SAMANALAWEWA HYDROELECTRIC PROJECT

RECOMMENDATIONS

FOR

REMEDIAL MEASURES TO BE TAKEN

FOR

SAMANALAWEWA RESERVOIR

MARCH 1993

SUPERVISING ENGINEER

Joint Venture Samanalawewa
Nippon Koei Co., Ltd
Electrowatt Engineering Services Ltd

DESIGN ENGINEER

Sir Alexander Gibb
and Partners Ltd

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1. Introduction

On completion of the extensive grouting carried out for the Right Bank Cut-Off Works in March 1992 impounding of Samanalawewa Reservoir recommenced. Water levels in the reservoir rose in a controlled fashion to El. 439m, with groundwater levels within the right bank ridge mirroring the reservoir water level fluctuations some 1 m below them.

At 13:00hrs on 22 October 1992 a water burst occurred at El. 400m on the right bank some 350m downstream of the toe of the dam, with right bank groundwater levels at approx. El. 438m. The volume of leakage immediately after the water burst was in excess of 7.5 m3/sec, however within 24 hours the groundwater levels throughout the right bank had fallen more than 20m and the volume of leakage had decreased to some 3m3/sec. Since 22 October 1992 reservoir levels have been lowered and maintained below El.430m. Groundwater levels have remained some 10m below reservoir level and the leakage volume has continued at the reduced rate of approx. 2m3/sec. The leakage is therefore acting as a natural drainage system, which has increased the stability of the right bank since the water burst occurred.

When the water burst occurred the project consultants, Sir Alexander Gibb & Partners Ltd (Design Engineer) and Joint Venture Samanalawewa (Supervising Engineer) consisting of Nippon Koei Co., Ltd. and Electrowatt Engineering Services Ltd, with the assistance of the Central Engineering Consultancy Bureau assessed the implications of the event and recommended remedial measures and investigations to control and reduce leakage in a safe and economical manner.

Due to the public criticism, and to confirm the remedial measures recommended by the project consultants, CEB employed a panel of international dam experts (the international third party review panel) to assess the safety of the dam and right Bank and to comment on the proposed remedial measures. This panel consisted of :

J.B.Cook	: Independent Consultant
P.Londe	: Independent Consultant
G.R.Post	: Independent Consultant
A.H.Merritt	: Independent Consultant

During their review the panel studied all the available information, including the proposals for the required remedial measures and held discussion with the project consultants, the OECF and their technical advisors and other interested parties.

In their review report, which has been copied to all interested parties, the panel concluded that:

* the most promising method of reducing leakage to acceptable levels was by constructing a blanket under water in the reservoir, which would not interfere with power production.

* the requirement to reduce leakage to an acceptable level is for economic, not safety, reasons.

The panels' conclusions endorse the general remedial measures proposed by the project consultants and based on this endorsement studies of alternative approaches to the wet method of blanket construction have been carried out.

The results of these studies are presented in this report. It is to be noted that commercial aspects including Sections 7 and 8 of this report have been prepared and finalized by JVS.

2. Necessity of Remedial Works

As discussed previously the remedial measures to reduce leakage at Samanalawewa are for economic reasons, not safety. Both the project consultants and the review panel have indicated that:

i) there is no possibility of the dam, or the right bank failing and therefore there is no risk of a catastrophic disaster causing damage to people and property downstream of the reservoir.

ii) if the groundwater level is the right bank ridge exceeds that at which the water burst occurred on 22 October 1992 at some time in the future then similar bursts in other area are likely.

iii) additional water bursts, while being alarming when they occur, will not compromise the safety of the dam and reservoir, however they are likely to result in increased leakage losses and this would not be acceptable on economic grounds.

It is therefore imperative that measures are taken to ensure that the groundwater level in the right bank is maintained well below the level at which the water burst occurred (El.438m) so that the risk of further instability and hence increased leakage is minimized. This must be achieved without increasing the current water losses from the reservoir and additional drainage measures are therefor not a long term option and groundwater control should be achieved by adopting one of two approaches:

a) Ensure that reservoir levels never reach the level at which the ground water caused the water burst. This could be achieved by operating the project as run-of-river scheme provided additional spillway facilities (called Second Spillway) are constructed to ensure that reservoir levels remain below El. 438m during floods. This approach has two major economic implications:

- The amount of firm energy that could be generated by a run-of-the-river scheme is significantly less than that produced by the original scheme

- The cost of constructing a second spillway, capable of discharging the design flood of 3,600 m3/sec, will be very high.

b) Create a positive cut-off on the right margin of the reservoir by either:

- Extending the existing grout curtain, which has been agreed by all parties to be technically impractical.

or:

- Constructing an upstream blanket over the areas of reservoir water ingress to control leakage, and hence groundwater levels, to less than the downstream requirements at Full Supply Level. The blanket could be constructed either in the dry, using conventional techniques, or in the wet by tipping or dumping.

In case of provision of a Second Spillway, a tunnel type spillway to be located below the existing spillway with its forebay crest elevation of approximately El 430 without gate can be considered to control the reservoir water level for the Run-of-the-River operation use. The sketch drawing of the tunnel spillway is shown in Fig. 2.1 which is designed to pass the design flood of 3,600 m3/sec and the total construction costs of such Second Spillway is estimated to be approximately J¥ 3,071 Million and Rs. 179 Million.

It is to also be noted the fact that the run-of-the-river type operation will result in the significant decrease of "Firm Energy". According to the results of optimization study of Samanalawewa reservoir in the "Additional Study" carried out by Electrowatt Engineering Services in 1985 and 1986, the energy production at the various maximum water level (low water level is fixed to be El. 424) are summarized as follows:

Max. Reservoir Level (m.a.s.l)	Firm Energy (GWh)	Energy (GWh)	Secondary Energy (GWh)	Total (GWh)	
460	366.47		58.83	425.30	<=Storage type operation mode (Blanketing)
455	338.94		83.15	422.09	
450	297.28		120.14	417.42	
445	258,74		153.34	412.08	
440	206.63		200.12	406.75	
435	147.76		253.27	401.03	
430	98.60		296.49	395.08	<=Run-of-River operation mode (Second Spillway)

As seen from the above table, if the Second Spillway is adopted for the permanent solution, though the total energy (firm plus secondary) will be reduced by approximately 30 GWh compared with the original scheme (or blanketing approach), the firm energy itself will be decreased to 27% of the original scheme, 120 MW.

For the economic comparison of the two approaches, the above indicates that the alternative thermal plant capacity value for the Second Spillway approach should be 27% (33MW) of the original scheme (or blanket approach).

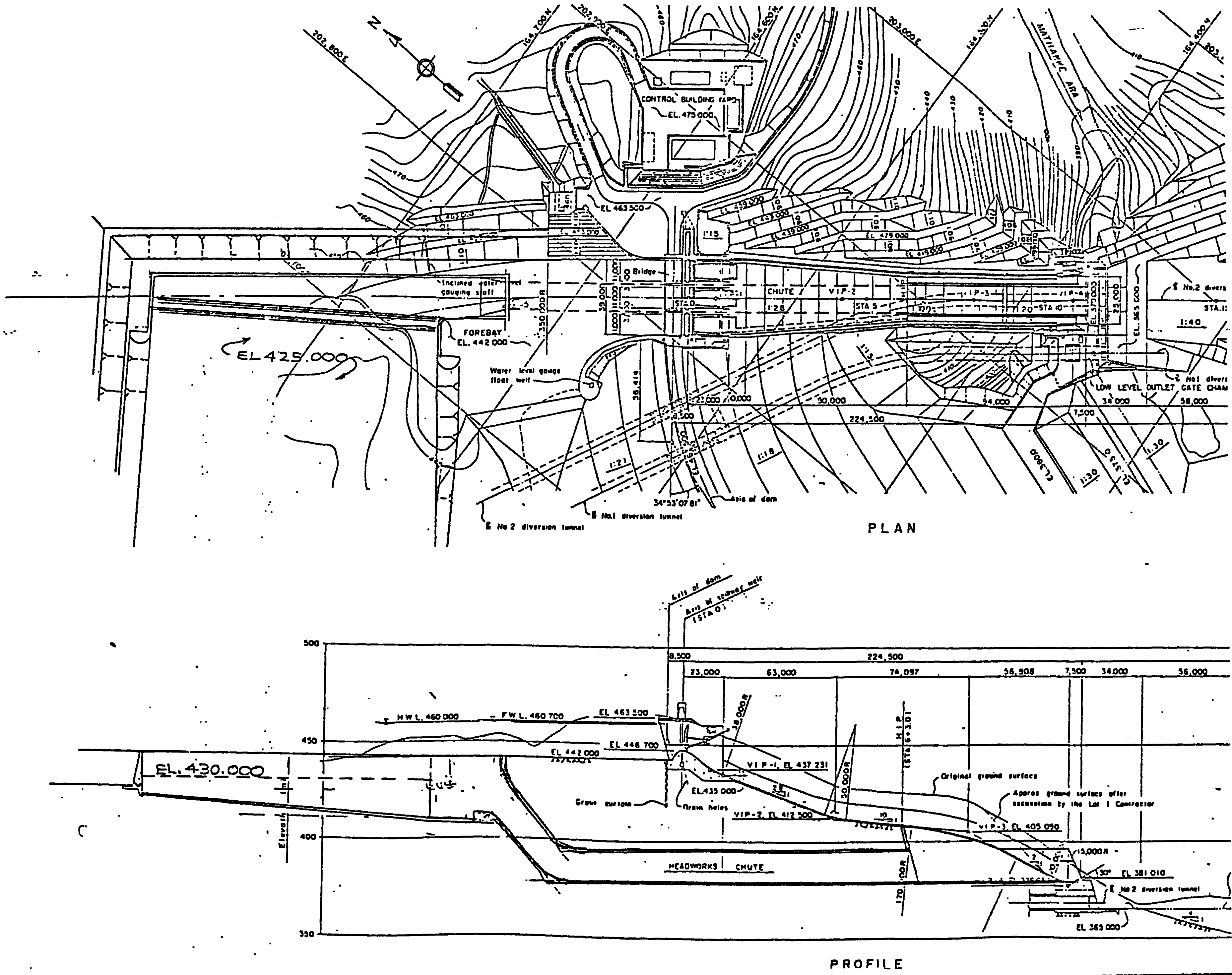
Taking into consideration of the construction costs estimated above including all the previous costs spent for construction of Dam, Waterway and Powerhouse, etc, and their expected annual energy production, economic and financial evaluation of the two alternatives are carried out and the Economic Internal Rate of Return (E.I.R.R) and Financial Internal Rate of Return (F.I.R.R) of each scheme are calculated as follows (for detail calculation, refer to Section 8):

	E.I.R.R	F.I.R.R
A. Run-of-the-River type operation mode with provision of Second Spillway	3.2%	7.1%
B. Storage type operation mode with provision of Blanketing	14.0%	7.6%

From the above, it is very clear that the storage type operation mode with provision of Blanketing is economically much superior to the run-of-the-river operation mode with provision of Second Spillway. Furthermore, all the parties concerned have agreed that the best approach to control the groundwater level, and hence leakage, in the right bank of Samanalawewa is to use the wet blanket approach. This approach, carried out when the reservoir level is above minimum operating level, ensure the minimum disruption to power generation (the scheme will be running as a run-of-the-river plant for the construction period).

The ultimate aim of the proposed remedial measures (wet blanketing) is to ensure that the Samanalawewa Reservoir provides the storage for power production as originally anticipated.

Fig. 2.1 Sketch Drawing of Second Spillway



3. Areas to be Treated

3.1 Main Blanket

Detailed study of the considerable amount of information available on the right bank, compiled from the investigations carried out, the grouting carried out and the results of the monitoring recorded since 1989, indicates that the section of the river bed between 700m and 1,700m upstream of the dam is assumed to be the area where significant water ingress to the right bank is occurring (Fig. 3.1) and should be the main target for blanketing. The approximate fill volume for this section is estimated to be 500,000 m3. This conclusion is supported by the following facts:

i) Before impounding, the groundwater level recorded in the right bank was almost flat at about E. 380m and it fluctuated in response to changing river levels (Fig. 3.2 and 3.3). Events have proved that these responses were most likely to have been due to the ingress and egress of water from the river and therefore the opening(s) into the river must be located around El.380m in the river channel. The river bed is at El. 380m around the center of the target section between 700m and 1,700m upstream of the dam.

ii) Three major faults, F-1, F-2 and F-3, intersect in the target section of the reservoir and a fault seen in the area of the water burst also trends into this section. These faults are probably associated with man subordinate shears which provide the openings for water flow.

iii) Chemical analysis of water samples taken for water quality assessments have shown a general pattern that apparently reflects the speed of groundwater movement:

- Groundwater in areas of intact rock and slow groundwater movement (Geological Area A) have a high sulphate ion (SO_4^-) content.

- Reservoir water typically has a low sulphate ion content.

Therefore groundwater with a low sulphate ion content is likely to be connected to the reservoir by privileged paths along which there is a relatively rapid flow of water. Groundwater of this type has been recorded at weir M1 (downstream of the dam), from the water burst (the natural drainage point), and at weirs S2 and S3 (on the Kalunaide Ara). These points are all associated with the faulting that intersects in the reservoir in the main target area.

iv) When constructing the right bank grout curtain, high grout takes were recorded at the bottom of the grout curtain in areas intersecting the faults F-1, F-2 and F-3. A number of piezometers were installed 80m below the bottom of the grout curtain in these zones and the results recorded since impounding began indicates that high permeability zones exist, ungrouted, below the grout curtain.

Based on these facts it is intended to target the main area of blanketing on a 1km long section of river bed between 700m and 1,700m upstream of the dam, where the main zone of water ingress is consider to exist.

3.2 Follow-Up Blanket

The groundwater response patterns observed to date indicate that the main zone of water ingress is likely to be within the main target section. However it is possible that other zones of ingress do exist, but their effects are masked by the size and efficiency of the main zone. Therefore provision must be made for additional blanketing work to be undertaken once the main target section has been covered. The target for additional blanketing would be identified based on groundwater level responses to the main blanketing operation and to the changes in ground water chemistry pattern as discussed in Section 5.

The extent of this follow-up work is unknown, it may not even be necessary, but the method employed to carry out the work should be such that it can be implemented with the reservoir at any level and at any time with suitable plant and operators left on site.

The period for the follow-up blanket is required for at least two major wet seasons after the main blanket is placed so that there will be sufficient time to confirm the reservoir level reach to Full Supply Level, and therefore a period of 1.5 years should be allocated. The fill volume is provisionally assumed to be 500,000 m3.

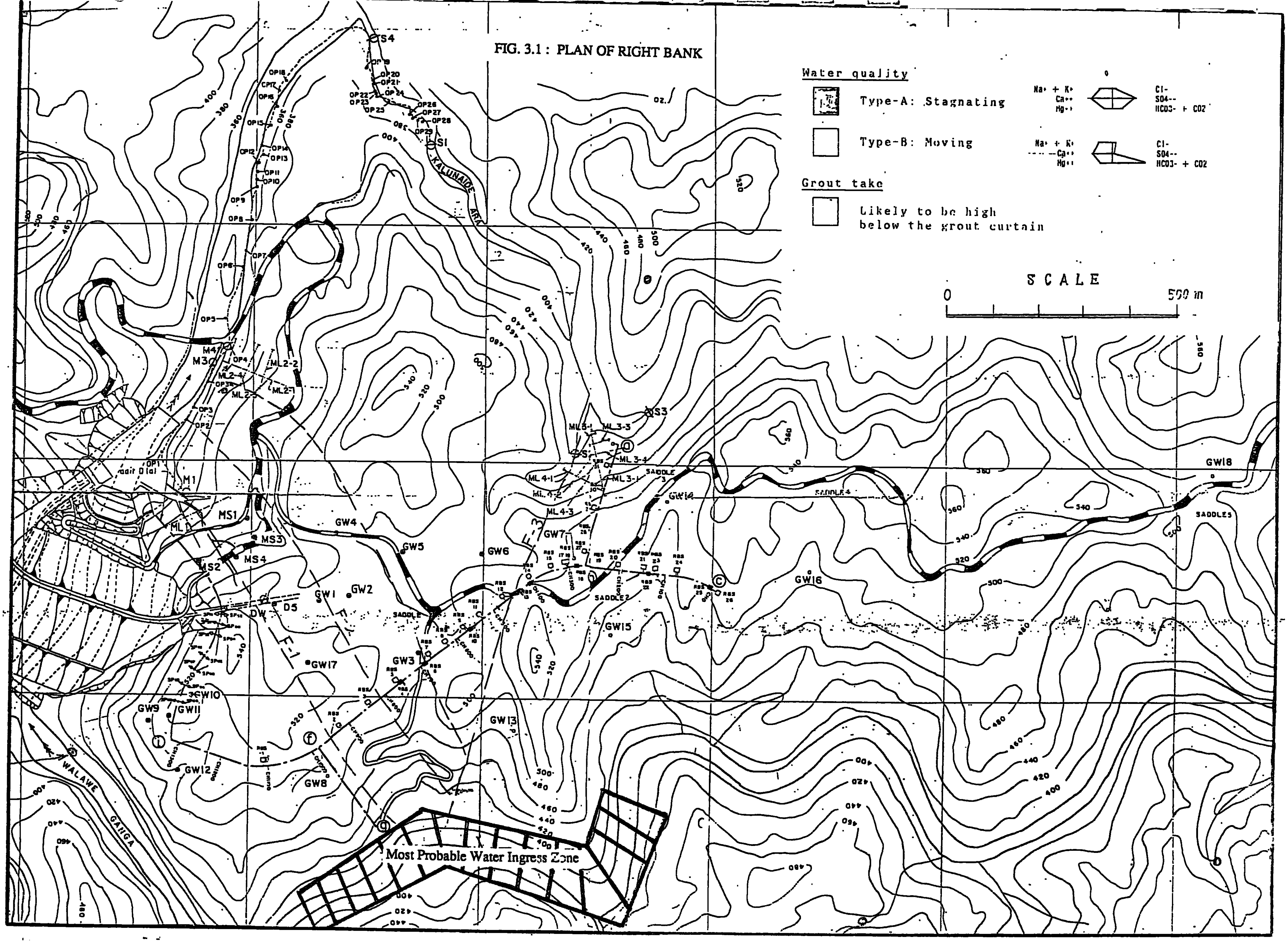


FIG. 3.1 : PLAN OF RIGHT BANK

FIG. 3.2 : River Water Level and Ground Water Table before Impounding

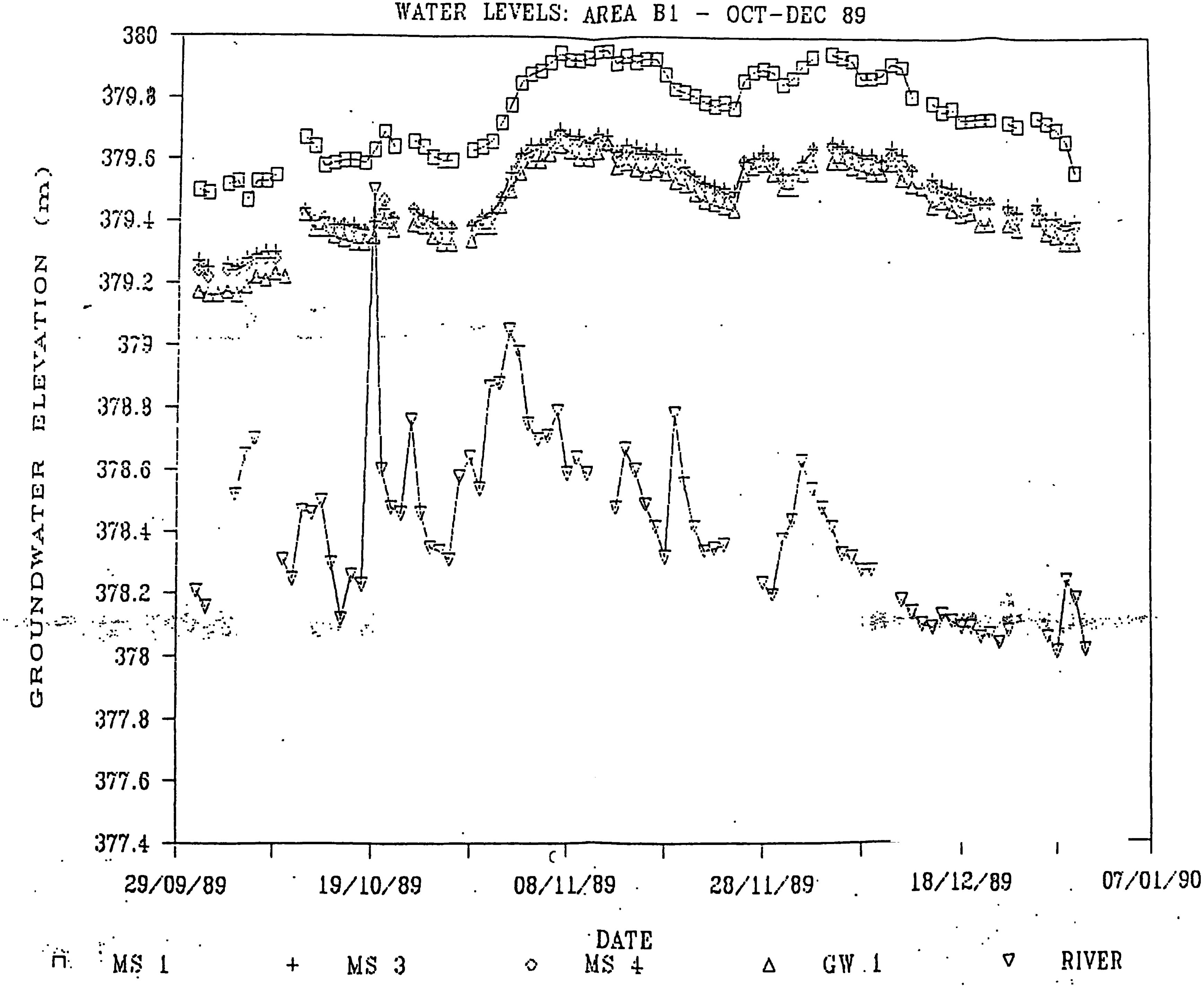
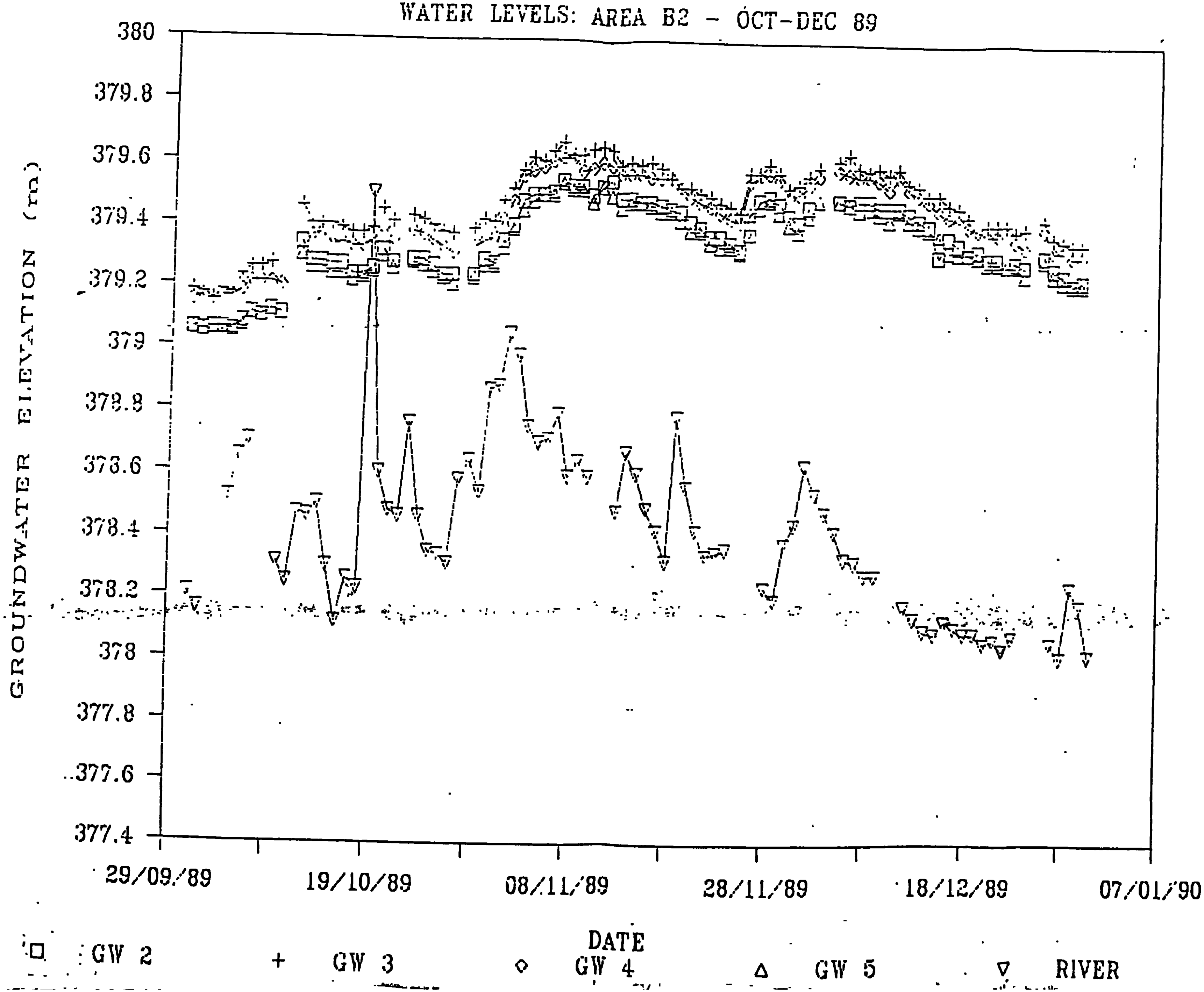


FIG. 3.3 : River Water Level and Ground Water Table before Imounding



4. Alternative Study of Wet Methods of Blanket Construction

4.1 General

Three alternative methods of constructing an impermeable blanket under water have been identified and studied:

i) Dumping using Dredgers
ii) Dumping using Bottom Dump Barges
iii) Side Dumping using Dump Trucks

To ensure a true comparison of the methods the following assumptions have been made:

a) As described in Section 3 the main target zone will be the section of the river bed between 700m and 1,700m upstream of the dam, as shown on Fig. 3.1.

b) The target blanket thickness will be 10m, over a 1,000m stretch of river bed, which results in the handling of some 500,000m3 of fill material.

c) Construction of the main blanket will take 1 year.

4.2 The Alternative Construction Methods

4.2.1 Dumping using Dredgers

The principle sequence of activities for this approach are identified in Fig. 4.1, which also summarizes the major construction aspects of the work and identifies the main plant requirements.

It is proposed that two 350 HP dredger pumps, which are readily available on the market, would be used. For the dredging operation to be successful it is essential that all material > 100mm in size is removed from the fill this would result in the need to double handle a significant portion of the fill. Once processed the fill would be transported to the reservoir margin and dumped into the reservoir along a working front some 30m wide, to create a sludge pile for pumping, as shown in Fig. 4.2. A survey/backup boat would also be required to support the discharge pontoon and for survey work etc.

To minimize hauling distances it would be necessary to select borrow area as close to the dredging site as possible, but in ordef to preserve the natural blanket on the reservoir margin the borrow area would have to be above Full Supply Level and access roads would have to be kept to a minimum. The top of the right bank ridge has been identified as a suitable source of fill, but borrow area above Full Supply Level have a negative impact on the environment as they involve the destruction of the natural forest cover. However with care this could be minimized by reafforestation after construction is complete.

Experience of the dredging technique in the marine environment suggests that contamination, with suspended solids, is likely to affect a greater area of the reservoir than either the other methods proposed.

4.2.2 Dumping using Bottom Dump Barges

The principle sequence of activities for this approach are identified in Fig. 4.3, which also summarizes the major construction aspects of the work and identifies the main plant requirements.
As shown in Fig.4.4 it is proposed that two 500m3 barges will be required and they will be supported by one pusher boat and one survey/backup boat for survey work and support.

Fill material will only have to be handled once as it can be loaded straight into the barges and due to mobility of the barges the borrow area does not have to be near the point of dumping. Fill material can therefore be obtained from below Full Supply Level on the left bank at Kinchigune, the original source of the core material for the dam. This reduces the environmental impact of borrowing for fill materials and preserves the natural blanket on the reservoir margin.

The advantages of this approach over the other two are that:

a) dumping activities are flexible and can easily be moved from location to location depending on the effects that the blanketing operation is having on the leakage and the monitoring system already in place.

b) dumping can be carried out with the reservoir water at any level

c) contamination of the reservoir water will be less than that caused by dredging.

4.2.3 Side Dumping by Dump Trucks

The principle sequence of activities for this approach are identified in Fig. 4.5, which also summarizes the major construction aspects of the work and identifies the main plant requirements. An illustration of the approach is given in Fig. 4.6.

Due to the simplicity of this operation dumping speeds are higher than the other two approaches, but because of its lack of flexibility in targeting areas for treatment, side dumping will require significantly more fill material than either Dredger Dumping or Barge Dumping.

Fill material will only have to be handled once, but to minimize haulage costs the borrow area will have to be as close to the target area as possible, as described for the dredger approach, and hence suffers the same environmental disadvantages. It might be possible to carry out side dumping from both margins of the reservoir to increase speed, but the spreading of the work force to accommodate this is considered inefficient and therefore costly.

Experience suggests that contamination of the reservoir will be less serious than the dredging method.

The significant disadvantage of this method will be the least flexibility to cope with additional dumping requirement which may be required in the course of raising reservoir level up to the Full Supply Level after completion of the main blanket at the river stretch of 1,000m described in Section 3.

4.3 Comparison of the Alternative Methods

To assess the technical merits of each approach it has been assumed that all equipment is available and can be mobilized at the same time. Based on this assumption the alternative methods have been assessed against the following aspects of construction:

i) Environmental impact

ii) Destruction of natural blanket below Full Supply Level for access

iii) Contamination of the reservoir water with suspended solids

iv) Flexibility to provide additional blanketing

v) Ease of Operation

vi) Ease of Maintenance

vii) Volume of fill required

viii) Construction costs (direct costs)

These are presented in the following matrix with clearly compares the merits and demerits of each method.

	Dredger	Dump Barge	Side Dumping
Environmental Impact	Most	Least	same as Dredger
Destruction of Natural Blanket	Most	Least	same as Dredger
Contamination	Most	Least	Intermediate
Flexibility	Intermediate	Most	Least
Ease of operation	Difficult	Intermediate	Easiest
Ease of Maintenance	Difficult	Intermediate	Easiest
Volume of Fill	Intermediate	Least	Most
Direct Costs excluding Follow-up Works	J¥ 2,718 Million Rs 160 Million	J¥ 2,510 Million Rs 148 Million	J¥ 2,550 Million Rs 151 Million

The matrix above shows that dumping using bottom dump barges has the most advantages over the other approaches, while dumping using a dredger has the most disadvantages. Side dumping is almost as advantageous as using the dump barges except a few aspects, particularly "flexibility". Therefore provided that there is no significant delay in procuring barges, as opposed to obtaining earth moving equipment, then the technique using bottom dump barges should be pursued

However if there is likely to be a long lead time required for the procurement of the barges then the earth moving equipment to service the barges should be mobilized to site as soon as possible and blanketing should commence using the side dumping approach until such time as the barge dumping operation can be carried out This dual approach may be required incase of significant delay in procuring barges to begin blanket construction at as early a date as possible.

Fig. 4.1: Dredging Method

Process	Major Equipment	Major Activities
Borrow Area: Clealing	Back-hoe 45T Dump-Truck Bull-dozer	Clearing, Survey Mobilization of Equipment, Electricity Supply, Access Road, etc.
↓		
Acquisition and Transport of Blanket Materials	Wheel Loader 45T Dump-Truck	Grizzly Plant
↓		
Removal of Over-size Materials by Grizzly		Removal of Over-size material
↓ 100 mm under only		
Loading and Trunsport of Blanket Matenals	Wheel Loader 45T Dump-Truck	River bed survey Assembling of dredgers
↓		
Disposing of Materials along Reservoir Slope	Bull-dozer	Assembling of slurry pipes
↓		
Pumping by Dredgers	2-Dredgers (350HP) Crane Boat Communication Boat Dumping Deck Survey Boat	Survey of dumped materials in Reservoir

Fig. 4.2: Dredger Method

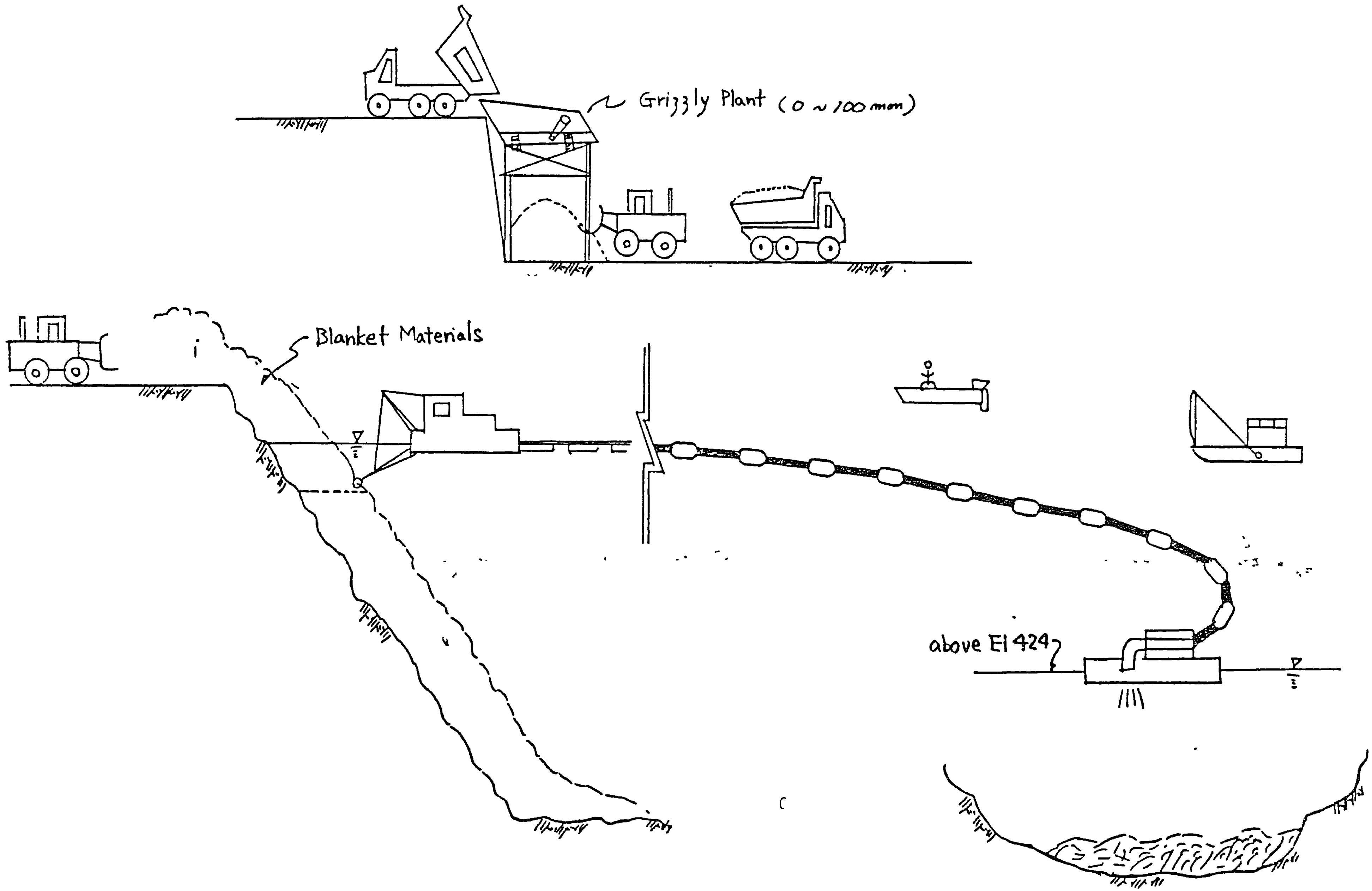


Fig. 4.3: Dump-Barge Method

	Major Equipment	Major Activities
Borrow Area: Clearing	Back-hoe 45T Dump-Truck Bull-dozer Wheel Loader	Clearing, Survey Mobilization of Equipment, Access Road, Electricity Supply, etc.
↓ Acquisition and Transport of Blanket Materials	Wheel Loader 45T dump-Truck Bull-dozer Back-hoe	Loading Plant, Survey of river bed, Assembling dock for dump-burge, boats, etc.
↓ Loading Plant		
↓ Loading and Transport of Materials by Dump-Barge	Tugboat 500 m3 Dump-Barge Communication Boat Survey Boat	Survey of dumped materials in Reservoir

Fig. 4.4: Dump-Barge Method

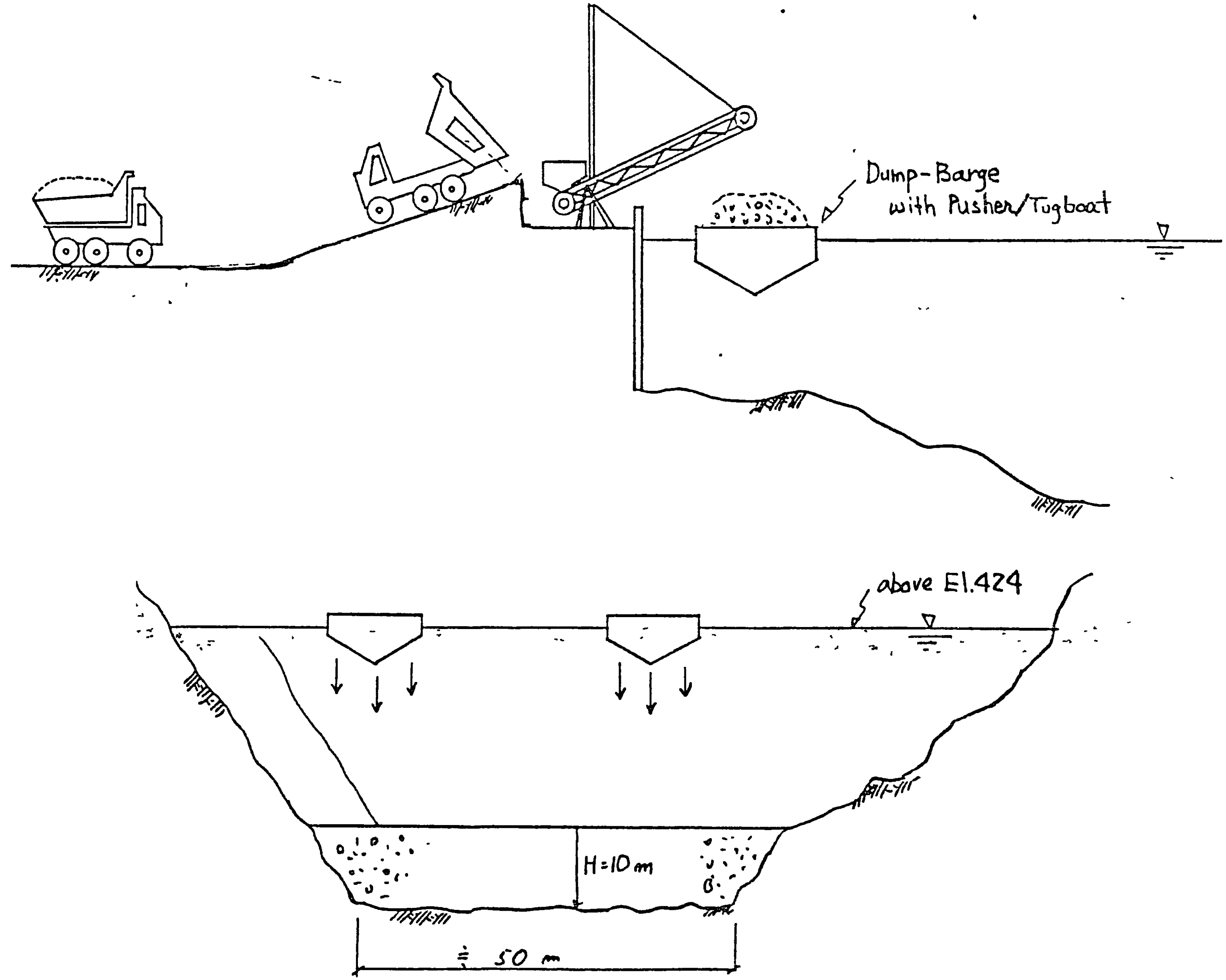
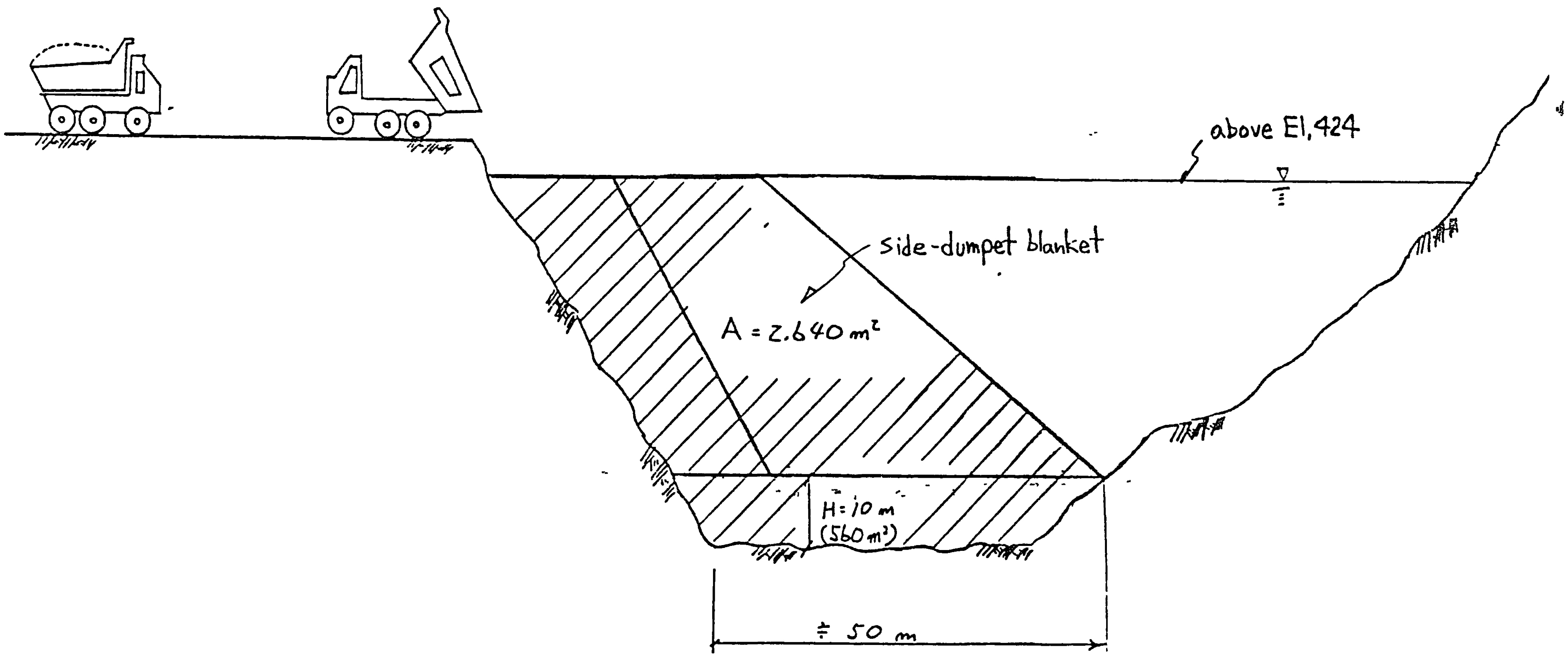


Fig. 4.5: Side Dump Method

	Major Equipment	Major Activities
Borrow Area: Clearing	Back-hoe 45T Dump-Truck Bull-dozer Wheel Loader	Clearing, Survey, Mobilization of equipment, Access Road, Electricity Supply, etc.
↓		
Acquisition oand Transport of Blanket Materials	Wheel Loader 45T Dump-Truck Bull-dozer Buck-hoe	
↓		
Side Dumping into Reservoir	Survey Boat	Survey of dumped materials in Reservoir

Fig. 4.6: Side Dump Method



5. Additional Investigations

Additional investigations have been recommended in the past and the international third party panel advised that investigations could be carried out if considered necessary. However investigations should not delay the construction of the blanket as there is sufficient data available to locate the major area of reservoir water ingress and construction of the blanket will be the most reliable method of identifying the actual zones In this respect, geophysical investigation (Seismic Reflection Survey) at the most probable section has been implemented under UK ODA finance.

To date the control of groundwater levels in the right bank exhibited by the main area of ingress between 700m and 1,700m upstream of the dam has been so great that the effects of any other areas of reservoir water ingress if they exist are completely masked Therefore it would be prudent to ensure that there are sufficient monitoring points to be able to identify other areas of ingress if they exist as sealing of the main area proceeds These subordinate areas of ingress can then be located and treated as necessary during Follow-Up blanket.

To identify actual zones of leakage considerable studies into the use of tracers have been made and due to the high permeability of the right bank ridge, and the long seepage paths involved, it has been concluded that the dilution of tracers after injection will be so great that they are unlikely to be useful indicators of the leakage source.

To date the most reliable indicators of potential leakage have been groundwater levels and sufficient monitoring stations exist around the main area of reservoir water ingress to monitor the blanketing of the area However south of the right bank cut-off works only two groundwater monitoring stations exists (GW16 and GW18) and subordinate areas of reservoir water ingress may exist along this section of the right bank ridge Therefore additional groundwater monitoring stations should be installed south of GW14

Over the last year the monitoring of both reservoir and groundwater quality has indicated that a distinct difference in sulphate content exists between reservoir water and slow moving groundwater as discussed in Section 3 1 Therefore groundwater that is low in sulphate is likely to be closely connected to the reservoir and this factor, when combined with groundwater levels and gradients, may be a useful tool for identifying subordinate leakage paths as sealing of the main area progresses

It is therefore recommended that the groundwater monitoring (both of levels and chemistry) should continue using the existing monitoring stations throughout the period of blanket construction In addition a series of groundwater monitoring boreholes should be drilled south of GW14 so that more reliable data on groundwater levels and chemistry can be obtained and monitored

These additional groundwater monitoring holes should be of sufficient diameter that reliable water samples can be collected from them and they should be drilled at the same time as blanketing of the main area is in progress It si envisaged that some 10 holes will be sufficient for the purposes described above

6. Outline Programme for the Remedial Works and Investigations

As stated in Section 4 it is anticipated that it will take approximately 1 year after mobilization period of half year to place the 500,000m3 of fill judged as necessary for the construction of the main blanket However it is recognized that further follow-up work may be required at any time until the reservoir has satisfactorily achieved Full Supply Level and that this follow-up work should be able to proceed with the reservoir water at any level Therefore based on the fact that it may take at least two full wet seasons to reach Full Supply Level after the main blanket is complete it is recommended that a period of 1 5 years with provisional quantity of additional 500,000 m3 is allowed for as the follow-up period

Additional investigations explained in Section 5 will be carried out in parallel with the blanket works and completed before commencement of the follow-up period

As discussed in Section 4 the use of Bottom Dump Barges provides the flexibility of targeting subordinate zones of leakage at any reservoir level with the minimum of equipment and manpower during the follow-up period In addition provision should be made for the barges and the necessary earth moving plant to become the property of the CEB after completion of the work so that any remedial measures to the blanket that may be required in the future can be carried out by them.

Assuming an order to commence work is issued in July 1993 a possible programme demonstrating this approach is presented in Fig 6 1 and the schedule of Engineering Services in Fig.6 2.

Fig. 6.1 : Programme for Remedial Measures and Relevant Activities

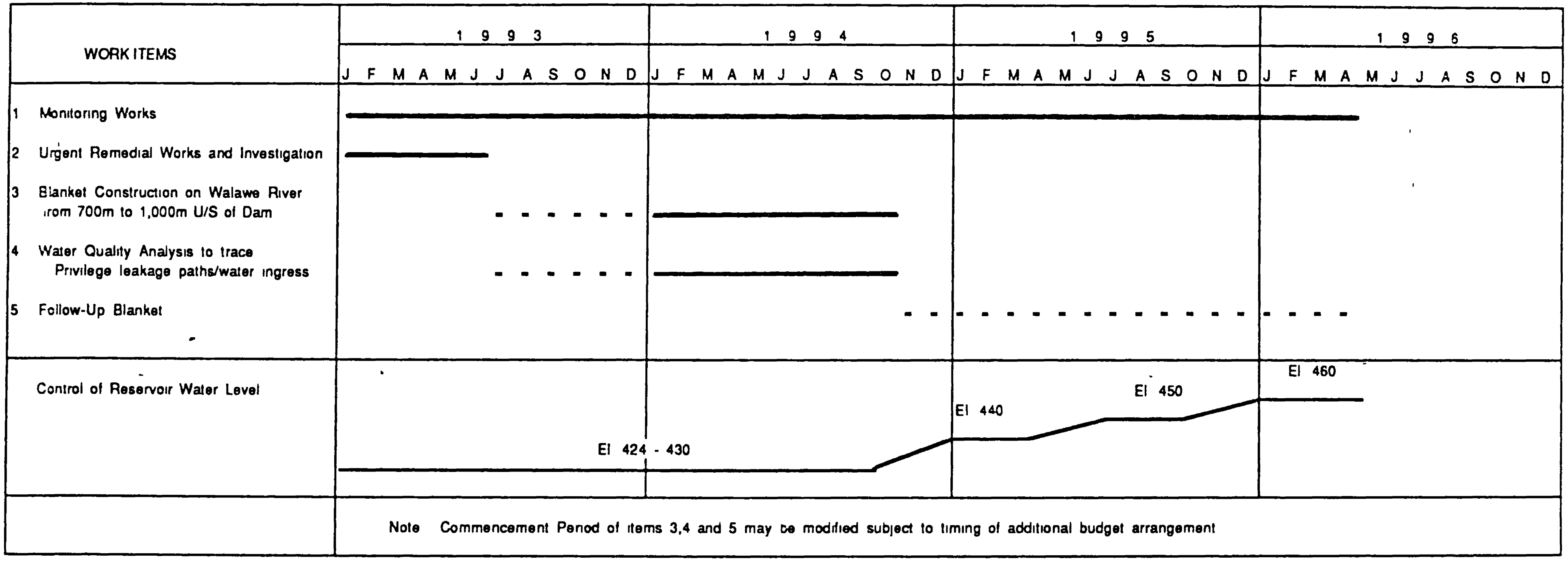
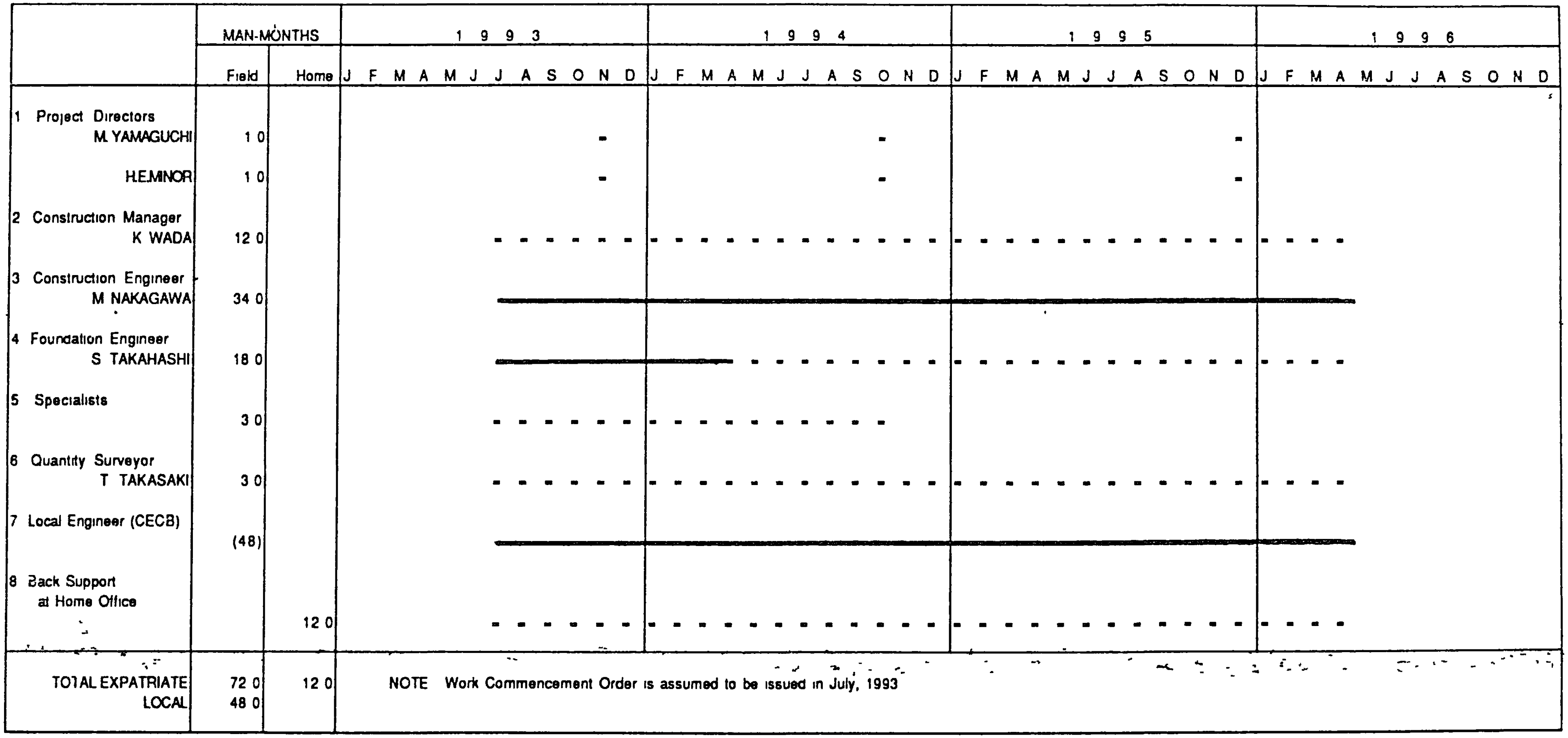


Fig. 6.2 : Manning Schedule (Engineering Services) for Remedial Measures and Relevant Activities



7. Cost Estimates

7.1 Total Project Cost

The total project cost for main blanket, follow-up blanket, additional investigation, engineering services including physical contingencies is estimated at J¥ 4,378 Million for the foreign currency portion and Rs 246 Million for the local currency portion as summarized in the following table

		J¥ (Million)	Rs (Million)
1. Main Blanket Works by Dump-Barges			
1 1	Manufacturing and Assembling of Dump-barges, boats, etc	1,087	64
1.2	Access Roads, etc	70	4
1 3	Transport, Loading, Dumping of blanket materials	1,016	60
1 4	Costs of equipment to be taken over for Follow-Up blanket	337	20
2 Investigations			
2 1	Drilling Bore Holes	111	7
2 2	Water sampling and chemical analysis equipment	100	
3. Follow-Up Blanket by Dump Barges (1.5 years)			
	Transport, Loading, Dumping of blanket materials	544	32
4. Final treatment at leakage area		200	20
5. Engineering Services (Supervising Engineer)		342	7
6 Physical Contingency (15% of 1 to 5)		571	32
	Grand Total	4 378	246

7.2 Annual Fund Requirement

The disbursement schedule including physical contingencies is prepared by allocating the required construction costs over the construction period explained in Section 6 (refer to Fig 6 1) as follows:

Year	Foreign Currency (J¥ Million)	Local Currency (Rs. Million)
1 (1,993)	1,556	82
2 (1,994)	1,872	105
3 (1,995)	618	32
4 (1,996)	332	27
Total	4,378	246

8. Economic and Financial Assessment of the Remedial Works

8.1 Comparison of Second Spillway and Wet Blanket

At the time of project implementation stage in 1986, the total project costs (financial costs) was estimated to be J¥ 29,880 Million , £ 51 27 and Rs 2,203 Million with the exchange rate of Rs.1=J¥ 8 0 and Rs 1=£ 0 028, giving the equivalent total project costs of Rs 7,769 Million, and the total economic costs of Rs 5,800 Million, and its Economical Internal Rate of Return (E I R.R) and the Financial Internal Rate of Return (F I R R) at the implementation stage were then estimated to be 38 1% and 10 4% respectively(refer to Implementation Programme, February, 1986)

After commencement of the Works, the right bank cut-off works was carried out with the additional Japanese fund of JY 3,264 Million and the works has been completed in early 1992, however the leakage from the right bank is approximately 2 m3/sec at the reservoir water level of El. 430.

As discussed in Section 2, there are two alternatives, namely construction of Second Spillway with run-of-river type operation mode and construction of Wet Blanket with storage type operation mode, and the economic and financial comparison should be carried out based on the same manner with same economic indices at the time of project implementation stage in 1986 so that the change and its sensitivity of the internal rate of return due to such additional costs of remedial measures from the original scheme can be fairly assessed on the same economic ground

The estimated cost of Second Spillway is approximately J¥ 3,071 Million and Rs 179 Million however its capacity value is reduced to 33 MW and the annual energy is reduced by 30 GWh compared with original scheme as discussed in Section 2, while the costs of Wet blanket scheme including investigations and relevant works is J¥ 4,378 Million and Rs 246 Million as estimated in Section 7 1 The total project costs (financial costs) for these alternatives including all the previously incurred costs such as Dam, Power Tunnel and P/H are therefore summarized as follows

	J¥ (million)	£ (Million)	Rs (Million)	Equivalent Total in Rs (*)
Run-of-the-River type operation mode with provision of Second Spillway	34,755	81 1	3,620	10,860
Storage type operation mode with provision of Blanketing	36,062	81.1	3,687	11,091

Note (*) . the exchange rates applied at the time of implementation stage

Based on the above total project costs and in the same manner of calculation procedures carried out at the time of the implementation stage in 1986 (refer to Table 8 1 for detail procedures), E I R R and F I R R of the two alternatives are shown in Table 8 2, 8 3, 8 4 and 8.5 and the results are·

	E I R R	F I R R
A. Second Spillway scheme	3 2%	7 1%
B. Wet Blanketing scheme	14 0%	7 6%

It is clear that the Wet Blanketing scheme is much superior to the Second Spillway scheme in terms of economic and financial indices and therefore recommended to be adopted for the remedial measure

8.2 Economic and Financial Evaluation of Wet Blanket Scheme

The costs of recommended Wet blanket scheme including investigations and relevant works is J¥ 4,378 Million and Rs 246 Million as estimated in Section 7.1, and the E I.R R and F.I.R R for the recommended scheme including all the previous costs are 14 0% and 7 6% respectively as discussed in Section 8 1(the costs/benefit streams for the recommended scheme are shown in Fig 8 4 and 8 5)

Though these values are decreased from that of implementation stage in 1986 which had been 38 1% for E I R R and 10.4% for F I R R it is still within the economically and financially justifiable range

Table 8.1 : Economic and Financial Evaluation Procedures

Calculation procedures taken at the implementation stage in 1986 are summarized as follows:

I. Economic Evaluation

1. Exchange rate to convert equivalent cost : Rs 1=J¥ 8.0, Rs. 1 0= £ 0.028
2. Economic conversion factor : Economic Cost = 75% of Financial Cost
3. Alternative Power Plant : Coal-fired thermal plant
   - Installation cost : Rs. 39,400/KW
   - Adjustment factor

	Hydro	Thermal
T/L loss	5 0%	2.5%
Forced Outage	0 5	5 0
Station Services	0 3	7.0
Overhaul	2.0	10.0

$$\text{Factor} = \frac{(1-0.05)(1-0\ 005)(1-0.003)(1-0.02)}{(1-0\ 025)(1-0\ 05)(1-0.07)(1-0.10)} = 1.191$$

   - Capacity Value : Rs 46,925/KW

4. Energy Value
   - Plant economic life · 25 years
   - Fuel type : Australian steaming coal
   - Fuel cost · Rs 235/M Kcal
   - Heat rate : 3,020 Kcal/KWh
   - Unit fuel cost . Rs 0.71/KWh
   - Adjustment factor

	Hydro	Thermal
T/L loss	5 0%	2 5%
Station Service	0 3	7.0

$$\text{Factor} = \frac{(1-0\ 05)(1-0\ 003)}{(1-0.025)(1-0\ 07)} = 1.045$$

   - Energy value = Rs 0.74/KWh

5. O & M cost :
   - 2 5% of capital cost for thermal plant
   - 0.6% of capital cost for hydro plant

II Financial Evaluation

1. Exchange rate to convert equivalent cost . Rs. 1=J¥ 8.0, Rs 1.0= £ 0.028
2. O & M cost . 0 7% of capital costs
3. Energy sales expenses : Rs 0 57
4. Long Run Marginal Cost (sales value) : Rs 3.5 /KWh
5. Sales energy : 88% of generated energy assuming transmission loss of 5% and distribution loss of 7%
6. N.P.V : Net Present Value

Table 8.2 : Economic Evaluation based on the Second Spillway Scheme (Unit equivalent Million Rs.)

EIRR= 0 032

YEAR	CPITAL COST	O&M COST	TOTAL COST	COAL-FIRED THERMAL	O&M COST	ENERGY COST	TOTAL BENEFIT	N P V OF COST	N P V OF BENEFIT
1,986	232		232	46			46	225	44
1,987	541		541	106			106	508	100
1,988	773		773	152			152	703	138
1,989	1,159		1,159	228			228	1,022	201
1,990	1 931		1,931	380			380	1,650	325
1,991	1,931		1 931	380			380	1,598	315
1,992	1,159	32	1,191	228	27	205	460	955	369
1,993	210	37	247		30	234	265	192	206
1,994	213	41	254		34	263	298	192	224
1,995		46	46		38	293	331	34	241
1,996		46	46		38	293	331	33	234
1,997		46	46		38	293	331	32	227
1,998		46	46		38	293	331	31	220
1,999		46	46		38	293	331	30	213
2,000		46	46		38	293	331	29	206
2,001		46	46		38	293	331	28	200
2,002		46	46		38	293	331	27	194
2,003		46	46		38	293	331	26	188
2 004		46	46		38	293	331	25	182
2,005		46	46		38	293	331	24	176
2,006		46	46		38	293	331	24	171
2,007		46	46		38	293	331	23	165
2,008		46	46		38	293	331	22	160
2,009		46	46		38	293	331	22	155
2,010		46	46		38	293	331	21	151
2,011		46	46	43	38	293	373	20	165
2,012		46	46	241	38	293	572	20	244
2 013		46	46	241	38	293	572	19	237
2,014		46	46	292	38	293	622	18	250
2,015		46	46	190	38	293	521	18	202
2,016	1,327	46	1,373	98	38	293	429	517	161
2,017		46	46		38	293	331	17	121
2,018		46	46		38	293	331	16	117
2,019		46	46		38	293	331	16	113
2,020		46	46		38	293	331	15	110
2,021		46	46		38	293	331	15	106
2,022		46	46		38	293	331	14	103
2,023		46	46		38	293	331	14	100
2,024		46	46		38	293	331	13	97
2,025		46	46		38	293	331	13	94
2,026		46	46		38	293	331	13	91
2,027		46	46		38	293	331	12	88
2,028		46	46		38	293	331	12	85
2,029		46	46		38	293	331	12	83
2 030		46	46		38	293	331	11	80
2,031		46	46		38	293	331	11	78
2,032		46	46		38	293	331	10	75
2,033		46	46		38	293	331	10	73
2,034		46	46		38	293	331	10	71
2,035		46	46		38	293	331	10	68
2,036		46	46		38	293	331	9	66
2,037		46	46		38	293	331	9	64
2,038		46	46		38	293	331	9	62
2,039		46	46		38	293	331	8	60
2,040		46	46		38	293	331	8	59
2,041		46	46		38	293	331	8	57
							TOTAL =	8,381	8,385

Table 8.3 : Financial Evaluation based on the Second Spillway Scheme(Unit; equivalent Million Rs)

F I R R= 0 071

YEAR	CAPITAL COST	O&M COST	SALES COST	TOTAL COST	POWER REVENUE	TOTAL BENEFIT	N P V OF COST	N P V OF BENEFIT
1,986	309			309		0	288	0
1,987	721			721		0	628	0
1,988	1,030			1,030		0	838	0
1,989	1,545			1,545		0	1,173	0
1,990	2,575			2,575		0	1,825	0
1,991	2,575			2,575		0	1,703	0
1,992	1,545	50	157	1,753	852	852	1,082	526
1,993	280	58	180	518	973	973	298	561
1,994	283	65	202	550	1,095	1,095	296	589
1,995		72	225	297	1,217	1,217	149	611
1,996		72	225	297	1,217	1,217	139	570
1,997		72	225	297	1,217	1,217	130	532
1,998		72	225	297	1,217	1,217	121	497
1,999		72	225	297	1,217	1,217	113	464
2,000		72	225	297	1,217	1,217	106	433
2,001		72	225	297	1,217	1,217	99	404
2,002		72	225	297	1,217	1,217	92	377
2,003		72	225	297	1 217	1,217	86	352
2,004		72	225	297	1,217	1,217	80	329
2,005		72	225	297	1,217	1,217	75	307
2,006		72	225	297	1,217	1,217	70	286
2,007		72	225	297	1,217	1,217	65	267
2,008		72	225	297	1,217	1,217	61	250
2,009		72	225	297	1,217	1,217	57	233
2,010		72	225	297	1,217	1,217	53	217
2,011		72	225	297	1,217	1,217	50	203
2,012		72	225	297	1,217	1,217	46	189
2,013		72	225	297	1,217	1,217	43	177
2,014		72	225	297	1,217	1,217	40	165
2,015		72	225	297	1,217	1,217	38	154
2,016	1,770	72	225	2,067	1,217	1,217	244	144
2,017		72	225	297	1,217	1,217	33	134
2,018		72	225	297	1,217	1,217	31	125
2,019		72	225	297	1,217	1,217	29	117
2,020		72	225	297	1,217	1,217	27	109
2,021		72	225	297	1,217	1,217	25	102
2,022		72	225	297	1,217	1,217	23	95
2,023		72	225	297	1,217	1,217	22	89
2,024		72	225	297	1,217	1,217	20	83
2,025		72	225	297	1,217	1,217	19	77
2,026		72	225	297	1,217	1,217	18	72
2,027		72	225	297	1,217	1,217	16	67
2,028		72	225	297	1,217	1,217	15	63
2,029		72	225	297	1,217	1,217	14	59
2,030		72	225	297	1 217	1,217	13	55
2,031		72	225	297	1,217	1,217	12	51
2,032		72	225	297	1,217	1,217	12	48
2,033		72	225	297	1,217	1 217	11	45
2,034		72	225	297	1,217	1,217	10	42
2,035		72	225	297	1,217	1,217	9	39
2,036		72	225	297	1,217	1,217	9	36
2,037		72	225	297	1,217	1,217	8	34
2,038		72	225	297	1,217	1,217	8	32
2,039		72	225	297	1,217	1,217	7	30
2,040		72	225	297	1,217	1,217	7	28
2,041		72	225	297	1,217	1,217	6	26
						TOTAL =	10,494	10,496

Table 8.4 : Economic Evaluation based on the Wet Blanket Scheme (Unit equivalent Million Rs.)

EIRR= 0 140

YEAR	CPITAL COST	O&M COST	TOTAL COST	COAL-FIRED THERMAL	O&M COST	ENERGY COST	TOTAL BENEFIT	NPV OF COST	NPV OF BENEFIT
1,986	232		232	169			169	203	148
1,987	541		541	394			394	416	303
1,988	773		773	563			563	521	380
1,989	1,159		1,159	845			845	686	500
1,990	1,931		1,931	1,408			1,408	1,003	731
1,991	1,931		1,931	1,408			1,408	880	641
1,992	1,159	32	1,191	845	99	221	1,164	476	465
1,993	207	37	244		113	252	365	85	128
1,994	254	41	296		127	284	410	91	126
1,995	82	44	125		134	299	433	34	117
1,996	52	46	97		140	312	451	23	107
1,997		46	46		141	315	456	10	95
1,998		46	46		141	315	456	8	83
1,999		46	46		141	315	456	7	73
2,000		46	46		141	315	456	6	64
2,001		46	46		141	315	456	6	56
2,002		46	46		141	315	456	5	49
2,003		46	46		141	315	456	4	43
2,004		46	46		141	315	456	4	38
2,005		46	46		141	315	456	3	33
2,006		46	46		141	315	456	3	29
2,007		46	46		141	315	456	3	26
2,008		46	46		141	315	456	2	22
2,009		46	46		141	315	456	2	20
2,010		46	46		141	315	456	2	17
2,011		46	46	158	141	315	614	2	20
2,012		46	46	894	141	315	1,350	1	39
2,013		46	46	894	141	315	1,350	1	34
2,014		46	46	1,080	141	315	1,536	1	34
2,015		46	46	703	141	315	1,159	1	23
2,016	1,327	46	1,373	362	141	315	818	24	14
2,017		46	46		141	315	456	1	7
2,018		46	46		141	315	456	1	6
2,019		46	46		141	315	456	1	5
2,020		46	46		141	315	456	0	5
2,021		46	46		141	315	456	0	4
2,022		46	46		141	315	456	0	4
2,023		46	46		141	315	456	0	3
2,024		46	46		141	315	456	0	3
2,025		46	46		141	315	456	0	2
2,026		46	46		141	315	456	0	2
2,027		46	46		141	315	456	0	2
2,028		46	46		141	315	456	0	2
2,029		46	46		141	315	456	0	1
2,030		46	46		141	315	456	0	1
2,031		46	46		141	315	456	0	1
2,032		46	46		141	315	456	0	1
2,033		46	46		141	315	456	0	1
2,034		46	46		141	315	456	0	1
2,035		46	46		141	315	456	0	1
2,036		46	46		141	315	456	0	1
2,037		46	46		141	315	456	0	1
2,038		46	46		141	315	456	0	0
2,039		46	46		141	315	456	0	0
2,040		46	46		141	315	456	0	0
2,041		46	46		141	315	456	0	0
							TOTAL =	4,519	4,514

Table 8.5 : Financial Evaluation based on the Wet Blanket Scheme (Unit equivalent Million Rs)

FIRR= 0 076

YEAR	CAPITAL COST	O&M COST	SALES COST	TOTAL COST	POWER REVENUE	TOTAL BENEFIT	NPV OF COST	NPV OF BENEFIT
1,986	309			309		0	287	0
1,987	721			721		0	623	0
1,988	1,030			1,030		0	827	0
1,989	1,545			1,545		0	1,152	0
1,990	2,575			2,575		0	1,785	0
1,991	2,575			2,575		0	1,659	0
1,992	1,545	50	169	1,765	916	916	1,057	549
1,993	277	58	194	528	1,047	1,047	294	583
1,994	339	65	218	622	1,178	1,178	322	609
1,995	109	68	230	408	1,244	1,244	196	598
1,996	69	71	240	379	1,296	1,296	169	579
1,997		72	242	314	1,309	1,309	130	543
1,998		72	242	314	1,309	1,309	121	505
1,999		72	242	314	1,309	1,309	113	469
2,000		72	242	314	1,309	1,309	105	436
2,001		72	242	314	1,309	1,309	97	405
2,002		72	242	314	1,309	1,309	90	377
2,003		72	242	314	1,309	1,309	84	350
2,004		72	242	314	1,309	1,309	78	325
2,005		72	242	314	1,309	1,309	73	302
2,006		72	242	314	1,309	1,309	67	281
2,007		72	242	314	1,309	1,309	63	261
2,008		72	242	314	1,309	1,309	58	243
2,009		72	242	314	1,309	1,309	54	226
2,010		72	242	314	1,309	1,309	50	210
2,011		72	242	314	1,309	1,309	47	195
2,012		72	242	314	1,309	1,309	43	181
2,013		72	242	314	1,309	1,309	40	168
2,014		72	242	314	1,309	1,309	38	156
2,015		72	242	314	1,309	1,309	35	145
2,016	1,770	72	242	2,084	1,309	1,309	215	135
2,017		72	242	314	1,309	1,309	30	126
2,018		72	242	314	1,309	1,309	28	117
2,019		72	242	314	1,309	1,309	26	108
2,020		72	242	314	1,309	1,309	24	101
2,021		72	242	314	1,309	1,309	22	94
2,022		72	242	314	1,309	1,309	21	87
2,023		72	242	314	1,309	1,309	19	81
2,024		72	242	314	1,309	1,309	18	75
2,025		72	242	314	1,309	1,309	17	70
2,026		72	242	314	1,309	1,309	16	65
2,027		72	242	314	1,309	1,309	14	60
2,028		72	242	314	1,309	1,309	13	56
2,029		72	242	314	1,309	1,309	13	52
2,030		72	242	314	1,309	1,309	12	48
2,031		72	242	314	1,309	1,309	11	45
2,032		72	242	314	1,309	1,309	10	42
2,033		72	242	314	1,309	1,309	9	39
2,034		72	242	314	1,309	1,309	9	36
2,035		72	242	314	1,309	1,309	8	34
2,036		72	242	314	1,309	1,309	7	31
2,037		72	242	314	1,309	1,309	7	29
2,038		72	242	314	1,309	1,309	6	27
2,039		72	242	314	1,309	1,309	6	25
2,040		72	242	314	1,309	1,309	6	23
2,041		72	242	314	1,309	1,309	5	22
						TOTAL =	10,330	10,327

9. Conclusions and Recommendation

This report identifies that

i) Remedial measures at Samanalawewa must be carried out as soon as possible for economic, not safety, reasons

ii) Construction of the remedial measures should be carried out in such a manner that it has the minimum impact on power generation Therefore construction should proceed with reservoir water levels above Minimum Operating Level (El 424m)

iii) The location of the major area of reservoir water ingress has been identified as the section of the Walawe Ganga between 700m and 1,700m upstream of the dam. The main blanket construction works will concentrate on this section of the river and it is estimated that some 500,000m3 of fill material will be required

iv) The blanket construction by dump-barge method is the most promising However a combined approach using dump-barge method and side-dumping method may need to be carried out using earth moving equipment assigned for dump-barge method at the initial stage before the barges are available at the Site, should the procurement of the barges be significantly delayed

v) In order to reduce the possibility of water bursts occurring in new locations, the blanket construction should be carried out with the reservoir level held at about El. 430m so as to control reservoir levels below the experienced maximum level as much as possible

vi) To minimize damage to the natural blanket on the right bank and to minimize the environmental impact of large borrow areas the source of the fill should be the Kinchigune Borrow Area, which was the source of the fill materials for the dam core.

vii) While construction of the main blanket is in progress additional groundwater monitoring boreholes should be drilled south of GW14 so that subordinate areas of reservoir water ingress if they exist can be identified for subsequent treatment. These boreholes should be of sufficient diameter to allow for the collection of water samples, for chemical analysis, as well as recording of water levels

viii) Provision for additional blanket works, Follow-Up Work, should be allowed to treat any subordinate leakage paths that are identified during construction This follow-up work may be required at any time until the integrity of the remedial measures have been proved to Full Supply Level Therefore the period during which follow-up work may be necessary is for at least two major wet seasons after the main blanket is placed, ie a period of 1 5 years The provisional fill volume for this period is estimated to be 500,000 m3

ix) The study of economic and financial aspects of the project show that the project is still sustainable with these additional costs of J¥ 4,378 Million and Rs. 246 Million to meet the growing demand for electricity in Sri Lanka.

It is therefore concluded that the proposed remedial measures should be implemented as soon as possible.

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