AN APPRAISAL OF TECHNICAL ASPECTS OF THE RAMBUKKAN OYA IRRIGATION SCHEME - SRI LANKA

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Table of Contents

TABLE OF CONTENTS (continued)

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I. Introduction

The Rambukkan Oya irrigation scheme will restore and enlarge an old dam and reservoir in the dry zone of Sri Lanka to irrigate about 6,000 acres of land. The scheme is located on the Rambukkan Oya (Stream) between Palaturuella and Pulaveli in the northern part of Monaragala District. The area is presently sparsely settled, depends on slash and burn rainfed agriculture, and lacks roads, schools, health services and other civic amenities. Presently less than 1 percent of the land area is used. About 2,400 families, presently landless, will be settled on the 6,000 acres to be irrigated.

Elements of the scheme consist of (1) physical infrastructure, (2) social infrastructure, and (3) resettlement. The physical infrastructure includes restoration of the dam, construction of irrigation canals and a diversion dam (anicut) construction of roads and land clearing and leveling. Some of the social infrastructure and resettlement aspects of the project include training of farmers in irrigation agriculture, development of proper water management, development of communities, health services, and schools.

The proposed reservoir will have a catchment area of 50 square miles, and will inundate 1,700 acres and have the storage volume of 40,000 acre feet at full supply level (FSL) of 244.0 MSL of which 2,500 is dead storage dedicated to sediment. The weighted average rainfall in the catchment area for 27 years is 84.7 inches of which about

60 percent falls in the months of October through February. Monthly average evapotranspiration exceeds monthly average rainfall 7 months of the year. And even during the monsoon season (October to February) there are years with some months where average monthly evapotranspiration exceeds the average monthly rainfall.

The average annual yield at Rambukkan Oya dam site is 117,874 acre feet with a maximum of 200,528 acre feet and minimum of 33,000 acre feet.[1/] These figures were obtained by adjusting the records at the gauging station 5 miles downstream. The drainage area at the gauging station is 62.0 square miles vs 50 square miles at the dam site. The period of record is 27 years from September 1947 to October 1974.

The Government of Sri Lanka (GSL) has conducted extensive field, laboratory and office investigations of the project, approved the project after preparing a feasibility study, and is now in the process of final design and economic analysis. These will be completed by the end of the year. The Government of Sri Lanka (GSL) has requested AID to finance the foreign exchange costs of the scheme. This report is an appraisal of the technical aspects of the irrigation works, water management, land utilization, construction methods, costs and environmental factors. The report is based on a two-week visit to Sri Lanka where the site was visited and extensive discussions were held with the Director of Irrigation, Deputy Director for Planning and the specialist involved in the design and implementation of the

[1/] Revised from PID totals.

project. For further details not covered in the report the PID should be referred to.

II. Irrigation Works

A. Reservoir

The proposed reservoir will have a catchment area of 50 square miles. It will inundate an area of 1,700 acres at its full supply level of 244.0 MSL. At full supply it will contain 40,000 acre feet of which 2,500 is for sediment and dead storage. The floor of the reservoir is jungle with mostly slash and burn cultivation. There are 90 acres in oranges and 37.4 acres in paddy. There is one village, Kurunduvinne, in the reservoir area. Most of the land is owned by GSL. The people living in the reservoir area will be relocated into the new irrigated area and will be given high priority in selection of their farms.

The vegetation in the reservoir area should not cause any adverse biological problems. First, except for the 2,500 acre feet of dead storage below elevation 210.0 feet, the floor of the reservoir will be exposed most years. Secondly, there are many uncleared reservoirs in the area with no reports of adverse problems. There is some marketable timber in the reservoir area that could be sold. The dead storage area could support a fishery and for this reason this area may want to be cleared. Also, because debris - logs, weeds and slash - can cause problems with the operation of the gates it may be advisable to clear the reservoir area. However, debris has not been a problem for Sri Lanka in the other reservoirs.

Seismic activity in Sri Lanka is very small, see Section 6 page 15, there are no major faults in the area. The loading of the earth by the reservoir will not cause any problems.

In conclusion inundation of the reservoir area should not cause any major social or environmental problems.

B. Hydrology

The yield from the drainage basin for the reservoir area (50 square miles) based on 27 years of record (September 1947 to October 1974) at a gauging station 5 miles downstream of the site (drainage area 62.0 square miles) has an average of 117,874 acre feet, maximum of 200,528 acre feet and minimum of 35,000 acre feet. Yearly yield for the site is given in the appendix.[1/] During the dry period (February to October), there are many days that the stream is dry. It may be dry from one-half month to four months each year, see PID.

The weighted average rainfall in the catchment area for 27 years of record is 84.7 inches of which about 60 percent falls in the period October through February, see Table 3 of PID. Average monthly evapotranspiration exceeds average monthly rainfall 7 months of the year. Even in the monsoon season (October to February), there are years with some months where average evapotranspiration exceeds the rainfall. Thus, supplemental water is needed (irrigation) for crop production.

The active storage volume in the reservoir is 37,500 acre feet. The average runoff is 3.1 times larger than the storage volume. In most

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[1/] This is a revision of Table 4 of the PID based on a longer record and change in D.A. for gauging station.

years, the reservoir will furnish supplemental water during the monsoon season and still be full at the start of the dry period. However, there will be little carry-over water from one season to another. Also, there will be some years that the reservoir will not fill and good water management will be imperative. During the 27 year period of record (1947 to 1975) there was 1 year with insufficient runoff to fill the reservoir.

The inflow design hydrograph (IDH) for determining the capacity of the spillway is based on a 100 year return period. The peak flow is 32,600 cfs and has a flood volume of 47,800 acre feet.

The IDH is obtained from a synthetic unit hydrograph. The derivation of the unit hydrograph uses Snyder's formula (given in standard hydrology texts such as "Hydrology for Engineers," 1958, by Linsley, Kohler and Paulus). The coefficients in Snyder's method were obtained by the ID in a 1973 study of 21 hydrologic stations in 14 river basins of Ceylon.[1/]

In the synthetic unit hydrograph method point rainfall depths for a given frequency and duration are used. These are determined from graphs prepared by the ID in the same 1973 study where the Snyder's coefficients were determined.[1/] The maximum point rainfall is adjusted to obtain aerial rainfall, rainfall excess and rainfall time distribution. These values are multiplied by the appropriate values of the synthetic unit hydrograph derived for the area to obtain the IDH.

[1/] "Development of Design Flood Hydrographs for Ungauged Catchments using Snyder's Techniques as adopted for Ceylon Catchments," 1973, D. G. L. Ranatunga, B.Sc., M.Sc. in Civil Engineering from the Imperial College, London, and A. A. Jayaratne, Research Assistant, ID Publication.

Values of 24 hour point rainfall totals for different return periods are:

Return Period	24 Hour
100 years	15.5 inches
200 years	17.2 inches
1,000 years	20.8 inches
10,000 years	26.7 inches

IDH for the 100, 200 and 10,000 year flood is given in the Appendix.

The use of a 100 year or 200 year return period for the IDH is a policy determination. The 100 year return period storm is used for minor projects and 200 year for major projects. As stated earlier the 100 year storm is used for this project.

This policy is based on economic consideration of only the cost of the loss of the dam not on the social and economic cost of the loss of the dam and resulting damage on the area downstream of the reservoir. The cost to Sri Lanka of failure of the dam should include the cost of replacing the dam, the cost of the loss of production from the project, the price of the damage done to the area downstream of the dam and potential loss of life. A 100 or 200 year return period is too great a risk on which to base the safety of the dam. With a 100 year return period, there is a 40 percent chance that the inflow design storm will occur in the next 50 years and a 63 percent chance it will occur in the next 100 years. There is a 38 percent chance that a flood with a 200 year return period will occur in the next 50 years.

The risk of having a dam overtopped by a flood with a larger return period than 100 years is not as great as it appears. This is because the top of the dams (BTL) are appreciably higher than the flood top level (FTL). This surcharge area plus the increase in discharge over the spillway resulting from the increase in head means that the dams are safe for a much larger flood with a larger return period. That the dams are fairly safe from overtopping by a large flood is attested to by the large number of large dams that exist in the country without a failure. The problem is that we do not know precisely what we are designing the spillways for. The spillways may be over designed. In the present case, the spillway crest is 231.5 MSL, the high flood elevation is 248.0 MSL, top of the gate is 244.0 MSL and the top of the embankment (BTL) is 255.0 MSL. Thus, there is a 7 foot surcharge before overtopping.

Evaporation statistics are given in the PID. The average yearly evaporation is 56 inches. With a reservoir whose storage capacity is only 55 percent of the average annual yield evaporation losses will not be a problem.

There is a UNDP proposed project to strengthen the hydrology division by providing some equipment and a technical adviser. The project is not presently funded and would not provide assistance in time for this project.

Spillways are constructed to protect the dam from being overtopped by a major flood and destroyed. These spillways are a major portion of the cost of a dam. In the Rambukkan Oya feasibility study the cost of the spillway is estimated as $505,000 out of a total cost for the dam including the spillway of $597,000, almost 1/3 of the cost. Failure of the dam would be a major social and economic catastrophe. The determination of the Inflow Design Hydrograph is then of major economic and social importance to the success of this or any other reservoir project in Sri Lanka.

It is recommended that a careful study be made of both the policy of using the 100 or 200 year return period as the design storm and the method of deriving the inflow design hydrograph. Methods other than Snyder's and unit graphs should be used as a check of the 100 year, 200 year and maximum probable flood calculations. A hydrologist familiar with topical hydrology should be provided to help in this study. This study would benefit Sri Lanka in the design of the other projects presently under consideration.

C. Dam

1. General

The proposed dam is 81 feet above the stream bed and is thus a large dam. The USBR book "Design of Small Dams" describes procedures for dams less than 50 feet. For dams higher than 50 feet more detailed design proceeds are needed, such as more detailed stability analysis of the embankment, more extensive exploration of the foundation, more careful determination of seepage under and through the dam, more restrictive design criteria, and more careful determination of the inflow design flood for spillway design.

The Irrigation Department of the Ministry of Irrigation, Power and Highways, which is responsible for the design and supervision of construction has a staff of well trained professionals with extensive experience in the design of large dams. They have successfully designed and completed over 20 high dams 6 of which were higher than 100 feet. The ID has the equipment and staff for the necessary hydrologic, geologic and soils investigations. For example they have 29 core drills capable of penetrating 1,500 feet of hard (granite) rock. Although the professional staff is very competent they are few in number and have a large number of projects under consideration. The older professional staff have received graduate training outside Sri Lanka but the younger staff have received their training only in Sri Lanka. With the large work load, the professional staff have difficulty keeping up with present practice by reading the professional literature. The younger professional staff have not had contact and interaction with professionals from outside Sri Lanka. One of the benefits of the project would be the exposure and interaction of the younger staff members with other professionals. Another benefit would be to provide funds for additional training for some of the subordinate professionals. This would enlarge the number of competent people in the ID.

2. Embankment

The dam embankment will be a rolled earth fill structure containing 210,000 cubes of earth (cube equals 100 cubic feet). The dam would be considered a homogeneous type except that a major part of the embankment will contain an old bund (embankment) of different properties. It will be 3,700 feet long, 81 feet high, 16 feet wide at the top, upstream slope of 2.5:1, downstream slope 2:1. A 12 foot wide berm is on the downstream slope at elevation 205.0 MSL or 50 feet below the top. The top of the dam (BTL) will be at 255.0 MSL. The bed of the stream is 174.0 MSL. The Full Supply Level (FSL) and high flood level (HFL) are 244.0 and 248.0 MSL respectively. The spillway (which serves as both a service and flood spillway has a sill elevation of 231.5 MSL and top of the gate elevation of 244.0 MSL. The lowest bedrock elevation is 168.0 MSL and is located under the present stream bed which is at elevation 174.0 MSL. Other elevations are given in Table 1 and 2.

A key way with a bottom width of 15 feet, depth of one-third the embankment height or to bedrock and side slopes of 1:1 will be constructed in the foundation. An estimated 16,500 cubes of earth fill will be in the key way.

The embankment (bund) of an old dam containing 70,000 cubes will be incorporated into the present dam. The bund is breached at three places, near the left abutment where the road goes through, in the center where Rambukkan Oya (Stream) goes through, and near the right abutment. The soil in the bund is sandy clay (SC) and it is not at maximum density. The bund is more pervious than the new embankment will be. The average elevation of the top of the bund is 220 MSL. The maximum elevation is 243 MSL. It has a top width ranging from 20 to 50 feet and side slopes ranging from 1.5:1 to 2:1. The feasibility report suggested that the bund be incorporated into the downstream portion of the embankment. However, the soils section is presently doing additional stability analysis to determine the safest location of the bund in the new dam.

Using the bund as part of the embankment in a dam this high must be carefully analyzed. The fact that it is more pervious than the new embankment and less pervious that the foundation, the lack of quality control and knowledge of soil mechanics in the design and construction of the old bund may leave regions, zones or layers of material in the bund which under the higher heads could lead to high seepage, piping, blowouts and eventual failure. Vegetation may also create areas of weakness. Even the extensive coring of the material may not uncover weak areas. With careful location of the impervious zones, cutoffs, filters, drains and careful location of the old bund in the cross section of the new dam the old bund may be safely incorporated in the embankment. But it will require careful analysis. Before funding the project, AID should have the embankment design reviewed by a specialist in soil mechanics for dams.

There is adequte soil with proper characteristics close to the dam and in the reservoir area with which to construct the embankment. There is adequate sound rock near the site for the riprap. A quarry and blasting will be needed but much of the rock with proper planning can come from the spillway excavation. There is plenty of sand in the area for concrete but the larger sizes in the concrete will come from the quarry.

3. Foundations

The base of the embankment will be on alluvium of varying thickness over bedrock. Both abutments are on bedrock as well as the spillway. The left bank sluice will be in the alluvium and the embankment. The thickness of alluvial overburden varies from 10 feet to 22 feet. The stream bed is 22 feet above bedrock and consists of coarse sand on top of clay sand (SC). The overburden consists of clay sand (SC) soil with a permeability coefficient ranging from 1,000 to 3,000 feet per year.

The bedrock consists of interbedded biotite, gneiss, biotite hornplende gnessis and granulite. The upper 10 to 20 feet of the bedrock is weathered. Below this weathered zone the rock is sound with few fractures or cracks. Under the Rambukkan Oya the bedrock is weathered with permeabilities that are larger than the sounder bedrock. Even though the core recovery in the weathered and fractured rock is about 100 percent, the loss of water is about 20.0 gpm at 90 psi. In the good, hard rock there is no loss of water even at 90 psi. Applied pressures for the permeability tests were 30, 60 and 90 psi and duration for each pressure was 10 minutes.

The foundation was core drilled at 16 locations with 10 holes in the spillway area. The depth of cores were from 25 to 62 feet and were always drilled into rock with a minimum of 80 percent core recovery.

The foundations for the dam embankment, spillway and outlet are good. Some provision for the weathered rock under the stream bed will be provided in the final design such as grout curtain, stripping, key way, upstream impervious bank or combination of these. At the abutments and under the spillway the weathered rock will be stripped and grouting as needed will be done. The engineers in the ID have the knowledge and equipment to decide what is needed and there is equipment available for grouting. At the spillway the excavation will be well into the hard rock to accommodate the radial gates.

4. Spillway

The spillway is designed for the 100 year return period storm as described in the section on hydrology. The IDH has a peak discharge of 37,600 cfs and a volume of 47.80 acre feet. The spillway will serve as both a service gate and emergency spillway. It will discharge all inflows in excess of the outlet works design capacity when the reservoir is at FSL 244.0 MSL.

The spillway is still under design consideration with several studies still in progress. It is located on the right bank where there is good bedrock for the foundations. The PID describes one scheme with 112 feet of gated and 112 feet of ungated. Another scheme is a gated spillway of 112 feet width. The final design will depend on decisions related to the IDH.

The foundations of the spillway are very good. The ID engineers are very capable of designing the spillway and stilling basin.

It is recommended that the ID continue studies to determine the least cost spillway that will protect the reservoir. The inflow design flood must be larger than the 100 or 200 year return period storm. At this time using the 10,000 year storm is recommended for the IDH. This storm has a peak discharge of 61,000 cfs and 94,800 acre feet of volume. In their studies the ID should not hesitate to let the 100 year or larger storms infringe into the freeboard.

Designing the spillway for the 10,000 year return period storm will increase the cost of the dam, but increase the safety against failure. The increase in spillway cost can be lowered by (1) additional hydrologic analysis, including the selection of the IDH return period, (2) careful sizing of the service section of the spillway in relation to the emergency section, (3) locating an emergency spillway that would only operate when an extreme event occurred, and (4) allow only a 0.5 to 1.0 foot freeboard during the extreme event. These will be elaborated on in the following paragraphs.

A careful analysis of the IDH using other techniques including the unit hydrograph based on the available records for the Rambukkan Oya may decrease the magnitude of the IDH. An analysis of the cost of the failure of the dam on the area downstream including the social as well as economic costs may rationally decrease the size of the design storm. For example, if the magnitude of the flood going over the spillway would do as much damage as the dam failing, then a smaller IDH could rationally be used. If the cost of the spillway would be more than the damages then a decision to decrease the IDH would be rational. However, the social and political cost of a dam failure must be kept in mind.

The number of service gates might be decreased so that only the annual, 5 or 10 year return period flows or some other RT flows be controlled. All other flows would go over the emergency spillway. The fewer gates the less the cost.

An emergency spillway section might be located on the left bank. It could be constructed of earth channel with a concrete sill or grass lined section to protect from erosion. It would only operate when flows exceeded the 200 return aerial storm.

5. Outlet

The outlet sluice is only to furnish water to the project. It consists of two gated tubes through the embankment. There are two gates for each tube. The gates are 5 feet high by 4 feet wide. The gates and their control tower are at the upstream end of the outlet, downstream of the gate, and the control tower is the energy dissipater of hydraulic jump type. The flow for the rest of the distance through the embankment has a free surface. The three tubes then discharge into a concrete lined canal with 115 cfs capacity. This canal is approximately 2,000 feet long where it ends at a bifurcation. At the bifurcation up to 65 cfs is discharged to the river through a Parshall flume for measurement purposes and a stilling basin. This flow is for the right bank canal which takes off from the anicut (diversion dam) two or three miles downstream. Up to 50 cfs is passed on to the left bank canal through a Parshall flume to service the left bank area. The sill of the outlet is at 210.0 MSL. The tubes are sized to furnish 115 cfs at low head, approximately 215.0 MSL. With wide open gates the discharge through the tubes will be considerably larger for all heads higher than 215.0 MSL. The maximum potential discharge at full supply level (244.0 MSL) is approximately 600 cfs. In accordance with Murphy's Law (if anything can go wrong it will) it is poor design to have a stilling basin and downstream canal designed for discharges less than potential.

It is recommended that the stilling basin be moved from beneath the embankment to downstream of the embankment. It is felt that locating it in the embankment is dangerous to the safety and construction details.

It is further recommended that the stilling basin, canal to the bifurcation and to the river, including the second stage stilling basin, be designed to take the minimum discharge that can come through the outlet.

6. Seismicity

Seismicity of Sri Lanka may be taken as pratically nil. Local tremors are felt at the rate of approximately once a year. These are not caused by deep-seated earthquakes, but are very local slight tremors, such as could be caused by landslides, rockfalls, and minor fractures of rock strata in the hills. These tremors do not exceed force 3 on the Modified Mercalli Scale. The most severe tremor experienced was force 4 (in 1973).

It is highly improbable that earthquakes that could cause damage to the proposed structure would occur.

D. Sedimentation

1. General

In the design of irrigation schemes, the sediment transported in the stream and the response of the river system to the change in flow regime must be carefully considered. The things to consider are (1) the upstream response of the stream to any dams or diversions, (2) magnitude of the loss of storage in any reservoir, (3) the downstream response of the river to the dams and diversion works, (4) sediment problems that may occur in handling the river during construction, and (5) the problems associated with the intake of sediments into the canal system.

2. Soil fertility

Some people think there is a sixth consideration concerning sediment - the fertilization of the floodplain by deposition of river-born sediments floodplain. Most sediments are inorganic silts, clays and sands. Most sediments flow to the sea. The value of sediment deposits is in the development of deep alluvial floodplain soils which takes centuries. These soils are fertile and have good structures but the deposits from a single flood add very little nutrients. When a flood occurs which inundates the alluvial floodplain, the problem is how to get rid of the deposits of silt and sand in order to bring the land back into production. The Ford Foundation in a recent study of the Nile River determined that the amount of nutrients deposited by the irrigation water prior to High Aswan Dam was negligible. Using their (Ford Foundation) figures, the nutrient value of the sediments was about equivalent to plowing 1,200 lbs. of straw into the ground per acre. In this project, the concentrations of sediment in the flow as determined from sediment stations in the area are lower than in the Nile, and flooding of the floodplain is infrequent. The fertility value of river-born sediments in this area approaches zero.

3. Reservoir siltation

The Irrigation Department used a figure of 0.5 acre feet per square mile per year as the sediment deposit into the reservoir. They thus arrived at a figure of 2,500 acre feet of storage loss at the end of the 100 years. Using independent methods, we conclude that the maximum storage loss at the end of 100 years will be on the same order of magnitude. We used the measured suspended sediment load on two streams in the region with similar slash and born agriculture and terrain. The suspended sediment rating curves for these two streams is given in the Appendix. The average suspended sediment concentration in these streams, increased by a factor of 2.5 for the unmeasured load and ignorance, was used to determine the total sediment load at the site. Using a density of 100 lbs. per cubic foot and 100 percent trap efficiency the loss of storage in 100 years was 2,400 acre feet.

4. Upstream river response

The upstream response of the stream to the dam will not be large. In general, this response is an increase in backwater resulting from the delta formation. As discussed in the previous paragraph, sediment deposition will be small. Also, the small storage to runoff ratio means that the reservoir will be drawn down to dead storage each year. Thus, the river will incise the delta and move the deposits further down in the reservoir area. This will further decrease any backwater problems.

5. Downstream river response

The downstream response of the river to the dam will be a decrease in stream bed elevation as the clear water picks up its sediment discharge. The banks are highly erosion resultant and vegetated so lateral migration will be small and stream response will be to lower its bed. The decrease in elevation will be controlled by the diversion dam downstream. Also, there is gravel in the stream bed which will armor plate the bed. The coarse nature of the bed material, erosion resistance of the banks, the diversion dam downstream all will reduce the downstream response of the stream to the dam so that we do not anticipate any major problems. Observations of other rivers downstream of dams and questioning of the ID Engineers support this conclusion. Nevertheless, the ID might want to use methods outlined in the "Small Dams Book" to determine the eventual elevation of the stream bed. This information would be valuable in determining the elevation of the sill on the stilling basins for the spillway and outlet flow to the river, for the right bank irrigation canal. These methods can also be used to determine the sand transport for the design of the sediment excluder needed at the diversion dam.

6. River handling

There will be no sediment problems in handling this river during construction.

7. Canal sedimentation

The design of the diversion structure must include a study of the potential inflow of sediment into the canal. The study must determine (1) will the sediment transported in the river create a problem (costly cleaning of the canal) and (2) if the sediment causes a problem design a sediment excluder or ejector system to keep the sediment out of the canal. In this case, there will be a decreasing sand load to the diversion dam, because of the upstream dam, but sand transported by the river if it gets into the canal will be deposited. The ID is studying the problem and will incorporate a sediment sluice in the diversion structure if the studies indicate it is needed.

8. Local scour

There will be local scour downstream of all stilling basins and downstream of the anicut (diversion dam). This is normal and is handled by placing riprap as needed. There is good rock, which must be quarried, in the area and the ID engineers are familiar with the problem and its solution.

9. Conclusion

The sediment problems for this dam are small and will not adversely affect its feasibility.

E. Anicut (Diversion Dam)

To serve the right bank area of about 3,000 acres there will be an anicut a few (1 or 2) miles downstream of the reservoir. It is presently planned to be a gated (radial) concrete structure 66 feet in length.

The 3 radial gates will be 20 feet wide and 12.5 feet high. Elevations for the structure are given in Tables 1 and 2 of the Appendix.

Two core holes were drilled at the site. Bedrock is 20 to 30 feet below the stream bed and is similar to that of the dam. If needed, an ejector (probably sluice) will be placed in the structure to keep sediment out of the canal. The structure, as presently conceived, will have cutoff walls to control seepage and uplift and a stilling basin. The design techniques are standard and there are no special problems at the site. The ID engineers have a good engineering design for the feasibility study and are proceeding to final design.

F. Canal and Distribution System

The canals are designed using the Manning's equation and nonerosive velocities for earth canals. The slope in the earth lined sections will be 0.00035 and 0.0005 ft/ft in concrete lined sections. Side slopes are 1.5 to 1 for both earth and concrete. Manning's N is 0.025 for earth and 0.02 for concrete. The latter value is higher than used in the U.S., but is based on ID Engineers' experience. At this time, the canals have the following characteristics at the upper or full supply end:

	Area	Bottom Width	Depth	Velocity	Q	Fr.
L.B. & R.B.						
Delivery canals	39.4	12	2.5	1.71	67	.19
Supply from dam	61.5	16	3	1.95	120	.20

Normal free board is 1.0 foot but this is adjusted upward if there is potential storm water inflow into the canal.

The outlets to the minor distributaries will be gated pipe and have a rated sill for water measurement. Checks will be incorporated to maintain the head on the minor distributaries.

The distributaries which will cut across the slope will have drop structures to maintain grade and prevent erosion.

Drainage channels for both seepage, tail water runoff, and end of ditch flow are incorporated into the delivery system.

The Department of Irrigation, ID for the costing study, is designing the canal and distributary system for about 10 percent of the project area utilizing maps with a scale of 1:6000 with 2 foot contour intervals. For one distributary system, they are completely designing the farm layouts. This includes the ditch system to each farm, the drainage systems, the farm layouts and the rough leveling necessary before settlement. This design is done from maps of a 1:1500 foot scale. These sample calculations will be utilized to determine construction costs for the entire project and this work is scheduled for completion by December 1, 1976.

There are no unusual problems with the design of the delivery system and the ID shows a high level of competence and experience in their design and construction. Standard typical design sections are given in the Appendix.

III. Water Management

A. General

Farm Water Management involves the process by which water is utilized and disposed of in the production of food and fiber. Various aspects have been neglected in Sri Lanka as has been the case in almost every other country in the world. The tanks, canals and distributaries deliver water to each farm where it is "disposed of" in a very inefficient manner.

The Government of Sri Lanka is aware of this deficiency and is beginning to do something about it. The GSL, World Bank, and U.K. jointly financed "Tank Modernization Project" will give some answers regarding criteria for better water utilization although many other agricultural inputs such as power, fertilizers, and supporting services are being stressed more than on-farm water management. A "Competitive Cultivation Program" is being sponsored by the Irrigation Department during Maha, 1976/77. This contest will involve 177 groups of farmers covering an area of 13,000 acres under the Rajangana Tank Scheme. Winners will be decided on the greatest production per unit of water delivered. Prizes will be useful equipment (two wheeled tractors, spray equipment, etc.) which can be utilized cooperatively by the winning groups.

By far the most significant GOSL activity addressing the problems of water management is the "Irrigation and Water Management Pilot Project - Mahaweli Ganga." Under this Project, it is proposed to study various on-farm techniques and procedures, which can be constructed and managed by small farmers and which will result in improved water use. The experimental site is on the Kala-Oya, and will include not only 40 acres of experimental area but also an area where 13 settlers will operate their farms and be involved in testing experimentally proven techniques. In this manner, the human aspects can be studied along with the physical, economic, and biological factors. Until such an adoptive research program identifies and describes appropriate water management technologies there will be no valid recommendations to give settlers on how to prepare for, develop, maintain, and manage their on-farm use of water.

B. Duty of Water

Water Management on the Rambukkana-Oya project will be handled as it is in all tank development schemes. The duty (amount of water to deliver to each farm) has been determined by calculating from climatological data the amount of water necessary to produce each of the suggested crops and adding an amount (30%) which is considered to be the in-transit losses from the tank to the farm.

The tank capacity is 37,500 acre feet or about 75 acre inches for each of the 6,000 project acres. The canal at capacity will carry an equivalent of 1/2 acre inch per day for each acre. Therefore, there is sufficient tank capacity to allow full canal flow for about 150 days each year. Peak consumptive use rates probably approach 1/4 inch per day, therefore, at such time, the system will have to be operating at 50 percent efficiency assuming crops on each acre.

Most systems in Sri Lanka operate much below a 50 percent overall efficiency of water use. The probable range is from 20 percent to 30 percent efficiency.[1/] One could conclude then that there is insufficient water storage capacity behind the Rambukkana bund to completely serve the project area. It must be remembered however, that the reservoir in most years, will be full after having met irrigation demands through the Maha season. Also, all acres will not be planted to rice nor will the peak period of water use fall at the same time on each acre. With present on-farm irrigation practices there is also an assumed supply of water coming to the lower lying paddy project areas from the irrigation on upland crops in the higher areas. This lateral movement of wasted water above and below the ground surface will reduce greatly and in some cases, eliminate the irrigation requirements on the lowest lying paddy acreage.

[1/] These estimates of irrigation efficiencies were obtained from discussions with ID officials and from reading various reports such as Draft Report Sri Lanka Irrigation Mission - FAO/IBRD and calculations of water delivery per acre versus crop water needs.

The new farmers will undoubtedly feel they need more water and in early years will probably not plant two crops per year on each acre. And, of course, in years of extreme drought the reservoir may not fill creating the need for careful management of the water and cutting back some of the cropped acreage. Certainly, water management technologies will be applicable to the Rambukkan-Oya. They should be implemented from the inception of the project. Increased production will undoubtedly occur along with the savings in water.

In summary there is sufficient water for the proposed area and the canal system is designed with sufficient capacity. It is recommended that the foreign exchange cost of the project include funds for the implementation of water management techniques.

C. Scheduling of Water

The canal system ends at a structure (turnout) which serves about 40 acres or some 15 farmers. However, the Project will construct a field channel system beyond the turnout and to each farm. The farmers must maintain the system below the turnout, while the Irrigation Department is responsible for it above the turnout. The farmers under one turnout (Yaya) use the water in a rotational system developed by themselves. Observations and questioning of farmers on the Gal Oya project (a much bigger project in the dry zone that has been in operation for over 10 years) indicate the farmers maintain and manage their part of the system. The ID has also maintained their part of the Gal Oya system.

The scheduling or time of delivery is decided prior to the growing season cooperatively by the Irrigation Department and the Cultivation Committees represented under the Scheme. Unless some unforeseen event occurs such as a power outage or heavy rains, the adopted scheduling calendar is followed.

This system represents a type of "water on demand" in that the farmers do have some voice in when they get water and the canal is closed during periods of no irrigation demands. This is certainly better than a system where the farmers have a constant supply whether needed or not. Until better on-farm water management technologies have been worked out, there is undoubtedly, no better system of scheduling the supply of water to each farm.

D. <u>Water Charges</u>

Historically, there has been no charge for irrigation water. The recently passed "Land Betterment Tax" will provide for taxing these lands which have been improved through construction of irrigation works. However, this tax cannot be considered a water charge since it is based on acreage alone and not on water used. It will undoubtedly be sometime before water is metered and charged for by volume, but with the enthusiasm for solving the water management problems within the GSL, this type of refined management will assuredly come.

IV. Land Utilization

A. <u>Soils</u>

Detailed reconnaissance soil surveys have been completed for the Project Area (see Appendix). The Project soils have been classified into 5 upland and 2 bottom land classes based on topography, depth and texture. There are a total of 2,300 acres in the upland group and 6,000 acres in the bottom land; therefore, the extent of the survey is somewhat beyond the Project boundaries. The upland soils range from deep well drained reddish brown loams to rather shallow (1 foot) sandy loams depending on the classification. About one-half of the upland acreage consists of well drained moderately deep noncalcic brown soils.

The bottom land soils are deep loams to clayey alluvium, which are poorly drained.

A more detailed survey to precisely delineate soil type boundaries and perhaps sub-classify is in progress. This survey will be used for actual farm layouts. The procedures used for the soil classification are those recommended by FAO in this publication entitled "Soil Surveys in Irrigation Investigations" and is essentially, the U.S. Bureau of Reclamation technique cropping pattern.

Specific rotations have been suggested for the upland areas. These include chillies, soya beans, ground nuts and maize. The bottom lands will be placed in rice with 2 crops per year. The upland crop suggestions are merely that, and farmers will not be required to follow strict rotation. They must however, not grow rice on the upland soils, since permeabilities are quite high and the Department feels that these soils are unsuited for paddy production. Undoubtedly with time, the farmers will work out suitable rotations for the upland crops.

V. Construction Methods

Hand labor is utilized wherever possible in the construction of head works and distribution systems. The main canals are constructed by machine, but all distributaries and field channels from it are hand dug. Much of the land clearing and all of the field bunds are hand constructed.

Based on observations and visits to 5 Project Sites, it is rather obvious that heavy equipment for construction is in short supply. The Machinery and Equipment Division under the Secretary of Irrigation, Power & Highways is in charge of equipment for the Ministry. Their Central Workshop was visited and it is apparent that a good equipment maintenance and repair program is being followed. The shops are well equipped with rather old equipment but spare parts are being made and undoubtedly machines are being utilized beyond their normal lifespan, due to such a program.

In the construction of the embankment and the supply canal earth moving and compaction equipment along with cement and quarry will be needed. This equipment includes crawler tractors, scrapers, bulldozers, trucks, draglines, sheep foot, and rubber tired compactors and compressors. For leveling the farm land some earth moving scrapers and land planes will be needed. Some concrete mixtures will also be needed.

In the construction of the dam and canal the quantities of earth to be moved, the distance they have to be moved and the quantity control needed for a safe structure rule out manual labor. For example, the ID has determined that a man can move 1 cube (100 cubic ft) 100 feet in a day. The embankment has over 140,000 cubes of earth, and borrow areas and over 2,000 feet away. This alone would require 2.8 million man-days of effort.

The GSL utilizes manual labor to a large degree in their construction of projects. They try to mix the proportion of manual labor and use of machinery to optimize the use of manual labor without sacrificing quality control or completion of the project in a timely fashion. They use manual labor on the minor canals, drains and distributaries. They use manual labor to prepare and pour the minor concrete structure including outlets. Large spillways require large amounts of concrete. There they will use more equipment. The stripping of the rock will be done by hand but major excavation will require compressors and jackhammers. Explosives are used where needed even if the stripping or quarry work is manual or by machine.

VI. Costs

The Irrigation Department has a high degree of competence in estimating the costs of their projects. They break projects down into appropriate subunits and have developed unit prices for all elements. A publication titled "Irrigation Department's Evaluation of Unit Prices and Rate Analysis" dated August, 1976, is available for pricing all quantities and elements of the project. This publication is periodically upgraded. A similar publication was used in pricing out this project.

VII. Environmental Aspects

The Project will change an area from rough, slash and burn agriculture supporting a few very poor families to an irrigated farming area supporting 2,400 to 2,500 families. The area once was irrigated by an old bund that was destroyed during civil unrest in the past. The people left the area and it reverted to semi-jungle.

The reservoir will cover about 1,700 acres but should not adversely affect the landscape. It will empty most years except for the dead storage area of 2,500 acre feet. Biological problems will therefore be small. Erosion of the stream downstream of the dam will be small and confined to the stream bed. There is no schistosomiasis in Sri Lanka. There are mosquitoes and mosquito borne diseases such as malaria. These could be a problem but the project is designed with drains so that stagnant water will be minimized. Also GSL recognizes the problem and has a future campaign to stamp out malaria. Seismic problems will not exist on their reservoir and dam site, see section II-C-6.

The sediment load in the stream or the stream response to the change in flow regime will not cause any major environmental problems, see the section on Sedimentation.

The permeability of the bedrock under the area is very low and there are no major or minor faults in the area. There will be very little seepage of water from the reservoir nor will the evaporation losses cause a significant loss of water or buildup of salts.

The floor of the reservoir is jungle with slash and burn agriculture. There are a few marketable trees in the area. Of the total 50 mi^2 of drainage area about the dam less than three acres will be inundated.

It is our professional opinion that the project will have a positive environmental impact.

VIII. Pilot Project Aspects

This project is one of many planned by Sri Lanka to increase her food production. The project could change some of the design features of the other projects with possible improvements, for example, the inflow design hydrograph.

The machinery provided for this project will be used to contract other projects. GSL has the machine shops needed to maintain the equipment.

The project will develop water management techniques, agronomic practices and methodology for the training of farmers in upland crop irrigation methods. These will be transferable to the new projects GSL is planning.

The decrease in water use that water management may provide in the development of their project can be transferred to the design of other projects decreasing their costs. These decreases in cost result from the smaller size irrigation structure and drains that would result if water use per acre is reduced.

The project will identify the technical assistance and training needed for Sri Lanka to meet its development goals. The present staff of the ID is very capable but it is small. As projects to improve agriculture and help the rural poor continue to be developed Sri Lanka will need more trained personnel. This project can help determine the type of training needed, serve as a training ground for additional staff and provide for short course, graduate training and travel to learn for some of the present professional staff.

IX. Conclusions, Issues and Recommendations

A. Conclusions

1. The project is in the final design and cost analysis stage and this should be completed by January 1, 1977.

2. The technical aspects of the project are very well conceived and the engineering works are well designed. There are, however, four issues in the design of the dam that need further action. These are size of the spillway, the design of the embankment, the size of the stilling basins and outlet canal, and location of the outlet stilling basin. These will be discussed later in this section.

3. The Irrigation Department has a very capable engineering staff. Each design section has capable engineers with advance degrees or graduate training. The staff, however, has a large work load and is spread very thin.

4. There are no major sediment problems with this project.

5. There will be sufficient runoff almost every year to fill the reservoir. In the period of record there was only one year out of the 27 when the runoff was less than the storage. The average annual runoff is 3.1 times the active storage volume of the reservoir,

117,874 acre feet versus 37,500 acre feet. Most years the runoff will be sufficient for irrigation during the wet season and have a full reservoir at the start of the dry season.

6. There is sufficient runoff and storage water available for irrigating the planned acres. Only one out of the 27 years of record was short of water.

7. The soils in the area have been competently classified. They are suitable for irrigation and for the planned crops.

8. There are no major adverse environmental impacts of this project. Sediment will not be a problem, seepage from the reservoir will not be a problem, salinity is not a problem, evaporation is not a problem, seismic potential is not a problem, adverse biological growth in the reservoir should not occur and, except for malaria, water borne diseases such as schistosomiasis will not be a problem. Malaria in the area is not now a problem. Although there is some malaria in Sri Lanka with good water management the project should not have any more stagnant water than presently occurs.

9. The project has many pilot aspects both for Sri Lanka and other parts of the world. It is a direct action project to help the rural poor. Information learned on good water management can be incorporated into existing and planned projects with potential increase in crop production, savings in water and decreased cost. With US/AID investment there would be outside technicians on the project. This would bring new ideas and approaches. AID technicians and contractors would also learn from this project. This information would help future projects. The project would also provide training for additional GSL technicians for the design and construction of future projects.

10. The GSL has competent state and private companies to construct the project. They use a good mix of manual labor and machines to optimize employment and still get the project completed in a timely fashion. They do need machinery such as excavators, motor scrapers, trucks, 4 and 8 yard concrete mixers, crawler trailers and compactors to construct this project. GSL has the ability to maintain the equipment and it would be available for use on other projects.

11. The ID has up-to-date prices of the various elements in the project. Their estimates of the cost of the project will be competently done and reliable.

B. Issues

As mentioned earlier there are four minor issues with this project.

1. The magnitude of the flood that the spillway is designed for may be too small. The policy is to base the inflow design hydrograph on the flow with a 100 year return period. This magnitude of flood accepts too large a risk for the safety of the dam. The policy, methodology for the IDH and spillway design need careful review. The issue is the size of spillways needed for the safety of the dam and the related costs.

2. This is a large dam (81 feet high) and is planned to incorporate an old bund into the embankment to reduce construction costs. The soils and foundation for the embankment are good and if carefully analyzed it should be possible to utilize the old bund in the embankment. The issue is to be sure that adequate safeguards have been taken in the design of the embankment. The safeguards are the location of the old bund in the embankment, location and adequacy of the impervious zones, filters and drains.

3. The outlet canal and stilling basins have a design capacity of 115 to 120 cfs. The outlet tubes have a potential discharge at full reservoir supply level of about 600 cfs. The ID depends on the gate tender to control the gates to be sure flows never exceed the capacity of the downstream works. There is the possibility that the flow in the outlet will exceed the capacity of the downstream conveyance structures and destroy them. This could occur by human failure or a flood occurring when the gates were unattended. The issue is, of course, the size of the downstream conveyance structures.

4. The final issue is the location of the stilling basin for the outlet works. One plan is to have the stilling basin in the embankment immediately downstream of the outlet gates. Stilling basin design is not a true science, they vibrate, and if placed under the embankment will require careful design and construction procedures. The basin should be located downstream and outside the embankment.

C. Recommendations

As a result of the study, recommendations are as follows:

1. A hydrologist experienced in tropical hydrology be sent to Sri Lanka to help review their inflow design hydrograph policy and methods for its determination.

2. The spillway design be carefully reviewed in light of any new IDH, the design to obtain the least cost alternative.

3. A competent soils mechanic expert, with dam embankment design experience, review the final embankment design.

4. The stilling basins and conveyance canal downstream of the outlet and the stilling basin for the flow that is returned to the river for the right bank canal be designed to handle the maximum discharge that can occur through the outlet with both gates wide open.

5. The stilling basin be located outside of the embankment.

6. Some funds be provided in the project for training of ID technical staff. This training to consist of short courses, specialized graduate training and travel to observe engineering and agricultural projects in other parts of the world.

The training would be to increase the competence of the younger professionals working under the section chiefs in each area of project design and implementation.

The training to be in water management, dam design, hydrology, engineering geology, project design, irrigation practice, etc. The ID has excellent professional people who are spread very thin. The training would enlarge the number of well-trained professionals.

7. Some funds be provided in the project for calculators, typewriters, drafting instruments and similar items needed to a design office. These items would increase the productivity of the various design sections in the ID.

APPENDIX A

PEOPLE CONTACTED

PEOPLE CONTACTED

T. Sivagnanan	Sec. Ministry of Irrigation, Power and Highways
Mahinda Silva	Sec. Ministry of Agriculture and Lands
A. Maheswaran	Director of Irrigation
R. U. Fernando	Deputy Director
M. G. C. P. Wijayatilleke	Deputy Director - Designs
K. B. de S. Karunaratne	Deputy Director - Research
Dr. E. Aheysutve	Director of Agriculture
Dr. C. R. Panabokke	Deputy Director - Agriculture Research
Dr. K. A. De Alwis	Land Use Division
J. A. Rajendram	Executive Engineer in Project Area
R. Thurairajah	D.I.E. Geological Engineering
J. A. J. Jayasuriya	D.I.E. Soils Laboratory
Dr. T. Sivapatham	Soils and Embankment Designs
W. Tennekoon	Drilling Superintendent
S. V. A. Buddhadasa	D.I.E. Irrigation Systems Designs
S. Sritharan	I.E. Project Designs
M. R. Jayasinghe	I.E. Project Designs
T. A. Diyagama	I.E. Project Designs
G. E. M. Gomez	D.I.E. Hydrology
A. A. Jayaratna	R. A. Hydrology
Dr. W. D. Jushua	Soil Physicist (Agronomy) I.D.
N. Karunakaran	I.E. Hydraulics Laboratory
N. Gomes	I.E. Hydraulics Laboratory
M. W. P. Wijesinghe	D.I.E. Hydrogeology

APPENDIX B

TABLES OF ELEVATIONS

TABLE 1

RELEVANT ELEVATIONS (DESCENDING ORDER)
RAMBUKKAN OYA PROJECT

ELEVATION MSL	COMPONENT	DESCRIPTION
255.00	Dam	BTL (Bund Top Level)
248.00	Reservoir	HFL (High Flood Level)
244.00	Reservoir	FSL (Full Supply Level)
244.00	R.B. Spillway	Gate Top Level
235.50	R.B. Spillway	Aug. Existing Ground Level
231.50	R.B. Spillway	Gate Sill Level
225.00	R.B. Spillway	Highest Bed Rock Level
225.00	Dam	Highest Bed Rock Level (Spill Area)
221.50	R.B. Spillway	Lowest Bed Rock Level
214.00	L.B. Sluice	Ground Level
210.00	L.B. Sluice	Sill Level
208.00	Command Area	Highest Field Level
205.00	Dam	D/S Berm Level
176.00	Barrage	BTL
176.00	Dam	Lowest U/S Toe Level
174.00	Dam	Stream Bed Level
174.00	Dam	Lowest D/S Toe Level
174.00	Barrage	HFL
168.00	Dam	Lowest Bed Rock Level (Stream Bed)
160.00	Barrage	Bank Level
153.90	Barrage	River Bed Level
131.0-134.0	Barrage	Bed Rock Level
107.00	Command Area	Lowest Field Level

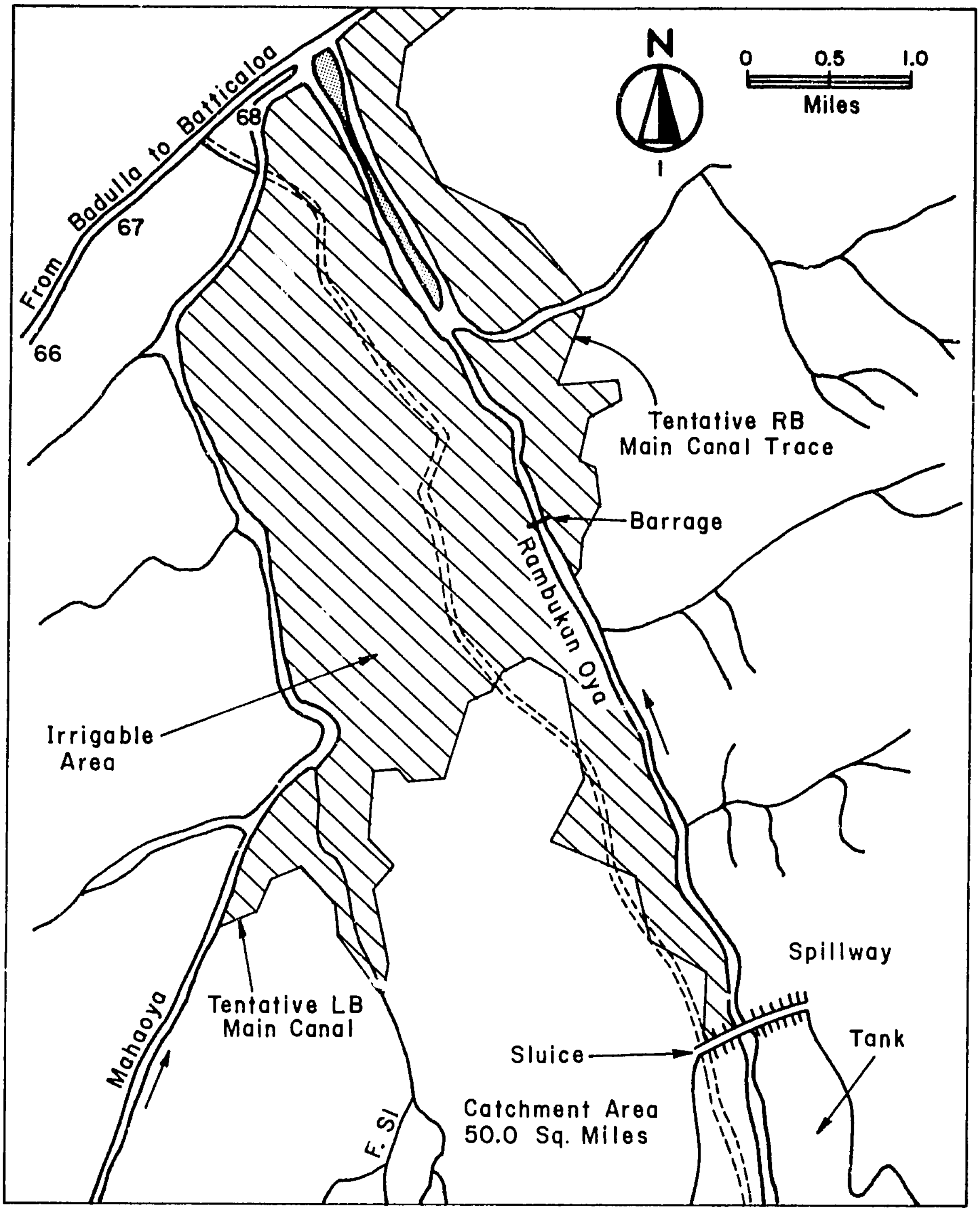
TABLE 2

RELEVANT ELEVATIONS (COMPONENT WISE)
RAMBUKKAN OYA PROJECT

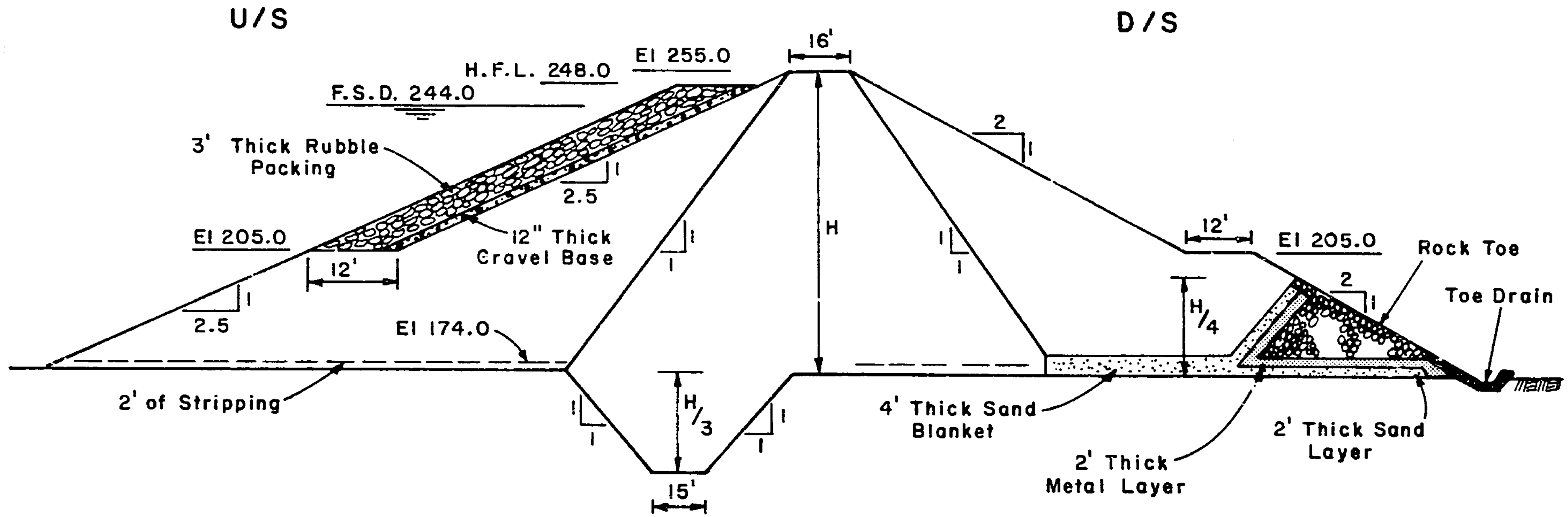
BARRAGE			
Bed Rock Level	131.0-134.0	MSL	20
River Bed Level	153.9	MSL	19
FSL	170.00	MSL	16
HFL	174.00	MSL	15
BTL	176.00	MSL	12
Bank Level	160.00	MSL	18
DAM			
Lowest Bed Rock Level	168.0	MSL (Stream Bed)	17
Highest Bed Rock Level	225.0	MSL (Spill Area)	6
Stream Bed Level	174.0	MSL	14
Lowest D/S Toe Level	174.0	MSL	14
Lowest U/S Toe Level	176.0	MSL	13
Downstream Berm Level	205.0	MSL	11
Bund Top Level	255.0	MSL	1
L.B. SLUICE			
Sill Level	210.0	MSL	9
Ground Level	214.0	MSL	8
R.B. SPILLWAY			
Lowest Bed Rock Level	221.5	MSL	7
Highest Bed Rock Level	225.0	MSL	6
Aug. Existing Ground Level	235.5	MSL	4
Gate Sill Level	231.5	MSL	5
Gate Top Level	244.0	MSL	3
RESERVOIR			
FSL	244.0	MSL	3
HFL	248.0	MSL	2
COMMAND AREA			
Highest Field Level	208.0	MSL	10
Lowest Field Level	107.0	MSL	21

APPENDIX C

FIGURES - PROJECT AREA AND STRUCTURAL ELEMENTS

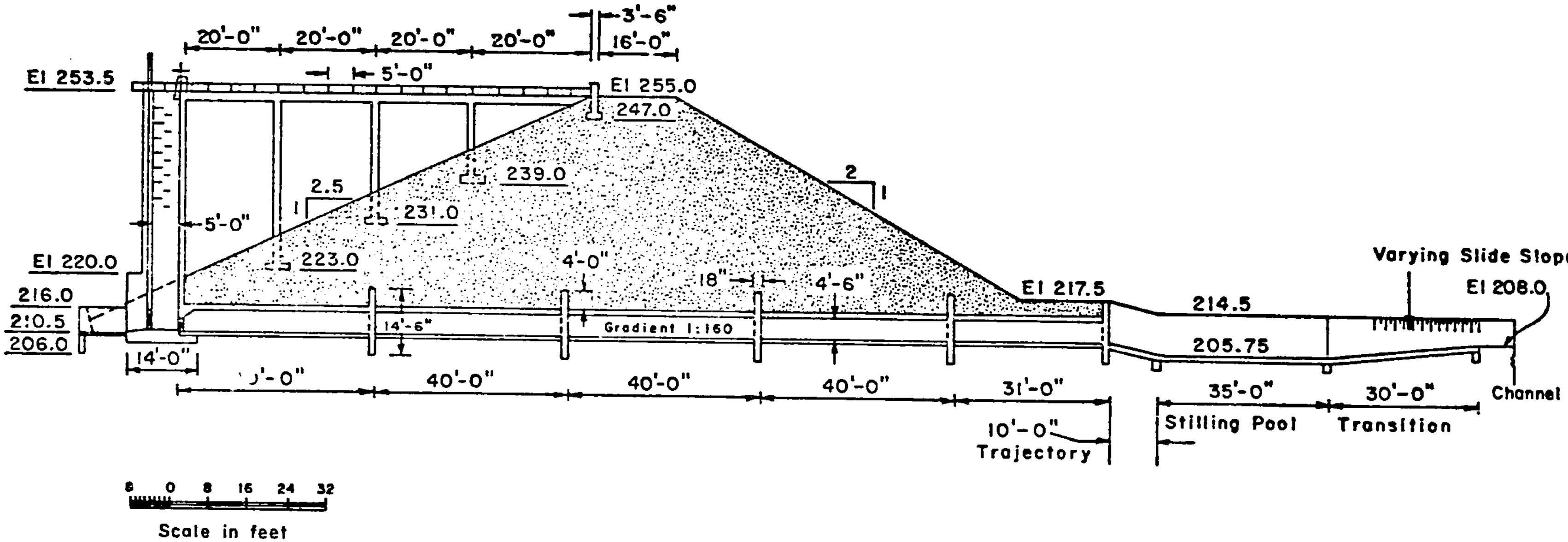


RAMBUKKAN OYA PROJECT AREA

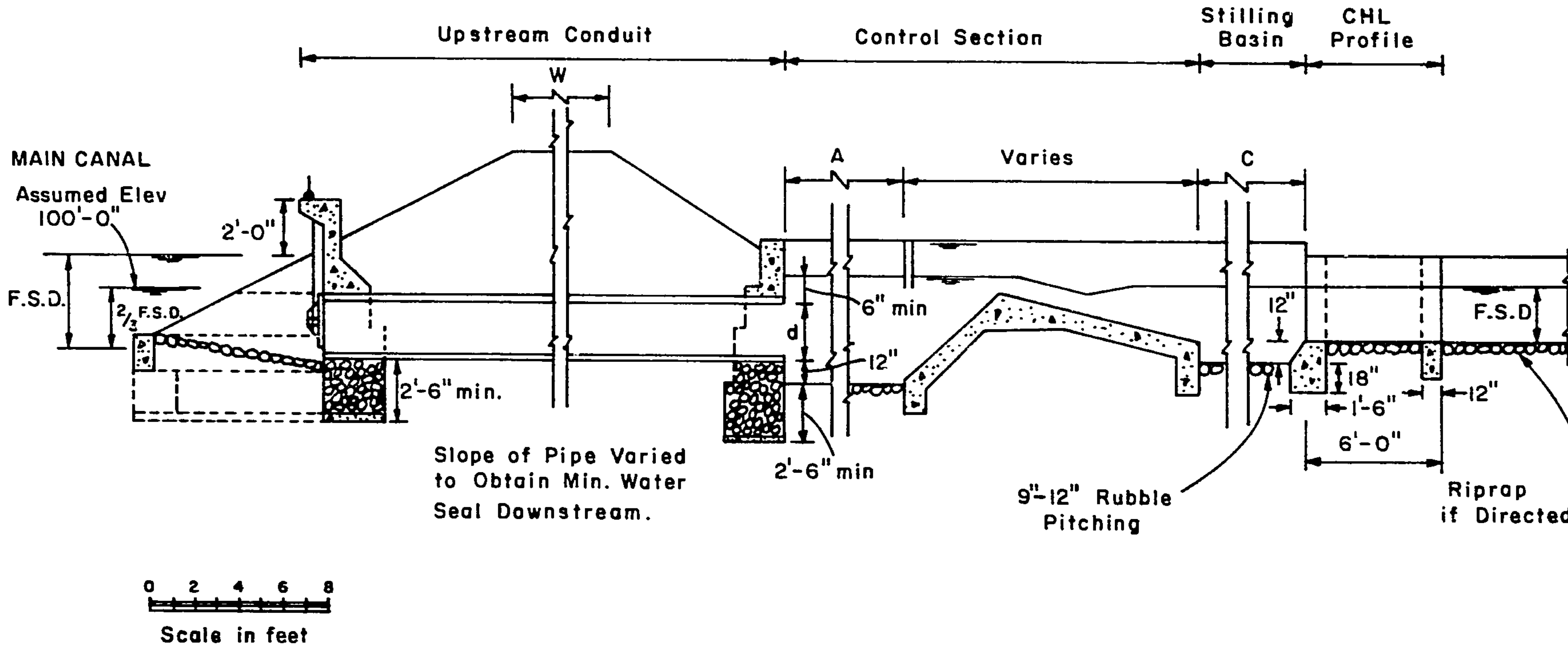


RAMBUKKAN OYA RESERVOIR SCHEME

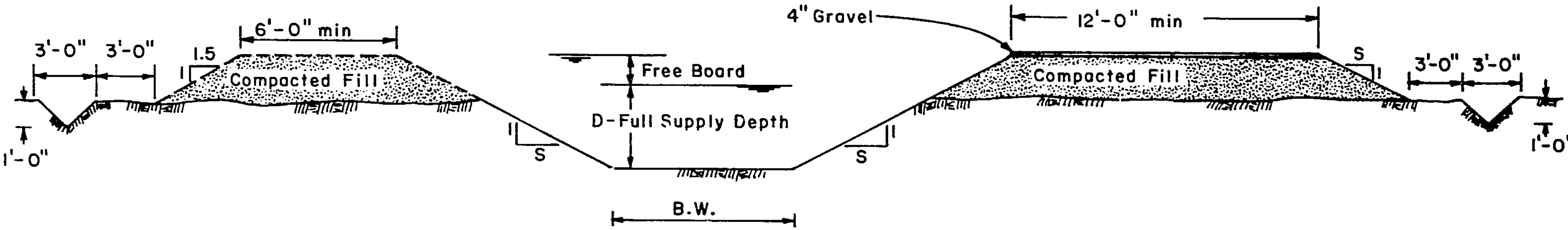
TYPICAL SECTION OF BREACH CLOSURE



RAMBUKKAN OYA L.B. SLUICE



TYPE PLAN FOR TURNOUT STRUCTURE
MAIN AND DISTRIBUTARY CANALS

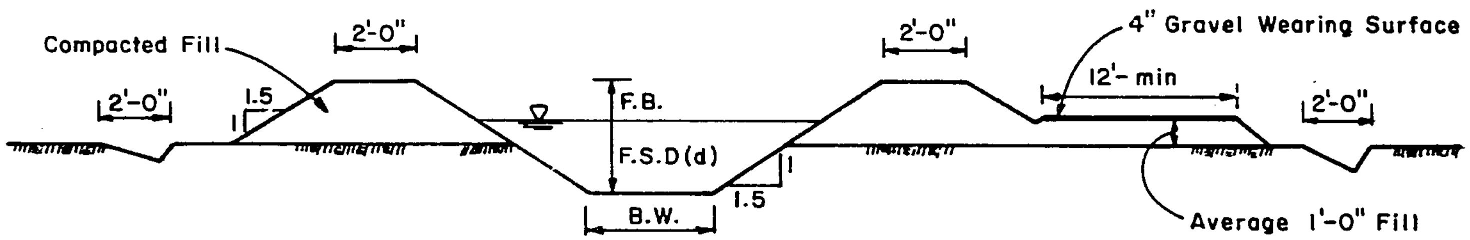


TYPICAL MAIN CANAL SECTION

Notes:

1. Double Banking Only Where Specified
2. Side Slopes: S = 2 if Discharge > 200 cfs
   S = 1.5 if Discharge < 200 cfs
3. Channel Spill Crest Level to be 0.5 feet above F.S.D.

F.S.D. (ft)	Flood Afflux (ft)	Free Board Above-D (ft)
1	0.5	2.0
2	1.0	2.5
3	1.5	3.5
4	2.0	4.0
5	2.0	4.5
6	2.0	4.0
7	2.5	5.0

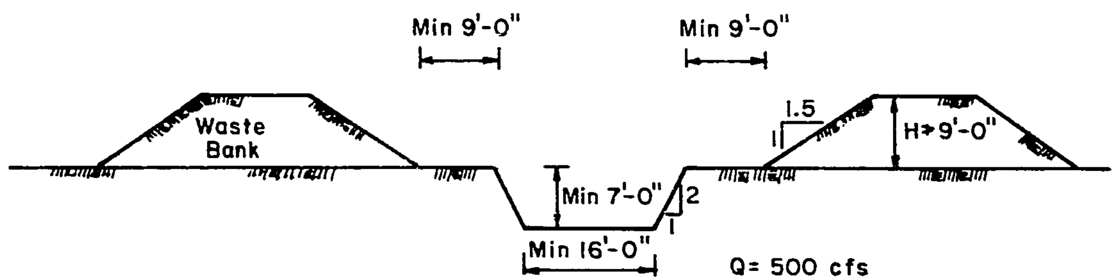


H = F.S.D. + F.B.

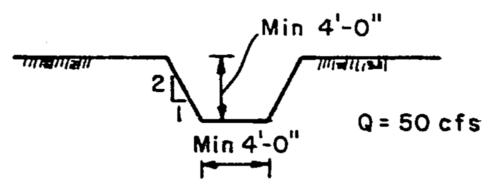
d = F.S.D.

TYPICAL SECTION OF A FIELD DISTRIBUTARY CANAL

Q	B.W.	d	H
1-2	1.0	1.1	2.6
3-6	1.5	1.6	3.0
7-8	2.0	1.7	3.5
9-11	2.5	1.8	4.0
12-14	4.0	1.8	4.0
15-18	5.0	1.8	4.3
19-21	6.0	1.8	4.3
22-24	7.0	1.8	4.3
25-30	8.0	2.0	4.5



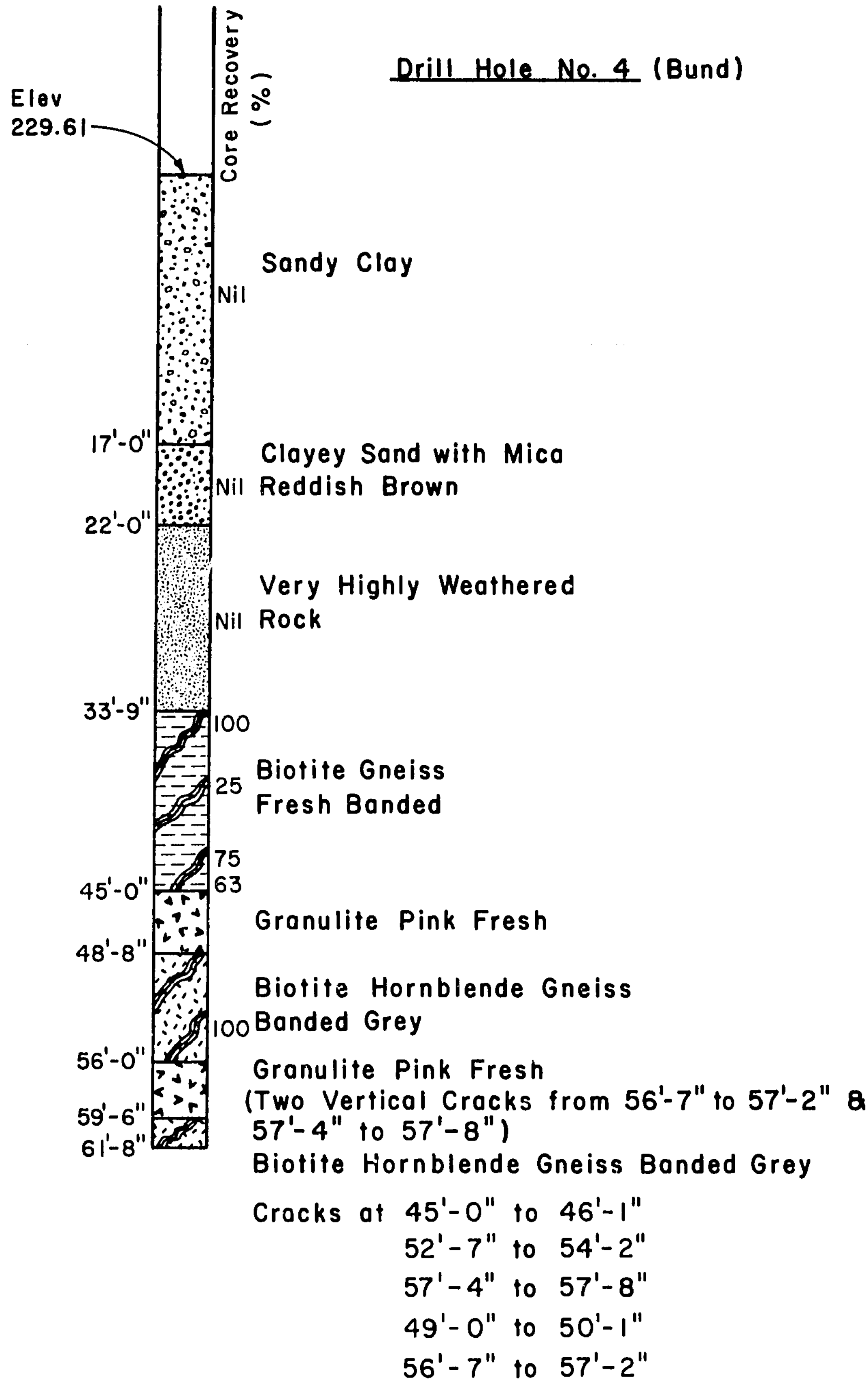
TYPICAL SECTION OF A SECONDARY DRAINAGE
FOR BLOCK BOUNDARIES, SPILL TAIL CHANNELS



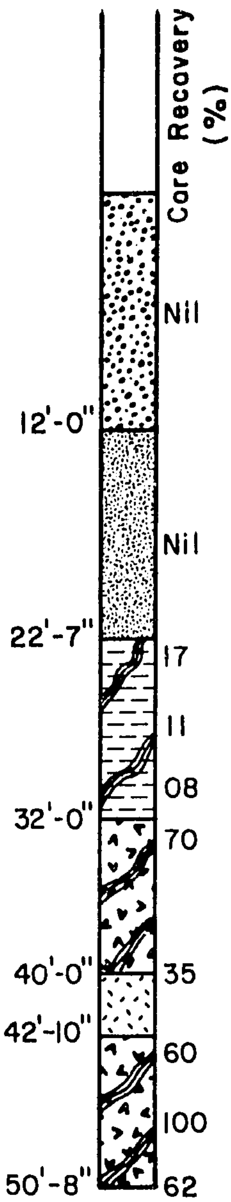
TYPICAL SECTION OF A DRAIN BETWEEN TURNOUTS

APPENDIX D

SELECTED CORE LOGS


Drill Hole No. 4 (Bund)
Core Recovery (%)
Elev 229.61
Sandy Clay
Nil
17'-0"
Clayey Sand with Mica
Nil Reddish Brown
22'-0"
Very Highly Weathered
Nil Rock
33'-9"
100
Biotite Gneiss
25
Fresh Banded
75
63
45'-0"
Granulite Pink Fresh
48'-8"
Biotite Hornblende Gneiss
100 Banded Grey
56'-0"
Granulite Pink Fresh
(Two Vertical Cracks from 56'-7" to 57'-2" & 57'-4" to 57'-8")
59'-6"
61'-8"
Biotite Hornblende Gneiss Banded Grey
Cracks at 45'-0" to 46'-1"
52'-7" to 54'-2"
57'-4" to 57'-8"
49'-0" to 50'-1"
56'-7" to 57'-2"

Drill Hole No. 6 (Bund)



Clayey Sand Brown

Very Highly Weathered Rock

Gneiss Decomposed and Disintegrated Light Brown

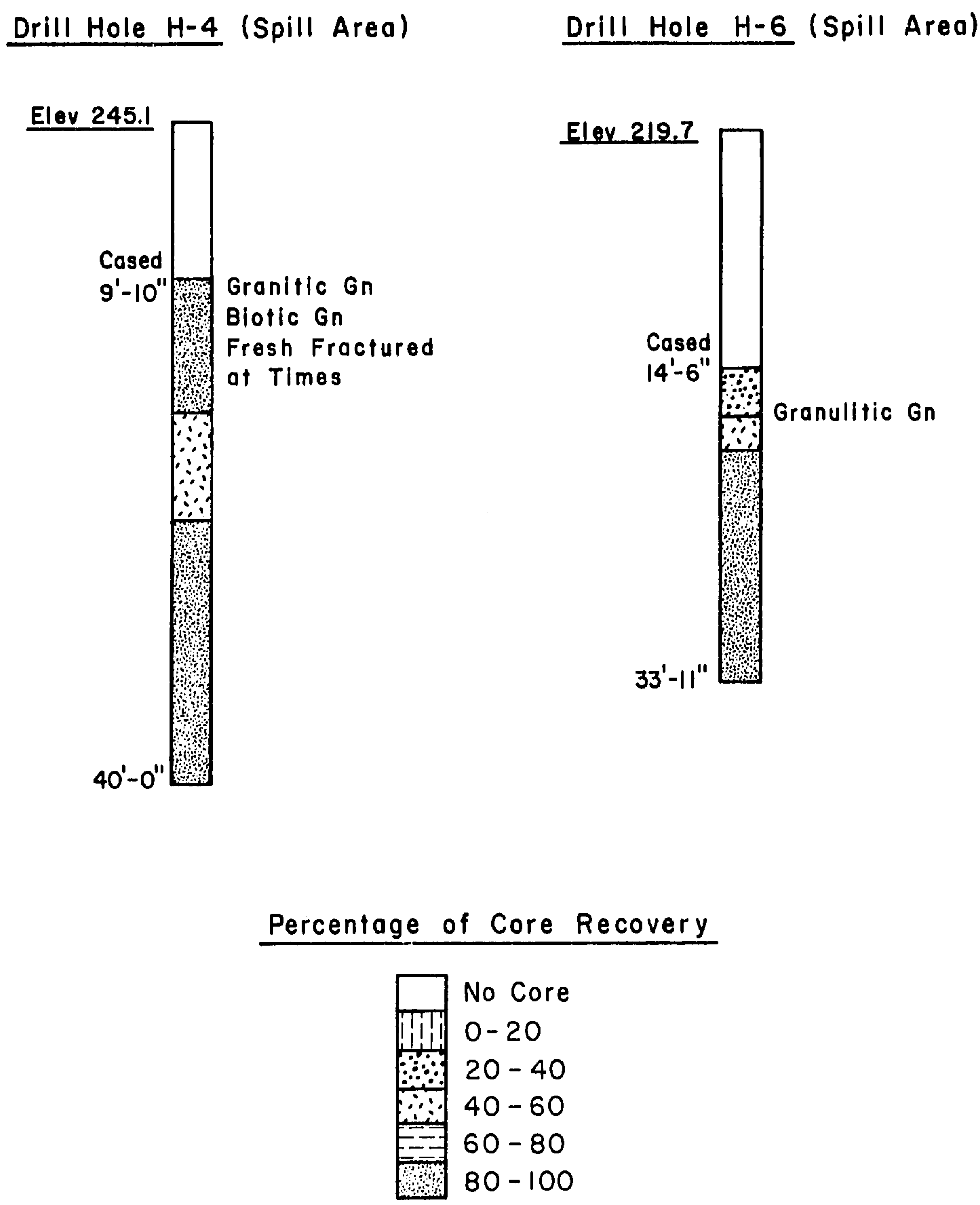
Granulite Gneiss Pinkish Highly Disintegrated Pieces about 1"

Pegmatite Highly Disintegrated Greyish

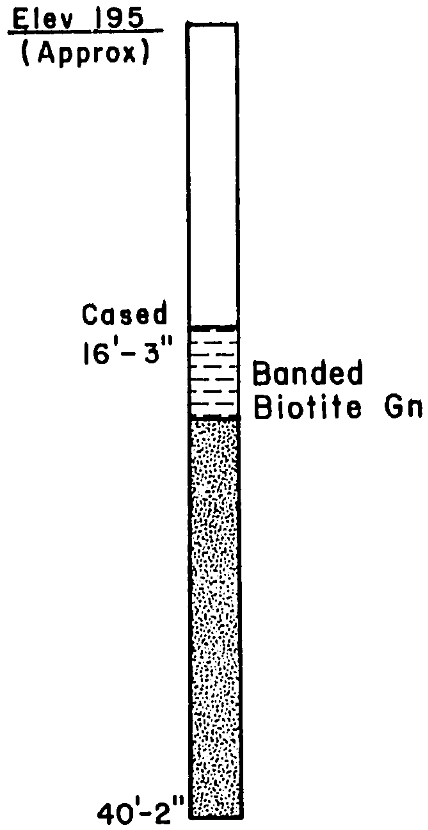
Pink Granulitic Gneiss Subjected to Alteration, Fresh Pinkish to Greyish

Series of Cracks from 32'-10" to 43'-7"
46'-11" to 47'-4"
48'-0"

Note: Grouted Hole Due to Complete Loss of Water at 43'-7"

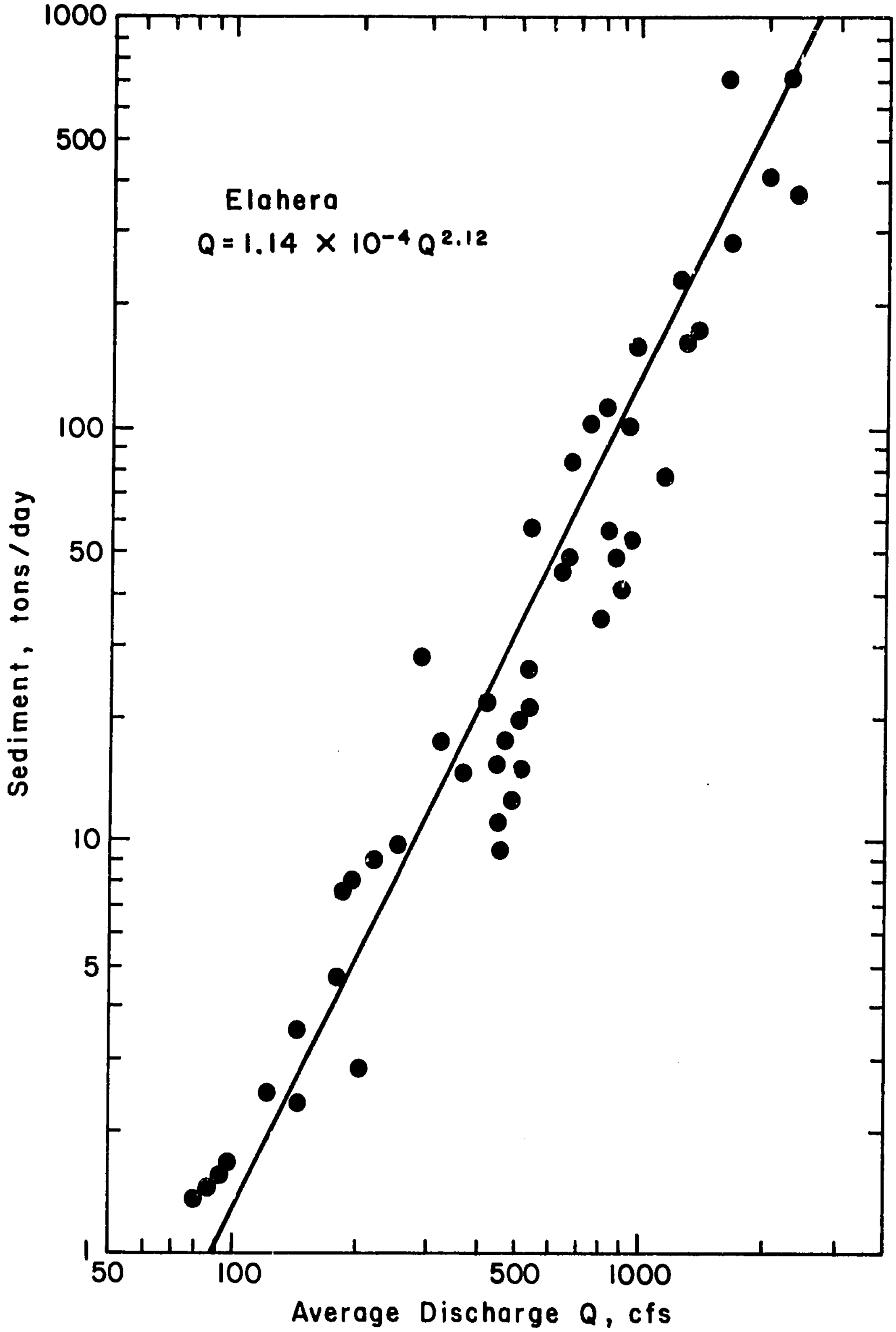

Drill Hole H-4 (Spill Area)
Elev 245.1
Cased
9'-10"
Granitic Gn
Biotic Gn
Fresh Fractured
at Times
40'-0"
Drill Hole H-6 (Spill Area)
Elev 219.7
Cased
14'-6"
Granulitic Gn
33'-11"
Percentage of Core Recovery
No Core
0-20
20-40
40-60
60-80
80-100

Drill Hole No. H-9 (Spill Area)

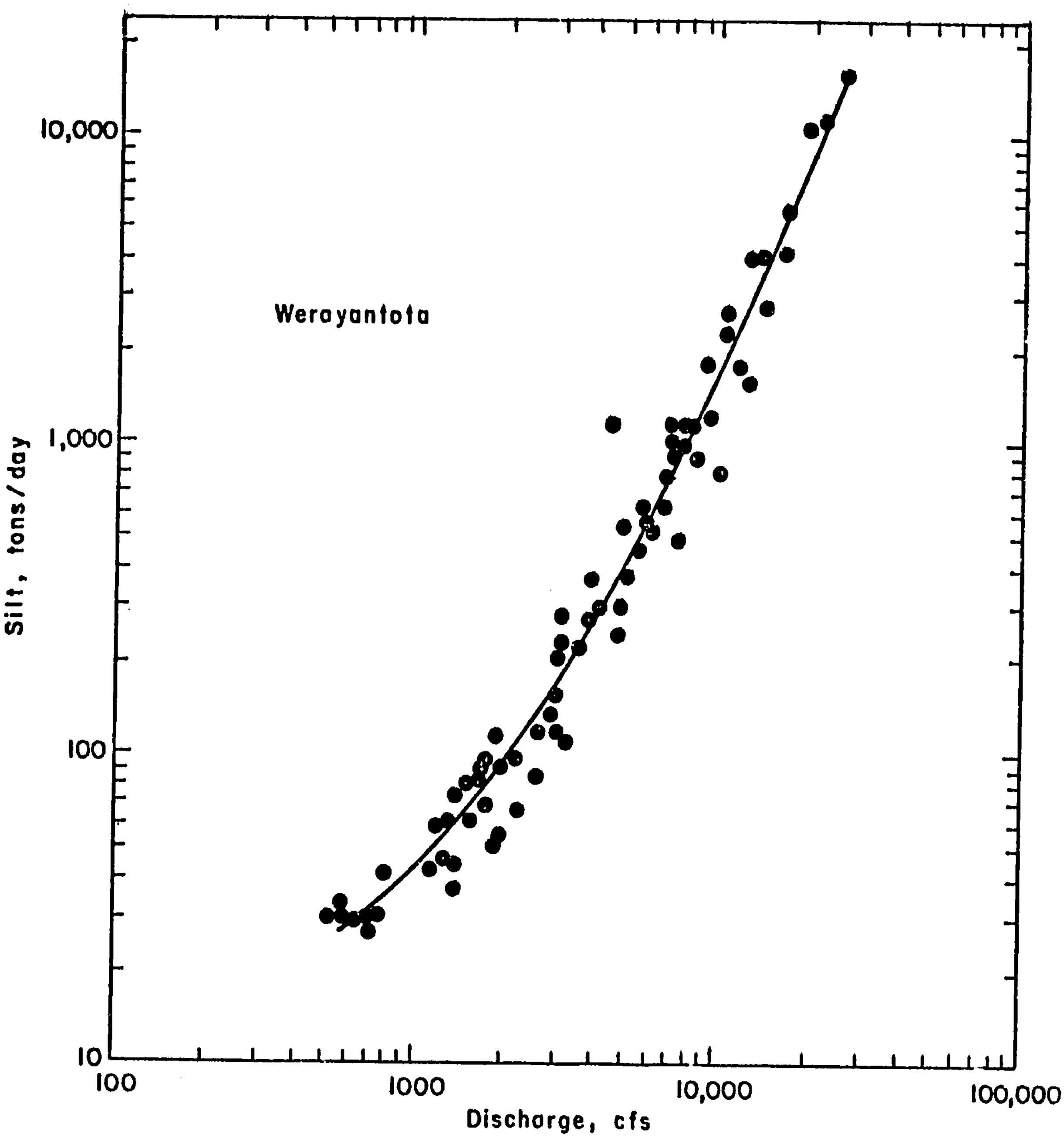


APPENDIX E

SEDIMENT RATING CURVES



Elahera Sediment Rating Curve, October 1967 to December 1975, Located 45 Miles West of Rambukkan Oyo. Drainage Basin Jungle and Slash and Burn Agriculture. D.A. 298 mi^2.



Werayantota, Located 30 Miles Southwest of Rambukkan Oya. Jungle and Slash and Burn Agriculture. D.A. 1560 mi^2.

APPENDIX F

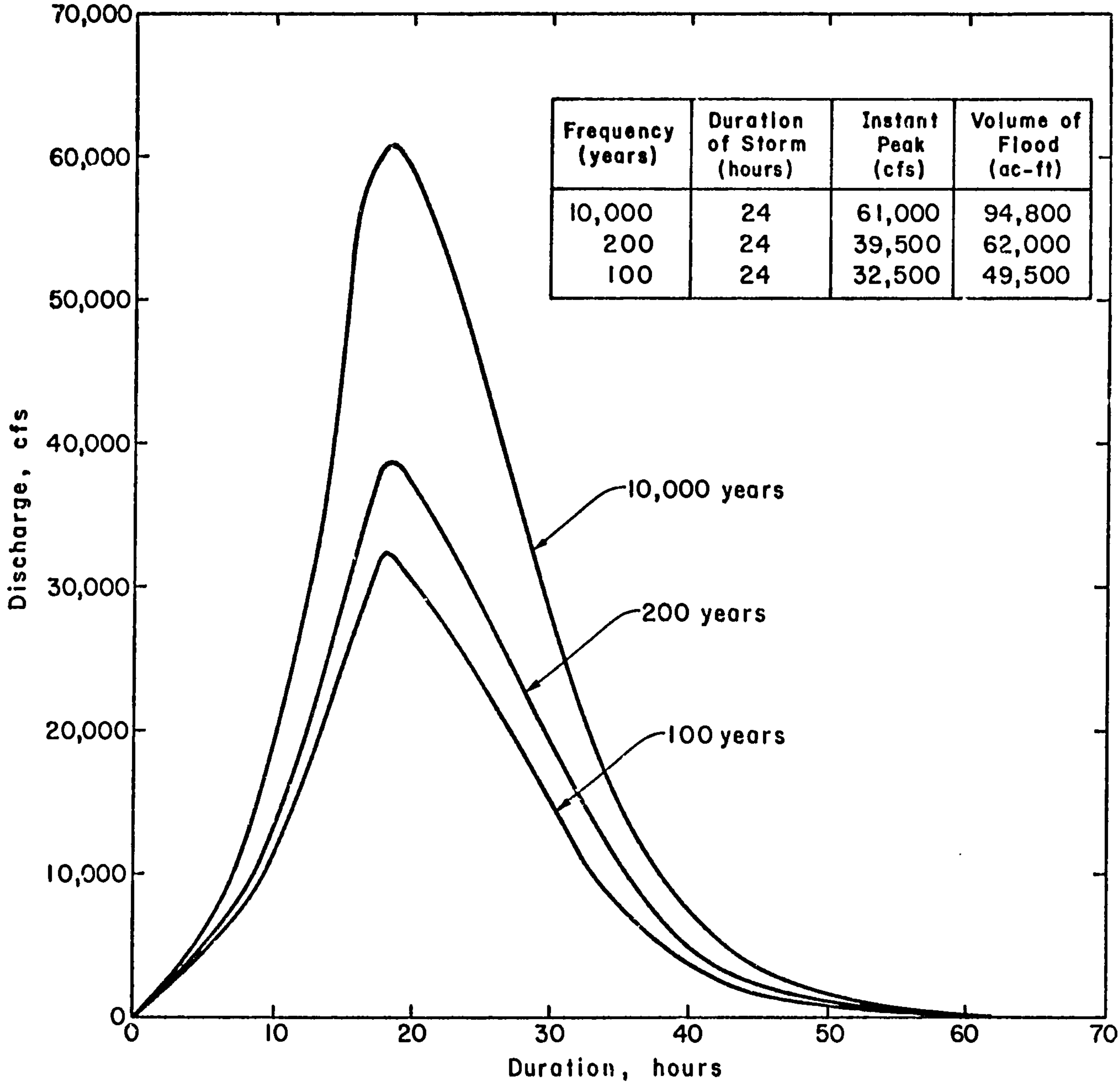
LIST OF ANNUAL PEAK DISCHARGE - RAMBUKKAN OYA

RAMBUKKAN OYA FLOOD PEAKS

Year	Date	Time	G.H.	Q
1947/48	30- 1-48	1:00 a.m.	11.65	3000
48/49	12- 1-49	2:00 p.m.	15.40	4950
49/50	27-12-49	5:00 p.m.	16.70	5800
50/51	17- 1-51	10:00 p.m.	15.00	4800
51/52	7- 1-52	2:00 a.m.	13.60	4000
52/53	23- 1-53	5:00 a.m.	10.70	2600
53/54	11- 2-54	5:00 p.m.	13.60	4000
54/55	8-12-54	1:00 p.m.	13.60	4000
55/56	11- 1-56	10:00 a.m.	8.80	1800
56/57	17- 2-57	8:00 p.m.	15.25	5000
57/58	25-12-57	3:00 a.m.	29.50	17175
58/59	16- 1-59	2:15 p.m.	12.90	3600
59/60	No Records Available			
60/61				
61/62				
62/63				
63/64	26-11-63	10:00 p.m.	14.40	4500
64/65	13- 2-65	Midnight	14.70	4700
65/66	1-12-65	Midnight	14.00	4200
66/67	20- 2-67	11:30 p.m.	13.45	3900
67/68	6-12-67	8:00 a.m.	16.90	6000
68/69	20- 1-69	Midnight	16.90	6000
69/70	No Records Available			
70/71	13-12-70	11:00 p.m.	18.80	6600
71/72	9-12-71	10:00	16.25	5700
72/73	21-12-72	Midnight	16.90	6000
73/74	28-12-73	12 Noon	14.10	4300
74/75				

APPENDIX G

SYNTHETIC 100, 200, AND 10,000 YEAR HYDROGRAPHS



Design Flood Hydrographs. Rambukkan Oya at Nilobe.
62.0 sq. mi.

APPENDIX H

ANNUAL WATER YIELDS (corrected)

YIELD AT RAMBUKKAN OYA DAM SITE (ACRE FEET)
CATCHMENT AREA 50 SQ. MI.

ER YEAR	YIELD AC. FT.
1947/48	78,834
48/49	144,044
49/50	164,116
50/51	114,872
51/52	47,244
52/53	35,000*
53/54	81,991
54/55	88,053
55/56	40,722
56/57	92,708
57/58	172,944
58/59	67,849
59/60	102,500*
60/61	102,500*
61/62	102,500*
62/63	100,129
63/64	189,104
64/65	114,848
65/66	131,607
66/67	140,794
67/68	139,479
68/69	200,528
69/70	197,523
70/71	105,004
71/72	143,512
72/73	135,527
73/74	148,626
74/75	

Average - 117,874 Maximum - 200,528 Minimum - 35,000*

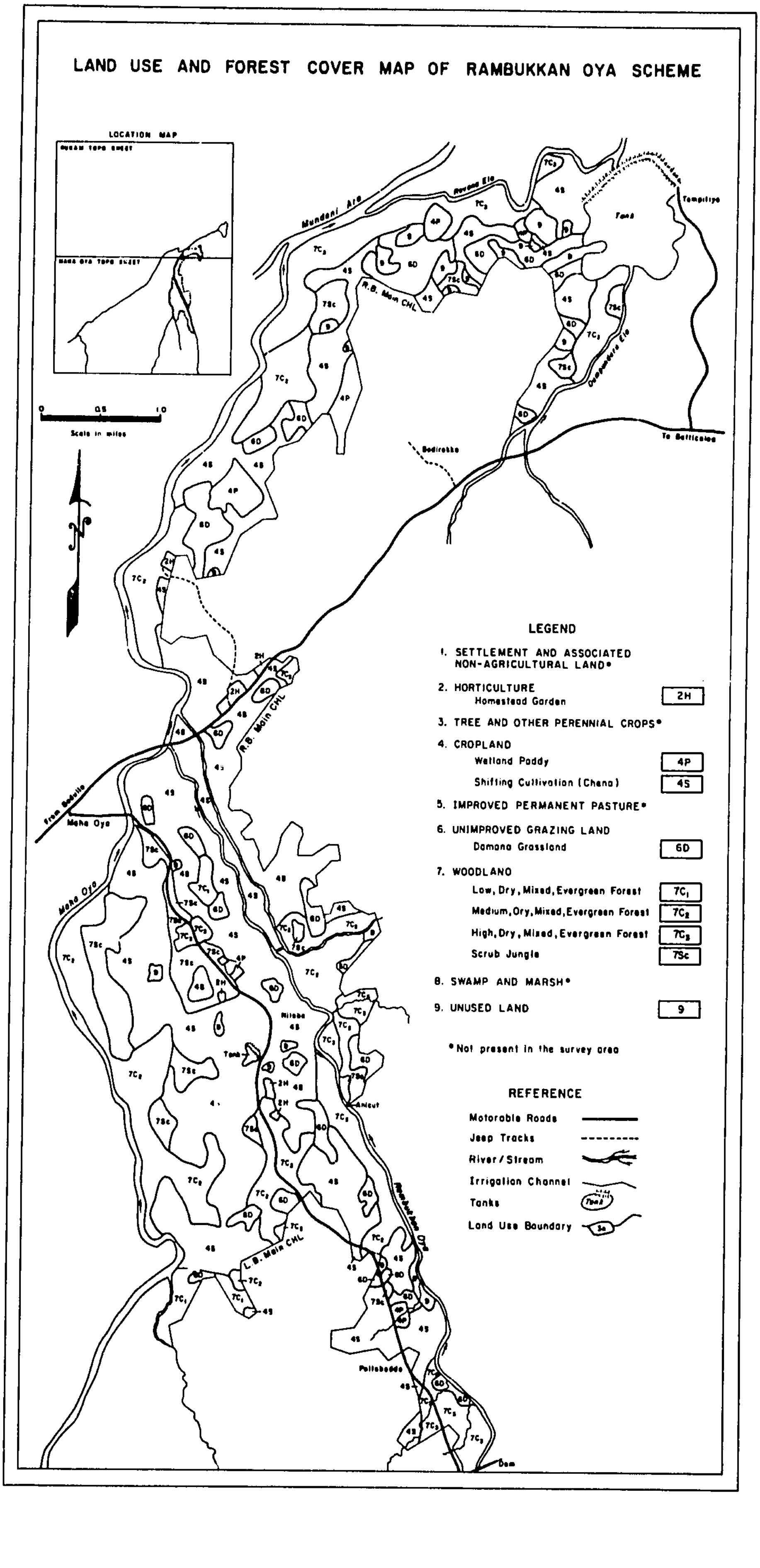
* - Estimated

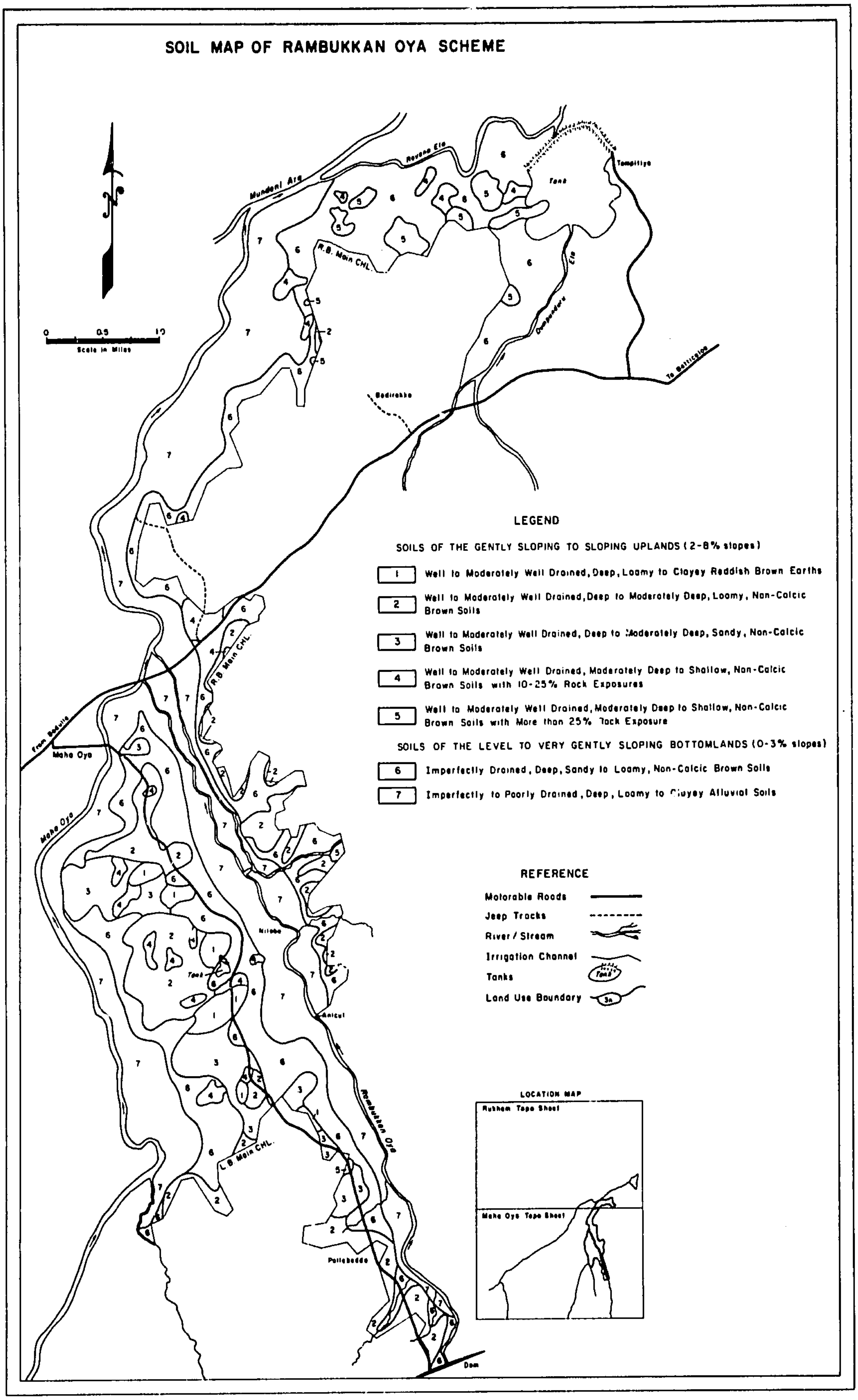
APPENDIX I

SOILS MAPS AND TABLES

SOILS OF RAMBUKKAN OYA SCHEME

Map Unit	Soil	Extent in Command Area L.B. (Acs)	R.B. (Acs)	Total (Acs)	Recommended Crops Maha	Yala
	Upland					
1	Well to moderately well drained, deep to moderately deep, loamy to clayey reddish brown earths.	190	--	190	Maize, Sorghum, Soya Bean, Cowpea	Chillies, Onions, Soya Bean, Green Gram, Cowpea, Tobacco
2	Well to moderately well drained, deep to moderately deep, loamy noncalcic brown soils.	820	215	1035	Maize, Sorghum, Soya Bean	Chillies, Onions, Green Gram, Cowpea, Tobacco
3	Well to moderately well drained, deep to moderately deep, sandy noncalcic brown soils.	530	--	530	Maize, Soya Bean, Chillies	Ground Nut, Chillies, Onions
4	Well to moderately well drained, moderately deep to shallow, noncalcic brown soils with less than 25% rock exposures.	130	175	305	-do-	-do-
5	Well to moderately well drained, moderately deep to shallow, noncalcic brown soils with more than 25% rock exposures.	5	225	230	-do-	-do-
	Bottomland					
6	Imperfectly drained, deep, sandy to loamy noncalcic brown soils.	1390	1710	3100	Rice	Upland Rice, Sorghum
7	Imperfectly to poorly drained, deep, loamy to clayey alluvial soils.	1455	1515	2970	Rice	Rice
	Total	4520	3840	8360		


LAND USE AND FOREST COVER MAP OF RAMBUKKAN OYA SCHEME
LOCATION MAP
Scale in miles
LEGEND
1. SETTLEMENT AND ASSOCIATED NON-AGRICULTURAL LAND*
2. HORTICULTURE
Homestead Garden 2H
3. TREE AND OTHER PERENNIAL CROPS*
4. CROPLAND
Wetland Paddy 4P
Shifting Cultivation (Chena) 4S
5. IMPROVED PERMANENT PASTURE*
6. UNIMPROVED GRAZING LAND
Damana Grassland 6D
7. WOODLAND
Low, Dry, Mixed, Evergreen Forest 7C1
Medium, Dry, Mixed, Evergreen Forest 7C2
High, Dry, Mixed, Evergreen Forest 7C3
Scrub Jungle 7Sc
8. SWAMP AND MARSH*
9. UNUSED LAND 9
* Not present in the survey area
REFERENCE
Motorable Roads
Jeep Tracks
River / Stream
Irrigation Channel
Tanks
Land Use Boundary
Mundeni Ara
Maha Oya
Rambukkan Oya
R.B. Main CHL
L.B. Main CHL
To Batticaloa
From Badulla
Tank
Anicut
Dam


SOIL MAP OF RAMBUKKAN OYA SCHEME
0 0.5 1.0
Scale in Miles
LEGEND
SOILS OF THE GENTLY SLOPING TO SLOPING UPLANDS (2-8% slopes)
1 Well to Moderately Well Drained, Deep, Loamy to Clayey Reddish Brown Earths
2 Well to Moderately Well Drained, Deep to Moderately Deep, Loamy, Non-Calcic Brown Soils
3 Well to Moderately Well Drained, Deep to Moderately Deep, Sandy, Non-Calcic Brown Soils
4 Well to Moderately Well Drained, Moderately Deep to Shallow, Non-Calcic Brown Soils with 10-25% Rock Exposures
5 Well to Moderately Well Drained, Moderately Deep to Shallow, Non-Calcic Brown Soils with More than 25% Rock Exposure
SOILS OF THE LEVEL TO VERY GENTLY SLOPING BOTTOMLANDS (0-3% slopes)
6 Imperfectly Drained, Deep, Sandy to Loamy, Non-Calcic Brown Soils
7 Imperfectly to Poorly Drained, Deep, Loamy to Clayey Alluvial Soils
REFERENCE
Motorable Roads
Jeep Tracks
River / Stream
Irrigation Channel
Tanks
Land Use Boundary
LOCATION MAP
Mundeni Aru
R.B. Main CHL.
L.B. Main CHL.
Rambukkan Oya
Maha Oya
From Badulla
To Batticaloa
Tank
Nilaba
Anicut
Pallebedda
Dam