SOME ENVIRONMENTAL ASPECTS OF DAM PROJECTS IN MALAYSIA : OPERATIONAL RESULTS AND OBSERVATIONS

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SUMMARY

The effects of reservoir projects on the environment, and vice versa, are well established but the scope and magnitude of these effects are more variable depending on many factors. In the case of dam projects in the tropical zone, these effects are also more uncertain due to the paucity of monitored data and systematic observations of operational characteristics through proper reservoir management programmes.

This paper outlines dam development in Malaysia and studies on environmental impact together with the post impoundment monitoring and other observations carried out during operation. Because of the constraints of institutional policy and resources limitation, monitored data are somewhat scarce but these have been supplemented by qualitative observations in arriving at the preliminary findings.

Four reservoir projects of various sizes are cited in discussing the selected environmental issues, which include population displacement and resettlement, the clearing and non-clearing of inundated areas, medico-ecology and public health, impact and changes in flora and fauna, and other geophysical effects such as sedimentation, water quality and physical erosion. The issue of public awareness and participation is also briefly touched upon in the broader context of energy development in the country.

1. INTRODUCTION

1.1 General

Dam construction in Malaysia is of relatively recent origin, the first dam being built around the turn of the last century. More than 40 dams have been constructed since then and the current plan for the next decade is to build 40 or more dams to meet the requirements for power generation, agricultural and water supplies. Most of the earlier dams were small in size and it was only during the last 10 years that dams higher

than 50 m have been built.

Until the early 1970s, the environmental impacts of dam projects were not taken into consideration by proponents of such projects. The requirements of the international funding agencies had a strong influence on the early adoption of Environmental Impact Assessment (EIA) in dam projects especially in the hydropower development sector. Since 1974 there has been an Environmental Quality Act (EQA) relating to the prevention, abatement, control of pollution and enhancement of the environment, but it was not until 1985 that EIA was made mandatory through the EQA (Amendment) 1985. Subsequent to this amendment an Order, the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987 was gazetted by the Government for enforcement with effect from April 1988.

The early study reports on EIA were rudimentary, consisting of largely qualitative assessments many of which were of a speculative nature. No standardised methodologies of impact assessment have been evolved since the introduction of EIA in the country and this is largely due to the fact that baseline data and qulified manpower were lacking. Despite these weaknesses techniques are improving as the mandatory EIA is applied to more dam projects.

There are a large number of environmental issues attributable to the creation of reservoirs. This paper aims at highlighting the issues pertaining to population displacement and resettlement, the clearing and non-clearing of reservoir areas, medico-ecology and public health, impacts and changes on flora and fauna and other geophysical and physical effects such as sedimentation, water quality and physical erosion. The issue of public awareness and participation is also mentioned in the broader context of energy development in the country.

Four reservoir projects of various sizes are cited in discussing the selected environmental issues and the salient features of these projects are as tabulated in Table 1. the general location of these projects is shown in Figure 1.

2. ENVIRONMENTAL STUDIES AND FINDINGS

2.1 Summary of environmental study findings

Environmental studies carried out for dam projects in Malaysia are usually conducted as part of the feasibility studies of such projects. These EIA studies normally comprise several baseline sub-studies covering socio-economic, medico-ecology terrestrial and aquatic ecosystems, mineral resources and tourism and recreational potential. Systematic

Name of Reservoir	Year of Completion	Rivers	Reservoir surface area km^2	Gross storage $x10^6m^3$
Cameron Highlands	1963	Bertam/Batang Padang	0.5	6.18
Temengor	1978	Perak	152	6050
Batang Ai	1985	Batang Ai	90	2650
Kenyir	1985	Terengganu	369	13600

Table 1
Summary of project features

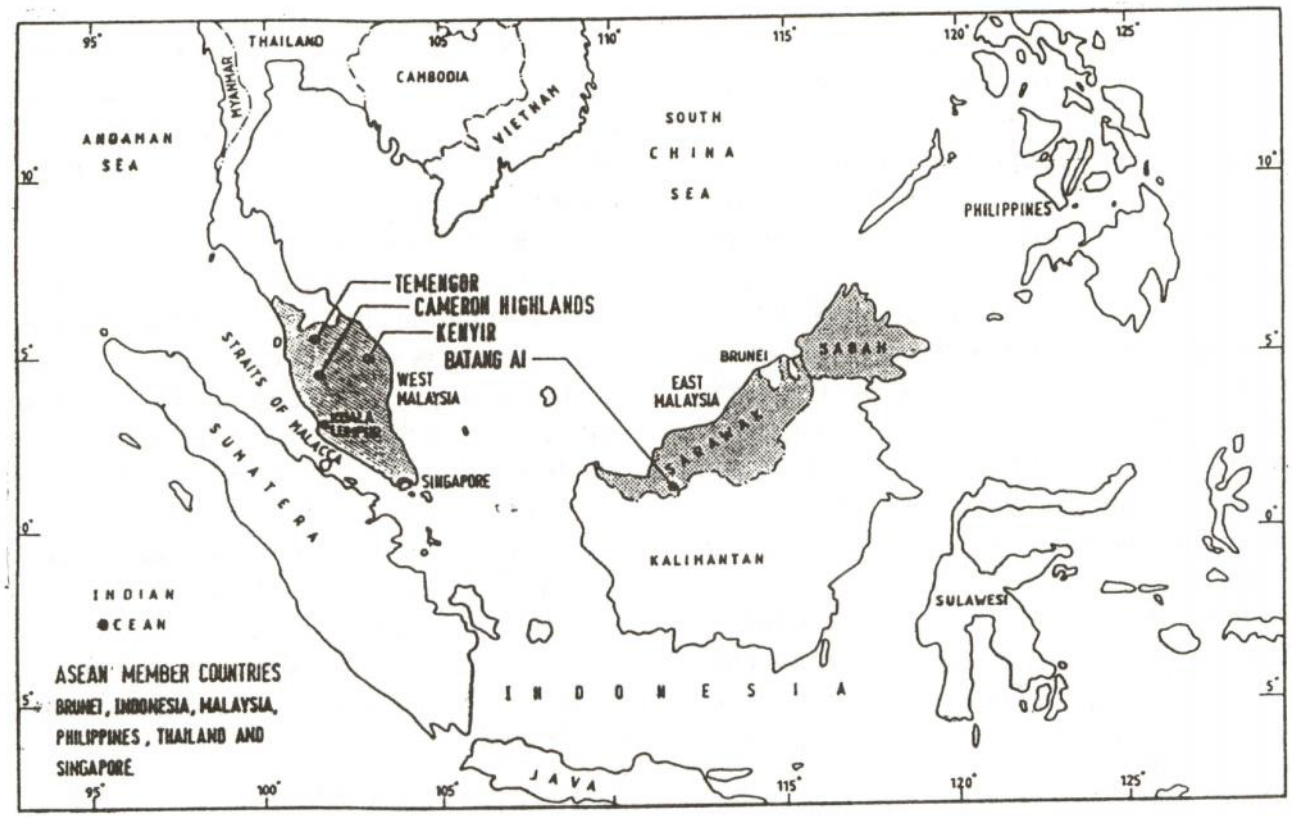


Figure 1
General location of projects within the Asean map

post impoundment monitoring of environmental parameters has yet to be carried out but certain ad hoc surveys of socio-economic, water quality, fishery and medico-ecology has been undertaken from time to time. Table 2 shows the feasibility findings of the environmental studies for Kenyir, Temengor and Batang Ai expressed in a simplified form to indicate the relative signficance of the adverse and beneficial effects of both the direct, or indirect or induced impacts.

2.2 Mitigation measures

Generally the mitigating measures involved were either in the form of engineering design or further studies and setting up of task forces or committees to mitigate predicted significant adverse impacts of reservoir projects. In most cases of dam development in Malaysia, the mitigation measures of the adverse impacts involved mainly further studies on abatement measures. This is obvious for the fact that data relating to the environment of the project were lacking especially in respect of the catchment and downstream aquatic ecosystems.

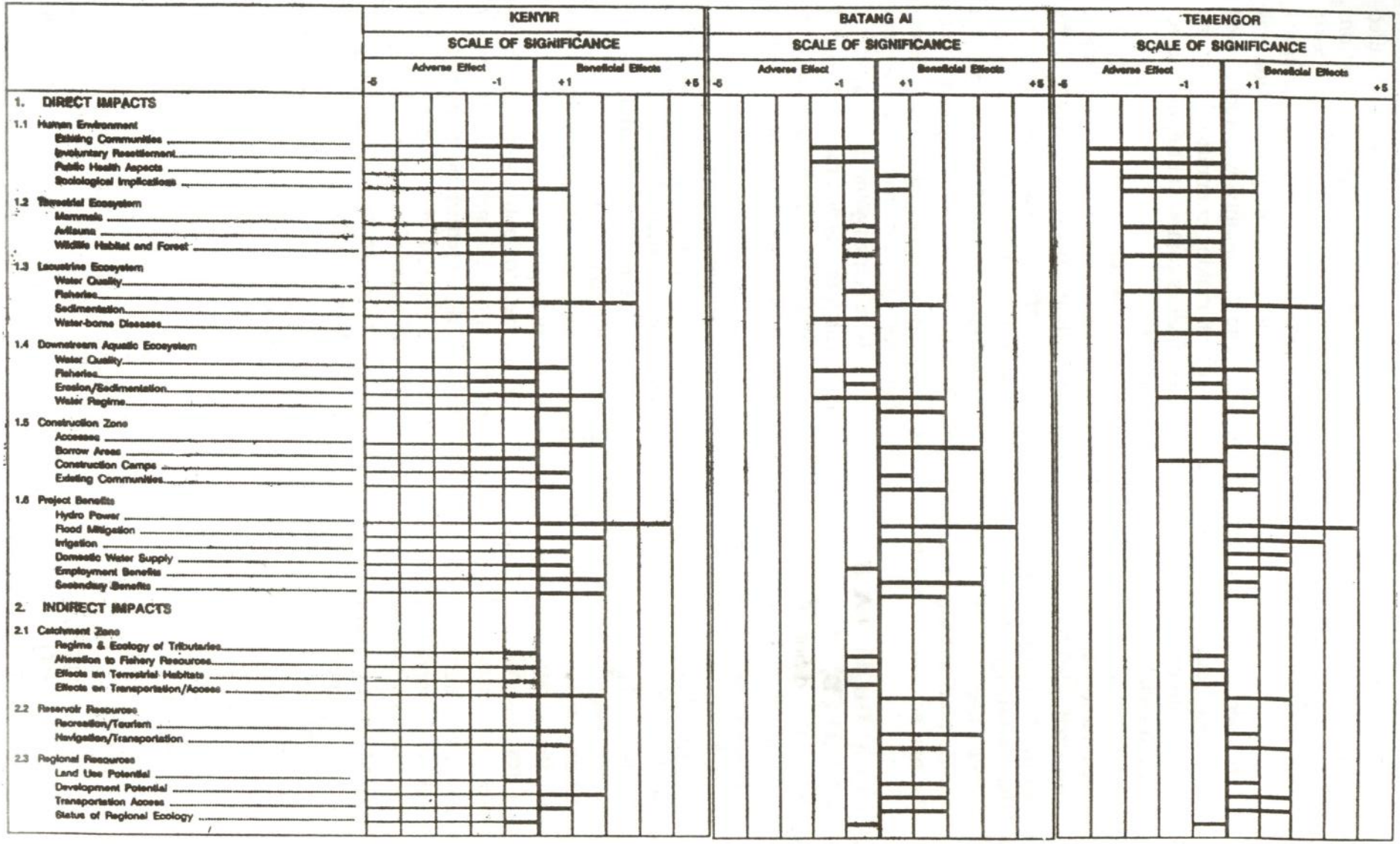
3. POST IMPOUNDMENT MONITORING

3.1 General constraints

One of the major constraints associated with the post impoundment monitoring is the lack of baseline data without which accurate assessment is impossible. Another common problem is the high cost of undertaking post-impoundment monitoring on an extended basis. Lacking of trained personnel in the collation, monitoring and analysis of data collected is also considered a contributing factor. These constraints usually resulted in a more ad hoc short term measures in environmental management which is not very satisfactory.

3.2 Shortcomings of the results

Due to paucity of baseline data, unskilled personnel and financial constraint, post impoundment monitoring tend to be based on qualitative observations rather than quantitative measurements and evaluations. This was evident in the post impoundment study conducted for Kenyir where lack of basic quantitative data and analysis have resulted



GENERAL CRITERIA FOR SCALE OF SIGNIFICANCE:

0-1 Relatively minor significance (i.e. a recognisable impact which does not require mitigating actions or does not generate important local benefits);

1-2 Slightly significant (i.e. a localized impact which is acceptable particularly if mitigating actions are possible or which generates localized important benefits);

2-3 Moderately significant (i.e. a regionally important impact which requires mitigating actions or which generates regionally quantifiable benefits);

3-4 Significant

4-5 Highly significant

(i.e. regionally or nationally important impact which requires extensive mitigating or compensatory actions or which generates important regionally or nationally quantifiable benefits)

TABLE 2 Simplified EIA Tabulation of Dam Projects

in the inability to fully address the effectiveness or otherwise of the mitigating measures undertaken for the project. The study can be considered a compilation of qualitative observations and in some instances a summary of perceptions.

Inadequate socio-economic baseline data were also experienced during the post impoundment socio-economic study for Temengor. Even though social impact assessment tends to rely more on qualitative data, the absence of such basic data made the comparison of predicted impacts and the actual outcome difficult. It was necessary to depend on the knowledgeable persons still living in the study area to provide the background information but sometimes such information is less than accurate or reliable.

4. IMPACTS PREDICTED AND OBSERVED

4.1 Environmental and Social Aspects

A study on selected aspects of the observed effects caused by or related to the development of the Kenyir dam upon the immediate and surrounding environment was conducted in late 1989. The aspects studied include the social and economic effects upon villagers downstream from the dam site, water conditions resulting from the impoundment and effects upon the biological systems such as forest and other vegetation types, fish species and terrestrial wildlife.

Table 3 shows the summary of the effects predicted prior to impoundment and the observations made six years later.

Involuntary resettlement in dam projects development is one of the impacts that cause profound economic and cultural disruption to the individuals affected and the social fabric of the local community. One of the earliest resettlement program ever experienced in Malaysia was during the construction of the Temengor Hydroelectric Project in 1974.

Some 136 families comprising of 1500 people were displaced by the reservoir development. The dislocation of the population was identified as one of the major environmental impact from the enviromental assessment made on the project. The assessment was based merely on officials of public agencies.

In spite of the absence of any detailed study of community needs and expectations of the villagers to be relocated, the basic principles relating to government responsibility, resettler rights and participation was exercised. The community was represented in the decision making committee in dealing with issues such as compensation, infrastructure needs, etc.

A new township was constructed to relocate these families. The resettlement township is about 50 km downstream of the dam with an area of about 1000 hectares. Each resettled family was provided with a 3 bedroom house on a 0.2 hectare lot with public facilities such as school, clinic, mosque, community hall and police station. Infrastructure facilities included paved access and service roads, electricity and treated water.

Each settler family was further provided with 5 hectares rubber trees together with a monthly subsidy until the planted trees reached maturity.

A socio-economic study of the resettled population was conducted in 1989 ten years after have been resettled. The study was to assess the socio-economic conditions of the population with some focus on psychological adjustment and the effectiveness of the resettlement program.

On the basis of both income and non-income indicators the results of the study showed that the resettled population have experienced a marked improvement in their general living standards which were comparable to those experienced in a similar voluntary settlement scheme.

Rubber tapping was the single most important occupation in the settlement and only a quarter of the working population had secondary occupation to supplement their income. Mixed farming and petty trading were the most popular form of supplementary occupation.

One focus of Temengor study was the socio-psychological aspects of the settlers. In the absence of recorded data before the villagers were relocated, the study was designed to make a comparison with a nearby

Subject	Identified Impacts	Observations
Watershed	Microclimate could be affected, but macroclimate will not.	Insufficient time lapse to conclude but there has been considerable increase in the total annual rainfall since impounding. Variations in monthly rainfall is, however, less distinct.
	Eroding of steep under careless landuse.	Some erosion along lake shores due to logging activities.
	Minor seismic activities may be experienced.	Tremors occurred one year after impoundment and intermittently in the following 3 years. Estimated acceleration at the dam between 0.01g and 0.05g. Created some fear among population downstream.
	Flash floods and siltation of rivers and lake may be caused by intensive or careless land use upstream, including logging.	Not yet demonstrated.
	River flow and sediment transport would be reduced.	River infalls act as sand traps.
	Water table around the reservoir will be raised.	Minor waterlogging of banks.
	Neram river will be flooded.	Confirmed.
	Aquatic fauna will be lost in the flooded streams, and migration of aquatic insects affected.	Not investigated.
	Riverine fish and fisheries will be affected.	Significant increase in fish population in initial period after impounding. Lately catches have been decreasing and much lower than predicted. Fisheries concentrated at infall points.
	Freshwater turtles will be seriously obstructed.	Disturbance to breeding spots affected freshwater turtles harvest.
	Submergence of forest by flooding, and death of vegetation by waterlogging in the catchment.	Confirmed about 370 km2 of forest submerged including about 3500 ha of the National Park area. Change in landscape from forested hills to lake scenery.
	Several islands will be created with seladang (wild cattle) in the largest of them.	Confirmed. Wildlife trapped by rising water. Public perception of increased elephant damage to crops and properties.
	The impoundment will enhance aquatic and terrestrial wildlife.	Not confirmed.
	Tourist potential will be improved.	Confirmed but not to predicted level.
	Impoundment may possibly encourage illegal settlements.	Only minor short-term illegal activities.
	Water-borne diseases may be spread.	Not confirmed.
	Much vegetation will decompose in the lake, and this decomposition will be slow because of the lake's depth. The initial period of nutrient enrichment will last two to five years. Stabilisation may occur after six to ten years.	Present critical conditions of dissolved oxygen below 13m (DO< 1mg/1). Nutrient enrichment indirectly confirmed by fish catches. Creation of clear, oligotrophic, oxygenated upper layer.
	Colonisation by carps will probably be successful. Fish yield should reach 50kg/ha/year initially, stabilising to 20kg/ha/year, totalling 1500 ton/year to 600 ton/year.	Carps of species already present form major part of catch. Catch estimated figure not confirmed but observed much lower catches.
	Aquatic weeds might flourish.	No aquatic weeds identified.
Downstream	Sedimentation will be increased and flushing reduced.	Not confirmed.
	Estuarine salinities may increase	Not confirmed.
	Freshwater turtle Batagur harvests will be affected.	Confirmed.
	Estuarine turtle Callagur populations will be unaffected or increased.	Not confirmed.
	Change in estuary configuration.	Severe coastal erosion at estuary coincides with the construction of the dam. Direct impact from dam construction not proven.
	Improvements in regional infrastructure.	Considerable extension and improvements of regional road system.
	Employment opportunities.	Short term during construction period and limited during operation. Employment in informal sector such as petty trading and small business has increased considerably.
	Limited adverse effects on fish and other aquatic fauna.	Fishing activity similar to that before impounding. Bloodshot-eye fishes reported downstream. BOD and DO concentration downstream fail to meet standard.

Table 3
Kenyir Environmental Studies and Observations

voluntary settlement scheme with regard to the level of socio-psychological well-being of the affected population. Generally the involuntary settlers were socially and psychologically less adjusted when compared to population of the voluntary scheme. Some felt that they have lost their status achieved in the former village especially in terms of land ownership. Some residents in the former village had larger pieces of land than others. However, when they were resettled, each family was only entitled to a standard size land. This to some extent creates dissatisfaction especially among those who were considered "rich" in their previous village. The study observed that the resettlement had contributed to breakdown of the social structure of the village. It dismantled the social stratification which had been part of the social fabric of the former village. So the "rich" were deprived of the status they used to have in spite of compensation paid for losing their lands.

The strong psychological attachment to the old village was also manifested in the pervading level of sadness ever since they left their homes for the new settlement especially for the older and "richer" people. The study indicated that the involuntary resettlement settlers were less happy than the voluntary scheme, because they felt they were forced to leave their village and to adjust socially and psychologically to a new environment and a new life style. Most of the settlers experienced cultural shock as they were not prepared for a sudden economic change from subsistence to cash economy which in many cases caused anxiety and tension.

No permanent communities were located in the impoundment area of the Kenyir dam project. Traditionally, the impoundment area has been utilized by a small group of Orang Asli (Aborigines). This group was resettled to a permanent site with amenities such as piped water supply, community hall and land for farming. This translocation has effectively halted the traditional way of life for the Orang Asli of shifting cultivation and may be perceived to be beneficial in the long term.

The construction of the Batang Ai dam involved the displacement of some 3000 people of the Iban tribe whose ancestors have living in the area for a few generations. The area affected was generally regarded as a poverty-striken area where extensive use of subsistence type shifting cultivation by the dwellers over the past decades has resulted in poor soils and depleted natural resources.

There are 418 families ("biliks") in the 26 longhouses involving some 3000 people. It was originally intenden that on account of the sentimental attachment these people have over their land they would be resettled within the catchment areas above the water level of the man-made lake. However, the terrain of these catchment areas is such that only a number of small pockets of land totalling 380 hectares could be identified as suitable for resettlement. A continuous block of land downstream of the lake in the Sebangki/Bui region with an area of approximately 3100 hectares was subsequently selected as the resettlement site.

The planning of the resettlement project was aimed to retain as far as possible the traditional Iban culture including the longhouse communities and padi cultivation. The strongly expressed preference is to maintain the longhouse style of life. The longhouses were therefore relocated "en bloc" in the resettlement area and each longhouse was located near an access road and provided with electricity supply and treated water.

A new community centre with a clinic, a police station, a post office, a shopping centre, an administrative centre, a community hall and provision for recreational facilities and places of worship was established to serve the resettled communities. A primary school was also provided at a location which is convenient for the school children to attend the school.

The adopted farm plan provided for 2 acres of terraced hill padi, 3 acres of cocoa, 5 acres of rubber and 1 acre of garden plot.

The plan incorporated the tradiditonal subsistence crop (hill padi), the traditional cash crop (rubber) which provided a moderate but fairly safe return, and an additional cash

crop (cocoa) which is slightly more risky but has the potential to yield a high income. The garden lot is for part-time planting of vegetables, fruit trees and if time permits for other cash crops. The farm plan was aimed at enabling the settlers to achieve higher standards of living when all the crops are matured.

In addition, an intensive programme has been implemented to develop reservoir fishery as an industry which could provide the people not only with a cheap source of protein but also job opportunities and additional cash incomes. A development plan has been drafted for promoting tourism industry for the area which would bring additional benefits to the people in the area.

The resettlement area was not far removed from the settlers' previous territory and the retention of farming activities and longhouse communities have mitigated against any feelings of being uprooted.

A socio-economic study of the resettled population was conducted in 1988, three years after resettlement. The study was aimed at documenting the socio-economic conditions of the communities after resettlement and to assess the effectiveness of the resettlement programme. The indication was that economically they were better off after resettlement. Paid employment during the construction of the hydro power project, construction of their new longhouses and establishment of their farms have made up to an equitable extent for the loss of income from their displaced lands.

Over the long term their new farms should ensure an appreciably higher level of income than they could obtain in their previous surroundings. In spite of the ritual importance of rice cultivation, they were now acutely aware of the economic value of cash crops. Improved housing and sanitation, provision of treated water and electricity, school and access to road communications have ensured not only greater physical well-being but also opportunities for diversification of their economic activities.

One particular problem which could arise is the shortage of land after distribution of property and land between siblings. It is Iban custom that children inherit land and property equally, regardless of sex, with those marrying out of their longhouse community relinquishing their rights. This, however, is a problem common to all Iban communities although it would be exacerbated where the amount of land is limited. This aspect needs to be considered in the longer term planning for these communities.

The construction of Kenyir dam has also significantly reduced the flood levels downstream of the dam resulting in the reduction of damage to infrastructure and properties and crops. This benefit is felt in the whole river basin. However, floods are still experienced in the downstream areas of other major tributaries which are not part of the river system affected by the Kenyir dam project.

On the other hand, flood control has also caused some losses to agriculture produce. Many villagers have reported that the agriculture lands along the river banks have become less fertile. In the past, flood waters added nutrients to the soil annually. It was also perceived that diseases to crops, especially vegetables caused by insects and rats are on the increase as a result of lesser floods.

4.2 Public Health

A medico-ecological survey was conducted prior to any project implementation to ascertain no major public health problems would occur due to the development. The primary aim was to establish base-line data with particular reference to vertebrate hosts, vector population and susceptible hosts in relation to their influence on the distribution of filariasis, malaria, schistosomiasis and gastro-intestinal parasites.

In Kenyir, the pre-implementation studies results is summarised as follows including remarks on observation made during and after implementation :

Zoonotic implications

There appeared to be no potential danger of parasites found in animals being transmitted to man during construction or after the completion of the project. This conclusion was derived from the fact that such cases

of infection in man were rare in Malaysia.

No cases of infection was reported during and after the implementation stage.

Entomological aspects

The study showed that the potential vectors of filariasis, malaria and dengue were present in the villages near the project area.

No cases of infection was reported during and after the implementation stage.

Potential health hazards due to snail transmitted diseases.

Based on the study findings there appeared to be little risk of an increase in the water-borne, snail transmitted diseases. The survey produced no snails of the type would transmit schistosomes in Malaysia.

No cases of schistosomiasis was reported to date.

Overall the Kenyir project appears to have no detrimental effect on health.

4.3 Water Quality

The construction of large tropical reservoirs has major effects on water quality both within the lake and also to downstream aquatic systems. One of the typical changes during stabilisation is oxygen depletion caused by decomposition of masses of terrestrial vegetation which usually is very much greater than the lake system can compensate for by diffusion or photosynthesis by aquatic plants.

Figure 2 shows the dissolved oxygen content within the reservoir and downstream of the dam for Cameron Highlands, Kenyir, Temengor and Batang Ai. Except for Ringlet reservoir in Cameron Highlands the inundated areas of these reservoirs were not cleared of forest vegetation. In Kenyir the impoundment started in late 1983 and filling of the reservoir to operating level was achieved within a year. As shown in Figure 2 the dissolved oxygen was initially within 2-4 mg/1 through the first 4 to 5 years and subsequently improved well above 7 mg/1 in 1989.

The water quality in the immediate downstream area of Kenyir dam met with the Malaysian Water Quality Standard for raw water except for biological oxygen demand (BOD) and dissolved oxygen (DO) content. The recommended interim standard of BOD for raw water is 3 mg/1 and for DO is between 5-8 mg/1. The low levels of DO and higher BOD levels is not surprising and is due to decomposition process that has been on-going in the reservoir.

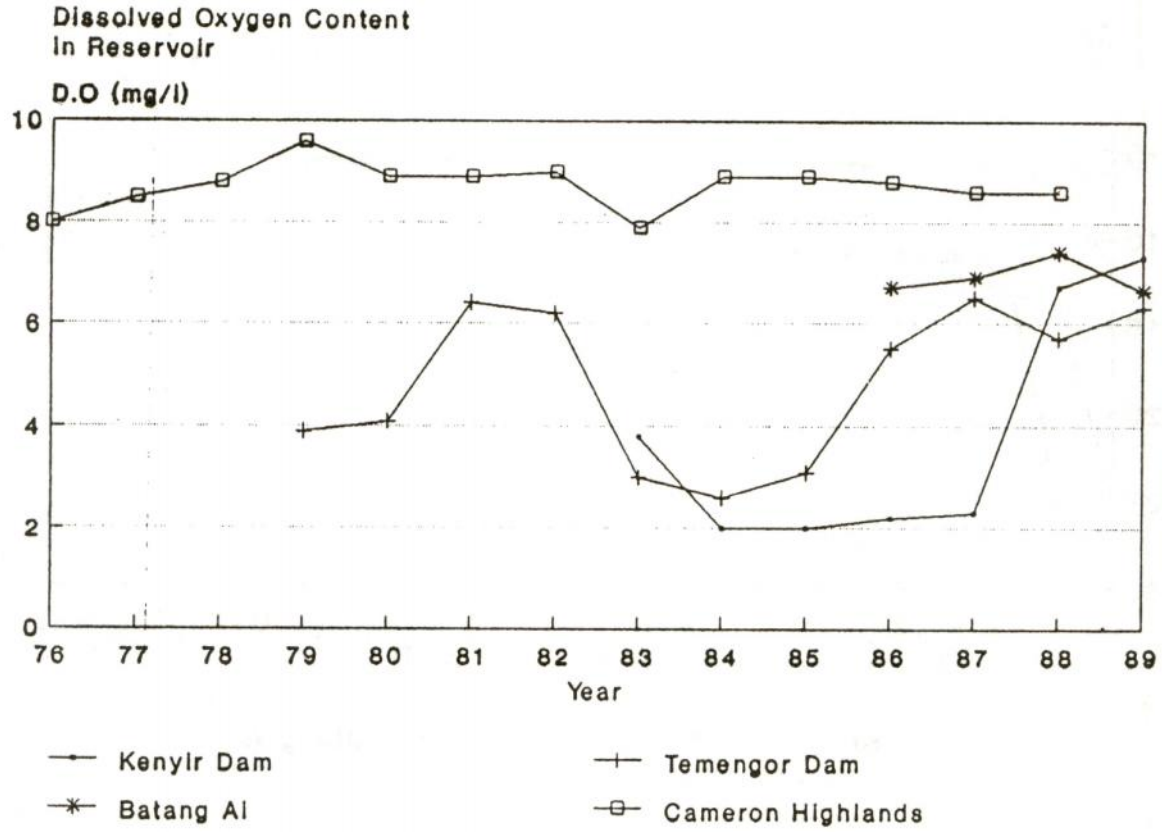
In the case of Temengor a similar trend of DO concentration in the reservoir was observed except that the depletion occurred at a later stage after the impounding. This can be explained from the fact that the impounding of Temengor took a longer period compared to Kenyir. The reservoir did not reach minimum operational level 3 years after impounding.

As expected, the Ringlet reservoir in Cameron Highlands which was cleared of forest vegetation prior to impounding shows a much higher DO content.

The DO level in the surface for both Kenyir, Batang Ai and Temengor is saturated but decrease with depth. Figure 3 shows the DO/depth profile in these reservoirs. In Kenyir a sharp decrease in oxygen level occurred at about 8m depth and a minimum oxygen level detected at 14m depth. In Temengor a sharp decrease occurred at about 6m depth while the depletion level at about 8m depth. The trend for Batang Ai shows same similarity with that of Kenyir.

Fouling of coolers in particular the generator air coolers and the lower guide/thrust bearing coolers has been experienced in Kenyir power station. The fouling of the coolers caused the generator temperatures to increase and consequently limits the maximum power output from 100 MW to as low as 80 MW often within a month of manual cleaning. The fouling was caused by the choking of the cooler tubes with silt, fine iron oxide particles and possibly organic matter. A similar problem was also experienced in Batang Ai and monthly manual flushing and clearing of generator air coolers has been carried out to overcome the fouling.

The existing cooling water system at Kenyir draws water from the tailbay, and pumps it through primary strainers, generator air coolers, lower guide/thrust bearing coolers,



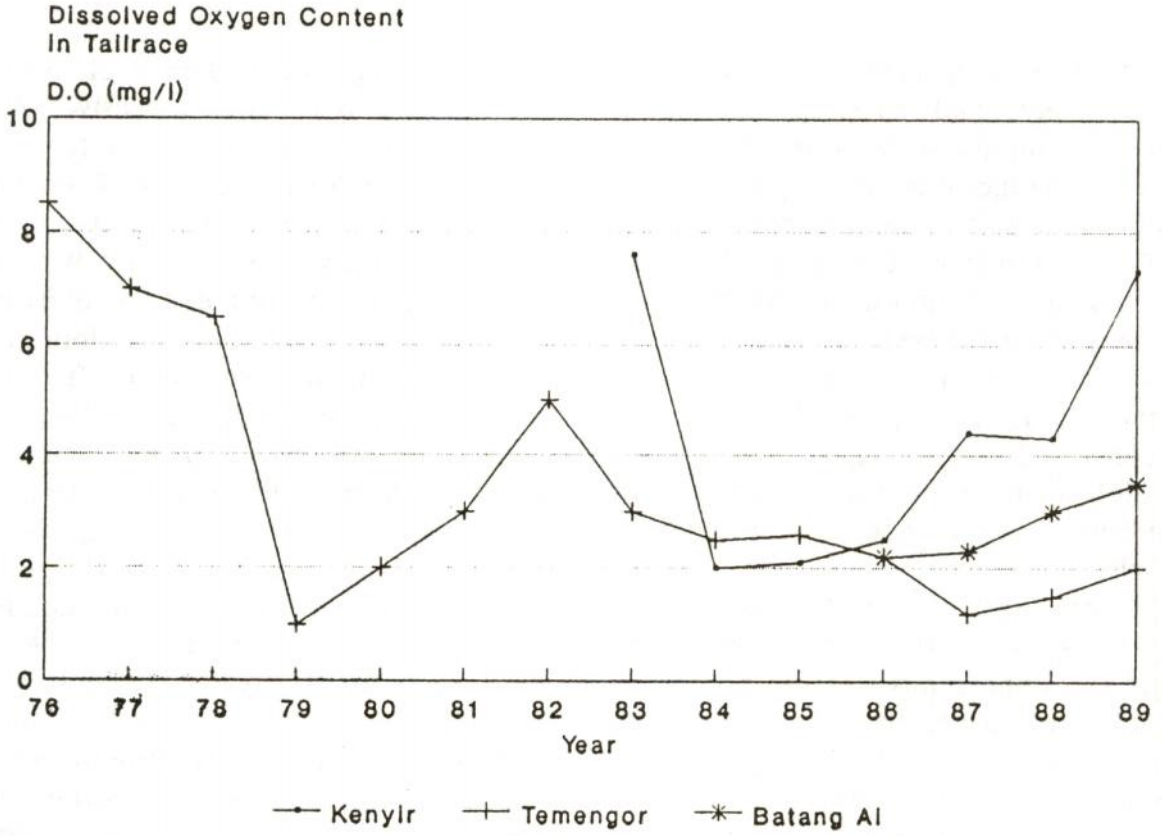


Figure 2
Dissolved Oxygen Content for Kenyir, Temengor, Cameron Highlands and Batang Ai

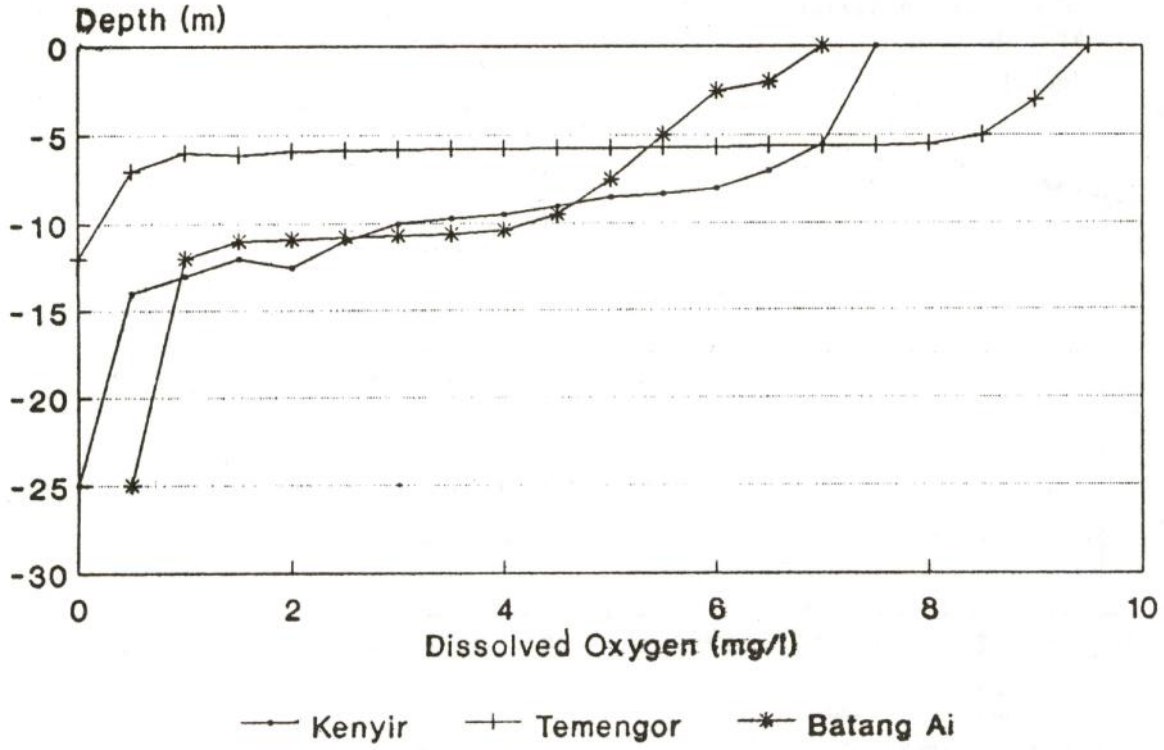


Figure 3
Dissolved Oxygen/Depth profile in Kenyir, Temengor and Batang Ai reservoirs

upper guide bearing coolers, turbine guide bearing coolers and governor oil coolers before returning the water to the draft tube. Tests were conducted by drawing water from the draft tube and it was observed that the fouling rate remained the same. The only effective solution from the test was by using the water from the reservoir through the water supply pipe at the intake. It was observed that the fouling rate ws much lower. The tests concluded that unstable iron from the reservoir form iron oxide after passing through the turbines and consequently form deposits along the cooler tubes when it was passing through the cooler system. Alternatively the direct water source from the reservoir did not get the opportunity for the formation of stable iron oxide thus minimising the choking of the cooler tubes. However the direct water source from the reservoir through the only pipe in one unit of the generator is not adequate to supply all the units in the station. Therefore other viable solutions were studied. Studies concluded that a closed circuit cooling water system would overcome the problems but it is an expensive solution.

Complaints of smelly water due to release of hydrogen sulphide from rotting vegetation, especially during initial few years was experienced at Kanyir and Batang Ai. However at Temengor the release of hydrogen sulphide gas caused some discolouration to lead based paint work and affected the performance of electrical contactors for relays and control equipment. Only small traces of the gas still persists to date.

Another aspect of water quality that affected station equipment was the pH value of the water in the reservoir. As experienced in Temengor the pH value of the water dropped progressively from initial value of 7.0 to below 5.0. The acidity also increased with depth. The highly corrosive water proved detrimental to the carbon steel turbine wicket gates which were subsequently replaced by stainless steel. The mild steel raw water piping and embedded piping were similarly affected. Due to this experience similar

equipment in Kenyir power station were supplied with stainless steel.

4.4 Climate

Whether, and to what extent climate can be changed by reservoirs is the subject of some controversy. It has been demonstrated experimentally that large reservoirs produce a new microclimate. A change in the rainfall pattern was reported to has been detected in Ghana around lake Volta, the peak having shifted from October to July and August, and rain fell for the first time at Aswan when lake Nasser was filled.

In Kenyir, the villagers and officers in the forestry and agriculture departments have expressed the opinion that there has been a substantial increase in rainfall since the impoundment of the reservoir. Rain occurs more regularly and the dry and wet seasons were discovered to be less distinct in areas close to the reservoir. The mean annual rainfall since impounding showed a significant increase compared to mean annual rainfall of periods 35 years prior to impounding.

The increase in the rainfall has affected rubber tappers and timber loggers. Rubber trees cannot be tapped and loggers faced operational difficulties during rainy periods.

4.5 Physical erosion

The EIA studies conducted for Kenyir identified the possibility of the alteration of the river course as far as 15 km downstream. The two most important processes in this regard were the removal of river sand bars for construction material in the vicinity of the dam and the erosion of sandbanks and river banks. Since the completion of the dam there has been some erosion of banks downstream especially at tributaries joining the main river. One of the worst erosions observed occurred at the confluence of the main river with one of the bigger tributaries. A section of road running along the bank has been seriously damaged. The operating regime also appears to have increased the deposition of sand at the site of a water supply intake located near this confluence.

Due to the seriousness of the problem the dam owner initiated a model study to look for remedies. The hydraulic model study confirmed that the altered balance of flood discharges due to the dam has hastened and extended the bank erosion. Following testing of a range of possible remedial measures it was concluded that the most appropriate and cost-effective solution to the bank erosion problem was the construction of a rip-rap revetment and groyne.

4.6 Aquatic flora and fauna

A blue-green algae, Microcystis aeruginosa, was first noticed to be spreading across the entire surface of the Ringlet reservoir some two years after impounding. The growth was brought under control by breeding plankton-feeding fish in the reservoir. Among the types of fish stocked in the reservoir were grass carp (Ctenopharyngodon idellus), silver carp (Hypophthalmichthys molitrix) and Javanese carp (Puntius goniono-tus).

After a lapse of more than a decade a sudden proliferation of algae was experienced in the Ringlet reservoir in early 1980. It was observed that the appearance of the algae coincided with the decrease of the plankton-feeding fish from the reservoir. Restocking of the particular plankton-feeding fish into the reservoir was carried out to overcome the problem.

In the early 60s it was thought that the lower temperatures of the Ringlet reservoir located at a relatively higher elevation of 1660m above mean sea level might have an inhabitory effect on the spreading of water hyacinth (Eichhornia crassipes). This assumption was incorrect when in the mid 1980s clusters of water hyacinth were found scattered along some edges of the reservoir. The sources of this aquatic plant are fish and pig farms located in the catchment of the reservoir. The most serious invasion of the water hyacinths on the Ringlet reservoir was in September 1988. Almost 33 hectares or 60% of the reservoir surface area was covered with water hyacinths. On all these occasions the problem has been effectively dealt with by mechanical removal.

For the Batang Ai reservoir, there seems to be no problem presented by floating aquatic plants such as hyacinth, water fern

or submerged species like uticularia spp. and celatophyllum even though these plants were present in the swamps prior to the dam impoundment.

4.7 Sedimentation

Land development, unconstrained by soil conservation measures, has resulted in continual sedimentation problems in the Cameron Highlands hydroelectric scheme. The clearing of forest within the catchment for agriculture and property develpment has led to widespread erosion followed by siltation and sedimentation. The sedimentation has affected the operation and energy generation of the scheme and is posing a threat of shortening the useful life of the Ringlet reservoir.

Studies have shown that there is a steady increase of silt load passing through the intakes into the reservoir. The silt yield has increased from $280m^3/km^2/yr$ in 1989 to more than $800m^3/km^2/yr$ in 1987. Deposition of silt caused the tunnel to be silted up and consequently reduced the capacity of the reservoir. It was estimated that the tatal volume of sediment in the Ringlet reservoir (excluding sediment removed) was about 2.1 million m^3, which represents 33% of the gross storage of the reservoir. Hence about one third of the storage capacity of the reservoir has been lost or filled up with sediment. The suspended silt also increased the wear and tear of the mechanical parts of the hydraulic machines. For instance the guide vanes of the trubine units in the power station have been replaced twice in 1982 and 1987 since commissioning in 1964. The damaged parts due to pitting, when inspected in 1987, were found to be severe after a lapse of only 3 years whereas a similar part under normal working conditions could have lasted for some 15 years.

A study conducted in early 1990 showed that the average annual energy output per m^3 of mean annual river runoff have dropped by about 20% compared with those in 1960s. Sedimentation and reduction in catchment water yield have been found to be the main factors affecting the generation and operation of the scheme.

In order to arrest the above problems the following preventive measures have been or are currently being carried out:

exclusion of silt at the major intake by constructing a new intake incorporating settling basins to trap sediment and modification of the overflow weir and downstream channel protection including an addition of an upstream deflector groyne to enhance the performance of the new intake.
desilting of the main conveyance tunnel.
desiltin fo the reservoir.

4.8 Induced seismicity

Several earth tremors occurred between 1984 to 1987 at Kenyir dam. The first tremor occurred a year after impounding. These events were minor although one of which was estimated to have induced an acceleration at the dam of between 0.01g and 0.05g. No damage was observed but to the nearby population the occurrence was a new phenomenon not experienced before and this created some fear among them.

5. PUBLIC PARTICIPATION

5.1 Public preference survey

Malaysia is currently a net commercial energy producer. However, with its increasing level of industrialisation the growth of energy consumption could outstrip national production in the foreseeable future. Although this situation is not likely to materialise until after the year 2000, increase in energy consumption and costs during the next decade or two could drastically change current public preferences towards energy forms, efficiency and safety.

A public preference survey for power generation systems was conducted in early 1990 in Peninsular Malaysia to address the issues of what power-generating systems the public would prefer and why.

The study tested the correlates of public preferences towards six different energy supply systems namely hydro, nuclear, coal, gas, oil, and solar. The main correlates are age, sex, education, employment, distance from power stations, differences between living near or away from power stations, income, awareness, beliefs, ideology, involve-

System Type	Mean Index	Rank
Hydro	.8793	1
Coal	.4906	5
Gas	.6240	4
Oil	.6366	3
Nuclear	.4593	6
Solar	.7393	2

Table 4
Mean Preference Index For Each System

ment, trust, and values.

Analysis of the data collected showed that hydro power system was the most favoured while nuclear was the least favoured mode of electricity generation. Hydro power system was generally the most favoured system irrespective of all variables with the exception that there is a weak correlation with sex which shows that women marginally favoured hydro more than man. Table 4 shows the ranking using mean preference index as a measure of preference.

The study condluded that future expansion of hydro power programme will meet little resistance from the public. The understanding of values and beliefs of the public such as this study would assist the planner in predicting the public behaviour of risk acceptance or avoidance.

6. CONCLUSIONS

Although environmental aspects in dam projects in Malaysia rely mostly on qualitative assessment, the future trend is to explore a more quantitative assessment. Efforts are being made by avrious parties involved in water resources development to improve the methods of assessing and monitoring the environment in relation to development.

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