KOTMALE – Environment and Earth Structures

Commenting on the possibilities of the danger to the ecology by building the Kotmale dam at its existing site and also on the instability of the geological structure in the area. L. Alexis wrote as follows in an issue of "The Ecologist" in June 1984.

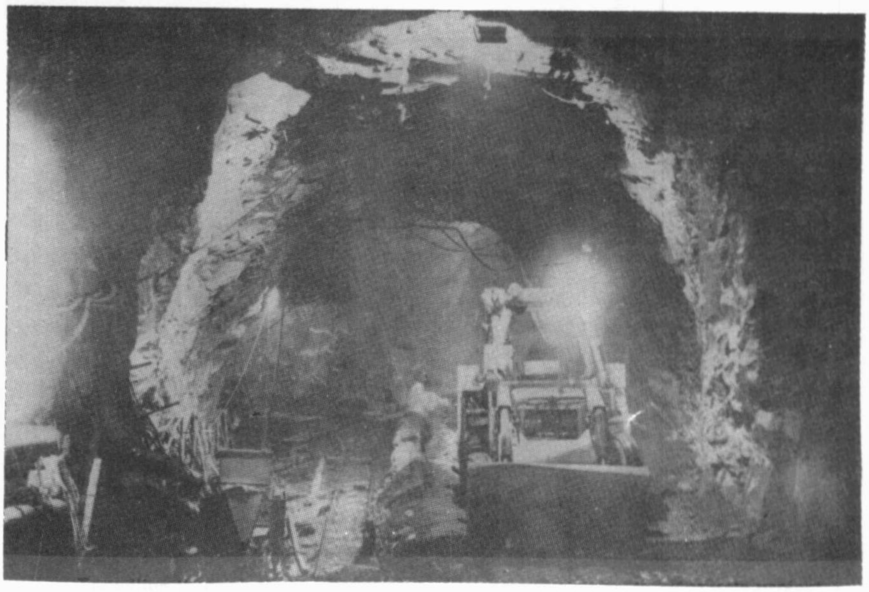
This dam is being constructed by the Swedish construction agency SKANSKA, which was awarded the contract without any competitive bidding.[1] Kotmale dam was going to be completed in 1984. However, after discovering limestone caverns beneath the origianl site, the entire project was moved 200 metres downstream. Now the expected completion date is February 1985.[2]

How a major hydroelectric dam could have been sited in such an unsuitable place is still uncertain. Pat Sadler, the chief resident engineer of the scheme, has said, "There's been a lot of geological studies done on this project in the past, but no one appeared to have co-ordinated the results of them and drawn the appropriate conculsion."[3] As another engineer put it, "The original site was not an obvious choice."[4]

A 1954 report – commissioned in 1947 after heavy rains washed away 200 villages and caused serious landslides in the Kotmale Valley – states:

"In the Kotmale Valley we have a rather unusual combination of geological, structural and topographical features which give rise to a strong tendency towards slope failures. Over these features man has no control . But superimposed on these are a different set of conditions for which man is responsible and which have increased the potentialities for slope falilures inherent in the area. These are in the main: (1) Removal of forest cover on the upper slopes of catchments, and from talus debris at the foot of scarp faces; (2) Inefficient drainage of steep slopes under plantation; (3) Ponding of water for paddy cultivation on terraces above unstable slopes."[5]

A 1979 report on the geology of the Kotmale area also warned against earth slides. The report states, "An investigation of the stability of the sides of the reservoir is necessary, in particular to the dam on the left bank. Slides of overburden and weathered rock are most likely to occur from the rim of the reservoir, and rock slides are a possibility. Slides are most likely to occur after heavy rains, and also after a sudden drawdown.[6]



Travelling through the Dumbara rocks for construction on the Kotmale project

A 1981 report details similar problems at the newly chosen site;

"The panel identified a variety of adverse geological features such as unstable soil and rock masses in the reservoir area, solutioned and cavernous limestone in the reservoir and below the dam site and deep and irregular weathering of rock or faults. The potential problems considered were reservoir landslides, leakage of water either into adjacent valleys or beneath the dam, sliding stability of the dam under varying conditions and the potential for piping around the foundation."[7]

In June of 1982, a major earthslip occured after heavy rains, threatening the entire project.8 After several tense days when the earthslips was monitored round-the -clock, some measures (including rock bolting and excavation) were taken to reduce the danger of the slide. Should an earthslip occur after the reservoir is filled – an ever present possibility – the consequences would be severe.

Construction 'mishaps' such as those described above have played havoc with the costs of the project. According to a 1981 World Bank Report on Sri Lanka, "Of all the projects in the Mahaweli Programme the cost of the Kotmale project has risen the most since 1979". The report attributes this "to the delay in implementation caused by the shifting of the dam site and continuing design changes."[9]

A survey undertaken in 1979 to determine the effect of the dam on those areas which would be submerged, revelaed that 1,410 acres of paddy would be flooded along with 3,744 acres of highlands; that 13,000 people would have to be moved; and that Rs. 29 million would have to be paid out in cash compensation for damage to private property other than land.[10]

The NEDECO Report estimated that the economic losses due to inundation would be 20 million rupees. However, the inundation of archaelogical and of natural reserves has not been valued separately.[11]

(Source: The Ecologist, Vol. 14, No. 5 - 6, 1984).

References

1. "Island Newspaper", 4 March 1982.
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3. Ibid, p. 29.
4. Ibid, p. 29.
5. R. Maclagan Gorrie, Report on Kotmale Landslips and adjoining River Catchments, Ceylon: Government Press Sept. 1954, p. 12.
6. Ministry of Mahaweli Development, "Mahaweli Projects and Programme" 1979, p. 6.
7. Ministry of Mahaweli Development, Mahaweli Porjects and Programme, Colombo: Information Service Ministry of Land Development, 1981, p. 25.
8. "Sun Newspaper" 21 June 1982.
9. "Island" Newspaper, 4 March 1982.
10. Ministry of Mahaweli Development, "Mahaweli Projects and Programme", 1979, p. 7.
11. NEDECO, Annex P vol. 5, p. 13.

KOTMALE PROJECT

The third of the Headworks in the Mahaweli Development Programme was commissioned at the end of August this year. The previous Headworks namely, the Victoria Project, was commissioned only two months earlier, while the next of the four Headworks, the Randenigala Project, is due for commissioning by mid 1986.

Both Victoria and Kotmale projects have had their own special features and challenges. The Kotmale Project is the uppermost of the major Headworks Projects being undertaken for implementation. Its function is to develop the hydro electric potential of a major tributary of the Mahaweli Ganga, namely the Kotmale Oya. It will also increase the amount of irrigation water available at Polgolla through regulation of flows in the Kotmale Oya. Preliminary studies were carried out on the Kotmale Project by United States Operation Mission for the U.S.A.I.D., followed by the UNDP/FAO – Irrigation Department joint "Survey" of the Land & Water Resources of the Mahaweli Ganga. Futher studies were carried out between 1973 and 1976 and in 1978 a team of British consultants together with the Central Engineering Consultancy Bureau prepared the final designs and provided Consultancy Services for the execution of the project.

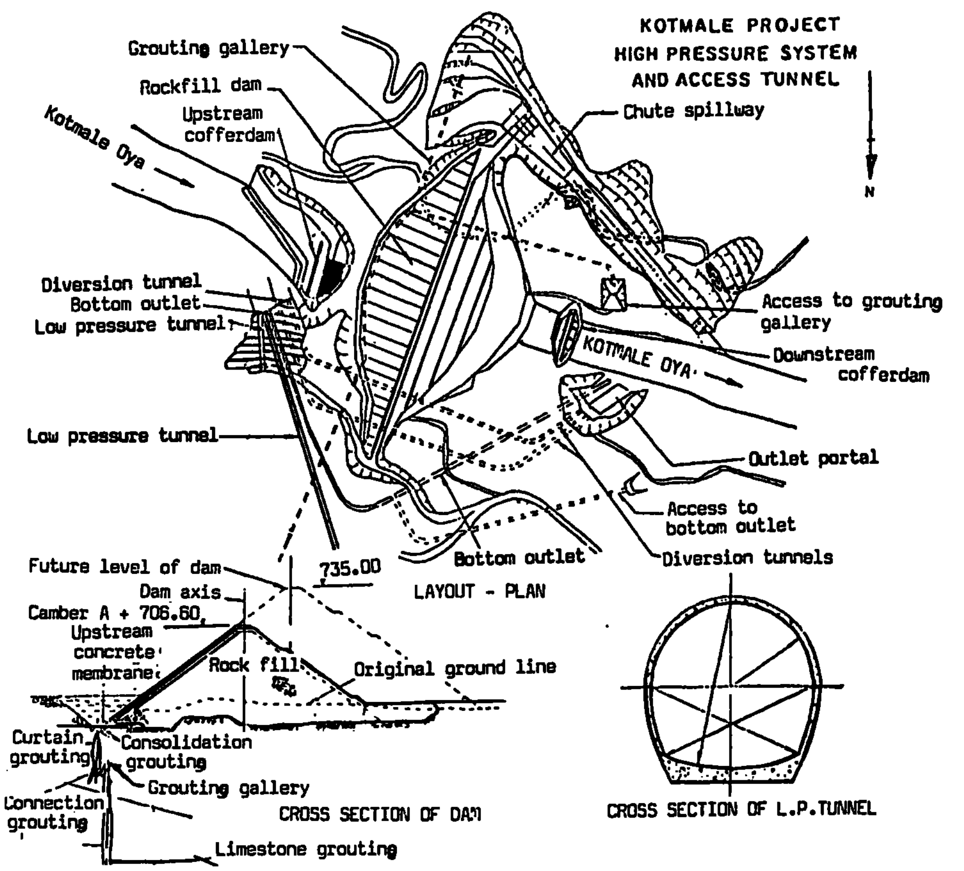
The First stage of the Kotmale dam was to impound the waters of the Kotmale Oya and form a reservoir of a 174 million cu. meters (141,000 acre-feet) capacity. The water stored in the reservoir is to be used for generation of electricity in an underground power plant after which the water will be led into the Mahaweli Ganga. A system of tunnels about 6.6 km (4.1 mls) in length convey the water from the reservoir to the underground and power house and machine chamber. In the machine chamber there are at present two 70 megawatt Vertical Francis turbines coupled to generators to provide electricity. A third similar machine is due to be added in 1986.

The dam site is at Kadadora located about 6.6 km (4.1 mls) upstream of the confluence of Kotmale Oya with the Mahaweli Ganga. The power house is underground and situated in the belly of the Atabage Mountain, about 6.4 km (4 mls) downstream of the Kotmale Oya – Mahaweli Ganga confluence. The project headworks lie on the right bank of the Mahaweli Ganga and is partly in the Kandy district and partly in the Nuwara Eliya district.

This is the first big dam on the river (ie. the one furthest up the river) and it may be observed that the intention of constructing of a dam at this point is to use the drop or head of the Mahaweli to generate hydro electric power at a number of sites along its length. The total extent together with the main tributary, the Kotmale Oya, that can be exploited before it reaches the sea is a head of 2,130 metres. The water released through the turbines or spillways of one dam will be directed to another one downstream and similarly passed through six or seven reservoirs before reaching the sea. In some cases the water would be extended for irrigation while in others it is for both irrigation and power and there are possibilities of a conflict in these interests and priorities between agriculture and industry. "New Scientist" raising this issue stated that having one system for both needs is cheaper than building one system for each. But it can lead to problems in a developing country such as Sri Lanka where industrial needs for energy may conflict with agricultural requirements for irrigation water. (See Box)

Geology

The Kotmale area has had a history of earthslips, landslides and other geological disturbances. Owing to this it was necessary to exercise



great care in the design of the various features of the project. (See Box). Soon after construction work was awarded and during the early stages of the dam construction, when excavations of the riverbed were in progress, the presence of a limestone layer underneath the bed rock below the dam and extending up to the reservoir, was discovered. These and other adverse features led to thorough investigation of all the geological features in order to see whether there are practical problems like landslides above the reservoir leakage of water through the dam foundation into adjoining valleys, earth tremors, etc. which could seriously affect the stability of the project. In mid 1982 a major earthslip was recorded at Kotmale and was the cause of serious concern and action for prevention of further slips (See Box).

A special panel of internationally renowned experts was appointed by the Ministry of Mahaweli Development, to examine all the geological data availabe, carry our further investigations and advise on the adequacy of the design proposed by the Consultants. The panel identified a variety of adverse geological features, such as unstable soils and rock masses in the reservoir area, solutioned and cavernous limestone in the reservoir bed and below the dam site, deep and irregular weathering of rock associated with strong lineaments representing faults. The panel considered that the problems could be handled within reasonable costs by adjusting the design in progress at that time, with some additions and modifications. Most of the recommendations have been incorporated into the design and the panels suggestions, regarding further investigations and monitoring of various aspects have been carried out or are being continued. These unforseen features resulted in a change of the dam's site and size and the delays increased the cost of the dam appreciably.

Project Features

The original proposal was to have the dam at a crest elevation of 735m (2411 ft.). However on the recommendation of a Panel of Experts the dam had to be shifted about 300m (980 feet) downstream in order to locate it on better foundations. Due to this change from the original site it had become necessary to build the dam to a lower crest elevation of 706.5m (2317 feet) in order to limit the expenditure to be kept within the available resources. According to one engineering viewpoint, however, this scheme increases the risk of flooding and damage by lowering the level of the cofferdam.

Organisation of Construction

In accordance with the agreement between the Governments of Sri Lanka and Sweden, made in 1978, the civil engineering of the project was organized through a series of negotiated contracts with the Swedish construction firm Skanska Cement guteriet.

Earthslips at Kotmale

The recent occurence of a major earthslip at the Kotmale power project worksite has brought this unique multi-purpose reservoir under the Mahaweli Accelerated Programme back into focus of public attention.

The landslide which occured over the slope of the newly erected tunnel intakes at Kadadora above the proposed crest level of 706 metres of the dam was the first major occurence of this nature at the Kotmale power project worksite since the commencement of the project in 1979.

We were assured by the CECB chief Dr. A. N. S. Kulasinghe that the landslide had been checked and practically arrested. From a slippage of about 20 millimetres a day the rate of slippage was now around 1 to 2 milimetres a day. 'You can't stop these things immediately or you could create other problems', he said. However, the remedial measures that were being implemented would check even this fractional movement completely.

The rains had caused the earth to slip by about 600 feet and large cracks on the earth were still visible. The earth that had fallen had slid dangerously close to the mouth of the tunnel. The first signs of mass movement we were told, had been observed on June 1, 1982 when cracks appeared beside the dam deviation road above the slope which had been excavated.

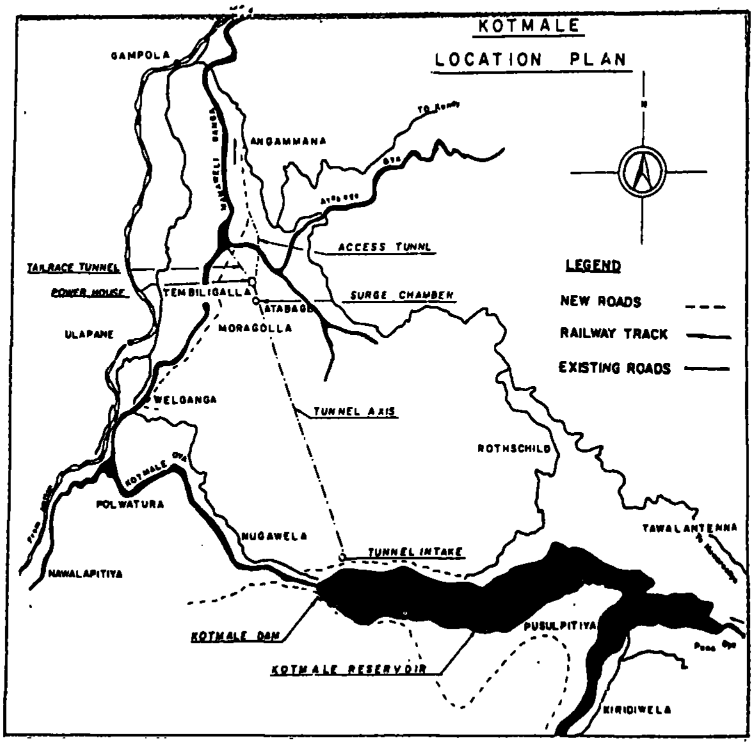
These cracks had been kept under observation and immediate instructions had been given to diversify all water entering the unstable slope from adjacent water courses. A rock filling bund erected at the toe of the slip and additional drainage measures at the upper-most elevation point, along with careful monitoring at three levels of the slope had helped to arrest the movement considerably.

Near the dam itself enormous construction machines were helping to drip six-metre long steel rock dowels to the two slabs of rock where movement is still being detected. Around 200 of these dowels will anchor the rocks firmly to the ground and prevent further slipping, we were told. However, the possibility of a major mass movement still exists and all parties on the site are well aware of this and are taking precautionary measures.

On the opposite side as well (area 5) where the Mahakanduru Oya has now been diverted a slip had begun and remedial measures were being taken. Here too we could see rock filling operations in progress and efforts to remove unstable overburden from the top.

Source: The Sunday Observer, July 25, 1982.

Main Features of Kotmale Project



The Dam

The dam has been constructed out of rockfill obtained from two quarries at the site on either banks above the reservoir levels. The rock had been laid on the cleaned river bed in layers and compacted by heavy machinery, including vibrating rollers. The dam has been made impervious by the construction of a reinforced concrete membrane on the upstream face of the dam. This membrane is of a 300 mm thickness (1. ft.) at the crest and increasing to 474 mm (1.6 ft) at the bed level plinth. The rock underneath the dam has been made impervious by a grout curtain of cement grout injected from the surface. In addition to sealing off the limestone bed under the dam foundation, a grouting tunnel had been constructed beneath the dam and grout had been injected across the limestone layer. In order to commence work on the dam the river had to be diverted. An upstream cofferdam which would not be overtopped by floods up to 1 in 15 year frequency was built and the river water was diverted to flow through two 9.2 m (30 ft.) diameter concrete – lined tunnels excavated in rock on the right bank. These tunnels were capable of discharging a 1 in 100 year flood of 1,700 cumecs (60,000 cusecs). One of the tunnels has now been permanently plugged with concrete (after the constructing of the dam) whilst the other serves as the intake tunnel to the Bottom Outlet. The Bottom Outlet is an emergency outlet to release water from the reservoir and thereby lower its level or as an irrigation by-pass without developing power. Water can be led through the second diversion tunnel which is the bottom outlet into a control chamber provided with valves to discharge upto 90 cumecs (3,200 cusecs) from the reservoir.

Provision for flood discharge is over a gate-controlled chute spillway at the left abutment of the dam. The spillway control structure has 3 radial gates 14m (46 feet) wide by 15 m (49 feet) effective height, that are programmed by computer to open and release flood waters. It has been constructed to discharge a 1 in 1000 year maximum flood of 5500 cumecs (196,000 cusecs) with only 2 of the 3 gates opened. A flip bucket at the lower end of the concrete lined chute will throw the discharge clear of the river banks into the centre of the river bed, to prevent scouring of river banks.

The intake to the tunnel carrying water to the power station is located on the right bank immediately upstream of the dam. At its entrance is a screen which could be raised above the water level for cleaning. About 165 m (540 feet) downstream of the intake is found a bulkhead gate located in a vertical shaft. By lowering this gate the tunnel can be dewatered for inspection of the tunnel.

Tunnel System

The first part of the tunnel system carrying the flow from the reservoir is a 6.4 m (21 feet) equivalent diameter concrete lined horse-shoe shaped low pressure tunnel. This is 6.6 km (4.1 miles) in length upto the upstream surge shaft, which protects the turbines from undue pressure shocks due to flow vairations in the tunnels. The surge shaft is a 15 m (49 feet) diameter concrete – lined vertical shaft constructed directly over the tunnel and connected to it by an orifice. The surge shaft has a gate by means of which the lower portion of the tunnel leading up to the power station can be dewatered. In this area are found the two downstream tunnel construction adits, one of which has been plugged with a steel bulkhead gate which can be opened when the tunnel is empty for inspection. From the upstream surge shaft water is conveyed to the turbines in the power station by a 400 m (1300 feet) near horizontal concrete lined tunnel and a 120 m (390 feet) long circular 5.5 m (18 feet) diameter concrete lined high pressure shaft steeply inclined. The bottom half of the high pressure shaft is steel lined. Near the power station the water is diverted into three pipes of 2.1 m (6.9 feet) diameter that supply the turbines.

Power Station

The power station which houses the electricity generating equipment is an underground cavern 67 m (220 feet) long by 20 m (66 feet) wide by 38 m (125 feet) high. This is the first underground power plant in Sri Lanka. The roof of the cavern is the shape of ar arch and the rock is secured in place by rockbolts and shotcrete. The near vertical sides are unlined but rock-bolted for safety. This excavated chamber houses 2 of the 67 Mega Watt generating units driven by vertical Francis Turbines. In 1986 a third similar unit is due to be installed. The chamber houses a part from the generators and turbines a 160 ton overhead travelling crane, 3 turbine inlet valves, drainage and dewatering systems, control boards, an office for maintenance staff and ancilliary equipment for the safe operation of all the machinery installed inside.

Machine Chamber

The main electrical cables from the generators and auxiliary cables are carried upto the switchyard which lies on the surface above the power station cavern through a cable cum ventilation shaft. This is a vertical shaft excavated in rock located towards one end of the machine chamber. It is 8.1 m (26.5 feet) in diameter and 200 m (656 feet) in height. The ventilation of the machine chamber is provided by air forced down ducts provided in this cable shaft. There is a hoist in this shaft for inspection and maintenance of the cables and to provide an emergency exit from the power station.

The first contract signed in August 1979 was the Initial Works Contract for the construction of Engineers' and Contractors' camps, access roads, diversion tunnels, quarry investigations, access tunnel to the underground power station etc. Most of this work was completed by the end of 1982. The next contract signed in December 1979 was for the construction of Underground Works such as the tunnel, the underground power station, the surge shafts, tail race tunnel and ancilliary works. All these works were completed by the end of 1984 except for the lifting arrangement for upstream Surge Shaft gate. The third contract signed in April 1982 was the reservoir works contract in which the main items of work were the cofferdam, concrete faced rockfill dam, spillway, and the bottom outlet.

Normal access to the power station is gained from a separate access tunnel 490 m (1650 feet) long which has its entrance portal close to the bridge across the Atabage Oya on the newly constructed access road. There is yet another tunnel from the machine chamber. This is the tailrace tunnel and it conveys water after passing through the turbines to the Mahaweli Ganga. It is 6.4 m (21 feet) in diameter and 635 m (2080 feet) in length. This tunnel is designed to flow full and has a downstream surge chamber to limit pressure shocks due to sudden variations in flow. At the downstream of each turbine draft tube gates are provided to isolate the machines from the tailrace for maintenance purposes.

Switchyard

The power generated by the machines in the underground chamber is transmitted to the national grid through a 220 KV Substation at a switchyard located on the surface above the machine chamber. This switchyard accommodates transformers and switchgear for the generators and the transmission lines to Colombo through Biyagama. The power lines from Victoria are also being routed through this sub-station. The control building housing the power station. control room and offices for the project and the ventilation building housing the ventilation equipment are all located in this switchyard.

The contractor was able to complete construction work on the rockfill dam ahead of schedule, and the "topping up" was ceremoniously completed on March 31, 1984. The construction of the upstream membrane commenced in May 1984 and was completed in October 1984. There were delays at the beginning on spillway construction but all work on the contract were completed and the spillway gates kept in the open position at the end of December 1984.

The electro-mechanical features of this project, such as the power plant turbines, generators and ancillary equipment; switchyard equipment such as transformers and switchgear; tunnel and spillway gates; bottom outlet valves and gates were obtained under 9 contracts through another Swedish Contractor ASEA. Most of the equipment are of Swedish manufacture, though ASEA obtained some steel gates from the French manufacturer NEYPRIC and a few items from Switzerland.

The spillway gates measuring 14 m (46 feet) wide by 15 m (49 feet) high are the largest ever to be erected in Sri Lanka. By the end of 1984 most of the electro-mechanical equipment was erected. At the reservoir areas three spillway gates have been erected and are capable of operation. The valves and gates in the Bottom Outlet control chamber and the tunnel intake gate have been erected and are operational. At the Power Station the first generator was due for commissioning in February 1985 and the second from April 1985. The transmission of power from Victoria through the Kotmale switchyard was achieved in September 1984.

New Proposals

Towards the end of 1983 the civil contractor SKANSKA submitted a proposal for the accelerated completion of the reservoir works so that impounding of water could commence in November 1984, four months ahead of the target date. The Government accepted this proposal after which the contractor stepped up progress to achieve this target. The main advantage of the proposal was that early completion of the dam enabled the impounding of the 1984/1985 monsoonal flows for power generation in March 1985. Otherwise by the latter date the flow in the river would have been insufficient. The Mahaweli Authority agreed to pay a bonus of Rs. 10 million per week as an incentive to the contractor for earlier completion, upto a maximum of Rs. 160 million.

The Government decided in 1984 to instal the third generator also at the Kotmale Power Station. The electro-mechanical contractor ASEA submitted a proposal which was accepted by the Government and a firm order was placed for the manufacture and installation of the third machine.

Programme for 1985

Most of the work on the Kotmale project was completed in 1984. The work carried over to 1985 on the civil construction side were the completion of wave-wall and roadway on top of the dam, surfacing of the access roads in the vicinity of the dam and power-station, additional grouting, backfilling to the concrete spillway chute wall and other minor works. The electro-mechanical contractor ASEA had completed erection and testing of generators 1 and 2. At the dam ASEA was completing erection of the 3rd spillway gate and the electrical circuitry so that the spillway gates could be raised or lowered by computer or by push button manual controls.

Employees

The contractors, Skanska and ASEA employed over 200 Swedish

SRI LANKA'S KOTMALE HYDRO PROJECT

E. M. Gosschalk *(Sir William Halcow Partners)* Eng. Consultants and A. D. Longman *(Kennedy and Donkin, Westbrook Mills Eng. consultants)*

Geology

The dam and reservoir site are under lain by metamorphic rocks of pre-Cambrian age and comprise gneisses and charnockites with salient limestone beds and minor quartzites. Structurally they form an anticlinorium plunging to the northwest, whereas the river runs from east to west in the area of the dam site. The dam site itself lies on the southwestern limb of an anticline resulting in the dip of the beds being approximately downstream with a dip angle of about 15^{o}. Major structural features of the area are strong lineaments, either master joints of faults, some of which extend for many kilometres.

Site investigations have been carried out at Kotmale since 1961 with more intensive work in 1979 and 1980. As a result, certain adverse geological characteristics of the dam and reservoir site have been identified as follows:

* unstable soil and rock masses forming the banks of the reservoir and at the project site;
* a thick bed of crystalline limestone underlying the dam site and outcropping in the reservoir, which is a potential cause of leakage from the reservoir;
* the possibility of reservoir-induced seismicity particularly in view of the strong near-vertical master joints and faults in the reservoir areas; and
* the presence of tectonically foliation shears beneath the dam foundations and in the project area generally.

Special investigations were put in hand to examine these adverse geological characteristics. The design of the various project features has been developed to deal with them.

The final proposals, including moving the site of the dam some 200 m downstream were adopted after review of the geological findings and the engineering proposals by an international Panel of experts convened by the Ministry of Mahaweli Development in May 1980.

Dam and Reservoir

The dam is 87 m high above river bed level, and has crest length of 600 m. The crest level of the dam is at an elevation of 706.5 m and it impounds a gross storage volume of 174 x 106 m3 at the top water level of 703 m. The live storage above the minimum operating level at elevation of 664.5 m is 152 x 106 m3. As the height of the dam is somewhat less than the economic height for the site as a result of financial restrictions, provision has been made in the design to raise it at a later date to about 28.5 m.

The dam hhas been constructed of rockfill obtained by quarrying rock at sites above the reservoir level on the left and right banks immediately upstream of the dam site, and is made impervious by a reinforced concrete membrane on its upstream face. It is the first dam of its type in Sri Lanka.

The rock beneath the dam has been made impervious by a grout curtain of cement grout injected from the surface. Silicate grout was also used in the central section where cement grouting did not achieve a satisfactory seal. In addition, to ensure that no leakage occurs through the limestone bed beneath the dam foundations, a grouting tunnel has been driven beneath the river bed and a grout curtain constructed across the limestone bed.

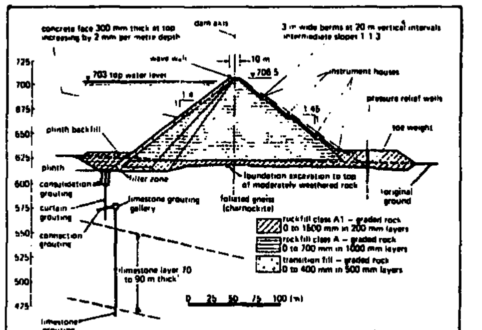
River Diversion

Two 92 m equivalent diameter D-shaped concrete lined tunnels under the dam's right abutment carried the flow of the Kotmale Oya round the dam site during constuction. An upstream cofferdam diverted all floods upto a 1-in-15 year frequency through these tunnels and the upstream part of the main dam was constructed at an early date to divert floods upto a 1-in-100 year frequency before major construction work on the dam fill began.

The Mahakandure Oya, a small left-bank tributary entering the Kotmale Oya immediately upstream of the dam site, was diverted during construction by a 20 m tunnel under the dam's left abutment.

Impounding commenced by the lowering of 70t slip gate to close the intake to the second diversion tunnel. At this time the first diversion tunnel, the Mahakandure Oya diversion and the upstream adit to the low pressure tunnel had to be closed by constructing concrete plugs. Construction of the plug in the second diversion tunnel then bagan. Until the reservoir rose to spillway crest level, the only remaining control was the bottom outlet.

Source: Water Power & Dam Construction March 1985.



A typical cross-section of Kotmale dam.

nationals during the peak construction period. The contractors staff were housed in a well laid out camp comprising 70 houses, a school for young children, club-house with swimming pool, tennis courts and other recreational facilities. The engineers camp which housed the staff of the consultants was built a short distance away and accommodated 18 foreign engineers, 24 Sri Lankan engineers, 20 technical officers and several other grades of staff. The labourers were housed in two camps in the vicinity of the work sites. During the construction period the total employment created was about 4500 men.

Cost Estimates

The estimated cost of construction in the early 1970's was Rs. 1,035 million of which the local component was Rs. 470 million and the balance Rs. 565 the foreign component. The allocation for power was Rs. 665 million and for irrigation Rs. 370 million. This estimate was consider-

We duly acknowledge as the main source for much of the basic data on the Mahaweli Projects the publications of the Ministry of Lands and Land Development and Mahaweli Development, particularly "Mahaweli Projects and Programmes 1980 to 1985".