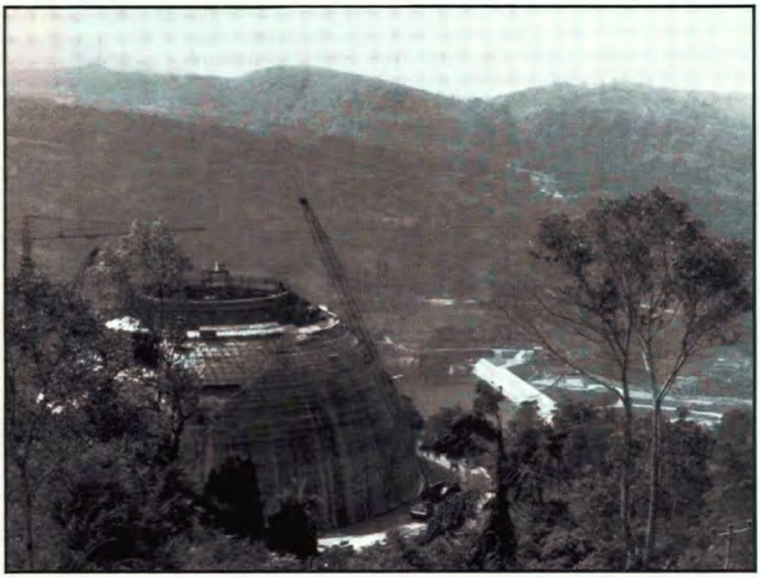
SIDA Evaluation Report, Infrastructure, Sri Lanka

1989/1

THE KOTMALE ENVIRONMENT

A study of the environmental impact of the
Kotmale Hydropower Project in Sri Lanka



By Dick Johansson

This study was carried out in Januari 1988 by Dick Johansson, Associate Professor in Tropical plant ecology.
Editing: Christer Pettersson

The views and interpretations expressed in this report are those of the authors and should not be attributed to the Swedish International Development Authority, SIDA.

Copies of this report can be obtained free of charge from SIDA in Stockholm.

The **SIDA Evaluation Report** Series is published by SIDA's Evaluation Section.

General Editor: Karlis Goppers.

Printed by: Fälths Tryckeri, Värnamo 1989.

ALLF: 171 8 201

ISBN 91-586-7102-1
ISSN 0283-0736

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY
S-105 25 STOCKHOLM: TELEX 11450 sida sthlm

SIDA Evaluation Report 1989/1, Infrastructure, Sri Lanka

The Kotmale environment

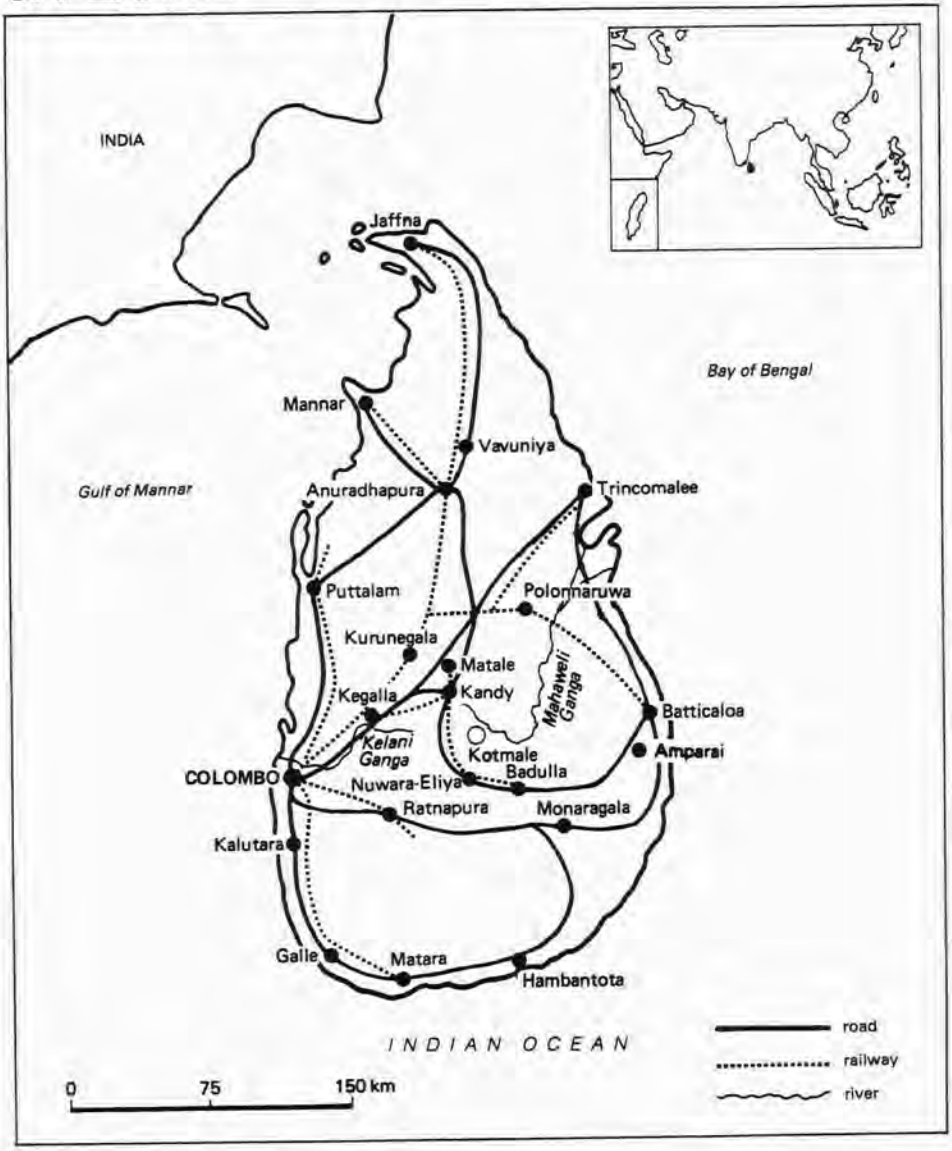
A study of the environmental impact of the
Kotmale Hydropower Project in Sri Lanka

by

Dick Johansson

SIDA
Stockholm 1989

SRI LANKA


INDIA
Bay of Bengal
Gulf of Mannar
Jaffna
Mannar
Vavuniya
Anuradhapura
Trincomalee
Puttalam
Polonnaruwa
Kurunegala
Matale
Kandy
Kegalla
Mahaweli Ganga
Batticaloa
Kelani Ganga
Kotmale
Amparai
COLOMBO
Nuwara-Eliya
Badulla
Ratnapura
Monaragala
Kalutara
Galle
Matara
Hambantota
INDIAN OCEAN
road
railway
river
0
75
150 km

The Kotmale environment

LIST OF FIGURES

APPENDICES

Executive Summary

This study judges the environmental impact of the Kotmale Hydro Power Project in Sri Lanka, which is aimed at utilising the country's major river, the Mahaweli Ganga, for power generation and irrigation.

Sweden through SIDA has provided some SEK 1.4 billion towards the financing of the project, which is one of the "lead projects" of the Sri Lankan Government's "Accelerated Mahaweli Programme".

The Kotmale project includes a 90 metres high rockfilled dam across the Kotmale Oya, a tributary of the Mahaweli Ganga, a six kilometres long reservoir holding 175 million cubic metres of water and an underground power station to which water is led through a seven kilometres long tunnel. The civil works have been executed by Swedish contractor Skanska and commissioning took place in August 1985.

The study is limited to a description of the present state of the environment in the area affected by the project and by the reservoir in particular. Social issues – like the situation of the evacuees – are not addressed here, since another study has been appointed to investigate the social effects of the project.

FINDINGS

The report finds that the construction of the reservoir is not likely to have affected any rare or endangered species since the habitat lost was man-made and densely populated. The same type of environment still exists immediately upstream of the reservoir and above the highest shoreline.

Roads and bridges were also affected by the flooding, but new road systems have been designed to alleviate the problems due to losses of old communication lines. However, on the northern side of the reservoir there is at present no all-weather road connection between Mawela and Sangilipalama New Town (New Kotmale) which is a drawback for the development of this area.

Furthermore:

• The aquatic life in the reservoir, plants and animals including fish, was very poorly developed at the time of the field inspection. However this was not surprising since the reservoir was almost empty 10 months earlier due to extreme drought and the aquatic life had not had time to develop during this short period.

• The shores exhibit a very sterile environment of naked soil. The future colonization of the shores by vegetation is dependent on the fluctuations in reservoir water levels. Signs of minor earthslips occur at several steep shore sections. This is a natural shore development process that will continue until a balance between the reservoir and the terrestrial environment is achieved.

• The home gardens and paddyfields represent an excellent example of a sustainable and optimal use of the land, although fish ponds seem to be absent. Furthermore, the paddyfields act as silt traps, which means that the silt does not reach the reservoir.

• A dense montane forest occurs on both the northern and the southern sides of the reservoir, although patchy in its distribution. This habitat is very valuable since it is a refuge for many floral elements of the virgin mountain forests, small mammals and birds, not to mention a large number of evertebrates.

• Large tea plantations cover the upper hillslopes and hilltops. Some of the tea estates are neglected or poorly managed and in various stages of degradation. The reservoir has no impact on the tea estates, but their management may have an effect on the reservoir through the release of silt from erosion due to improper land use practices.

• Montane grasslands are common at high altitudes, especially north of the reservoir around the Peacock Hill. The grasslands seem neither to be cultivated nor used for pasture. Their origin, i.e. whether it is a natural vegetation type or a degraded man-made one which has emerged through repeated burning, is a matter of controversy.

The whole Kotmale valley is a mecca of mass movements with over 300 discrete failures mapped during a survey in 1979 – 1980. Oral and written evidence shows that major mass movement events took place in 1933, 1947, 1957, 1958, 1970 and 1979. Soil creep is probably occurring more or less continuously in the Kotmale valley.

There are no scientific data that suggests that the existence or operation of the reservoir has caused mass movements and recent cracks in hundreds of the houses in the area, but it would be fair to recognize the possibility of a link between some mass movements and the existence of the reservoir.

The diversion of water at the Kotmale reservoir has abstracted the old river course below the dam from its pre-impoundment flow of water. The environmental impact of the diversion is first of all related to the long stretch of rapids which have disappeared with the particular aquatic life associated with this type of habitat. It is difficult to tell if any rare or endangered endemic species have suffered from this since no inventories of fauna or flora were performed before the diversion, but immediately upstream of the reservoir similar habitats of the same quality are very common.

Migrating fish are naturally hindered by the Kotmale dam in their movements. However since there are a series of barrages lower down in the Mahaweli Ganga at Victoria and Randenigala the Kotmale dam will only affect the fish population upstream of the Victoria dam.

The domestic use of water does not seem to have been impaired on the stretch between the Kotmale dam and the Mahaweli Ganga.

The altered hydrology in the river-bed between the Kotmale dam and the confluence with Mahaweli Ganga may have a potential impact on the breeding of, for example, mosquitoes. However, even under the pre-impoundment waterflow, parts of the river-bed dried up in the dry seasons creating a breeding habitat for mosquitoes.

The water released through the tailrace canal contains very little silt, the bulk of which has been deposited in the reservoir. This means that the silt-carrying capacity of the water increases, i.e. the clear water discharge has a high erosion potential. An open erosion scar of about 100 metres, in old river sediments, occurs on the right bank of the canal near the inflow into the Mahaweli Ganga.

The erosion capacity is rapidly diminished after the confluence with the Mahaweli Ganga which is loaded with silt from upstream areas.

Sediment yield by erosion and silting of the reservoir appear to be modest at present and could possibly be partly attributed to silt trapping in paddy fields.

There is no direct or indirect evidence of the occurrence of hydrogen sulphide in the water released through the power plant or any other signs of impaired water quality in the tailrace canal.

RECOMMENDATIONS

- 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.
- A new all-weather road should be constructed between Mawela and Sangilipalama New Town (New Kotmale) to fill the only gap in the road system circumscribing the reservoir and to create possibilities for draining "slide-prone" sections of the valley slopes.
- The limnological study of the reservoir should be maintained over a long period of time to avoid conclusions based on sketchy data.
- 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.

• A pilot project to assess the potential of establishing fish pond cultures should be initiated.

• The remains of the dense montane forest should be gazetted to assess whether it is worthwhile protecting.

• 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.

• A detailed programme to acquire data and to test various hypotheses of the causes of mass movements in the Kotmale valley should be compiled by a group of specialists.

• 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 of the signs of active erosion downstream of the tailrace outlet.

• The actual input of silt into the reservoir should be measured, and the rate of siltation should also be assessed by inspection of the reservoir bottom at low water levels.

CHAPTER 1
Introduction

Most hydropower developments are largescale ventures which, apart from the obvious benefits, inevitably lead to some negative consequences. Land will be flooded, and hydrological regimes altered. There will be consequences for vegetation and wildlife, man and his livelihood.

The development and application of means to mitigate or reduce the impact is therefore an important part in any hydropower project.

Environmental aspects of the Accelerated Mahaweli Development Programme are discussed in a report by NEDECO (1979) and an Environmental Assessment, mainly related to the Project areas downstream of the Kotmale reservoir, was performed by TAMS (1980).

The Accelerated Mahaweli Development Programme did not include any specific pre-impoundment studies of the environmental impact of the Kotmale hydropower project.

The following assessment of the impact is thus based upon information on the pre-impoundment situation which could be retrieved and on the prevailing situation in the area of influence.

The Terms of Reference for the short-term mission are outlined in Appendix 1.

A large number of environmental parameters have been screened in an effort to cover a broad spectrum of the most relevant fields of impact. In this way the most important aspects of environmental consequences may be identified, although quantification or detailed information may be lacking.

Very generous assistance in fact finding, directly or indirectly through the Mahaweli Authority, simplified the work in Sri Lanka. The Swedish International Development Authority (SIDA) in Stockholm and Colombo provided all necessary support for a successful field visit and for introduction to various sources of information. Skanska AB gave valuable help on matters of a practical nature.

The help received is greatly appreciated. The fieldwork was performed in an

extremely friendly atmosphere with the resident population who provided valuable information on the local conditions.

THE PROJECT

The Kotmale Hydropower Project is not merely another energy project in a mountain valley but an integral part of the huge Accelerated Mahaweli Development Programme, which in its turn was based on the Mahaweli Development Programme.

Mahaweli development programme

The Mahaweli Programme is a multi-purpose river valley development programme. It includes energy production, storage reservoirs, canals and irrigation projects, as well as new settlements.

The potential of the Mahaweli Ganga has long been recognized. Diversion and use of the water of the river was originally carried out by the ancient inhabitants of the island. They, inter alia, diverted the Amban Ganga, a tributary to the main river, at Elahera and Angawedilla. In addition, irrigation systems were established throughout the dry zone using a series of man-made storage tanks (cf. Brohier, 1934; Leach, 1959).

More recent studies concerning the diversion of the Mahaweli Ganga into the dry zone were initially conducted by the Irrigation Department.

In the 1950s and early 1960s the resources of the Mahaweli Basin were studied in the Canada – Ceylon Colombo Plan Project (Hunting Survey Corporation, 1962) and by the United States Operations Mission. As a result of these investigations, the Food and Agriculture Organization of the United Nations was requested to prepare a Master Plan for proposed developments of the Mahaweli Basin (UNDP/FAO, 1969).

According to the recommendations of the Master Plan, 360 000 ha of land was to be irrigated and more than 500 MW of hydropower to be produced from a variety of projects. The entire project was to be completed over a 30 year period.

The first project implemented was the Polgolla Diversion which was completed in 1976 with World Bank assistance.

The Accelerated Mahaweli Development Programme

In 1977, the Government decided to accelerate the implementation of the Development Programme, concentrating on a few major reservoir-projects (Table 1), thus reducing the completion period to five years. Storage and irrigation facilities would be sufficient to supply water for 128 000 ha and for the upgrading of 32 000 ha.

Implementation of the accelerated programme started in 1978.

Details of the programme, as well as an interdisciplinary overview of the developments so far, appear in Johansson, 1987. The incorporation of environmental measures in the programme is described by Jansen (1986).

A few miles downstream of Randenigala work on a fourth hydropower station with associated reservoir has started in 1987. The reservoir will have a gross volume of 21 million cubic metres and an installed effect of 52 MW.

Table 1 Major reservoirs of the Mahaweli Programme.

Reservoir	Capacity million cubic m	Hydropower * Development (MW)	Extent of land benefited (ha)
Kotmale	174	201	36,500
Victoria	722	210	45,000
Maduro Oya	467	-	46,750
Randenigala	860	122	30,200

** Hydropower Development refers to the installed capacity in Megawatts*

The Kotmale Project

A full feasibility study was conducted from 1973 to 1976 by the Water Power Development Consultancy Services of India, and this provided the basis for the project.

The scheme envisaged the construction of a major 95 metres high and 600 metres long rockfill dam across the Kotmale Oya.

The idea was to create a reservoir two km wide and 10 km long with a total storage capacity of 174 million cubic metres. The water impounded by the reservoir is conducted through a seven km long headrace tunnel, down a steeply inclined high pressure shaft and on to an underground power station, the first of its kind in Sri Lanka. It will have a total installed capacity from three Francis turbines of 201 MW. After power generation, the water is discharged through a 645 metres long tailrace tunnel to the outfall in the Mahaweli Ganga at the Atabage Oya confluence. In addition to the generation of power, the main purpose of the project, the regulated water will increase the supply of water for irrigation purposes through the Polgolla tunnel and also improve power output at the Ukuwela and Bowatenne power stations.

Construction work started in September 1979 and was completed in November 1984.

SKANSKA AB, Sweden, served as the main contractor (Appendix 5). Further details of a technical nature are given in Appendix 4.

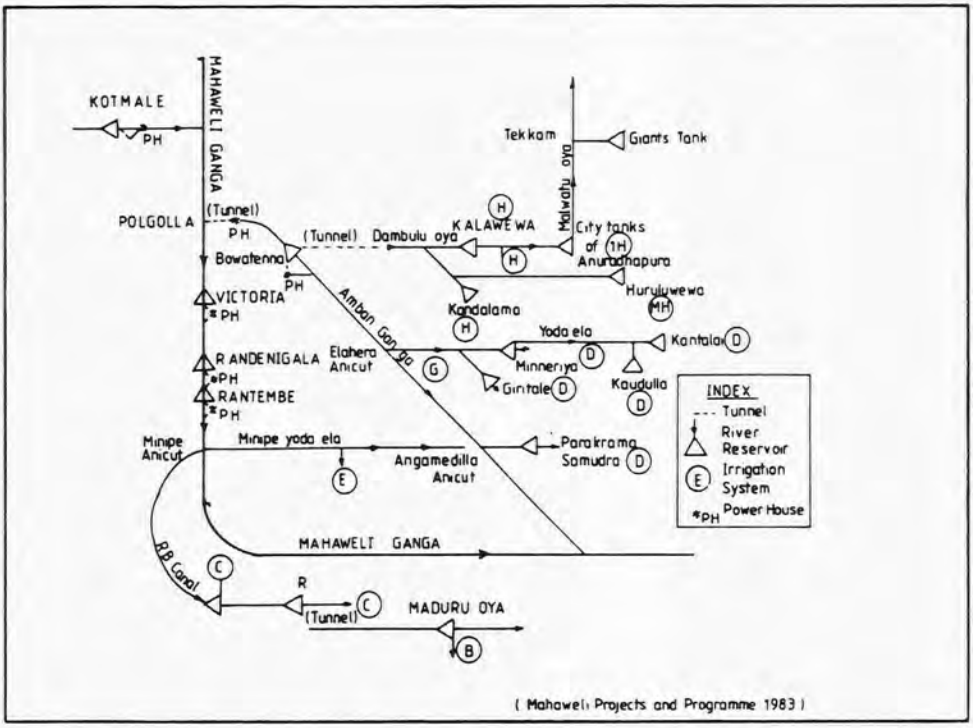


Figure 1 Water distribution diagram of Accelerated Mahaweli Programme (From Madduma Bandara, 1985).

CHAPTER 2
The catchment

THE MAHAWELI GANGA AND THE KOTMALE RIVER

Kotmale Oya is one of seven major tributaries of the Mahaweli Ganga. The headwaters of the Mahaweli Ganga rise in the core of the Central Highlands at Nuwara Eliya with elevations in the vicinity ranging from 1 200 metres to over 2 000 metres. The river itself originates in the Hatton Plateau, a formation to the southwest with elevations ranging around 1 400 metres. The river flows north from this plateau until it curves around the town of Kandy in the Kandyan Plateau at an elevation of 500 metres. From here it flows east towards the dry zone lowlands, crossing the wet zone boundary at an elevation of approximately 100 metres. Finally it turns north again and reaches the sea near Trincomalee about 180 km NNE of its starting point (Figure 2). About four km upstream from the confluence of the Mahaweli Ganga and the Kotmale Oya, the latter has been impounded forming the Kotmale reservoir which has a catchment of about 554 sq. km upstream from the damsite (Figure 3).

Records of the pre-impoundment water quality of the Kotmale Oya at the damsite are available from 1963 to 1969 (Appendix 6).

Residues of chlorinated pesticides, from water samples collected by TAMS in November 1979 and analyzed by Central Agricultural Research Institute, Peradeniya, revealed the presence of Aldrin (0.02 microgr./l), Dieldrin (0.04 microgr./l), BHC as total HCH (0.21 microgr./l), Endosulfan (0.06 microgr./l) and DDT (0.47 microgr./l).

The chlorinated (or organochlorine) pesticides are very persistent often remaining for years before they are broken down into less harmful by-products. The use of chlorinated pesticides, however, decreased in the mid 1970's, with the introduction of the less harmful organophosphate types of pesticides. The relatively high concentrations, especially of DDT, may thus reflect a previous heavy use of chlorinated pesticides. Up-to-date measurements of pesticide residues should give an answer to the trend of pesticide break-down and of pesticide use in the catchment.

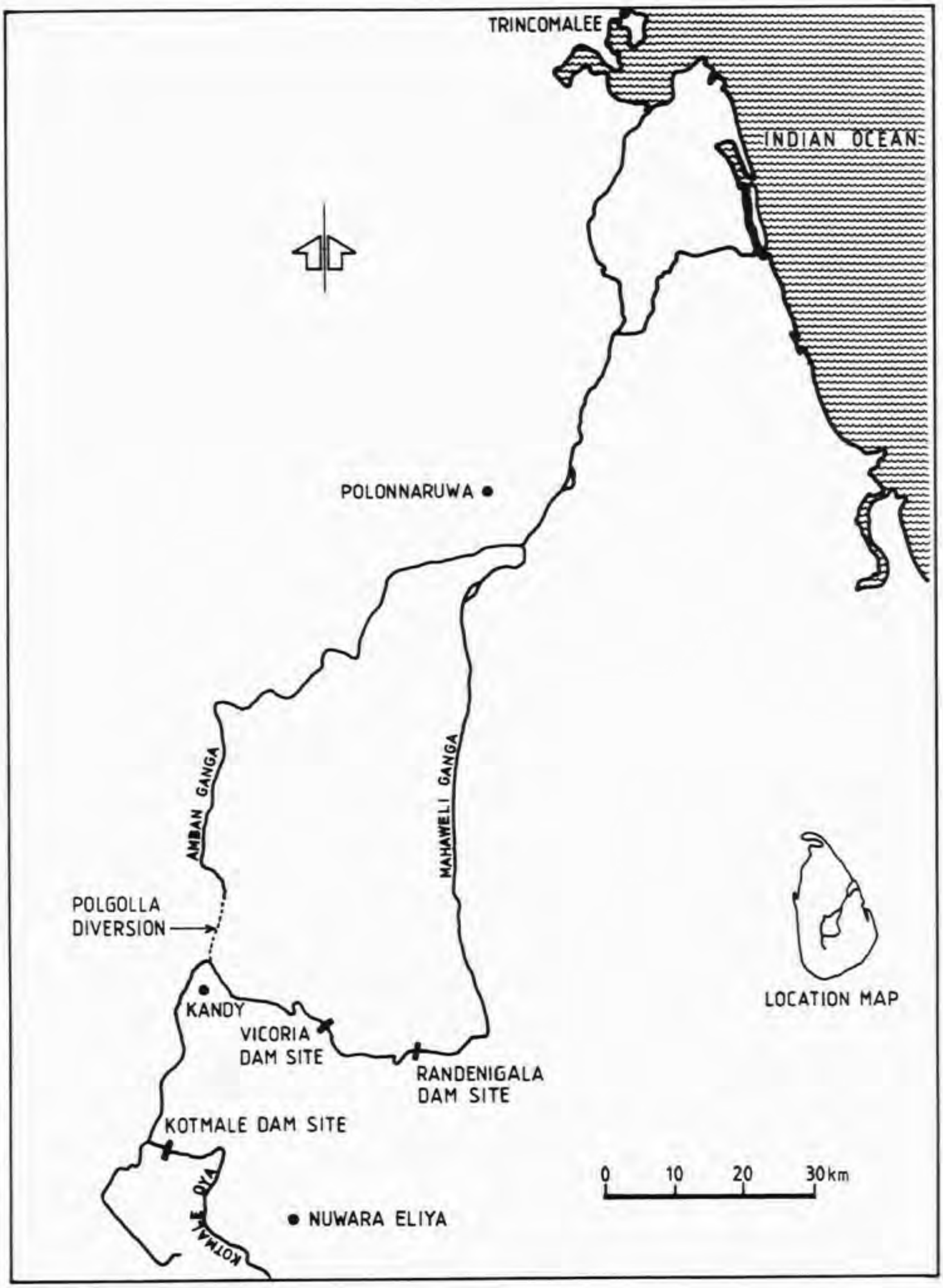


Figure 2 Mahaweli Ganga, Kotmale Oya and the location of some major reservoirs.

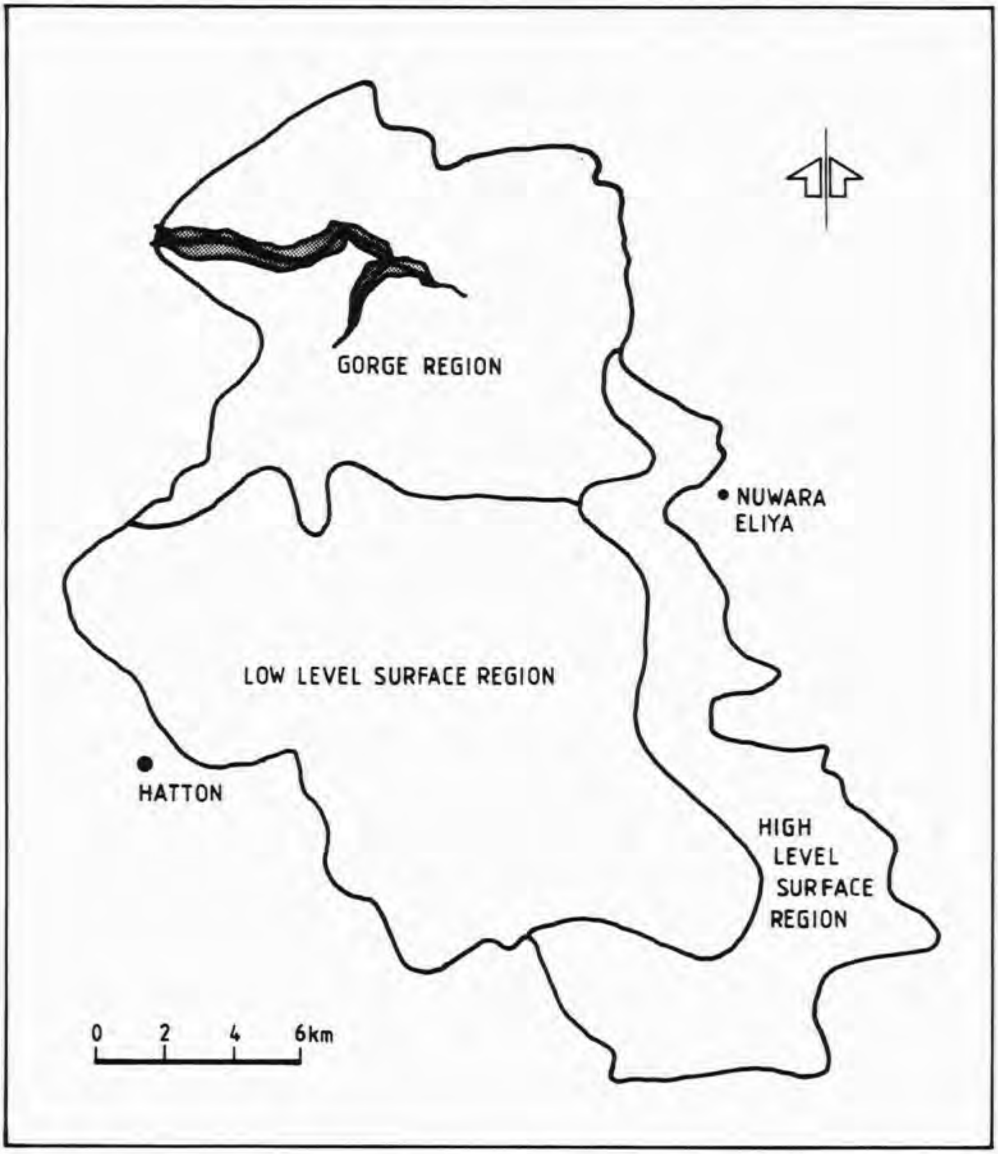
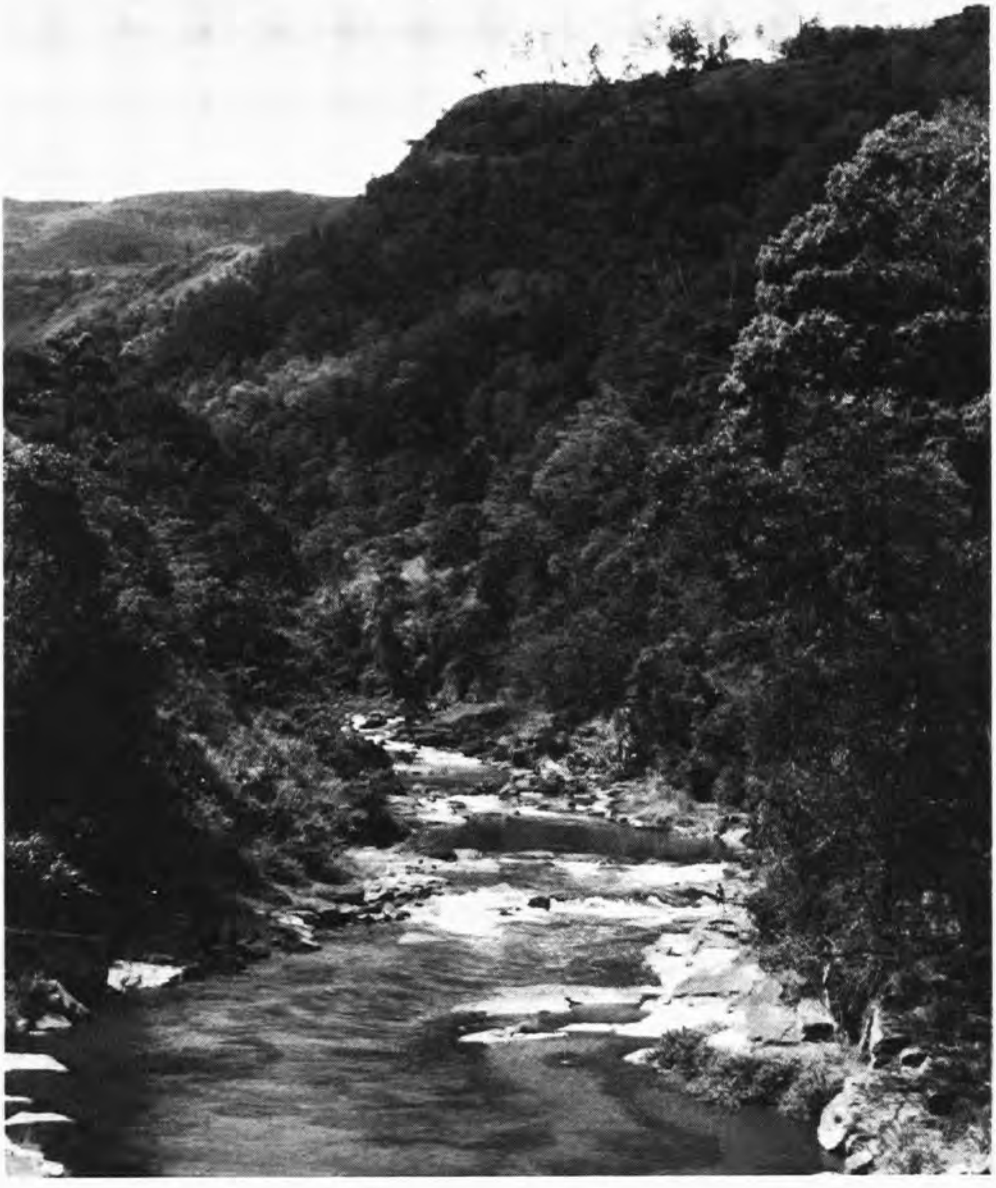


Figure 3 The three physiographic regions of the catchment above the Kotmale reservoir.

TOPOGRAPHY AND LAND USE

The catchment includes:

1) a high level surface, which covers about 20 percent of the area. This surface, which lies at an altitude of about 2 200 – 2 300 metres, consists of low undulating hills covered by dense montane forest.



1.The Kotmale River about 1 km upstream from the inflow to the Kotmale reservoir. In this section the river passes through a land system with deep narrow valleys and steep slopes, the latter covered by tea plantations or derived grass land. A narrow strip of riparian vegetation delimits the rocky river bed. There are numerous rapids and small waterfalls in this section, which keep the water entering the reservoir saturated with oxygen. The swift flow of the river, especially during peak flow, suppresses the development of rooted aquatic or semi-aquatic vegetation.

2) a low level surface at an altitude of about 1 400 metres. This surface of low undulating hills is used almost exclusively for tea cultivation and covers about 40 percent of the catchment area.

3) a gorge region of steep slopes in an area of high relief. The three main tributaries, the Kotmale, the Pannu and Pundula Oya, flow at the bottom of the gorge region (Picture 1). Land use is complex in this section, with paddy on the mudslide aprons in the valley floors, home gardens and occasionally patches of semi-natural forest on the boulder tongues and steeper slopes and tea cultivations on higher areas. The gorge region covers about 40 percent of the catchment area.

CLIMATE

The lowest part of the catchment lies at about 700 metres while the highest point, the Totupolakanda Peak rises to 2 380 metres.

The large differences in altitude are naturally reflected in the climatic parameters and a large variation of, for instance, temperature and rainfall may occur even for localities geographically very close to each other. Climatic data has been collected at the Kotmale damsite since December 10, 1986.

The Kotmale catchment experiences a monsoonal distribution of rainfall with the period of greatest rainfall during the Southwest Monsoon or Yala, from May to September. The next wettest months are the intermonsoon periods, October, November and March and April. The Northeast Monsoon, or Maha, during December and January produces the least rainfall and the month of February is usually the driest month of the year. However, large seasonal variations may occur from year to year. Figure 4 gives the distribution of rainfall and evaporation during 1987 at the damsite.

The temperature varies very little throughout the year. For instance, the temperature at the Kotmale damsite measured in the morning the first day of each month during 1987 varied between 21°C and 25°C only.

HYDROLOGY

The data on annual rainfall and runoff at Peradeniya in Mahaweli Ganga 12 km downstream of Kotmale reveals certain facts concerning altered hydrological regimes. During the period from 1945 up to 1978, the percentage run-off from the rainfalls indicates a gradual increase over the years (Manchanayake; undated).

This means that less water is retained in the soils after a rainfall. The changes observed are probably due to vegetation degradation in the catchment, which tend to make the soils less pervious.

The same trend has also been observed for instance at the station at Kotmale Oya at Talawakelle.

The large seasonal variations in rainfall are strongly reflected in the inflow to the

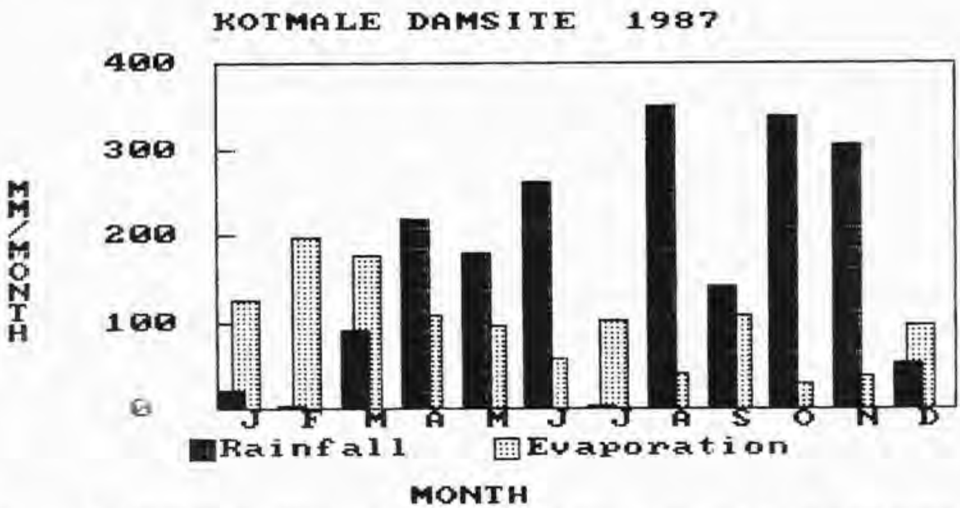


Figure 4 Monthly distribution of rainfall and evaporation in 1987 at Kotmale.

Kotmale reservoir (Figure 5) since there are no lakes or swamps in the catchment that retard the water flow. Furthermore, a large part of the catchment area is covered by tea plantations with low water- retaining capacity.

SEDIMENT YIELD BY EROSION IN THE RESERVOIR CATCHMENT

Rates of erosion

Direct sediment measurements have been made in Mahaweli Ganga at Peradeniya,

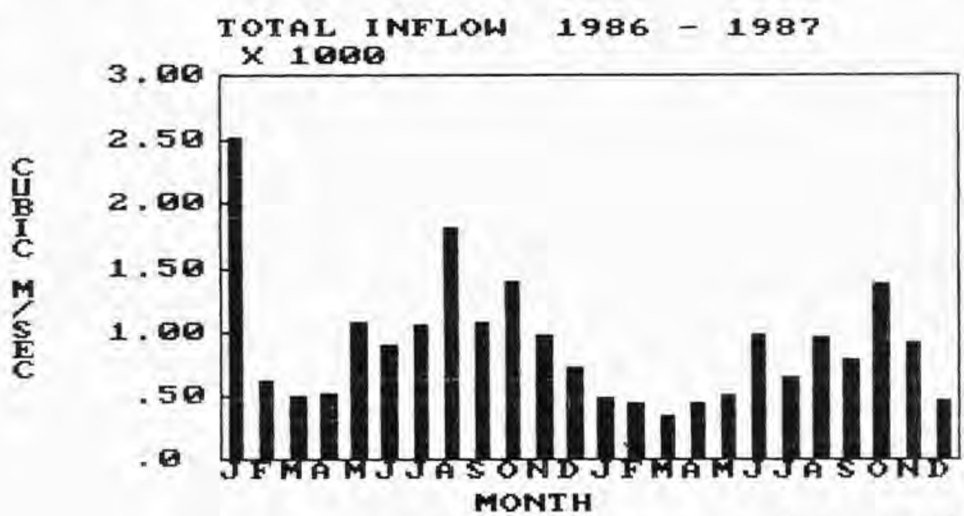


Figure 5 Inflow of water to the Kotmale reservoir during 1986 and 1987.

about 12 km downstream of Kotmale Oya's inflow (NEDECO, 1979). The suspended sediment yield was calculated at 300 cubic m/sq. km/year for tributaries to the Mahaweli Ganga, presumably including Kotmale Oya. In a mainly theoretical study by Russell (1980) the suspended sediment yield was estimated at 180 cubic m/sq. km/year.

The additional bedload yield was considered to be eight percent of the suspended sediment yield.

The figures may seem low and could possibly be attributed to soil properties, infiltration and silt trapping in paddy fields.

In this context a reference to an early observation may be of interest:

"Ceylon presents a great contrast to other countries in the absence of scour and of damage done by the torrents of rain which pour off the steep hill slopes cleared for coffee. When once the surface layer of vegetable mould has disappeared, partly blown partly washed away, the water runs off slopes of 30 to 60 without being discoloured, and the clearness of the mountain streams in the coffee districts, even in the heaviest floods, is most remarkable. "(D A Vincent, 1882).

Recommendations

Although the estimated rates of erosion at present seem to be modest, all possible efforts should be made to decrease the negative impact from the erosion, which degrades the land and causes silting of the reservoir. The silt trapped in the reservoir occupies storage volume, i.e. the reservoir is slowly losing its capacity to retain water, with negative economic consequences for power production.

What can be done about the sedimentation in the reservoir? A first and primary consideration is how the land in the catchment area should be used and managed in order to minimize erosion.

The degree of erosion is closely related to the plant cover of the ground, the rainfall erosivity, slope, soil erodibility, and land use.

Since generally speaking nothing can be done about the rainfall, and very little about the slope or erodibility of the soil, the only factors which may be controlled are land-use and the degree of plant cover. These two factors are furthermore closely interrelated.

Panabokke (1986) has outlined various actions that can be implemented in this respect.

The Canadian International Development Authority (CIDA) is at present planning a project concerning watershed protection of the Kotmale catchment. The planning of this programme (CIDA, 1987) should be closely followed by the Mahaweli Authority in order to incorporate ideas of interest to the long-term protection of the investment in the Kotmale reservoir.

CHAPTER 3
The reservoir

BASIC DATA

The flooding of the narrow valley has resulted in an elongated shape of the reservoir (Picture 2 and Figure 6). The main part of the reservoir is oriented in an east – west direction, but at the inflow of the Kotmale river the direction is North to South. The length of the East – West part is about 8.5 km and the North – South part about 3 km at full supply level. The width, which is about 1 km near the damsite, slowly decreases toward the inflows at Pannu (Puna) and Kotmale rivers. At full supply level the surface area is about 615 ha (6.15 sq.km). The greatest depth, about 75 metres, at full supply level, is found at the damsite.

The relationship between water levels and storage volumes appears in Figure 9 and between water levels and surface areas in Figure 8.

Key data on the reservoir appear in Table 2.

The water level of the reservoir has fluctuated greatly during 1986 and 1987 (Figure 9). Apart from a "natural" fluctuation depending on the operation of the power plant, an extraordinary drawdown of the water level in conjunction with the steel lining of the high pressure shaft has also taken place during this period.

The drawdown in 1987 thus more or less emptied the whole reservoir, which is evident on the satellite registration of March 1, 1987 (Figure 6).

Table 2 Kotmale reservoir. Areas and volumes.

	Water level (m.a.s.)	Area (sq.km)	Volume (mill. cubic m)
Full supply level	703	6.2	174
Spillway	688	4.2	96
Minimum supply level *	665	1.7	20
Bottom outlet;	632	0	0

Minimum supply level refers to the lowest level for the operation of the power station.

2. Kotmale reservoir at the damsite, January 22, 1988.

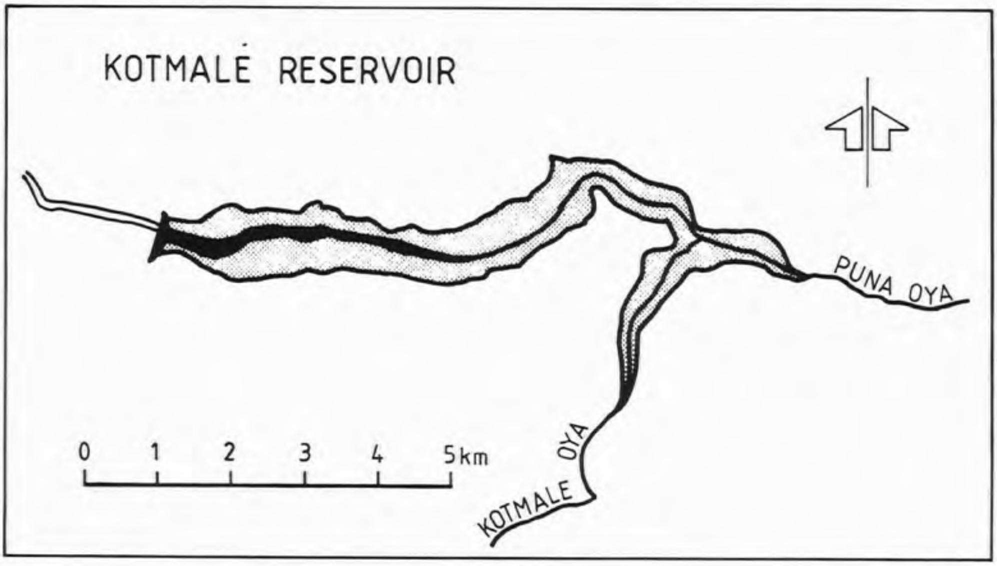


Figure 6 Sketch-map of the Kotmale reservoir at full supply level, +703 m, and at a draw-down to +649.76 m. The extension of the reservoir at the draw-down (black area) is based on a satellite registration of March 1, 1987.

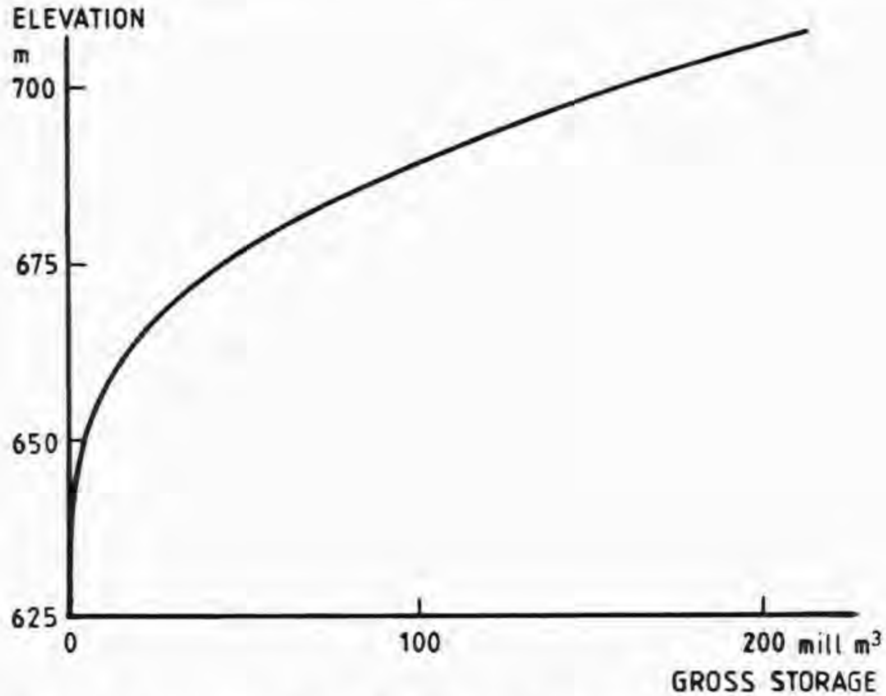


Figure 7 Storage volume of the Kotmale reservoir at various water levels.

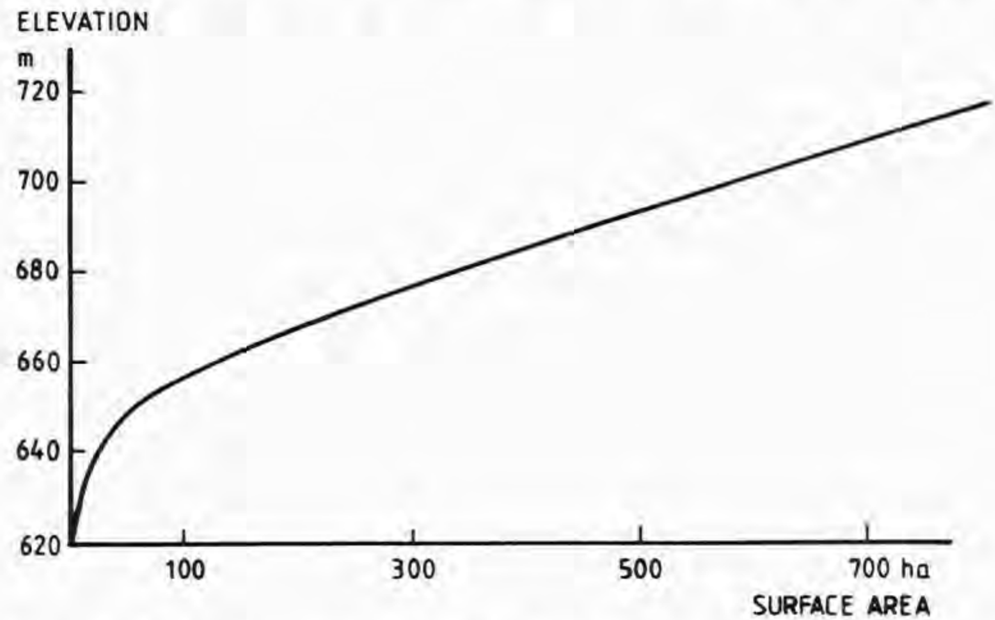


Figure 8 Surface area (ha) of the Kotmale reservoir at various water levels.

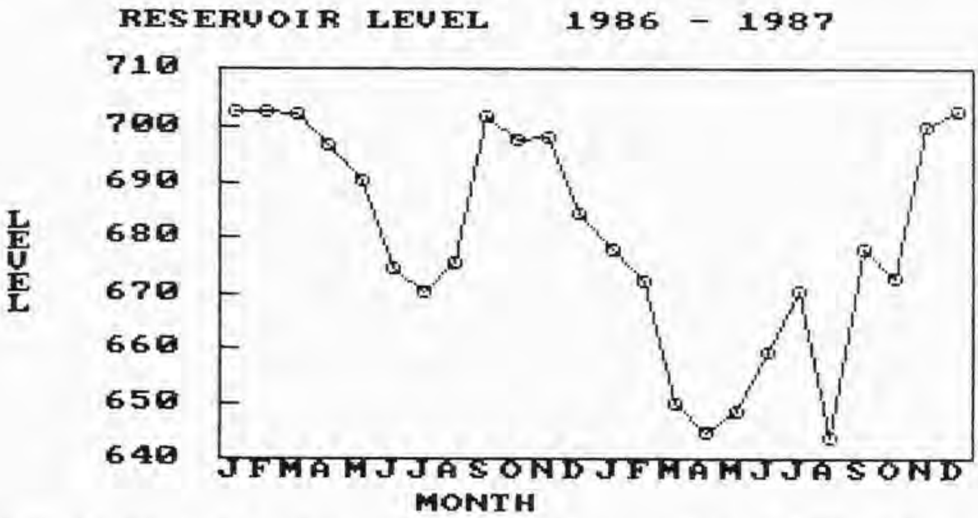


Figure 9 Changes in water level of the Kotmale reservoir during 1986 and 1987.

RATE OF SILTUATION OF THE RESERVOIR

Sediment input

The values of erosion in the catchment calculated by Russel (1980) give a total sediment yield of both suspended sediment and bedload of 107 698 m per year, which is a loss in the reservoir volume of about 0.06% each year. The 0.03% loss calculated by Russel (1980) is based on a larger reservoir volume than the one which was implemented. The calculations above have not accounted for streambank erosion or the trapping efficiency of the catchment itself, i.e. the sediments actually delivered to the reservoir. To some extent, these two factors cancel each other out.

Even with these unaccounted for, the value of about 108 000 cubic metres appears to be a conservative estimate.

RECOMMENDATIONS

The actual input of silt into the reservoir should be measured in the Kotmale Oya and Pannu Oya close to the inflow of these rivers into the reservoir. It is essential that the silt content is measured at varying rates of discharge and in particular during flash floods and during periods when the water is rising. It would also be possible to assess the rate of siltation by inspection of the reservoir bottom when the water level is down. Sampling of the depth of the silt already deposited, especially near the inflow areas of the reservoir, would give an indication of volumes and characteristics of the sediments.

ENVIRONMENTAL IMPACT OF THE INITIAL FILLING OF THE RESERVOIR

Vegetation and wildlife

The area flooded was utilized by man in many ways, but mainly for paddy cultivation and home gardens. The high population density and the prevailing landuse make it fair to assume that none of the natural vegetation or undisturbed wildlife habitats remained and that the wildlife present before the flooding was of the kind normally associated with man-made habitats. It is not likely there has been any loss of rare or endangered species or of sensitive wildlife habitats. Furthermore, exactly the same environment still occur above the highest shoreline.

Inhabitants

The people residing in the areas flooded had to leave for new settlements upslope of the river valley in the tea estates, or at other locations downstream of the reservoir after compensation for property lost had been paid. Sites and objects of, for example, a cultural and religious nature were also impounded (Picture 3). The impoundment affected some 66 villages and 4 tea estates leading to the evacuation of some 2 691 families (Bulakulama, 1979).

Since the entire subject of resettlement will be treated in a separate study no further consideration will be given to the matter in this assessment.

However, it may be mentioned that certain religious and cultural objects collected before the impoundment will be stored in a new imposing structure under construction on the slope above the dam (Picture 4).

3. Some objects and sites of a cultural or religious nature were flooded. The remains of a temple appear at the draw-down of the reservoir surface. January 16, 1988.

4. A very large dagoba under construction on the slope above the Kotmale dam. It has a diameter of 200 feet at ground level and the dome will have a height of 100 feet, on top of which a 173 feet, high "spear" will be placed. January 20, 1988.

Road systems

The Kotmale reservoir inundated portions of the Nawalapitya-Sangilipalama road, the Ulapane-Pussellawa road and the Tawalantenna-Talawakele road, all important roads of the area belonging to "B" and "C" class standards (Senanayake, undated).

Much of the foot and vehicle traffic before the inundation went across the river valley itself, mainly in a north-south direction. Furthermore, bridges across the river valley for vehicles were rare.

New road systems to alleviate the problems caused by the flooding have been designed. Some of these have already been implemented, whereas others are in progress. The following developments may be mentioned in this context: On the southern side of the reservoir there is inter alia a new road from the dam crest to the Nawalapitiya-Sangilipalama road. New construction is also being carried out on the latter road, for example between Kalapitiya and the Kotmale Oya bridge and between Niyangandora and Sangilipalama. On the northern side there is a new road to Kotagahapitiya and Dorogalla, and a partly newly constructed road between Kadadora and Maswela (Figure 10). There is, however, no all-weather road between Mawela and Sangilipalama New Town (New Kotmale), which is a drawback for the development of this area.

New major bridges include the one over the dam crest of the Kotmale reservoir, an almost completed (January 1988) bridge over the Kotmale Oya near the inflow to the reservoir and another over the Puna Oya near Sangilipalama.

To simplify travel across the river valley and the reservoir, people are ferried over in small boats at three or four different locations at scheduled intervals, e.g. between Morape and Wataddara, Maswela and Nawangama and Kosgolla and Niyangandora (Picture 5).

Recommendations

On the northern side of the reservoir there is at present no all-weather road connection between Mawela and Sangilipalama New Town (New Kotmale). For

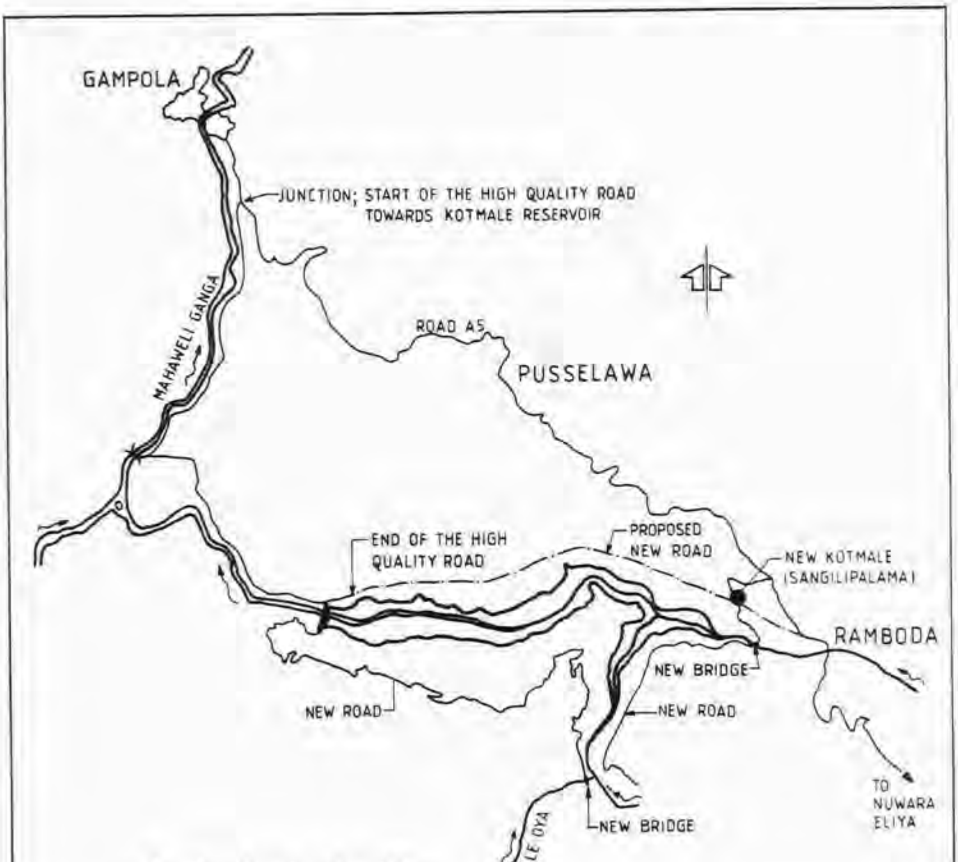


Figure 10 Sketch map of some new road systems around the Kotmale reservoir. The alignment of the road proposed in this study is broadly outlined by dots.

5. Ferry services are maintained at different locations, here between Kosgolla and Niyangandora. Jan. 15, 1988.

instance, a road between Mawela and Balapokuna near New Kotmale would fill the only gap in a road system circumscribing the reservoir. Furthermore the construction of a new road between New Kotmale and Mawela could also be viewed in a larger perspective since it opens new possibilities for a direct road connection between Ramboda/Tawalantenna and Gampola following the northern side of the reservoir instead of taking the climb over the Pusselawa pass. The proposed new road along the reservoir would thus take advantage of an existing road of high standard running between the reservoir and 1.5 km outside Gampola and built in connection with the Hydropower Project. An 18 – 20 km stretch of a high quality road could then be incorporated and become a vital link in the major road network of the country.

This new link would save time and fuel since it follows a gentle gradient in the terrain and has no steep climbs.

There is one more potential advantage of a new road and upgrading of old roads on the northern side of the Kotmale reservoir. If properly designed, the road could diminish the risk of soil creep or saturation of the soils on the slopes. A thorough study of the soil and geohydrophysical characteristics etc. should reveal the possibilities of obtaining extra benefit from the road construction. Caution must be exercised in this matter, however, since road construction may give a negative result visavis drainage if the physical prerequisites have not been properly accounted for.

To sum up, the proposal for a new road construction would: 1) improve the transportation and travels for the inhabitants around the reservoir, 2) serve as a vital link in the national road system and 3) create possibilities for draining and stabilizing the "slide-prone" sections of the valley slopes.

CHAPTER 4

The reservoir environment

ECOLOGICAL UNITS

The environment of the reservoir area may be divided into six large-scale ecological units with profound differences in physical and biological conditions (Figure 11):

- The aquatic environment of the reservoir (1)
- The shores of the reservoir (2)
- Home gardens & paddy fields (3)
- Humid montane forest (4)
- Tea cultivations (5)
- Montane grasslands ("Patanas") (6)

THE AQUATIC ENVIRONMENT

Aquatic life

At the time of the survey (January 1988) the reservoir showed a poor development of aquatic life, which is not at all surprising. In March 1987 the reservoir was almost dry, but a stream of water floating through the old river bed (Figure 6). This means that the reservoir had been entirely filled during the rainy seasons in 1987 thus giving it an age of only 10 months .

The aquatic life was to a great extent forced to restart its development. The fish population, for instance, had probably diminished to very low numbers, due to limitation of space, scarcity of food and increased predation.

The low presence of fish in the reservoir is indirectly shown by the absence of fishermen or people engaged in fishing activities on the shores. The only fishing actually observed was that of two young boys who managed to catch some carp-like fish 8 – 10 cm long.

However, even more striking was the absence of fish-eating birds. The Little Egret, Egretta garzetta garzetta; Linn., the Pond Heron, Ardeola grayii; Sykes, and the White-Breasted King Fisher, Halcyon smyrnensis fusca; Boddaert, feeding on

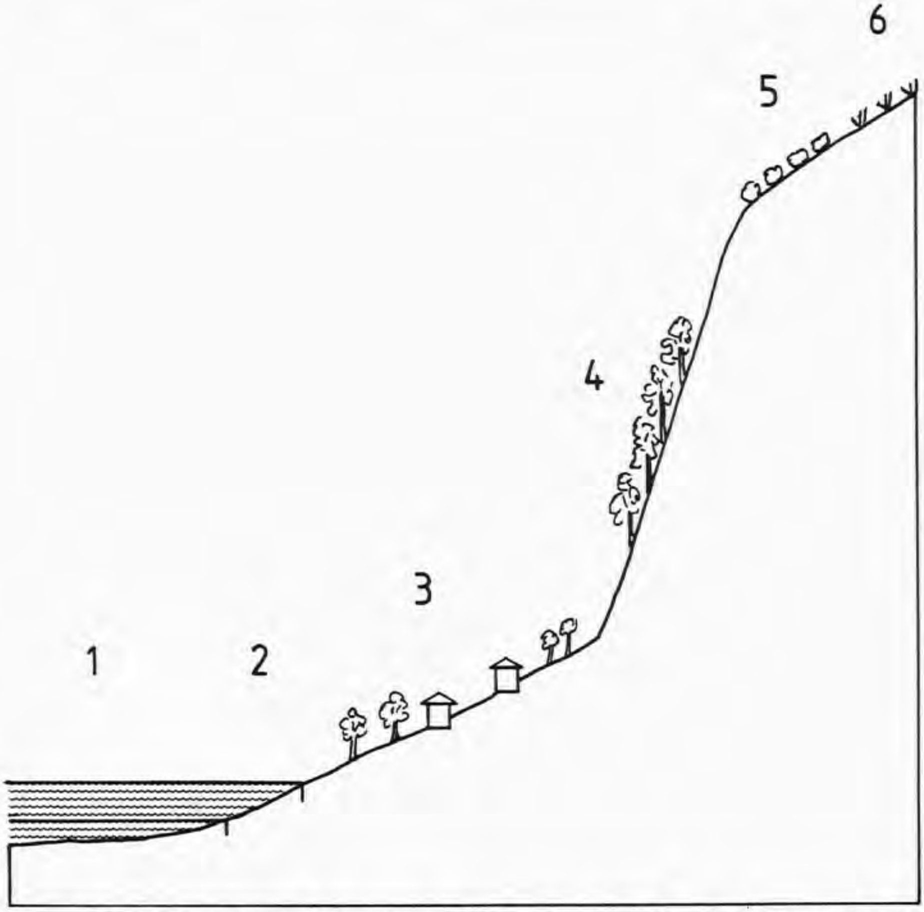


Figure 11 Sketch figure of the sequential distribution of the six large-scale ecological units in the reservoir area.

small fish in shallow waters, were the only species observed, and in small numbers only.

Not a single specimen of ducks, cormorants or other open water species of birds were observed. Rooted aquatic macrophytes were also entirely absent. Even more surprising was the lack of freefloating aquatic macrophytes, since they are less sensitive to water fluctuations. The Salvinia fern, Salvinia molesta, a feared water weed, does occur in the Kotmale Oya immediately upstream of the reservoir but was not observed in the reservoir itself. It will certainly establish itself in the reservoir when suitable conditions evolve.

To put it briefly – the aquatic life has suffered from the large artificial regulation of the man-made lake.

Limnological data

A limnological study of the Kotmale reservoir commenced in September 1987 on behalf of the Mahaweli Authority. The work is being performed by the Dept. of Zoology, University of Sri Jayewardenepura, with Dr Swarna Piyasiri as the Chief Investigator. Water chemistry data is collected at three stations in the reservoir at regular intervals (about once a month). Furthermore, plancton dynamics and physical aspects are monitored in this long-term programme which is also being implemented in the Victoria and Randenigala reservoirs.

At present, there is no data available from the study, which, however, will in time provide some of the data necessary for an optimal management of the new man-made lake from a multi-purpose point of view, e.g. the possibilites of introducing or stocking the reservoir with suitable fish species to increase the yield.

Water quality data from the pre-impoundment period is available from sampling points in Kotmale Oya at the damsite (Appendix 6), and upstream of the dam from Kotmale Oya at Talawakelle and from Pannu Oya at Ramboda (TAMS, 1980 b).

Environmental Impact

Schistosomiasis or Bilharziasis, a common disease often associated with the creation of man-made lakes, is fortunately not found in Sri Lanka.

Breeding of mosquitoes may occur in shallow pools during the drawdown phase of the reservoir but the rapid drying of the ground probably prevents such a development on any large scale.

The matter of climatic effects is often discussed in connection with the creation of very large reservoirs. However, even in semi-arid and arid regions the theoretical lake effect, e.g. cooling by evaporation from the water surface and increase in humidity (and rainfall), is difficult to verify by measurements in the near shore areas (Amissah- de Heer, 1969).

The narrow shape and relatively small surface area of the Kotmale reservoir coupled with the wet zone conditions makes the lake effect a theoretical issue of no importance to the surrounding areas (cf. Dasnayake, 1986).

Recommendations

The limnological study in progress should be maintained over a long period of time to avoid conclusions based on sketchy data. Regular monitoring is necessary for the understanding of the natural dynamics of the aquatic system and for the discovery of changes which act as signs of alarm. The data collected may also be used for decisions on future stocking of the reservoir with fish if the natural regeneration is slow. Stocking, however, should only be contemplated after some years when the growth of a natural population has had a chance to show its development potential.

Investigations of pesticide residues should also be included in the sampling programme.

THE SHORES

The shore habitat

The drastic drawdown of the water level in the reservoir in 1987 and 1988 (Figure 6) has made it impossible for rooted aquatic or semi-aquatic vegetation to become established.

The entire shore habitat is a zone of exposed dry coarse mineral soil without vegetation (Picture 6). Mud bottoms seem to be absent with one exception. At Maswele, there are old paddy terraces of muddy soils, which now lie on the shore. These shores have a dense cover of grass between altitudes of approximately 699 – 703 metres. The grass is grazed by domestic buffaloes which gives the surface a lawn-like appearance.

The drawdown zone is a very sterile environment. Wading birds (except for a few fish-eating ones) were totally absent, which indicates that there is also very little life in the soils of the shores. As a matter of fact, the shores have a desert-like appearance with regard to habitat and life.

Erosion

Signs of abrasion and slips at the shores are common. About 400 metres upstream of the damsite on the southern shore, two slides have occurred after the impoundment, both on steep slopes. One, on a small peninsula, is estimated to be 30x15x2.5 m in size, which means that about 100 cubic metres have slid into the reservoir. The other, located on a very steep vegetated hillside, has deposited a heap of colluvium with some large boulders at +703 m. The volume is estimated at 80 cubic metres.

Fresh scars from "slides" occur at several places around the reservoir, e.g. in the north eastern shore section below Gankewela, where the shores are steep.

The shore development processes now in progress were postulated in the pre-impoundment geomorphological surveys. The process can be regarded as part of a normal shore development and it will thus continue until a balance is achieved between the reservoir and the surrounding physical environment (Picture 7).

Environmental Impact

It is likely that a rather fast drawdown of the water levels will be a fairly regular occurrence and that the water level will remain at a fixed level (+703 m) for a short time only. Should this be the case, the possibilities for a development of a productive shore environment must then be regarded as very remote.

6. A steep shore with slip scars. Southern shore, about 400 metres from the dam, January 22, 1988.

Recommendations

An inventory of the "slips" along the shoreline should be undertaken in order to obtain an overview of the situation.

The inventory could easily be made by boat. Location and size of the individual slips should be recorded as well as estimates of the volumes involved. The occurrence of slips should be compared with the location of pre-impoundment "landslides" mapped by Russel (1980).

Implanting of grass should also be considered after some years if no natural vegetation has become established on the uppermost parts of the shores.

HOME GARDENS AND PADDY FIELDS

Home gardens

The slopes along the rim of the reservoir are entirely used for so-called home gardens or rice cultivations.

The home gardens, often visible as a grove surrounded by paddy land, are usually a very well balanced polyculture.

Several layers or strata are utilized; the three uppermost formed by arboreal vegetation. Tall and medium sized trees form a closed canopy providing shelter for more sensitive plants below.

7. A rather steep section of a shore near Muslimgama. Abrasion has removed a layer of the topsoil exposing the root system of the felled trees. Coarse sand washed out by the waves is deposited in thin parallel stripes reflecting different levels of reservoir draw-down. January 15, 1988.

Tall emergent trees, 30 – 40 metres high, form the upper most stratum. The cultivars include a number of indigenous species which have edible fruits, "honey-flowers", medical components etc. Below the emergents a mixture of palm trees and fruit trees shape the second stratum built up by Toddy palms, Areca palms (Betel palms), Coconut palms, Bread fruit, Jack fruit, Mango and various citrus trees.

Small to medium sized trees of Coffe and Cloves form the third stratum into which Bananas and Plaintains also reach.

The fourth vegetation layer contains Papaya "trees" of varying sizes, Manioc, Taro, Cardamom, Pineapple and Green Pepper which climb the tall trees.

The home gardens of the Kotmale Valley are an excellent example of a sustainable and optimal use of the land. Under the protective cover of the tall trees, various crops flourish and erosion is virtually non existent. A rich bird life completes the picture of a land use in balance with the environmental prerequisites. Bird species observed in this environment are listed in Appendix 8.

8. Green pepper.

9. Home gardens and paddy fields in Kotmale valley upstream of the reservoir. January 22, 1988.

Paddy fields

Paddy rice is cultivated on irrigated land, giving two crops per year. This cultivation technique keeps the soil saturated for 7 – 8 months per year. The paddy fields act as efficient silt traps. This monoculture is poor in wildlife. Wading birds, e.g. the Pond Heron (the Paddy bird) and the Little Egret, however, search for food on the flooded fields.

A long-standing water regulation technique used for paddy cultivation could also be used for aquaculture, i.e. the rearing of fish and other water organisms. The absence of small-scale aquaculture is somewhat puzzling and is probably the only missing link in a completely optimal use of the natural resources of the area.

Recommendations

The zone of land around the reservoir immediately above the full supply level (+703 m) could be utilized for aquaculture where water and topographical conditions permit, i.e. below the paddy terraces. Here, water is channelled down the slopes and it would be possible to utilize the surplus water leading it into shallow ponds where suitable fish species are reared.

Aquatic polycultures, i.e. where several organisms could be reared thereby increasing the productivity of the pond, should also be of interest. To make use of the reservoir water, cage culture, i.e. the production of harvestable fish in floating cages, should also be considered. A pilot project should be initiated to assess the potential of aquaculture in the environment at the reservoir. There is long-standing experience of aquaculture in various forms in Sri Lanka a knowledge which should be used in the implementation of a trial programme at Kotmale (cf. Fernando, 1973; Mendis, 1976; Ministry of Fisheries, 1980).

HUMID MONTANE FOREST

Occurrence and age

Remains of a mature humid montane forest occur on the steep slopes of the escarpment on the southern side of the reservoir. The dense forest stretches almost five km from the dam in a West – East direction. On the northern side of the reservoir the dense forest is more patchy in its distribution, mainly restricted to a narrow zone immediately below the steep escarpment of Mt Peacock.

The forest may hardly be called virgin, but is anyhow a very valuable asset since this type of vegetation has become increasingly rare due to exploitation by man. Floral elements of the forests which once covered the hills and valleys but cleared for coffee and tea plantations approx. in the mid 1800s, are certainly represented in the forest remains on the escarpments. This habitat is also a refuge for many birds and small mammals, not to mention a large number of endemic evertebrates.

Environmental Impact

The Hydropower Project as such is not likely to cause any harm to the forest, but there may be indirect effects from the general increase in development in the area. A certain amount of logging does occur on a small scale and an increase in demand may have repercussions on the forest remains.

Recommendations

The remains of the dense humid forest near the reservoir should be gazetted with regard to floral composition, physiognomy and wildlife characteristics.

If the results are as expected, i.e. that valuable or rare specimens or genotypes of plants or animals occur or that the habitat as such is rare, means to protect and support the forest must be considered.

First of all, the legal status of the forest has to be investigated, i.e. ownership, present utiliztion, etc.

A protection of a national heritage object, to which rare and endangered forest species belong, would be benefical to the Mahaweli Programme in three ways:

1) it would maintain a green fringe of dense vegetation preventing rapid run and erosion on the slopes;

10. Dense humid forest below Rogersongama on the southern slopes of the reservoir. January 22, 1988.

2) it would also stabilize the slopes through the rootsystem of the large trees;

3) the very idea that a forest reserve and a wildlife sanctuary could be realized as a spin- off effect of a hydropower development carries a lot of goodwill that would be credited to the Mahaweli Programme.

There is considerable accumulated experience from the previous work on wildlife conservation plans for the lower parts of the Mahaweli system (c.f. L. de Alvis, 1986) which can be implemented in this proposal.

TEA PLANTATIONS

Distribution and role

Tea plantations cover very large areas on the hillslopes and hilltops around the reservoir. Some are neglected or poorly managed and are in a state of degradation.

The project has no direct effect on the plantations, but if people who are resettled at the tea estates start with a different form of land – use, i.e. small cultivations, forest replanting and forestry, the new activities will have an effect on the reservoir. However, by and large there will not be an increase in silt reaching the reservoir

11. Erosion in tea plantation at the Rothschild tea estate on the northern slopes of the reservoir. January 16, 1988.

since tea plantations are generally major silt producers and a change in land use would instead decrease the erosion processes.

Environmental Impact

The neglected or poorly-managed tea plantations are a potential threat to the life-time of the reservoir owing to the relaese of silt from the naked soil surfaces around the tea bushes.

12. Grassland, neglected tea plantation and reforestation of grassland in the far distance. Dorogalla. January 20, 1988.

Recommendations

A policy how to handle the degraded tea plantations around the reservoir should be agreed upon since the present state of affairs is a suboptimal land use with potential negative consequences for the Kotmale reservoir.

MONTANE GRASSLAND OR PATANAS

Occurrence and origin

Extensive areas of grassland occur on the highest hilltops or at high altitudes, especially north of the reservoir around Peacock Hill (Picture 12). The grassland seems neither to be cultivated nor used for pasture.

The montane grasslands or patanas of Sri Lanka may be divided into three main groups: the wet, the intermediate and the dry patanas. The grassland near the reservoir may be classified as the intermediate type supporting a tall-grass cover (up to 1.5 m high) composed of Arundinella villosa, Chrysopogon zeylanicus and Cymbopogon nardus, with Themeda tremula as a common associate.

There is considerable controversy about the origin of patanas. Pearson (1899) and Holmes (1951) regarded patanas as a disclimax resulting from frequent burning of an early woody vegetation, while de Rosayro (1945, 1946a,b,c) considered them as an edaphic grassland climax which has never reached the woody vegetation stage.

The available evidence is inadequate to discriminate between these two hypotheses (Pemadasa and Mueller- Dombois, 1979).

Environmental Impact

While the Hydropower Project has no influence on the environment of the montane grassland, the grassland may have an impact of the reservoir as a source of silt.

Regular burning of the dry grass at the end of the dry seasons expose the mineral soils to heavy showers at the beginning of the wet seasons before the new growth has developed.

Recommendations

There is no doubt that the high rainfall of the grassland areas is sufficient for a rather luxuriant type of forest vegetation and that the soils can support several species of trees. Reforestation projects, using eucalyptus and pines have been tried with success. However, it would be challenging to try to restore some of the natural forest vegetation that was cleared to give space for coffee and tea plantations. An array of indigenous species should be selected for trial cultivation in small plots. The final aim should be to create a well balanced and diversified species composition of the initial planting to provide the most favourable conditions for the natural successions to follow.

Seeds should preferably be chosen from indigenous species and especially ecotypes from the regions to be aforested or revegetated, since the offspring from these individuals, by natural selection, are more fit to withstand the many obstacles which occur during germination and growth.

Aerial seeding, i.e. the dispersal of seeds by aircraft, should also be contemplated (Johansson, 1986). This method permits large areas to be seeded in a short time when conditions are most favourable, in this case after burning the grass, i.e. in the early wet season. Aerial seeding is furthermore particularly suitable for remote and inaccessible areas, and can be used regardless of the topography or traversability of the terrain to be seeded. The basic concepts of this technique are outlined in Appendix 8.

Monocultures, e.g. for production of firewood should also be initiated on the degraded land, But the areas utilized for firewood production should be kept low and the production should mainly aim at a local supply only.

CHAPTER 5

Soil movements in the periphery

GENERAL

The terminology used in connection with rapid mass movements of soils and rocks is somewhat confusing. There are several different types of landslides and similar rapid mass movements. The processes are often difficult to classify as they are transitional to each other.

The general classifications of landslides and related phenomena are according to Temple and Rapp (1972), based on the type of material involved and the type of movement.

Material

In the classifications two types of landslide material are generally distinguished, namely "rock" and "debris". Rockslides consist predominently of coarse bedrock material of boulder size detached from bedrock in situ. Debris slides consist mainly of material from the soil cover or weathered mantle (regolith) or other loose deposits on a slope.

The post-impoundment slope failures in the Kotmale area have involved the soil cover and the upper thoroughly-weathered regolith i.e. debris, and to a very limited extent rock material.

Classification of mass of movements

In the classifications, three types of slope failure movements are distinguished: fall, slide or flow.

Fall is the free falling of material through the air down a cliff, or the bouncing of individual blocks of rock or soil down a steep slope.

Slide is a rapid movement of a mass of rock or debris, gliding on one or several slide planes on the substratum and creating considerable friction and erosion along the slide scar.

Debris flow is movement by plastic flow or by shear along many planes in masses of soil or debris.

13. Rock ledge on the southern shore of the reservoir near the damsite.

A very brief field inspection indicated the occurrence of the following mass movements at the Kotmale reservoir:

Rockfalls probably occur from the prominent rock ledge which protrudes into the reservoir on the southern side near the damsite. This area is uninhabited (Picture 13).

No recent slides in the sense outlined above (rapid movements on glide planes) were observed.

The post-impoundment "landslides" observed in the Kotmale valley may be characterized as debris flow.

The term "soil creep" is frequently used in connection with the phenomena observed, and it is a good and easily understandable description of the most common post-impoundment mass movement. For this reason, the term "soil creep" will be used when reference is made to slow debris flows.

THE PRE-IMPOUNDMENT SITUATION

The Kotmale valley is bordered by steep cliffs near the perimeter of the reservoir. The cliffs have gentle foot slopes, so called talus slopes, formed by colluvium and debris derived from the high cliffs and upslope sources by various processes of mass movement. These include landslides i.e. deep rotation slumps, rockfalls and debris flows (mudslides). Creep movements are also effective on deep weathered rock, available data ranging from 4.4 cubic cm/cm/year to 12.4 cubic cm/cm/year. Slow downhill creep of entire slope sections have created a "hummocky" ground in the lower parts of the valley (Kumara & Kulasinghe, 1986). It seems that talus slopes >18° in gradient are subject to mass movements.

As a matter of fact, the whole area is a mecca of mass movement with over 300 discrete failures mapped in the valley during a survey in 1979 – 1980 (Brunsden and Doornkamp, 1980).

Mass movements must thus be regarded as a normal process and in no way an exception. In the Kotmale area, oral and written evidence shows that exceptional mass movements (landsliding), for instance, took place in 1933, 1947, 1957, 1958, 1970 and 1979. A large area of slumping occurred in 1933 while the main period of mudslide activity took place in 1947. Soil creep, being less dramatic, is probably occurring more or less continously in the Kotmale valley.

THE POST-IMPOUNDMENT OBSERVATIONS

In 1986, a survey of houses damaged by landslide or soil creep was undertaken in seven villages:

Niyangandora, Wataddara, Pusulpitiya, Nawangama, Kalapitiya, Gankewala and Maswela (Vitanage, 1986). The approximate location of the areas examined is shown in Figure 12.

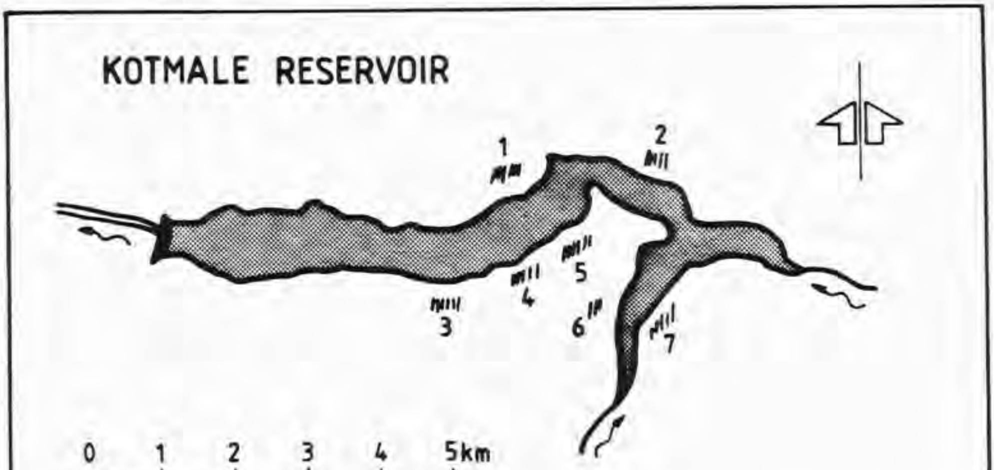


Figure 12 Approximate location of village areas surveyed in 1986 for damage to houses from mass movements. 1 Maswele, 2 Gankewela, 3 Wattadora, 4 Pusulpitiya, 5 Navangama, 6 Kalapitiya, 7 Niyangandora.

All of the villages are situated on talus slopes prone to occasional landslides and soil creep.

Nearly 550 houses were examined in detail in six villages. In Maswele the few houses subjected to damages were not surveyed in detail but examined and the degree of damage evaluated. The damage occurs in the form of cracks along the floor and across the walls, as well as along the ground. Some houses have already collapsed and others have been badly damaged (Pictures 14, 15 and 16).

The number of houses examined and the occurrence of cracks is summarized in Table 3.

Unfortunately no dates are available on when the cracks on the houses were first observed or the rate of their further widening.

The orientation of the cracks is generally parallel to the slope. However, Vitanage (1986) states that there is some correlation of the orientation of the cracks observed and the orientation of the fractures (joints and lineaments) previously mapped in the Kotmale reservoir catchment area (Vitanage 1981).

In addition to the seven village areas mentioned, signs of mass movement reflected in cracks in houses were observed during the field study in Muslim Gama and Delgolle.

Table 3 Occurrence of cracks in houses examined in 1986 (Data from Vitanage, 1986).

Village	No. of houses	No. of cracks
Gankewela	23	16
Wataddora	286	151
Pusulpitiya	56	46
Navangama	32	33
Kalapitiya	13	34
Niyangandora	137	232
Total	547	512

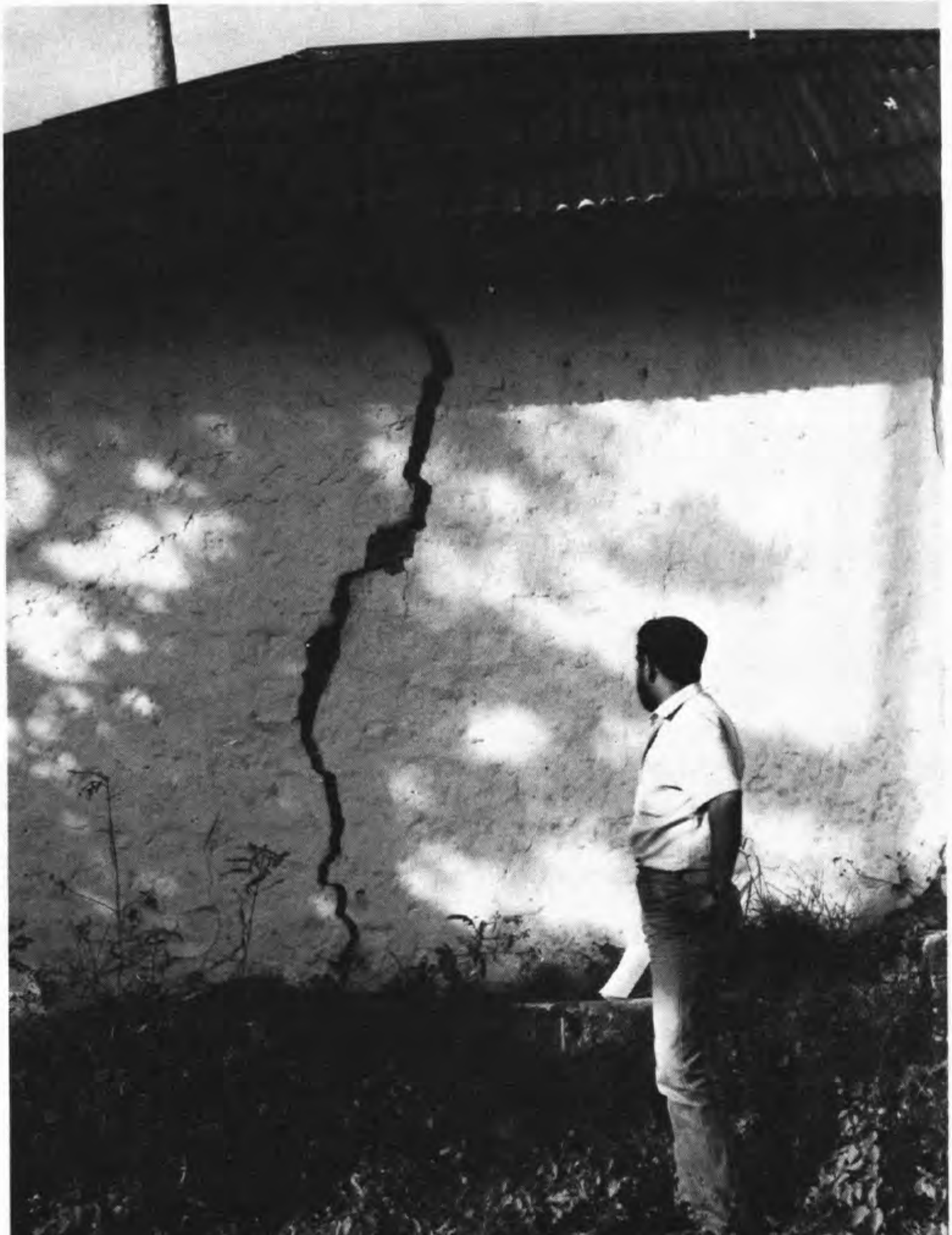
THE RESERVOIR AND SIGNS OF SOILCREEP

As already mentioned mass movement phenomena are part of a natural process in the Kotmale valley. However, after the creation of the reservoir there have been statements made that these processes have become more frequent.

The question is simply whether the existence or operation of the reservoir could be responsible for the recent mass movements on the slopes adjacent to the reservoir. Is there a link between the creation and operation of the reservoir and the damaged houses? Four possibilities are conceivable:

- There is no direct link.
- There is a direct link.

14. Deep cracks across the wall and floor of a house at Wataddora, January 17, 1988. The cracks run parallel to the slope and the reservoir shore line.



15. Deep cracks through the wall and floor of a house at Maswele, January 17, 1988.

16. Collapsed house at Pahalagammedda, Niyangandora. The damage is stated to have occurred in 1986. This area is badly affected by slides and soil creep, and all houses werw abandoned by January 19, 1988.

- There is an indirect link.
- In some cases there is a link in others not.

The "no direct link" hypothesis

This hypothesis is based on the fact that high rainfall is the main cause of the various mass movements in the Kotmale valley, with the prevailing land use practices as an accessory contributor to the recent developments.

Rainfall

It is generally accepted that high rainfall events are a major cause of mass movements. A study by Brundsen & Dornkamp (1980) of the rainfall records for Hellboda Hill station located immediately north of eastern tip of the reservoir, at an altitude of 1 070 m, shows some correlation between peaks in the rainfall graphs and landsliding events in the Kotmale valley. However, rainfall data covering 24-hour periods may be inadequate for this type of analysis. In a study of a large scale landsliding event in the Uluguru Mountains in Tanzania, which triggered over 1000 landslides and mudflows within a 75 sq.km area in three hours, Temple and Rapp, (1972) state:

> "It is possible that extreme rainfall intensities over periods of 30 minutes to one hour are the critical parameters for the build-up of porewater pressure and for shear failure".

Land use

The detrimental effect on soil stability, for instance, when the forest cover becomes degraded, is well documented from mountain areas all over the tropical zone.

As a matter of fact, the land use practicies were singled out as the man-made contribution to the devastating landslides which occurred in the Kotmale valley in 1947:

> "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 failures 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" (MacLagan Gorrie, 1954).

There are no field measurements available from the pre- or post-impoundment periods that can be used to verify a definite connection between the impoundment and the occurrence, frequency or type of mass movements. In the absence of scientific data based on field measurements the rainfall and land use hypothesis stands strong.

The "direct link" hypothesis

This hypothesis is based on the assumption that slopes adjacent to the reservoir will be subject to a raised water table and higher pore-water pressures than before the impoundment as well as to changes in the pore-water pressure during drawdown of the water level, which may induce mass movements particularly in the "old" landslide deposits. Activation of old slide deposits is postulated by Russel (1980) who states:

> "It is likely that much of this material (old mudslides) will reach the reservoir in the first years after the filling".

Reactivation of old landslides by the reservoir is described by Vitanage (1986):

> "Some parts of the old landslides, e.g. at Kalapitiya, Wataddera, Rogensengama have been reactivated after the reservoir filling and construction of new roads".

Similar observations are put forward by Kumara & Kulasinghe (1987):

> "Revival of the old slides and development of new slides was observed on the colluvial slopes after the impoundment".

The draw-down of the reservoir is also linked with the observed mass movements at Niyangandora:

> "The series of deep, well-developed fractures (convex towards the E-W trending reservoir bed) along paddy fields and the village gardens in Pahalagammedda, and Niyangandora indicate the creep of the land along the lower slopes towards the reservoir bed. This creep movement is probably the effect of draw-down of the reservoir" (Vitanage, 1986).

However, no scientific documentation which supports the statements is presented.

Furthermore, there are many statements from the local population that sliding and cracking in the walls of houses appear after a rapid drawdown of the water level in the reservoir.

The "indirect link" hypothesis

It is well known that impounding of large reservoirs may induce seismicity in areas previously considered to be aseismic.

The seismic shocks in their turn may trigger mass movements of various kinds.

In 1982, four seismograph recorders were installed at 10 to 20 km intervals to cover all major linaments of the Kotmale Project area. In Victoria Project Area, 4 additional seismographs were installed. Up to November 7, 1986, no anomalous seismic activity had been reported during or after the impoundment with the exception of a seismic event of 2 M near Mailapitiya (Vitanage and Kehelpannala, 1986).

According to M J Fernando (Master Plan Office, Colombo) no anomalous seismic activity had been recorded up to January 1988. The previously mentioned study on the large-scale sliding in the Ulugru Mts in Tanzania also addressed the question of whether the slides had been triggered by an earthquake shock. Tectonic activity was not found to be a causal factor in the landsliding, although the Uluguru Mountains are a strongly seismic area.

The compromise hypothesis

The compromise hypothesis or "In some cases there is a link, in others not" is not founded on scientific evidence but on common sense. It would be rather strange if all soil movements, regardless of distance to the reservoir, topographical location, pecularities of the terrain, slope, properties of soil, drainage, land use etc. should have the creation of the reservoir as a common cause, considering the natural occurrence of soil movements prior to the filling of the reservoir.

On the other hand, it would be fair to recognize the possibility of a link between some mass movements and the existence of the reservoir. If the latter assumption is to be validated, an inventory and analysis must be made of the specific parameters which may influence soil movements at each site.

ENVIRONMENTAL IMPACT

Mass movement

Apart from the impact on human infrastructures sediments will also reach the reservoir through various processes of mass movement. Several types of mass movement occur in the slopes adjacent to the reservoir (c.f. Brunsden & Doornkamp 1980). Three classes only are recognized by Russel (1980): rock falls, deep rotational slumps (slides) and mudslides (debris flows).

Because of their distance from the reservoir, rockfalls in the valley will not reach the water except along the charnockite cliffs immediately upstream of the dam site. Falls are frequent here according to Russel (1980).

Most of the deep rotational slumps (slides), although of large volume, are hazards of a low order in terms of sedimentation. This is because they are located generally far from the water level and seem to move relatively infrequently and then only cover short distances. However, at the upper end of the reservoir, a certain number of small slumps close to the water level are thought likely to move into the water during the life of the reservoir.

The mudslides are thought to be a source of considerable sediment in the reservoir. Movement of the mudslide type occurs relatively frequently in the valley, usually associated with heavy rainfall. Many slides are close to the reservoir in the valley floor so that much of the material will reach the water.

Russel (1980) estimated the total amount of sediments that would move into the reservoir during its lifetime by mass movement to be 3 137 400 cubic metres, about half of which by rock falls, and half by mudslides. However, these estimates are based on a higher full supply water level of the reservoir than was actually implemented. This means that the location of the shorelines at full supply level are lower than the ones used in calculation by Russel (1980).

The lower level of the shorelines is of significance for the amounts of rockfalls from the charnockite cliff near the dam site. Some rockfalls will thus not reach the reservoir. The amounts calculated for the mudslides should also be reduced.

However, if the calculations of mass movements by Russel (1980) are used, and the assumption that half of this amount will reach the reservoir during the first 10 years, 156 870 cubic metres/year will enter the reservoir during this period. This figure represents 0.09% of the reservoir volume.

The total amount loss of reservoir volume from sediment supply by the rivers (0.06%) and from mass movements at the reservoir (0.09%) will thus amount to 0.15%/year during the first ten years.

RECOMMENDATIONS

In the presentation of the four hypotheses, visavis the cause of the soil creep observed after the impoundment, it is easy to observe two facts:

- there are many opinions and statements claiming a certain cause;
- there is regretfully a marked absence of scientific data to back the claims.

Thus, first of all there is a need for more facts.

However, there will be no simple answer to the real cause even after a detailed survey and monitoring phase because of the many factors involved in the process of n.ass movements. Important facts will always remain unknown due to lack of data, e.g. frequency and duration of local rainfall at critical dates. Furthermore, the importance of underlying geological structures and soil (debris) characteristics at various depths will be difficult to obtain and interpret. Many factors also coincide, e.g. heavy rainfall, the filling of the reservoir and the saturation of the soils, which make it difficult to relate an observed soil creep to the filling or the saturation of the soil. Similarly, the drawdown of the reservoir level coincides with the dry period and the natural drying up of the soils. Thus, it is easy to postulate that, even with a considerable number of relevant facts available, there will be many opinions on how to evaluate the data and how to judge their importance for the initiation of a particular process of mass movement.

The difficulties described above should discourage the attempts to obtain more facts based on measurements in situ. A detailed programme should be made by a specialist of sites to be monitored and of methods to be used.

For instance, the widening of cracks in the soil could be followed during a period of years related to a number of other factors, e.g. rainfall, water levels of the reservoir, seismicity and land use.

The new meteorological station at Kotmale damsite could also be equipped with instruments which measure the rainfall continuously instead of at the 24-hour intervals at present, since intensive short period rainfalls may be of relevance in the analysis.

It is essential to start a long-term build-up of environmental data with regard to mass-movements on the slopes around the reservoir. When data are available, the debate of future events will become more rewarding and causes can possibly be identified. There will also be opportunities to develop countermeasures.

CHAPTER 6

The downstream environment

THE DIVERSION

During the operation of the power station the water of the Kotmale reservoir is diverted through a 7.2 km long headrace tunnel to an underground power station from where the water is discharged through a 0.5 km long tailrace tunnel into the Mahaweli Ganga (Figure 13). The water level of the reservoir is not allowed to reach above +703 m. The regulation of the full supply water level is performed by the release of water over the spillway. At such events, water is discharged into the old river bed of the Kotmale Oya.

THE RIVER-BED BETWEEN THE KOTMALE DAM AND THE TAILRACE OUTLET

The diversion of water at the Kotmale reservoir has abstracted the old river course below the dam from its pre-impoundment flow of water.

The riverbed is not entirely dry since water enters it from numerous small water courses, and ABOUT 15 l/s leak through the dam itself, which is perfectly normal (Picture 17). A small but steady stream which has given rise to an aquatic environment of a peculiar type thus occurs, even in the dry season.

The stretch mainly affected concerns the 4 km between the dam and the confluence of Kotmale Oya with Mahaweli Ganga.

In this section, the river passes through a deeply cut gorge section with steep river banks and steep hillsides above. The river bed is more or less entirely made up of clean-washed bedrock (Picture 18). There is no riparian forest except for occasional trees. Tall grasses line the banks of the river.

ENVIRONMENTAL IMPACT OF THE DIVERSION OF WATER

The physical environment

No signs of changes in the physical environment could be observed. In time, however, it is likely that the finer sediment from the slopes will accumulate on the riverbed slowly transforming the environment into sectors of vegetated wetland with

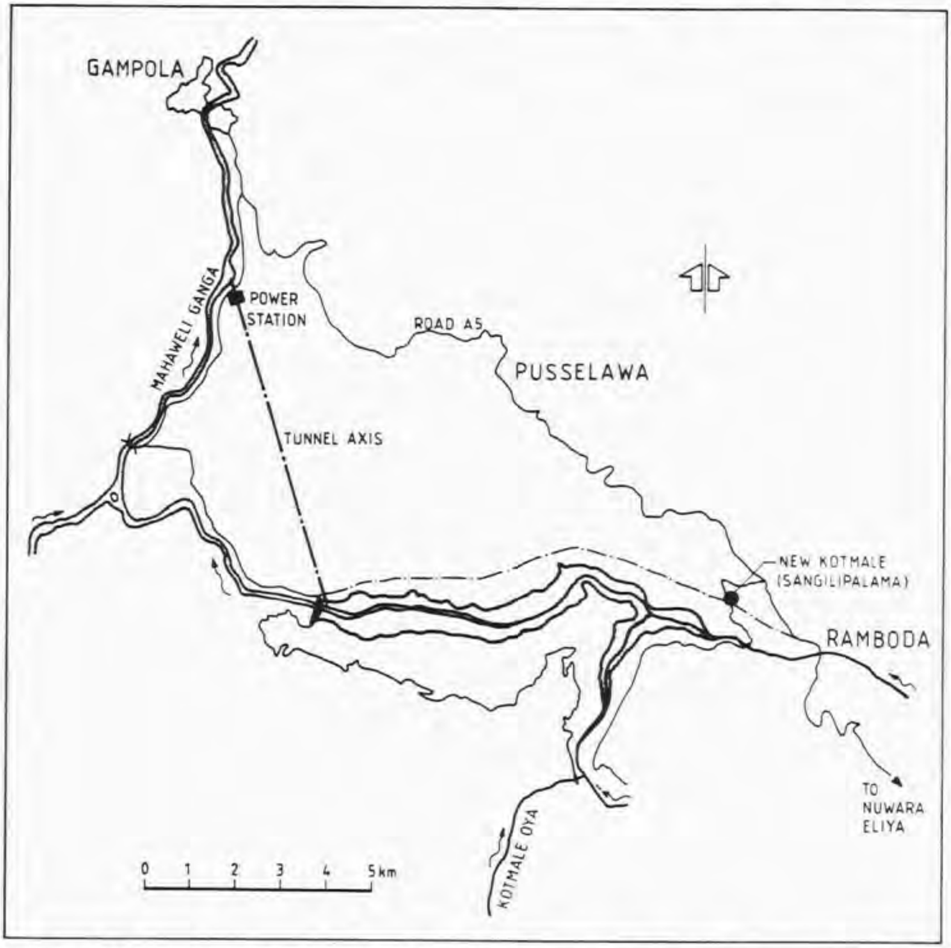


Figure 13 The diversion of water from the reservoir through the tunnel to the power plant affects primarily the old riverbed environment in Kotamale Oya and to a minor extent the Mahaweli Ganga, which has its unregulated water flow intact. The volume of water in the Mahaweli Ganga will thus be reduced from the confluence of the two rivers down to the tailrace outlet, a distance of about 4 km.

various semi-aquatic and aquatic plants. That is, of course, always provided that no large releases of water from the reservoir take place. In such an event the loose sediments, and the associated biological life, will be washed away.

Vegetation and wildlife

First of all, a long stretch of rapids have disappeared with the particular aquatic life associated with this type of habitat. Instead there is a minor stream (at least in the dry season) of clear water flow between rocks and boulders devoid of periphyton (attached aquatic vegetation). The environment gives a sterile impression

17. The river-bed a short distance below the Kotmale dam. January 22, 1988.

reflected in the paucity of animal life (Picture 18). Three species of birds only, the Grey Wagtail, Montacilla cinerea melanope; Pallas, the Grey- Headed Yellow Wagtail, Montacilla flava thunbergi; Billberg, the Common Sandpiper, Acitis hypoleucos; Linn, were observed in this habitat and only occasionally and in well spaced-out territories.

It is difficult to tell if any rare or endangered endemic species have suffered from this since no inventories of fauna or flora were performed before the diversion. What can be said is that immediately upstream of the reservoir, similar habitats of the same quality as the ones lost through the diversion, are very common (cf. Picture 1).

Migrating fish are naturally hindered by the Kotmale dam in their movements. Since there are a series of barrages lower down in the Mahaweli Ganga at Victoria and Randenigala, the fish population affected is the one between the Victoria and the Kotmale dams.

In the Environmental Assessment by TAMS (1980) the matter of fish ladders is discussed:

> "At the present time, it is not recommended that consideration be given to installing fish ladders or comparable conveyances to

18. The river-bed near Mawatura, approx. 3 km down- stream of the Kotmale dam. January 20, 1988.

> permit upstream passage of fish during spawning migrations. There are few species adversely affected by blockage of migration routes; and none of these species are of exceptional economic value. If further study warrants by-pass devices, it is likely that they could be installed after the dams are constructed."

However, little is known of the occurrence of migrating fish species in the Mahaweli Ganga prior to or after the implementation of the Accelerated Mahaweli Development programme. Further knowledge of migration patterns etc. is needed before any conclusion can be drawn of the need of fish ladders and their potential value (cf. Jinadasa, 1986).

One species which may have become significantly affected is the Mahsier, Tor khudree; a popular game fish. The Mahsier is known to undergo seasonal upstream spawning migrations. The new dams combined with an inability of the Mahsier to adapt to lake habitats have probably resulted in a significant decline in the population of this species in the Mahaweli Ganga.

Other fish which may have become adversely affected by interference with migration patterns are probably the endemic Mountain Labeo, Labeo fisheri; Olive

Barb, Barbus sarana; and Long-Snouted Barb, Barbus dorsalis. These species are all believed to migrate annually up the main rivers to spawn in very small hill streams. The Barbs, which may well occur in the Kotmale reservoir, are known to leave tanks or villus to enter upstream rivers and streams. Occasionally large concentrations of these fish are found in very small streams.

Young eels also migrate upstream annually, returning after several years to spawn at sea.

Very large specimens of eel were caught in pools downstream of the Kotmale dam when the dam was closed and the water was diverted for the first time. Their migration upstream is nowadays probably blocked at the barrages of Randenigala or Victoria.

Downstream fish movements are also blocked by the Kotmale dam and the others downstream of the river. However, fish may be swept over the spillways or drawn into the power intakes. A substantial number of fish which pass through power turbines do survive, the losses usually being due to physical injury.

Human implications

The domestic use of water does not seem to have been impaired on the stretch between the Kotmale dam and the Mahaweli Ganga. The basic flow from small side streams is sufficient for the domestic supply even during the dry seasons. For instance, water is pumped from a small overflow barrage in the river-bed below the SKANSKA camp, but only a minor portion of the flow is utilized. Furthermore, there is no industrial or agricultural use of the river water in the section discussed.

The altered hydrology in the river-bed between the Kotmale dam and the confluence with the Mahaweli Ganga may have a potential impact on the breeding of e.g. mosquitoes. A small stream flow in a large river-bed may form small pools of stagnant water at minor changes in the hydrology and at occasional rains.

These pools may provide the Anopheles culicifacies mosquito, which is probably the sole vector of malaria in Sri Lanka, with suitable breeding sites. This species is known to breed in river bottoms, while the adults of the species reside close to man.

Clemesha (1934) reports the following for Anopheles culicifacies:

> "The optimum breeding place for this species is a (sandy) stream running over flat country (and which) is almost empty (due to) drought. The water must be clear ... (and) there must be a good portion ... on which the sunlight plays for a good number of hours ... Very small collections of water in the sand are much favoured, foot or hoof marks are frequently full of larvae ... provided they are in the sun. It is useless to look for A. culicifacies, except in sunny places."

This breeding habitat correlates with the riverine distribution of epidemic malaria in Sri Lanka and with maximum transmission following drought periods.

However, even during the pre-impoundment water flow, parts of the riverbed dried up in the dry seasons creating a breeding habitat for mosquitoes.

ENVIRONMENTAL IMPACT OF THE RELEASE OF WATER

General

The water released into Mahaweli Ganga through the tailrace outlet originates from the levels above 665 metres in the reservoir. Depending on the degree of drawdown, the water which enters the tunnel towards the power plant may originate from near the surface or at the most from a depth of 38 metres when the reservoir stands at full supply level (+703 m).

The depth from which the water is drawn may be of certain importance since if it is essentially surface water it may be poorer in nutrients and richer in phytoplanktons compared to the bottom water. The latter may contain high concentrations of dissolved nutrients and may occasionally be deoxygenated and laden with hydrogen sulphide.

There is no direct or indirect evidence of the occurrence of hydrogen sulphide in the water released through the power plant. The occurrence of hydrogen sulphide, which is a gas that easily leaves the water, is usually immediately noticed by its foul smell at the power station. The stinking gas is detected by the human olfactory sensor (the nose) even in very low concentrations. Also at the tailrace outlet the occurrence of hydrogen sulphide in the water would be revealed by a foul smell.

The tailrace outlet ends in an open canal with swift-flowing shallow water (Picture 19) where a large number of fish-eating birds assemble for food gathering. The species include The Indian Shag, Phalacrocorax fusicicollis; Stephens, The Little Cormorant, Phalacrocorax miger; Vieillot, and The Little Egret, Egretta garzetta garzetta; Linn.

Whether or not the prey is fish moving upstream against the current to feed or spawn, or fish from the Kotmale reservoir that have passed through the turbines is unknown. In any case, the animal and plant life of the aquatic habitat at the tailrace outlet indicates a healthy environment.

The water released through the tailrace canal contains very little silt, the bulk of which has been deposited in the reservoir. This means that the silt-carrying capacity of the water increases, i.e. the clear water discharge has a high erosion potential. An open about 100 metres long erosion scar, in old river sediments, occurs on the right bank of the canal near the inflow into the Mahaweli Ganga.

The erosion capacity is rapidly diminished after the confluence with the Mahaweli Ganga, which is loaded with silt from upstream areas.

19. The tailrace canal.

However, some impact by erosion in the river-bed and on the river banks can be anticipated.

Recommendations

Information should be compiled on the fish population in the Mahaweli Ganga between the Victoria and the Kotmale reservoirs, and in particular the migration patterns.

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 of the signs of active erosion downstream of the tailrace outlet. The potential impact on the riparian environment from erosion should also be assessed.

APPENDIX 1

Terms of reference

STUDY ON THE ENVIRONMENTAL IMPACT OF THE KOTMALE HYDRO POWER PROJECT IN SRI LANKA

Background

The Government of Sri Lanka decided in 1978 to launch the "Accelerated Mahaweli Programme", a very extensive development undertaking with the object of utilising for power generation and irrigation the resources of the country's major river, the Mahaweli Ganga. The programme, which was expected to be completed in about six years, required foreign aid financing on an unprecedented scale.

Sweden through SIDA has provided grant aid of the order of some SEK 1.4 billion towards the financing of one of the "lead projects" of the accelerated programme, the Kotmale Hydro Power Project. The civil works have been executed by Skanska and commissioning took place in August 1985 following project completion some six months ahead of schedule.

The Kotmale project includes a 90 metres high rockfill dam across the Kotmale Oya, a tributary of the Mahaweli Ganga, a 6 kilometres long reservoir holding 175 million cu.metres of water and three generating units of 67 MW each in an underground power station to which water is led through a 7 kilometres long tunnel. Discharge is in the Mahaweli Ganga some 4 kilometres downstream of the confluence of that river and the Kotmale Oya. Kotmale is located at an altitude of aboutr 700 metres above sea-level at a bee-line distance 80 kilometres east of Colombo.

Recognising that major hydro power development may have an environmental impact, SIDA is planning to conduct a study of any such impact of the Kotmale project. Environmental data were not assembled in any systematic manner in the feasibility study of the project or else before the project was commenced. The proposed environmental study will therefore have to be limited to a description of the present state of the environment in the area deemed to be affected by the project and by the reservoir in particular. On this basis recommendations should be made regarding measures to reduce negative effects and to sustain positive ones.

During the initial operation of the plant, significant leakages were observed near the machine chamber. De-watering of the system disclosed longitudinal cracks in the high pressure shaft and in the incline tunnel which expert opinion ascribed to the phenomenon of "hydraulic fracture". Both the shaft and the tunnel are now being steel lined, and this work is expected to be completed by the end of 1987 and power generation resumed in early 1988. The plant will then have been out of operation for 18 months.

The Kotmale area is regarded as slide prone, and some have in the past warned against locating a major dam and reservoir in the area. This refers to slides due to reservoir induced seismicity and to water saturated earth in the hillsides adjacent to the reservoir. SIDA will be commissioning a special desk study on these subjects based on relevant data regarding the Kotmale area.

In the area inundated by the reservoir there lived about 15,000 persons. They have been evacuated to new settlements in the Kotmale region or downstream with access to irrigated land. SIDA will be commissioning a study for the purpose of obtaining information about the situation of the evacuees and their adjustement in the new settlements. This will include investigating the infrastructure facilities lost in the Kotmale area when the reservoir was impounded and action taken to have facilities replaced. It follows that this aspect need not be covered in the environmental study.

In 1986 there were a number of landslides in the Kotmale area as a result of which people living at affected sites had to be evacuated to new settlemets in the area. This group will be included in the study on the evacuees, and the environmental study should include obtaining data on the landslides with a view to assessing whether there was a causal link between the existence of the reservoir and the occurrence of the slides.

Terms of Reference

Taking into account the coverage of the above-mentioned other studies the terms of reference of the environmental study will be as follows:

- Collect and prepare background material in the form of information from central and local authorities, literature and published reports, unpublished material and information from surveys in progress.

- Compile and analyse data from maps and aerial photos.

- Conduct field trips to selected areas to check the actual situation and to collect additional information.

- Based on the above, identify the large scale ecological units and arrive at a delimitation of the area directly or indirectly affected by the project both geographically and in a dynamic sense.

- Describe briefly the major ecosystems and their components.

- Describe the present state of the environment in the reservoir area.

- On the basis of data regarding the 1986 landslides in the periphery of the reservoir, examine the question whether these slides may have been induced by the existence of the reservoir.

- Describe trends of the environmental developments in a short term and a long term perspective.

- Recommend measures which could be taken in order to reduce existing or potential negative trends in the environmental development.

- Identify ways to sustain or enhance positive environmental developments.

For the assignments SIDA requires the services of a qualified consultant who has relevant academic qualifications and wide experience of similar work. Preference will be given to candidates whose background includes assignments on environmental aspects of hydro power development in the tropics, particularly in developing countries. The consultant should have a very good knowledge of English so as to be able to prepare a report in that language, to be shared with the Sri Lankan authorities concerned.

The assignment should be carried out within a period not exceeding two months, and approximately one-third of this time would be required for field work in Sri Lanka. Documentation of relevance available at SIDA will be placed at the disposal of the consultant, and while in the field he will receive assistance from the Development Cooperation Office of the Swedish Embassy in Colombo as regards introduction to the authorities, transport arrangements etc.

APPENDIX 2

Persons met

We would like to express our appreciation to the following institutions, agencies and individuals for providing information and assistance in the preparation of this report:

Mr M.B Adikaram, Upper Mahaweli Peripheral Develpoment Unit
Mr H.M Asoka Kumara, Mahaweli Authority
Mrs E. Asplund, SIDA, Colombo
Dr A. Attanayake, Mahaweli Authority
Mr S.K. Chandrasekara, Kotmale Project
Mr I.M.B.S.A Ekanayake, Kotmale Project
Mr M.J. Fernando, Master Plan Office
Mr. L. Godamunne, Mahaweli Authority
Mr K.H.S. Goonetileke, Mahaweli Authority
Mr M. Jansen, Mahaweli Authority
Mr H.B. Jayasekera, Central Engineering Consultancy Bureau (CECB)
Mr S.K. Jayawardana, Kotmale Project
Mr U.E.Koswatta, CECB
Mr H. de Mel, SIDA, Colombo
Col. I Samarawickrema, Ministry of Mahaweli Development
Mr J. Traneus, SIDA, STockholm
Miss S.K. Udangamuwa, Kotmale Project
Dr S. Uduwalage, CECB
Mr L.G. Ädel, Skanska AB, Colombo

Kumara, H.M.A. and Kulasinghe, A.N.S. 1986. - Slope Stability in the Kotmale Area. - Int. Geomorphology, 1986, Part I, pp. 111-119. John Wiley & Sons Ltd.

Leach, E.R. 1959. - Hydraulic society in Ceylon. - Past and Present, 15, 2-25.

Maclagan Gorrie, R. 1954. - Report on Kotmale Landslips and adjoining River Catchments, Ceylon. - Government Press, Sept. 1954, p. 12.

Madduma Bandara, C.M. 1985. - The Mahaweli Strategy of Sri Lanka. Great Expectation of a Small Nation. - In Lundqvist, Lohm and Falkenmark (eds) Strategies for River Basin Management, pp. 265-277. - D. Reidel Publishing Co.

Manchanayake, P. - Mahaweli & its Development Area. A Hydrological Study.

Mendis, A.S. 1976. - The Role of Man-made Lakes in the Development of Freshwater Fisheries in Sri Lanka. - In: Symp. on the Development and Utilization of Inland Fishery Resources, 17th Session, pp. 245-257. - Indio-Pacific Fisheries Council, Colombo.

Ministry of Fisheries, 1980. - Inland Fisheries Development, 1980-1984. Revised Implementation Programme. - Technical Committee on Inland Fisheries Development, Colombo.

NEDECO, 1979. - Mahaweli Ganga Development Programme. Implementation Strategy Study Annex A, Hydrology.

NEDECO, 1979 a. - Mahaweli Ganga Development Programme, Implementation Strategy Study, Annex K, Environmental Aspects, (32 pp.).

Panabokke, C.R. 1986. - Mahaweli after ten years. An overview of the environment. - S.L.A.A.S., Symp. Nov. 1986.

Pearson, H.H.W. 1899. - The botany of Ceylon patanas. - Journal of the Linnean Society, 34:300-365.

Pemadasa, M.A. and Mueller-Dubois, D. 1979. - An ordination study of montane grasslands of Sri Lanka. - Journal of Ecology 67:1009-1023.

de Rosayro, R.A. 1945. - The montane grasslands (Patanas) of Ceylon, I. - Tropical Agriculturist 101:206-216.

de Rosayro, R.A. 1946. - The montane grasslands (Patanas) of Ceylon, II, III, IV. - Tropical Agriculturist, 102:4-16, 81-94, 139-148.

Russel, J.R. 1980. - Kotmale Project Geomorphological Survey, Volume II, Sedimentation. - Gov. of Sri Lanka, Ministry of Mahaweli Development.

Senanayake, D.D. (undated). - Planning and design of roads around the upper reservoirs of the Mahaweli Project. - Mim. report 8 p. + 2 Annex.

SKANSKA, 1985. - Kotmale. A HYDROPOWER PROJECT. - Skanska AB, Danderyd, Sweden.

Survey Department of Sri Lanka, 1984. - Kandy and Nuwara Eliya Districts. Land use 1979/1981. (Map on a scale of 1:100 000). Survey Department, Colombo.

TAMS, 1980. - Environmental Assessment. Accelerated Mahaweli Development Programme. Vol. I. Main Report. - Ministry of Mahaweli Development, Colombo.

TAMS, 1980a. - D:o Vol. II. Terrestrial environment.

TAMS, 1980b. - D:o Vol. III. Aquatic environment.

TAMS, 1980c. - D:o Vol IV. Human environment.

Temple, P.H. and Rapp, A. 1972. - Landslides in the Mgeta Area, Western Uluguru Mountains, Tanzania. - Geogr. Annaler 54A, 3-4, pp. 157-193.

UNDP/FAO, 1969. - Mahaweli Ganga Irrigation and Hydro-Power Survey. - Final Report, Vol. I, II, III, SF:55/Cey-7, Rome.

D'A Vincent, F. 1882. - Report on the conservation & Administration of the Crown forests in Ceylon.

Vitanage, P.W. 1981. - Geology and structure of the Kotmale project area. Vol. I and II. - Sir William Halcrow and Partners and C.E.C.B.

Vitanage, P.W. 1986. - Landslide (creep) damaged houses in the villages around the Kotmale reservoir project area. - Mim. Report to the Mahaweli Authority, 27 pp.

Vitanage, P.W. and Kehelpannala, W. 1986. - Linaments and Tectonics around Victoria and Kotmale Reservoirs and the Engineering Geological Implications. - Institute of Fundamental Studies, Hatane, Kandy.

APPENDIX 4

Kotmale hydro power project – summary project description

A 600 m (1,968 ft.) long rockfill dam with a concrete membrane will be constructed across Kotmale Oya. The full supply level of the reservoir will be 703 m (2,306 ft.) MSL which will provide a gross storage capacity of 175 m.cm (141,000 ac.ft.). The crest elevation will be 706.5 m (2,317 ft.) MSL. The concrete membrane on the upstream face will have a thickness of 300 mm (1 ft.) at the crest increasing to 500 mm (1.6 ft.) at the plinth. The chute spillway located on the left bank will have three gates of size 14 m x 15 m (46 ft. x 49 ft.) capable of discharging 5,550 cumecs (196,000 cusecs) with all three gates open.

River diversion will be effected through two 9.2 m (30 ft.)diameter "D" shaped lined tunnels capable of discharing 1,700 cumecs (60,000 cusecs) which is the 1 in 100 year flood. The bottom outlet installation will be situated in an underground chamber on the right bank and access thereto will be through an access tunnel from a point downstream of the dam. Water will be drawn in through an inlet tunnel and will be discharged to the river through an outlet tunnel. It should be capable of discharging a minimum of 420 cumecs (14,820 cusecs) with the water level at 690 m (2,263 ft.) MSL.

The intake structure, located on the right bank, is capable of discharging 113 cumecs (4,000 cusecs). The 84 m deep gate shaft with an area of 24 m^2 is located 250 m downstream of the intake.

The water conductor system consists of a 6,560 m (21,517 ft.) long 6.2 m (20 ft.) diameter horseshoe shaped lined low pressure tunnel, 15 m (49 ft.) diameter 140 m (459 ft.) deep surge shaft, and a high pressure tunnel system. The lower end of the high pressure tunnel system leading into the underground machine chamber will be steel lined. The steel lined section will initially be 4.8 m (15.8 ft.) diameter bifurcating twice to serve each machine with a gradual reduction of diameter to 2.1 m (6.9 ft.).

The machine chamber will be 67 m x 18 m x 34.7 m (230 ft. x 59 ft. x 114 ft.) capable of housing three machines. The downstream surge chamber will be located just downstream of the machine chamber and the horseshoe shaped lined tailrace tunnel will be 6.2 m (20 ft.) in diameter and 645 m (2,116 ft.) long. The transformers and switchyard will all be located on the surface immediately above the machine chamber. A cable cum ventilation shaft will connect the machine chamber to the switchyard area.

Two Francis type turbines directly connected to the vertical shaft generators with an installed capacity of 134 MW will be commissioned initially. The increase in system firm energy due to the introduction of Kotmale Project has been estimated at 460 GWh with a long term average annual total of 500 GWh.

(From "Specific Agreement on the Kotmale Hydro Power Project" between the Government of Sweden and the Government of Sri Lanka, 1982).

APPENDIX 5

Kotmale hydropower project

Client	The Government of the Democratic Socialist Republic of Sri Lanka, represented by: Mahaweli Authority of Sri Lanka Ministry of Mahaweli Development. No. 500, T.B. Jayah Mawatha Colombo 10, Sri Lanka
Consultant Civil Works	Halcrow Water Burderop Park Swindon, Wiltshire SN4 OQD, England
Consultant Electrical and Mechanical Works	Kennedy and Donkin Westbrook Mills Godalming, Surrey GU7 2AZ, England
Associated Consultant	Central Engineering Consultancy Bureau (CECB) No. 500, T.B. Jayah Mawatha Colombo 10, Sri Lanka
Main Contractor Civil Works	Skanska AB S-182 25 Danderyd, Sweden
Specialist Contractor Grouting Works	Stabilator AB S-182 25 Danderyd, Sweden
Main Contractor Electrical and Mechanical Works	ASEA AB S-721 83 Västerås, Sweden
Sub-Contractors – turbines, valves	Boving-KMW Turbin AB Box 1010 S–681 01 Kristinehamn, Sweden
– spillway gates	Kollin & Ström AB Tunavägen 290 S-781 35 Borlänge, Sweden

– penstock and gates	Gränges-Hedlund AB Hammarbyvägen 40 S-104 80 Stockholm, Sweden
– ventilation	Fläkt AB Sickla Allé 13 S-104 81 Stockholm, Sweden
Financing	The Government of Sri Lanka Swedish International Development Authority (SIDA) Birger Jarlsgatan 61 S-105 25 Stockholm, Sweden

APPENDIX 6

Pre-impoundment water quality data of Kotmale Oya at the damsite from March 1963 to October 1979 (records from Government Analyst's Department and TAMS, 1980, volume III).

Parameter	Range	No. of sampling occassions
Temp. °C	22.5	1
D.O. mg/l	8.2	1
pH	6.4-7.2	8
Hard. mg/l	9-14	6
E.C.	18-50	8
TDS mg/l	13-40	7
S.S. mg/l	20-90	4
Turb. JTU	8-140	4
HCO_3 meq/l	0.16-0.30	7
Cl meq/l	0.17-0.28	7
SO_4 mg/l	3	3
Tot. N	0.01-0.26	4

APPENDIX 7

Birds

Birds observed in or around the home gardens on the slopes adjacent to the Kotmale reservoir. January 15-23, 1988. (Nomenclature according to Henry, 1971).

Vernacular name	Scientific name
The Black Crow	Corvus macrorhynchos culminatus; Sykes
The House Crow	Corvus splendens protegatus; Madarasz
The Ceylon Blue Magpie	Cissa ornata; Wagler
The Ceylon Grey Tit	Parus major mahrattarum; Hartert
The Common Babbler	Turdoides striatus striatus; Dumont
The Red-Vented Bulbul	Molapes cafer cafer; Linn
The Southern Magpie-Robin	Copsychus saularis ceylonensis; Sclater
The Ceylon Ashy Prinia	Prinia socialis brevicanda; Legge
The Brown Strike	Lanius cristatus cristatus; Linn.
The Ceylon Common Mynah	Acridotheres tristis melanosternus; Legge

Vernacular name	Scientific name
The Ceylon Common Drongo	Dicrurus caeutescens leucopygialis; Blyth
The Common Grackle	Eulabes religiosa indica; Euvier
The Ceylon Grackle	Eulabes ptilogenys; Blyth
The Ceylon Hill Munia	Uroloncha kelaarti kelaarti; Jerdon
The Spotted Munia	Uroloncha punctulata lineoventer; Hodgson
The Ceylon House Sparrow	Passer domesticus soror; Ripley
The Indian Skylark	Alauda gulgula australis; Brooks
The Ceylon Bush Lark	Mirafra affinis ceylonensis; Whistler
The Grey-Headed Yellow Wagtail	Montacilla flava thunbergi; Billberg
The Hill Swallow	Hirundo javanica domicola; Jerdon
Lotens Sunbird	Cinnyris lotenia lotenia; Linn
The Ceylon Red-Backed Woodpecker	Brachypternus benghalensis erithronotus; Viellot
The Ceylon Small Barbet	Xantholaema rubricapilla rubricapilla; Gmelin
The Stork-Billed King-fisher	Pelargopis capensis gurial; Pearson

The Ceylon White-Breasted Kingfisher	Halcyon smyrnesis fusca; Boddaert
The Indian Edible-Nest Swift	Collocalia fuciphaga unicolor; Jerdon
The Common Coucal	Ceatropus sinensis parroti; Stresemann
The Emerald-Collared Parakeet	Psittacula calthorpae; Blyth
The Ceylon Serpent Eagle	Spilornis cheela spilogaster; Blyth
The Ceylon Spotted Dove	Streptopelia chinesis ceylonensis; Reichenbach
The Cattle Egret	Bubulcus ibis coromandus; Boddaert
The Pond Heron	Ardeola grayii; Sykes

APPENDIX 8

Aerial seeding as a method of improving degraded vegetation in the tropics

Basic concept

1. Trees and shrubs are sometimes strikingly rare or absent in areas where soil and climate, mainly rainfall, would be able to support open woodlands or forests.

2. The reason for this is often associated with past or present man-made degradation of the original plant cover, e.g. by tree-felling, fires and through the impact of domestic animals.

3. If trees and shrubs are rare or absent, the amount of seeds will be low or non-existent. Subsequently there will be a poor regeneration, or none at all, even when favourable climatic conditions occur, e.g. during a sequence of years with rainfall above the average.

4. The bulk of the seeds from trees and shrubs are mostly deposited very close to the parent individual, even seeds which are adapted to be dispersed by the wind. This means that immigration of seeds is negligible in a short-term perspective.

5. Trees and shrubs are important since they decrease evaporation and increase rainfall penetration of the ground. Furthermore they draw nutrients to the soil surface and provide a refuge for many species. They are also important in many respects to man and domestic animals.

6. By means of a man-made dispersal of seeds, so called direct-seeding, from suitable species of trees and shrubs, it is possible to increase the establishment of woody vegetation in degraded habitats.

7. Seeds should preferably be chosen from indigenous species and especially ecotypes from the regions to be aforested or revegetated, since the offspring from these individuals, by natural selection, are more fit to withstand the many obstacles which occur during germination and growth.

8. The scale of the degradation is already so large that methods of combatting the destructive developments have to be equally large-scale.

9. Dispersal of seeds by terrain-crossing vehicles or airplanes permits large areas to be seeded in a short time when conditions are most favourable.

10. Aerial seeding is furthermore specially suitable for remote and inaccessible areas, and can be used regardless of the topography or traversability of the terrain to be seeded.

SIDA EVALUATION REPORT SERIES

1987/1 **EXTENSIVE RURAL DEVELOPMENT**
An Evaluation of the Zone I Programme in Guinea-Bissau
by Jan Olsson, Lars Smedman, Göran Widerström

1987/2 **FOREIGN EXCHANGE ZAMBIA**
An Evaluation of the Auction System in the Zambian Economy
by Rudolf Jalakas

1987/3 **DROUGHT AND DESTABILIZATION**
An Evaluation of Swedish Disaster Relief in Mozambique 1983 to 1985
by Tom Alberts and Krister Eduards

1987/4 **HEALTH CENTRES–IN NEED OF TREATMENT**
A Joint Evaluation of Sweden's Support to Health Sector Development in Tanzania 1972–1976
by Lillemor Andersson-Brolin, Frants Staugård

1987/5 **TRAINING FOR PUBLIC SERVICE**
An Evaluation of Sweden's Co-operation with Zimbabwe in Public Service Training 1982–1986
by Astrid Dufborg, Merrick Jones, Elisabeth Lewin

1987/6 **LOOKING BOTH WAYS**
Swaziland between South Africa and SADCC
An Evaluation of Sweden's development co-operation with Swaziland
by Samuel Falle, Karlis Goppers and Lars Johansson

1987/7 **PAPER, TIMBER AND MINORITIES**
An Evaluation of Sweden's support to Forest Industry in Bangladesh by Karlis Goppers, Hans Nordin and Jan Valdelin.

1987/8 **FORESTRY FOR THE POOR**
An evaluation of the SIDA supported Social Forestry. Project in Tamil Nadu, India
by Mike Arnold, Axel Bergman, Göran Djurfeldt

1988/1 **MIGRANTS BY NECESSITY**
A report on the living conditions of forestry workers in the SIDA supported Bai Bang Programme.

1988/2 **SISTERHOOD ON TRIAL**
An evaluation of the performance and linkages of the sister industries in Tanzania
by Jerker Carlsson, Sverker Alänge, Kim Forss, Serve Malai, Sari Scheinberg

1988/3 **IMPROVE YOUR BUSINESS**
An Evaluation of a ILO/SIDA Regional small scale business promotion Project in Africa
by Claes Lindahl and Rob Dainow

1989/1 **THE KOTMALE ENVIRONMENT**
A study of the environmental impact of the Kotmale Hydropower Project in Sri Lanka
by Dick Johansson

1989/2 **FISH FARMING FOR RURAL DEVELOPMENT**
An Evaluation of SIDA/FAO supported aquaculture in southern Africa
by Karlis Goppers and Jim Miller

THE KOTMALE DAM ENVIRONMENT

The area of the Kotmale Hydropower Project in Sri Lanka has problems of mass movements of soil, water regulation and land use. Some of them are caused by the dam construction, and can be mitigated, while others seem to be natural to the area.

These are some of the findings of this evaluation which suggests that road construction and detailed land use planning be undertaken, in order to drain the valley slopes and reduce silt into the reservoir.

Sweden's bilateral development co-operation, handled by SIDA since 1965, comprises 17 programme countries: Angola, Bangladesh, Botswana, Cape Verde, Ethiopia, Guinea-Bissau, India, Kenya, Laos, Lesotho, Mozambique, Nicaragua, Sri Lanka, Tanzania, Vietnam, Zambia and Zimbabwe.

Each year about 30 of SIDA's over 200 projects are evaluated. A number of these evaluations are published in the SIDA Evaluation Report Series. Copies of the reports can be ordered free of charge from SIDA, S-105 25, Sweden.

ISBN 91-586-7102-1
ISSN 0283-0736

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY