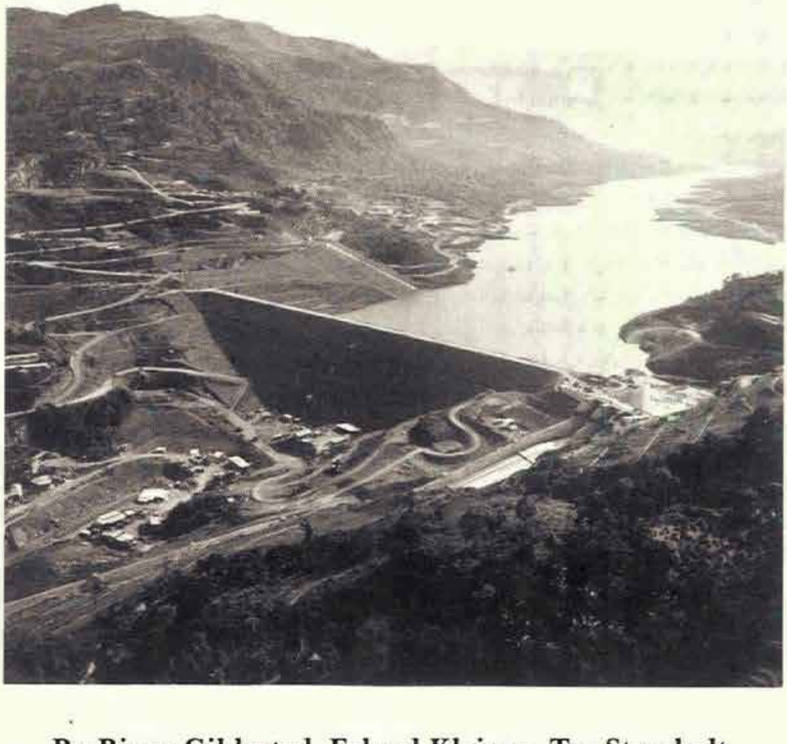
SIDA Evaluation Report, Infrastructure, Sri Lanka

1991/2

A FLAWED SUCCESS

An Evaluation of SIDA Support to the Kotmale Hydropower Project



By Bjørn Gildestad, Erland Kleivan, Tor Stavsholt

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY SIDA STYRELSEN FÖR INTERNATIONELL UTVECKLING

This report is the result of an evaluation carried out in November 1989 by an independent study team consisting of Bjørn Gildestad, Erland Kleivan, Tor Stavsholt of Norpower.

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SIDA
Stockholm 1990

SRI LANKA

bisståndsprojektet Kotmale
väg
järnväg
0
50
100
km
INDIEN
Bengaliska
bukten
Mannar-viken
Jaffna
Mannar
Vavuniya
Trincomalee
Anuradhapura
Puttalam
Polonnaruwa
Batticaloa
SRI LANKA
Mahaweli Ganga
Kurunegala
Matale
Kandy
Ampara
Kegalla
Kelani Ganga
Kotmale
Nuwara-Eliya
Badulla
COLOMBO
Monaragala
Ratnapura
Kalutara
Hambantota
Galle
Matara
INDISKA OCEANEN
Karta: Stig Söderlind, © SIDA

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ABBREVIATIONS

The abbreviations and specialized terms used in this report are listed below:

Organizations etc.

AMDP	Accelerated Mahaweli Development Programme
CEB	Ceylon Electricity Board
CECD	Central Engineering Consultancy Bureau
MASL	Mahaweli Authority of Sri Lanka
MDB	Mahaweli Development Board
MDP	Mahaweli Development Programme
NEDECO	Netherlands Engineering Consultants
ODA	Overseas Development Administration, UK
RVDB	River Valleys Development Board
SIDA	Swedish International Development Authority
WMS	Water Management Secretariat

Technical Abbreviations

GWh	Gigawatt-hour (10^6 kWh)
hm^3	mill. m^3
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
MVA	Megavolt-Ampere
MW	Megawatt (10^3 kW)
ton	metric ton, 1,000 kg

CHAPTER 2
SUMMARY

The Kotmale Hydropower Project is the project in the Mahaweli Development Programme located furthest upstream. It is a multipurpose project, serving both power production and irrigation needs.

This evaluation report is an attempt to give a technical and economic ex post review of the project. Separate reviews have been performed regarding the environmental effects of the project and on the socio-economic effect of the relocation of four thousand families living in the affected areas.

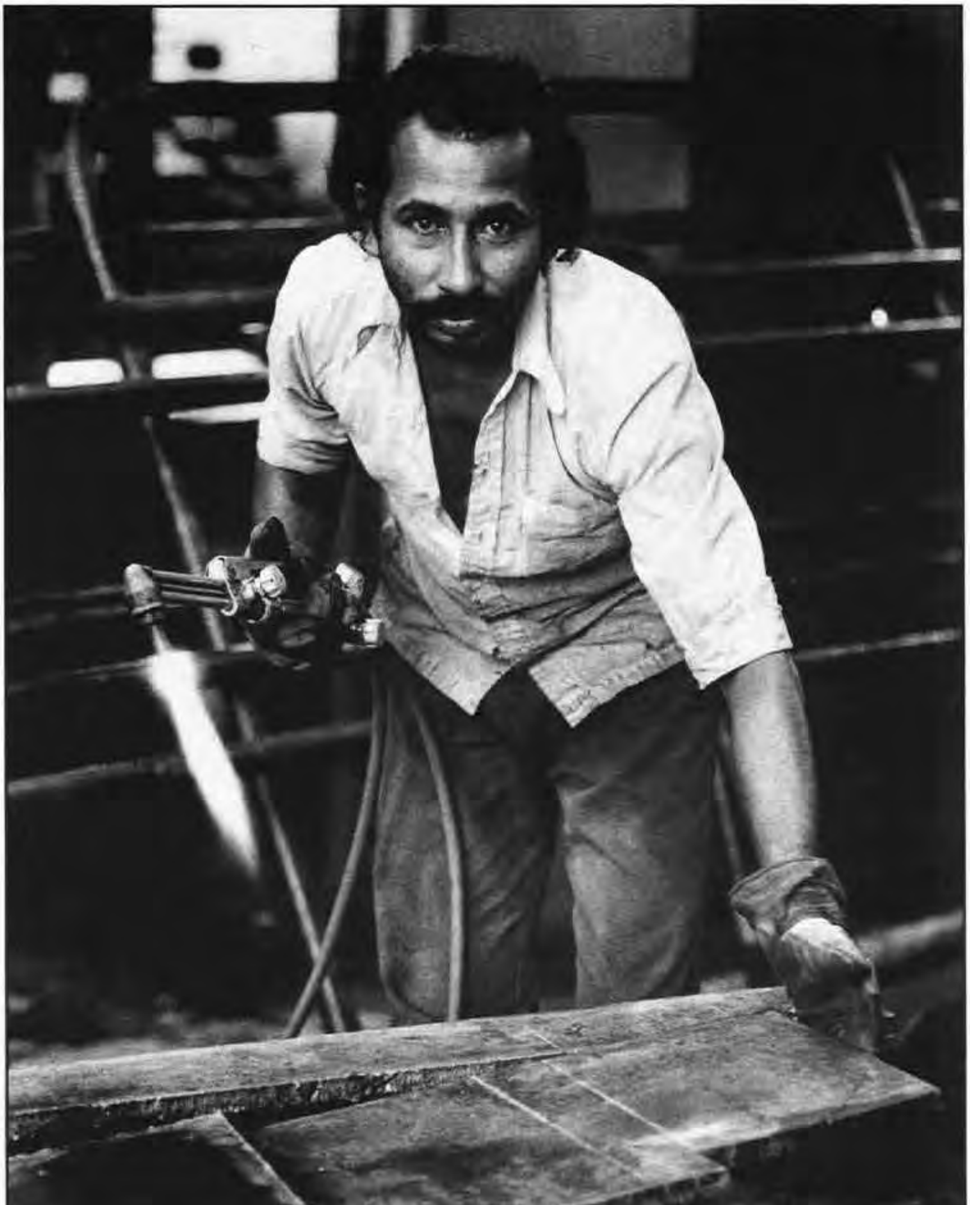
The evaluation has been sponsored by SIDA, the main purpose being to examine the extent to which the project achieved its objectives as these were stated in the 1982 decision of the Swedish Parliament to provide significant assistance to the project.

A secondary objective has been to provide lessons for the planning of future projects of this nature to the Government of Sri Lanka and the donor community.

The report concludes that the project has suffered from rush planning and start-up. The basic design features were not optimal for the given geological conditions, and the absence of competition in the selection of contractor and equipment supplier together with costly design — mostly on the Client's insistence — eventually led to an unnecessarily costly project.

It is the Mission's opinion that the leakages in the unlined part of the pressure shaft followed by a shutdown of the plant for repairs could have been avoided had rock pressure testing and ensuing change of design been performed during the excavation of the tunnel and shaft.

The Swedish Government, although having financed 68% of the foreign exchange component of the project, had little or no influence on design,



A welder at the Metal-Workshop, Kotmale. The local employees have attained skills that will be valuable in similar projects in the future. Many are now working overseas, sending their earnings back to their families in Sri Lanka.
Photo: Heldur Netocny, SIDA Photo Archives

selection of consultants, contractors and equipment suppliers. The SIDA-appointed Team of Experts that was brought into the picture after the Parliament's decision to provide assistance to the project could influence only the progress of construction work already defined by contracts and specifications.

The implementation of the project was carried out professionally and efficiently, and the power plant as it now stands is of a very high standard. Being properly maintained and operated in the future, the Kotmale will continue to play an important role in Sri Lanka's power supply.

The economic evaluation that has been carried out based on thermal energy as an alternative to Kotmale's hydropower, resulted in a relatively low internal rate of return. A high oil price scenario combined with strict claims to profitability on the alternative thermal energy production (8%) is necessary in order to bring Kotmale's internal rate of return above 6%. In all three oil price scenarios the internal rate of return from Kotmale is lower than the rate of return demanded from thermal power.

The main findings from the economic evaluation of Kotmale can be summarized as follows:

- Regarded strictly as a hydropower scheme, Kotmale gives a small economic return compared with regular standards. The return is, however, definitely positive.
- The delayed production start together with the repair costs are factors with important effect on the economic return.
- Prospects of high oil prices would improve the project's viability.
- Kotmale also serves irrigation purposes and contributes as well to the economy of hydropower plants downstream. Thus there are reasons to claim that parts of Kotmale's construction costs should be shared with other projects.
- Further attendance to the needs of the evacuees which might even triple the relocation costs, would not gravely deteriorate the economy of the project.

CHAPTER 3
PREFACE

In April 1989 SIDA awarded the contract for this ex post evaluation of Kotmale to Norpower, Norway, and the evaluation study was carried out and written by a team consisting of:

Mr Bjorn Gildestad, Economist	Economic and financial aspects
Mr. Erland Kleivan, Norpower	Civil engineering aspects
Mr. Tor Stavsholt, Norpower	Electrical and mechanical aspects and team leader

The evaluation was carried out through meetings and interviews in Stockholm and Swindon and two weeks of field work in Sri Lanka which included a three days visit to the power plant

The team wishes to thank all who have so willingly assisted in providing valuable information and background material for the study, both in Sri Lanka by staff of the Mahaweli Authority, CECB, CEB and Skanska, as well as in Sweden and England by Skanska, ABB (ASEA), Halcrow Water and Kennedy & Donkin, and for the assistance given by SIDA in Stockholm and the Swedish Embassy in Colombo.

The terms of reference for the evaluation study is attached as Appendix 1.

CHAPTER 4
PROJECT DESCRIPTION

4.1 THE MAHAWELI DEVELOPMENT PROGRAMME

The Mahaweli Development Programme of which Kotmale Hydropower Project is an important part, is the largest single development programme undertaken by the Government of Sri Lanka. Its prime objective has been to harness the water of Sri Lanka's largest river, the Mahaweli Ganga, by creating reservoirs for the development of hydroelectric energy and for the agricultural development of a considerable area of new lands through diversion and irrigation.

While this general programme has been under way since 1968, a dramatic speed-up in the implementation of the various integrating schemes became possible from 1977 through massive monetary support from several donor countries, under what was named the Accelerated Mahaweli Programme (AMP).

Under this very ambitious programme has been developed approximately 92,000 ha of irrigable land, for a projected settling of some 87,000 families in the downstream areas, with roads, schools and other infrastructure included, and the following four reservoirs have been established, three of which include hydroelectric power plants as well (the National totals with respect to hydroelectric capability are added for comparison):

Project (Sponsor country)	Live storage (hm^3)	Installed Generating capacity (MW)	Mean annual production (GWh)
Kotmale (Sweden)	147	201	445
Victoria (UK)	688	210	686
Randenigala (FDR)	565	126	428
Madura Oya (Japan)	473	-	-
AMD totals (1988)	1,873	537	1,559
S.L. hydropower totals (1988)		815	3,054

The relative importance in Sri Lanka of the Mahaweli development Programme is reflected by the map shown as Fig. 4.1.

4.2 KOTMALE HYDROPOWER PROJECT

4.2.1 General

In capital expenditure the Kotmale has become the costliest single project within the Accelerated Mahaweli Programme. Located further upstream than any other project on the Mahaweli Ganga, roughly 80 km due east of Colombo, the reservoir drains an area of 544 km^2 of the catchment of the tributary Kotmale Oya.

The project area is located approximately 30 km south of Kandy.

4.2.2 Main features of the project

The Kotmale Hydropower Project includes the reservoir with a regulation dam of major proportions, the underground power plant with tunnel waterways, and the above ground switchyard onto which also the transmission line from the Victoria project is connected.

A longitudinal section along the waterway is shown in Fig. 4.2 and a crossection of the dam in Fig. 4.3. A comprehensive tabulation of project data is found in Appendix 2.

A most noteworthy feature is the alinement of the nearly 8 km long waterway which over the last 2 to 3 km, before its outfall in the Mahaweli Ganga some 6 km downstream of the confluence with Kotmale Oya, follows a fairly

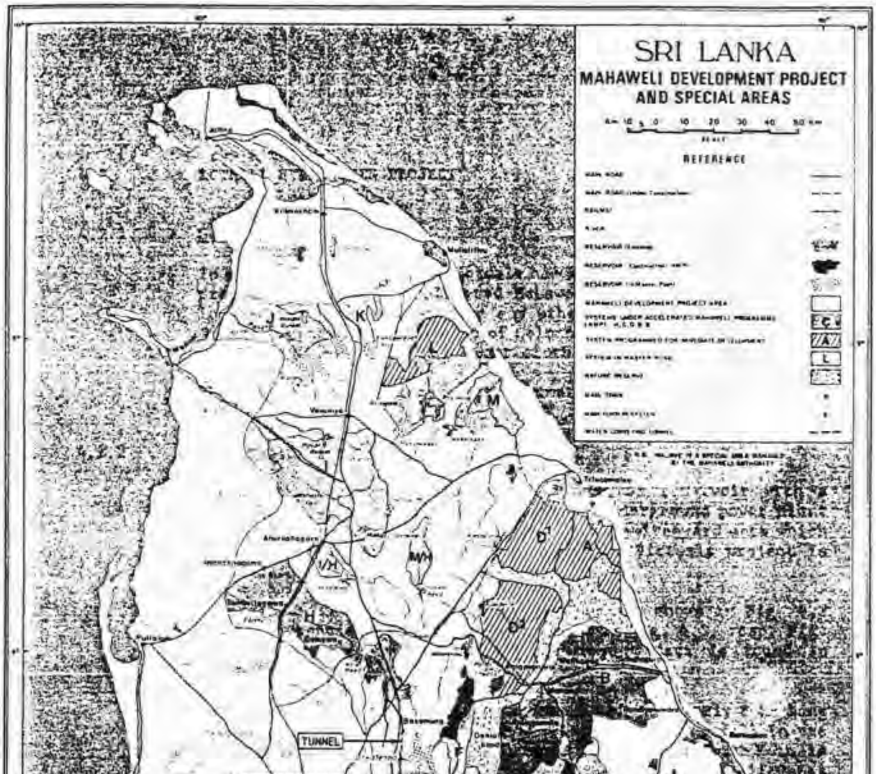


Fig. 4.1 Map of Sri Lanka

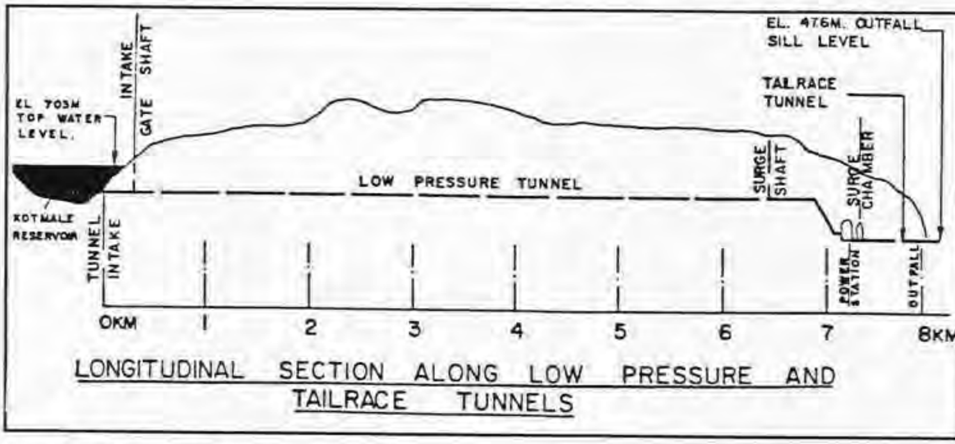


Fig. 4.2 Kotmale Hydorpower Project

prominent ridge between the Mahaweli Ganga and another, minor tributary from the right, Atabage Oya. It is highly probable that this particular topography explains the low inherent horizontal rock stress level which eventually caused the rupture of the upper part of the pressure shaft during first filling, an event followed by shutdown of the plant while the shaft was repaired, and steel liner installed here and in the 400 m long inclined tunnel. The circumstances around this failure are discussed further in Chapter 7, section 7.6.

4.2.3 Multipurpose aspects of the project

Even if Kotmale is designated as a hydropower plant and is basically built for energy generation, it serves a secondary function in irrigation of land in the dry zone downstream, under the Mahaweli Programme. Earlier plans for the Kotmale Reservoir featured a higher dam with a gross storage volume of 410 hm^3, against the present 174 hm^3. This larger reservoir would have retained a substantial portion of the flood flows that are now lost, and made it possible to irrigate an area of 92,000 ha, already cultivated, but most of which is now lacking irrigation water. Also the power production in Kotmale would have benefitted to some extent from this larger reservoir due to the increase in the mean head as well as in the volume of turbinated water, as most of the irrigation water would first pass through the power station.

Instrumental in the irrigation aspects is the Polgolla diversion weir and

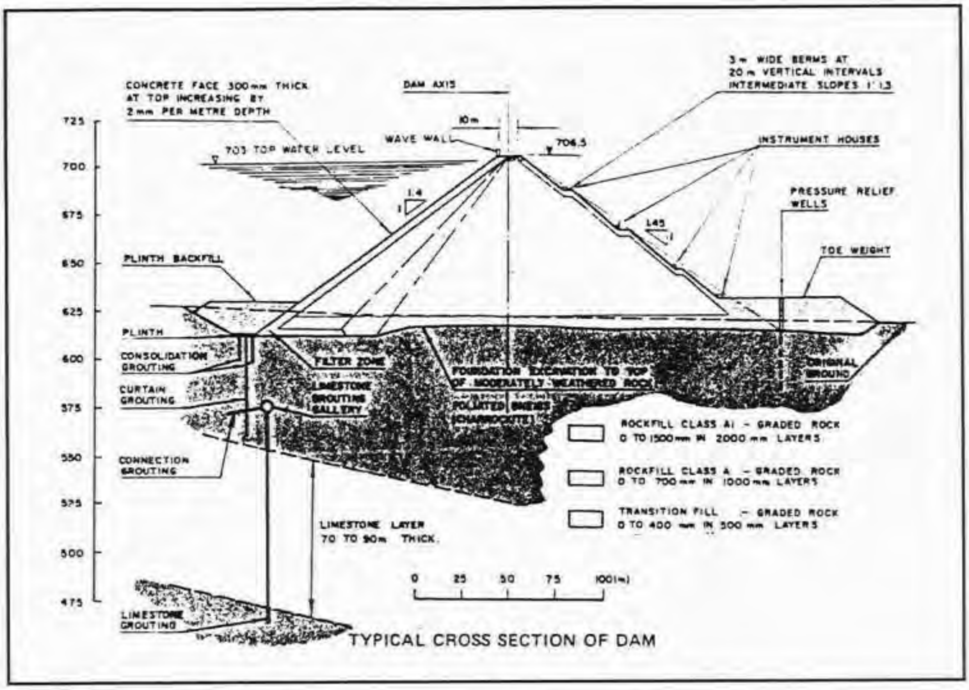


Fig 4.3 Dam Cross Section

The Kotmale Dam 1984
Photo: Heldur Netocny, SIDA Photo Archives

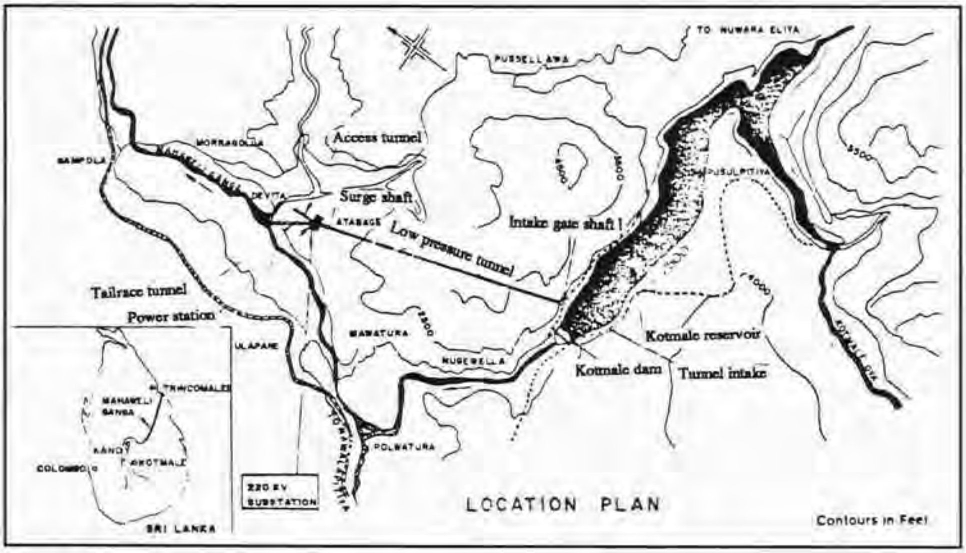


Fig 4.5 Kotmale HPP, Location

tunnel, which can divert the flow of Mahaweli Ganga from a point 25 km downstream of the Kotmale tailrace over to the adjacent watershed of Suda Ganga. This diversion scheme was built in anticipation of a large reservoir for Kotmale. It was completed in 1976, four years before construction started for Kotmale and is under the present storage conditions at Kotmale utilized only to a minor degree.

4.2.4 Plans for future raising of the dam

As stated above, a substantial area of irrigable and cultivated land is now lacking water due to the deficient storage capacity in the reservoir of Kotmale.

There is apparently no alternatives for storage of the waters in the upper reaches of Mahaweli Ganga, apart from raising the dam of Kotmale to a higher level. This will of course require that the spillway with gates are raised correspondingly. Plans in three alternatives — dam crest raised to El +715, +725 and +735 — have been submitted, indicating a total construction cost of 3,181 mill.LKR (1985) for the last alternative and a construction time of two to three years.

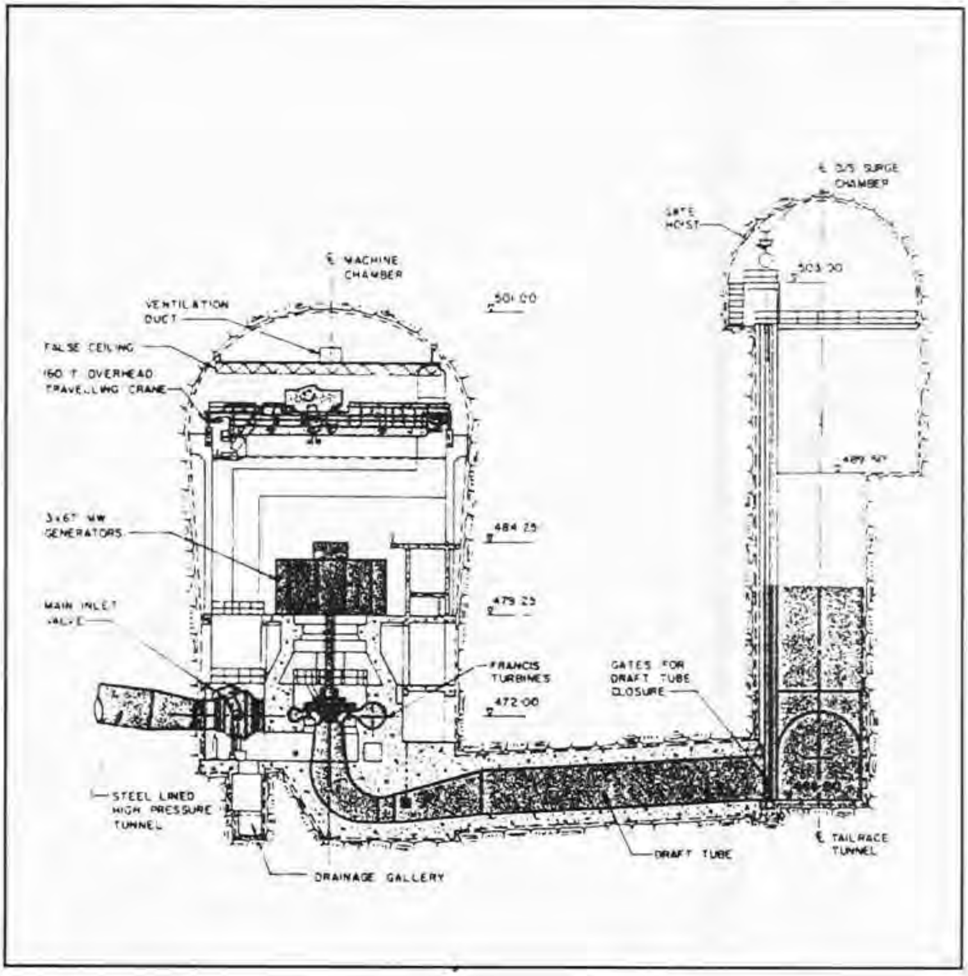


Fig 4.4 Powerhouse Cross Section
Above left: The Francis Turbines are istalled, 1983.
Below left: The completed powerhouse with the three 3 x 67 MW Generators.
Photo: Skanska, Björn Enström

CHAPTER 5
FINANCING OF THE PROJECT

5.1 SWEDISH FINANCING ASSISTANCE

From 1978 on the Government of Sri Lanka started utilizing Swedish import support allocations for financing of the Kotmale Project. In 1978/79 a total of SEK 75 mill was granted to Sri Lanka as import support, of which about 67 mill was channelled to Kotmale. The Government of Sri Lanka believed that the import support resources over a period of five to six years would suffice to cover a major proportion of the foreign costs of the project. This was, however, based on the 1978 project cost estimates which included neither all project works nor escalation through inflation or project financing costs.

The latter item had to be taken into account since the import support funds were disbursed only once annually and special bridging finance arrangements therefore had to be made. The Government of Sri Lanka subsequently secured bridging finance from a Swedish commercial bank, Skandinaviska Enskilda Banken.

An agreement on import support was made between Sweden and Sri Lanka in May 1979 providing for an additional amount of SEK 210 mill in the three Swedish financial years 1979/80-1981/82, of which the main part was tied. In this connection Sri Lanka noted its intention of using all these resources towards financing of the Kotmale Project. By a later agreement the amount was increased to 240 mill. In the end Sri Lanka came to use all these years' import support from Sweden for Kotmale, tied parts as well as untied.

At the beginning of 1979 the cost of the project had been revised upwards. The 1981 total project costs were estimated at about SEK 2,500 mill, of which SEK 2,127 were in foreign currency.

Table 5.1
Kotmale's Financing from Import Support, SEK mill.

Financial year	Tied	Untied	Total
1978/79		67	
1979/80	60	10	70
1980/81	65	15	80
1981/82	75	15	90
Total			307

Table 5.2
Kotmale Project Costs and their Financing, current SEK and LKR in mill

	SEK	LKR
Project Costs:		
El- mech Works		
Unit 1 and 2	175	54
Unit 3	106	29
Other Mech Works	136	23
Civil Works	1,583	1,535
Repair	106	185
Consultancy	64	382
Resettlement	436	
Financing Costs	262	
TOTAL	2,432	2,643
Financing:		
Grant	1,088	
Import Support	307	
Soft Loan	256	
Loan	102	
TOTAL	1,753	
Other resources	679	

It was obvious from the escalation of project costs that Swedish financing assistance from support resources was no longer realistic. Such resources would have to be drawn well into the 1990's long after the completion of the project.

Furthermore, the final bill would include a significant amount of interest on the bridging finance. In these circumstances, the Government of Sri Lanka in 1981 appealed to Sweden to consider other aid financing arrangements.

The new financing arrangement covered the six Swedish financial years 1982/83-1987/88 and provided for grant assistance totalling SEK 1,088 mill. This was in addition to the amount of SEK 307 mill previously disbursed as import support. The total grant thus eventually amounted to current SEK 1,395 mill.

The grant assistance related to the foreign exchange part of the project's civil works. For the electro-mechanical works a subsidized credit of SEK 256 mill, guaranteed against the aid appropriations, was provided from Skandinaviska Enskilda Banken. This soft credit was used to finance the two first generating units and the other electro-mechanical works. Additionally a commercial credit of SEK 102 mill was obtained in 1987 from the same bank for the third unit.

Comparing the relevant items of the foreign component costs of Table 5.2 with the investment budget which was the basis for the Swedish grant (see ref. 19, Regeringens proposition, bilaga 1) it will be seen that the final costs correspond well with the estimate of 1981, see Table 5.3.

No commitment was made by Sweden with regard to other aspects of the project. SIDA later commissioned a study on the environmental impact of the project. SIDA has also financed a study on the situation of the evacuees from the Kotmale reservoir area. Costs of these two studies are not included in table 5.2, nor are the costs of the SIDA Progress Review Missions and of the training in Sweden of Kotmale operational staff.

Table 5.3
Final Project Cost Compared with 1981 Estimate, Foreign Component
SEK mill.

	Regeringens Proposition	Project Costs Table 5.2
El-mech Works excluding unit 3	280	311
Civil Works	1,640	1,583
Consultancy	50	64
Interests during construction	157	137
TOTAL	2,127	2,095

5.2 SRI LANKAN FINANCING

The local costs of all works, current LKR 2,643 mill, were supposed to be borne by the Sri Lankan Government; this was also the case with the foreign exchange parts of the repair costs for the high pressure system at SEK 106 mill and fees for the two British project consultants at GBP 6 mill (SEK 64 mill).

Another cost component which came to strain Sri Lankan foreign currency resources during the construction period was the interest on loans, and in particular the costs of the bridging finance arrangements for Kotmale of the early 1980's. In the years 1979 to 1989 the Sri Lankan Government paid current SEK 262 mill in finance costs on these credits, with more than a half, 137 mill, falling on costs connected to the bridging finance facilities (limited to SEK 650 mill in 1983).

The sum of foreign exchange project and financing costs were larger than the financing facilities provided by Sweden, which can be seen from Table 5.2. The Sri Lankan Government thus had to resort to other foreign exchange resources for an amount of SEK 679 mill in current value.

CHAPTER 6
PROJECT IDENTIFICATION, PREPARATION AND APPRAISAL

6.1 MAHAWELI DEVELOPMENT PROGRAMME (MDP)

The following is an excerpt from the World Banks's "Overview of The Accelerated Mahaweli Programme" which is annexed to the Bank's 1988 report on Sri Lanka:

The Mahaweli River Basin formed the cradle of Sinhalese civilization from the fifth century B.C. Following repeated invasions from South India and the decline of the Polunnaruwa civilization, the irrigation networks and agricultural fields so characteristic for this area were abandoned and fell into disuse. The region was denuded of people as malaria spread and large numbers migrated to the southwest.

Efforts to repopulate the Mahaweli Basin were initiated in the early and mid twentieth century, and some notable reservoirs and waterways were constructed. Two major projects were implemented before the MDP in the post-independence era, namely the Gal-Oya and the Walawe Project.

Two major feasibility studies were undertaken concerning what is now called the Mahaweli Development Programme. The first by the UNDP and FAO conducted in 1968 envisaged a large scale programme spread over 30 years. The second conducted by the Netherlands Economic Development Corporation (NEDECO) in 1978 examined the prospects of acceleration.

6.2 ACCELERATED MAHAWELI DEVELOPMENT PROGRAMME (AMDP)

The Mahaweli Development Programme is the largest single development programme undertaken by the Government of Sri Lanka. To implement the

AMDP outlined in the NEDECO study a separate Ministry of Mahaweli Development was created in September 1978, and the acceleration of the Mahaweli Development Programme is normally traced to this date. The Mahaweli Authority of Sri Lanka (MASL), an umbrella organization for planning and implementing was established in 1979. The MASL, the Mahaweli Development Board (MDB), the River Valleys Development Board (RVDB) and the Central Engineering Consultancy Bureau (CECB) were all placed under the purview of the Ministry of Mahaweli Development.

The AMDP had three main components: (1) the four main headworks projects of Kotmale, Victoria, Randenigala and Maduru Oya, of which the three first are hydro-electric power projects as well; (2) the downstream engineering and irrigation works; and (3) the irrigation, settlement and agricultural development of new lands in systems H,B,C and G. See figure 4.1. The three power plants Kotmale, Victoria and Randenigala are now completed adding more than 1000 GWh of firm energy to the power system.

6.3 APCOS' KOTMALE STUDY

The Kotmale Project is an important component of the Mahaweli Development Programme. Preliminary surveys and studies for the Kotmale Project were carried out during the preparation of the two previously mentioned Master Plans for the Mahaweli Ganga basin. From 1973 to 1977 the Indian consulting firm WAPCOS carried out a comprehensive feasibility study of the Project. With some changes this study forms the basis for the project as it stands today.

6.4 SWEDISH INVOLVEMENT IN THE KOTMALE PROJECT

It was recognized by the Government of Sri Lanka that an undertaking of the magnitude of the AMDP would require massive foreign financing as well as involvement of foreign consultants and contractors. Commitments regarding three of the four headworks were made by the United Kingdom (Victoria), Canada (Maduru Oya) and the Federal Republic of Germany (Randenigala-Rentembe).

Sweden's development assistance to Sri Lanka in the financial year 1977/

78 (1 July-30 June) included a major component of "import support" on grant terms. In the aid agreements this was described as "goods and services for development purposes" to be selected by the Government of Sri Lanka. Some of the funds were tied to deliveries from Sweden, but nothing prevented Sri Lanka from using the entire import support component for procurement from Sweden. While it was assumed by Sweden that recipient countries would normally utilize import support resources to procure a "mixed basket" of goods, nothing barred them from using the resources for a single commodity or for a supply contract involving equipment as well as services.

In 1978 the Government of Sri Lanka inquired whether there would be any Swedish objection to the utilization of present and future import support allocations towards the financing of the Kotmale Project. Due to the circumstances referred to, no objections could be raised on the Swedish side. SEK 67 mill. of these allocations were used on Kotmale project in 1978/79. The Government of Sri Lanka believed that the import support resources over a period of five to six years would suffice to cover a major proportion of the foreign costs of the project. This was based on the 1978 project cost estimate of SEK 645 million. However, that amount did not include the electromechanical works, special reinforcement of tunnels and shafts, cost escalation through inflation or project financing costs. The latter item had to be taken into account since the import support funds were disbursed only once annually and special bridging finance arrangements therefore had to be made. The Government of Sri Lanka subsequently secured bridging finance from a Swedish commercial bank.

In early 1979 the Government of Sri Lanka also decided to entrust the civil works of the project to a Swedish contractor, AB Skånska Cementgjuteriet (now Skanska). It was assumed that this would be welcome on the Swedish side. The agreement between the two countries on import support resources included the provision that, "whenever feasible", procurement should be undertaken on the basis of competitive tendering. However, no tenders from other Swedish contractors were called for. The Sri Lanka authorities did not regard a tender procedure as "feasible" as it would inevitably delay commencement of the project. Skanska was chosen on the basis of the company's internationally recognised standing as a contractor.

An agreement on import support was made between Sweden and Sri Lanka in May 1979 providing for an amount of SEK 210 million in the three Swedish

The three flood-gates are convex in shape to better withstand the pressure from the water masses. Beneath them lies the spillway that leads the water back to the river channel. Photo: Jan E Carlsson, SIDA Photo Archives

financial years 1979/80-1981/82. This amount was later increased to SEK 240 million. In this connection Sri Lanka noted its intention of using all these resources towards the financing of the Kotmale Project.

A contract for the initial works was entered into between Sri Lanka and Skanska in August 1979, and a second contract was made a few months later covering the underground works.

Already at the beginning of 1979 the cost of the project had been revised upwards to some SEK 1,300 million. This estimate did include some items not covered by the previous estimate of 645 million. As a result of the abovementioned delays and design changes, the total project cost was estimated at about SEK 2,500 million in 1981. This amount also included the electromechanical works which had been entrusted by Sri Lanka to the ASEA group, Sweden's leading manufacturer of electrical equipment. The cost was estimated at the beginning of 1982 at SEK 325 million. The Government of Sri Lanka had appointed the British firm Kennedy & Donkin to be Project Engineer in respect of the electromechanical works, in association with Halcrow Water and CECB.

It was obvious from the escalation of project cost that Swedish financing assistance from import support resources was no longer realistic. Such resources would have to be drawn well into the 1990's, long after completion of the project. Furthermore, the final bill would include a significant amount, possibly of the order of SEK 500 million, in the form of interest on the bridging finance. In these circumstances, the Government of Sri Lanka in 1981 appealed to Sweden to consider other aid financing arrangements.

Because project financing had been provided under the umbrella of import support and not in the form of "project support", the question of an initial Swedish assessment of the Kotmale Project had not arisen. Following Sri Lanka's appeal about a review of the project financing arrangements, SIDA commissioned a study of the project which was undertaken at the end of 1981. Having received the report on the study, The Ministry for Foreign Affairs requested SIDA to submit a proposal for further financing of the project. SIDA's proposal was revised by the Ministry, and in the Spring of 1982 a bill was presented to Parliament on the subject and approved with no dissenting vote.

The new financing arrangement approved by Parliament covered the six Swedish financial years 1982/83 — 1987-88 and provided for grant assistance totalling SEK 1,088 million. This was in addition to the amount of SEK 307 million previously disbursed as import support. The new grant assistance related to the civil works of the project, and for the electro-mechanical works a subsidised credit of SEK 256 million, guaranteed against the aid appropriations, was to be provided.

In July 1982 the two Governments concluded a "Specific Agreement on the Kotmale Hydro Power Project" containing the financing arrangement approved by the Swedish Parliament.

To mark the transition of the project to "project support", the Specific Agreement included provisions for a team of independent experts appointed by SIDA to monitor project progress and to assist towards the solution of any technical problems arising. The team carried out eight review missions from 1982 to 1985, and their reports to SIDA and MASL are a source of detailed information about the progress of the project and cost developments.

The Government of Sri Lanka had decided in 1984 to order a third 67 MW unit from ASEA, and a commercial credit guaranteed by the Export Credit Board of Sweden was obtained for the purpose. Due to the closing down of the plant for 18 months in 1986-87, commercial operation of the third unit took place only in the first quarter of 1988.

Swedish financing of the project (SEK 1,395 mill. on grant terms and a credit of 256 mill.) is directed entirely towards the foreign costs related to the work of the Swedish Contractors. When the Specific Agreement was signed, this financing was estimated to cover some 75% of those costs. No commitment was made by Sweden with regard to other aspects of the project or to the AMDP in general. However, the rising concern with environmental considerations in Sweden's development assistance caused SIDA to commission a study on the environmental impact of the project. The field work was undertaken in early 1988 and the report was presented in June of that year.

The impounding of the reservoir necessitated the evacuation and resettlement of some 3,000 families located in the area to be inundated. While this was entirely the responsibility of Sri Lanka, it was agreed between the two countries in 1984 and reaffirmed in 1986 that a study on the evacuees and their situation in the new settlements should be undertaken by SIDA. Planning of the study was much delayed, and the work commissioned to a Sri Lankan university institution began only in June 1988. Because of the disturbances due to the ethnic conflict it was not possible to adhere to the original timetable for the conduct of the study. Part 1 of the draft report was submitted in February 1989 and part 2 in June 1989.

The two studies mentioned are being financed by SIDA from funds outside the annual aid allocations to Sri Lanka. Such funds were also used to finance the progress review missions of the SIDA team of experts until completion of the project. The costs of subsequent missions of the team were born from the "Consultancy Services Fund" which is part of the SIDA financed annual development cooperation programme in Sri Lanka. The fund has also financed the training in Sweden of operational staff for Kotmale organized on behalf of SIDA by the SwedPower Company. A third and final such programme was completed in November 1988.

There is no provision in the Specific Agreement for a joint ex-post evaluation of the project. However, it is SIDA's standard procedure to conduct such evaluations whenever major project support has been provided. The magnitude of the Kotmale project and its unique history make an evaluation exercise mandatory. After the power plant now has been in commercial operation for more than one year following the above mentioned repairs, it has been agreed between SIDA and GSL to conduct the evaluation this second quarter of 1989.

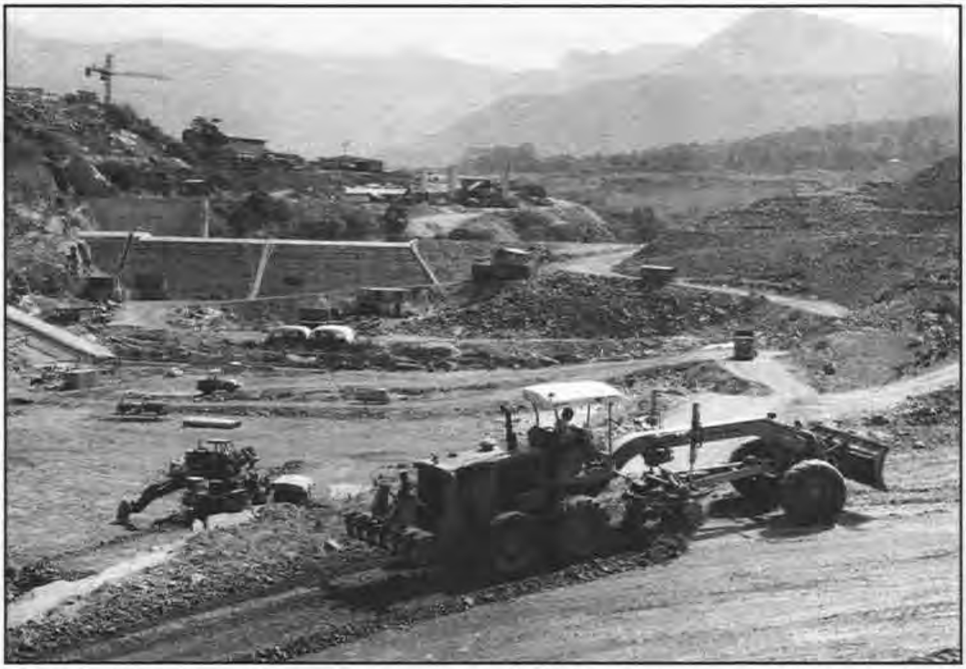
In spite of this massive involvement of Swedish funds, mostly in the form of grant money, Swedish authorities represented by SIDA, had very little influence on the way the money was spent and on the execution of the project. The Team of Experts that was appointed as part of the Specific Agreement on the Kotmale of 16 June 1982, came into the picture too late to have any influence on the critical design phase. It is normally during this phase that the options are still open to technical improvements and money-saving.

When the Team of Experts started their assignment, construction works were already well ahead, and the team's efforts had to be directed towards monitoring progress of the different works and to making recommendations about measures to help overcome constraints that impeded the progress of the works. Cost effective recommendations by the team were naturally limited to questions related to construction works that were already defined by the technical specifications. This is also clearly reflected in the terms of reference for the team.

6.5 SELECTION OF CONSULTANTS, CIVIL CONTRACTOR AND EQUIPMENT SUPPLIERS

As mentioned above Sir William Halcrow & Partners (Now Halcrow Water) were appointed to be lead consultants for the project in association with CECB and later Kennedy & Donkin. Their services included overall planning, coordination, design and supervision. The consultants were appointed without any competition and may not have been the most experienced group for the part of the project that concerns the underground work. Also Skanska as main civil contractor and ASEA as supplier of all electrical and mechanical equipment were selected without any competition. This may undoubtedly have saved several months in getting started, but is a procedure that normally leads to higher prices. This issue is commented upon further in Chapter 7, Section 7.6.

The fact that CECB, at the same time as being consultant in association with Halcrow, also was the instrument of the Client, the Mahaweli Authority led to



When the SIDA Team of Experts came to the site the design phase was over. The Team of Experts thus had no influence on the design of the project. Although the Swedish Authorities donated large sums of money to the project they had very little influence on the way the money was spent.
Photo: Jan E Carlsson, SIDA Photo Archives

CECB sometimes playing a double role: that of the Consultant and that of the Client's representative. As an example it is the Mission's impression from the interviews conducted that the question of the costly and debatable concrete lining of the low pressure tunnels was decided by CECB in their role as the Client's representative.

CHAPTER 7
PROJECT IMPLEMENTATION

7.1 GENERAL

For a project with extensive tunnelling and dam works like at the Kotmale, the civil works are always time-critical, since the lead time for electromechanical delivery is normally less than 24 months.

In order to reach their initial goal of test operation before the end of 1984, the Mahaweli Authority of Sri Lanka (MASL) decided to have the main civil works contracts awarded within the second half of 1979. Initial work in the field consequently started in August of that year, and already three months later these works had revealed that the ground conditions at the site of the rockfill dam departed significantly from what had been expected. The work with the documents for the dam contract, still not awarded at that time, were suspended and an international panel of experts brought in to assess the situation. Their report of May 1980 concluded with the advice to relocate the dam to a site 2-300 m further downstream. It was further decided to lower the dam by 28.5 m and to change the design from an impervious central core to an upstream concrete diaphragm; further to shift the diversion tunnels to the right side and the spillway to the left, and finally to introduce grouting galleries and deep grout curtains.

All these changes delayed the construction start of the dam to late 1981, meaning that the project completion date had to be moved to Dec. 1985, now with the dam contract on the critical line and not the underground works contract.

In spite of having now settled for a lower dam (see sections 4.2.3 - 4.2.4), the new location and design caused a substantial increase in the cost of this part of the project. A decision made at this time by the Sri Lanka authorities to concrete line all waterways of the power plant indicated a cost increase also for the underground works. Expected higher escalation expenditures due to the prolonged construction time accentuated the cost picture. It was at this juncture that the project was "refinanced" with a major grant approved by the Swedish Parliament in May 1982.

An important instrument in the implementation of the project was the Team of Experts, appointed by SIDA in July 1982 to monitor project progress and to assist towards the solution of any technical problems arising. This 3-member team carried out eight review missions from Sep. 1982 to Feb. 1985, at which time the regular construction period was approaching the end.

In retrospect it may be regretted that this team was established at a time when it was too late to influence the basic design of the power plant, the request for which there is consequently no mention in their Terms of Reference.

An acceleration of the construction programme, proposed by the contractors in Nov. 1983, was eventually agreed upon by all parties involved, with power production to be initiated in Feb. 1985 and with impounding of water in the reservoir as early as Nov. 1984, thus taking advantage of the north-east monsoon precipitation for storage. Although this "Super Accelerated Programme" — as it was named — proved successful, commercial power production on a regular basis commenced only in Dec. 1987. The delay came from deficiencies of the pressure shaft, revealed shortly after the first filling of the waterways, and manifested by excessive leakage into the powerhouse area (see Section 7.6 for comments on this event).

As a result of these inconveniencies, the SIDA Team of Experts was reactivated, reinforced to include specialists and given a set of new Terms of References. The Team submitted four reports from Nov. 1985 to Dec. 1987. In the period from March 1985 to May 1986 the power plant was operating intermittently, interrupted by shutdowns for gaining access to the waterway in order to perform investigations and/or provisional repair work. After MASL had reached their final decision to steel-line the entire pressure shaft and the inclined tunnel, the plant was closed continuously for 18 months till restart of the operation in Dec. 1987.

In their position as Client, MASL were vested with the power to make decisions on most technical and contractual matters, e.g. the signing of all contracts related to the Mahaweli Programme.

Among their other responsibilities were to take the necessary measures to relocate people in the reservoir area including the building of new roads and bridges, and further to act as the coordinator of interfacing works such as the Victoria transmission line.

It is the Missions impression that in a general sense MASL succeeded well in their efforts. Particularly could be mentioned the good working relationship established with the SIDA team of experts when acting as advisors to MASL in regard to the progress of the works.

On the negative list of merits by MASL could be mentioned the following:

- Late relocation of people, roads and a bridge caused delay in the storage programme for the first filling of the reservoir, with an estimated 146 hm^3 of water being bypassed for that reason, despite timely warnings from the SIDA team of experts.
- Reluctance in reaching decisions, e.g. regarding staffing of the Engineers office or choosing one design alternative out of several, did sometimes put the construction programme in jeopardy.
- The decision to concrete line all tunnel waterways has added unnecessary costs to the project (see section 7.6.2.2).

7.2 CIVIL WORKS

7.2.1 The Contracts

The work of the civil contractor Skanska AB was performed under three separate negotiated contracts and a later Supplementary Agreement for the repair work that followed the pressure shaft failure:

Table 7.1
Civil Works Contracts

	Item	Award date	Tender	Paid	Escalation	Total
			Sums in million LKR*)			
IWC	Initial works	04.08.79	562.18	786.16	186.82	972.98
UWC	Underground works	18.12.79	1,065.90	1,238.77	638.36	1,877.13
RWC	Reservoir works	Oct.1981	3,010.00	2,997.41	581.42	3,578.83
-	Repair work	1986	-			542.77
TOTALS			4,638.08	5,022.34	1,406.60	6,971.71

*) For conversion to SEK: Multiply by 0.3.

Notes:

1) The table figures include additional work procured through a number of Variation Orders (V.O.s.), e.g. the Repair Work which was performed under V.O.s. 45, 51, 52 and 54.
2) The civil work costs related to the installation of Unit no. 3 are included.
3) Claims: Total claims under these contracts amounted to LKR 85 mill., of which LKR 43 mill. has been allowed and is included in the table figures.
4) Reference 28: Final Engineering Report of May 1989, by Halcrow Water.

The Initial Works Contract (IWC) contained the following activities, with each items' share shown as percentage of the total (973 mill. LKR):

1.	General	25.1 %
2.	Accommodation	18.7 %
3.	Workshop & Offices	10.3 %
4.	Access Roads	9.2 %
5.	Temporary Bridge over Kotmale Oya	0.4 %
6.	Diversion Tunnels (damsite)	29.8 %
7.	Clearance of Damsite	-
8.	Site Investigation	0.3 %

9.	Trial Quarry	0.6 %
10.	Trial Embankment	0.4 %
11.	Access Tunnel	2.2 %
12.	Daywork	0.5 %
13.	Unallocable Variation Orders	2.5 %
		Total 100 %

As mobilization had been under way since early in the year, work in the field for the IWC could start already four days after contract award, with Dec. 1984 as the target for completion of the entire project. It was during the excavation for the portals of the dam diversion tunnels (see item 6 above) in early Nov. 1979 that the true ground conditions of the damsite were revealed.

The works under this contract were virtually complete by 1982.

The Underground Works Contract (UWC) and the Reservoir Works Contract (RWC) were initially planned as one single contract, but split into two by the delay caused by the change in design and location of the dam. The RWC contained all works for the dam and the reservoir, while the UWC included all remaining civil works, above ground as well as underground.

The Supplementary Agreement included the major repair work for the pressure conduit, such as excavation of a new tunnel adit of large cross section from the surface into the middle of the inclined tunnel, for the transportation of full-diameter steel liners to be installed at two headings; excavation of a 400 m long drainage and grouting tunnel parallel to the low pressure tunnel, upstream of the surge shaft; a total of some 500 m of new steel liner; an additional 30 m of concrete lining in the low pressure tunnel, etc.

7.2.2 Local Participation

During the most intensive periods the Contractor's workforce counted as many as 6,000 local employees. Over the years 1,200 -1,300 individuals were given a six months training programme by the Contractor, and received certificates as machine operators or drivers. More than 700 of them were employed at Kotmale for some time period.

In monetary value, the local component of all civil works contracts came to approximately 18 %. If larger quantities of construction materials such as cement and reinforcing steel had been available locally, this share could have risen significantly.

7.3 HYDRAULIC STEELWORK

The hydraulic steelwork was supplied under four (sub)contracts tendered for by ASEA as prime contractor, and one contract tendered for by Skanska, as follows:

Contract KOT/E1:	**High Pressure Steel Lining** Included supply and erection of the waterway-liner, from spherical valves through bifurcations to lower 1/3 point in pressure shaft.
Contract KOT/E2:	**Diversion and Low Pressure Tunnels Gates and Screens** Included supply and erection of surge shaft gate, intake gate and screen, diversion tunnel gate, model study, etc.
Contract KOT/E3:	**Spillway Equipment** Included supply and erection of radial gates and stoplogs.
Contract KOT/E4:	**Bottom Outlet Equipment** Included supply and erection of conduit, valves, etc., and supply of tools and spares.
Repair Work in Pressure shaft and Inclined tunnel, Skanska's V.O.'s 45-51-52-54:	**Steel lining**

The costs, tendered and final, were as follows:

Table 7.2
Hydraulic Steel Contracts

Sums in million LKR*		
Contract	Tender	Final
KOT/E1	53.26	70.37
KOT/E2	66.31	126.42
KOT/E3	181.03	206.17
KOT/E4	61.04	59.51
Repair Work	(Hydraulic steel part unknown)	
	361.64	462.47

*) The basic figures are composed of two currencies; LKR and SEK. For conversion from SEK to LKR, assumed here 1 SEK = 3.23 LKR

Some of the hydraulic steel components were procured from France, e.g. the surge shaft gate, the bottom outlet equipment and the liner for the repair work, but most of the components came from Sweden.

Kennedy & Donkin provided the specifications.

7.4 ELECTRO-MECHANICAL EQUIPMENT

7.4.1 The Contracts

The electrical and mechanical equipment apart from what has been described under Section 7.3 as Hydraulic Steelwork was supplied by ASEA under four contracts:

- Contract KOT /P1: **Power station Plant.** Included power station crane, nos. 1 and 2 generators and turbines and associated equipment, and inlet valve and draft tube gate for no. 3 turbine.
- Contract KOT/P2: **220 kV Substation.** Included ventilation and air conditioning plant, 220 kV switchgear, generator transformers for units 1 and 2 and auxiliary equipment; 13.8 kV switchgear and cables and common equipment for both units; spares.
- Contract KOT/P1A: **Power Station Plant - Unit 3.** Included no. 3 generator and turbine and associated equipment.
- Contract KOT/P2A: **Substation Plant - Unit 3.** Included 13.8, 132 and 220 kV switchgear related to unit 3 and unit 3 combined generator and interbus transformer.

The costs, tendered and final, were as follows:

Table 7.3

Elmech Equipment Contracts

Sums in million LKR

Contract	Tender	Final
KOT/P1	320	397
KOT/P2	150	216
KOT/P1A	282	316
KOT/P2A	112	135

7.4.2 Description

The underground power station is equipped with three vertical shaft generating units with Francis turbines and spherical inlet valves. Two units were initially installed in 1985 and a third unit was added in 1987 (For data see Project Data, Appendix 2). The turbines have their maximum operating efficiency at the present dam level , but are mechanically designed also for the higher dam crest. The output from the generating units is conducted via 15 kV polyethylene insulated cables through the vertical cable shaft to the 220/132 kV open air switchyard on top of the cable shaft.

Generators 1 and 2 are connected to single phase transformer banks 13.8/220 kV with one single phase unit as common spare. Generator 3 is connected to a single phase, three winding transformer bank 13.8/132/220 kV. This bank also acts as a bus connection transformer between the 220 and 132 kV busses. The transformer banks are placed in the switchyard and are air cooled. The 220 and 132 kV switchgear is of a conventional open air type with minimum oil circuit breakers.

The powerhouse protection and control equipment is placed in a suite of machine control panels in the machine hall, that allows the units to be operated from there. There is likewise a control building in the switchyard with relay and control panels for the switchyard equipment. The generating units can also be operated from this control building. The switchyard buildings also contain an emergency diesel generator set, medium voltage switchgear and ventilation equipment.

The power station is connected to the grid via one 220 kV double circuit line to Victoria, one to Biyagama substation near Colombo and one 132 kV double circuit line to the Polpitiya/Habarana connection.

7.5 PROJECT ORGANIZATION

7.5.1 General

Under the command of the Mahaweli Authority (MASL) as the Owner of Kotmale Hydropower Project, all consultancy and engineering services including site supervision were provided by an ad hoc engineering organization composed of the following three associates:

Lead partner:	Sir William Halcrow & Partners (Halcrow Water) Burderop Park, Swindon, Wiltshire SN 4 OQD United Kingdom
Responsibility:	Overall planning, coordination and civil engineering design and supervision.
El-mech partner:	Kennedy & Donkin (K & D) Westbrook Mills, Godalming, Surrey GU 7 2AZ United Kingdom
Responsibility:	Electrical and mechanical engineering design, and supervision for turbine-generator units and switchgear.
Local partner:	Central Engineering Consultancy Bureau (CECB) 500 T.B. Jayah Mawatha, Colombo 10, Sri Lanka
Responsibility:	In association with Halcrow Water and K & D, to provide engineers and technicians for the majority of the design and supervision jobs, to provide support services and facilities in Sri Lanka including main design office and all transport.

7.5.2 Design Office of the Consultants

The design staff chart included 60 positions. The offices were located in Colombo, within the Ministry of Mahaweli Development building.

Shortage of personnel, particularly experienced design engineers, proved to be a problem and a matter of concern for the Contractor (Skanska), the SIDA Team of Experts and of course the Consultants over a long period of time.

A further impediment to progress was reportedly a certain indecision on the part of the Consultants to choose one solution from several possible alternatives.

These problems were, however, gradually overcome, and their true impact on the progress of the work was probably negligible, in spite of the frequent complaints filed by the Contractor over lack of work drawings.

7.5.3 Site Supervision Office

The site staff for the supervising of all civil works included 46 positions.

This office was reportedly managed in the most efficient and professional way and — helped along by the SIDA Team of Experts at certain occasions — developed a good working relationship with the Contractor.

7.5.4 The Contractors' Organizations

The office of the civil works contractor was reportedly well organized and staffed by professionals.

Less well organized was allegedly the contractor for the hydraulic steel work (ASEA), who had chosen to direct and coordinate this work from Sweden. Their site representative appeared not to have been given the authority required for a smooth progress. This situation may have been attributable to the contractor's unfamiliarity with supplying this type of equipment. In all other respects their site organization seemed to function well.

7.6 COMMENTS ON DESIGN, CONTRACTING AND IMPLEMENTATION

7.6.1 General

While the preceding sections of this chapter should be regarded as a description of facts, the following reflects the Mission's opinions on certain conditions upon which design, contracting and implementation were based. Even if these activities were more interwoven here than in a normal case — due to the precipitate haste of the construction start, with the Contractor appointed prior to the Consultant — they will be commented upon separately.

It should be kept in mind that any ex post evaluation may easily be tainted by the knowledge of events happened. It has not been the Mission's intention to take undue advantage of this benefit of hindsight, and the comments here should not be regarded as mere criticism of any party involved.

7.6.2 Comments on the Design

7.6.2.1 The Dam

A considerable number of design reports and geological studies, one of them dating as far back as 1966, were available when the Consultants started their work early in 1979. The most central of these is probably the feasibility report of Jan. 1978 by WAPCOS, where the (initial) site of the dam and the type of dam with an impervious central core was proposed. Further studies were under way and reports coming in during 1979, e.g. the "Report on Seismic Refraction Survey of proposed Chute Spillway and Tunnel intake Sites and Correlation by Diamond Core Drilling", by Geotech, March to April 1979.

It is difficult without a detailed study of all this documentation, to state whether or not the extent of the performed field investigations could be considered adequate at the time when the final design with tender for the dam was prepared in the autumn of 1979. There is, however, reason to question the quality of some of the investigations, in particular the seismic report referred to above. It should have been expected that the adverse conditions for the diversion tunnel portal, revealed through the Contractor's tentative excavation, (see also 7.2.1) were identified at the time of the seismic survey had the results been interpreted more precisely.

Due to swift action on the part of the Consultants, however, the new damsite was established before much wasteful work had been done at the original site. The bulk of the extra cost incurred by this change in dam location is more likely to be found in the LKR 50 mill. bonus later paid to the Contractor for an early completion of the work under the "Super-Accelerated Programme", by which the time lost from these changes was virtually regained.

The dam is furnished with a chute type spillway with three gates, but without any emergency spillway. It is evident from the topography why an ungated spillway solution could not be considered. There are, however, records of embankment dams having failed due to overtopping as a result of spillway gates having failed to open in a critical flood situation. In later years certain financing institutions like the World Bank have tended to make it mandatory to design embankment dams with an extra spillway, e.g. an emergency fuse plug, to alleviate such conditions, and the International Commission on Large Dams (ICOLD) have addressed the problem in their Bulletin of 1986 on Design of Spillways for dams, by ICOLD Committee on the hydraulic of dams.

The international panel of experts have no mention of the issue in their report of May 1980. The Mission, after having visited the site and studied the operation procedures and the hydrologic data, have found the safety against a disastrous overtopping reassuring for the following reasons:

- Maximum capacity chosen for the spillway is exceedingly ample: 5550 m^3/s as reservoir outflow from a catchment area of 544 km^2.
- Operation and maintenance procedures make continuous presence of operators at the dam mandatory.
- Power supply for gate operation is ensured in all situations by an emergency diesel generator at the dam, with automatic start included.
- In case of jamming of one or more gates, a rockfill embankment with an upstream concrete slab is able to endure a possible overtopping to a higher extent than any other embankment type dam before collapsing.

7.6.2.2. The Low-Pressure Waterways

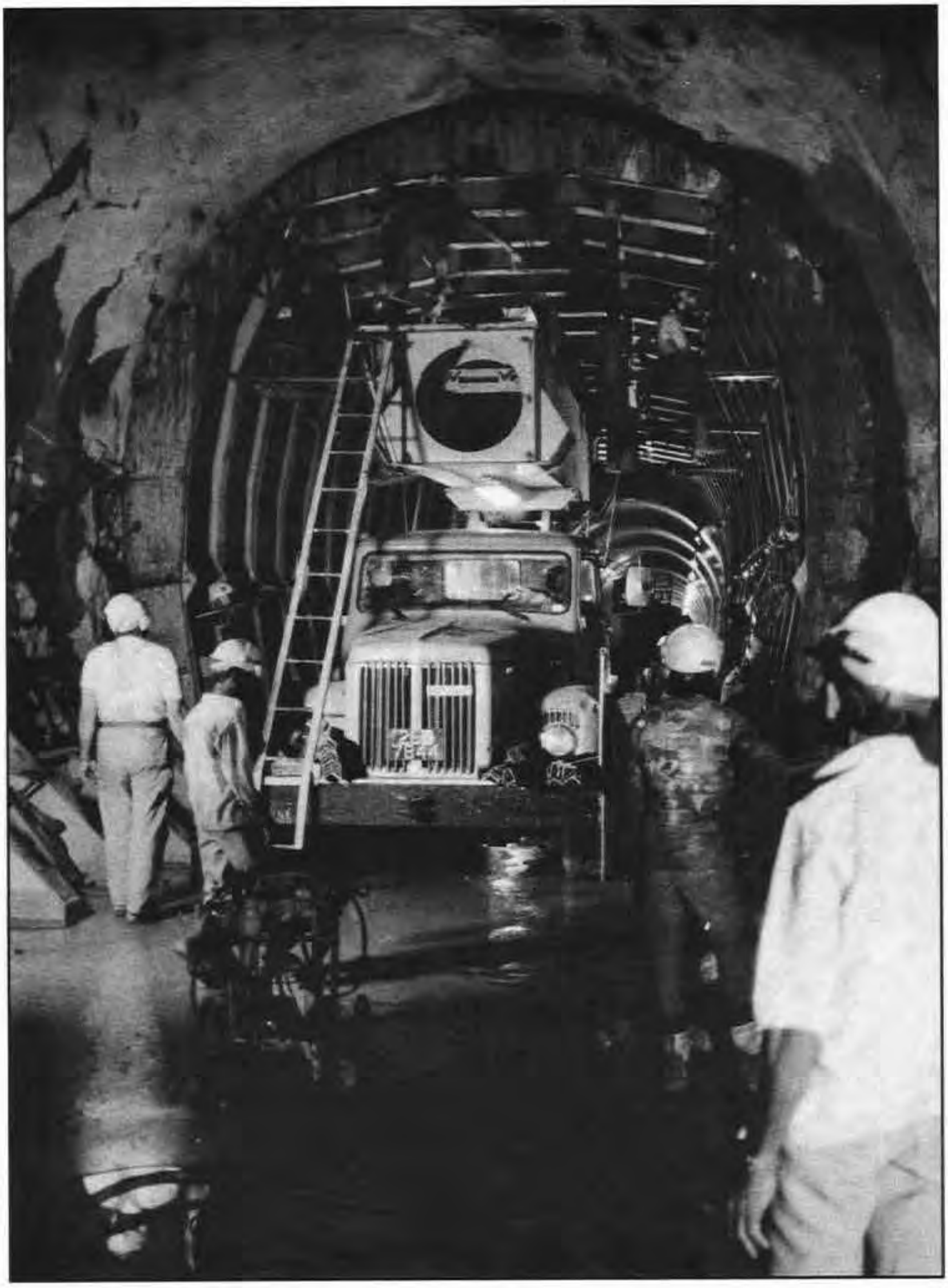
The headrace and tailrace tunnels represent a large share of the value of the underground works contract. The entire length of these waterways has been concreted, and to a large extent also cement grouted. This solution may have come about more by a principle having been laid down by the Client than as a choice made by the Consultants; see Section 7.1, 4th paragraph.

The rock mass stability along these tunnels was very good, manifested by the unusually small volume of temporary rock support required —e.g. for the entire headrace at a cost below LKR 20 mill.

An alternative to this extremely cost- and time-consuming solution was to allow the use of unlined tunnels; unlined meaning that rock support would be applied only where rock mass of poor quality was encountered, and with little or no support installed elsewhere. The price to be paid, aside from a larger cross-section to reduce velocity and balance headlosses, would have been to accept and expect a few minor rockfalls during the lifetime of the plant.

This economic solution has been used by Scandinavian power developers for several decades, also in rock of inferior quality compared to Kotmale's. A performance study covering a total of 2,500 km of basically unlined waterways in Norway over a period of 20 - 25 years found only 5 - 6 cases of large rockfalls that had caused operational disturbances. Repair work was in most cases delayed to an opportune time when a shutdown was required for other reasons, such as for maintenance of the electro-mechanical machinery.

Rough calculations indicate that unlined low-pressure waterways of 55 m^2



Concrete lining of a tunnel. Considerable costs could have been saved by using unlined low-pressure waterways. Photo: Skanska, Björn Enström cross-section would have saved LKR 150-200 mill. of the investment, or 10% of the UWC contract. With a Swedish contractor, well familiar with the unlined concept, there is all the more reason to believe that such a solution would have been successfully implemented, avoiding the waste of that money.

7.6.2.3 The Pressure Shaft

Unlined high pressure tunnels and shafts in rock have been designed for many decades in various parts of the world and with variable success. The use of this economical design started early in Norway and is today commonplace, with more than 80 unlined shafts/tunnels where the static water head is higher than 150 m now in operation — the highest head being 1000 m.

The crucial issue in a successful design of an unlined pressure conduit in rock is to ensure that the "active" rock cover is adequate in relation to the internal pressure in the conduit. Where the tunnel follows a ridge, as is the case here, the stress relieved condition of the rock should be taken into account, and it is prudent to adjust the actual topography as shown in Fig. 7.1 to allow for "inactive" portions when measuring the depth of overburden.

Present day (1989) procedures in the design and construction of unlined pressure conduits often call for a flexible approach with "design - as - you - go". Unless conclusive hydraulic fracturing tests along the conduit alinement already exist, such tests are made from the conduit proper during the construction, in order to identify the precise location of a safe interface of steel lined/unlined conduit.

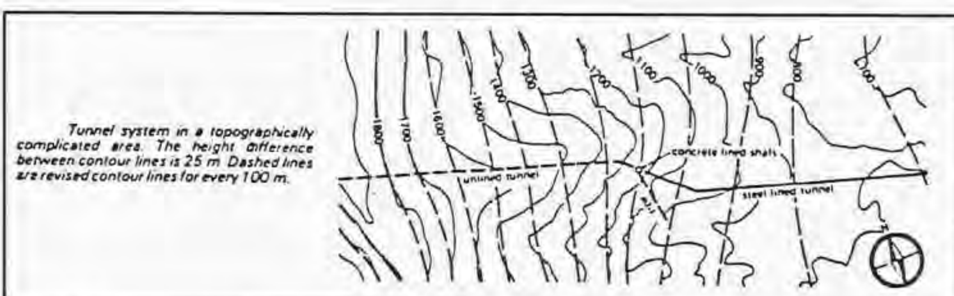


Fig. 7.1 Revision of Contours (From Bibliography item 7, 1984.)

The detailed design of the Kotmale pressure conduit took place from 1979 and the construction from 1981. The concept appears to be the same as shown in WAPCOS' study of Jan. 1978, a design which probably dates back to 1976-77.

In order to obtain both an opinion on the cause of the shaft failure and a fair assessment of the state of the art in that time period (1978-83) the Mission retained Dr. Bjørn Buen, an independent engineering geologist with extensive experience from the international scene in the design of unlined pressure conduits. In his report, attached as Appendix 4, Dr. Buen expresses the following views:

- The failure mechanism was hydraulic jacking on vertical joints
- Rock stress testing by overcoring gave inconclusive results in this case
- The failure could have been avoided had the design been updated and pressure testing applied during construction.

7.6.2.4 The Upstream Surge Shaft with Gate

This shaft is 142 m high, 15 m in diameter and fully concrete lined, with restricted orifice and furnished with a roller gate w/h = 3.8/4.8 m, stored on a surface platform at El. 765+/-. The shaft is located some 400 m upstream of the penstock knee, or 550 m from the powerhouse, measured along the waterway.

A gate placed in this position on the waterway would conventionally be intended to serve as an emergency penstock closure valve. As the setting operation will now take many hours, that function is obviously out of the question, which leaves the gate to serve as closure of the penstock for maintenance such as painting, without having to drain also the low-pressure tunnel. Since that sort of work must take place during a longtime seasonal shutdown of the power plant, the intake gate could serve the same purpose, as there would be ample time for slow draining and refilling of the low-pressure tunnel.

The gate therefore appears to be an installation that readily could have been omitted. Its final cost came to LKR 52.5 mill.

The Kotmale Powerhouse under construction.
Photo: Heldur Netocny, SIDA Photo Archives

7.6.2.5 The Powerhouse

Records show that the excavated volume of an underground powerhouse with Francis type machinery, and with the transformer located in the cavern, vary between 80 and 200 m3 per installed MW. This ratio reflects to some extent the given head and the number of units chosen, but also the designers' effort to economize with space.

The Kotmale powerhouse accommodates no transformers since these are placed above ground, and has an excavated volume of approximately 40,000 m^3. With 204 MW installed capacity, the ratio is 196 m^3 per MW, i.e. near the upper end of the scale.

A more compact structure could have been achieved by simple means, such as placing the pressure conduits in an oblique position relative to the powerhouse axis, which gives easier access to the spherical valves for the overhead crane hook and may cut 1-1.5 m from the width of the cavern. Another 1-1.5 m reduction in width could have been attained by placing the suite of machine control panels near the access end of the powerhouse instead of along the downstream wall. The space above crane girder level also seems to be on the generous side. A total reduction of the excavated volume by

10,000 m^3 was apparently attainable, corresponding to reduced civil works cost of LKR 10-15 mill.

The number of power units at Kotmale, hardly a choice made by the Consultants but still a part of the design, is insufficiently documented. With three units installed, the plant factor is very low compared to that of Victoria HPP downstream, likewise with three units:

Name of HPP		Plant factor 3 units	(2 units)
Kotmale,	average energy	28.1 %	(42.1 %)
	firm energy	15.0 %	(22.7 %)
Victoria,	average energy	48.7 %	
	firm energy	31.6 %	

If the third unit at Kotmale had been left out, the plant factor would be as shown in the right column.

For more detailed comments, see the following paragraph.

7.6.2.6 Electro-Mechanical Equipment Design

Most of the electrical and mechanical equipment in the power house and the switchyard is of a conventional design. It is of good quality, manufactured by reputed manufacturers and should be expected to give no special problems in the future regarding durability and maintenance. During the visit to the site and after having gone through the design, the Mission noted some features about the chosen design that could be discussed:

The Mission is not convinced that the chosen design with the transformers placed in the switchyard offers the best and safest solution. The fact that the cables to the transformers are routed through the vertical cable shaft without any fire separation between the different cable groups may represent a higher fire hazard than envisaged even if the cable sheaths are made of flame retardant PVC. To place the transformers unprotected in the switchyard also offers an easy target for sabotage. The Mission feels that a better solution would have been to place the transformers in the cavern with 220 kV cables through the access tunnel duly protected against mechanical damage from traffic in the tunnel. It is probable that the transformers could have been accommodated within the same volume of rock that is now excavated. The switchyard could then have been placed in the vicinity of the access tunnel entrance together with a portal building containing auxiliary equipment, control room, offices, store rooms and other facilities.

The 220 kV transmission line from Kotmale to Biyagama has a capacity of about 2x600 MVA which is sufficient to transmit all the power from Kotmale, Victoria, Randenigala and Rantembe on one circuit. The 132 kV line from Kotmale to the Polpitiya / Habarana line has a capacity of about 2x100 MVA, but the actual capacity is limited to the 90 MVA of the interbus transformer of unit 3. In the case of the Kotmale - Biyagama line out of service the generation of the above mentioned group of power stations will have to be reduced. The Mission has not had the opportunity to go into a more detailed load flow study, but it seems as if a 250 MVA interbus transformer between the 220 and 132 kV busses would have been a better solution than the 90 MVA three winding generator transformer of unit 3.

The installation of the third generating unit during the 1987 repairs does not seem to be well justified. This was done, as has been understood, on the insistence of CEB and also paid by them. The plant factor for three units and mean annual energy is only 28.1%. This means in simple terms that the 502 GWh of mean energy can be generated in 2,460 of the annual 8,760 hours at full 68 MW load on all three units. In comparison Victoria , also with 3 units, has a plant factor of 48.7. Even with two units Kotmale would have had a lower plant factor (42.1%) than Victoria. The bus coupling effect of unit 3's generator transformer could have been achieved by only installing the generator transformer in anticipation of the generating unit being installed when the dam crest is raised.

It was also registered that the generators did not have any fire protection equipment like Halon or CO2. Even if the generator windings are made of non - flammable materials, oil vapour and oil leakages from the bearings still constitute a certain fire risk. Although the use of fire extinguishing installations on generators has diminished as insulation material has become less flammable, statistics show that still most of the generators in underground power stations have such equipment. The figure below is taken from Water Power & Dam Construction, Oct. 1985: "Fire prevention and protection in underground hydro stations", and shows statistics relating to underground stations built during the last 15 years before 1985.

–Fire extinguishing agents for generator/transformer units										
Country	Japan	Switzerland	Austria	UK	Canada	Italy	West Germany	Norway	USA	Brazil
Number of units	9	6	7	10	10	24	2	58	4	**
Water	7		4	10		14	2			
CO_2		6						40	4	
Halon 1301	2					10*		18		

Note: * 8 of the 10 units have a combination of Halon 1301 and low pressure water spray for cooling.
**Information not available

Table 7.4
Fire prevention of generator units in underground power stations

The Mission has looked into the effects on the speed and pressure rise due to higher water velocity after steel lining of the upper part of the shaft and the inclined tunnel. Calculations carried out by the turbine manufacturer show that with the actual guide vane closing time of 7.2 sec. the speed rise at full load rejection at the present highest water level of 703 m will slightly exceed the guaranteed values (51% against 45%), and the pressure rise at maximum future level of 731.5 will exceed the guaranteed 333 m by 8 m. The speed rise seems acceptable since the generator is guaranteed to withstand a speed rise of about 93%. When the dam crest is raised, the guide vane closing time may have to be increased in order that the guaranteed pressure is not exceeded (this again will increase speed rise!).

7.6.2.7 Conclusion on Design

In retrospect it is easy to conclude that the UWC-part of the power plant, without exceeding the budget of that contract, could have been given the following design features:

- Unlined low-pressure tunnels; the saved money to be used for
- a fully steel-lined pressure shaft;
- powerhouse relocated to a position 3-400 m upstream of the present site;
- a surge shaft of approximately 100 m² area, basically unlined, at the site of the present shaft, without a gate.

There are indications that the unit prices for the Kotmale dam contract are considerably higher — possibly 30-50 % — than they would have been, had the job been tendered internationally. Photo: Björn Enström, Industrifotografen AB

7.6.3 Comments on Contracting

7.6.3.1 Civil Works

As mentioned under section 7.2.1 all civil works contracts were negotiated with a contractor already appointed by the Owner (MASL). The fact that no competition took place thus explains the high lump sums and unit prices of these contracts.

Two other major hydropower developments on the Mahaweli Ganga were implemented during the same time period — the Victoria HPP from 1981 to 1984 — and the Randenigala HPP from 1982 to 1986. The civil works were here in both cases contracted through national tendering within each of the two donor countries — the United Kingdom and the Federal Republic of Germany respectively.

In the case of Kotmale, the problem may simply have been that national tendering was impractical due to natural limitations in the foreign potential of the Swedish heavy construction industry. Also, the Sri Lankan authorities were extremely keen on a speedy start of the construction, and even if regular tendering in Sweden had been possible, the process would have taken some time — perhaps 6 months.

In Sri Lanka there were allegedly at that time no construction company with the necessary resources to undertake any of these HPP contracts. The major part of the labour force was, however, recruited locally. With three large developments going on more or less simultaneously, the impact of this sudden increase in employment on the local economy must have been noticeable. The steep rise in the Colombo Consumer's Price Index, shown in Fig. 7.3, may be an indication of that. Records from other countries in the region (Thailand, Burma)indicate that the prices for civil works in the hydropower industry have been nearly stable during the period 1981 to 1985, when quoted in USD and based on international tendering.

An attempt will be made to assess the Kotmale civil works contracts in regard to the following:

- Escalation
- Unit prices for similar work in Sri Lanka
- Unit prices for similar work internationally.

The conclusions are summarized as follows:

Re Escalation:

There is reason to believe that escalation payments on the three civil works contracts have served only to compensate the Contractor in a fair way for inflation.

Re Unit prices for similar work in Sri Lanka:

There are indications to show that the unit prices for the Kotmale civil works contracts are at least 10-20 % higher than they might have been, had competing tenders in Sweden been called for and responded to.

Re Unit prices for similar work internationally:

There are indications to show that the unit prices for the Kotmale dam contract are considerably higher — possibly by 30-50 % — than they would have been, had the job been tendered internationally.

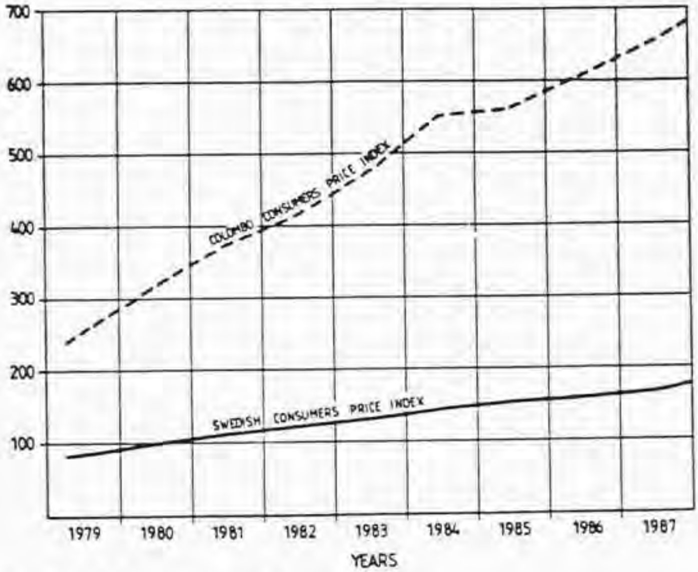


Fig. 7.3 Consumer's Price Indices

One great advantage of negotiated contracts is that few claims and disputes tend to arise during the work, which indeed proved to be the case here. Also, for the building of a major dam it is imperative to have an experienced contractor of good reputation and with strong financial, technical and human resources — requirements which in the end may count more than the price alone, and which were all met by the appointed contractor.

The most difficult contractual matter to be solved came from a provision on separate payment for cement and concrete, that served as a no-incentive for the Contractor to apply economic mixes. As fines were lacking in the sand aggregate, cement was actually for a period used as a substitute for fines. When it was found necessary to import cement from overseas — contrary to the conditions of the contract — a ruling from the Secretary of the Ministry of Mahaweli Development was required in order to resolve the issue of establishing the correct quantum of payment.

7.6.3.2 Hydraulic Steel Work, Contracting

The known costs — tendered and paid — of the hydraulic steel work contracted are tabulated in Section 7.3. The cost of the hydraulic steel component for the repair work is included in the total paid to the Contractor (see table Section 7.2.1) and constitute probably a large part of that total.

The prices paid for the supply and erection of the hydraulic steel work in general seem to be in line with what could be expected under the circumstances, meaning that the prices are somewhat higher than normal.

There are, however, two recorded cases of severe cost overrun:

- Contract KOT/E4 - Bottom outlet equipment, referred to by the SIDA Team of Experts in their Progress Review no. 4.
- Contract KOT/E2 - the surge shaft gate; which was originally tendered for LKR 21.5 mill. and which finally cost LKR 52.5 mill. The overrun is allegedly attributable to changes and redesigning, taking place after the initial contract award. It is difficult to understand the reason for this dramatic rise in cost, and also difficult to understand the need for this gate in the first place (see paragraph 7.6.2.4).

7.6.3.3 Electro-Mechanical Equipment, Contracting

ASEA supplied the electrical and mechanical equipment under the following contracts:

Contract name and description		Contr. date
P1	Power station plant	26.06.81
P2	220 kV substation	09.07.81
P1A	Power station plant, unit 3	17.09.84
P2A	Substation plant, unit 3	17.09.84

The prices of some of the items under these contracts have been checked against international prices of similar equipment and also against the Swedish consumer price index and the relevant Swedish labour cost development (SNI 38, column 80).

The following FOB prices for equipment contracted in 1981 under contracts P1 and P2 and in 1984 under contracts P1A and P2A have been obtained from CECB. The prices are net without contract price adjustment (CPA) for increases in material and labour cost.

	Prices in SEK x 1000 FOB 1981	1984	Increase (%)
Generator incl. excitation	12,715	25,450	100
Turbine incl. governor	12,792	22,040	72
Spherical valve	4,260		
Generator transf.	3,349	7,088	112

It must be noted that the generator transformer for unit 3 ordered in 1984 is a three winding inter-bus transformer and as such more expensive, say 20%, than the generator transformers for units 1 and 2. Spherical valves for all three units were ordered under contract P1 in 1981.

The 1981 prices seem to be about 30-40 % higher than the prices that have been checked on similar equipment. As for the sharp price increase from 1981 to 1984 of identical equipment for unit 3, the Swedish consumer price index from 1981 to 1984 has gone up 28% and the labour cost index referred to in the ASEA contracts, 31%. One should note, however that the rate of exchange of USD to SEK was very high in 1984, about 8.5 in mid 1984 against 5.0 mid 1981, so that expressed in USD the price increase between units 1 and 2 in 1981 and unit 3 in 1984 is moderate.

7.6.4 Comments on Implementation

7.6.4.1 Civil Works

The image formed by reading the various reports from the SIDA Team of Experts and others, after having interviewed some of the participants of the supervising team, and by inspection of all accessible components of the power plant - is that the work has been performed professionally and expeditiously according to specifications.

What particularly has impressed the Mission is that the Contractor managed to overcome the logistics problem, and was able to set and meet earlier deadlines for completion.

7.6.4.2 Hydraulic Steel Works, Implementation

As mentioned under Section 7.5.4 the Contractor's site representative lacked the necessary authority to make decisions. This may account for the fact that certain components installed do not comply with the specifications, e.g. is the control for the spillway gates still subject to malfunctioning.

7.6.4.3 Electro-Mechanical Equipment, Implementation

From information gathered through interviews, reports and visits to the site the Mission's impression of the implementation of the electro-mechanical contracts, i.e. detailed design for construction, manufacture, transport, erection and commission, was carried out in a very professional manner and with highly skilled personnel. During erection ASEA was commended for their ability to cope with tight time schedules and adverse erection site conditions.

CHAPTER 8

PLANT OPERATION, POWER AND ENERGY PRODUCTION

8.1 TRAINING

The successful operation and maintenance of any power plant depends to a very large degree on a qualified staff and the management of this staff. In this respect staff *training* is a key word and a subject that is often underestimated and neglected in many developing countries.

For the Kotmale project a comprehensive training programme in Sweden was sponsored by SIDA, starting with the first batch in 1983 and going on till November 1988. About 35 engineers, superintendents and engineering assistants participated. From interviews at the plant the Mission got the impression that the training had been successful, relevant and necessary for the starting up of the plant. This impression is confirmed by the evaluation made by SwedPower (Ref.22), and also by Mr. S.Welihinda, Director, Training, CEB after his visit to Sweden in 1985.

In addition to the SIDA - sponsored training, several operators underwent practical training both, in Sweden and on site during erection on the actual equipment to be installed. This was, as is usual, part of the contracts for the electromechanical equipment.

Of the engineers who received training, 7 are presently working at Kotmale, 3 have left CECB, one died and the remaining are working in other parts of the utility.

The power station manager confirmed during the Mission's visit that regular refreshment courses for various categories of personnel was an established practice within CECB.

Another important type of training took part during the construction period when the civil contractor Skanska trained different types of machine operators. Although this type of training was not directly relevant for the operation and maintenance of the power plant, it nevertheless was necessary for the implementation of the construction works and also added an important side-effect to the country in that about 1300 truck drivers, bulldozer and shovel operators, excavator operators and others were trained and issued with an Operator's Licence. The training required a separate school, specially allocated vehicles and 5 full time expatriate instructors.

Skanska employed more than 700 of the trained operators during the construction period, and many of them were subsequently offered job opportunities abroad, especially in the Middle East, earning important foreign currency for Sri Lanka.

8.2 POWER PLANT OPERATION AND PERFORMANCE

The first generating unit was put into commercial operation in June 1985, but because of the unfortunate incident of the leakages of the pressure shaft and the subsequent closing down of the station, first for inspection and later for 18 months for repair work, only 90 GWh were generated in the first year of operation and 107 GWh in the second year. Normal production was resumed in 1988 when also units 2 and 3 were commissioned and put into commercial operation. Total production from all three units in 1988 was 434.8 GWh.

Since then the plant has been in normal operation, and the plant organization is established and seems to be functioning well. An organization chart of the present organization is presented in Figure 8.1. A total of 120 staff is employed, including 48 security guards. In addition to the CEB operation and maintenance staff comes the staff of the Water Management Secretariat under the Mahaweli Authority. This staff of 35 with its own security guards is responsible for the operation and maintenance of the dam including spillway gates and the reservoir. This split responsibility for the operation and maintenance of the power plant seems unnecessarily complicated and probably leads to some doubling up of personnel.

According to the power station manager few operational problems have been encountered during the year and a half when the plant has been in normal operation. The few problems have all been teething problems that have easily been dealt with. No excessive wear and tear have been registered

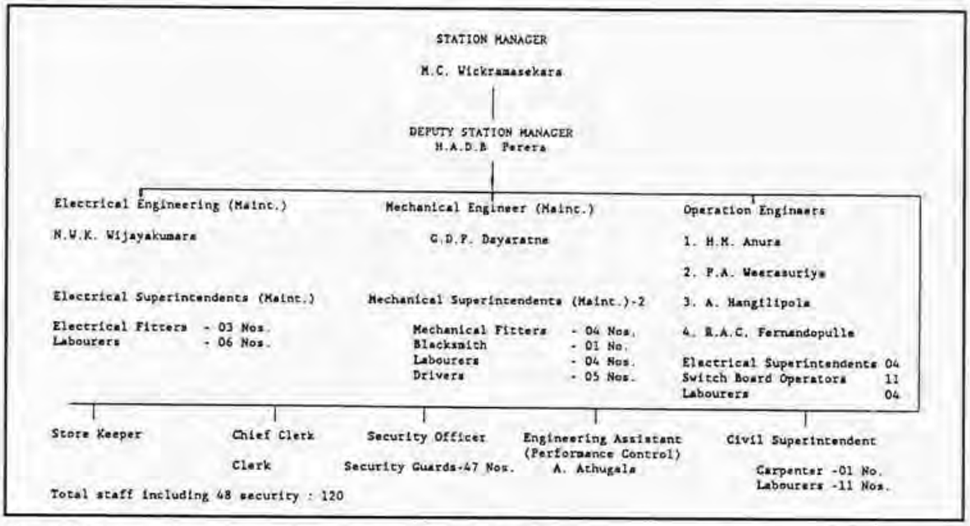


Fig 8.1 Power Plant Operation Organization Chart

on the turbines in the way of cavitation and sand abrasion; nor any clogging of cooling water system due to silting.

The power plant gave a very clean and tidy impression, and the Mission feels confident that the plant is operated by a competent organization with adequate support from its Head Office in Colombo. This support covers various types of specialist services like for instance regular relay control from the CEB Protection Branch and operational planning from the Load Dispatch Center.

The Mission registered some mild complaints about lack of an electric workshop, of storage capacity for large spare parts and other bulky equipment; it was also pointed out that the contracted equipment deliveries lacked some essential testing instruments which one would have expected would have been included in the specifications. An oil filter for transformer oil was also needed.

The Mission supports these requirements as they are all important for the future maintenance and the upkeep of a high maintenance standard. One would also have expected that office space for the power station administration to be part of the planning of a plant this size. As of now the administration is housed in temporary quarters used during by the consultant for the electro-mechanical works during construction.

About 1300 truck drivers, bulldozer and shovel operators, excavator operators and others have been trained and issued with an Operator's Licence. Many of these have later been offered jobs over-seas by Skanska, earning valuable foreign currency for Sri Lanka.
Photo: Mats Sundgren, SIDA Photo Archives

8.3 EXPECTED POWER AND ENERGY OUTPUT

Since the commissioning of the plant after the repairs in 1985-87, the power station has had only one year of full production- in 1988-when a total of 434.82 GWh was generated. In 1985, 89.80 GWH and in 1986, 107.16 GWh was generated.

The expected generated output of a hydro power plant is conventionally characterized by (1) the mean annual energy which is the expected average over a number of years, normally 30, to include most hydrological variations, (2) the firm energy which is that part of the mean annual energy that can be guaranteed with a certain probability, and (3) the secondary energy which is that part of the annual energy that cannot be guaranteed. The mean annual energy is thus the sum of the firm and secondary energy.

Various values for the expected energy output of the Kotmale plant have been used:

	Firm	Mean Annual	
Halcrow	310	455	
Acres	270	502	
CEB	240	440	(Constant diversion at Ukuwela)
CEB	276	440	(Without diversion at Ukuwela)

The Mission has not been able to establish reliable data related to water requirements for irrigation, energy production, and operating policies of the reservoirs. Without going into more detailed studies of the one of the calculated outputs being the more likely it is therefore suggested to use the figures recommended in the WMS/Acres June 1985 study, (see Executive Summary, Recommendations). The reason for this is (1) to use the same reference base as the ODA Victoria Evaluation and (2) that the values recommended are the result of a reasonably thorough treatment of the irrigation aspect.

Consequently the following generation values are used here and also in Chapter 11 for the economic evaluation of the project:

Annual firm energy	270	GWh
Annual secondary energy	232	GWh
Annual average energy	502	GWh
Installed Capacity	204	MW
Average annual plant factor	28.1	%

The average annual energy refers to an installed capacity of two generating units and will have to be adjusted somewhat upwards for lesser spill with three units as now installed. This is, however, beyond the scope for this evaluation. The installed generating capacity is taken as 3x68 MW which is the turbine rated power at 201.5 m net head.

It is also necessary for the economic evaluation to make some assumptions regarding the future possibility of despatching the secondary energy of Kotmale. Looking at the production figure for 1988 of 434.8 GWh this corresponds to 71% of Kotmale's secondary energy was being dispatched.At the same time only 5% of the total system secondary energy was dispatched. 71% may be somewhat more than what can be expected as an average the first few years, and in the economic assessment two alternative assumptions have been made:

1. From 1989 - 1994, 50% of the secondary energy is being dispatched, and from 1995 onwards, 80%
2. From 1989 - 1994, 30%, and from 1995, 80%. This is the same assumption as used in the Victoria evaluation.

8.4 POWER SYSTEM DEMAND

A question that is always raised when making long range generation planning is this: when is the right time to introduce new generating capacity into the system to meet the system demand at that time, and does that new generating capacity represent the least cost alternative? It has been documented in previous studies by the World Bank and others that CEB's forecasts over the last several years have erred on the high side by a considerable margin. This is clearly seen on Fig. 8.2 which shows previous demand forecasts versus actual development (source CEB). What not could reasonably have been foreseen was the decline in growth of demand resulting from the civil disturbances that started in 1983.

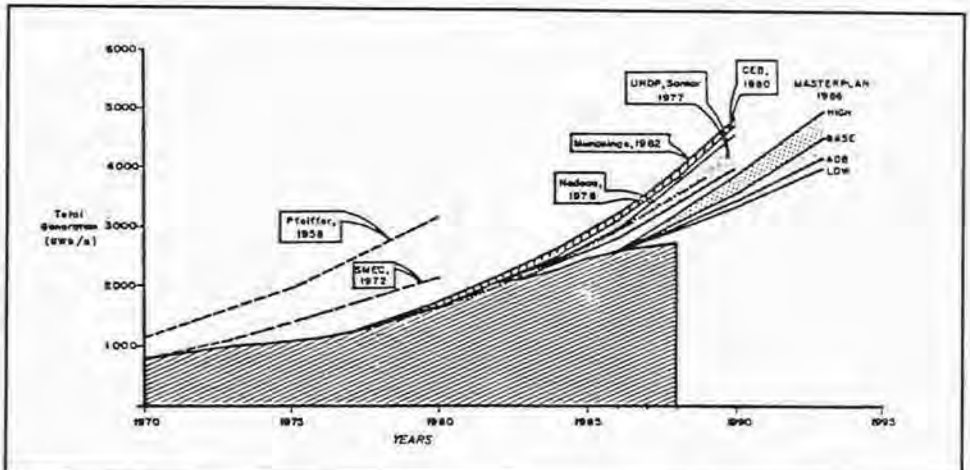


Fig. 8.2 Previous demand forecasts vs. actual development

The AMDP brought three large hydro power projects onto the power system from 1984 to 1986: Victoria in April 1984, Kotmale in June 1985 with the first unit and Randenigala in September 1986. This added 1020 GWh of firm energy to the system, increasing the hydro power firm capacity by 67%. With those three plants the hydro power system had the following composition :

	Firm Annual Energy (GWh)	Average Annual Energy (GWh)
Kotmale	270	502
Victoria	446	886
Randenigala	303	494
Ukuwela	164	164
Bowatenne	49	64
Canyon	143	178
New Laxapana	436	515
Polpitiya	389	466
Wimalasurendra	84	120
Old Laxapane	252	293
Total System	2,536	3,682

In 1987 when all these plants should have been in full operation there was an additional thermal capacity of 270 MW available, consisting of a mixture of diesel, gas and oil fired steam units, some of which were near retirement (Kelanitissa oil fired 50 MW). The gross generation in 1987, with Kotmale out for repairs, was 2,707 GWh of which as much as 530 GWh was thermal. In addition there were power cuts amounting to about 40 GWh due to lack of thermal generating capacity (malfunctioning of diesel sets) and an exceptionally dry year.

With Kotmale functioning one could have expected to generate at least 270 GWh more hydro power and avoided the power cuts and saved costly gas generation. CEB have calculated the extra costs of not having Kotmale in operation in 1987 to be LKR 1,300 million, estimating the cost of power cuts to 15 LKR/kWh and extra gas generation LKR 700 mill.

In 1988 the gross generation was 2,799 GWh of which 2,597 GWh from hydro power. This is only 61 GWh more than the system firm energy. Kotmale generated the same year 435 GWh which corresponds to a utilization of 71% of its secondary energy in addition to its firm energy.

There does not seem to be any doubt that the timing of Kotmale was more or less correct. In hindsight and in view of the effects of the civil disturbances maybe one year too early. This is evident from what was experienced in 1987 when Kotmale was out for repairs, and even in 1988, when Kotmale generated 87% of the mean annual production, one had to resort to 200 GWh of costly thermal generation.

Without the civil disturbances, the system demand in 1986-87 might have been 200-300 GWh higher than the actual figures with even more demand for Kotmale and the other power plants under the AMDP.

8.5 KOTMALE AND RURAL ELECTRIFICATION

How has the energy from Kotmale and the other power plants in the AMDP been dispatched? Who has benefitted from the added system capacity?

When additional capacity is added to a power system it is normally not earmarked for any special consumer or consumer group. The added capacity satisfies a demand that is there and without political control it goes to those consumer groups that are willing to pay according to the existing tariffs, and who are connected to or can easily be connected to the power system.

Fig. 8.3 shows the development of the CEB sales to the different consumer categories from 1968 to 1988 together with the development of the system losses. Since 1978 there has been an even growth of sales to the domestic consumer group which in 1988 catered for 16.5% of the total sales. Losses within CEB's system are 17%, but the actual total losses are about 20% if losses within Local Authorities' systems are included. Efforts are being done to reduce system losses, and the aim is to reduce the present value of 29% to 9-10% by the year 2000.

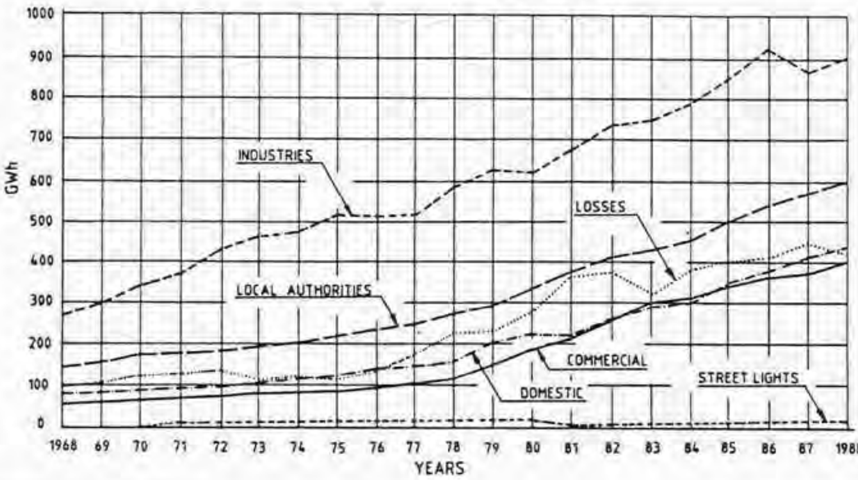


Fig. 8.3 CEB sales by consumers

How has the rural population benefitted from the added capacity to the system? Fig. 8.4, taken from CEB's Statistical Digest for 1988, gives the following figures for completed rural electrification schemes from 1977 to 1988:

Year	No. of Schemes	Total at end of of the year
1977	140	943
1978	262	1,205
1979	551	1,756
1980	359	2,115
1981	377	2,492
1982	540	3,032
1983	457	3,489
1984	635	4,124
1985	894	5,018
1986	1,103	6,121
1987	1,077	7,198
1988	882	8,080

There has been a sharp increase in completed schemes the four last years since 1985 when 3956 schemes were completed against 2009 the four previous years. From 1984 to 1988 the percentage of households electrified increased from 16 % to 25 %. The rural electrification schemes have mostly resulted in domestic consumers with low load -50-60 kWh per month - being connected. Rural industry has to very little extent been encouraged by the electrification, contrary to what was anticipated by the planners.

Of the total number of domestic consumers about 63% fall within the group consuming up to 60 kWh/month which can be classified as rural, although of course some of them will live in urban areas. This group of 63% consumed only 25% of the total domestic consumption of 392 GWh in 1988. This corresponds to a net consumption of 100 GWh. Adding 15% for losses one may say that the rural electric consumption in 1988 represented almost half of Kotmale's firm power.

There has undoubtedly been a strong political willingness in Sri Lanka to improve the living conditions for the rural population, this also includes rural electrification. But it would be wrong to look at the power projects of the AMDP as rural electrification projects. They are too large for that; apart from being vital to the country's electric power supply, which also includes rural supply, they are also key elements in the Mahaweli irrigation scheme.

What one may say is that parallel to the construction of the power plants of the AMDP there has been a sharp increase in completed rural electrification schemes that have benefitted from the new electric power being available through the CEB power system.

CHAPTER 9

HYDROLOGY AND SEDIMENTATION

9.1 HYDROLOGY

9.1.1 General

The Consultants' hydrologic basis is the historical monthly flow series available over 26 years (1950-75) for Morape gauging station, located approximately 2 km upstream of the damsite.

Also available was a monthly flow series over 27 years (1945-1971) for the Polgolla site, and rainfall data from 19 stations located in the Kotmale drainage area, covering 66 years (1907-1972) — the minimum length of record for any one station being 35 years and the maximum 65 years.

This basic material is compiled in the WAPCOS' feasibility study of 1973-76.

9.1.2 Design Flow

The average flow at the Morape gauging station was found to be Q_{mean} = 32 m^3/s, while the Kotmale power installation is designed for 3 x 35 m^3/s, or Q_{design} = 105 m^3/s.

9.1.3 Floods

Based on rainfall data from the most severe storms on record (900 mm over 48 hrs) and the unit graph method, a design flood of approximately 5,600 m^3/s has been calculated, assumed as the 10,000 years flood. The maximum capacity of the spillway was chosen at 5,550 m^3/s.

9.1.4 Comments on Hydrologic Data

The credibility of hydrologic data may be quite variable. No reference has been found regarding this gauging station — whether calibrations took place and how frequent the calibrations may have been — whether daily staff reading was used, or an automatic limnigraph installed, etc. Rainfall data are very much depending on how conscientious the attendants may be, and can also be of a mixed quality.

Aside from this lack of knowledge on the credibility of data, the Mission has noted the following:

- Using monthly averages of discharges in production calculations may tend to give lesser spills and higher productions than a more accurate calculation based on daily averages.
- A simple flow-duration curve is a very useful tool for evaluating the size of the installation. No such curve has been found among the received documents.
- The ODA Evaluation Report on the Victoria Project, located downstream, addresses the issue of hydrology in depth, and concludes with implying that "a more thorough analysis would probably have lead to a reduction in the streamflows at Victoria by about 10 per cent". However, it remains to be seen whether this statement is true, and even if it should be, that doesn't mean it would be valid also for Kotmale, whose drainage area is only a fraction of Victoria's and whose hydrology should be much simpler to evaluate.
- In their Report on Environmental Impact (1988), SWECO notes that rainfall records from the area seem to indicate increasing percentage of runoff from a given rainfall, interpreted as a trend of degrading vegetation in the catchment, serving to impair infiltration. If this is a correct interpretation, it could mean further increases in water losses by spilling from the reservoir.

9.2 SEDIMENTATION

The most recent guideline for quantifying the rate of erosion in the catchment is found in SWECO's Report on Environmental Impact (1988), with reference to two studies from 1979 and 1980 from measurement of suspended sediment yield in the Mahaweli Ganga.

Sedimentation is not going to be a major problem for Kotmale. No abrasive effect on the turbines has been registered, nor any silting in the cooling water pipes. During the boat trip on the partly filled reservoir, no signs of erosion or earthslides that could cause any concern were observed. Photo: Skanska, Björn Enström

Measured in litre/km^2/year, and allowing for additional bedload yield, the erosion rates were calculated at 0.33 and 0.19 respectively, which is very low.

The Mission's own impression after having visited the area and having interviewed personnel in attendance at the dam and in the powerhouse, is that sedimentation is not going to become an important issue for Kotmale: No abrasive effect on the turbines has been registered, nor any silting in the cooling water pipes. Also, a boat trip on the partly filled reservoir (Water level El. 681) did not disclose signs of erosion or earth slides to any extent that should cause concern.

CHAPTER 10
PROSPECTS FOR THE FUTURE

10.1 AVAILABILITY OF STAFF

The electrical and mechanical equipment at the Kotmale power plant will go on functioning for another 30 - 40 years if well looked after and properly maintained. The civil works like dam, tunnels, power station, cavern etc. will have an — for all practical purposes — almost unlimited life span.

To achieve this long life with high availability and unreduced equipment efficiency it is necessary to have a an operation and maintenance staff well trained and with a high sense of responsibility for the upkeep of the high inherent standard of the plant.

The CEB is a fairly large and seemingly well organized utility with a large group of hydro power plants which gives the utility a good opportunity of job rotation and systematic training of engineers, operators and maintenance crews. Refreshment courses are already an established practice with CEB although the Mission did not have the opportunity to study this more in detail.

The present staff at Kotmale seems well qualified and the impression the Mission got during the visit to the site was one of neatness and competence. There should be no reason for CEB not being able also in the future to recruit qualified staff to Kotmale provided they are given a competitive salary and decent housing and adequate schooling for their children.

10.2 QUALITY OF PLANT

As has been mentioned previously under Chapter 7, both the civil works carried out and the electrical and mechanical equipment installed are of a high standard and good quality and supplied by well reputed manufacturers.

The present staff at Kotmale seems well qualified and the impression the Mission obtained during the visit to the site was one of neatness and competence. The photo shows the control building at the switchyard. Photo: Skanska, Björn Enström

The power plant should be able function well the years to come without significant problems, provided it receives proper maintenance and operation. Availability of spare parts from the manufactures should also be ensured, although one may expect some problems in the future, as the manufacturers stop making this and that type of equipment and they gradually run out of spares. But that is a common problem all utilities with long lasting equipment has to face sooner or later.

Both the civil works and the electrical and mechanical equiptment are of a high standard and supplied by manufacturers with a good reputation. The electrical and mechanical equiptment will go on functioning for 30-40 years if well looked after and well properly maintained. The dam, tunnels, power station cavern etc will have — for all practical purposes — an almost unlimited life span.
Photo: Heldur Netocny, SIDA Photo Archives

10.3 MAINTENANCE MANAGEMENT

While electric power generation of power utilities in developing countries are generally well conceived, engineered and implemented, it is noted that not all utilities provide the same attention to the maintenance of the same facilities once constructed. This was clearly manifested in a study financed by the Asian Development Bank in 1988, Regional Study for Improving Power Plant Maintenance Management, in which the team leader of this Mission also was team leader.

Kotmale has already got a system for planned maintenance based on a well proven manual system that has been in use for many years by the Swedish Vattenfall. The plan is now to have this system computerized at Kotmale, an effort that is meant to be done by Kotmale's own staff. This system — be it manual or computerized -should be a sound base for future maintenance as long as it is being used and adhered to. In many utilities in developing countries maintenance suffers from lack of spare parts, the purchase of which are often hampered and delayed because of scarceness of foreign currency and bureaucracy in the ordering process. The Mission discussed this point at length with CEB and concluded that this does not seem to cause any problem, at least not at the present time.

As previously mentioned the Mission received some complaints about limited storage facilities for large size spare parts and other equipment and also about lack of instruments and equipment required for maintenance. This should be looked into and if found justified, remedied.

As a conclusion the Mission does not see any reason why Kotmale with the present organization should not be able to maintain its present standard provided the local staff continues to be of a high professional quality and that a "maintenance oriented culture" is encouraged by the CEB central management.

10.4 CONFLICTS BETWEEN POWER PRODUCTION AND IRRIGATION

The major uses for water in the Mahaweli Development are for irrigation and for hydropower generation. Normally these uses are not in conflict with each other, but conflicts will arise and have arisen in Kotmale when at low reservoir level there is a need to divert more water through the Polgolla tunnel for irrigation than available in the unregulated upper part of the Mahaweli Ganga. Under such circumstances irrigation water is released through the dam bottom outlet without being used for power generation. This year in March, April and May 66.8 mill. m^3 have been released corresponding to a loss of generation of about 34 GWh at a value of round LKR 60 mill. There was no such release in 1988.

This diversion will of course also influence the power production of the lower plants in the Mahaweli Ganga. The balance between power production and irrigation is not only a question of economy, but has also a socioeconomic aspect almost impossible to quantify. The Mission can only state as a fact that irrigation has a negative effect on Kotmale as a power producer but there is not yet enough statistical material available to establish how this will affect the firm and/or average annual production in the future.

CHAPTER 11
ECONOMIC AND FINANCIAL EVALUATION

11.1 PRINCIPLES

On basis of information made available to the Mission, an ex post economic evaluation of the Kotmale Hydropower Project has been undertaken, comprising inter alia unit cost of production and internal rate of return calculations. An appraisal in broad socio- economic terms has been attempted at, including direct as well as secondary benefits and costs. Sensitivity analysis techniques have been resorted to in some cases of deficient information on secondary effects.

11.1.1 Calculation Period

The calculation period for the Kotmale Project is set to 50 years departing from the start of the construction works. It thus comprises the period 1979-2029. Economic life time for electro-mechanical equipment is normally 20-50 years. Dam, tunnels, powerhouse and related works may normally be considered to have a useful life well beyond the repayment period of 50 years. In the present study the electro-mechanical equipment is assumed to have a life span of 30 years counted from the installation of the first unit in 1985. Any residual values at the end of the 50 years period have been omitted from the calculations, their discounted value being insignificant.

The economic life times used for different types of work and equipment are given in Table 11.1.

11.1.2 Discount Rate and Base Year

The discount rates proposed for the study will be in real terms, excluding the inflation rate. Consequently all economic figures, costs and benefits, for the past and the future will have to be recalculated into base year prices. The base year selected for the analysis is 1988, the first year with normal production.

The discount rate should in principle reflect the opportunity cost of capital for public sector lending relevant for Sri Lanka. The World Bank usually recommends a minimum discount rate of 10% for evaluation of Bank financed projects. Sensitivity analysis will be performed on three alternatives, 6%, 8% and 10%.

11.1.3 Price Indices

Expenditures for each year are referred to a common base year, 1988. A Water and Power Construction Index from the Bureau of Reclamation, Denver, USA is selected to represent the foreign cost component. For the local component is used the cost index for construction activities from the Ministry of Local Government, Sri Lanka.

11.1.4 Conversion Rates

Expenditures in foreign currency, mainly SEK, have been converted to LKR by means of the relevant year's exchange rates. The constant rate of SEK/LKR 0.3 used i a by Skanska for recalculation of SEK into LKR during the Kotmale Project's construction period, is regarded irrelevant when it comes to input in economic analysis. The LKR has in fact been less expensive than SEK 0.3 over the greater period of the Kotmale Project's construction period. Thus figures in this analysis will differ to some extent from records where the 0.3 rate has been used.

11.2 PROJECT COSTS

11.2.1 Capital Costs

The total project costs of Kotmale over the period 1979- 89 amounted to 10,173 million in current LKR. Cost figures are based on information from the Mahaweli Authority, Ceylon Electricity Board (CEB) the consultants and the contractors.

The costs can be distributed on the following components:

Table 11.1
Kotmale Capital Costs,
LKR in millions

Components Foreign	Foreign Comp	Local Comp	% Comp
Electro- Mechanical Equipment and Hydraulic Steelworks (Economic life time 30 years):			
Unit 1 + 2 (P1)	364	33	92
Switchyard unit 1+2 (P2)	197	20	91
Unit 3 (P1A)	291	25	92
Switchyard unit 3 (P2A)	131	4	97
Steel lining (E1)	64	6	91
Gates and Screens (E2)	123	9	93
Spillway Equipment (E3)	204	7	97
Bottom Outlet (E4)	58	2	97
Civil Works (Economic life time 50 years):			
Initial Works (IWC)	779	269	74
Underground Works (UWC)	1,512	339	82
Repair Works	562	185	75
Reservoir Works (RWC)	3,018	517	85
Foreign Consultancy	227	74	75
Local Consultancy		308	0
Roads		286	0
Resettlement		436	0
Miscellaneous		123	0
Subtotal	7,530	2,643	74
TOTAL, current LKR in mill.		10,173	

The foreign exchange component is on the average 74%, ranging from over 90% on electro-mechanical works to 0 on road building and resettlement costs.

Among the cost components listed in Table 11.1 are, for the purpose of a broader cost/ benefit analysis, included the following project or project related items not comprised by the Swedish grant and soft loan financing:

- Local costs for the civil works and for the electro- mechanical works.
- Fees for the two British consulting companies.
- The third generating unit (P1A and P2A).
- The 1986 to 1987 repairs in the high pressure system (repair costs).
- Evacuation and resettlement of the affected population in the reservoir area, including compensation paid.

Table 11.2
Annual Capital Costs, LKR mill.

	Foreign Comp	Local Comp	Total
1979	219	80	299
1980	611	306	917
1981	1,128	361	1,488
1982	730	224	955
1983	1,612	384	1,996
1984	1,410	432	1,842
1985	526	238	764
1986	300	198	498
1987	358	176	534
1988	402	343	745
1989	234	-100	134
SUM	7,530	2,643	10,173

The figures for annual capital expenditure indicate a top of the activities in 1983- 84. The negative figure for 1989 is caused by some adjustments of previous expenditures.

11.2.2 Financing Costs

At the outset the Kotmale project was subject to considerable project financing costs, because the Swedish import support funds were disbursed only once a year, and special bridging finance arrangements had to be organized. The Government of Sri Lanka secured bridging finance from the Swedish commercial bank Skandinaviska Enskilda Banken. The interest costs borne by the Sri Lankan Government amounted to current SEK 262 mill. during the construction period 1979-89, of which SEK 137 mill. belonged to the bridging finance facilities (see Chapter 5).

Financing costs like payment of interest contribute to redistribution of a project's benefits. In the case of Kotmale the share of the benefits remaining in Sri Lanka was thereby reduced.

However the internal rate of return or the cost benefit ratio of a project as such should not be affected by the eventual distribution of the benefits. Payment of interest is therefore netted out from the costs of the project before calculating its internal rate of return.

For calculation of production costs per kWh output, capital costs should be charged with interest during the construction period. The relevant interest rate here should reflect the opportunity cost of capital for public sector lending.

Thus, normally the actual interest and other charges on funds used to finance the project are not taken into account in the economic evaluation. For the Kotmale analysis the same discount rates (alternatives) will be used to assert the costs of hydropower production as in the thermal power alternative.

As will be seen from Chapter 5 the interest payments by the Central Bank of Sri Lanka cover loans which form only parts of the foreign exchange component of Kotmale, while the local costs have not been charged at all. However all capital costs should be charged in an economic analysis.

The discount rate will in this study be fixed at 6%, with sensitivity calculations alternatively on basis of 8% and 10% (see Section 11.1.2).

11.2.3 Maintenance and Operation Costs

Future maintenance and operation costs for the plant will have their foreign component, mainly consisting of imports of spare parts. Expenditures on spare parts are, however, at present small, supplies being drawn from stocks built up by the contractors. Thus there may be some discrepancy between typical maintenance expenditures the first years and later in a power plant's life. Nevertheless, all use of spare parts should be calculated at its proper costs, stocks will eventually have to be replenished. On the other hand initial difficulties may cause operation costs to be somewhat higher at the outset than later on.

In this study standard methods are used to estimate maintenance and operation costs for the Kotmale over the life span of the plant, the foreign component being a fixed part of the costs.

The annual maintenance and operation costs over the lifetime of the Kotmale project are estimated to constitute 1% of total capital costs in fixed 1988 prices. The foreign component is set to 20% of these costs, that is to say 0.20% of total capital costs.

11.2.4 Resettlement and Environmental Costs

Impoundment of the reservoir resulted in the evacuation and resettlement of some 3,000 families living in the reservoir area and 900 families in areas affected by landslides. The costs of evacuation and resettlement amounted to current LKR 436 mill. as they appear in the information from the Mahaweli Authority. To what extent payments and other arrangements for the benefit of the evacuees have compensated them for their real losses is discussed in Chapter 13. Implications for the economic return of the Kotmale Project are discussed in Section 11.4.6.3.

11.3 PROJECT BENEFITS

11.3.1 Hydropower Output

The direct benefits of the hydropower plant consist of firm and secondary energy, evaluated at relevant prices over the lifespan of the project.

Installed capacity at Kotmale is 3 x 68 MW, including the third unit which was commissioned in 1988. The dam crest level is for the time being at 706.5 m above sea level, which will be the basis for the evaluation. Provisions have, however, been made to raise the height of the dam up to what is regarded as the economic level 735 m.

The analysis is conducted on the assumptions that the average annual output from Kotmale will consist of 270 GWh firm power and 232 GWh secondary power over the productive part of the calculation period (see Chapter 8, Section 8.3).

Production at Kotmale started in 1985, when the actual output was 90 GWh. In 1986, the year when the plant was closed down for repair works, the production was 107 GWh. The plant did not resume operation until late December 1987. The production in 1988 was 435 GWh.

The analysis is based on normal output from Kotmale after 1988. For the years 1989 to 1994 it is assumed that 50% of the secondary power can be sold, with the percentage increasing to 80% from 1995 onwards.

Table 11.3
Kotmale Annual Energy Sales, GWh.

	Firm	Secondary	Sum
1985	90	0	90
1986	107	0	107
1988	270	165	435
1989-94	270	116	386
1995-	270	186	456
Average 44 years	262	167	429

The average figures for annual energy sales comprise the 44-year production period from 1985 to 2029, the end of the calculation period, excluding the year when the plant was closed down.

11.3.2 Secondary Benefits

According to the TOR, the Mission should also identify, to the extent possible, secondary benefits of the project, such as:

- Irrigation benefits.
- Local employment and local incomes created during the construction period.
- Employment opportunities in Sri Lanka and overseas resulting from training provided by the contractors (the civil contractor in particular) and subsequent work experience in the project.
- Government revenues obtained from income taxes paid by expatriate contractor staff.

- Present and future utilization of the housing, office and ancillary facilities established at the project site.
- The cost of the switchyard installations and related facilities attributable to the handling of power from the Victoria Project.
- The existence of a high- quality, all weather road from the outskirts of Gampola to the dam site.

11.4 ECONOMIC EVALUATION

11.4.1 Hydropower Unit Cost of Output

The Kotmale Project will first be evaluated solely as a hydropower scheme, on basis of direct, calculated costs and without any consideration of secondary benefits. In this way a reference point will be created from which to measure the influence of secondary benefits etc.

Annual repayments of capital invested in the Kotmale Power Plant is calculated on basis of fixed 1988 price level for capital costs, life span for electro- mechanical equipment and their installation costs of 30 years, and for the dam and tunnel works of 50 years. Alternatives for discount rates are chosen in accordance with the calculations for thermal power.

Interest have been calculated of the invested capital during the construction period. The investment period lasted from 1979 to 1989. The plant started production in 1985, but with a disruption in 1987 due to the close down for reparations.

Thus both under production and standstill, capital was added to the project.

Unit costs of production at Kotmale has thus been calculated as the sum of:

- Repayment of Costs of Electro- Mechanical Equipment and Hydraulic Steelworks.
- Repayment of Civil Works.
- Repayment of Interest calculated for the Construction Period.
- Operation and Maintenance Costs.

All these costs together with the electricity output will vary over the production period of Kotmale. Average figures of LKR per kWh can therefore be calculated for the years over the production period. Figures in Table 11.4 refer to the years from 1995 onwards, namely 270 GWh output of firm power and 186 GWh sales of secondary power, 456 GWh total.

Table 11.4
Unit Costs of Production at Kotmale, LKR/kWh

	Discount	Rates	
	6%	8%	10%
Production from 1995 onwards	2.33	3.09	3.97

11.4.2 Comparison of Hydro- with Thermal Production Costs

Hydropower output from Kotmale will in the internal rate of return calculations for this analysis be compared with what it would have cost to generate power from alternative sources relevant to Sri Lanka. The application of thermal power costs may be defended by a reasoning that in the long run availability of hydropower will be limited, and thermal generation thus appear to be required (see also Section 11.4.4).

For a comparison between hydro and thermal power costs per kWh it must be taken into account that output from a hydro plant consists of firm and secondary power, while the output from a thermal plant is all firm power, which means that there is not the kind of uncertainty in delivery caused by hydrological variations as experienced with a hydropower plant.

For firm power from a hydro plant, thermal energy at its full production cost will be the alternative, while secondary energy merely substitutes for thermal plants which are switched off when the secondary energy is available. Secondary energy will consequently be valued lower than firm, namely at its variable costs consisting mainly of fuel expenditures.

Thermal systems equivalent to hydro plants have been investigated by ODA in the Victoria Study. For the purpose of the Kotmale evaluation the ODA cost figures have been revised in order to accommodate them to Kotmale's firm energy plant factor of 15%. They have also been escalated by 6% to compensate for price increase in the period from the Victoria study up to 1988, according to the price indices in Section 11.1.3.

Thermal cost per kWh has been calculated for three different future oil price scenarios. The low alternative predicting a price of USD 16 per barrel, the middle 26.5, and the high outlooks forecasting USD 42.5 per barrel in year 2000.

The alternative discount rates used in calculation of thermal construction costs are 6%, 8% and 10%.

Table 11.5
Thermal Generation Costs for
Evaluation of Hydropower, LKR/kWh Hydro Energy

Oil Price Scenarios:	Low		Middle		High	
Discount Rates	Full	Variable	Full	Variable	Full	Variable*)
6%	2.32	0.83	2.70	0.88	3.47	0.84
8%	2.54	0.85	2.87	0.92	3.74	0.89
10%	2.77	0.87	3.07	0.94	4.01	0.95

*) Full thermal costs with all cost elements included. Variable costs of thermal production, which mainly, but not only comprise fuel costs.

In order to permit comparison of hydro firm energy costs per kWh with the alternative thermal generation, the value of the secondary energy has been deducted from the hydro production costs. Secondary energy is valued at the variable costs fetched from Table 11.5.

In these calculations LKR/ kWh from Table 11.4 first have been multiplied with annual energy production at Kotmale, 456 GWh. From this is deducted the secondary power of 186 GWh multiplied with Variable costs (of thermal production) from Table 11.5. The result has been divided with 270 GWh to arrive at Kotmale's production cost per kWh firm power in Table 11.6.

Table 11.6
Kotmale Firm Power Production Costs, LKR/ kWh
Oil Price Scenarios:

	Low	Middle	High
6%	3.36	3.33	3.36
8%	4.63	4.58	4.61
10%	6.10	6.06	6.05

The full thermal costs of thermal power production from Table 11.5 can now be compared with the costs of firm power generation at Kotmale in Table 11.6 The different oil price scenarios do not influence the hydropower costs very much, only through deduction of the value of the secondary power.

The oil price, however, has a significant impact on the profitability of thermal power production. Hydropower production at Kotmale thus becomes less expensive than the thermal alternative at the high oil price scenario combined with the lowest, 6%, discount rate. Thermal is the cheapest in all other cases. As can be seen from Tables 11.5 and 11.6 demand for a higher rate of return, reflected in the discount rate, affects hydropower costs much more than thermal.

11.4.3 Internal Rate of Return

The internal rate of return of a project is the interest rate which makes the present values of benefits over the life span of the project equal to the project's discounted costs.

At this stage of the analysis the benefits from Kotmale will comprise only energy benefits. Additional benefits will be treated later. Firm hydro energy output has been evaluated at full thermal energy production costs, and secondary energy at thermal variable costs (see Table 11.5).

The costs comprise annual maintenance and operation expenditures and the investment costs for the Kotmale Project. Additionally all the electro-mechanical works in connection with the plant are supposed to be renewed after 30 years and their costs have duly been recorded anew at year 2015.

The internal rate of return has been calculated for the three price scenarios for oil price development, and three sets of discount rates. Contrary to Section 11.4.2, the discount rates here only affect the price of thermal power which is used to evaluate the hydropower output from Kotmale. The Kotmale Project's discount rate will in this case be the outcome of the analysis, the internal rate of return. Here the Kotmale project costs therefore are calculated net of all other interest payments.

Table 11.7

Internal Rate of Return of the Kotmale Project (per cent).

Discount	Oil Price Scenarios		
rates	Low	Medium	High
6%	3.5	4.4	5.8
8%	4.0	4.8	6.3
10%	4.5	5.2	6.8

As expected internal rate of return for the hydropower plant increases with prospects of higher oil prices, which will influence the rate through evaluation of the energy output.

Higher discount rates here imply that the demand for economic return from capital invested in the thermal plant increases. This also makes hydropower projects more lucrative. However, the return from Kotmale in all alternatives remains lower than the return claimed from the alternative thermal scheme.

The high oil price outlook combined with a discount rate of at least 8% is needed to make Kotmale's internal rate of return increase beyond 6%, which nevertheless was chosen as the minimum alternative of return from the thermal plant. In any case it fails to reach the World Bank standard of 10%.

The internal rate of return of Kotmale should be compared with the actual real rates of return, less inflation rates, in Sri Lankan industry.

11.4.4 Alternative Methods to Evaluate Energy Output

The Sri Lankan electricity tariffs may be rejected as measure of benefits for hydropower plants on grounds that they are too low to reflect the actual willingness to pay.

Average CEB sales price of electricity was in 1988 LKR 2 per kWh. This is price at distribution level from which must be subtracted distribution costs to arrive at figures comparable with the costs per kWh discussed above. The average price fell in real terms by roughly 30% from 1982 to 1986. From 1986 to 1988 the price has been about constant (figure 11.1).

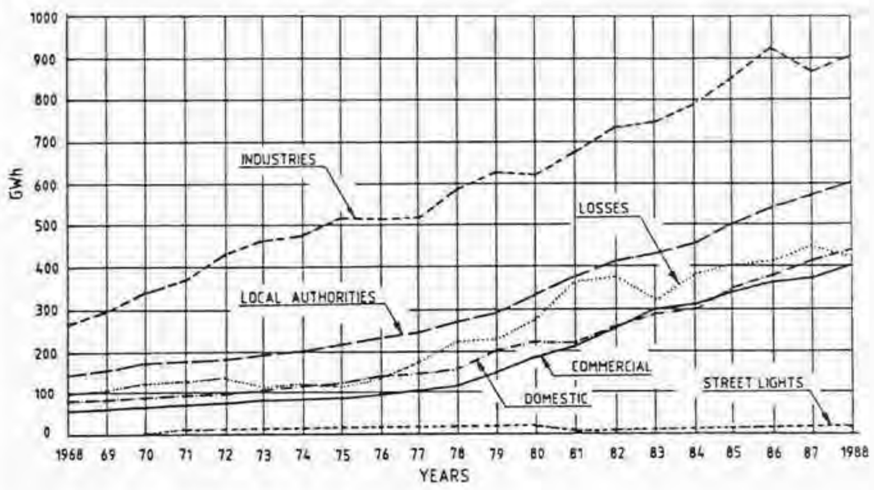


Fig 11.1: Development in Average CEB Sales Price LKR/kWh

However, it has not been ascertained to which extent Sri Lankan consumers are willing to pay average tariffs corresponding to for instance costs of thermal power production (plus distribution costs). Probably the market clearing price would manifest somewhere in between.

The Long Run Marginal Cost has been calculated by the CEB to LKR 1.70 at energy generation, and LKR 2.98 at distribution level. According to economic theory capacity of production should not be further expanded unless the consumers are willing to pay LRMC. However, for development reasons the Sri Lankan government may wish to subsidize consumers through electricity prices, thus passing on to them greater shares of the benefits from grants obtained abroad.

The willingness-to-pay concept will in this case not be a relevant measure of benefit, as electricity would be produced by one means or another. What really matters is whether the chosen project is cost effective. Thus it might be relevant to compare hydro electricity with the costs of the next resort when hydropower possibilities are exhausted, which will be thermal power.

For the Victoria hydropower project it was stated in the ODA evaluation that the energy output would have to be evaluated at a price 40% over the actual 1985 tariff to give the project a 10% rate of return (on the power component). The CEB average tariff in real terms was 8% lower in 1988 than in 1985.

11.4.5 Secondary Benefits

Secondary benefits from the Kotmale Hydropower Project may be evaluated by assuming that some of them might have been undertaken as separate schemes, without being connected to or motivated by the hydropower plant. In that case they would have had to defend their own costs.

According to World Bank recommendations, each component of a multipurpose project must be able to support its specific (separable) costs and in addition, the total of the remaining benefits of the components must equal or exceed the remaining (common) costs of the project.

Secondary benefits of the Kotmale project, if they fulfil these requirements could thus have their specific costs netted out of the project.

11.4.5.1 Irrigation

The most important of the secondary benefits are the enlarged irrigation facilities derived from construction of the Kotmale reservoir. Such benefits will manifest also when the water is used for power production, by evening out the water flow over the drier parts of the year.

Ex post studies of the irrigation benefits from the Kotmale project have not yet been completed. It has, however, been stated that the present irrigation benefits from the reservoir are "of a limited nature arising only from the improved regulation of river flows picked up at the Polgolla diversion barrage on the Mahaweli Ganga downstream. However after raising the dam, regulated additional supplies would be available to form up and extend irrigation to about 20 000 ha in Ambanganga valley and adjoining areas." (Mahaweli Projects and Programme 1988, Ministry of Mahaweli Development).

The declining oil prices in the early 1980's were accompanied by falling rice prices. The price of rice, which was USD 386 per metric ton in 1978, stood at USD 210 in 1986. Additionally, development costs for agricultural land increased severely during the period. Thus it was found in the ODA evaluation that irrigation benefits from the Victoria Project were negative at discount rates above 6%.

Few if any of the costs of the Kotmale Project are directly attributable solely to irrigation purposes, that is to say, they can not as such be separated from the

The flood-marks in Gampoa 1913 – 1978. Gampoa is situated downstream of the Kotmale Dam. One important secondary benefit is the levelling out of the waterflow to prevent floods and to distribute water during the dry season.
Photo: Lars Sundegren, SIDA Photo Archives

hydropower costs. However, a normal practice with multipurpose projects is to allocate the shared cost elements of the project by the ratio of discounted power to irrigation benefits over the lifetime of the project. The shared cost elements would in this connection comprise the following items from Table 11.1: initial and reservoir works, spillway equipment, bottom outlet, roads, resettlement, probably only local consultancy, and miscellaneous.

Although estimates of irrigation benefits are still lacking, an analysis based on the sensitivity approach can be performed, so as to trace the impact on economic return from the Kotmale Hydropower Project of different assumptions about the benefit share between hydropower and irrigation. Cost shares, hydro to irrigation of 90- 10%, 70- 30% etc of common elements will be proposed with the earlier 100- 0% as reference.

In this connection it should be borne in mind that the annual operation and maintenance costs of Kotmale will decrease proportionally with the capital cost reductions since we have assumed that these costs constitute 1% of project costs.

Table 11.8
Evaluation of Irrigation Benefits.
Impacts on the Kotmale Project's Internal Rate of Return (%).

Oil Price	Discount	Cost Shares Attributed to Hydro			
Prospects	Rates	100%	90%	70%	45%
Low	6%	3.5	3.9	4.8	6.2
Medium	8%	4.8	5.2	6.1	7.7
High	10%	6.8	7.3	8.4	10.1

By successively retaining less shares of the costs common to irrigation and hydropower production within the Kotmale Hydropower Project, its internal rate of return surely will increase. Still, however it is difficult to obtain a rate on level with what has been demanded of discount rates for the thermal plant. To achieve this, it is necessary to ascribe about 55% of the costs of the shared components to irrigation (45% to hydro). On the other hand this will probably render the irrigation schemes uneconomical.

The World Bank standard of 10% return is met if in addition the high oil price prospects might be expected.

The consequences of sharing Kotmale's capital costs, as an upstream reservoir, with downstream projects, might be analyzed by means of a similar approach. It may be argued that only 45% of Kotmale's Initial Works and Reservoir Works costs should be charged to the project. The rest should be attributed to Victoria and Randenigala as they benefit from the Kotmale reservoir.

The cost share of 45% applied here is assumed equal to Kotmale's share of the sum of gross heads for the three projects, Kotmale 211 m, Victoria 184 m and Randenigala 70 m.

11.4.5.2 Other Secondary Benefits

Training and Employment

A major aim of the Mahaweli Development Programme has been to create employment in the country. Two forms may be distinguished. "Temporary" employment was created as a result of the construction work, which terminated when this construction phase ended. More "permanent" employment resulted from agricultural and fishery schemes connected to the Mahaweli Development Programme, and industrial schemes like for instance the Greater Colombo Economic Commission.

1984, under the Super Accelerated Works Programme of the Kotmale marked a peak in the execution of the Kotmale project and in the employment of personnel including some 220 Skanska staff, 40 ASEA staff and about 4500 locally hired personnel.

At present 155 persons are permanently employed as operation staff of Kotmale.

Regarding permanent employment the impact of the Kotmale scheme can not be distinguished from other projects in the same area. Employment opportunities created should be counted as new settlers from outside the area, not including those resettled originally living in the system. Increased facilities for agriculture will, however depend on the importance of the reservoir for irrigation purposes.

Further benefits to Sri Lankans emerged from employment opportunities in the country and overseas because of training provided by the contractors (the civil contractor in particular), and subsequent work experience in the project. The loss of machine operators trained by Skanska in fact created problems for the project. Quite a number of them quit work to go overseas to the Gulf states in the mid 1980's when employment opportunities were good there.

Roads

The project provided the region with some new or reconstructed roads of excellent standard, in particular the one from Gampola to the dam site. The road construction might be considered a separate scheme, as outlined in Section 11.3.2, and hence its costs netted out from the Project costs as such. Road construction, however, constitute a modest share (LKR 286 mill.) of the total costs, and its deduction will not influence the economic return of Kotmale to any extent. By excluding them the internal rate of return increases in the order of 0.17- 0.20.

The project provided the region with some new or reconstructed roads of excellent standard. Photo: Jan E Carlsson

Utilization of Housing and Offices

Present and future utilization of the housing, office and ancillary facilities established at the project site may well be regarded as secondary benefits from the project.

Buildings are now utilized for school purposes. About 25 students (secondary school) are accommodated, have their classrooms and use the sports facilities there. The scheme, undertaken by the American Waterfields Institute, will be expanded to about 100 students from 1990.

Construction costs of accommodation facilities are also in the order of LKR 150- 200 mill, hence netting them alone out of the project costs will improve economic return similarly to the road costs, by 0.15.

Cost of Switchyard Installations

The cost of the two feeder bays including erection is, based on prices from the contract, estimated to SEK 7 mill. or LKR 23.3 mill. This is only 0.2% of the total construction cost and as such negligible.

One might argue that this cost should be attributed to the Victoria costs

The kitchen in one of the newbuilt houses for workers families. These houses as well as offices and ancillary facilities at the project site may well be regarded as secondary benefits of the project. Some of these buildings are now used for school purposes.
Photo: Jan E Carlsson

since the two bays form the termination of the double circuit line from Victoria to Kotmale and are part of the transmission line required to transmit power from Victoria to the Colombo area. But then one might as well argue that part of the cost of the transmission line and terminal equipment going out from Kotmale to the load centre should be attributable to Kotmale.

The cost of the two Victoria Feeder bays have therefore not been omitted from the cost evaluation.

11.4.6 Other Factors Influencing Economic Return

11.4.6.1 Delays

Construction of Kotmale was originally planned to take place during the period August 1979- December 1984. The project, however, suffered from two major delays because of technical difficulties. The first occurred in 1980, when geotechnical findings caused temporary suspension of the work and relocation of the dam site 2- 300 m further downstream. The incident is treated in details in Chapter 7. Without the later super acceleration of the project, this would have delayed the project about a year.

In 1985 cracks were discovered in the high pressure shaft (see Sections 7.1 and 7.6), causing the plant to be closed for reparations during 18 months. Repair costs amounted to SEK 106 mill. (foreign component) and LKR 185 mill. (local component) distributed over three years.

The incidents surely affected economic return of the project. If the delays could have been evaded, full production could have started perhaps 2 years earlier. It may thus be of interest to compare the economic return from Kotmale with the return from a project without these difficulties, whether they could have been foreseen or not.

It is here assumed full production from 1985 and onwards, with 50% sales of secondary power up to 1994 and 80% later. The repair costs for the high pressure system are excluded.

Table 11.9
Kotmale Without Delays or Repair Cost.
Effect on the Internal Rate of Return.

Oil Price Prospects and Costs	Discount Rates	Realised Schedule	No Delay or Repair Costs
Low	6%	3.5	4.5
Medium	8%	4.8	6.0
High	10%	6.8	8.5

Kotmale without the mentioned delays or repair costs would have had a considerably higher economic return, from 1 to 1.7 increase, depending on the discount rate imposed on thermal generation of energy. The larger production in the early part of the calculation period is very valuable for the project's economic return.

11.4.6.2 Oil Price and Foreign Currency Constraints

A highly disturbing factor for the Project was the oil price collapse. Kotmale was conceived in the light of the experiences of the 1970's, with oil prices envisaged as possibly rising further. The prospect of avoiding oil imports and

Steel lining of the pressure shaft, Kotmale 19866. Photo: Skanska, Björn Enström
Shortly after the first filling of the waterways there was an excessive leakage from the pressure shaft into the powerhouse area. In the period from March 1985 to May 1986 the power plant was operating intermittently. The plant was then closed for 18 months to steel-line the entire pressure shaft and the inclined tunnel. Without delays or repair costs Kotmale would have had a considerably higher economic return. See table 11.9

thus save large amounts of foreign currency expenditures were cornerstones for the project.

Then the oil prices fell to about the half in two years 1984- 1986. As an oil importer Sri Lanka after this should be in a position to benefit from the decrease in oil prices, which ought to render superfluous costly schemes for development of alternative energy.

As expected the internal rate of return rises sharply with prospects of higher oil prices. (Table 11.9). The highest forecast in this analysis, USD 42.5 per barrel in 1988 prices is, however, far below what was envisaged from viewpoint in the early 1980's.

For the analysis it would be proper to regard the foreign exchange part of the Kotmale Project as the counterpart to the savings on reduced oil import. It will not be reasonable to consider the Kotmale capital cost as "sunk", even if a large per cent of it emerged as assistance from Sweden assigned particularly for this hydropower project. At the outset when the project was financed by an import support the capital's alternative value was unquestionable, but this must also be regarded as the case with the later grant assistance.

Considering foreign exchange savings particularly important, (more important than saving of domestic resources), generally implies that the country's currency is regarded as overvalued. To include this effect in an economic analysis some increment factor should be assigned to all foreign cost components of a project, or equivalently, some reduction factor to local components.

A reasoning along these lines implies that also the hydro power prices should be affected by the reduction factor. In the evaluation these prices contain their local cost component through construction costs of the thermal plant. The local component of maintenance and operation costs of the hydro plant will also be affected.

The World Bank has proposed a reduction factor of 15%, to be applied on the local cost component. This has been utilized by ODA in the Victoria evaluation.

The sum of these effects on internal rate of return for the project is given in Table 11.10.

Table 11.10
Higher Value Assigned to Foreign Exchange
Effects on Internal Rate of Return

Oil Price	Discount	Reduction	Factor	
Prospects	Rates	0%	-15%	-100%
Low	6%	3.5	3.7	4.9
Medium	8%	4.8	4.9	6.2
High	10%	6.8	7.0	8.2

The World Bank proposed factor of -15% is here applied to increase the impact of the use of foreign exchange in the project as compared with local resources. The effect on the internal rate of return of this exercise is, however, modest.

By applying a conversion factor of 100% the impact of all costs of local input to the project is annihilated or shadow- priced equal to 0. In this case only the foreign exchange resources are regarded as scarce. For a developing country like Sri Lanka this is a point of view with economic sense.

Kotmale's local cost share is small, so even if the local input was free of charge (-100%), the rentability would not fully rise to World Bank standards of 10% or defend discount rates equal to those demanded for thermal generation. The difference in internal rate between reduction factors 0% and 100% is 1.4.

11.4.6.3 Resettlement Costs

The study on the evacuees from the Kotmale reservoir and its vicinities (see Chapter 13) concluded that a number of them are not satisfied with their situation which they find has deteriorated compared with before relocation. In the study there are, however, no estimates as to the extent of compensation needed to restore the previous standard of living for those who were affected by the Kotmale Project.

The costs of resettlement, compensation to evacuees etc amounted to LKR 436 mill. up to 1989. It might be of interest to state to which extent additional compensation disbursements might influence economic return from the Project.

Table 11.11
Compensation for Evacuees,
Impact on Project Economic Return

Oil Price Prospects	Discount Rates	Original Compensation	Increase 300%
Low	6%	3.5	3.0
Medium	8%	4.8	4.3
High	10%	6.8	6.3

In Table 11.11 the project's expenses for resettlement are increased by 300%. This reduces the internal rate of return by 0.5. Still it can be concluded that if expenses of that order were foreseen, they would not alone have had a decisive influence on whether to go ahead with the project or not.

11.5 UNIT ENERGY INVESTMENT COST FOR KOTMALE, VICTORIA AND RANDENIGALA

Using construction cost data for the three projects provided by Mahaweli Authority, and ACRES' production data, the following unit energy investment costs are calculated (total construction costs divided by annual energies):

Table 11.12

Unit energy investment cost, the three projects seen separately

Plant	Total investment mill. LKR	Average energy GWh/yr LKR/kWh	Unit cost of energy
Kotmale	10,173	502	20.26
Victoria	9,062 1)	886	10.23
Randenigala	5,631 1)	494	11.40
Total	**24,866**	**1,882**	**13.21**

1) Data from end 1987; final figures somewhat higher.

Since the Kotmale reservoir is the one located furthest upstream, its water may be utilized by all three plants in energy production - assuming such use of the water to be more profitable than the irrigation alternative.

It would thus seem reasonable that the construction costs of the reservoir, including a share of the general costs, should be divided between the three projects, e.g. by a ratio corresponding to their head. This principle is particularly applicable where the separate hydro installations on a river are owned by different utilities.

Assume here that the distribution key follows the ratio of mean gross head; at Kotmale 211 m, Victoria 184 m and Randenigala 70 m, or 465 m in total, yielding 45% chargeable to Kotmale and 40%, resp. 15% to Victoria and Randenigala.

The common cost to be distributed is the entire Reservoir Works Contract, LKR 3,579 million, and an assessed 75% of the Initial Works Contract, 0.75 x 973 = LKR 730 million, or a total of LKR 4,309 million.

Using this principle as a guideline for re-distribution of costs will give the following unit costs:

Table 11.13
Unit energy cost, after redistributing the Kotmale reservoir costs

Plant	Total investm. adjusted mill. LKR	Average energy GWh/yr	Unit cost of energy LKR/kWh
Kotmale	7,803	502	15.54
Victoria	10,786	886	12,17
Randenigala	6,277	494	12,71
Total	**24,866**	**1,882**	**13.21**

11.6 MAIN FINDINGS

The main findings regarding the economic evaluation of Kotmale can be summarized as follows:

- Kotmale regarded strictly as a hydropower scheme, gives a small economic return compared with regular standards. The return is, however, definitely positive.
- The delayed production start together with the repair costs were factors with serious effect on economic return.
- Prospects of high oil prices would improve the project's viability.
- Kotmale also serves irrigation purposes and contributes as well to the economy of the hydropower plants downstream. Thus there are reasons to claim that parts of Kotmale's construction costs should be shared with other projects.
- Further attendance to the needs of the evacuees which might raise the relocation costs (for example threefold) would not gravely deteriorate the economy of the project.

CHAPTER 12
ENVIRONMENTAL EVALUATION

The environmental impacts of the Kotmale Hydropower project were studied in a report commissioned by SIDA*. The catchment, the reservoir, the reservoir environment and the downstream environment were investigated.

In the following the consultant's recommendations are included in extenso:

- The catchment above the Kotmale reservoir should be subject to detailed land use planning in order to reduce the input of silt into the reservoir. This will protect the investment in the hydropower project and provide support for a sustainable use of the land assets in the catchment.
- The actual input of silt should be measured at the Kotmale Oya close to the inflow into the reservoir as a test of the theoretical calculations and as a means to follow the trend of charges and to be able to take action when necessary.
- A new all-weather road should be constructed between Mawela and Sangilipalama New Town (New Kotmale), since it would first of all fill the only gap in a road system circumscribing the reservoir. Secondly the new road could also be integrated in the national road system since it opens possibilities for a direct road connection between Ramboda/ Tawalantenna and Gampola utilizing the 18-20 km stretch of high quality road built in connection with the Kotmale Hydropower Project. A third advantage of the proposed new road is that it creates possibilities for draining "slide-prone" sections of the valley slopes.

* Published in SIDA Evaluation Report Series 1989/1 "The Kotmale Environment".

- The limnological study of the reservoir should be maintained over a long period of time to avoid conclusions based on sketchy data. Sampling of pesticide residues should preferably be included in the study.
- Stocking of the reservoir with fish should only be contemplated after some years when the indigenous population has had a chance to show its development potential.
- An inventory of the shorelines should be undertaken in order to gain an overview of earthslips and other shore developments in progress. Implanting of grass should also be considered after some years if no natural vegetation has got foothold on the uppermost parts of the shores.
- A pilot project to assess the potential of establishing fish pond culture should be initiated. Other forms of aquaculture may also be included.
- The remains of the dense montane forest should be gazetted to assess whether it is worthwhile protecting. A protection of the montane forest would be beneficial to the Mahaweli Development Programme in three ways:

  1) the forest prevent a rapid runoff and erosion on the slopes

  2) the root systems of the large trees in the forest stabilize the slopes

  3) the good-will effect which accompanies the protection of an object of national heritage
- A policy should be laid down on how to handle the degraded tea plantations around the reservoir since if poorly managed, they may have negative consequences for the reservoir as producers of silt.
- Trials to revegetate the improductive grasslands on the hilltops around the reservoir should be initiated preferably using indigenous species. Large-scale methods, e.g. aerial seeding should also be considered as a complement to traditional planting by hand.
- A detailed programme to acquire date and to test various hypotheses of the causes of mass movements in the Kotmale valley should be compiles by a group of specialists. In the implementation of the programme preference should be given to studies which try to investigate the

triggering mechanism behind the soil creep at a number of villages. The programme should also include analysis of practical methods on how to arrest or mitigate soil creep or other forms of mass movement.

- Information on the fish population in the Mahaweli Ganga between the Victoria and the Kotmale reservoirs should be compiled and in particular the migration patterns of valuable fish species.
- The incidence of malaria downstream of the reservoir should be followed since altered environmental conditions may influence the breeding conditions of mosquitoes.
- An inventory should be made to the signs of active erosion downstream of the tailrace outlet. The potential impact on the riparian environment from erosion should also be assessed.

The Sri Lankan Ministry of Lands, Irrigation and Mahaweli Development has commented on the environmental report in a letter to SIDA dated June 9, 1989. The recommendations have to a great extent been accepted and some of them are under way to be implemented. The report has thus been well received.

CHAPTER 13
SOCIAL EVALUATION

The impoundment of the reservoir necessitated the evacuation and resettlement of 3,056 families, or some 15,000 people living in the area to be inundated with the present and future dam crest levels. In addition came 905 families affected by landslides in the upstream area. The problems connected to relocation of evacuees from the Kotmale reservoir and its surroundings have been studied by the Department of Geography at the University of Sri Jayewardenepura in an investigation commissioned by SIDA. Two reports have emerged, on the evacuees relocated upstream, and on those relocated downstream.

The Mission met with two of the authors of the report*, Professors Karunanayake and Abhayaratne. Some of the conclusions from the reports will be referred here, notably those which describe economic conditions for the relocated families.

The Kotmale Project has made a profound impact on the life of people in the Kotmale valley. Traditional lifestyles have been disrupted, and innovations have arrived like the provision of electricity, roads, townships. People have migrated in from other parts of the country. Kotmale is moreover only one of the elements in the gigantic Mahaweli Development Programme, which has implied relocation of a total of over 30 thousand families.

13.1 The Resettlement

Out of the 3961 evacuated Kotmale families 2,239 have resettled upstream (in the Kotmale vicinity), and the rest downstream in areas developed under the Mahaweli Programme.

* The report is not published. It is available in manuscript at SIDA.

15,000 people previously living in the dam area have been resettled. Those who moved upstream were given 0.8 ha of tea land. But many of the evacuees were not familiar with tea growing, and most of them are not yet able to generate a satisfactory income. 80% of the evacuees are dissatisfied with the compensation received. The relocation cost may be at least threefold without any large effect on the project's viability.
Photo: Rolf Larsson, SIDA Photo Archives

Table 13.1:
Relocation of Kotmale Evacuees.

	Reservoir	Landslide	Total
Upstream settlers	1,334	905	2,239
Downstream settlers	1,722		1,722
in System H	- 794		
in System B	- 730		
in System C	- 198		
Total	3,056	905	3,961

Among these families not all have been displaced because of reservoir inundation, but also by other circumstances related to the Kotmale scheme. Of these may be mentioned workers employed at the tea plantations acquired for evacuee relocation. The estate workers so moved numbered a thousand.

Included are also 905 families affected by events of landslides in the reservoir ares. It is doubtful whether the landslides were caused by the impounding of the reservoir. The Kotmale region has long been noted as a landslide prone area. Surely the landslide incidents added to the relocation problems.

The main groups of settlers focused in the study are thus, reservoir evacuees upstream, reservoir evacuees downstream and landslide evacuees.

The evacuation was conducted without any incidence of violence, although it was indeed a compulsory relocation. To overcome resistance various strategies of persuasion, especially of opinion leaders were followed. The potential benefits for the evacuees and also for the country were stressed. In the aftermath it may appear that some of those promises have not (as yet) been fulfilled.

The reservoir evacuees were given the option of resettlement either in upstream or downstream areas of the AMDP. The landslide evacuees were not provided with any option but resettlement in the Kotmale area.

Resettlers to some degree had to adapt to entirely new circumstances. Those who went downstream for instance moved from a half way subsistence economy to a market oriented one.

13.2 Compensations

Former tea plantations were bought for redistribution to evacuees.

The reservoir evacuees choosing to resettle upstream were allotted 0.8 ha of tea land. On downstream location the resettlers were to benefit from 1 ha of paddy land and 0.2 ha of highland.

Landslide evacuees were to be resettled near their villages of origin and to receive tea allotments.

As the lands belonging to the landslide evacuees were not acquired by the government, those were compensated for the loss of dwellings only, whereas the reservoir evacuees were entitled to compensation of loss both of land and dwelling.

The reservoir evacuees were eligible for compensation for the loss of both house and property, while the landslide evacuees were to be compensated for the loss of house only.

Some reservoir evacuees have been compensated for the loss of crops as well.

The landless in both groups were to benefit by receiving land as relocatees. Thus all relocatees got a clear title to land,

The would be evacuees had been promised infrastructure facilities as well as relocation assistance. All families were to be provided with a few basic agricultural implements.

Each tea estate worker deprived of his workplace was compensated with a sum of LKR 10,000.

Housing allowance of LKR 1,500 per family were given. Later this amount increased up to LKR 1,750. Additionally LKR 405 was allotted to each family so as to promote construction of sanitary toilet.

Difficult settlements were granted subsistence allowances from LKR 400 to LKR 600 per family.

19 % of the reservoir evacuees have received between LKR 25 thousand and LKR 49.9 thousand in compensations, 40% LKR 50 thousand or more. Among landslide evacuees comparable figures are 18% and 24%. Some 9% of the reservoir evacuees and 5% of the landslide evacuees report to have received no compensation at all.

In terms of income, evacuees downstream appear better off than evacuees upstream.

13.3 Reports of Problems

A number of the evacuees seem to be dissatisfied with their situation. It appears for instance that had the difficulties of relocation in Kotmale been known, many more would have opted to go downstream. A majority all the same characterizes information on relocation as acceptable with reservations.

80% report dissatisfaction with the compensation received. Apparently the amount to some degree has been dependent on the bargaining strength of the recipient.

Prior to the evacuation there was some opposition from the plantation workers' trade unions, which did not, however manifest itself among the estate workers.

Assistance to put up new houses are reported not to be adequate.

Some evacuees encountered climatic difficulties in the new settlements, water supply and fuelwood was scarce.

Non availability of land for relocation made it difficult to keep the promises of area allotments. The extent of tea allotments came to vary between 0.8 and 0.2 ha. Some of the tea areas needed rehabilitation. Most evacuees were previously not experienced in tea cultivation. Tea growing also faced marketing problems.

Small holder tea growing is not yet capable of generating satisfactory income level for the majority of the evacuees. Other crops, livestock farming, fish breeding, mulberry cultivation etc have thus been put forward as possible schemes to improve the economy. Market opportunities are, however, limited.

In the downstream areas some of the settlers had to wait 2-3 years to receive irrigation water. In the meantime compensations and savings were frittered away.

Employment in the non-farm sector has been limited. Small scale industry is lacking in the area.

Communication network is still deficient, electricity supplies to settler households are much felt need in all hamlets.

Some of the evacuees did not show up or have left their allotments. In systems H, B and C the absentees are in the order of 10.7%, 12% and 4.5% respectively. Some of these families still habit the Kotmale area. One of the reasons may be security problems.

13.4 Conclusions

Apparently there is a need to follow up the situation for the Kotmale evacuees and provide them with additional facilities and development opportunities. The necessary extent and costs of such an effort is as yet unknown. The crucial question for the evaluation of the Kotmale project is what implications additional costs in this respect will have for the economic returns from the project. In Section 11.4.6.3 this issue was discussed, and the conclusion is that relocation costs may be at least three fold increased without any large effects on project viability.

CHAPTER 14
CONCLUSIONS

14.1 GENERAL

Kotmale as it stands today plays and will play an important role in Sri Lanka's electric energy supply. As to Kotmale's role as part of the AMDP irrigation scheme, the Mission has not been able to evaluate that part to the extent desired. Through its regulating effect it benefits also the energy production capacity of the downstream located power plants.

The power plant is of a very high technical standard, and will, provided it is maintained and operated systematically and with competence, continue to serve Sri Lanka for many years to come.

14.2 FINANCING

The project has suffered from rush planning and implementation, and this has served to increase costs, partly because of chosen design and unforseen construction delays, and partly because of high prices due to lack of competitive bidding.

Swedish financing in the form of grants and soft loans amounted to 68% of the total foreign exchange part of the project costs. In spite of this heavy involvement by the Swedish Government in the financing of the Kotmale, the Government has, due to the way the way it was brought into the project, had little or no influence on the design and the construction costs.

14.3 DESIGN AND IMPLEMENTATION

The SIDA Team of Experts, although doing an excellent job, was brought into the project too late to have any influence other than on the progress of the construction works then already well under way. The Team was also instrumental in achieving the goals of the socalled "Super-Accelerated-Programme".

With a team of experts consisting of engineers with considerable experience from design and implementation of underground power plants attached to the project from the outset, more influence on the design could have been achieved. In the Mission's opinion, the design was the basic cause of the problems that later occurred in the unlined pressure shaft — an interesting case of failure deserving to have been brought to the attention of the international professional community through publications by e.g. the SIDA team of experts.

The implementation of the project, i.e. the execution of the construction works and the manufacturing and erection of the equipment, was carried out professionally and expeditiously according to specifications. It is, however, the Mission's opinion that the delays due to the relocation of the dam could have been avoided with better interpretation of the site investigations. Furthermore, the delays and much of extra costs caused by the hydraulic splitting of the rock in the concrete lined part of the pressure shaft could have been avoided if the design had been updated and pressure testing had been applied during excavation.

Considerable cost saving could have been achieved by not adopting the costly and time-consuming solution of concrete lining of the low pressure tunnels and the surge shaft and by also omitting the surge shaft gate.

The selection of contractor and equipment supplier without competition helped in getting the project under way may be 6 months earlier, but has probably led to an extra cost of 20-30 % over and above what could have been achieved by international competitive bidding. Even if international bidding was not acceptable with Swedish financing, a better influence on costs could have been achieved had the Swedish Government, represented by SIDA, been brought more effectively into the project from the beginning.

The Mission is not convinced that the third generating unit should have been installed at this stage with the present dam crest level.

14.4 OPERATION, POWER AND ENERGY PRODUCTION

The Mission feels confident that the power plant, as it stands today, is of high quality, and that the CEB staff entrusted the important task of operation and maintenance, is qualified and well motivated.

With the present dam crest level of 706.5, Kotmale will contribute to the power system with 270 GWh of firm annual energy. The average annual production will be 502 GWh, and the composition of the power system will decide how much of the secondary energy can be dispatched in the future. In this evaluation 80% has been used for the calculation of the economic benefits of the project.

14.5 ECONOMIC EVALUATION

Total project cost over the period 1979 - 89 amounted to LKR 10,173 in current value. The unit energy investment cost, i.e. total construction costs divided by mean annual energy is often used to compare hydropower projects. With a total project cost of LKR 10,173 million and mean annual energy of 502 GWh, this gives for Kotmale LKR 20.26 per kWh. Similar figures for Victoria and Randenigala based on investment cost received from MASL give 10.23 and 11.40, respectively.

For comparison the same specific price for a Norwegian plant, Dokka HPP, considered to be an expensive project, now under commissioning, and producing 520 GWh mean annual energy, is NOK 4.04 which corresponds to LKR 18.4.

The internal rate of return of Kotmale with three generating units has been calculated at different discount rates, using thermal power costs as alternative source. With the chosen oil price scenarios and the three different discount rates - 6%, 8%, and 10% -, the return from Kotmale is in all three alternatives lower than the return demanded from thermal power, and only the high oil price scenario combined with a discount rate of at least 8% brings Kotmale's internal rate of return above 6%

The main findings from the economic evaluation of Kotmale can be summarized as follows:

- Regarded strictly as a hydropower scheme, Kotmale gives a small economic return compared with regular standards. The return is, however, definitely positive.

- The delayed production start together with the repair costs are factors with important effect on the economic return.
- Prospects of high oil prices would improve the project's viability.
- Kotmale also serves irrigation purposes and contributes as well to the economy of hydropower plants downstream. Thus there are reasons to claim that parts of Kotmale's construction costs should be shared with other projects.
- Further attendance to the needs of the evacuees which might even triple the relocation costs, would not gravely deteriorate the economy of the project.

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APPENDIX 1
TERMS OF REFERENCE

for a mission to undertake a technical and economic evaluation of the Kotmale Hydro Power Project

1 OBJECTIVES

1.1 The main purpose of the evaluation is to examine the extent to which the project achieved its objectives as these were stated in the 1982 decision of the Swedish Parliament to provide significant grant assistance and in the Specific Agreement on that assistance concluded the same year. In the assessment of the project's power production benefits, three generating units should be taken into account although the third unit, strictly speaking, has not been aid financed. The evaluation should also include a review of the 1988 environmental impact report and of the report on the ongoing study of the resettlement of the evacuees. On the latter subject, although no funds were provided by Sweden for resettlement, the evaluation should attempt to establish the effects of the evacuation and resettlement process and the extent to which involuntarily resettled households have benefitted.

A review of the project along these lines should be summarized in an assessment of the extent to which the project has contributed and will contribute towards the solution of the principal problems to which the Accelerated Mahaweli Development Programme (AMDP) addressed itself, namely, shortage of power, shortage of foreign exchange due to import of rice and fuel for thermal power generation, and high unemployment.

1.2 A secondary objective of the evaluation is to provide lessons for the planning of future projects of this nature to the Government of Sri Lanka and the donor community.

1.3 During the period of project execution there arose in Sri Lanka conflicts and disturbances of an ethnic origin which have cost thousands of lives, led to widespread destruction of infrastructure and property, and caused a serious decline in the economy and economic activity of Sri Lanka. It will be necessary for the evaluation to take account of these developments and any effects with a direct or indirect bearing on the immediate and long-term benefits of the project.

2. BACKGROUND DATA

In order to obtain background data for the evaluation proper, the mission should review and analyze Ceylon Electricity Board (CEB) projections of the demand/supply situation of the Sri Lanka power system from 1970 onwards as against actual demand/supply. This should include data on energy demand in various consumer categories and regions as well as projections and actuals referring to the role in the power system of hydro power projects under AMDP. Due attention should be given to identified constraints such as inadequate transmission facilities. transmission losses, revised streamflow estimates, and tariff policies.

Further relevant background data should be obtained in the form of information on the implementation since 1977 of rural electrification schemes and on schemes under consideration by CEB. On the basis of such data, estimates should be made of the number or rural households having access to electrical power present and likely to have such access in the foreseeable future.

3. TECHNICAL EXECUTION

The mission should review and assess the technical execution of the project by the contractors and the basis of the coordinated work programmes, the progress reports of the Mahaweli Authority of Sri Lanka (MASL) to SIDA, the progress reports of the SIDA team of experts and the mission's own observations. The assessment should also include the following:

- The handling by the Project Engineer(s) of matters concerning design, choice of electro-mechanical equipment, site supervisor and project coordination, with special attention to the functioning of the tripartite Project Engineer arrangement and contract response.

- The handling by MASL of decisions on technical, contractual and related matters and, in this context, the manner in which technical problems arising in project execution were examined and resolved.

- Quality standards in project execution and the time required for completion of work, the latter particularly from entry into force of the Specific Agreement and with reference to the implementation of the Super-Accelerated Work Programme.

The above review should examine whether any technical problems which arose could reasonably have been foreseen if further site investigations and design studies had been undertaken at the planning stage. The object of such an examination should be to identify the correlation, if any, between cost overruns and undue haste in project design and implementation.

4. PROJECT COSTS AND INTERNAL RATE OF RETURN

4.1 The mission should calculate the final project cost (items as defined in the Specific Agreement, including two generating units and related electro-mechanical equipment) against the estimated appended to the Agreement. For purpose of a broader cost/ benefit analysis calculations should also be made of the final cost of each of the following project or project related items not included in the Swedish aid financing:

a) Local costs for the civil works and for the electro-mechanical works

b) Fees to the two British Project Engineers

c) Interest during the construction period

d) The third generating unit

e) The 1986 to 1987 repairs in the high pressure system

f) Evacuation and resettlement of the affected population in the reservoir area, including compensation paid.

4.2 The mission should identify, to the extent possible, secondary benefits of the projects, such as:

- Irrigation benefits
- Local employment and local incomes created during the construction period
- Employment opportunities in Sri Lanka and overseas resulting from training provided by the contractors (the civil contractor in particular) and subsequent work experience in the project
- Government revenue obtained from income taxes paid by expatriate contractor staff
- Present and future utilisation of the housing, office and ancillary facilities established at the project site
- The cost of the switchyard installations and related facilities attributable to the handling of power from the Victoria Project
- The existence of a high-quality, all-weather road from the outskirts of Gampola to the dam site.

The mission should comment on the relevance of such benefits for the economic evaluation of the project and on the extent to which certain benefits should be disregarded due to (a) their value being too insignificant in relation to the overall project costs to warrant consideration or (b) their being of such a nature that they should, wholly or in part, be netted out from the cost of the project.

4.3 The mission should calculate the internal rate of return of the project on different cost side premises so as to show also the benefits resulting from the financing of a significant proportion of the civil works by grant assistance.

Intractable problems often arise in estimating the economic benefits of electricity supply, particularly when tariffs are below their economic cost so as to understate the consumers' willingness to pay. Given the actual data on the cost of the project, a calculation of its internal rate of return would be facilitated by the results obtained if CEB were to run its planning generation models ex post. However, because such an exercise, if at all feasible, would be time consuming an approximate analysis along these lines will probably have to suffice.

In this part of the evaluation, guidance may be obtained from the methodology used in the evaluation of the Victoria Project carried out under the auspices of the Overseas Development Administration as well as for World Bank guidelines for the appraisal and evaluation of electric power projects.

4.4 The mission should obtain data on the final costs of the Victoria and Randenigala AMDP projects for comparison with the final costs of the Kotmale project, taking into account

- the award of contracts for Victoria and Randenigala on the basis of national competitive bidding in the respective donor countries as against contract awards for Kotmale by negotiated contracts with one Swedish contractor only
- such differences in the execution of the three projects as were due to adverse geological features necessitating design change during the construction periods as well as to other relevant circumstances.

5. PROSPECTS FOR THE FUTURE

The mission should examine the prospects for successful operation of the Kotmale Hydro Power Plant and assess its likely life, taking into account

- the availability of qualified operational staff (and the role of the training of such staff in Sweden under programmes financed by SIDA outside the allocation for the project itself)
- established programmes for maintenance of plant equipment and ancillary facilities

- the financing of the operation of the plant and of maintenance programmes and the possibility of budgeting restraints due to scarcity of foreign exchange and other circumstances

- the repairs in the underground high pressure system undertaken in 1986-87

- any problems that might arise from inadequate water flow into the reservoir

- the possibility of conflicts arising between power interests (CEB) and irrigation interests (Ministry of Mahaweli Development - MASL) due to the determination of priorities regarding the use of reservoir storage resources

- such constraints as have resulted from, or is likely to result from, the developments referred to in para 1.3. above.

6. ROLE OF THE SIDA TEAM OF EXPERTS

The mission should comment, and seeks the views of the concerned Sri Lankan authorities, on the role performed by the SIDA team of experts with regard to both monitoring of project progress and advice on technical matters.

7. CONDUCT OF THE EVALUATION

The mission should refer to and draw upon as appropriate all relevant documentation on the project and on the AMDP. Some of the work will take place in Sri Lanka, and the mission should hold discussions as necessary with the authorities concerned, notably the Ministry of Mahaweli Development, MASL and CEB, as well as with such other persons in Sri Lanka and elsewhere whose experience and expertise may be of assistance. In Sweden, the mission should hold discussions with representatives of the civil contractor and the electro-mechanical contractor, with the SIDA team of experts and with the concerned SIDA headquarter staff.

8. REPORT

The missions should summarize its findings under the above items in a report in English presenting a full assessment of the impact of the project.

APPENDIX 2
PROJECT DATA

HYDROLOGIC CONDITIONS

- Catchment area at dam site	544 km^2
- Observed mean flow at dam site	32 m^3/s
- Observed maximum flow at dam site	1,340 m^3/s

DAM AND RESERVOIR

- Dam type:	Rockfill with concrete membrane
- Rockfill volume	4.8 mill m^3
- Maximum height above river bed	87 m
- Crest length	600 m
- Average depth of grout curtain	170 m
- Crest elevation	El. 706.5 m
- Full reservoir supply level	El. 703.0 m
- Maximum flood level	El. 704.3 m
- Minimum operating level (power)	El. 665.0 m
- Minimum reservoir level (irrigation)	El. 663.0 m +/-
- Capacity of bottom outlet tunnel, with reservoir level at 665.0 m	90 m^3/s
- Reservoir volume above level 665.0 m	152 hm^3
- Reservoir volume below level 665.0 m	22 hm^3
- Capacity of gated chute type spillway	5,550 m^3/s

HEADRACE TUNNEL

- Length of concrete lined "low pressure tunnel" (A = 32 m^2) between intake and surge shaft	6,540 m
- Tunnel length from intake to intake gate shaft	250 m
- Length of steel lined 5.6 m dia "inclined tunnel" (A = 24.6 m^2) between surge shaft and penstock knee	410 m
- Height of 15 m dia concrete lined surge shaft (A = 176.7 m^2) with restricted orifice (a = 4.9 m^2 + gate slot)	142 m

PRESSURE SHAFT

- Length of steel lined 60° inclined penstock 4.8 m dia (A = 18.1 m²)	125 m

UNDERGROUND POWER STATION

- Size of rock cavern (L/W/H)	67/20/38 m
- Installed turbine capacity	3 x 68 = 204 MW
- Turbines	
o Type	Vertical Francis,
center El. 472	
o Rated power, at 201.5 m net head and Q = 37.2 m³/s	68,100 kW
o Speed	375 rpm
o Inlet	Spherical valves
- Generators	
o Type	Vertical 3 bearing
o Rated power	90 MVA at 0.85 pf
o Voltage	13.8 kV
o Cooling	Closed air/water
- Overhead crane capacity	160 ton
- Highest present headwater level	El. 703 m
- (Highest future headwater level	El. 731.5 m)
- Lowest tailwater level	El. 477 m +/-
- Highest tailwater level	El. 489 m +/-
- Maximum present gross head	226 m
- Height of 8 m dia cable- and ventilation shaft to switchyard	192 m

TAILRACE TUNNEL

- Length of concrete lined tunnel (A = 32 m²)	635 m
- Sill level at downstream end	El. 476.5

SWITCHYARD

- Rated voltage	132 and 220 kV

ENERGY PRODUCTION

- Firm energy	270 GWh
- Secondary energy	232 GWh
- Average annual energy	502 GWh

APPENDIX 3
MAIN EVENTS LISTED CHRONOLOGICALLY

WAPCOS feasibility study	Jan 1978
Halcrow appointed Project Engineer in association with CECB	13 Feb 1979
Agreement between Sweden and Sri Lanka on import support	May 1979
Skanska contracted Initial Works4	Aug 1979
Skanska contracted Underground Works	18 Dec 1979
Works suspended on dam site	Nov 1979
Dam expert proposal on new dam site	May 1980
Report on optimum dam height, Halcrow,	Jul 1980
Report on modified scheme, Halcrow,	Jan 1981
ASEA contracted elmech works P1	Jun 1981
P2	Jul 1981
E1Nov	1981
E2Dec	1981
Skanska contracted Reservoir Works	Oct 1981
SIDA project appraisal after Sri Lanka appeal to assist in financing of project	Nov 1981
Regeringens Proposition 1981/82:215 approved	4 May 1982
Specific Agreement on the Kotmale HPP	16 Jul 1982
ASEA contracted spillway equipment E3	Jan 1983
Civil Disturbances in Sri Lanka	23-27 Jun 1983
ASEA contracted bottom outlet equipment E4	Oct 1983
ASEA contracted unit 3 P1A, P2A	Sep 1984

Impounding of reservoir started9	Nov 1984
Filling of H.P. System24	Feb 1985
Commissioning of Unit 1 (synchronized)	26 Apr 1985
Commercial operation of Unit 1	8 Jun 1985
Commissioning of Unit 2	Postponed
Commercial operation of Unit 2	Postponed
Close-down of station for inspection	Sep 1985
220 kV line completed	Sep 1985?
Report on leakage from high pressure system	Nov 1985
Refilling of waterways, start	24 Feb 1986
Review on remedial measures on H.P.System	Feb 1986
Report on measures to be taken to safeguard the life of H.P. System	Mar 1986
Close-down of station for repairs	May 1986
Repairworks on H.P. System	May 86 - Dec 1987
Refilling of waterways after repairs, start	4 Dec 1987
Final report on remedial measures to safeguard life of H.P.System	Dec 1987
New commissioning of generating units:	
Unit 1 (synchronized)	19 Dec 1987
Unit 2 "	26 Feb 1988
Unit 3 "	8 Feb 1988
Commercial operation of generating units:	
Unit 1 (second time,after repairs)	19 Dec 1987
Unit	27 Apr 1988
Unit 3	10 Mar 1988

APPENDIX 4

REVIEW NOTES ON REPORTS ON PRESSURE TUNNEL FAILURE by Dr. Ing. Bjørn Buen

1. General

Basis for comments are 4 reports from SIDA team; November 85, February 86, March 87 and December 87. Excessive leakage, 3,000 l/min., impaired the operation of the plant in 1985.

Cracks running along the pressure shaft invert and roof. The cracks were taken as indications on deformation in the rock mass. Temporary repairs were done and the pressure shaft was operated for some months in 1986. The initial leakage was 3,000 l/min., but decreased gradually and was measured to be 500 l/min. at the time of shutdown.

Steel lining of the pressure shaft and the inclined tunnel was done by December 1987.

Some stress measurements in drillholes, presumably using overcoring of triaxial cells have been done. The stresses measured range from 10,2 MPa in compression to 1,7 MPa in tension.

No pressure/leakage curves or pressure/grout take curves are presented. Thus the only clue to rock mass behaviour is the "full scale testing".

2. Failure mechanism

The cracks in the concrete lining indicate rock mass deformation. The deformation may either be caused by shear displacement or by direct hydraulic jacking on joints, see figure 1.

The failure as reported seems to be consistent with a hydraulic jacking on vertical joints running parallel to the shaft.

Low horizontal stresses in the E-W direction also fit the topography of the area, the shaft situated in a pronounced ridge running N-S.

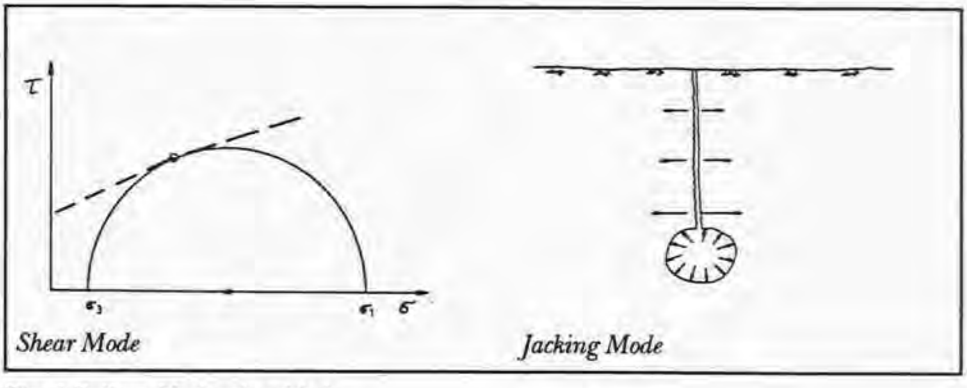

Fig. 1 Failure Mechanism Modes

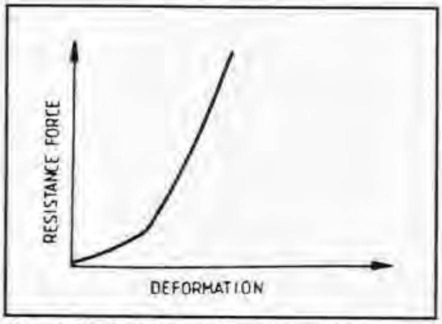

Fig. 2 Rock deformation Principle

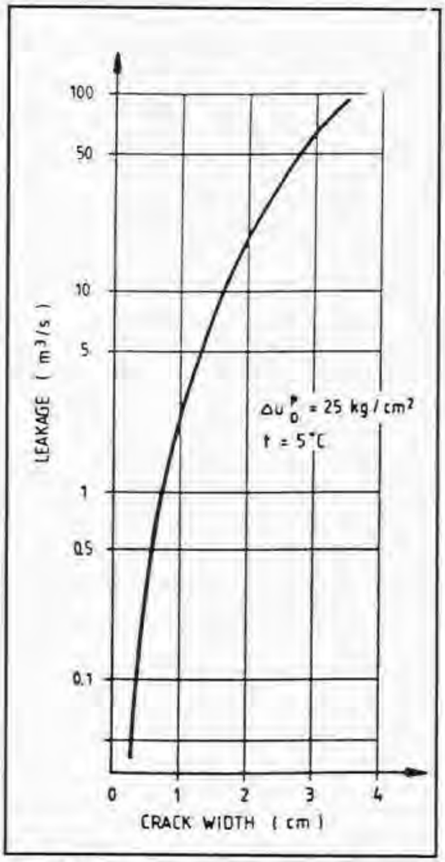

Fig. 3 Leakage as a Function of Crack Width (Per meter length)

In a case of jacking on vertical joints, the rock mass will deform until the deformation resistance in the rock mass balances the water pressure. In an unweathered rock mass the necessary deformation is usually small, see figure 2.

The diagram in figure 3 is taken from NGI /Norwegian Geotechnical Institute) Report 54202-2 1/7/74 and illustrates theoretical leakage from an 1 m long joint.

The figure indicates that actual deformation and joint openings have been small.

The fact that the leakage did gradually diminish may be explained by partly a natural clogging of millimetre size channels by silt and sand and partly by saturation of the rock mass. The saturated rock mass means that the groundwater table is elevated and therefore the leakage gradient reduced. This is a natural process and may be illustrated by measurements on the Warangoi HPP in Papua, New Guinea. The leakage from the 7 km long commission was 280 l/s at the time of commission and 10 l/s one year later. The leakage at the startup was in accordance with predicted value (250 l/s), ref. Buen & Barlindhaug, Bergmekanikkdagen Oslo 1983, TAPIR Publishers.

Thus it may seem that a possible stabilization could have taken place given a little more time. This is however speculative and could in any case not have been recommended as an alternative to the lining executed.

3. Tests and measurements

When testing for behaviour rock mass exposed to high pressure water, it seems to be a growing acceptance of pressure testing in drillholes.

The pressure/leakage curves give valuable information about rock mass behaviour. The tested rock mass volume is also several orders of magnitude larger than the one obtained by the indirect methods as e.g. overcoring.

A publication by B.A. Leijon from Luleå, called "Relevance of pointwise rock stress measurements - an analysis of overcoring data", International Journal of Rock Mechanics Vol. 26/1986, underlines this.

Leijon recommends ±2 Mpa as a standard deviation on mean stress. More or less the same conclusions were reached by Leijon and Stillborg in International Journal of Rock Mechanics Vol. 19/1986.

It is an open question whether proper pressure testing and interpretation during construction could have revealed the present problem. The reports prepared to SIDA do not show if the Review Team did consider this.

4. Could the failure have been predicted/avoided?

The reason for the failure seems to be that the design criteria for a pressure shaft with a permeable lining was not met; the virgin stresses in the rock mass were too low. The general design principles should at the time of design have been well known.

It is also interesting to note that in 1979, at the 4th ISRM Conference in Montreux, a failure in many ways identical to the Kotmale case was reported, see Seeber G., Demmer W. "Die Schaden im Hattelberg - Druckstollen als folge eines aussergewöhnlichen Spanningszustandes" Vol. 1 P. 533 ISRM CONF. 1979.

Also in this case a pressure tunnel with permeable lining was placed directly along the axis of a ridge.

The same was the case at CHIVOR HPP in Colombia. Also here the pressure tunnel followed a ridge, see Broch E. 1984 "Unlined Pressure Tunnels in Areas of Complex Topography", Water Power and Dam Construction 26:11.

The answer to the question in the heading seems to be affirmative. At the time of construction all the necessary testing methods had been reported internationally and also the two most recent failures of pressure tunnels with resemblance to the Kotmale project had been reported.

It should not have been impossible to detect the problems.

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An evaluation of SIDA Support to the Kotmale Hydropower Project by Bjørn Gildestad, Erland Kleivan and Tor Stavsholt

A FLAWED SUCCESS

The Mahaweli River Basin formed the cradle of Sinhalese civilisation from the fifth century BC. Following repeated attacks the land was abandoned. Two and a half thousand years later the Government of Sri Lanka started the Mahaweli Development Programme to repopulate the area.

The Kotmale Hydropower Project is part of this programme. It is the second largest Swedish development project ever, with grants totalling SEK 1,5 billion. The project started in 1978 and by 1987 the station was in full operation delivering 204 MW to local industries and households.

The main conclusion of this evaluation by Bjørn Gildestad, Erland Kleivan, and Tor Stavsholt of Norpower is that the Kotmale powerstation is of very high technical standard and is now functioning well. But the projects internal rate of return, although positive, is low compared to other similar projects. The project was rushed. There was no competitive bidding wich surely caused higher costs. A leakage, which could have been avoided with a design based on proper rock pressure tests, proved very expensive. The resulting shutdown for repair is the main reason for the low internal rate of return.

Sweden's bilateral development co-operation, handled by SIDA, comprises 18 programme countries: Angola, Bangladesh, Botswana, Cape Verde, Ethiopia, Guinea-Bissau, India, Kenya, Laos, Lesotho, Mozambique, Namibia, Nicaragua, Sri Lanka, Tanzania, Zambia, Zimbabwe and Vietnam.

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