

VICTORIA PROJECT

Victoria Multipurpose Project was the second of the four large multipurpose projects to be completed, when its dam and hydro electric scheme were formally inaugurated in April this year. This project is one of the key elements in the Mahaweli Master Plan. Following a study in 1962 of the resources of the Mahaweli Ganga basin by the Hunting Survey Corporation of Canada, a Master Plan for the development of the basin's hydro electric and irrigation resources was completed by the FAO and UNDP in 1968. This Plan identified the Victoria Falls site as a prime location for a dam and a storage reservoir. A feasibility study commissioned in May 1978 and completed early in 1979 formulated a project to harness the Mahaweli's resources for both power and irrigation. This project included:

- * the Victoria Dam (122 metre or 400 ft high concrete arch and measuring 507 metres (or 1,663 ft along the crest)
- * a power tunnel (5.7 kilometre long: 6.2 metre diameter)
- * a power station (three 70 MW machines—initially with provision for 3 further 70 MW machines)
- * the diversion works at Minipe, a transbasin canal, additional storage reservoirs and development of irrigated agriculture in the area known as System C.

The study also considered closely the effect of other existing and planned storage and diversion schemes on the Mahaweli Ganga. Several specialised foreign consultants, assisted by Sri Lanka's Central Engineering Consultancy Bureau, established the feasibility of the Victoria Project and demonstrated:

- * The economic advantages of exploiting the maximum feasible height of the dam permitted by existing upstream river control works.
- * The optimum power station tail-water level to correspond to that of the next projected reservoir downstream at Randenigala.
- * The requirement to design the Victoria Project as a staged development so that the installed capacity could be doubled in the future when the power station operates at a period of peak power demand.
- * The need to build an extensive transmission system at the higher voltage level of 220 KV to transmit power from the various Mahaweli Developments to the load centres.

Of the various alternative types of dam considered, it was decided that a concrete arch dam would be the most economic solution if the geological conditions were suitable.

Exploratory work, under the direction of the Irrigation Department, provided evidence of the rock and geological conditions in the gorge. This was supplemented by a concentrated programme of drilling, testing and geophysical investigations for which a British specialist contractor was appointed. Using equipment flown to Sri Lanka the contractor, Soil Mechanics Ltd., carried out the major part of these supplementary investigations covering the tunnel line and the power station site as well as the site of the dam in the last quarter of 1978. By the beginning of 1979, it was possible to confirm the feasibility of an arch dam for the site. The dam location selected was between the Hulu Ganga confluence and the Victoria rapids across the Mahaweli. The catchment area at this dam site is 1,869 sq.km. (730 sq.miles).

By the middle of 1980 the main Civil Engineering and Mechanical Plant

contracts had been awarded and work was started on the dam. By early 1981, however, initial work was falling behind schedule with "soft rock" problems halting work. (see box)

Construction of the 122 metre high arch was divided into 36 blocks and there were reports that under the first of these unsuitable material had been found. These reports stated that the sites overlying gneiss contained a limestone intrusion, and at the interface of these a thin laminated layer of weather black rock had been discovered. This material varied in nature but was found to be fundamentally a hornblende schist containing, among other minerals, biotite. Apparently, layers were flaking off when softer samples of the rock were squeezed by hand.

"The material is not suitable to found a dam on" Dr Paul Back, a partner of the dam's consulting engineer Sri Alexander Gibb & Partners told a correspondent of the British journal "New Civil Engineer", early in 1981. "It is being removed and replaced with dental concrete" he said. At this stage contractors required several weeks for additional excavations and started concreting only by March 1981, thus putting back work by 6 to 8 weeks although this delay was covered up as work progressed.

The river diversion through the temporary opening in the dam was affected on target in January 1982; and the handing over of the spillway blocks to enable the contractors erecting the automatic radial gates to proceed with this work was achieved on schedule in November 1982.

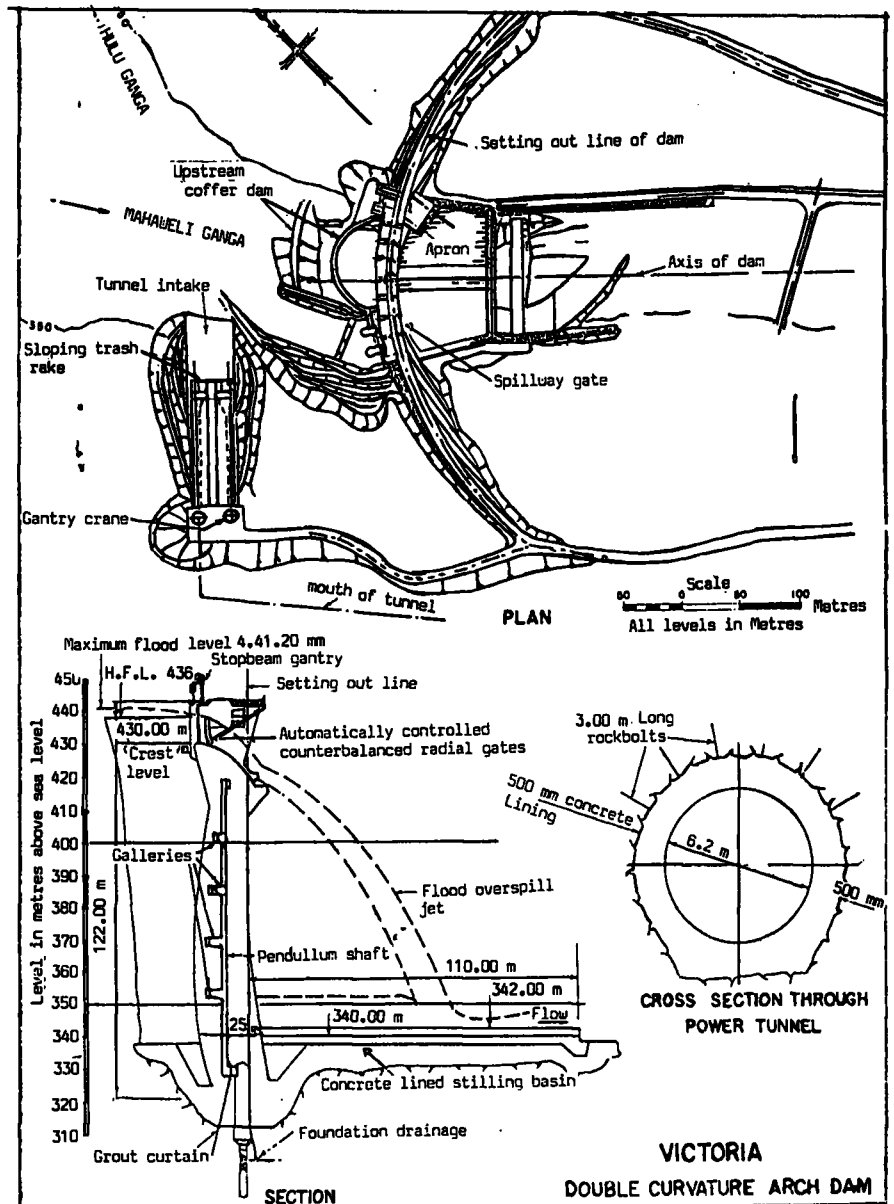
A feature of the automatic radial gates is that they do not have to depend on the power supply to be opened; they open when predetermined water levels are reached and electric power is required only to close the gates. Eight radial gates, 12.5 metres (41 ft), wide and 6.5 metres (21 ft) were provided. The gates over-spill with an effective width of

100 metres (328 ft) is capable of passing a discharge of 8,200 cu. metres per second (289,542 cusecs) under a head of 11 metres (36 ft). Two low level sluices have been provided in order to make provision for drawing down the reservoir at initial filling or at any subsequent time and also to pass silt which may accumulate immediately above the dam. Other features are a circular tunnel 6 metres diameter (19.7 ft) and concrete lined throughout, and a 21 metre (69 ft) diameter concrete lined chamber for dealing with surges in the tunnel.

Work on the tunnel, power station, hydraulic equipment contracts and on the electrical and mechanical plant contracts proceeded concurrently with the work on the dam. The rate of concrete placing reached record levels during 1983 using modern methods of mixing and placing concrete, such as travellers on high lines above the dam called "BLONDINS". More than 50 percent of the total volume of dam concrete was placed in that year and this enabled the impounding of the dam on target in early April, 1984.

The initial setbacks to the construction programme were due to delays in mobilising the necessary funds and setting up the construction facilities for the dam. Next, in the foundation excavation work unfavourable geological conditions resulted in additional delays. Measures were therefore taken to accelerate the construction programme by providing incentives in order that the contractors could bring in extra resources.

The excavation of the tunnel was interrupted due to poor geological conditions in a portion of the tunnel roof which collapsed. (see box) The re-alignment of the tunnel trace in this reach was necessary and also a relocation of the surge chamber to avoid the bad patch. The final "hole through" was achieved on November 17, 1982. Concrete lining of the tunnel was slow during the first half



of 1983 but it gathered momentum thereafter. The grouting work on the tunnel was ready for filling by July 12, 1984.

The main contractor Balfour Beatty Nuttall faced more than one set back on their work at Victoria and there were fears in 1981 whether they could pull through successfully. The journal "New Civil Engineer" in an issue of December 1981, drew attention to the plant nightmare that racked Victoria tunnel. This journal reported that the joint venture BBN was battling to recover from a series of difficulties "which had both jeopardised timely completion of the huge Victoria dam

project in central Sri Lanka and called the contractor's abilities into question. From the start, BBN knew that the programme for the double curvature arch dam—financed largely by a £ 100 million grant from Britain's Overseas Development Agency—was extremely tight. A host of early problems, mainly with mobilisation of plant and labour, led to a state early in 1981 when many people doubted whether recovery was possible."

"Management changes and a colossal effort stemmed the rot, and the contractor met its first target date—river diversion by mid January 1982. This was achieved despite dis-

Victoria Tunnel Fault

Rock on the southern outfall drive had proved remarkably good. Trouble had been expected where the line crossed a limestone bed, but none occurred.

Then last summer, with about 600 m of the drive completed on a steady 1 in 20 uphill slope through quartz gneiss, a probe hole driven ahead of the face detected water under this high pressure. Grout was pumped in, but after advancing a further few metres yet more grout had to be injected. In all 233 tons of grout were used to form a shell round the tunnel.

Tunnelling was resumed, but after firing the second round on August 1, 1981, the tunnel boss saw water to flow from the face. He immediately withdrew his men and equipment, just in time to avert a catastrophe as tonnes of rock and water broke down onto the area where they had been working, the water cascading through the tunnel and out of the portal.

Returning to the face, 24 m of tunnel were found to be full of broken material washed out of an unforeseen fault. When the flow eventually subsided after four or five days, some 100,000m³ of water were reckoned to have flooded out.

Removal of the debris began, while shotcrete, mesh and extra rock bolts were applied to the roof: but as fast as material was removed, more poured in from the collapsed roof ahead. To form a safe base from which to advance, seven steel arch ribs were erected at 1m spacing and concreted, while falls continued.

From cored holes drilled ahead, the fault was found to be 5 m wide with broken rock either side and several secondary faults, crossing the tunnel line at 45 degrees and laying back over the tunnel at 70 degrees dip. As more material was cleared, a "chimney" could be seen on the left shoulder some 10m ahead of the

last rib. Its height was subsequently estimated at around 50m though understandably no one was going to take a close look.

Fragments of rock "as big as a desk" continued to tumble down. Twice, further major falls filled the face, with muck back throughout the ribbed length.

Careful mucking out with a Hymac backacter working from the protection of the ribs removed around 3500 m³ and allowed a bulkhead to be erected against the front of the ribs. The tunnel was then concreted to the shoulders. The crown and part of the cavity above were then filled by blowing concrete through a placer pipe inserted through a 25mm hole drilled from behind the ribs.

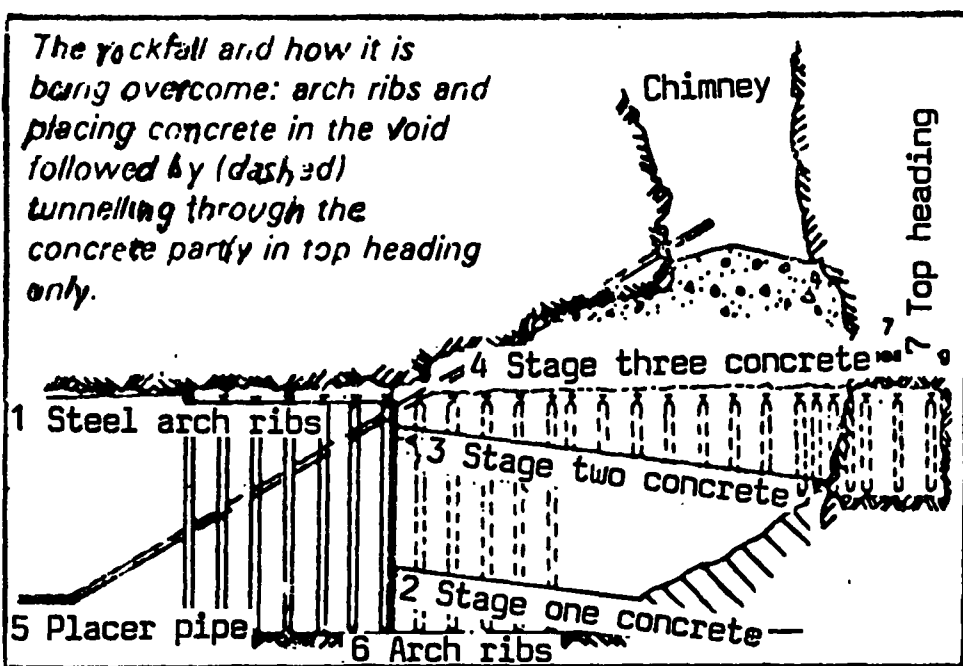
With full protection at last installed, BBN started to tunnel through the concrete. The first 5m were advanced by very careful blasting—three or four times per metre—and installing five more arch ribs. The contractor then opened a 3m by 3m top heading to investigate the ground ahead, mucking

out with a small Eimco 622 tracked overloader originally brought in for work on the dam. The crown member of the heading's protective steelwork will eventually be incorporated into the full size ribs as the tunnel is opened out, so avoiding any unnecessary ground disturbance.

When NCE visited the site earlier this month the heading had penetrated the fault beyond the concrete. The face was timbered up, with removal of only one board at a time to allow mining by hand of the soft "gung" behind. Meanwhile, a series of probe holes were providing drainage to prevent any further water-pressure build-up. By the end of the week, 13 ribs had been completed and the heading was entering better ground.

However, problems are far from over. Probes indicate a 60m length of bad faulting and BBN estimates that, even with no further setbacks, it will be mid March next year before the bad section is cleared. And no one knows what further faults may be encountered on the remaining sections.

Source: *New Civil Engineer*, 17/24 December 1981.



covery of unexpected limestone cavities under the dam foundation and downstream apron, and a flood which inundated the foundation works in September 1981.

Next, the 5.8 km long power tunnel was causing concern. Delayed mobilisation and poor driving rates had already put progress well behind programme when a major rockfall brought the outfall drive to a complete halt. The tunnels could only be completed on time with a vast injection of cash."

These problems were finally overcome and on April 7, 1984 Sri Lanka's President closed the Victoria dam in a formal impounding ceremony which began the accumulation of water that built up to a 43.8 km reservoir storing 688m. One of the foreign engineers associated with the project commenting on this situation stated "the first flow of water through the 5.8 km tunnel engineered by Balfour Beatty Nuttal, to Sri Lanka's largest power station, built by Costain International, was the practical demonstration most needed to still local doubts about the scheme's feasibility. For the consulting engineers, Sir Alexander Gibb & Partners in association with Preece Cardew & Rider (part of the Ewbank Preece Organisation), the main contractor, Balfour Beatty Nuttal, and the 12 other British firms, keeping to the original April deadline was a matter of some relief. (At peak there were over 5,000 Sri Lankans employees directly engaged by BBN).

"It was of crucial importance to start impounding the reservoir by April 1984, and a 200 strong team of British and other experts working with Sri Lankan engineers toiled in the tropical heat for extended hours to meet the seemingly impossible deadline.

The entire contract and planning stage had been telescoped into 18 months, and the four year building time was short for a project of such scale.

From the outset the project had the advantage of the latest methods: The use of advanced computerised technology showed that the double curvature arch design was the cheapest of all alternatives, and geophysical tests confirmed the site's suitability. Models at Wallingford, near Oxford, Britain's leading hydrology centre, established the feasibility of the plan to divert the Mahaweli.

Balfour Beatty Nuttall found new ways of saving on contract time. Yet by early in 1982, with work well under way, the full scale of the difficulties involved in the project had begun to appear. Work slipped behind schedule as rockfalls and flooding showed how unexpected factors could further slow down a scheme that itself required the excavation of some 670,000 3^m of rock and soil.

New geological predictions warned of unsound rock that could occur in pockets at many places along the route of the tunnel. Sir Alexander Gibb decided to reposition the surge chamber and re-route the tunnel accordingly. The project went ahead, and the 6.2 m internal diameter tunnel is now a monument to human determination. By January 1984 the Victoria Dam was completed, 120 m above foundation level, 520 m long at the crest, (25 m thick at base and 6 m at the crest), containing 610,000 3^m of concrete. The creation of this huge artefact in only five years from

its planning stage has made the world take notice."

There were considerable setbacks during the mobilisation and initial construction period. The Engineer's evaluation of these delays totalled to an extension of the contract completion period by 4 months in Dam and Tunnel contracts. However, swift action was taken to correct this situation and a substantial additional bonus was built into the contract for completion of the construction within the original contract period.

The principal benefits from the Victoria project were hydropower production and providing a regulated source of water for irrigation. (see box)

Earlier all available flows in the Mahaweli Ganga were diverted at Polgolla, with a maximum capacity of 57 cubic metres per second (2,000 cusecs) for generation of hydro-power at Ukuwela. When the Victoria reservoir was completed the diversions at Polgolla were limited to the minimum requirements for irrigation only, thereby reducing the total hydro-power production at Ukuwela. This loss is compensated by extra energy generation from the higher heads available at Victoria and Randenigala. Studies reveal that about 600 GWH (600 million units) of firm energy can be generated while about 200 GWH of secondary energy can be added to the grid. Meanwhile, the regulated releases from Victoria (even without Randenigala reservoir) are capable of meeting the irrigation requirements for lands in Systems B and C where about 70,000 hectares (175,00 acres) of new lands can be developed.

At the price of oil prevailing in 1979, and basing the benefits from hydro-power production in comparison with energy produced by oil, the internal rate of return had been computed to be over 12 percent. Though the inflationary trends pushed up the investment cost of the Victoria project, the increase in price of oil

was at a higher rate, and this made the project more attractive.

Under the estimate of the Master Plan of 1968 the cost of Victoria Multi-Purpose Project was estimated at Rs. 740 million of which Rs. 155 million was allocated to irrigation and the balance to power. The foreign component of the cost was Rs. 350 million and the local component Rs. 390 million. The kind flow of foreign funds (£ 145 million) for the accelerated Mahaweli Program is given below:

- First release United Kingdom £ 4.75 million (for the feasibility studies, consultation and the supervision of construction).
- Outright Grant £ 100 million to meet of the costs of civil engineering headworks.
- Additional grant £ 13 million for further expenditure on civil engineering headworks.
- Additional grant £ 7.25 million for further expenditure on civil engineering.
- Commercial credit £ 20 million for electro mechanical equipment.

The total cost of Victoria Headworks is £ 145 million (foreign) and Rs. 2,511 million (local), making a total cost of Rs. 7,890 million. Balfour Beatty Nuttal were awarded the contracts for construction of both the dam and tunnel at a cost of Rs. 1,468 million for the dam and Rs. 645 million for the tunnel; while the Power House building contract, at a cost of Rs. 251 million, was awarded to Constain International Ltd.

The international journal "World Water" in its issue of May 1984 also made reference to this situation as follows: "Britain has given \$ 160M in aid towards dam construction costs - a figure which includes a top-up grant given last year to help meet

In 1981 costs on the Victoria Project were estimated at Rs. 7,456 million on the following basis:

	Rs. M.n
Dam	2,338
Tunnel	939
Power Station	259
Hydraulic Equipment	613
Physical Contingencies	512
Bonus on Civil Contract	60
Electro-mechanical Contracts	871
Cables	63
Transmission Lines	102
Consultancy	432
Digane Township	104
Work by other Agencies	328
Overall Contingencies and Parity Changes	835
	7,456

inflation costs. In total UK contractors have walked away with contracts worth about \$ 250M on this tied-aid project with BBN taking the lion's share with a \$ 180M dam contract".

There is no doubt that the value of expenditure increased considerably since 1978, just as much as the value of the revenue or returns on this investment were also expected to have moved up proportionately. An estimate published in the British journal 'New Scientist', earlier this year (see para) states that inflation pushed up on the Victoria Project from an estimated £ 700 million in 1977 to £ 2,000 million in 1983 (an almost 3 fold increase), while foreign grants have stayed more or less at the same level. This journal argues, however, that the cost to Sri Lanka has increased from an earlier estimate of £ 300 million to £ 1,600 million today. It also maintains that three countries, Britain Sweden and West Germany, are the most substantial foreign investors, and "the financial help provided by these countries will eventually return through payments to contractors and consultants. Britain, for example, has given £ 160 million in aid, and British companies have signed contracts to the value of £ 250 million." (See Box)