Ministry of Agriculture, Eritrea

March, 2000

To: Land resource department (MoA)

Dear Sirs

This report entitled Berhnet earthfill dam is prepared in Oct 1998. A revision and upgrading of this report has been carried out in March 2000 in respect of cost escalation as well as some technical aspects.

This design report is prepared by **Mesfin Tewolde** [Irrigation/civil Eng], **Solomon Tareke** (Agricltural Eng-MoA) and **Teklay Gebrehiwot** (Geologist – universal consultancy) in collaboration with other staff members of the Study and Design Division.

Senior engineers, **Mr.Nandasena** (irrigation and water engineer), **Mr Thomas** (irrigation engineer), **Mr Somayajulu** (irrigation engineer) scrutinized the whole report and finalized it after carrying out the necessary modification.

This report has been approved by Mr **Mogos Wolde Yohannis,** head of Study and Design Division of Ministry of Agriculture

Sincerely

Mogos Wolde Yohannis
Head, study and design section

CC: MOA, Zoba Debub, Mendefera

-Irrigation and Soil Conservation Division
-Horticultural Development Division, ASMARA

PROJECT SUMMARY

The revised Berhnet Dam Project report contains the original report as it is and the modifications carried out taking into account the decisions taken at the meeting held on 20.10.2000 under the chairmanship of Director General Land Resources and Crop Production, MoA.

The major changes or modifications made in the revised report pertain to the following:

- Shifting the location of intake structure to upstream toe of the dam and provision for a sluice tower with an access from high ground instead of an approach provided from the top of the dam in the original report,
- Provision of intermediate filter layer below the Random Rubble Masonry in the upstream slope of the dam.
- Modification in the horizontal toe filter provided in the down stream of the dam.

The modifications made in the original report are appended at the end of the report along with the revised drawings. Revised estimate also has been incorporated in the report. The changes made and new items added are shown in bold letters in the cost estimate and detailed quantity estimate.

The original and revised cost estimates of the Berhnet Dam are 6,072, 904 and 5,770,000 Nakfas respectively.

Towards achieving self-sufficiency of food production in Eritrea, with the available land resource, assured water supply as per the crop requirement should be guaranteed without solely depending on the rainwater. Rainfall in Eritrea is erratic and unreliable. The runoff from the catchments of rivers and streams drains down the steep terrains within a short period after raining. As a result, the farming communities are facing severe problems and are at risk right from sowing to harvesting. Therefore storing water during the rainy season is an important requirement for irrigation, subsequently for sustainable growth and development. This could be

achieved through development of series of reservoirs and water retaining structures such as dams and weirs across the streams, rivers as well as proper utilization of the available scares water resources.

A dam has been proposed to be constructed near Berhnet village to improve the living conditions of the villagers and to supplement irrigation water requirements. An earth fill dam suiting the topography and geology of the dam site has been selected keeping in view of the available sandy clay soil in abundance for construction. Estimating a period of construction as 4-months, the over all deployment of resources for completing the Berhnet dam has been planned.

The major national productions in Eritrea depend up agriculture, agro pastoralism and pasturalism. This project to be funded by the African development bank aims in the development of agriculture, especially horticulture in the country. The major constraint in horticulture development is the scares availability of water. This project strives to harvest water for horticulture use. Horticulture development with the help of improved irrigation facilities shall contribute to the development of living standards of Berhnet villagers and in general to the development of Eritrea.

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1. INTRODUCTION

Berhnet dam project is located at Berhnet village about 14 Km west of Adi keyih town. Its geographical location lies 14^0, $50^{'}$ N and 39^0, 21E with an average elevation between 1800m to 2400 amsl. The Dam consists of an earth fill dam across Ruba Agula stream to irrigate about 20ha of land near Berhnet village. The reservoir will help the villagers of Berhnet towards mitigating domestic water shortage as well as drinking water for livestock. There are about 350 families (households) at Berhenet. An average household size is ranging from 3-4 people and hence the population number is estimated to be around 1200. Agriculture is still in the low level of development. It is the main source of livelihood for the villagers. Berhenet has an area of about 100 ha cultivable land having an average land holding area of 0.75ha per family.

The catchment area of the project constitutes mountains of Derea village. The stream is locally called Ruba Agula. The stream has a total catchment area of 4.8 sq.km. Normally the flood peaks occur during the months of June, July and August. Considering 20% of the annual rainfall as surface run off, the average annual yield is estimated to be around 480 000 $m^3.s^{-1}$. The data record obtained from the nearest meteorological station indicates that the mean monthly temperature varies between 10^0 C to 27^0 C. During the coldest season, the temperature ranges from 8.4^0 C minimum to 23^0 C maximum. An average annual rainfall of the project area is about 500 mm. Having a uniform rain distribution, the area gets rain between Junes to September.

Most of the soils in the area are suitable for irrigated agriculture and soil compositions vary from clay loam to sandy loam. Barley, Wheat, Maize and Beans are the major crops grown in the area. In May 1998 during the National Campaign, terraces and check dams were constructed to minimize sediment flow in to the stream as well as to control soil erosion damage. Generally the villagers were depending for water on the seasonal streams and dug wells. In 1992 a borehole was drilled to alleviate drinking water problem of the villagers as well as the livestock's.

Good stone is available for the construction of masonry and also for rip rap. Dressing of stone is required for masonry work. Clay silt soil is available in the vicinity for the construction of the dam body. Clay soil for the core portion of the dam is to be selected and transported from nearby sites .All other construction material like sand, cement, steel and pipes for sluice and hand rails are to be transported to the site from Adi Keyih town.

2. HYDROLOGY

The total catchment area of the project is 4.8 sq.km and is characterized by so many hills having an average land slope of about 30^0. The vegetation cover is estimated to be 40 %. The rainfall record of Adi keyih metrological station for the period 1994-99 was used in the assessment of the yield and peak discharge.

Table 2.1 Rain fall data of Adi keyih area

Year	**Annual Rainfall (mm)**	**Rainfall (average 10 days total in mm)**
1994	620	34.44
1995	476	26.44
1996	387	20.37
1997	613.4	26.67
1998	392.5	32.71
1999	283.4	23.62
Average	**462.5**	**27.38**

Daily average rainfall = 2.738 mm.

Assuming 50% of daily average rainfall will occur in one peak hour, peak hour rainfall

$$= \frac{2.738}{2} = 1.369\text{mm}$$

Assuming that 20 % of the average annual rainfall (462.5 mm) over the entire catchment (4.8 sq. km.) will appear as yield of the catchment in the year

= 4800000 * 0.4625 * 20 / 100 = 443520 cumecs.

The total yield is estimated as 443520 cumecs

The peak discharge is estimated as 28 cumecs. (Details at annexure)

Catchment area	: 4.8 sq. km.
Average annual Rainfall	: 462.5 mm.
Peak discharge	: 28 cumecs
Annual average yield	: 443520 cum.

CATCHMENT

Area	4.8 sq. km
Vegetation	Shrubs
Slope	App. 30^0

3. SURVEYS AND INVESTIGATIONS

3.1 Soil Test Analysis

Three soil samples collected from the proposed reservoir area were tested and the details are as contained in Table 3.1.

Table 3.1 Soil test result

sample No	% sand	% clay	%silt	Soil type
1	27.46	27.91	44.63	Clay loam
2	52.76	15.39	31.85	Sandy loam
3	57.59	10.51	31.58	Sandy loam

The results in Tbale 3.1 indicate that the soil is clay / sandy loam. The clay loam soil can be used as core material of the dam and the sandy loam can be used for filling the rest of the dam.

3.2 Geo Technical Investigation

Geotechnical report contains all geological information required for the major hydraulic structures of the proposed dam site at Berhnet.

During the study period, all data collection methods have been used. For the design of the dam, necessary hydraulic and engineering data have been considered. The data collection mainly focused on foundation investigations, geology of the site and construction material availability both in terms of quantity and quality.

All tests performed in the laboratory combined with the field observations, mainly concentrated on identification of sub-surface materials along the dam foundation, right and left abutments as well as the reservoir area.

Engineering geological map of the survey areas was prepared at the spot with the help of surveying instruments. This map delineates borrow sites, available natural material for construction and units with different engineering properties.

3.2.1 Method of investigation

The method of investigation for the site consists of both desk study and field exploration. Desk studies were conducted with the help of relevant maps and images such as: -

a. Land SAT MSS Satellite imagery (SC:1:100,000),
b. Aerial Photographs (SC:1:50,000), and
c. Topographic map (SC:1:10,000).

The data obtained from these sources was a great help in planning as well as defining the exploration target area of the project.

Field investigations for the site were directed on detail study of surface and sub-surface geological exploration. Sub-surface geotechnical explorations were performed using dug pits in order to determine the stratigraphy. These comprised centers of the river bed (foundation), left abutment, borrow area and reservoir area of the proposed dam. The dug pits assessed were rectangular with dimensions of 5m by 2m at the surface.

3.2.2 General geology

Geology of the site and its surrounding is characterized by meta-volcanic and weakly metamorphosed sediments. These rocks belong to the basement complex ranging between the Precambrian and lower Paleozoic eras. These formations are intruded by late and post tectonic granites uncomfortably laid with Mesozoic sand stone. Again, they are intruded by tertiary alkaline intrusive and each major unit is described as Sand stone unit, Meta-volcanic and Meta-sediments.

Sand Stone Unit

Geologically, the Sandstone mesas in the project area are the extension of Enticho formation. Study on the sequences show mainly whitish, pale yellow to reddish brown and thin to massive bedded sand stone. Usually, they are sub-horizontal, medium to coarse arraigned cemented with silica. Their main occurrence is as steep cliffs or in large outliners separated by deep valleys. The cliffs attain maximum height about 40m surrounding the project site. Further, north this sand stone unit thin and are expressed in mesa-like cap on hills. These sand stone are often affected by block and wrench faulting having a localized slump feature. They directly overlie the basement rocks including chlorite schist, phyllites and slates in successions.

Chlorite schist

To wards east, at 2 - 5km distance from the project site, there is chlorite schist that underlay the Enticho sand stone. This schist rock is generally slightly to faintly weathered at surface, but on the river bed it is faintly weathered greenish, fine grained and sound rock with tight foliation. Jointing exposures as observed have planar surface. The general trend is 360^0 E and dipping 70^0 due west.

Meta-Sediments and marble deposits

Regionally there are weakly metamorphosed basement complex of meta-sediments ranging from slate to phyllites and from chlorite to sericite intercalated with schist, marble and dolomite units.

The marble and dolomite deposits are exposed at Endhish, which is 10km away of the project site. This marble is dark gray, fine grained and highly fractured having a surface coverage of $3km^2$. It occurs as thin layers and lenses bounded by intrusive body along the road at Endhish. Even though, the surface coverage is not extensive it has considerable depth.

3.3 Features of Project Area

Location & Accessibility

The project area is located at about 116 km south of Asmara near Adikeyih. Berhenet dam site is situated in the main Agula riverbed with in the coordinates of 14^0,50' North and 39^0,21' East and elevation of 2200 mamsl.

It is accessible through the main asphalt road leading to Adi keyih up to110km and then turning 6km north on dusty off road. This dusty road needs complete maintenance and improvement.

Physical setting

Morphologically, the project area lies on the central high land at an elevation about 2000 mamsl. The dam site in the gorge is formed by undulated hills of meta-sediments. These hills are also overlain by flat sand stone plateau.

Geology of the dam site

Eighty percent of the general geological set up of the catchment area is mainly characterized by phyllites to sericite and chlorite schist. Fifteen percent is made up of sand stone caps, which overlay the meta-sediments. The rest is established by colluvial soils that are found along the flood plain of Agula river.

Geology of the river course

The moderately gentle Agula riverbed has an average width of 30 meters and a gradient of 0.008%. This river bed is established by alluvial sediments ranging from medium to coarser sand with few pebbles and little exposed bedrock, whereas the river bank is made up of silty clay having thickness varying from 2 - 2.5.

Geology of the reservoir

The gentle and moderately flat lands of Agula reservoir area is established by considerable thickness of colluvium and alluvium deposits resting on top of the weathered phylites and chlorite sericite schist. These colluvium deposits are the products of mechanical weathering of the phylites and chlorite- sericite schist forming silty caly soil. These soils are very compacted, but due to sever erosion they are being easily eroded and they are now forming caves Beneath this soils there are unconsolidated alluvial sediments having a variable texture ranging from sand to pebbles and gravels with sandy silt matrix as revealed in the lithology . The total volume of the compacted silty clay soil in the reservoir area is estimated to be 5000 m^3.

Geological condition of the left and right abutment

Both abutments are geologically made up of slightly to moderately weathered rock units with thin foliations resulting from the sericite to chlorite schistocity. These foliated schist rocks are very sound and tight at depth. The schist rocks are overlain by weathered zone and colluvial soil of very shallow thickness.

Available joints of diverse trend in the right and left abutment were recorded in order to determine their general orientation, persistence, aperture and nature of filling to decide water tightness of the abutments.

The proposed underground dam axis has an orientation of $N30^0$ E and general orientation of the foliation trend is $N10^0$-30^0 E which is roughly parallel to the dam axis. Thus, the foliation trend does not have any impact on dam leakage, since the trend is toward the dam axis and becomes very sound at depth.

Foundation investigation

Agula riverbed contains alluvial sand at the center, whereas in the sides or at the edge of the river, there is little exposed sericite - chlorite schist with silty clay soil. In order to determine the depth to bedrock in the riverbed, a test pit was dug manually. Based on this test pit and exposures around the area, the depth to fresh and massive bedrock is estimated to be 6m.

Engineering geological properties of the soil units

The engineering geological section of this report shows, engineering properties of the observed soil units including their relative distribution and vertical depth in the area.
Accordingly, three soil samples collected from the sections of the proposed reservoir area were tested and the details are as follows.

I, Clay loam

This clay layer was encountered from the section of the galley developed in the reservoir area. The color is mainly pale yellow to brownish. Clay content is 27.91%, sand content 52.6-57.5 % and silt of 31%. There fore, the over all material is considered as sandy loam soil.

II, Sandy loam soil

This clay layer was encountered from the section of the galley developed in the reservoir area. The color is mainly pale yellow to brownish. Clay content ranges 10.5-15.3%, sand content 27.46% and silt of 44.63%. There fore, the over all material is considered as Clay loam soil. The engineering properties of this soil are contained in Table 3.2.

Table 3.2 Engineering Properties of Unified Soil Classes

		Unified soil class	
	Important properties	**CL**	**SM**
General	Typical name	Silty clay	Silty sand
	Shear strength	Fare	Good to Fair
	Compressibility	Medium	Low
	Workability as construction material	Good to Fair	Fair
	Permeability when compacted	Impervious	Semi-pervious
Embankm	Compaction characteristics	Fare to Good	Good with close control
	Type of roller desirable	Sheep foot	Rubber-tired or sheepfoot
	Resistance to piping	Good to Fair	Fair
	Ability to take deformation without shearing	Good to Poor	poor
	General description and use	Stable impervious cor blankets.	fairly stable, not well suited to shells, but may be used for impervious cores
Foundatic	Bearing value	Good to poor	Good to poor depending on density
	Requirement for seepage control	None	Up stream blanket and toe drains

4. AVAILABILITY OF CONSTRUCTION MATERIALS

One of the first tasks in this stage of study was to assess sufficiency and quality of various construction materials for the proposed Berhnet dam site. Hence, a surface and subsurface investigation in the project area and its surrounding was made to quantify availability of construction materials that could be obtained in quantity and quality. This was because proximity of available construction materials to the job site has a direct influence in the projects cost.

This section describes all necessary construction materials expected from the project vicinity. The materials include soil for embankment, sand - rocks sources for masonry work and gravel for filter fill.

Selection of appropriate borrow area for soil embankment were given priority and accomplished during the detail stage of investigation i.e. possible borrow area has been designated.

Borrow Area

Some representative soil samples have been taken from the proposed barrow site in the proposed reservoir area. Samples collected from sections of the galley are tested in a laboratory. According to field observations, the soil in the proposed borrow area is dominated by silty clay soil, generally compact, uniform and free from over size materials like boulders, cobbles or pebbles. Classification according to the laboratory analysis shows the soil types from the natural pits were CL soil. This borrow area has a width of 10m, length of 250m and depth of 2m. Thus, the total volume of CL soils that could be obtained from this borrow area is 5,000m^3. This means, there is enough soil for both the core and cover of dam body.

Source of rocks (Quarry Area)

Abundant source of rock for rip rap is available 2.5km away of the dam site. Investigations made on this deposit are based on the availability, shape and size of individual rock mass as well as easy excavation and workability of the rock source.

As already mentioned in the general geology section, there is chlorite schist that underlay the Enticho sand stone at 2-5km due East from the project site This metamorphic chlorite schist is equivalent to basalt or dolorite in hardness, that predominantly consist chlorite crystals in parallel orientation. This rock unit has a total volume of 10,000 m^3 within total surface coverage of $2km^2$ and each block size covers $2.5m^2$. From these rocks, the planar boulder can be taken by manpower. In some elevated places, where large concentration of these planar boulders are available in size and quantity, loaders and dump trucks can be used. This schist rock is suitable as a rip rap to protect the dam upstream side slope from wave action, scouring of down stream slope, effect of rain on the surface and animals grazing..

Source of sand deposit

The Agula river course has well-graded sand deposit. The sandy riverbed has a length of 2km, width of 10m and minimum depth of 2m. This is described in detail in the river geology section of this report. Thus, sufficient quantity of the required volume of sand can be collected from riverbed. The sand classified, as SW is fit for filter, masonry and other concrete works.

Source of gravel

Proper gravel size deposit was not observed in any site investigated so far. Therefore, reasonable source for gravel-sized materials shall be collected from near by crushing plant at Adi-Kieh.

Source of water

The source of water that can be used during construction of the proposed dam is available near the existing Hawatsu dam, which is 4km east of the project site. Clean water for the intended purpose can be obtained from hand dug wells upstream of Hawatsu dam.

5. CONCLUSION & RECOMMENDATION (GEOLOGICAL PART)

The following major points are forwarded as a result of the investigations and studies made

- Cut off trench in both abutments can reach up to 2 meters in side the rock units and this is supposed to clean all debris as well as smoothing of irregularities,
- The estimated foundation excavation is 1.0 meter depth which is considered to clear all overburden.
- During excavation in the barrow site for construction material, depth of excavation should not reach to bedrock. This is because the barrow site is in the dam reservoir and exposing the bedrock may cause leakage,
- Maintenance of 6km dusty access road to the dam site after the main highway is essential, and
- The recommended dam structure as per availability of construction materials and stability of foundation is earth fill with fresh chlorite schist rip rap both on down and upstream sides.

6. DESIGN FEATURES

General description of the project

Dam

Co-ordinates	14^0 50’ North, 39^0 21'East.
Crest elevation	2205.0 m.
Maximum height	18.1 m.
Crest length	180 m.
Crest width	6 m.
Maximum base width of dam	76 m
Volume of dam	66920 cum

Reservoir

Water spread area at normal pool level	7.5 ha
Gross storage at normal water level	454 533 $m.^3$
Dead storage	46 572 $m.^3$
Live storage	407 961 $m.^3$
Free board	2.2 m
Total volume at maximum water level	5 07 653 $m.^3$
Maximum water level	2203.64 m.
Normal Supply level	2202.8 m.
Dead storage level	2194 m.
Deepest bed level	2186.9 m.

Spill Way

Location	Right bank
Type	Natural gravity flow

Design discharge of the spillway	28 $m.^3.s^{-1}$
Width of the spillway	27 m
Water depth at the spillway (Afflux)	0.84 m
Length of spillway (longitudinal profile)	50 m
Piers for footbridge across spillway	6 Nos of 1.2m high and 0.6m width
RCC Slabs over footbridge across spillway-	7 of 3.5m long each width1.2m and 150mm thick

Sluice

Out let, pipe diameter	400 mm
Maximum flow	0.9 $m.^3s^{-1}$
Draw down time	8days

Preparation of Dam Foundation

Topsoil at the dam foundation should be removed to a depth of 1.0 m or up to hard strata to eliminate top loose material and have a good bond between the new filling and the existing earth. A core trench has been proposed to anchor the dam body with the foundation. The trench shall be excavated to a depth of 6.0 m with side slopes 1:1 and bottom width of 4 m. The core extends up to the hard strata. The trench and the core of the body shall be filled with clay soil. The bearing capacity of the foundation has been checked and found to be safe.

Side Slopes

The side slope of 1:3 on the upstream and 1:2 for the down stream are proposed. Random rubble masonry in cement mortar of 0.5 m thick is proposed on the up stream slope length to resist the erosion due to wave action and to protect the side slopes. The down stream slope shall be protected from erosion by planting and growing good grass on it. Two berms of 1.0 m width are provided on the down stream slope at 7.0m heights from the ground level.

Toe Filter

To reduce and control the seepage through the body and pore pressure as well as to avoid the erosion of fine particles through the toe, a sand filter is proposed for a width of 25.0 m. from the down stream side toe of the dam and running over the entire length of the dam. The height of the filter could be 1.0 m. composing gravel and a course sand layer. (Details as shown in the drawing)

Spill Way

Natural spill way is proposed on the right side of the dam taking into consideration of the geographical and geological characteristics. A spillway of 22 m is required for the expected flood discharge. In addition, it is proposed to have a pedestal bridge over the spillway with six piers of 0.6m wide 1.2m high and RCC slab over the piers there by making the total spill width to 27m (details at annexure). The depth of flow over the spill way is considered as 0.84 m. A retaining wall on the left side (dam side) of the spillway of about 2.2 m high with 0.5 m. top width and 0.8 m bottom width is proposed. A foundation of 1.2 m. width and 0.5 m depth is proposed for the retaining wall. This shall be constructed with random rubble masonry. The spill length of 50 m shall be with rubble masonry as per requirement of the site at the time of construction depending on the structural condition of the soil after excavation.

Sluice cum Outlet

The outlet is designed to act mainly as auxiliary spillway and to draw down the reservoir for maintenance or other works to be carried out in addition to act as silt excluder when operated during flood season.

The intake structure whose bottom level coincides with the dead storage level is protected with trash rack. The conveyance pipeline is a 0.40 m diameter steel pipe of 7.0 m length each. The gate is provided on the upstream side of dam with vertical movement by shaft and handle for controlling the operation under custody of a responsible person only. Stilling basin is provided to dissipate the energy of water that comes out from the outlet pipe. The inlet structure and stilling basin would be constructed with masonry work. Details of the gate and masonry are as in the drawing.

7. IRRIGATION SYSTEM

Crop water requirement has been computed for the irrigable area of 20 ha. using meteorological data of Adi keyih, which is the closest meteorological station to the project area (details are in annexure). A combination of four crops i.e. Maize Barley, Cabbage, and Pepper for a 90-day crop season has been assumed for the computation.

From the results, for 12-hour irrigation the maximum water requirement (1.93 l/s) per hectare was observed in May. Assuming irrigation interval of 4 days, water requirement for the year is computed.

Maximum duty per hectare with 12 hour irrigation = 1.93 $l.s^{-1}.ha^{-1}$.

Water requirement for 20 ha for 12 hours irrigation period $= \frac{20*1.93*12*3600}{1000} = 1667.2$cum

Number of irrigation per season = 90/4 = 22.5 say 23

Water requirement for one crop season = 23*1667.5

= 38352 cum.

Water requirement for one year assuming 3crops = 38353 * 3= 115058 cum.

Total evapo transpiration per year estimate. = 1642 mm. of water.

Assuming that 60% evaporation annually = 986 mm. say 1.0 m.

Surface area of the reservoir = 7.5 ha.

Volume of evaporation = 7.5 * 10000 * 1= 75000 cum.

The reservoir holds a live storage of 407961 cum of water out of which 75000 cum is estimated loss on account of the evaporation. The balance is 332961cum, which is sufficient for the irrigation of vegetable crops for one year and the surplus storage will be carried forward and used in the following year for any failure or delay in the monsoon.

8. RESERVOIR

The reservoir area has been surveyed and the contours plotted. From the contour map the reservoir capacity has been estimated and the optimum capacity was decided. The reservoir formed by constructing the proposed Berhnet dam has a gross storage of 454533 cum. at FSL (2202.8m). At dead storage level (2194 m.) the capacity is 46572 cum. A live storage of 407 961 cum of water is available for the irrigation of the lands in the command area for three crops when the reservoir is full. A small portion of the capacity is likely to be lost in the form of evaporation and seepage. A gross free board of 2.2m has been allowed in the design to prevent the dam being overtopped during any other high floods. The capacity of the reservoir at Maximum Water Level is 507653 cum. and the design afflux of water is 0.84 m. It is proposed that the water from the reservoir will not be drawn directly for irrigation. The irrigation shall be from the infiltration wells to be dug in the downstream near to the application point in the command area. Whenever required the dewatering of the reservoir shall be through upstream controlled sluice cum outlet (sill level 2194m). Dead storage will be available to the villagers and live stock for drinking water during delay or failure of normal monsoon. The loss of reservoir capacity due to seepage is likely to improve the ground water table in the downstream where the command area lies. As such this need not be considered as complete loss of storage.

It is likely that the reservoir capacity may get reduced due to siltation in due course in view of the catchment characteristics and silty soil in the upper reaches. Keeping this in view, the out let sluice is proposed with alternate opening 3m above the DSL and connected to the same pipeline for desiltation and dewatering purposes when the siltation reaches above the DSL level. This opening is closed initially and when needed, gate is to be provided with proper structure.

It is proposed to fence the reservoir area and dam so that easy access to the cattle and unauthorized persons is avoided.

9. IRRIGATION PLANNING

The water for irrigation is proposed to be drawn from the infiltration wells to be dug in the down stream near to the irrigable land. The ground water table in the vicinity will be fully charged by the water stored in the reservoir. As such the infiltration wells shall be not more than 3-4 m depth. This will not only reduce the transportation losses / conveyance losses but also economise the power in lifting for irrigation water from the reservoir directly.

10. ENVIRONMENTAL IMPACT ASSESSMENT

The present environment of the Berhenet village and surroundings of the proposed dam and reservoir will be protected fully and only positive impact, which shall improve the environment, in general is envisaged. The reservoir shall help in cooling down the atmosphere with humid conditions. The growth of vegetation and trees in the catchment and hills shall be possible with the availability of water and other activities in the area. The cattle shall have better fodder than at present. Detailed Environmental Evaluation questionnaire for small dam projects was compiled for obtaining the Project Environmental Evaluation Clearance. The clearance in Environmental Assessment form 81 from Department of Environment, Government of Eritrea has been obtained and copy enclosed with this report.

11. FENCING

With a view not only to protect the dam structure and its components including the reservoir, from the stray cattle and unauthorized people accessing, but also protecting the quality of water stored, fencing the dam and reservoir is proposed. Barbed wire fencing with Reinforced Cement Concrete poles fixed in plain concrete is designed. The details of construction are as per the drawing enclosed. Provision for this work has been made in the estimate.

COST ESTIMATES

The total cost of the project is estimated at 6063900 Nakfa (6.06 M. Nakfa). The estimate has been prepared using the quantities given in the bill of quantities and taking into account the prevailing rates. The project can be taken up as and when the aid / donor agency conveys the acceptance for funding.

Table 10.1 Cost estimate

Sr.no	**Description**	**Estimated Amount (in Nakfa)**
1	Dam construction	4667 300
2	Sluice cum out let construction	552 500
3	Spillway construction	235 700
4	Approach path improvement	40 000
5	Fencing	15 000
6	Contingencies & Unforeseen	553 400
	Grand Total	**6063 900**

Table 10.2 Detailed quantity estimate

		Description	Unit	Quantity
1.		**Dam**		
	1.1	Excavation of top soil & stones in the foundation for the dam body	Cum.	9642
	1.2	Trench Excavation for core foundation	Cum.	7560
	1.3	Core filling up to FSL	Cum.	20000
	1.4	Construction of R/R masonry 0.5 m thick U/S slope	Cum.	2650
	1.5	Construction of Rip Rap of .0.30m thick on the crest	Cum.	324
	1.6	Construction of the toe wall in R.R Masonry	Cum.	64
	1.7	Construction of 1.0m thick sand toe filter	Cum.	2628
	1.8	Earth filling in the dam body	Cum.	66920
2.		**Sluice Cum Outlet and Stilling Basin**		
	2.1	1:3:6 Cement concrete in foundation	Cum.	3
	2.2	Random rubble masonry in head wall & wing walls	Cum.	1070
	2.3	1:2:4 R.C.C. concrete in slabs	Cum.	0.2
	2.4	Supply & installation of steel pipes 400mm dia. and 7.0 m. long including collars and joints	Nos.	9
	2.5	Supply & installation of vertical sliding gate with hoisting mechanism	No.	1
	2.6	Supply & installation of gate valve 400mm dia. at the down stream	No.	1
	2.7	Earth excavation in stilling basin foundation	Cum.	30
	2.8	Random rubble masonry in stilling basin including walls	Cum.	25
3.		**Spillway**		

Table 10.2 continued……

		Description	Unit	Quantity
	3.1	Earth and rock excavation	Cum.	4860
	3.2	Random rubble masonry in CM 1:4for retaining wall 30 m. long and piers for foot bridge	Cum.	69
	3.3	Rubble pitching of.30/.40 m thick for the spill crest	Cum.	513
	3.4	RCC Slab 150mm thick 1:2:4, 27m long in 7 pieces	Cum.	5
4.		**Approach Road**		
		Improvements to the approach road	km	4
5.		**Fence** Fencing dam and Reservoir	item	1

12. FINAL CONCLUSIONS AND RECOMMENDATIONS

Irrigation refers to techniques of augmenting the water supply to crops in a region of little rainfall or during the dry seasons. Modern irrigation is concerned with the optimal way of using, surface or ground water source for agricultural practice. It is a science little practiced in Eritrea and its wide scale introduction to farmers would lead to a better use of the country's agricultural potential.

Agriculture is the foundation of Eritrea's economy. Although Eritrea has a considerable potential for irrigated agriculture, rain fed agriculture is the predominant practice in the country. But the rainfall is unreliable and inadequate in most parts of the country.

The country's agricultural production is such that even the people's basic food needs remain unfulfilled. Although there are various factors, which contributed to this problem, the back ward ness of farming techniques and the total reliance on the unreliable rains are the main causes for this situation.

Small-scale irrigation development could have more direct beneficial impact on the peasantry and it is one of the main components for sustainable agricultural development.

As this project is technically sound and economically viable, it is recommended for implementation

13. ANNEXURE

Details of hydrologic analysis.

Hydrologic computations.

Different methods used for computation of peak discharge are as follows: -

- **Slope area method**

A representative cross – section at a river reach selected, profile surveyed and plotted.

Total cross – section area = 7.7 m^2

Measured Wetted perimeter = 9.2 m

Hydraulic radius (A / P) = 7.7 / 9.2 = 0.837 m

Slope measured = 0.03 ~ 3 %

From Manning's formula: -

$$V=\frac{1}{n}R^{2/3}\sqrt{S}$$

Where, n = Manning roughness coefficient.

R = Hydraulic radius.

S =Slope of the reach.

From the general procedure for estimating 'n' value and considering factors of Berhenet Catchment area, 'n' assumed to be 0.043.

$V = 1/0.043 \times (0.837)^{2/3} \sqrt{0.03} = 3.577 m/s$

$Q = VA$

$= 3.577 \times 7.7 = 27.55\ m^3/s$ ~Say 28.0 m^3/s

- **Using Dicken's Formula**

$Q = C M^{¾}$

Where

C = catchment coefficient depending on catchment characteristics, Ranging from 250-2500

M = catchment area in sq. miles, and

Q = runoff in cusecs.

Presently M = 4.8 sq. km. =4.8 / 1.6*1.6 = 1.875sq. Miles

Assuming the value of C as 600

$Q = 600*1.875^{¾}$

= 961.4 cusecs or 27.22 m^3/s

Adopt a discharge of 28 cum.

Details of the dam structure.

Maximum height is determined according to the water volume harvest from the Catchment of 4.8 sq km. The dam is homogeneous type with clay and sandy loam. The soil for the dam is locally available. The dam height is proposed as 18 m .At the crest level (2205 m) the length of the dam is 125.5 m. The reservoir can hold a capacity 454533 cum at FSL (2202.8 m.). The maximum reservoir level will be at 2203.64 m. At this stage, the reservoir can hold a volume of 507653m^3 of water.

Freeboard above FSL.

The net free board should be sufficient to prevent waves from over topping the dam. Wave height for moderate size reservoir can be determine by Hawk slay's formula.

$$h = 0.014 (Df)^{1/2}$$

Where,

h = Height of wave under maximum wind velocity(m)

Df = Fetch length (m)

Therefore; free board may express as follows:-

$$\text{Free board} = 1.5h + 0.05H \text{ (m)}$$

Where

H = Maximum height of the dam = 18.1m

Df = from the topo map = 500m.(i.e. only $\perp$ length)

$$H = 0.014 (500)^{1/2} = 0.31$$

Free board = 1.5x0..31+ 0.05x 18.1

= 0.46+ 0.9 = 1.36m.

Apply net free board of 1.36m and considering the afflux over the spillway of 0.84m, gross free board =1.36+0.84 =2.2m

Top level of the dam

F S L + Free Board = 2202.8+2.2 = 2205m

(18.1 m above the deepest bed level i.e. 2186.9m)

Top width of Dam

The top width for dams exceeding 5m in height may be determined by the following formula.

Merri man's formula

$$B = 0.2H + 1.5m$$

Where,

B = Top width (m)

H= Height of dam above the stream bed (m)

$$B = 0.2x18 + 1.5m.$$

$$B = 5.1 \text{ m}$$

Trautwine's formula,

$$B = 1.1 H ½ +0.5m$$

$$B = 5.17 \sim 6m$$

Adopted top width of the dam = 6.0 m

Pressure on the Foundation

Considering the maximum section of the dam, with 6.0 m top width, 96.5 m bottom width and 18.1 m height,

Area of the section = (6+96.5)/2 *18.1 sq.m

Volume of 1.0 m length = (6+96.5)/2 *18.1 * 1.0 cu.m

Weight of the structure per meter length assuming density of soil as 1.8 t /cum = (6+96.5)/2 *18.1 * 1 * 1.8 t / cu.m

Pressure on the foundation = (6+96.5)/2 *18.1 * 1 * 1.8 / (96.5 *1.0) t / sq.m. = 17.3 t / sq.m.

Against 25 to 45 t/ sq.m allowable for the dense soils. As such, the pressure on the foundation is within the allowable limits.

Cut off Trench

The objective of the cut–off trench is to function as an anchorage of the dam. It guarantees a good contact between the dam and the foundation. Mainly it prevents seepage immediately beneath the dam. In present case, it will have an average depth of 6m, a bottom width of 4m and side slopes 1:1 (trapezoidal section) to reach the bedrock. The main dam body is to be properly keyed to the abutments on both sides by continuing the core trench into the abutments at least for 2.0m.

U/S Slope protection

500 mm thick Randum Rubble masonry surface cover is proposed, for the protection of the up stream side slope from wave action and erosion of the dam.

Hydraulic design of Sluice cum out let

Assuming a diameter of steel pipe as 400 mm, the flow at each elevation starting from maximum head up to a minimum head of 1m is considered for computing the draw down time.

To make this calculation, elevation –vs. - capacity curve is plotted.

Maximum discharge $Q_{max} = 0.9 m^3/s$

Minimum discharge Q_{min} is considered at 1m level

Q min = 0.28 cumecs.

Draw down time

Taking average discharge =0.58 m^3/s

Total volume above dead storage = 407 961m^3

$Q=AV \rightarrow$ = 0.129 x 5.45 = 0.624 m^3/s

Draw down time = $\frac{407961}{0.6}$ = 703381 seconds

Draw down Time =195 hr or 8 days

Collars for Outlet

Collars will be required to reduce the seepage by increasing the path (length of the seepage line along the outside of the outlet at least by 25 %.

Hence, the collars are provided as follows

$$2 N X > 0.25L$$

where

L = length of pipe = 61 m

X = the projection of each collar

N = number of collars

Therefore to determine the seepage length

Assume the space between collars = 7 m which is the length of one pipe

N = 9

To determine the projection of each collar

$2N\ X \geq 0.25\ L$

$$X=\frac{0.25*61}{2*9}=0.85\text{m}$$

Seepage length = L + 2(x) N

= 61 + 2 * 0.85 * 9 =76.3 m

Spill way

Hydraulic design

The peak discharge calculated from hydrologic Analysis is $Q = 28\ m^3/s$

From weir formula. $Q = CLh^{3/2}$

$28 = 1.7x\ Lx\ (0.84)^{3/2}$

Where,

L = spilling length

H = height above spillway = 0.84m assumed

C = coefficient of discharge = 1.7

L =21.39 m say 22m

Proposing a pedestal bridge over the spillway with six piers each of 0.6m width and allowing for the losses, the total width of the spill is provided as 27m. RCC slab of 150mm thick 1200mm wide is proposed. Nominal reinforcement of 10 mm steel bars at 150mm spacing in both directions is provided with 25mm cover from bottom surface. Handrails of 800mm high are provided with 18mm GI pipe fixed through the steel uprights fixed to the masonry piers.

14. DRAWINGS

1 Layout Map

2 Profile of the dam

3 Maximum section of the Dam at deepest bed level

4 Dam section at sluice cum outlet Level

1. Detail of spillway

2. Outlet Detail (Stilling Basin)

6 Plan (top view) of sluice cum out let

7. Fence and Gate