing site. This would abut the area where it is proposed to relocate Ban Napeng village.

North of Ban Veungkham, adjacent to the Mekong River. This would be more difficult for access to the site because of high banks at either landing place and a considerably longer distance for barges to travel. A high level bridge could possibly be constructed from the general area to Don Sadam, but this would be about 400 m long and involve constructing a number of piers in the fast flowing stretch of the river downstream of Phapheng Falls.

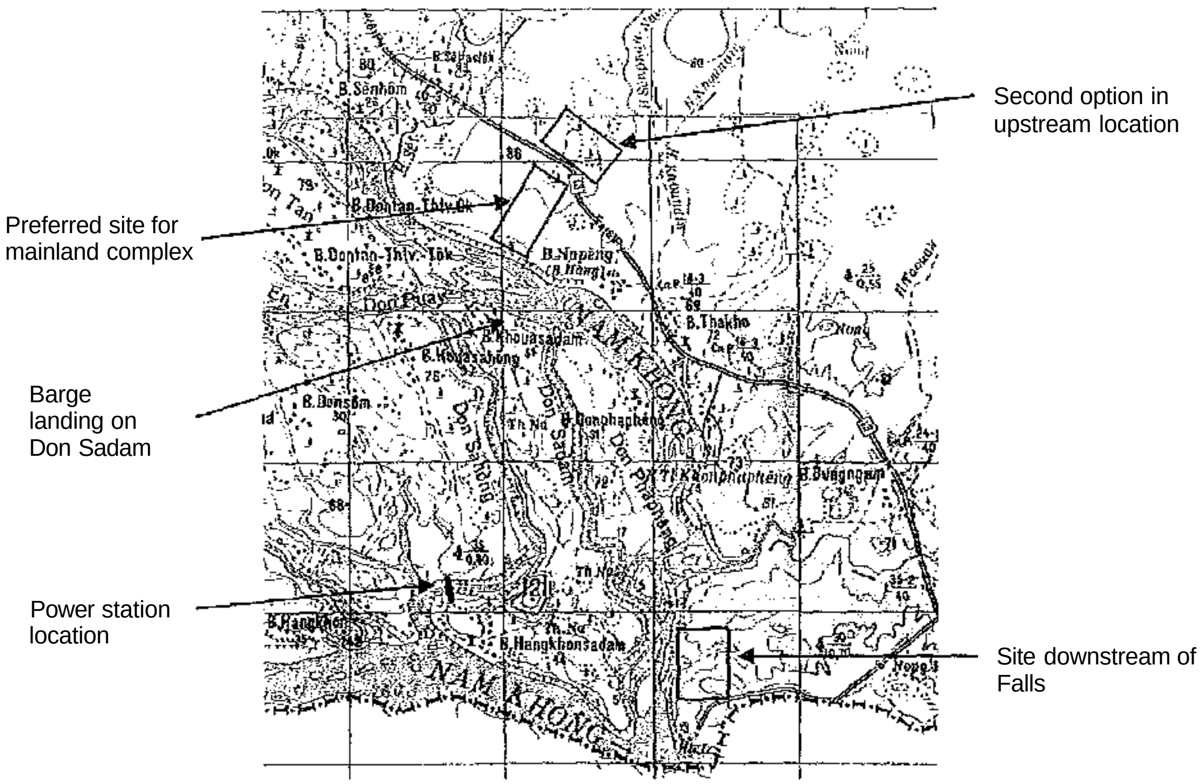


Figure 12-3 - Alternative sites for Mainland Complex

Constniction planning for this report is based on the first option, but it will be the responsibility of the EPC contractor to select the option that best suits his construction planning.

The following facilities will be located within the Mainland Complex:

(i) An office complex with adequate capacity for staff employed by the following:

Owner's Engineer
EPC Contractor
Major Sub-Contractors

(ii) Storage areas for bulk deliveries of constniction materials including constniction timber, reinforcing and stmctural steel, cement, concrete aggregates and explosives.

(iii) Warehouse facilities for the receiving and storage of miscellaneous consumable materials.

(iv) Bulk fuel storage.

(v) A facility for fabrication of special formwork, including that required for conduit transitions.

(vi) Temporary storage of components of the mechanical and electrical equipment for the Project.

12.5.5 Project Village

The Project location is relatively isolated and there are few community facilities close by (e.g. medical, religious, education, shopping and entertainment facilities).

Whilst it is envisaged that part of the unskilled labour force required for construction and equipment installation will be available from local communities, it is believed that the majority of management, engineering, supervisory and skilled labour will need to be recruited from major centres. To ensure the availability of a competent team of staff and employees to execute the Project, it is believed appropriate housing and community facilities will need to be provided to attract and retain a suitable labour force.

In order to minimize the volume of required cross-river transport and the area of land required *on* the islands, it is proposed that the project village be located within the mainland complex as previously explained.

The following facilities will be required:

(a) Housing Accommodation

Accommodation facilities will be required for the following:

- Company representatives
- Owner's Engineer
- EPC Contractor
- Major Subcontractors
- VIP Guests/Visitors

For each of these, accommodation will be required for the following categories of employee:

(i) Married Staff, including Expatriate Specialists
(ii) Single Staff, including Expatriate Technicians
(iii) Married Workers
(iv) Single Workers

For single employees, messes will be required

(b) Village Services

The following basic services will be required:

- Streets and footpaths
- Stormwater drainage
- Street lighting
- Power Supply and distribution
- Communication facilities
- Water treatment and storage
- Sewerage treatment works
- Garbage disposal site (incineration/burial)

(c) Community Facilities

In view of the numbers of employees and their families, various community facilities, including the following, will be required:

- Community/Recreation Hall
- Medical Clinic/Hospital
- School and Playground
- Temple
- Post Office
- Basic Shopping Facilities
- Outside recreational areas, e.g. soccer field

Senior and expatriate staff may be allowed to use the entertainment and recreational facilities available at the Khonephapheng Resort.

(d) Layout

Figured 12.4 is a sketch showing a suggested tentative layout of housing, office and community facilities. The final design will need to consider requirements for a permanent village to be created by retention of selected housing and facilities to form a functional village.

It should be noted that this layout has been prepared with limited knowledge of national and local customs. Accordingly, modifications may be necessary to meet these customs and also any special preferences of the Government and/or developer,

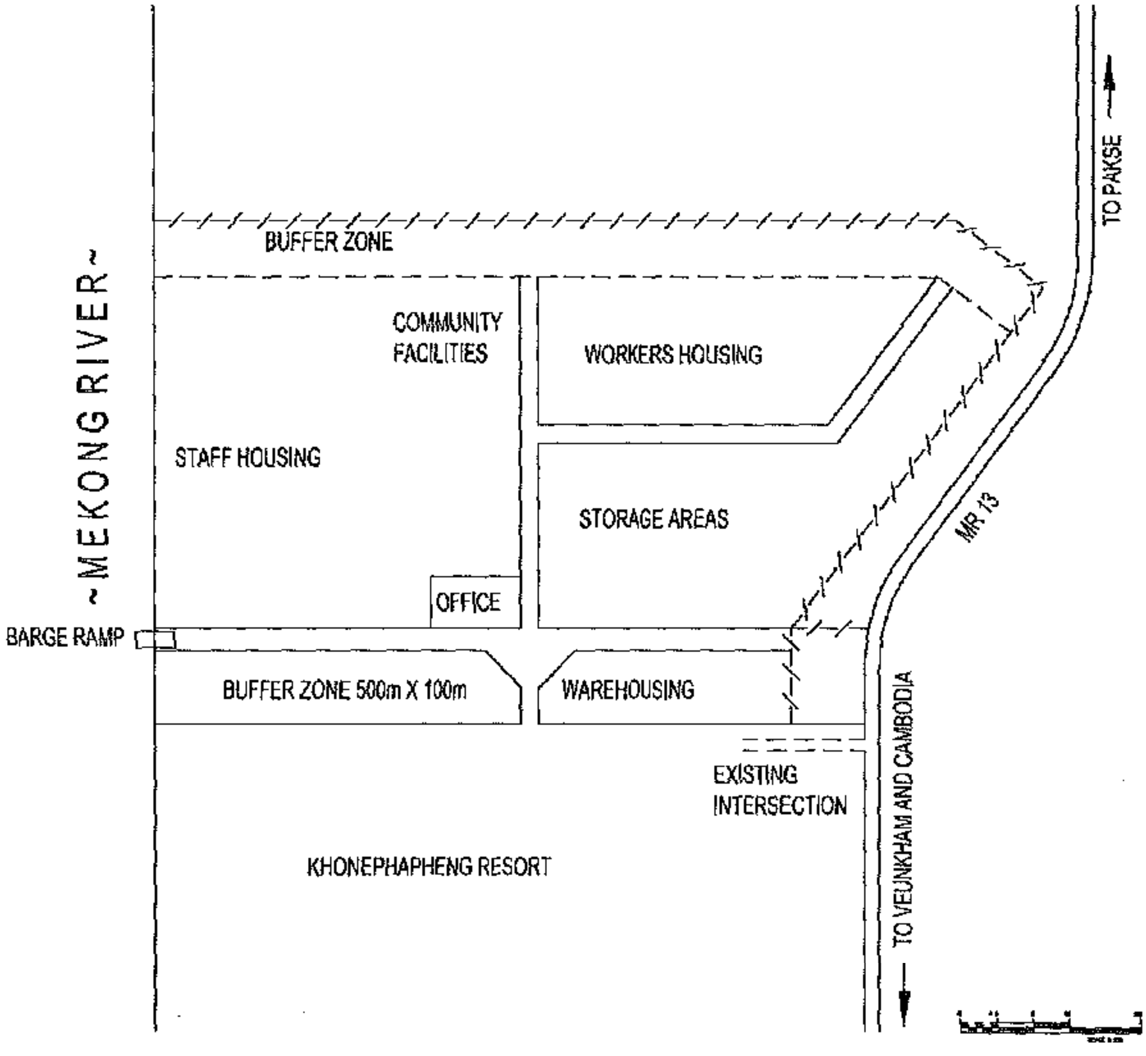


Figure 12,4 - Tentative Layout of Mainland Facilities

12.5.6 Construction Power

Construction power can be provided by constructing a new double circuit 22 kV transmission line from Ban Hat substation to the vicinity of Ban Nakasang and then across the Mekong to Don Tan, Don Puay and then Don Sahong.

The design of this system will enable the system to be modified to provide the power required on a permanent basis for Power Station services.

It is recognized that there could be disniptions to the power from this source and that it will not service all construction sites and accordingly, diesel generating sets will also be required.

12.6 Permanent Village for Operators and Maintenance Employees

Permanent housing and community facilities will be required for Power Station operators, maintenance employees and their families.

It is considered preferable to locate these facilities on the mainland rather than on Don Sadam. Selected housing and facilities provided for the construction phase can be retained to create a permanent village.

This would mean that only the operators will need to cross the river to their workplace on Don Sadam. River crossings by families and for the supply of foodstuffs and other goods would not be required.

12.7 Safety

In addition to the normal safety issues associated with major construction projects, special attention will be required for the following aspects:

- Use of river transport for the conveyance of employees from the mainland to the project site.
- Power Station construction where much of the work will be associated with expanses of vertical walls.

Safety regulations will be required and strictly enforced for all water transportation operations, especially those associated with the conveyance of heavy loads. Measures will be required to prevent inappropriate practices, such as overloading of vessels, and to ensure that all river transport is controlled by experienced operators.

Safe and secure access facilities will need to be provided to elevated work locations within the Power Station and regular safety appreciation sessions and inspections conducted to ensure the observance of safety regulations.

12.8 Construction Schedule

The start of project construction is dictated by the date by when the flow of the Hou Sahong can be successfully achieved.

The Mekong River is subject to relatively predictable seasonal variations in flows and river diversion can only be carried out during the annual period of low flows which is traditionally January to May.

In view of the current status of the feasibility and approval processes, the earliest realistic start date is January 2009 and the construction schedule is based on this date.

Once successful river diversion has been achieved, construction access roads constructed and construction facilities established, construction activities are straight-forward although they involve relatively large amounts of repetitive work, i.e. bulk excavations, concrete works, embankment construction and face-slab slipforming.

Work can proceed simultaneously in many areas but will require effective planning and continuous monitoring to ensure availability of materials and efficient allocation of resources.

Two major target dates have been identified for civil construction works:

- Completion of Power Station Substructure to allow installation/ operation of the Main Power Station Gantry Crane - September 2010.

- Power Station Water-tight - September 2010.

The first date represents the situation where installation of the Generating Sets can commence.

The second date represents the situation where the lower levels of the Power Station are protected by the stoplogs and draft tube gates. The earliest dates for removal of the main upstream and downstream cofferdams are dependent on the achievement of this milestone. Upstream cofferdam removal is obviously additionally dependent on the completion of the Containment Embankments and Right Bank Saddle Dam,

For Electrical and Mechanical works, the following target dates have been identified for the first unit:

- Factory Testing - September 2010
- Delivery to Site - March 2011

The construction schedule is shown on Figure 12-5 at the end of this Section.

12.9 Transport of Heavy Plant and Equipment

Heavy loads to be transported to the project fail into two categories:

(i) Construction equipment, including bulldozers, excavators, tower crane components and the like,
(ii) The generator sets, transformers and stoplogs to be installed in the Power Station.

For the first category, this study allows for the design and procurement of a barge with a load capacity of 120 tonnes. Barge loading ramps will be designed and constructed to allow low-loaders transporting the equipment to be safely driven on and off the barge.

For the second category, there are a number of options and their use will depend largely on the location of manufacture of the items and the decision of the EPC Contractor.

One option is the use of road transport to convey the items from the selected port of arrival from the country of manufacture and then using the procured barge to transport the items to Don Sadam. Potential ports of arrival are Danang in Vietnam and Bangkok in Thailand. After arriving on Don Sadam, the items would then simply be transported to the Assembly/Unloading Bay of the Power Station for unloading and subsequent movement and lowering into final position using the station cranes.

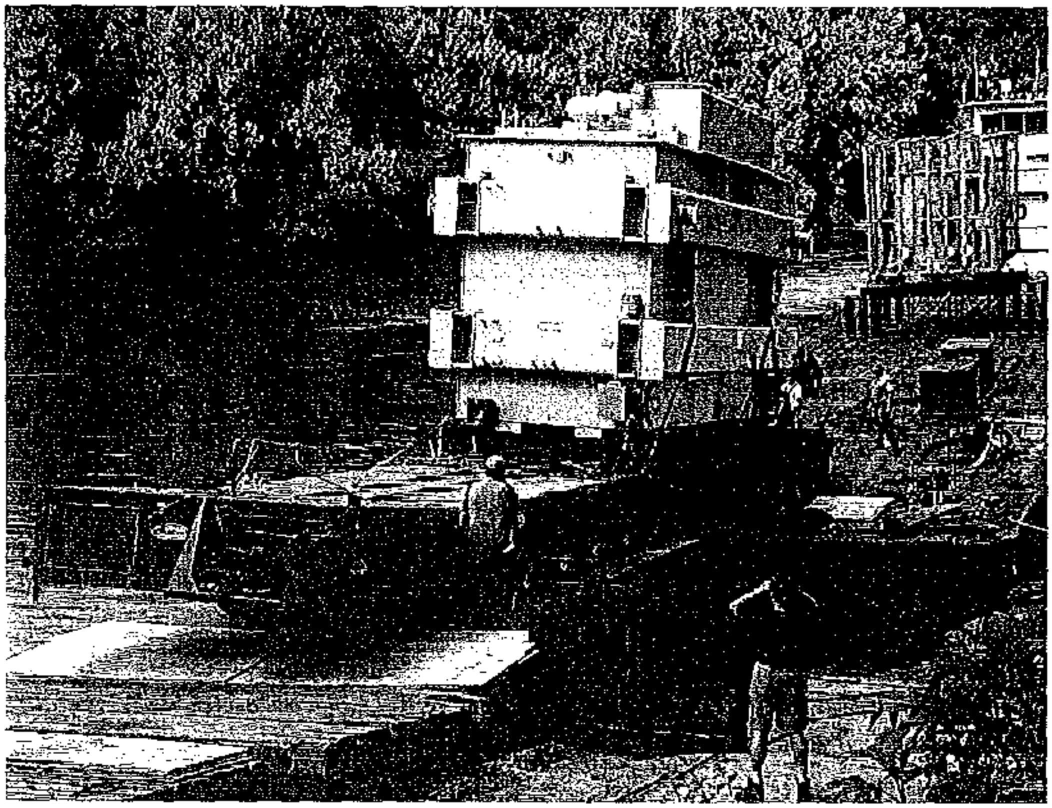
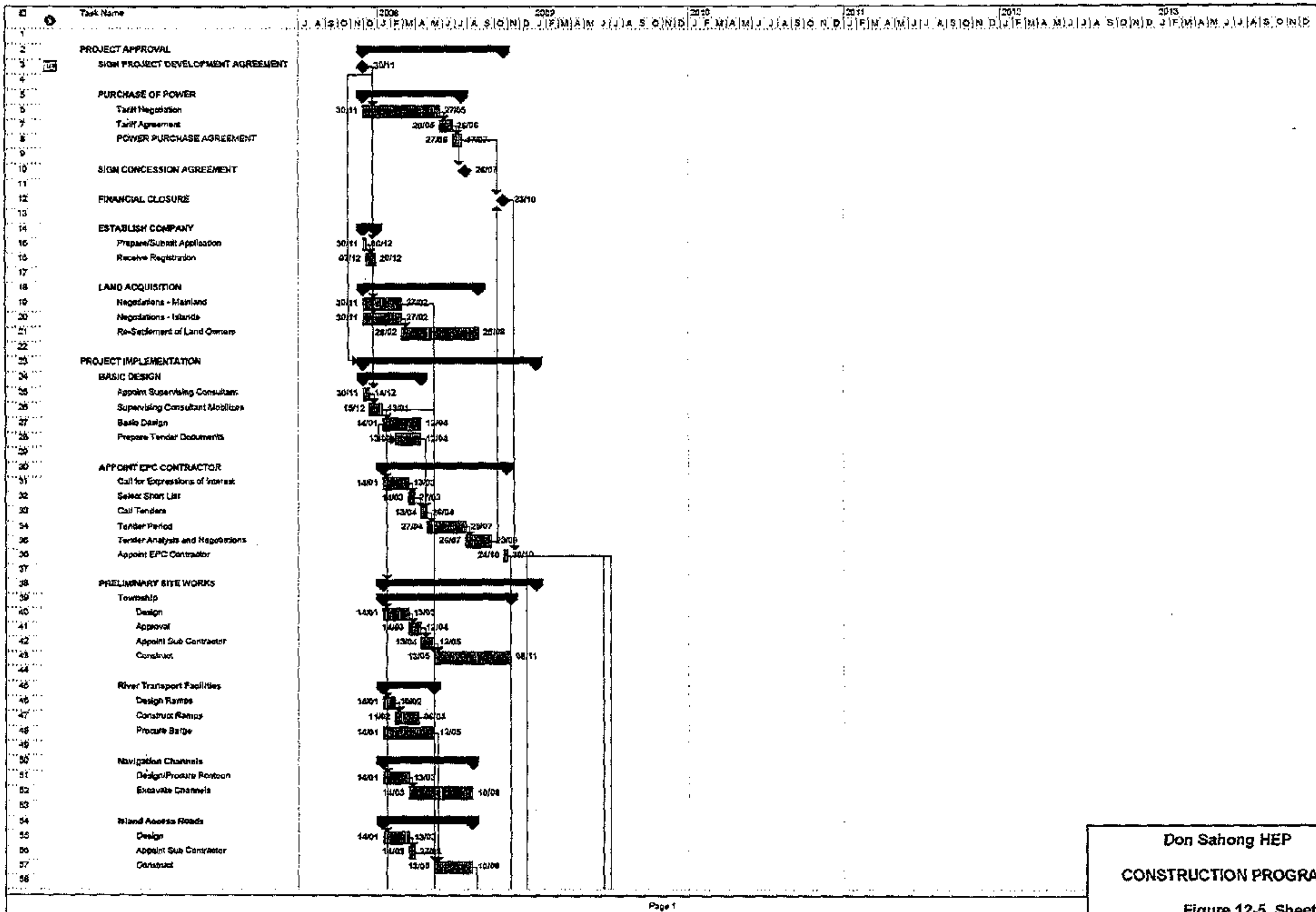


Photo 12.3 Loading Power Transformer on to Barge

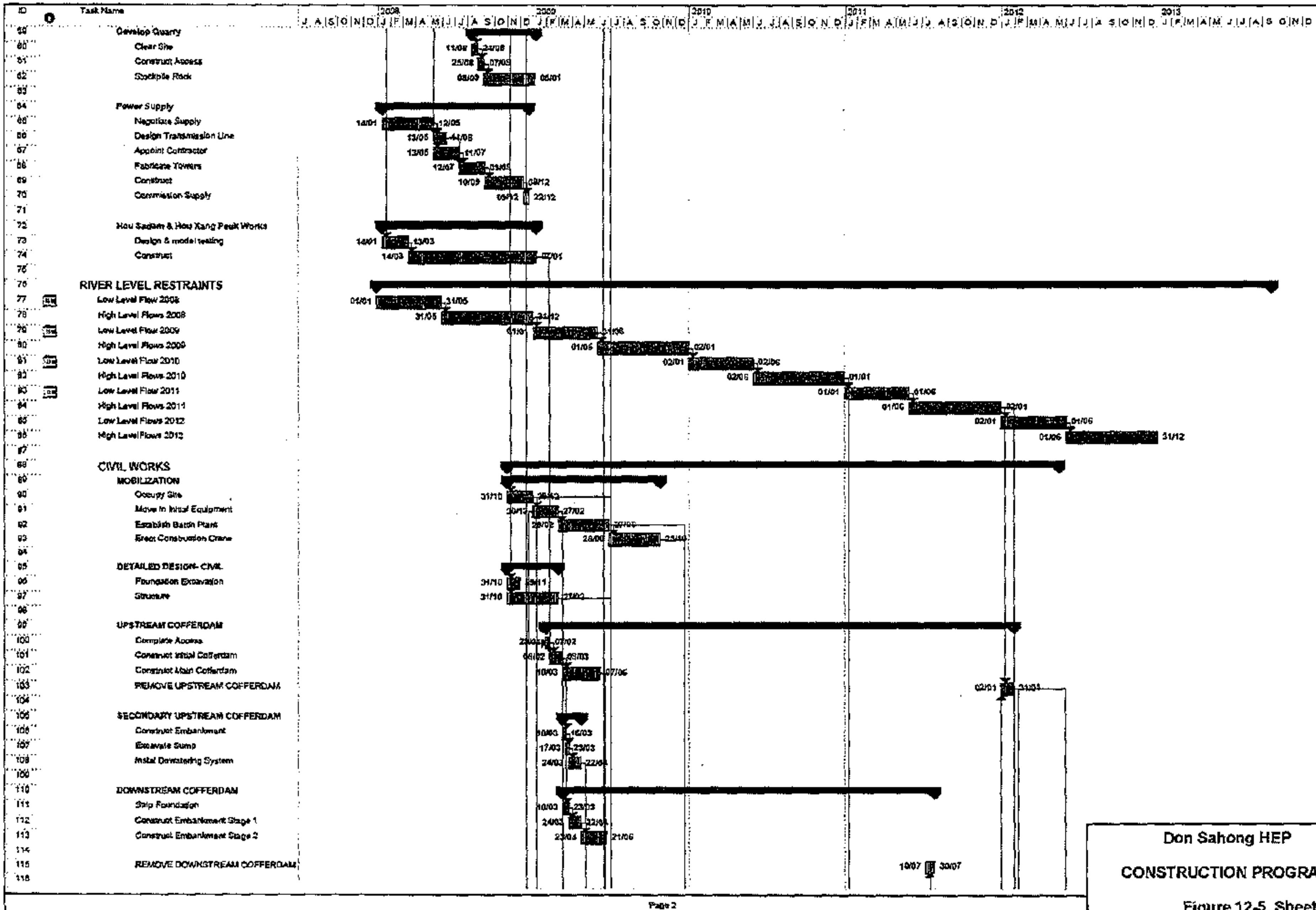
A second option would be the use of river transport to convey the items up the Mekong River to the downstream end of Hou Sahong. With this option, specially designed facilities will be required to transfer the items from the river transport and then to the Assembly/Unloading Bay for subsequent handling with the station cranes. Also, unless special purpose air-cushion vessels (hovercraft) were used, transport would only be possible in the high flow season as the Mekong above Kampong Cham has limited depth and MRC advises that vessels are restricted to 80 DWT upstream of Kampong Cham in the low flow period and *15* DWT above Stung Treng.



Don Sahong HEP

CONSTRUCTION PROGRAM

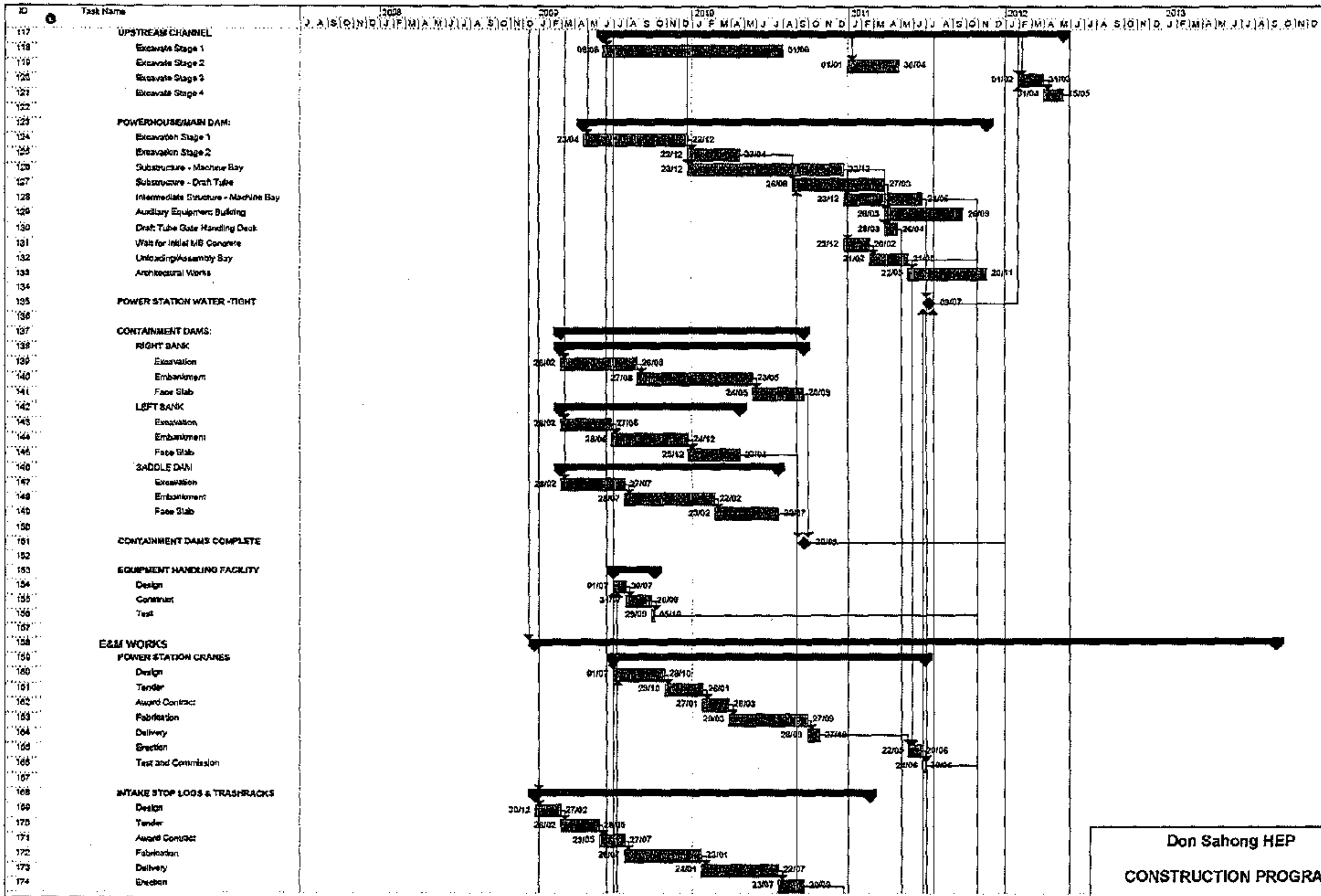
Figure 12-5, Sheet1 of 4



Don Sahong HEP

CONSTRUCTION PROGRAM

Figure 12-5, Sheet2 of 4



Don Sahong HEP

CONSTRUCTION PROGRAM

Figure 12-5, Sheet 3 of 4

ID	Task Name	Start	Finish
175	Test and Commission	23/12	20/02
176			
177	DRAFT TUBE GATES		
178	Design	30/12	27/02
179	Tender	28/02	28/05
180	Award Contract	29/05	27/07
181	Fabrication	28/07	23/05
182	Delivery	24/05	10/11
183	Erection	27/04	25/06
184	Test & Commission	26/06	9/07
185			
186	GENERATING UNITS		
187	Design	30/12	30/06
188	Tender	1/07	29/09
189	Award Contract	30/09	28/11
190	Fabricate Draft Tube Liners	29/11	27/06
191	Deliver Draft Tube Liners	28/05	25/08
192	Fabrication	29/11	18/12
193	Delivery and Unloading	30/05	22/05
194	Unit 1 Erection & Embedment	30/10	29/05
195	Unit 2 Erection & Embedment	27/01	27/07
196	Unit 3 Erection & Embedment	27/03	25/09
197	Unit 4 Erection & Embedment	26/05	24/11
198	Unit 5 Erection & Embedment	15/07	23/01
199	Unit 6 Erection & Embedment	28/09	24/03
200	Unit 1 Test & Commission	30/05	28/06
201	Unit 2 Test & Commission	28/07	26/08
202	Unit 3 Test & Commission	26/09	25/10
203	Unit 4 Test & Commission	25/11	24/12
204	Unit 5 Test & Commission	24/01	22/02
205	Unit 6 Test & Commission	25/03	23/04
206			
207	TRANSFORMERS		
208	Design	30/12	30/04
209	Tender	1/05	30/07
210	Award Contract	31/07	12/09
211	Fabrication	13/09	12/09
212	Delivery	13/09	9/02
213	Unloading & Installation	10/02	10/04
214	Test & Commission	17/04	18/04
215			
216	SWITCHYARD		
217	Design	1/07	30/07
218	Construct Footings	24/05	22/08
219	Procure Equipment	31/07	26/07
220	Erect Equipment	23/08	21/10
221	Test & Commission	16/12	20/12
222			
223	TRANSMISSION LINE WORKS		
224	Design	1/07	28/09
225	Fabricate and Deliver Initial Towers	29/09	30/03
226	Faricate and Deliver Remaining Towers	31/03	29/06
227	Erect Initial Towers	31/03	30/03
228	Erect Remaining Towers	31/03	16/09
229	String Conductors	17/09	15/11
230	Test & Commission	16/11	15/12

Don Sahong HEP

CONSTRUCTION PROGRAM

Figure 12-5, Sheet 4 of 4

SECTION 13

COST ESTIMATE AND RISK

13.1 General

The Construction Cost estimate is shown in Table 13.1. It is an estimate of the cost of design and construction, in $US at June 2007 price levels, inclusive of contractors' margins. Other costs, such as development and legal costs are excluded. All rates are free of tax as indicated in the MoU.

Table 13.1 - Construction Cost Estimate
(all costs in millions of US$)

	180 MW	240 MW	300 MW	300 MW	360 MW	400 MW	480 MW
	6x30MW	6x40MW	6x50MW	5x60MW	6x60MW	8x50MW	8X60MW
Mainland facilities	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Access to Don Sahong, roads on Don Sahong, power to site etc	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Lowering Hou Sahong entrance							
to RL 66	27.8	27.8					
to RL 65			39.3	39.3	39.3		
to RL 64						56.5	56.5
to RL 63							
Embankments	6.6	6.6	6.6	6.6	6.6	*6.6*	6.6
Power Station							
Civil Works	36.9	38.4	40.8	40.6	44.2	50.4	55.2
Cranes	1.4	1.7	2.0	2.3	2.3	2.0	2.3
Trashracks, gates and hoists	9.1	0.8	12.8	12.5	14.8	16.8	19.4
Turbine + generator	108.0	126.6	148.4	140.5	168.6	198.4	224.8
Balance of plant	39.6	48.6	57.6	53.0	63.6	76.8	84.8
Power Transformers	4.8	6.2	7.2	6.6	7.9	9.7	10.5
Substation & connection to Ban Hat	29.6	30.4	30.8	29.8	31.2	32.5	44.4
Tailrace improvement	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Allowance for other items in EPC contract	12.1	12.2	12.3	12.3	12.4	12..6	12.8
Engineering	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Total	297.0	320.4	378.9	364.6	412.0	470.8	538.4
Contingency 10%	29.7	32.0	37.9	36.5	41.2	47.1	53.8
Total construction cost - US$	326.7	352.4	416.8	401.1	453.2	[1] 517.9	592.2
Transmission line costs							
To Ubon	70.5						
To Stung Treng	(no cost to project as World Bank has made grant to GOL and RGC to construct this 115 kV line and will be in service before project goes on line)						
Environmental costs	28.1						

13.2 Civil Construction

13.2.1 Method

Quantities were calculated for each of the components of the permanent works as the preferred project arrangement, operating levels and type and number of generating sets established,

Similarly, the quantities of temporary works, such as the lengths of haul roads, were determined during the construction planning process.

The estimated cost for each of these items was then calculated by a unit cost to the calculated quantity.

Items for which there is no representative quantity were assigned lump sums.

13.2.2 Selection of Unit Rates

The lumps sums and unit rates adopted are intended to reflect factors such as

(i) the need for imported equipment and materials.
(ii) the transport costs inherent with a relatively isolated location.
(iii) the inherent lack of skilled local labour and hence the need to provide accommodation and community facilities to entice and retain a suitable work force.
(iv) the need for storage and re-handling, especially of bulk materials, as, in general, delivery vehicles will not be able to transport materials direct to the construction site.

For each classification of work, the rate was selected after consideration of rates from various sources including projects of similar nature, i.e. projects located in remote areas and subject to factors (i), (ii) and (iii) listed above.

13.2.3 EPC Contractor Costs

EPC costs include allowance for insurances and performance bonds, general overheads, engineering and supervision, and profits.

13.3 Electrical and Mechanical Plant

Lump sum estimates were derived separately for the supply of major components of mechanical and electrical plant.

13.3.1 Turbines and Generators

Turbine and generator manufacturers were reluctant to provide budget costs for plant items, citing legal problems, over commitments on other projects and volatility in steel prices. For the latter reason also, historic data bases are of little use.

However, one European manufacturer, who had provided prices for similar sized plant in the recent past for another project in Laos, did provide prices for turbines and generators on a CIF Bangkok port basis. To convert these prices to installed prices, including transport from Bangkok, the prices were increased by 15 %.

A verbal estimate was provided by the Chinese representative of a European manufacturer. The basis for this estimate was ex factory in Renminbi Yuan. A loading of 25% has been added to cover shipping and insurance and installation.

A Chinese trading house has also quoted for what we believe to be cost estimates for the complete plant - turbine, generator and BOP - FOB. These were also adjusted upward by 25% to cover shipping and insurance and installation.

Table 13.2 displays the various cost estimates, including the estimates used for the project costing, after considering the various data.

Table 13.2 - Turbine and Generator Estimates

Item			30 MW	40 MW	50 MW	60 MW
European manufacturer [1,2]						
Bulb Turbine CIF	CIF CIF Instal	Euro US$ US$	6.5 8.8 10.1	8.4 11.3 13.0	9.8 13.2 15.2	11.1 15.0 17.2
Kaplan Turbine	CIF CIF Instal	Euro US$ US$	7.5 10.1 11.6	9.7 13.0 15.0	11.3 15.2 17.5	12.8 17.2 19.8
Generator for Bulb Unit	CIF CIF Instal	Euro US$ US$	4.75 6.4 7.4	6.1 8.2 9.5	7.2 9.7 11.2	8.2 11.1 12.7
Chinese representative of European manufacturer						
Bulb Turbine & Generator[3,4]	Ex fact Ex fact Inst	RMB US$ US$	90.0 11.7 14.6	100 13.0 16.2	125 16.2 20.3	150 19.5 24.4
Chinese trading house						
Plant complete	FOB Inst	US$ US$	9.9 12.4	12.1 15.2		18.4 23.0
Consultant data base						
Kaplan generator	Instal	US$	6.8	8.8	10.2	11.6
Costs used for project estimate						
Bulb Turbine + generator	Instal	US$	18.0	21.1	24.8	28.1
Kaplan Turbine + generator	Instal	US$	17.8	20.8	24.4	27.6

Notes: 1. Quotations were for rated head of 17 m
2. Quotation in Euro and converted to US$ at 1.35
3. Quotation in RMB and converted to US$ at 7.7
4. Add 25% for shipping and installation

13.3.2 Balance of Plant

Estimated costs of balance of plant covering generator switchgear, the unit LV & HV connections, station AC & DC supplies, SCADA and communications is given in Table 13.3.

Table 13.3 - Balance of Plant Cost Estimates (millions of US$)

Item	30 MW	40 MW	50 MW	60 MW
Generator HV & LV connections	**1.4**	1.8	2.1	2.3
Control/auxiliaries	**5.2**	6.3	7.5	8.3
Total	**6.6**	**8.1**	**9.6**	**10.6**

13.3.3 Transformers

Based on information provided by transformer manufacturers, Table 13.5 sets out costs for three-phase power transformers.

Table 13.4-Transformer Cost Estimates (millions of US$)

Item	30MVA	50MVA	60MVA	70MVA
Three-phase power transformer	0.80	1.04	1.21	1.32

13.3.4 Hydromechanical Equipment

Cost estimates for trashracks, gates and hoists and cranes have used the consultant's data base of similar equipment.

Table 13.5 - Cost Estimates for Gates and Cranes (millions of US$)

Item	30 MW	40 MW	50 MW	60 MW
Bulb units				
Trashracks	0.16	0.21	0.25	0.32
Bulkhead gates/stop logs	0.35	0.46	0.58	0.69
Gantry crane	0.12	0.14	0.18	0.21
Draft tube gate	0.92	1.04	1.15	1.27
Draft tube hoist	0.58	0.81	0.98	1.15
Generator Gantry	0.69	0.81	0.98	1.15
Turbine Gantry crane	0.69	0.81	0.92	1.04
Kaplan units				
Trashracks	0.24	0.31	0.39	0.47
Bulkhead gates/stop logs	0.31	0.39	0.54	0.66
Guard gates	0.47	0.60	0.81	0.98
Gantry crane	0.12	0.14	0.18	0.21
Draft tube gate	0.10	0.13	0.17	0.20
Draft tube gantry	0.16	0.17	0.20	0.22
Power station OHT crane	0.92	1.15	' 1.38	1.73

13.3.5 Transmission Lines

Transmission line costs for manufacture, delivery and erection were based on a rate of US$ 235,000/km, based on quotes from contractors and recent tenders. This has been increased to US$ 250,000/km, where appropriate, to cover any substation modifications, environmental measures, design and supervision.

13.4 Design and Project Management

Design costs have been assessed from first principles for all the permanent works except the project village and the operators' village. Included are costs for site investigation and also a design presence on site during construction. The allowances for design in the estimate have been calculated as appropriate percentages of the direct costs, derived by rounding up these first principles estimates to ensure unforeseen events are covered.

13.5 Risk Analysis and Contingencies

The main areas of risk have been identified as follows:

Major Risk Items

1. Successful construction of cofferdams in the limited construction period available due to seasonal fluctuation of river levels.
2. Transport and handling of heavy items including generating sets and transformers.
3. Government approvals for importation of equipment and spare parts.
4. Government approvals for importation of materials.
5. Government approvals for employment of expatriate employees, including engineers and skilled tradesmen.

Medium Risk *Items*

1. Continuity of supply and delivery of imported construction materials, e.g. steel reinforcement, cement.
2. Continuity of supply and delivery of locally available construction materials, e.g. sawn timber, aggregates.
3. Continuity of supply and delivery of consumable items such as fuel and explosives.
4. Security for the transport and storage of explosives.
5. Availability of adequate numbers of skilled/experienced tradesmen and plant operators.
6. Security at site for the safety of local residents.
7. Securing of suitable sites for the disposal of surplus excavated materials

Low Risk Items

1. Continuity of access and construction activities in the event of abnormal climatic conditions.
2. Stability of excavated batters
3. Unforeseen geological conditions

13.6 Cash Flows

Table 13.6 shows the basic annual expenditure schedule for the project, based on the construction program presented in Section 12.

Table 13.6 - Estimated Annual Cash Flow

Year 1	Year 2	Year 3	Year 4	Years
20%	25%	35%	17%	3%

SECTION 14

ECONOMIC AND FINANCIAL EVALUATION

14.1 Introduction

The Energy Modelling for the Project, as reported in Section 11, addressed numerous parameters, Bulb, Kaplan and Propeller Turbines, and combinations of these at various design heads. The study also incorporated alternative levels of excavation to the Hou Sahong entrance to optimise energy production, while allowing minimum environmental flow ranging from 800 - 1200 nrVsec through other channels.

From the findings of the Energy Model Studies, seven (7) plant configurations using Bulb Turbines and having station installed capacities varying from 180 to 480 MW with different Hou Sahong entrance level excavation were chosen for detailed economic and financial evaluation. The basic details of the 7 options are listed in Table 14.1.

Table 14.1 Basic Details of Proposed Plant

Option	Plant Configuration and Installed Capacity	Hou Sahong Entrance Excavation (Level & Costs) (US$ millions)	Construction Costs (US$ miiiions)	Average Annual Energy (GWh)	Capacity. Factor (%)
A	6 x 30 = 180 MW	66 m (US$2 7.8 m)	US$ 326.7 m	1460.5	92.6
B	6 x 40 = 240 MW	66 m (US$ 27.8 m)	US$ 352.4 m	1838.1	87.4
C	6 x 50 = 300 MW	65 m {US$ 39.3 m)	US$ 416.8 m	2140.2	81.4
D	5 x 60 = 300 MW	65 m (US$ 39.3 m)	US$401.1 m	2140.4	81.4
E	6 x 60 = 360 MW	65 m (US$ 39.3 m)	US$ 453.2 m	2375.0	75.3
F	8 x 50 = 400 MW	64 m (US$ 56.5 m)	US$ 517.9 m	2528.0	72.15
G	8 x 60 = 480 MW	64 m (US$ 56.5 m)	US$ 592.2 m	2659.6	63.25

Notes: (a) Environmental flow = 1000 m^3/sec.
(b) Construction costs include Hou Sahong Entrance Excavation costs.

The Construction Costs indicated in Table 14.1 varying from US$326.7 for a 180 MW power plant up to US$ 592.2 for a 480 MW power plant only cover the cost of the power plant and directly associated civil works. The cost of project development, non-engineering advisory services, costs related to environmental mitigation / compensation and transmission lines to EGAT are not included.

14.2 Estimates and Assumptions

Table 14.2 indicates the other project-related costs and basic assumptions to be used in financial evaluation using a Financial Model.

Table 14.2 Estimates and Assumptions used in the Financial Model

(a)	Basic Tariff in PPA	6.25 USc/kWh (escalated at 1% per annum)
(b)	Debt: Equity Ratio	75:25
(c)	Cost of borrowing	9.5 %
(d)	Loan Grace Period	Nil- repayments commence at COD
(e)	Loan Repayment Period	8 years
(f)	Depreciation (Straight Line)	30 years
(9)	PPA Duration after COD	30 years
(h)	Royalty to Laos Government	2.5% of revenue
(0	Corporate Tax Holiday after COD	7 years
(J)	Corporate Tax on Net Profit after Tax Holiday	10%
(k)	Commercial Operation Date (COD)	1 January 2013
(l)	Energy Loss due to Unplanned Outages	3%
(m)	Cost of Transmission Line to Ubon (EGAT)	US$ 70.5 m
(n)	Transmission Losses to Ubon	5%
(o)	Cost of Transmission Line to Stung Treng (EdC)[1]	-
(P)	Transmission Losses to Stung Treng [1]	-
(q)	Environmental Costs including mitigation measures	US$ 28.1 m
(r)	Development Costs	US$ 20 m
(s)	Construction costs (for 6 x 360 MW)	US$ 571.8 m
(t)	Interest during construction	Capitalised into Total Project Cost
(u)	Annual 0 & M Costs (Percentage of Construction Costs)	3 % (escalated at 2% per annum)
(v)	Rehabilitation Costs (Percentage of Turbine and Generator Costs every 10 years)	10%
(w)	Energy Saies	90 % to EGAT ; 10% to EdC

Note: 1. As the World Bank has granted the Lao and Cambodian Governments funds to construct a 115 kV transmission line from Ban Hat to Stung Treng and this fine will be more than adequate to carry the exported energy to Cambodia, it is assumed that there is no cost to the project. Also assumes metering for Cambodian export at Ban Hat, so no transmission losses.

The Project Costs for the seven (7) options for the base case financial evaluation are as indicated in Table 14.3.

Table 14.3 -Total Project Costs

	180 MW (6x30 MW)	240 MW {6x40 MW)	300 MW (6x50 MW)	300 MW (5x60 MW)	360 MW (6x60 MW)	400 MW (8x50 MW)	480 MW (8x60 MW)
Breakdown of Costs	US$ million	US$ million	US$ million	US$ million	US$ million	US$ million	US$ million
Construction Costs (Table 14.1)	326.7	352.4	416.8	401.1	453.2	517.9	592.2
Transmission Line to EGAT (Table 14.2)	70.5	70.5	70.5	70.5	70.5	70.5	70.5
Environmental Costs (Table 14.2)	28.1	28.1	28.1	28.1	28.1	28.1	28.1
Development Costs (Table 14.2)	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Project Capital Cost	**445.3**	**471.0**	**535.4**	**519.7**	**571.8**	**636.5**	**710.8**
Interest during Construction @ 9.5%	78.2	82.9	94.8	91.9	101.5	113.4	127.0
Total Project Cost	**523.5**	**553.9**	**630.2**	**611.6**	**673.3**	**749.9**	**837.8**

14.3 Economic Evaluation

The financial model runs gave Internal Rates of Return (IRR) and Net Present Values (NPVs) for a 10% discount rate as indicated in Table 14.4, which also indicates the Interest accrued during construction at the selected borrowing rate.

Table 14.4 - Initial screening

Option	Plant Configuration & Installed Capacity	**IDC** (US$ million)	IRR (%)	iRR Ranking	NPV (USS million)	**NPV Ranking**
A	6x30 = 180MW	78.2	11.7%	7	64.2	7
B	6 x 40 = 240 MW	83.0	14.0%	5	172.8	6
C	6 x 50 = 300 MW	94.8	14.4%	3	214.3	5
D	5 x 60 = 300 MW	91.9	14.8%	2	230.7	3
E	6 x 60 = 360 MW	101.5	14.9%	1	259.4	1
F	8 x 50 = 400 MW	113.4	14.3%	4	248.5	2
G	8 x 60 = 480 MW	127.1	13.4%	6	218.6	4

The IRR tabulation indicates that Option E (360 MW capacity Power Plant) is ranked highest at 14.9 % IRR, with Option D (300 MW Power Plant) ranked next at 14.8 % IRR.

In the case of the NPV tabulation, Option E (360 MW Plant) is ranked highest with an NPV of US$ 259.4 million while Option F (400 MW Plant) is next with an NPV of US$ 248.5 million and Option D lower with NPV of US$ 230.7 million.

The IRR and NPV results are indicated graphically in Figures 14.1 and 14.2 respectively.

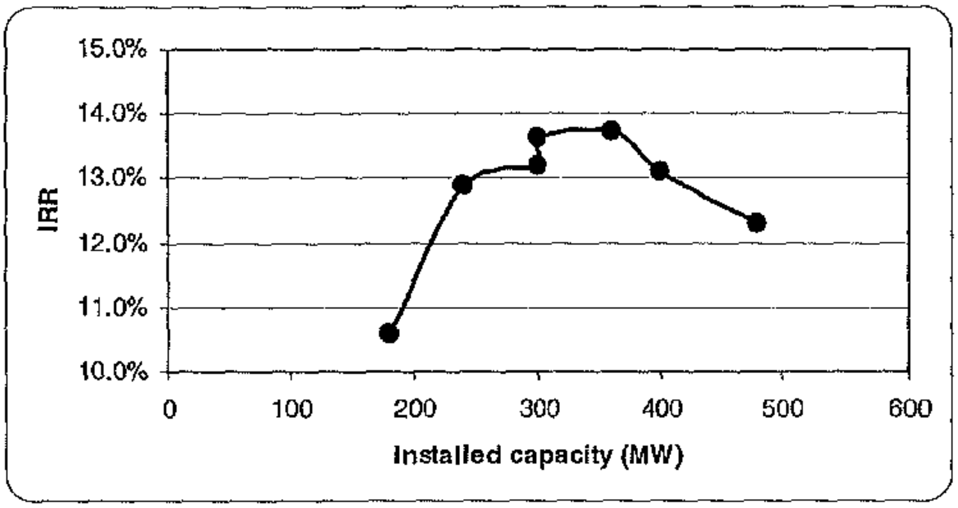


Figure 14.1 - Variation of IRR with installed capacity

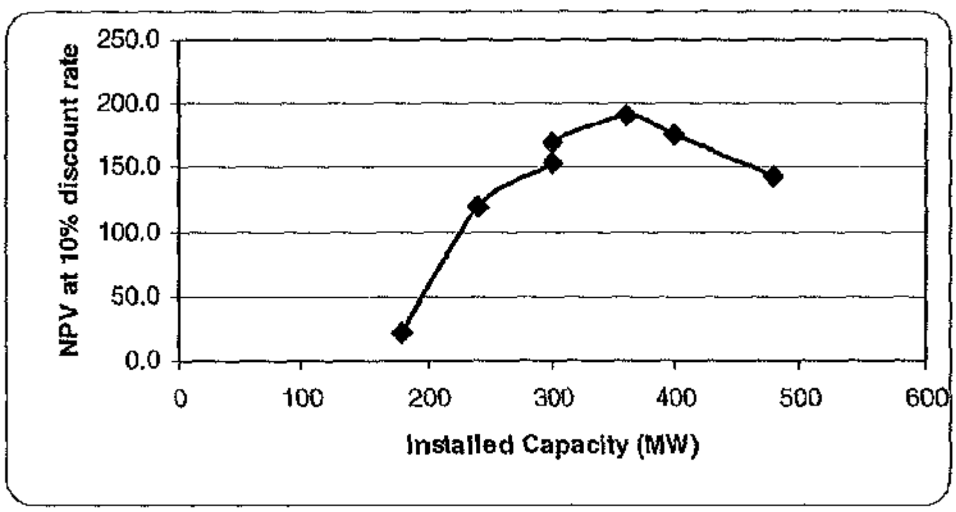


Figure 14.2 - Variation of NPV with installed capacity

14.4 IRR and NPV after Tax

Further financial modelling runs were conducted to determine the IRR and NPV for the 7 options with payment of corporate tax of 10 % after a 7-year tax holiday. The results obtained are indicated in Table 14.5. Again the highest ranking IRR(T) and NPV(T) are for the 360-MW Option E.

Table 14.5 - Ranking of Installed Capacity after Financial Evaluation

Option	Plant Configuration & Installed Capacity	IRR(T) (%)	Ranking/Order of Priority	NPV (T) (USS million)	NPV Ranking
A	6x30MW = 180MW	11.2%	**7**	46.0	**7**
B	6 x 40 MW = 240 MW	13.6%	**5**	148.2	**6**
C	6x50MW = 300MW	13.9%	**3**	185.5	**4**
D	5 x 60 MW = 300 MW	14.4%	**2**	201.5	**3**
E	6 x 60 MW = 360 MW	14.5%	**1**	227.2	**1**
F	8 x 50 MW = 400 MW	13.9%	**4**	214.6	**2**
G	8 x 60 MW = 480 MW	13.0%	**6**	183.8	**5**

14.5 Sensitivity Studies on Selected Options

The thi'ee best-ranked options in the financial model runs reported in Sections 14.3 and 14.4 are shown in Table 14.6, together with Option B (240 MW).

Table 14.6 Rankings of Options B, D, E and F

Option	Plant Configuration (MW)	Rankings			
		IRR	NPV	IRR(T)	NPV(T)
B	6 x 40 MW = 240 MW	**5**	**6**	**5**	**6**
D	5 x 60 MW = 300 MW	**2**	**3**	**2**	**3**
E	6 x 60 MW = 360 MW	**1**	**1**	**1**	**1**
F	8 x 50 MW = 400 MW	**4**	**2**	**4**	**2**

Sensitivity studies were earned out for Options B, D and E for the variations of input parameters, as shown in Table 14.7.

Table 14.7 Variations of Input Parameters

Input Parameters	Values	Base
Debt: Equity	70:30	75:25
Interest on Debt	10%	9.5 %
Loan Repayment Years	6	8
Tariff (US0 per kWh)	6.0	6.25
Tariff (US0 per kWh)	5.75	6.25
Royalty (% of revenue)	5	2.5
O&M cost escalation	3% pa	2% pa
Construction Cost	110%	100%
Delay to COD	1 year	0
Environmental Flow (m^3/sec)	1200	1000
Export to EGAT/EdC	100/0	90/10

The results of the sensitivity model runs are presented in Table 14.8.

As well as presenting NPV(T) and IRR(T), Table 14.8 also shows the Equity IRR (EIRR). The EIRR for the base case for the (6 x 40) 240 MW station is 17.8 %, for the (5 x 60) 300 MW station is 19.7% and 20.0% for the (6 x 60) 360 MW station.

The first variations considered were financial implications involving debt:equity ratio and interest on borrowing. Changes in these parameters impact the NPV(T), the IRR(T) and the return to the investor as they affect the amount of capital borrowed, quantum of interest on the borrowed capital and the length of repayment (annual repayments). An increase in equity to 30%, higher borrowing rate or shorter repayment period decrease the EIRR, but the returns are still attractive.

Changes in tariff and royalty impact on the income stream. The base case is based on an estimated tariff of 6.25 US¢/kWh, delivered at Ubon or Stung Treng (transmission losses having been factored into the income). A tariff of only 6.0 US¢/kWh will reduce NPV by about 15%, while having an EIRR about 94% of the base case and a decrease in tariff to 5.75 US¢/kWh, reduces these ratios still further to 30% and 88% respectively. Each 0.1 US¢/kWh change in the tariff modifies the NPV by about US$10 million for a 240 MW installed capacity and about US$12 million for a 300 MW station and US$ 13 million for a 360 MW station. The EIRR is reduced by about 0.5% per 0.1 US¢/kWh for the range of installed capacities.

Table 14.8 - Sensitivity to Variations

Station capacity	6 x 40 MW			5 x 60 MW			6 x 60 MW		
Project cost est (excluding IDC)	US$471.0 mill			US$519.7 mill			US$571.8 mill		
Ann Average Energy	1838.1 GWh			2140.4 GWh			2375.0 GWh		
	NPV(T) ($ mil)	IRR(T) (%)	EIRR (%)	NPV(T) ($ mil)	IRR(T) (%)	EIRR (%)	NPV(T) ($ mil)	IRR(T) (%)	EIRR (%)
Base case	148.2	13.6	**17.8**	**201.5**	**14.4**	19.7	227.2	**14.5**	20.0
Equity 30%	152.1	13.7	17.4	205.9	14.5	**19.2**	232.0	14.6	19.4
Borrowing cost 10%	145.4	13.5	17.3	198.5	14.3	19.2	223.8	14.4	19.5
Repay over 6 years	148.2	13.6	17.1	201.5	14.4	18.8	227.2	14.5	19.1
Tariff 6.0 c/kWh	123.2	13.0	16.7	172.4	13.8	18.5	194.9	13.9	18.8
Tariff 5.75 c/kWh	98.2	12.4	15.6	143.4	**13.2**	17.4	162.6	13.3	17.6
Royalty 5% of revenue	130.8	**13.2**	17.0	181.3	14.0	18.9	204.8	14.1	**19.2**
O&M cost escalated at 3% per annum	139.9	13.4	17.6	192.4	14.2	19.5	216.6	14.3	19.8
Construction costs increase 10%	111.0	**12.5**	15.8	160.3	13.2	17.5	181.7	13.3	17.7
Commissioning delayed 1 year	97.0	12.2	14.7	141.5	12.9	16.1	160.6	13.0	16.3
Environmental flow 1200 m^3/s	116.5	12.9	16.4	168.9	13.7	18.4	193.0	13.9	18.7
Export only to Thailand	144.7	13.5	17.6	197.5	14.3	19.5	227.7	14.4	19.8

Construction costs have included a 10% contingency allowance, but if the cost of construction increase by 10%, whether it be due to general escalation in commodity prices (oil and steel in particular) or to unforeseen construction problems, the project becomes less attractive (NPV reduced by 20% and EIRR reduced by 13% for 360 MW station).

Similarly, if the commissioning date is postponed by a year, the loss of that year's revenue would have a similar' effect. Delay in commissioning could be due to unforeseen construction problems, inclement weather (higher than average river flows), and delays in plant manufacture. The PPA duration is for 29 years for modelling purposes.

The other significant impact on the project is availability of water for operation, particularly during the low flow period. The base case assumes that the power station will only use flows in excess of 1,000 m /s at Thakho, this flow being designated the 'environmental flow' which will pass over the Phapheng Falls and Hou Sadam. This flow, which is roughly equal to the minimum recorded flow, was assessed as a level that would not decrease the visual impact of the falls and maintain adequate flow through Hou Sadam for fish migration puiposes.

If, however, it is mandated that the 'environmental flow' be increased to 1,200 m^3/s, there will be a decrease in the NPV which will make the project financially less attractive.

A final sensitivity involves export of energy only to Thailand. This has a slightly lower NPV, IRR and EIRR because the transmission losses to Ubon are greater than to Stung Treng.

SECTION 15

CONCLUSIONS AND RECOMMENDATIONS

15.1 Conclusions

15.1.1 Introduction

Construction of the project meets the aims of the Government of Laos to promote the export of electrical energy to neighbouring countries so as to expedite economic growth in order to alleviate poverty and achieve its social development goals and is in accordance with the aim of the Mekong River Commission's Hydropower Development Strategy,

> *The efficient and socio-economically and environmentally appropriate generation and distribution of hydropower in the riparian countries, in a cooperative and well co-ordinated way, is promoted;*

its immediate objective that

> *Hydropower resources of the Mekong mainstream and its tributaries are developed according to true least-cost planning, fully considering environmental and social impacts.*

and its basic vision that

> *The increasing demand for affordable electric energy in the MRC member countries is met with minimal negative impacts on the environment and local people, thereby promoting economic growth for the countries' mutual benefit.*

As discussed in the accompanying Environmental Impact Assessment, mitigating measures proposed will eliminate or minimize social and environmental impacts.

15.1.2 Technical and Energy Modelling Studies

Seven (7) plant capacities ranging from 180 MW to 480 MW were studied in detail. Energy modelling studies considered various combinations of unit sizes, number of units, design heads, flow quantities, and other parameters. The basic flow data was the 82 years (1924 to 2006) of daily flow record at Pakse, 150 km upstream of the project site. There are no significant tributaries between Pakse and the site and the daily records at Pakse were compared with corresponding records at Stung Treng, 50 km downstream, in Cambodia before deciding that Pakse flows are a true representation of the total Mekong River discharge at the site. In all, the energy model was run for 543 different combinations of parameters.

The studies included the necessity to maintain adequate flow in channels parallel to the Hou Sahong for fish migration and visual impact purposes (environmental flow).

The project site characteristic of low head (11 - 13 m) during the wet heavy flow period and high head (22 m) during the dry, low flow period made it necessary to carry out extensive studies on design head and type of prime mover (turbine) to be used. In addition, to optimise the use of the large quantity of water available in the heavy flow period, the necessity for deepening the Hou Sahong entrance channel was studied in detail.

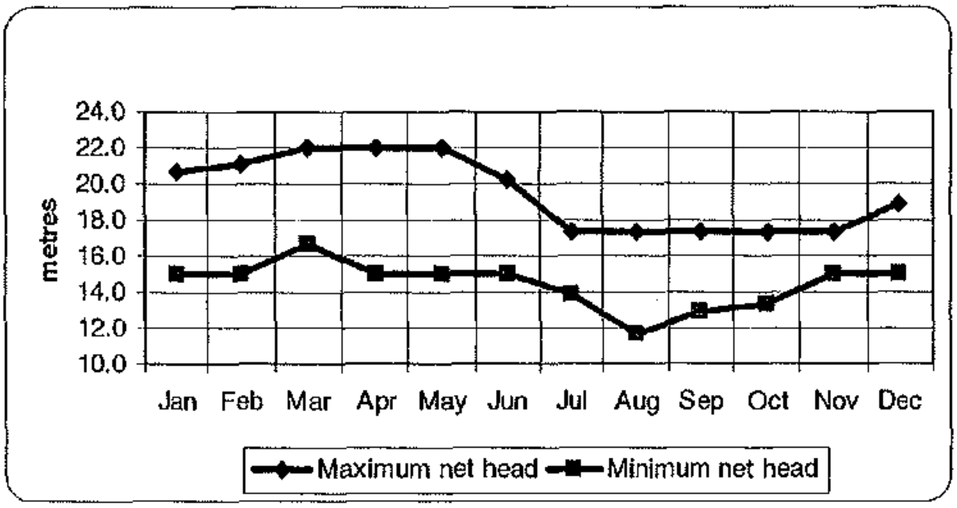


Figure 15.1 - Annual variation in maximum and minimum net head

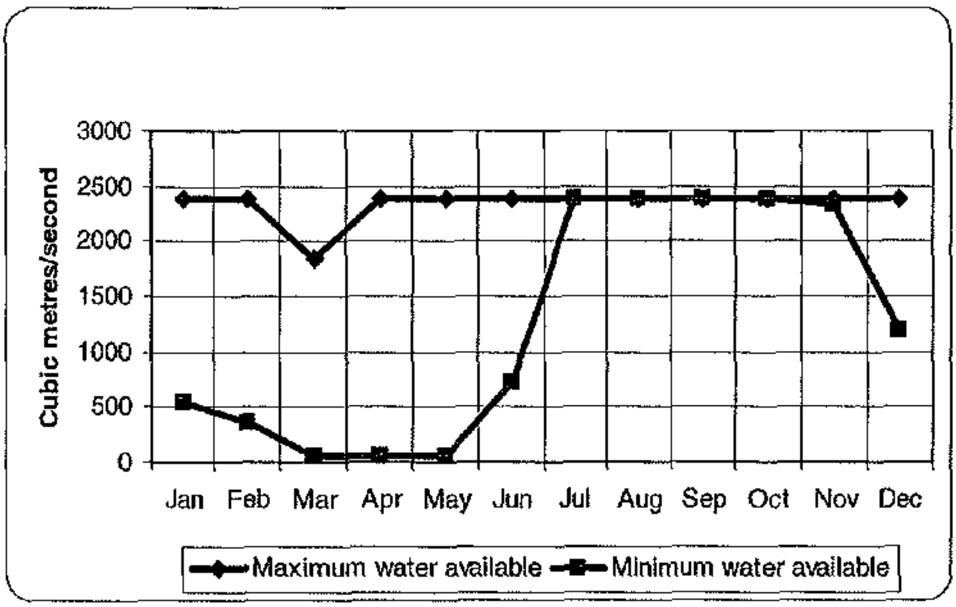


Figure 15.2 - Annual variation in maximum and minimum water available through Hou Sahong for generation

The studies indicated that the optimum design head was 17 m, and the Hou Sahong entrance channel deepening to vary between 3 to 6 metres, depending on the station capacity. Figures 15.1 and 15.2 show the maximum and minimum net heads and the water available through Hou Sahong for energy generation with channel improvements.

15.1.3 Energy Production

The above-described studies resulted in the average annual energy for the finally selected seven (7) plant capacities with optimum design features, as shown in Table 15.1.

Table 15.1 - Average Annual Energy
(based on Design Head of 17 m and Environmental Flow of 1,000m³/sec)

Option	Plant Configuration and Installed Capacity	Hou Sahong Entrance Excavation Level	Average Annual Energy
A	6x30 = 180 MW	66 m	1,460.5 GWh
B	6 x 40 = 240 MW	66 m	1,838.1 GWh
C	6 x 50 = 300 MW	65 m	2,140.2 GWh
D	5 x 60 = 300 MW	65 m	2,140.4 GWh
E	6 x 60 = 360 MW	65 m	2,375.0 GWh
F	8 x 50 = 400 MW	64 m	2,528.0 GWh
G	8 x 60 = 480 MW	64 m	2,659.6 GWh

15.1.4 Construction Costs and Program

The Project Capital Costs for the selected seven power plant options (excluding IDC) are estimated as indicated in Table 15.2, inclusive of Hou Sahong entrance channel excavation as well as 230 kV Transmission lines up to Ban Hat Sub-Station, environmental mitigation measures and development costs.

Table 15.2 - Construction Costs

Option	Installed Capacity	Construction Costs
A	180MW	US$ 445.3 million
B	240 MW	US$471.0 million
C	300 MW	US$ 535.4 million
D	300 MW	US$519.7 million
E	360 MW	US$571.8 million
F	400 MW	US$ 636.5 million
G	480 MW	US$710.8 million

Section 12 presents the detailed construction plan for the Project. It is estimated that the major works can be completed in four years from financial closure and signing of the Concession Agreement. Assuming that these can be concluded by the end of 2008, the power station will be in commercial operation by first quarter 2013.

15.1.5 Energy Sales and Transmission Lines

In addition to supplying electricity to southern Laos, opportunities exist for export of energy to both Thailand and Cambodia through the Ban Hat 115 kV substation. While the delivery to Cambodia would be the easiest through the extension of the 115 kV transmission line from Ban Hat to Stung Treng, which will be constructed in the near future under World Bank funding, the demand in Cambodia will not match the output from the proposed Don Sahong Hydroelectric Project for many years.

For the purpose of this study, a 230 kV transmission link to Ubon costing US$ 70.5 million for export of electricity to EGAT has been included. However, the ultimate decision on the transmission route will rest with EGAT.

15.1.6 Environmental Mitigation Measures

Environmental issues are discussed at length in the Environmental Impact Assessment report. However, a major physical intervention is required as the construction of the powerhouse in the Hon Sahong will effectively close this channel which is a major route for fish migrating in upstream and downstream directions during all seasons.

Remedial mitigation measures to ensure that fish can freely migrate include design and carrying out improvements to both the Hou Sadam and the Hou Xang Peuk, the channels immediately east and west of Hou Sahong, to replicate the Hou Sahong. This work will include excavation to modify the flow conditions and clearing of vegetation in and around the stream banks. This work will be completed before initial work begins on coffer damming the Hou Sahong to facilitate construction.

A total budget provision of US$ 28.1 million for environmental mitigation and compensation measures has been included in the Project cost estimate (Table 15.2).

15.1.7 Economic and Financial Evaluation

Economic and financial evaluations were carried out on the complete range of seven power station configurations shortlisted in the study - 6 x 30 MW (180 MW) to 6 x 80 MW (480 MW).

Using a tariff of 6.25 c/kWh, escalated at 1% per annum, for all the seven power station capacities the internal rate of return (IRR) exceeded 11.7%, with a maximum of 14.9% for the 6 x 60 MW option. Impacts of taxation and other financial parameters made little difference to the ranking of the alternatives, with the 6 x 60 MW option having the highest IRR after tax of 14.5% and a net present value (NPV) of US$ 227.2 million.

The sensitivity of the IRR, NPV and internal return on eequity (EIRR) was studied for the 6 x 40 MW (240 MW), 5 x 60 MW (300 MW) and 6 x 60 MW (360 MW) options for variations of basic parameters, such as construction cost, interest rate and repayment period of loans, debt:equity ratio, tariff, length of construction period, royalty, etc. In all cases the 6 x 60 MW (360 MW) option again gave the best returns in terms of IRR, NPV and EIRR.

15.2 Recommendations

Based on the results of the Economic and Financial Evaluation, it is recommended that a 360-MW Power Plant with following features and costs be implemented.

15.2.1 Power Station Layout

The recommended arrangement comprises the construction of a reinforced concrete powerhouse approximately 150 metres above the lower end of the Hou Sahong, adjacent to the village of Ban Hangsadam (on the left bank) and hamlet of Ban Hangsahong (on the right).

The powerhouse structure and its accompanying retaining embankments will contain water in the existing Hou Sahong channel, the water level varying with the level of the Mekong River at the upper end of the channel. The maximum level is estimated to be RL 74.5 and the lower level RL72.

The powerhouse houses six bulb-type units each of 60 MW capacity. The units have a design head of 17 m and a corresponding flow of 400 cubic metres per second.

Under existing natural conditions, the river bed level at the upstream end of the channel will restrict flow into the channel so that the units would not be able to operate continuously. To overcome this constraint, approximately 2.0 million cubic metres of rock will be excavated to a maximum depth of 6 metres in the upper 2 km of the channel.

While the operating head is a maximum during the low flow periods when the level of the Mekong below the Great Fault Line is at a minimum, there is insufficient flow in the Mekong to operate at the full 360 MW capacity. Maximum energy output is achieved during the wet season when there is sufficient water to enable the six units to operate at full capacity.

A constraint during the low flow season is the need to maintain flow over the Phapheng Falls about 3.5 km downstream of the Hou Sahong entrance and to ensure flow through other channels, notably the Hou Sadam, for fish migration. After considering the long-term flow patterns it has been assessed that an 'environmental flow' of 1,000 m^3/sec will be sufficient to provide an undiminished visual appearance of the falls, so important to the tourism industry in southern Laos, and for fish migration needs in other streams. The implication of this is that the power station will only use flows in excess of 1,000 nrVsec, as measured at Pakse, for generation. This is reflected in the lower monthly energy production figures in months January to May in Table 15.3.

Table 15.3 Monthly Energy Production (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Minimum	100.1	63.3	22.8	13.2	42.6	196.7	235.5	191.1	194.0	237.8	224.8	190.2	1988.7
Average	192.7	129.8	106.0	97.9	170.3	233.3	254.5	238.7	230.6	256.4	235.8	228.3	2375.0
Maximum	232.1	196.3	171.2	170.2	240.6	252.2	263.8	263.6	254.7	263.4	254.8	237.7	2611.2
95% exceedance	141.1	80.3	58.2	36.1	84.0	207.6	246.9	218.5	205.7	249.6	227.1	211.3	2130.6

Table 15.4 Monthly Generation Capacity (MW) - Continuous 24-hour operation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum	317.8	315.1	276.0	310.7	353.5	359.7	359.7	359.7	359.7	359.7	359.6	342.4	359.7
Average	260.3	192.5	143.1	136.6	230.1	325.7	343.8	322.4	321.8	346.3	329.1	308.5	272.4
Minimum	102.0	69.5	10.9	10.9	10.9	130.1	271.0	184.6	234.9	254.5	309.2	200.4	10.9

Table 15.3 indicates the estimated minimum, average and maximum monthly energy outputs of the 360 MW station, based on a simulated operation study using the 82 years of daily flow records at the Pakse gauging station, 150 km upstream of the power station site. Table 15.4 indicates the average monthly generation capacity of the station, also governed by the water availability. Figure 15.3 graphically shows the annual variation in monthly energy, while Figure 15.4 indicates the average monthly generation capacity.

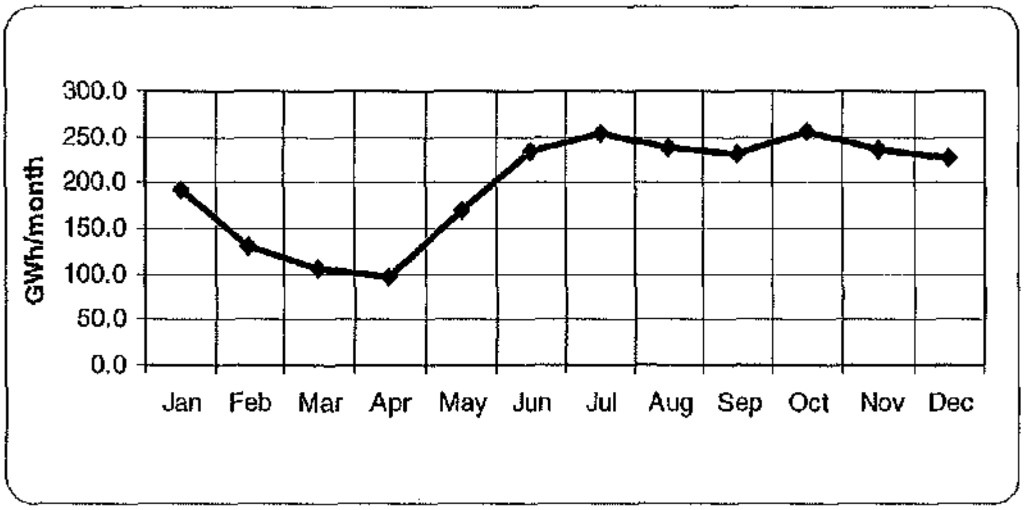


Figure 15.3 - Average monthly energy production for recommended 360 MW arrangement

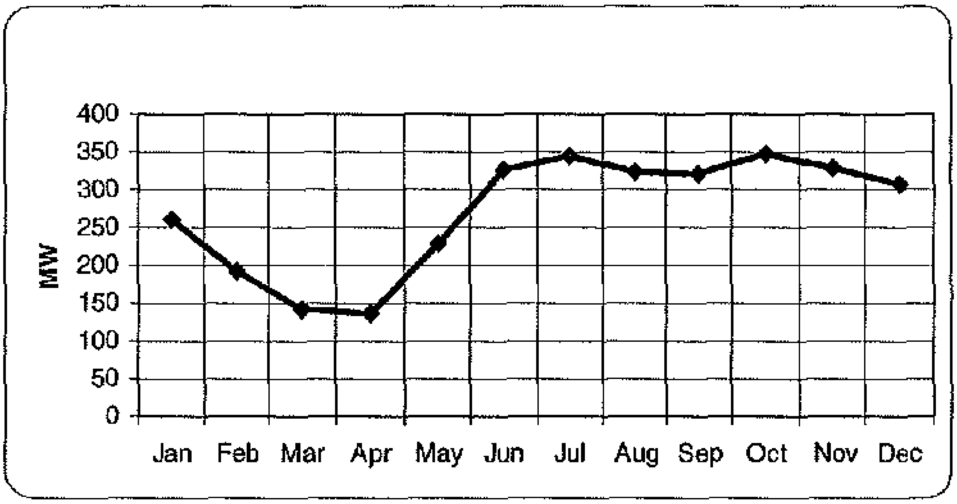


Figure 15.4 - Average monthly generation capability for recommended 360 MW arrangement

15.3.2 Cost Estimate

The project cost estimates for the development of a 6 x 60 MW power station are summarised in Table 15.5.

Table 15.5 - Construction Cost Estimates

Details	Cost (US$ millions)
Mainland facilities	5.5
Access to Don Sahong, roads on Don Sahong, power to site etc	6.0
Lowering Hou Sahong entrance	39.3
Retaining embankments	6.6
Power Station	
Civil Works	44.2
Cranes	2.3
Trashracks, gates and hoists	14.8
Turbine + generator	168.6
Balance of plant	63.6
Power Transformers	7.9
Substation & connection to Ban Hat	31.2
Tailrace improvement	2.6
Allowance for other items in EPC contract	12.4
Engineering	7.0
Total	412.0
Contingency 10%	41.2
Total construction cost - US$	**453.2**
Transmission line costs to Ubon	**70.5**
Environmental mitigation costs	**28.1**
Development Costs	**20.0**
TOTAL	**571.8**
INTEREST DURING CONSTRUCTION (based on 9.5% financing, 75:25 debt:equity and 4 years construction period)	**101.5**
TOTAL PROJECT COST	**673.3**

SECTION 16

REFERENCES

Compagnie Nationale du Rh6ne in cooperation with Acres International Limited; *Mekong Mainstream Run-of-River Hydropower* Main Report October 1994

Electrowatt-Ekono in association with Hagler Bailey; *Power Sector Strategy Study,* Febmary 2001

Lao People's Democratic Republic; National Policy - *Environmental and Social Sustainability of the Hydropower Sector in Lao PDR (No. 561/CP1),* 7 June 2005

Lao People's Democratic Republic; *Electricity Law (No. 02-97/NA),* 2 April 1997

Lao People's Democratic Republic; *Law on the Promotion of Foreign Investment (No. Il/NA),* 22 October 2004

Lao People's Democratic Republic; *Water and Water Resources Law* 11 October 1996

Lao People's Democratic Republic; *Environmental Law (No. 02/99/NA),* 3 April 1999

Lao People's Democratic Republic; *Enterprise Law* 2005

Maunsell Ltd in association with Lahmeyer GmbH: *Power System Development Plan for Lao PDR.* Final Report, August 2004

Mekong River Commission; *Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin,* 5 April 1995

Mekong River Commission; *Preliminary Procedures for Notification, Prior Consultation and Agreement,* 12 November 2002

Mekong River Commission; *MRC Hydropower Development Strategy,* October 2001

Mekong River Commission; *Overview of the Hydrology of the Mekong Basin,* November 2001

Mekong River Commission; *MRC Navigation Strategy,* August 2003

Mekong River Commission; *Lower Mekong Hydrologic Yearbooks*

Pholsena, S and Phonekeo, D; *Lao hydropower potential and policy in the GMS context* United Nations Symposium on Hydropower and Sustainable Development, Beijing, October, 2004

Phomsoupha, X; *Power Sector Development in Lao PDR.* Tokyo, 24 October 2006,