

**A CO-ORDINATED PROJECT FOR  
PARTICIPATORY DEVELOPMENT OF  
MINI & MICRO HYDEL RESOURCES  
IN THE WESTERN GHATS**

**FINAL REPORT  
Vol. I & II**

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**LOCAL LEVEL DEVELOPMENT**

**CDS, Thiruvananthapuram, Kerala**

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# ENERGY AND POWER: The Critical Infrastructure

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## 1.1 INTRODUCTION

Energy has always been a deciding factor in the progress of mankind. Economic status of countries is often assessed in terms of their per capita energy consumption. Of all forms of energy, electricity has the highest versatility and convenience of use. Per capita electricity consumption in India is 334 kWh/year. This is very small compared to industrialised countries which amounts to nearly 10000 kWh/year. The figure for Kerala is only 278 kWh/year which is even lower than the national average. (*Source: Economic Review 1999*). Shortage of electricity has been a major constraint for the industrial advancement and hence the overall development of Kerala.

Power is the rate of flow of energy. In common parlance, the term energy is used to denote all forms of energy. The term power is usually used in the context of generation and consumption of electric power (eg. power cut, power shortage, etc.). Electricity can be generated from various sources. So far we have been successful in generating electric power from the following sources:

1. Fuels (Fossil fuels as well as biomass)
2. Flowing or falling stream of water
3. Ocean tides
4. Ocean Waves
5. Ocean Temperature Differences (between the surface and the bottom)
6. Winds
7. Solar radiation
8. Geothermal energy
9. Atomic nuclei

These energy resources have been broadly classified into:

- a. Conventional
- b. Non conventional

Conventional technologies to tap energy include fossil fuelled thermal plants, atomic reactor and large hydro electric projects. All others, including small hydro schemes and biomass based systems, are usually termed non conventional.

Fossil fuels meet a greater proportion of global energy requirement than any other source. Principal fossil fuels are coal, natural gas, petroleum and its derivatives. However, all these are finite and non renewable.

Biomass (including firewood and agroresidue) are more difficult to handle and process, but they are renewable.

Energy contained in flowing or falling streams can be tapped either by storing water in high level reservoirs using large dams, or by run of the river projects. The latter is more eco-friendly since it does not result in large scale deforestation or inundation. However, this technique will not help to tap all the energy available during flood seasons.

Ocean tides and waves have enormous power within them. The OTEC (Ocean Temperature Energy Conversion) also have enormous potential. They are quite clean and highly promising. But these technologies are not yet mature.

Another resource with a good deal of potential for generating electricity is wind power. Wind machines with hundreds or even thousands of kilowatt capacities are readily available, almost off the shelf. India has more than 1000MW of installed capacity in wind farms, mostly in Tamil Nadu.

Hot water and steam escape from surface vents at many places on earth due to geothermal phenomena. Such natural sources are being used to generate power in favourably endowed places.

In nuclear power plants, the heat energy produced by controlled atomic fission is used for producing steam. The energy of steam is used for rotating turbines to generate power.

Solar energy can be directly converted into electricity using photovoltaic cells. Alternatively, solar thermal energy can be harnessed directly to power Rankine Cycle Power Plants to generate electricity.

All these sources have their own advantages and disadvantages.

Fossil fuels are the most widely used sources. Its technology is the best developed one. Ecological hazards and non-renewability are the main drawbacks. Even if air and water pollution can be brought within reasonable limits, nothing can be done to reduce the emission of CO<sub>2</sub>, which is a Green House Gas.

Hydro energy has so many advantages like cleanliness, easy availability, abundance etc. But large hydro power plants could be problematic owing to inundation of huge areas of land/forest.

Wave and Tidal, as well as OTEC energy sources have very low accessibility. They are site specific. The technology is too young and expensive.

Wind power is a fast emerging technology. In favourable locations, it is quite economical. But the locations are to be carefully chosen. Isolated units may not be profitable. In large numbers, they are often cheaper than conventional power plants. Even though the initial cost is rather high, the recurring cost is negligible. Their major limitations are their low dependability and high site specificity.

Solar energy, though geographically and climatically conditioned, is the most abundant source of energy. The total amount of solar energy falling on the surface of the earth is 16,000 times the total energy used by the humans. However, the harnessing of solar energy still poses several problems. More technological developments are needed to reduce the cost, especially for photovoltaic systems. In the final analysis, the Sun is the only source of truly renewable energy.

Geothermal stations are highly location specific. But wherever geothermal energy is available in plenty, they are very economical.

There was a time when nuclear energy was expected to provide the answer to all our future energy needs. But today only a few believe so. They are now bogged down with almost unsolvable problems like ecological hazards, safety, waste management and cost. Only very few countries are actively pursuing that option. It seems to be a dead-end now.

## 1.2 WORLD SCENARIO OF POWER CONSUMPTION

Industrialisation and the quest for better quality of life have increased drastically the consumption of electrical energy during the latter half of this century. It has been estimated that total electricity consumption of the world in 1997 was 13, 673,975 MU\*. Low and middle income countries account for the consumption of 3,977,263 MU, which is 29% of the total consumption, whereas the industrialised countries account for 9,696,712 MU, which is 71% of total consumption (Source: Human Development Report, 2000).

Also, the pattern of World energy use and Trends in energy use has been given in Table 1.1 and 1.2 respectively.

**Table 1.1**  
**World Energy Use (Million Tons of Oil Equivalent)**

Coal	2122	22%
Oil	2940	30%
Natural Gas	2173	23%
Nuclear	579	6%
Renewable **	1833	19%
Total	9647	100%

(Source: *State of the World, 1999*, Lester Brown, World Watch Institute, New York)

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\* MU = Million Units or Million kilo Watt hour (kWh)

\*\* Renewables - Biomass, Hydro, Wind, Geothermal, Solar

**Table 1.2**  
**Trends in World Wide Energy Use**

Source	Average Annual growth rate
Wind Power (90-97)	25.7%
Solar Photovoltaic (90-97)	16.8%
Geothermal Power (90-96)	3%
Natural Gas (90-97)	2.1%
Hydro electric Power (90-96)	1.6%
Oil (90-97)	1.4%
Coal (90-97)	1.2%
Nuclear Power (90-97)	0.6%

(Source: *State of the World, 1999, Lester Brown, World Watch Institute, New York*)

### 1.3 NATIONAL SCENARIO

India consumes only 3.25% of world=s total energy production even though we have one sixth of the world population. Our per capita consumption is only 19.36% of world per capita consumption of electricity.

As pointed out earlier, every available source that is eco-friendly and economically viable has to be tapped to meet the growing energy needs. In this context the renewable sources have an important role to play, especially in the long run. The estimated potential of various non conventional energy resources in India are given in **Table 1.3**.

**Table 1.3**  
**Estimated Renewable Energy Potential of India (MW)**

SHP (up to 3 MW)	10,000 MW	Energy form waste-1700 MW
Bio mass power	19,000 MW	Ocean Energy Power -50,000 MW
Wind Power	20,000 MW	Solar Power - 20 MW/km <sup>2</sup>

(Source: Citizen=s Fifth Report and TERI Data Book 2000)

Power generation in India from various sources as per Citizen=s Fifth Report (1998-99) are given in Table 1.4. Also, identified reserves of different energy resources in our country is given in Table 1.5 (TERI Data Book -2000, Citizen=s Fifth Report- 99). Total energy demand was 413,490 MU and supply account for only 365,900 MU. This shows a deficit of 47,590 MU which is 8.8% of the demand. In India, 42.37% of total population is able to access electricity. While the percentage of accessibility of rural areas is only 30.4%, the urban accessibility is 75.78%. Our annual growth rate in electricity consumption is 8.35%.(TERI Data Book, >99). The power consumption pattern of our nation is given in detail in Table 1.6 (TERY Data Book-2000).

**Table 1.4**  
**Existing Power Production in India as on 31 March 1999**

Thermal	67,560 MW
Nuclear	2,225 MW
Hydro	22,443 MW
Wind	1,025 MW
Total	93,253 MW

(Source: Citizen=s Fifth Report -1999)

**Table 1.5**  
**Identified re serves of different energy resources in India**

Untapped Hydro	84,000 MW @ 60% PLF
Coal Reserve	79,106.19 million tonnes
Lignite	29,355 million tonnes
Crude oil	746 million tonnes
Natural gas	692 billion cum.
Uranium	6700 tonnes

Thorium	3,63,000 tonnes
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*(Source: TERI Data Book 2000, Citizen's Fifth Report - 1999)*

**Table 1.6**  
**Power Consumption Pattern in India (connected load, MW)**

Domestic	55,600,0MW	31.73%
Industrial (LT & MT)	25,400 MW	14.5%
Industrial (HT, EHT)	32,000 MW	18.23%
Commercial	13,000 MW	7.4%
Irrigation	42,200 MW	24%
Public Lighting & Water Supply	3,060 MW	1.75%
Railway traction	2,150 MW	1.22%
Miscellaneous	1,950 MW	1.11%
Total	1,75,000 MW	100%

*(Source: TERI Data Book 2000)*

#### **I.4 STATE SCENARIO**

The supply and demand for electricity in Kerala have been estimated variously. According to the Fifteenth Power Survey, the requirement as on 1999-2000, is for a peak demand of 2,763 MW of power and 13617 MU of energy. The present installed capacity is only 2343 MW, which causes a deficit of 420 MW. The effective availability is still less. There are 21 generating stations; hydro(16), thermal (3) and wind farm (1). Total per capita consumption of electricity in Kerala is 278 kWh per year. The detailed power consumption pattern of our state is given in Table 1.7 (Economic Review-99).

**Table 1.7**  
**Power Consumption Pattern in Kerala**

Domestic	45.09%
Industrial (HT, EHT)	30.44%
Industrial (LT)	6.3%
Commercial	8.55%
Irrigation	3.85%
Public lighting	1.52%
Water supply	2.27%
Bulk Supply	1.85%

*(Source: Economic Review >99)*

It has been established provisionally that, by 2002 AD, Kerala will be able to generate only 1938.8 MW from large and medium Hydel sources. The balance will have to come from thermal, small hydel or other renewable sources. In view of the environmental impact of thermal power plants, as well as their high costs, as large as possible a share has to come from renewable sources. It is a fact that small hydel schemes being the most developed and proven technology, represents the best bet, to the extent that it is available.

Fortunately, Kerala has a significant potential for small hydro power generation in the 41 west flowing and 3 east flowing rivers. ANERT has identified and published a list of 182 possible sites located at various river basins of our state. Some of the sites identified under this programme (WGSHP) are also included in the list. The list is given as **Annexure 2** along with this report.

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### **SMALL HYDRO PROJECTS: Concepts and Status**

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#### **2.1 CLASSIFICATION**

The Central Electricity Authority has issued guidelines on how various hydro power stations should be classified (see Table 2.1).

**Table 2.1**  
**Classification of Small Hydro**

Small Hydro Projects	Has individual units with capacity from 1000/2000kW and total capacity limited to 15000 kW.
Mini Hydro Projects	Has individual units with capacity from 100 kW to 1000 kW and total capacity less than 2000 kW
Micro Hydro Projects	Has individual units with capacity upto 100 kW and scheme itself has total capacity of 100 kW

#### **2.2 ADVANTAGES OF SMALL HYDRO PROJECTS (SHP)**

- < Suitability for de-centralised development and hence multiple initiatives.
- < Utilization of local technology and local applications
- < Development of local economy. Can improve material and cultural life of local residents.
- < Low cost, easy maintenance and better reliability.
- < Reduced transmission loss.
- < Mature technology and small investment risk compared to other renewable energy sources.
- < Little environmental impact during construction, probably some positive impact on environment.
- < Short gestation period, practically no resettlement, submergence or deforestation problems.

Above all, they are usually located in rural areas, hence can be considered an important rural energy source. They could play a significant role in rural economic development.

### **2.3 FACTORS FOR SHP DEVELOPMENT**

Based on the experiences from various countries, the basic requirement for SHP development can be summarised as:

- < Sustainable SHP sites, with reasonable access.
- < Nearness to load centres or the grid.
- < Necessary funds and support.
- < Local Expertise to appropriate the technology as per local requirements.
- < Preferential policies from central and local government.

It has been observed that policy, funding and expertise are decisive factors to stimulate SHP development.

### **2.4 BASIC PHILOSOPHY**

The small/mini hydro stations don't envisage large reservoir storage. They use run off water for generating power. Only a small diversion weir and an intake pond are usually required. The maximum size of the pond need not be more than one day's inflow during lean period. The pond normally occupies the river bed and a very small area from banks. The average requirement of pond area is about 0.2-0.4 ha. per MW as compared to 10-15 ha. per MW in case of large storage stations.

The SHPs run as base load stations during monsoon period, with suitable pondage design, they can be made to run as peak load stations during summer season. So they always contribute to peak load. The large capacity utilisation during monsoon period, in fact, helps us to preserve water in the existing large dams, for summer. In effect, they are *indirect tools for interbasin water transfer* through the process of local conservation.

Treatment of catchment area which leads to increased subsoil retention of monsoon precipitation has a direct impact on its economics.

Planning for large number of units simultaneously, offers the possibility of standardization and mass production, which could lead to substantial reduction in project costs.

## **2.5 SHP SCENARIO**

The world's first small hydro plant was installed in USA in 1882. The first station in India, with a capacity 139 kW, was installed at Darjeeling in 1897. This was followed by two 200 kW plants in Simla in 1908 and later by several other installations. In India, the estimated total capacity of small hydro projects is about 10,000 MW from 5000 to 6000 potential sites. At present, 216 plants with an installed capacity of 155.38 MW (as on 31-3-98) are under operation and 208 schemes are under construction with installed capacity of 230.4 MW. According to estimates, it has been provisionally found that, Kerala has a maximum potential of 1000 MW. The first Hydel system in Kerala was a mini hydel station of 450 kW capacity which was installed and operated in Munnar in 1905. It was in the private sector and later on it was closed down. At present, there is a private station with a capacity 2x250 kW at Vaguvurai in Munnar. ANERT has installed 2x10 kW plants one each at Sugandhagiri and Pookkott in Wayanad district. Recently, a power station of 5 MW has been commissioned in Maniyar, under private sector. According to the latest reports, 4 plants with 3.5 MW have been installed and 30 plants with a total capacity of 156.35 MW are under construction. This includes 18 projects (installed capacity 102.35 MW) being undertaken with Chinese collaboration. A few stand alone micro hydel stations of very small capacity (kiloWatt range) have been recently commissioned in Kannur and Idukki districts.

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## Chapter III

### **SHP DEVELOPMENT: A Cost Reduction Approach**

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It is a fact that the SHP potential of Kerala has been barely touched so far. Different estimates have been made about the total potential of various small hydel locations in Kerala. Hydel engineers with a conventional outlook have always been arguing that the small hydro is far more costly than the large schemes. There is only potentially true in this argument. Presently, we don't take into account the social cost of big dams. Also we have not fully explored the possibilities of cost reduction in the case of SHPs. Considerable scope exists for reducing the cost of the SHPs. One method is to achieve cost reduction through standardisation.

As per the Panchayati Raj legislation, the Panchayats have been granted the power to pursue small hydel projects. This opens up a major possibility for the Local Self Government (LSG) institutions to take the initiative and to conduct studies on the feasibility of small hydel projects and also to implement them. However, if such efforts are scattered and unco-ordinated, no gain can be made from the economics of scale or number. It was felt that there is a distinct possibility for cost reduction if a fairly large number of similar units could be planned simultaneously. Therefore, IRTC prepared a project proposal for studying this in depth, which was approved and funded under the Kerala Research Programme on Local Level Development (KRPLLD) scheme of the Centre for Development Studies (CDS).

#### **3.1 OBJECTIVES**

The objectives of the study are;

- < To assess the technical and economical feasibility of 30-40 sites in the western ghats.
- < To carry out preliminary optimization studies to assess the energy potential and the optimal economic level exploitation.
- < To standardize turbo generator units for various heads and sizes.
- < To prepare a preliminary report which would define fundamental technical concepts. Also to propose a methodology which can be used for studying the small hydel potential along with the relative benefits and cost for proposed programmes.

#### **3.2 PROJECT METHODOLOGY**

To begin with, enquiries were made with all the 14 district panchayaths of our state regarding their interest for participating in a preliminary survey to identify the small hydel sites in their districts as part of the Western Ghats Small Hydel Programme (WGSHP). Only five district panchayaths viz., Malappuram, Palakkad, Trissur, Idukki and Pathanamthitta responded, in spite of personal follow up. A detailed plan was worked out for the identification of potential sites with the help of local residents. Maximum people=s participation was ensured by involving the local panchayats at every stage. Initially 156 sites were identified. After a preliminary screening 108 sites were short listed. All the sites were visited by the project team and 31 sites were finalised for detailed study.

The sites were selected based on the following factors:

- < availability of flow for maximum period,
- < accessibility to the site,
- < nearness to power grid,
- < less ecological impact, and
- < ease of civil construction and penstock erection

The preliminary data collection with the help of local volunteers started from March 1997 onwards. This mainly included measurement of flow and collection of physical and topographical information. This study lasted for 52 weeks. Detailed investigations were made during 1997-99 for the preparation of drawings, design and estimate of the engineering structures proposed in the scheme, and for the preparation of feasibility report. These are detailed below.

### **3.2.1 Reconnaissance survey**

Before starting the topographical survey the project area was thoroughly explored, which gave an overall idea of the site and its principal features. Possible instrument stations were located for theodolite surveying and a topographical survey was conducted for obtaining topographical details of the site. The possible locations for diversion structure and power house were identified and the details were taken using tacheometric survey.

### **3.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of each site was located using the toposheet. The total area covered under each site was measured. The topography of each catchment area was studied in detail. Maximum flood discharge at each site during the period 1997-99 was measured.

### **3.2.3 Topographical Survey**

Tacheometric survey was conducted at all project sites for the preparation of contour map. A transit theodolite having a stadia telescope was used for the purpose. The reduced levels of the temporary bench mark was fixed to be +500.000 metres. The instrument was fixed at a station and sighted to the levelling staff held at suitable points. The horizontal angles, vertical angle and stadia readings were noted. A number of instrument stations were located such that enough data were collected to prepare the contour map. We entered these collected data into a computer for computerised calculation. These data and computed reduced levels of located points were used for the preparation of contour map.

### **3.2.4 Contour map**

Contour map is a drawing which shows the elevational details of a place. The data collected by survey were used to calculate the horizontal distance, vertical distance and the reduced level of various points on the ground. The survey details were plotted on a sheet of paper at a scale of 1:500. The undulations on the site, the location of the falls and other topographical features were identified from the map. The location of the weir, the alignment of penstock and the location of power house were also determined using this contour map prepared.

### **3.2.5 River flow data**

Observations were made continuously for a period of 12 months within the time span of March 1997 to March 1999. The water level observations were taken every week. A suitable location for gauging station was identified such that the flow at that point was identical to that at the waterfall. The cross sectional details of the point were noted for calculating stream discharge. A

measuring gauge was fixed at this point to measure the flow level. The peak flow was also recorded. Using the collected data, the weekly discharge hydrograph of each site was prepared. The services of local volunteers were utilised to the maximum possible extent for this activity.

### 3.2.6 Flow duration curves

The flow duration curve was obtained by plotting discharge against percentage flow of exceedance. The power corresponding to 40% flow of exceedance has been noted for each site. It is given in **Table 3.1** as an indicator of the power potential of the site. This table also gives a clear picture regarding location, head, type of flow and standardised head of various sites. Discharges corresponding to various percentages of exceedance (from 20% to 90%) are reproduced in **Table 3.2**. The determination of two crucial parameters, the economic potential and choice of installed capacity is a much more complex task. This is discussed in sections 3.4 and 3.7 below.

**Table 3.1**  
**The physical features of the selected sites**

Sl. No.	Name of site	District	Location (Panchayat)	Act. Head	Standardised Head	Power at 40% flow of exceedance (kW)	Nature of flow
1	Adianpara	Malappuram	Chaliar	17.62	20	360	Perennial
2	Mayampully	Malappuram	Chaliar	23.46	20	360	Perennial
3	Aruvikkal Anchuruli	Idukki	Kanchiar	21.31	20	300	Seasonal
4	Adakka kundu	Malappuram	Kalikavu	29.39	33	25	Seasonal
5	Chakkimali	Idukki	Arakkulam	32.54	33	20	Seasonal
6	Nellikappara	Pathanamthitta	Aruvappulam	32.54	33	40	Seasonal
7	Upputhodu kuthu	Idukki	Mariyapuram	33.13	33	450	Perennial
8	Urumpallu	Idukki	Arakkulam	36.48	33	350	Seasonal
9	Madatharuvi	Pathanamthitta	Ranni	41.38	43	550	Seasonal
10	Kallimali kuthu	Idukki	Rajakkad	42.39	43	80	Seasonal
11	Gandhisarakapadi	Idukki	Kanjikuzhi	42.98	43	80	Seasonal
12	Pathinaramkandam	Idukki	Vathikkudi	45.13	43	160	Perennial
13	Thekkum thoni	Idukki	kanjikuzhi	49.00	50	525	Perennial
14	Chengara	Pathanamthitta	Konni	50.96	50	60	Seasonal

15	Murrikasseri kuthu	Idukki	Vathikudi	54.22	50	190	Perennial
16	Manpilavu	Pathanamthitta	Chittar	73.00	90	90	Seasonal
17	Mukkali	Palakkad	Agali	82.00	90	350	Seasonal
18	Elapilly	Idukki	Arakkulam	84.17	90	450	Seasonal
19	Idukki-Valara	Idukki	Adimali	84.93	90	3400	Seasonal
20	Thrissur-Valara	Thrissur	Athirapilly	87.78	90	1400	Seasonal
21	Poomala	Idukki	Velliamattom	88.00	90	200	Perennial
22	Kalkandy	Palakkad	Agali	95.23	90	240	Perennial
23	Vellachattapara	Palakkad	Alanallur	124.08	125	700	Seasonal
24	Kozhival kuthu	Idukki	Munnar	127.80	125	7500	Perennial
25	Pamble	Idukki	Kanjikuzhi	136.64	140	800	Perennial
26	Vattompara	Idukki	Kanjikuzhi	140.74	140	800	Perennial
27	Chembukatty	Palakkad	Adimali	142.10	140	1500	Seasonal
28	Thendillam	Palakkad	Kizhakkanchery	149.86	140	750	Seasonal
29	Panamkudantha	Pathanamthitta	Narayanamoozh i	153.20	140	200	Seasonal
30	Keezhar kuthu	Idukki	Kanjikuzhi	183.80	180	5400	Perennial
31	Attala	Palakkad	Karimba	210.00	190	3400	Perennial

**Table 3.2  
Flow Discharge data of selected sites**

Sl. No.	Name of site	Discharge in cumecs for various Percentage flow of exceedence							
		20	30	40	50	60	70	80	90
1	Adianpara	11	8	2.4	1	0.7	0.4	0.062	0.045
2	Mayampully	11	8	2.4	1	0.7	0.4	0.062	0.045
3	Aruvikka l Anchuruli	3	2.3	1.85	1.1	0.6	0.2	0.06	0.015
4	Adakkakundu	0.3	0.25	0.1	0.09	0.06	0.03	0.009	0
5	Chakkimali	0.13	0.12	0.07	0.02	0.009	0.004	0.002	0
6	Nellikapara	0.36	0.3	0.15	0.12	0.02	0.01	0.004	0
7	Upputhodukuthu	2.6	2.1	1.8	0.8	0.06	0.033	0.027	0.017
8	Urumpallu	2.44	1.76	1.4	0.54	0.12	0.05	0.04	0.014
9	Madatharuvi	3	2.4	1.45	0.28	0.1	0.04	0	0

10	Kallimalikuthu	1.4	0.72	0.24	0.07	0.04	0.03	0.015	0
11	Gandhisrapadi	0.45	0.32	0.26	0.14	0.095	0.011	0.004	0
12	Pathinaramkandam	0.6	0.53	0.5	0.44	0.38	0.25	0.16	0.15
13	Thekkumthoni	2.44	1.76	1.4	0.53	0.08	0.012	0.002	0
14	Chengara	0.21	0.19	0.15	0.065	0.008	0	0	0
15	Murrikkasserikuthu	0.6	0.53	0.5	0.44	0.38	0.25	0.16	0.15
16	Manpilavu	0.96	0.36	0.24	0.16	0.055	0.02	0	0
17	Mukkali	0.71	0.65	0.52	0.42	0.15	0.099	0.04	0
18	Elapilly	1.13	0.99	0.66	0.22	0.064	0.027	0.012	0
19	Idukki-Valara	10.7	7.52	5.02	1.18	0.69	0.13	0.004	0
20	Thrissur-Valara	2.54	2.27	2.04	1.5	0.2	0.1	0.02	0
21	Poomala	1.41	1.29	0.3	0.18	0.063	0.035	0.022	0.012
22	Kalkandy	1.6	0.78	0.35	0.29	0.23	0.16	0.12	0.001
23	Vellachattapara	2.25	1.5	0.73	0.5	0.09	0.06	0.009	0
24	Kozhival kuthu	13	10	8	3	1.2	0.75	0.6	0.35
25	Pamble	3.58	2.45	0.76	0.43	0.25	0.07	0.04	0.024
26	Vattompara	3.58	2.45	0.76	0.43	0.25	0.07	0.04	3.58
27	Chembukatty	5	3	1.47	0.5	0.2	0.02	0.01	0.009
28	Thendillam	2.4	1.4	0.7	0.33	0.11	0.04	0	0
29	Panamkudantha	0.62	0.524	0.2	0.11	0.04	0.009	0	0
30	Keezhar kuthu	7	6	4	1	0.48	0.36	0.1	0.02
31	Attala	3.65	3.05	2.5	1	0.6	0.18	0.14	0.1

### 3.2.7 Flood flow determination

There are various empirical methods for calculating maximum flood discharge. The calculations were done using Dicken=s formula, Inglis Formula, Ryve=s formula and also the Nowab Jung Bahadur Formula. Out of these the Dicken=s Formula is said to be the most suitable for Western Ghats region and has been used in this project for the structural design.

### 3.2.8 Use of pondage to meet peak load

In smaller streams the flow is highly variable. In several cases, the flow thins out considerably

during the lean season. A pondage system which stores the inflow during off peak hours and helps to generate useful power during peak hours suggested. But a few of the streams run dry in summer and hence cannot contribute even to peak capacity during the lean season. Still they can be used for energy contribution during monsoon period. As the monsoon fades out, the inflow decreases, and the machines will not be able to work continuously. But still they can work either at part load, or at full load for reduced periods, taking advantage of the pondage. If we follow the latter mode, each unit will be delivering full load whenever it is working. When the pond level falls below the draw down level, the machine can be shut down until the pond fills up again.

### 3.3 POWER POTENTIAL

The power potential P of a site in Watts is given by the formula

$$P = \eta \rho g Q H$$

where,  $\eta$  = Efficiency of turbogenerator system

$$\rho = \text{density of water in kg/m}^3 \times g \text{ (acceleration due to gravity in m/sec}^2\text{)}$$

$$Q = \text{Discharge in cumecs (m}^3\text{/sec)}$$

$$H = \text{Head in meters.}$$

$$\eta - \text{can be taken to be, say 75\% or 0.75}$$

$$\rho = 1000 \text{ kg/m}^3 \times 9.81 \text{ m/sec}^2 = 9810 \text{ kg/m}^2\text{/sec}^2 \quad 10,000 \text{ kg/m}^2\text{/sec}^2$$

$$\text{Therefore, power P (W)} = 0.75 \times 10,000 \text{ (kg/m}^2\text{/sec}^2\text{)} \times Q \text{ (m}^3\text{/sec)} \times H \text{ (m)}$$

$$\text{Or } P = 7.5 Q H \text{ (kW)}$$

### 3.4 SELECTION OF UNIT SIZE

For optimization of unit size, the following parameters were assumed.

Rate of return on investment - 15%

Loan repayment period	-	10 years
Average O&M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit) - Rs. 2.5 and 3.0 (Two cases)

Investment cost (Rs.in Crores per MW) - 3.0, 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed if the proposal is to be profitable. This can be taken to be the break even plant capacity factor (PCF) for the site under the specified conditions.

Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.

As an example, let the capital cost of **Pamble** (Site No.25) be Rs. 3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

X = 3,500 hrs.

It follows that, any combination of machines, that can work at full capacity for over 3500 hours,

can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of Plant Capacity Factor, which is defined as the ratio of the actual amount of energy obtained, to the maximum energy that can be obtained from the given installed capacity, during an year.

ie,  $PCF = \frac{\text{Actual working hours}}{\text{Installed capacity} \times 365 \times 24}$ .

In this case, for the value of X = 3500 hours,  $PCF = \frac{3500}{8760} \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% under the given flow conditions, is economically viable for this site.

From the Flow Duration Curve and Chart for the Pamble Site (reproduced as Fig 3.1 and Table 3.1 respectively), it is seen that a capacity of about 750 kW can be maintained for almost 40% of the time. The corresponding discharge is 0.714 m<sup>3</sup>/s.

The yield from this machine will consist of two parts;

1. When the machine is working at full capacity continuously, during the flood season, when the flow exceeds 0.714 m<sup>3</sup>/s. From the graph and chart, this occurs for about 39.35% of the time, or for about 3447 hours. The energy output for this duration is 2.585 MU.
2. Energy can also be generated at full capacity, by making use of the pondage, for a few hours a day, even when the inflow is less than 0.714m<sup>3</sup>/s. The total contribution from this mode of operation is equal to the energy potential of the total discharge below the 0.714 cumec limit. This is calculated and indicated in the flow data chart (Table 3.3) and is seen to be 0.870 MU.

Thus the total energy yield from the 750 kW machine will be 3.455 MU. This works out to a PCF of  $\frac{3.455 \times 10^6}{(750 \times 8760)} = 0.525$  or 52.5%.

Since this PCF is higher than the break even value, we can check the feasibility for still higher capacities, following a similar procedure.

For an installed capacity of 1000 kW, which corresponds to about 37.5% flow of exceedence from the chart, the total energy yield is the sum of:

(1)  $1000 \text{ kW} \times (0.375 \times 8760) = 3.285 \text{ MU}$  at continuous operation, and (2) 1.085 MU, which is the cumulative energy potential, as obtained from the Chart (Table 3.3)

Total Yield =  $3.285 + 1.085 = 4.37 \text{ MU}$ .

The plant capacity factor, corresponding to this yield is given by :

$\text{PCF} = 4.37 \times 10^6 / (1000 \times 8760) = 0.5$  or 50%.

Similarly, For 2.5 MW, (for 30% flow of exceedence)

$\text{PCF} = (8610000 / 2500 \times 8760) \times 100 = 39.3\%$

This PCF is approximately equal to the break even value of 40%.

So 2.5 MW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

The units selected can be one of the following combinations:

(1MW x 2 + 0.5 MW x 1) or (2MW x 1 + 0.5 MW x 1) or (1MW x 1 + 0.5 MW x 3) or even (0.5MW x 5).

The last is very unlikely as the cost per MW will go up significantly as the number of units increases too much. The second option has limited manoeuvrability to take advantage of the pondage, when the inflow falls. The choice between 1<sup>st</sup> or 3<sup>rd</sup> options will depend on the total picture that emerges from the entire family of sites.

Similarly, maximum possible capacities for four different combinations of tariffs and investment costs can be calculated as indicated below:

The combinations considered are;

Tariffs (per Unit) - Rs. 2.5 and 3.0 (Two cases)

Investment cost (Rs.in Crores per MW)	-	3.0, 3.5 (Two cases)
Break even PCF for Rs. 2.5/unit and Rs. 3 Crores per maga watt is	-	34%
Break even PCF for Rs. 3 / unit and Rs. 3 Crores per mega watt is	-	28.5%
Break even PCF for Rs. 3 / unit and Rs. 3.5 Crores per mega watt is	-	33.3%

The maximum possible economically viable capacity for all these four cases are shown in Table 3.4

**Table 3.4  
Economically Viable Maximum Capacity at Different Costs and Tariff**

	Rs.3.0 Crores/MW	Rs.3.5 Crores/MW
Rs.2.5/Unit	4 MW	2.5 MW
Rs.3.00/ Unit	5.5. MW	4 MW

### **3.5 STANDARDISATION AS A MEANS FOR COST REDUCTION**

#### **3.5.1. The case for standardisation**

One reason for the comparatively high cost of small hydro equipment is that the turbines, usually one of a kind, require a high cost for design and development. If we can choose a large number of turbines of identical specifications (head and discharge), the development cost as well as fabrication cost can be reduced considerably. Naturally, we may not get exactly identical sites. So some deviation in head and flow rate may have to be conceded by making a compromise between the saving in cost as a result of standardisation and the loss in revenue as a result of lower energy generation.

In this project, we have tried to strike a balance between these two and to evolve a new approach to cost reduction through standardisation.

### **3.5.2. Categorisation of sites according to head**

The effective head available at these 31 sites varied from 17.62m at Adianpara to 210m at Attila. Tentatively, these 31 sites are clubbed into 9 head groups: 20m (3), 33m (5), 43m (4), 50m (3), 90m (7), 125m (2), 140m (5), 180m (2). This is indicated in **Table 3.1**. Using the concept of economic return, the minimum number of hours that a unit should run in an year (or the break even plant capacity factor) was worked out for every site (**page no.19**). On the basis of this criterion, the maximum installed capacity of each site was finalised. The turbine sizes were selected judiciously. For every site, a combination of given turbine unit sizes. - 0.25MW, 0.5MW, 1MW, 1.5MW, 2MW, 5MW were chosen to satisfy capacity requirement.

From budgetary quotations obtained, it is clear that a cost reduction of at least 15% or above is possible if we order for multiple units (ie, say 4 units of the same turbine, at a time). We can make use of this favourable situation by selection of convenient sized units which add up to the total requirement for each site. Needless to say, this methodology has to be carefully applied by treating the entire family of sites as part of a single system.

### **3.6 CIVIL WORKS**

Each site requires a diversion weir and an intake structure. The height of the weir is so adjusted as to create a pond with a capacity to hold, as far as possible, one full day's inflow during lean months. This stored water will be fully utilized to operate the turbine at full load for about 3 to 4 hours, during the peak load time. The machine is shut down for the rest of the day. When the inflow is larger during monsoon and at times during occasional showers between monsoons, the machines can be operated in two or more spells of three to four hours each, or even continuously. Thus, through a judicious mix of continuous and intermittent operation, one can extract maximum energy from any given site. Feasible dam height, area of submergence etc., too will have to be considered while finalising the pondage.

### **3.7 DESIGN CONSIDERATIONS FOR CIVIL WORKS**

The important civil engineering works required for the project are a weir, intake structure, penstock and a power house. A weir is constructed to have a small storage and to divert the

water from stream to the intake. The intake structure takes water from the weir and leads it to the penstock. The penstock is a pressure pipe which carries water to the turbine. It can be made of steel, cast iron, plastics (Poly Vinyl Chloride, High Density Poly Ethylene) and concrete.

A power house is required for the purpose of housing the electro mechanical equipment. It can very well be a small building of one or two rooms.

### **3.7.1 Design of Weir**

*Stability Analysis:* A gravity dam is a structure which is designed in such a way that its own weight resists the external forces. The preliminary analysis of all gravity dams can be made easily by isolating a typical cross section of the dam of unit width. This section is assumed to behave independently of the adjoining sections. In other words, the dam is considered to be made up of a number of cantilevers of unit width each, which act independently of each other. This assumption of independent functioning of each section disregards the beam action in the dam as a whole.

The stability of dam can be analysed in the following steps.

1. Consider unit length of dam.
2. Work out the magnitude and direction of all vertical forces acting on the dam and their algebraic sum i.e.,  $\Sigma V$ .
3. Similarly work out all the horizontal forces and their algebraic sum i.e,  $\Sigma H$ .
4. Determine the leverarm of all these forces about the toe.
5. Determine the moments of all these forces about the toe and find out the algebraic sum of all these moments i.e.,  $\Sigma M$ .
6. Find out the location of the resultant force by determining its distance from toe.  
 $x = \Sigma M / \Sigma V$ .
7. Find out the eccentricity (E) of the resultant (R) using  $E = B/2 - x$ . It must be less than  $B/6$  in order to ensure that no tension is developed anywhere in the dam.
8. Determine the vertical stress at the toe and the heel using  $p = (\Sigma V/B) \pm (12E/B)$ .

9. Determine the maximum normal stresses. They should not exceed maximum available values.
10. Determine the factor of safety against over turning as equal to  $\Sigma$  (stabilising moment)/ $\Sigma$  (Over turning moment).
11. Determine the factor of safety against sliding, using sliding factor:  $\mu \times \Sigma V / \Sigma H$ . Sliding factor must be greater than unity.

### **3.7.2 Penstock**

It is laid below the weir. The important parameter in penstock design is the economic diameter of the pen stock. Economic diameter is the diameter for which the annual cost, which includes the cost of power lost due to friction and charges for amortization of construction cost, maintenance, operation, etc. is the minimum. Empirical formulas for economic diameter of penstocks are recommended by various authors based on data of existing penstocks (by regression method), among which, following empirical formula is recommendable for mini-hydros.

$$D_e = C_1 C_2 Q_0^{0.43} H_0^{-0.14}$$

in which;

$D_e$  - Economic diameter (m)

$Q_0$  - Design discharge of the penstock or plant (Cms)

$H_0$  - Design head of the plant (m)

$C_1$  - Coefficient taking into consideration the energy cost in the area; 1.2 for areas where energy cost is low, 1.3 for areas where energy cost medium and 1.4 for areas where energy cost high or exists no alternative source

$C_2$  - Coefficient taking into account the material of penstocks; 1 for steel penstocks, 1.05-1.1 for wood-stave pipes and 0.9-0.95 for plastic pipes (for small mini-hydros)

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**CONCLUSIONS AND RECOMMENDATIONS**

**4.1 RESULTS**

The results pertaining to the 31st sites are presented in Part II of the this report. **Table 4.1** and **Table 4.2** show the summary of results and the results of standardisation. The following conclusions are based on those results.

**Table 4.1**  
**Economically viable proposed unit size**

Sl. No.	Name of site	Tariff (Rs./Unit)	Installed Capacity for Rs.3.5 crores/MW	Proposed Unit size
1	Adianpara	2.50	1 MW	0.5 MW x 2
		3.00	1.75 MW	1MW x 1+ 0.5MWx1+ 0.25MWx1
2	Mayampully	2.50	1 MW	0.5 MW x 2
		3.00	1.75 MW	1MW x 1+ 0.5MWx1+ 0.25MWx1
3	Aruvikkal Anchuruli	2.50	550 kW	500 kW x 1+ 50 kW x 1
		3.00	650 kW	500 kW x1+100 kW x 1+ 50 kWx1
4	Adakkukundu	2.50	100 kW	100 kW x 1
		3.00	125 kW	100 kW x 1 + 25 kW x 1
5	Chakkimali	2.50	40 kW	50 kW x 1
		3.00	50 kW	50 kW x 1
6	Nellikappara	2.50	100 kW	100 kW x 1
		3.00	125 kW	100 kW x 1 + 25 kW x 1
7	Upputhodukuthu	2.50	750 kW	500 kW x 1+ 250 kWx1
		3.00	1 MW	500 kW x 2
8	Urumpallu	2.50	450 kW	250 kW x 2
		3.00	750 kW	500 kW x 1+ 250 kWx1

9	Madatharuvi	2.50	75 kW	50 kW x 1 + 25 kWx1
		3.00	150 kW	100 kW x1 + 50 kW x 1
10	Kallimalikuthu	2.50	200 kW	100 kW x 2
		3.00	450 kW	250 kW x 2
11	Gandhismarakappadi	2.50	150 kW	100 kW x 1 + 50 kW x 1
		3.00	250 kW	100 kW x 2 + 50 kW x 1
12	Pathinaramkandam	2.50	350 kW	250 kW x 1+ 100 kW x 1
		3.00	450 kW	250 kW x 2
13	Thekkumthoni	2.50	1 MW	500 kW x 2
		3.00	1.5 MW	1 MW x 1 + 0.5MW x 1
14	Chengara	2.50	90 kW	50 kW x 2
		3.00	100 kW	50 kW x 2
15	Murikkasseri kuthu	2.50	550 kW	500 kW x 1+ 50 kW x 1
		3.00	650 kW	500 kW x 1+ 100 kW x 1 + 50kWx1
16	Manpilavu	2.50	250 kW	250 kW x 1
		3.00	400 kW	250 kW x 1+ 100 kW x 1
17	Mukkali	2.50	650 kW	500 kW x 1 + 100 kW x 1 + 50kWx1
		3.00	750 kW	500 kW x 1 + 250 kW x 1
18	Elappilly	2.50	850 kW	500 kW x1 + 250 kW x1 + 100kWx 1
		3.00	1 MW	500 kW x 1 + 250 kW x 2
19	Idukki - Valara	2.50	7 MW	5 MW x 1 + 1 MW x 2
		3.00	10 MW	5 MW x 1 + 2 MW x 2 + 1MWx1
20	Thrissur - Valara	2.50	2.5 MW	1 MW x 2 + 0.5 MW x 1
		3.00	3 MW	1 MW x 3
21	Poomala - Njandirukki	2.50	850 kW	500 kWx1 + 250 kWx1 + 100 kWx 1
		3.50	1.1 MW	500 kW x 2 + 100 kW x 1
22	Kalkandi	2.50	950 kW	500 kW x 1 + 250 kW x 2
		3.50	1.25 MW	500 kW x 2 + 250 kW x 1
		2.50	2 MW	1 MW x 1 + 500 kW x 2
23	Vellachattappara	3.50	2.75 MW	2 MW x 1 + 500 kW x 1 + 250kW x 1

24	Kozhivalkuthu	2.50	13 MW	5 MW x 2 + 1 MW x 3
		3.50	16 MW	5 MW x 3 + 1 MW x 1
25	Pamble	2.50	2.5 MW	1 MW x 2 + 0.5MW x 1
		3.50	4 MW	2 MW x 1 + 1 MW x 2
26	Vattompara	2.50	2.5 MW	1 MW x 2 + 0.5MW x 1
		3.50	4 MW	2 MW x 1 + 1 MW x 2
27	Chembukatty	2.50	4MW	2 MW x 1 + 1 MW x 2
		3.50	6 MW	2 MW x 3
28	Thendillam	2.50	2 MW	1 MW x 1 + 500 kW x 2
		3.50	3 MW	2 MW x 1 + 1 MW x 1
29	Panamkudantha	2.50	450 kW	250 kW x 2
		3.50	650 kW	500 kW x 1 + 100 kW x 1 + 50kW x 1
30	Keezharkuthu	2.50	10.5 MW	5 MW x 2 + 500 kW x 1
		3.50	13 MW	5 MW x 2 + 1 MW x 3
31	Attala	2.50	6 MW	2 MW x 3
		3.50	7.5 MW	5 MW x 1 + 2 MW x 1 + 500kW x 1

**Table 4.2**  
**Total number of units for the combination of Rs. 2.5 / Unit and Rs. 3.5 Cr / MW**

No. of units size MW	Head in meters							
	20	33	43	50	90	125	140	180
0.025			1					
0.05	1	1	2	3	1			
0.10		2	4		3			
0.25		3	1	1	4		2	
0.50	5	1		3	5	2	4	1
1					5	4	7	
2							1	3
5					1	2		2

## 4.2 CONCLUSIONS

- < The present project is an attempt to use standardisation as a method of cost reduction in Small Hydel Projects. This has been brought out by examining a limited sample of 31 sites. These sites have been identified with the help of local residents after inspecting 156 possible locations in 5 districts. The results show that a sufficiently large number of units are required so as to warrant attempts at standardisation. This demands that a large number of sites are taken up for implementation in a co-ordinated manner.
- < A most important finding of the study is that the economical size and yield from a given site could go up significantly (by as much as 50% or even more) if the permissible tariff is increased from Rs.2.50/kWh to Rs.3.0/kWh. This shows the importance of having an enlightened policy in this regard.
- < This sample is by no means exhaustive, even within the chosen districts. We are sure that many more sites can be identified by conducting an exhaustive search of all the 14 districts. However, such an investigation was outside the scope of the present work, and has not been attempted. Yet this is something which has to be done. The district panchayaths should take this up on a priority basis.
- < The implementation of these projects should be undertaken on a co-ordinated basis. Only then can we take advantage of the possibilities of standardisation. Projects involving units of a given size should be taken up together, or in sequence, so that orders can be placed for equipment of identical specifications, in a large number.
- < This naturally precludes assigning possible project sites to Independent Power Producers (IPP) on a first come first served basis. On the other hand, there should be a concerted and co-ordinated effort on the part of a designated Nodal Agency, which should prepare the Detailed Project Reports (DPRs) and assign specific projects according to a predetermined schedule of implementation. Too many members contesting among themselves, often working at cross purposes, and competing for the most promising sites, is a situation to be

avoided, at all costs.

### **4.3 RECOMMENDATIONS**

Even though the study did not address the specific issue of management, in view of the experience we gained through the interaction with various agencies and stake holders, the following recommendations have been formulated.

- < Grama Panchayat should be encouraged to conduct/commission feasibility studies of potential SHP sites within their area.
- < Projects up to 100 kW could be undertaken by the grama panchayats for implementation. Bigger projects may be taken up by Jilla Panchayats.
- < The procedure for granting clearances should be simplified and decentralised.
- < The Power Plant and Distribution System for stand alone systems should be managed by a local beneficiary committee. Grid connected systems should be managed by Small Hydel Companies formed at the district level.
- < For grid connected systems, the power has to be sold to the State Electricity Board at an agreed tariff rate. The guidelines on pricing, prescribed by MNES can be followed. For the stand alone system, the power is distributed according to the needs of the locality and the tariff for power consumption can be fixed on a Acost plus  $\cong$  basis.
- < The capital for the project may be raised from Bank Loans, Shares, Donation , etc. Equity can be collected from beneficiaries, including Local Self Government Institutions (LSGIs).
- < SHP development offers an excellent industrial opportunity. This can be usefully integrated with the planning for the industrial sector. It is desirable and viable to form a consortium of already existing public sector technical units in the state, that have so far shown initiative in such projects. Turbine, electrical equipment including alternators and transformers and even

penstocks can be locally manufactured. This will have a salutary effect on our economy.

- < The formulation of a *master plan* for harnessing the Small Hydro Potential of the state is necessary, if advantage is to be taken of the benefits of standardization. A sequential programme to take up the various sites can then be worked out. This should be the responsibility of the designated nodal agency. Implementation can be done by NGOs - in the case of micro hydro projects, or district power companies in the case of mini and small hydro projects. Local Self Government Institutions (LSGIs) can extend financial support.
  
- < The role of the government and the KSEB should be that of facilitators. The KSEB should be obliged to purchase any power produced by any enterprise at a pre-fixed price. This price can be fixed by state government and revised from time to time in accordance with the guidelines of the MNES. The importance of offering a reasonable purchase price, and its impact on enhancing the economically exploitable potential is clearly brought out by the study. It is seen that even within this limited sample, if the purchase price is raised by 20% (from Rs.2.50 to Rs.3.00 per kWh), the economic potential goes up by 35% (from 62.405 MW to 84.15 MW)

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## VOLUME II: SITE SPECIFIC DETAILS

1. Adianpara
2. Aruvikkal Anchuruli
3. Mayampilly
4. Adakkakundu
5. Chakkimali
6. Nellikkapara
7. Upputhodukuthu
8. Urumpallu
9. Madatharuvi
10. Kallimali
11. Gandhi Smarakappady
12. Pathinaramkandam
13. Thekkumthoni
14. Chengara
15. Murikkasseri
16. Manpilavu
17. Mukkali
18. Elappilly
19. Valara (Idukki)
20. Valara (Thrissur)
21. Poomala
22. Kalkandy
23. Vellachattapara
24. Kozhivalkuthu
25. Pamble
26. Vattompara
27. Chembukatty
28. Thendillam
29. Panamkudantha
30. Keezharkuthu
31. Attala

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## Annexure-B

## List of Identified Small Hydel Sites of Our State

Sl. No.	District	Rivers	No. of sites	Capacity (MW)	Category			Energy (MU)
					Small	Mini	Micro	
1	Kasaragod	Chandragiri, Kariangode	7	5.15	1	6	0	17.93
2	Kannur	Kariangode, Kuppam, Valapattanam	31	47.05	9	22	0	136.28
3	Kozhikkode	Chaliyar, Mahe, Kuttiadi	34	154.00	17	17	0	386.15
4	Wynad	Chaliyar, Kabani	13	20.65	4	9	0	68.37
5	Malappuram	Chaliyar	27	27.86	4	22	1	81.42
6	Palakkad	Bharatapuzha, Chalakudi	24	39.12	9	10	5	100.21
7	Thrissur	Chalakudi, Keecheri	12	42.30	6	6	0	120.65
8	Eranakulam	Periyar	4	12.60	3	1	0	117.74
9	Kottayam	Manimala, Pamba, Meenachal	4	11.65	2	2	0	35.54
10	Idukki	Muvattupuzha, Periyar	84	163.89	35	48	1	631.14
11	Pathanamthitta	Pamba, Pallickalaar	28	48.55	14	14	0	243.95
12	Alappuzha	-	0	0.00	0	0	0	0.00
13	Kollam	Kallada, Ailarakode	7	5.80	3	4	0	69.33
14	Thiruvananthapuram	Karamana, Neyyar, Vamanapuram	10	7.33	2	7	1	39.63
<b>Total</b>			<b>285</b>	<b>585.95</b>	<b>109</b>	<b>168</b>	<b>8</b>	<b>2048.34</b>

1. Just identified	<b>128</b>	4. Detailed Investigation Done	<b>32</b>	7. Chinese Co-op. Schemes
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		<b>18</b>
2. Preliminary Investigation Done <b>39</b>	5. Allotted/Agreement Signed <b>12</b>	8. Under Construction <b>7</b>
3. Feasibility Survey Done <b>39</b>	6. To be Done by KSEB <b>6</b>	9. Commissioned <b>4</b>
<b>Total - 285</b>		

## **1. ADIANPARA**

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**District : Malappuram**

**Panchayath : Chaliyar**

**Head : 20 m.**

**Flow : Perennial**

**Suggested  
Capacity : 1000kW/1750kW**

## **1.1 GENERAL**

### **1.1.1 The site**

Adianpara is a scenic water fall located in the F<sup>t</sup> ward of Chaliyar Grama Panchayath in Malappuram district. The site is at a distance of 10 km from Nilambur. There is bus route from Nilambur to Namboorippady which is motorable through out the year. From there also buses are available to Muttiel except in monsoon season. Jeep services are available through out the year. From Muttiel there is only 1 km to the site and a motorable road reaches very near the site. The nearest 11 KV line is about 1.75 km away from site.

The water fall is located at 76° 12' 15"E longitude and 11° 21' 5" N latitude. The catchment area measured from toposheet is 28.50 sq.km The fall is situated at an elevation of 360m from MSL, in Kanjirappuzha stream which begins at an elevation of 1442m from MSL. It is flowing almost in a moderate slope after the fall and joins the Chaliyar river which drains into the Arabian sea. There is another fall on the upstream side of this fall which is called Mayampilly. The location map of the site is shown in **Fig.No. 1.1**.

### **1.1.2 Topography**

The site is situated in the Nilambur forest which is very dense. The land is having moderate slope in this area. There is no possibility of land slide. The chances for soil erosion are very less. Both sides of the stream and its upstream have sheet rocky surface. There is a gorge of 2.5 m wide on the upstream side of the fall. The site is perennial. Number of rainy days exceeds 50% in its catchment.

## **1.2 FIELD INVESTIGATION**

### **1.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 20m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 1.2.2 Catchment area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Adianpara site was located using the toposheet. It is shown in **Fig.No.1.2**. The total area of catchment is measured and it comes to nearly **28.50 sq km**. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about **20 cumec**

### 1.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200 (**Annexure A.1**). The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and marked in the above map, along with the contours of the area.

### 1.2.4 River flow data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, and the cross sectional details of that point were noted for calculating the stream discharge. A measuring gauge was fixed at that point to measure the peak flow. Using the collected data (**Table 1.1**) the weekly discharge hydrograph of the site was plotted. It is given in **Fig. No. 1.3**.

### 1.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 1.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 1.2**. These data are used for calculating energy potential and selection of unit sizes in **section 1.4**.

### 1.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 1.3**. The value obtained from Dicken=s formula, which is

commonly used for Western Ghats region has been used for the structural design of diversion structure.

**Table 1.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	307.96	543.04	90.90	826.45

### 1.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine and generator and it=s cost have been estimated after consulting various agencies.

#### 1.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 98% is only 0.02 cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 3 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 20 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project to produce 150 kW with a dependability of 50%, or 360 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;            P = Power output in kW  
                           Q = Discharge in cumec  
                           H = Head in metres

Referring to table 1.2,  $\eta$  = Overall efficiency (Here it is assumed as 0.75).

For 50% exceedence,  $Q=1\text{m}^3/\text{s}$ ,  $P = 10 \times 1.00 \times 20 \times 0.75 = \mathbf{150 \text{ kW}}$ .

For 40% exceedence,  $Q=2.4\text{m}^3/\text{s}$ ,  $P = 10 \times 2.4 \times 20 \times 0.75 = \mathbf{360 \text{ kW}}$ .

For 30% exceedence,  $Q=7\text{m}^3/\text{s}$ ,  $P = 10 \times 7 \times 20 \times 0.75 = \mathbf{1110 \text{ kW}}$ .

### 1.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 1000kW power output for about 30% of the time. The output reduces to 360kW if we take the percentage flow of exceedence as 40%. The energy input corresponding to 30% exceedence will be  $(30/100 * 1000 * 365 * 24) = 2.69 \text{ MU}$ . The flow after 30% time can be utilized by providing a small pondage. The quantity of water available from 30% to 100% time is calculated to be  $22848135\text{m}^3$ . Energy obtained from this water is calculated to be 0.952 MU.

Total amount of energy produced =  $2.69 \text{ MU} + 0.952 \text{ MU} = \mathbf{3.64 \text{ MU}}$ .

It may be noted that, this much amount of energy can be generated for the particular year of measurement. If higher flows are available during any year, it will enable higher production and vice versa.

### 1.3.3 Pondage requirement

A plot of surface area Vs. elevation is given in **Fig.No.1.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 1.4**. From this information, a capacity elevation curve of the pondage is prepared and is given in **Fig.No. 1.6**.

**Table 1.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy ( kWh)
1	295.5	0	0	0
2	296	259.6	103.84	4
3	298	786.4	1149.84	48
4	299	2220.6	2653.34	111
5	300	3345.4	5436.34	227

As the terrain is suitable for storing only 5400 m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 227 kWh. If a single 250 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, since pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4.5m, to create a pondage of 5400 m<sup>3</sup> is suggested.

#### 1.4 SELECTION PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan Repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. If the project is to be economically viable, each combination of tariff and capital cost selected above will

demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Adianpara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

This means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of ***Plant Capacity Factor***, which is defined as the ratio of actual amount of energy obtained during an year to the maximum energy that can be obtained from the given installed capacity during the same year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.00 per kWh and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for these two conditions.

**a. Tariff: Rs.2.50/KWh and break even PCF of 40%**

For an installed capacity of 1000 kW, which corresponds to about 30.7% flow of exceedence from the chart, the total energy yield is the sum of:

$1000 \text{ kW} \times (0.307 \times 8760) = 2.69 \text{ MU}$  at continuous operation for 30.7% time of an year, and 0.952 MU, which is the cumulative energy potential from 30.7% to 100% time as obtained from the Chart (**Table 1.2**).

So total yield = 2.69 MU + 0.952 MU = 3.642 MU.

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 3.642 \times 10^8 / (1000 \times 8760) = 41.5\%$$

*This PCF is very near to the break even value of 40%. Hence installed capacity of 1000kW is acceptable.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Corresponding to an installed capacity of 1.75 MW (for 19 % flow of exceedence)

$$\text{PCF} = (5310000 / 1750 \times 8760) \times 100 = 34.6\%$$

This PCF is very near to the break even value of 33.3%.

*Therefore, 1.75 MW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 1.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Installed Capacity for Rs.3.5 Crores/MW
Rs.2.5/Unit	1 MW
Rs.3.00/ Unit	1.75 MW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 1) or (0.5 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 1MWx1 + 0.5 MWx 1+0.25MWx1) or (1.5 MW x 1 + 0.25 MW x 1)

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 1.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. A small building of one or two rooms will suffice.

### 1.5.1 Weir

A Gabion weir has been proposed on the Kanjirappuzha stream, at a bed level of +495.500 metres. The base width of the weir at bed level is **7.5 m**. The structure is 4.50 m high having a length of 60 m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. No. 1.7**.

### 1.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the steel penstock for 1000kW installed capacity, is calculated as **1.9 m** and the penstock can carry a maximum flow of **6.67cumec**. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and calculated the length, which comes to **147m (Fig. No. 1.8)**.

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 9 m x 8m to accommodate 1000 kW, generator and standardised turbine.

## **1.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The electricity generated would be connected to the existing power grid system at Nilambur by a 300m transmission line. A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 11kV, with three phases, 50 cycles per second and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **1.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Adianpara. The project could generate either 1000 kW or 1750 kW of hydro power depending on the permitted tariff. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **1.7.1. Environmental impact on land**

Total area of catchment is about 28.5 square kilometres of land in Kanjirappuzha. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi ever green and deciduous. The land at left bank of stream is owned by private persons and the right bank is forest land. Stream sections are mostly rocky large sized boulders are plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **1.7.2 Environmental impact on water**

The Kanjirappuzha, which drains to Chaliyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.3345ha. No forest land will be submerged. Above all, this accounts for only 0.3345 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **1.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **1.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 1000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1750kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **2. ARUVIKKAL ANCHURULI**

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**District** : Idukki  
**Panchayath** : Kanjar  
**Head** : 20 m.  
**Flow** : Seasonal  
**Suggested Capacity** : 550 kW / 650kW

## **2.1 GENERAL**

### **2.1.1 The site**

The Aruvikkal Anchuruli water fall is located in the 3rd ward of Kanjiyar Grama Panchayath in Idukki district. The site is at a distance of 7 km. from Kattappana. There is bus route from Kattappana to Kakkattukkada. From Kakkattukkada junction, it is possible to reach the site by travelling a distance of 2km through the Anchuruli reservoir road. The nearest 11 KV line is about 500m away from the site.

The water fall is located at 77° 4' 17" E longitude and 9° 45' 29" N latitude. The catchment area measured from topo sheet is 0.625 sq.km. The falls are situated at an elevation of 300m from MSL in Kanjiyar stream which begins at an elevation of 860m from MSL. The stream is flowing through moderate slopes. After the fall, the stream joins to Kattappanayar which is draining to the Idukki reservoir. Location of the site is shown in **Fig.No.2.1.**

### **2.1.2 Topography**

The site is situated outside the forest area. Both sides of the site are owned by private persons. There is no possibility of land slide and the chances for soil erosion are negligible. The bed of the stream is hard rock. The site is perennial and number of rainy days exceeds 50% in its catchment.

## **2.2 FIELD INVESTIGATION**

### **2.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 20m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **2.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Aruvikkal Anchuruli was located using the toposheet. It is shown in the **Fig.No. 2.2**. The total area of catchment is measured from the toposheet and it comes to nearly **0.625** sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about **5 cumec**

### **2.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:250. Undulations of the site, the location of the falls and other topographical features were identified from the contour map. Location of the weir, alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.2**.

### **2.2.4 River flow data**

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was located on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of that point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 2.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 2.3**.

### **2.2.5 Flow duration curve**

Using weekly discharge hydrograph, percentage flow of exceedence was calculated. From this flow duration curve was calculated (**Fig.2.4.**). The same curve also functions as percentage flow of exceedence graph. The river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 2.2**. These data are used for calculating energy potential and selection of unit sizes in **section 2.4**.

### **2.2.6 Peak flow determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 2.3** The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 2.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	18.28	23.15	7.38	34.64

## 2.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project. But a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

### 2.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 98% is only 0.01 cubic metre per second. A discharge of 0.01 cubic metre per second can produce only about 1.5 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 20 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 275 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;  $P$  = Power output in kW  
 $Q$  = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 1.3 \times 20 \times 0.75 = \mathbf{195.00 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 1.85 \times 20 \times 0.75 = \mathbf{275.00 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 2.3 \times 20 \times 0.75 = \mathbf{355.00 \text{ kW}}$ .

### 2.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 275kW power output for 40% of the time (146 days). The output reduces to 90kW if we take the percentage flow of exceedance as 60% (219 days). The energy input corresponding to 40% flow of exceedance will be  $(40/100 * 275 * 365 * 24) = 0.9636 \text{ MU}$ . The flow after 40% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be 10371715 m<sup>3</sup>. Energy obtained from this water is 0.432 MU.

So, total amount of energy produced = 0.432 MU + 0.9636 MU = **1.4 MU**.

It may be noted that , this much amount of energy can be generated for the particular year of measurement. If higher flows are available during any year, it will enable higher production and vice versa.

### 2.3.3 Pondage requirement

A plot of surface area Vs. elevation is given in **Fig.No.2.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 2.4**. From this information a capacity-elevation curve of the pondage is prepared and is shown in **Fig.No.2.6**.

**Table 2.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	497.50	0.000	0.000	0
2	498.00	145.313	36.330	2
3	499.00	439.063	328.518	14
4	500.00	698.438	897.270	37
5	501.00	810.938	1651.958	69
6	502.00	1281.25	2698.050	112

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water. The terrain is suitable for storing only 1280 m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 112 kWh. If a single 100 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4m, to create a pondage of 1280 m<sup>3</sup> is suggested.

## 2.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan Repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine

tune the cost in relation to site specific conditions. Only ranges could be indicated if the project has to be economically viable. Each combination of tariff and capital cost selected above will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Aruvikkal Anchuruli be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$\mathbf{X = 3,500 \text{ hrs.}}$$

This means, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained during an year to the maximum energy that can be obtained from the given installed capacity during the same year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3 per unit and Rs. 3.5 Crores per Mega Watt for X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff : Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 550 kW, which corresponds to about 8% flow of exceedence from the chart, the total energy yield is;

$550 \text{ kW} \times (0.08 \times 8760) = 0.3854$  at continuous operation for 8% time of an year, and 1.53MU, which is the cumulative energy potential from 8% to 100% time as obtained from the Chart (Table 2.3).

So total yield =  $1.53\text{MU} + 0.3854\text{MU} = 1.92 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 1.92 \times 10^8 / (550 \times 8760) = 40 \%$$

*This PCF is equal to the break even value of 40%.Hence installed capacity of 550 kW is acceptable.*

Therefore, **550 kW** will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

**b.Tariff : Rs.3.00 / kWh and break even PCF of 33%**

Corresponding to an installed capacity of 650 kW (for 4% flow of exceedence)

$$\text{PCF} = (1950000 / 650 \times 8760) \times 100 = 34.25\%$$

This PCF is very near to the break even value of 33%.

Therefore, **650 kW** will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.

**Table 2.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	550 kW

Rs.3.00/ Unit	650 kW
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The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit; we can opt: (0.5MW x 1 + 0.05 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt: (0.5 MW x 1 + 0.1MW x 1 + 0.05MW x 1).

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 2.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of size 7.5m x 10m.

### 2.5.1 Weir

A concrete weir has been proposed on the Kattappanayar, at a bed level of +296.000m. The base width of the weir at bed level is 2.5m. The diversion structure is 4m high having a length of 18m at the top with a central broad crested free over fall type spill way. The cross sectional details of the existing ground and typical section of the proposed diversion site are shown in **Fig.No.2.7**.

### 2.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, The penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 1.5m. The penstock can carry a maximum flow of 3.67 cumec with a velocity of 2.0 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the

length was calculated, which comes to 158m (**Fig.No.2.8**).

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is gentle but increases up the hill towards south direction. The power house is of size 10m x 7.5m, to accommodate 550 kW generator and standardised turbine.

## **2.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 550 kW. The electricity generated would be connected to the existing power grid system by a 500m transmission line. A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brush less excitation system and rated to generate 11kV, three phases, 50 Hz. It is a suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **2.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Aruvikkal Anchuruli (Idukki Dist). The project aims to generate about 550 kW or 650kW of hydro power from a fall having a head of 20m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **2.7.1 Environmental impact on land**

Total area of catchment is about 0.625 sq. kilometres of land in Kaanchiyar stream. The upper catchment is rocky and with little vegetation cover. The site is situated out of forest. The area on both the banks of the stream is owned by private persons. There is no possibility of land slide and the chances for soil erosion is negligible. The bed of the stream is hard rock. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **2.7.2 Environmental impact on water**

The Aruvikkal Anchuruli, which drains to Idukki reservoir is the basins of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.128 hectare. No forest land will be submerged. Above all, this accounts for only 0.2327 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **2.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It require only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **2.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 550kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 650kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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### **3 . MAYAMPILLY**

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**District** : **Malappuram**  
**Panchayath** : **Chaliyar**  
**Head** : **20 m.**  
**Flow** : **Perennial**  
**Suggested Capacity** : **850 kW/ 1 MW**

### **3.1 GENERAL**

#### **3.1.1 The site**

Mayampilly is a scenic water fall located in the I<sup>st</sup> ward of Chaliyar Grama Panchayath in Malappuram district. The site at a distance of 15 km from Nilambur. There is bus route from Nilambur to Namboorippady which is motorable through out the year. From there also buses are available to Muttiyel except in monsoon season. Jeep service are available through out the year. From Muttiyel there is only 1 km to site and a motorable road exists near to the site. The nearest 11 KV line is about 3 km away from site.

The water fall is located at 76° 11' 30" E longitude and 11° 21' 39" N latitude. The catchment area measured from toposheet is 27 sq.km. The falls are situated at an elevation of 400m. from MSL, in Kanjirappuzha stream which is begins at an elevation of 2000m. from MSL. It is flowing almost in a moderate slope after the fall and joins the Chaaliyar river which drains in to the Arabian sea. There is another fall on the downstream side of the fall which is called Adianpara. Location map of the site is shown in **Fig. No.3.1**

#### **3.1.2 Topography**

The site is situated in the Nilambur forest which is very dense. The land is having moderate slope in this area. There is no possibility of land slide and the chances for soil erosion is very less. Both sides of the stream and its upstream have sheet rocky surface. Upstream side of the fall is almost in a elevated terrain and lot of boulders are available at site. The site is perennial and has good rainfall in the catchment. The site is perennial and number of rainy days exceeds 50% in its catchment.

### **3.2 FIELD INVESTIGATION**

#### **3.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. The total head of the site was found to be 20 m. A possible location for diversion structure and power house are identified and the details were taken using tacheometric method of surveying.

### 3.2.2 Catchment area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Mayampilly site was located using the toposheet. It is shown in **Fig.No.3.2**. The area is measured and it comes to **27 sq. km**. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 20 cumec.

### 3.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.3**.

### 3.2.4 River flow data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was located on the downstream of the fall, where the whole water is flowing through that point, cross sectional details of that point were noted for calculating the stream discharge. A measuring gauge was fixed at that point to measure the peak flow. Using the collected data (**Table 3.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig.No. 3.3**.

### 3.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 3.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 3.2**. These data are used for calculating energy potential and selection of unit sizes in **section 3.4**.

### 3.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 3.3**. The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 3.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	307.96	543.04	90.90	826.45

### 3.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But, a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated after consulting various agencies.

#### 3.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 98% exceedence is only 0.02 cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 3 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 20 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 150 kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence,  $Q=1\text{m}^3/\text{s}$ ,  $P = 10 \times 1.00 \times 20 \times 0.75 = \mathbf{150 \text{ kW}}$ .

For 40% exceedence,  $Q=2.4\text{m}^3/\text{s}$ ,  $P = 10 \times 2.4 \times 20 \times 0.75 = \mathbf{360 \text{ kW}}$ .

For 30% exceedence,  $Q=7\text{m}^3/\text{s}$ ,  $P = 10 \times 7 \times 20 \times 0.75 = \mathbf{1110 \text{ kW}}$ .

### 3.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 1000kW power output for 30.7% of the time (112 days). The output reduces to 360kW if we take the percentage flow of exceedence as 40% (183 days). The energy input corresponding to 30.7% time will be  $(30.7/100 * 1000 * 365 * 24) = 2.69 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 30% to 100% time is calculated to be  $22848135\text{m}^3$ . Energy obtained from this water is calculated to be 0.952 MU.

Total amount of energy produced =  $2.69 \text{ MU} + 0.952 \text{ MU} = \mathbf{3.64 \text{ MU}}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 3.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No.3.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 3.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.3.6**.

**Table 3.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area ( $\text{m}^2$ )	Capacity ( $\text{m}^3$ )	Energy (kWh)
1	497	0	0	
2	498	238.00	119.00	5
3	499	283.80	379.90	16

As the terrain is suitable for storing only 380 m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 280 kWh. If a single 250 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 2m, to create a pondage of 380 m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

### 3.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Mayampilly be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

This means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 1000 kW, which corresponds to about 30.7% flow of exceedence from the chart, the total energy yield is the sum of:

1000 kW x (0.307 x 8760) = 2.69 MU at continuous operation for 30.7% time of an year, and 0.952 MU, which is the cumulative energy potential from 30.7% to 100% time as obtained from the Chart (Table 3.3).

Total yield = 2.69 MU + 0.952 MU = 3.642 MU.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 3.642 \times 10^8 / (1000 \times 8760) = 41.5\%$$

This PCF is very near to the break even value of 40%.

*This PCF is very near to the break even value of 40%. Hence installed capacity of 1000kW is acceptable.*

*So 1 MW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33%**

Corresponding to an installed capacity 1.75 MW, (for 19 % flow of exceedence)

$$PCF = (5310000 / 1750 \times 8760) \times 100 = 34.6\%$$

*This PCF is very near to the break even value of 33.3%. Hence installed capacity of 1000kW is acceptable.*

*Therefore, 1.75 MW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 3.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	1 MW
Rs.3.00/ Unit	1.75 MW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 1) or (0.5 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 1MW + 0.25 MW x 3) or (1.5 MW x 1 + 0.25 MW x 1)

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

### 3.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake

structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of size 9mx 7m.

### **3.5.1 Weir at Mayampilly**

A concrete weir has been proposed on the Kanjirappuzha stream, at a bed level of +597.000 metres. The base width of the weir at bed level is 2m. The concrete structure is 2m high having a length of 8.2m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and a typical section of the structure are shown in **Fig.No. 3.7**.

### **3.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 1.9m. The penstock is designed for a maximum flow of 6.67 cumec with a velocity of 2.35 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 71m (**Fig. No. 3.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north direction. The power house is of size 9m x 7m, to accommodate 1000kW, generator and standardised turbine.

## **3.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 1000 kW. The electricity generated would be connected to the existing power grid system at Mayampilly by a 2km transmission line. A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated

to generate 1000kW, 11kV three phases, and 50 Hz . It will be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **3.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Mayampilly (Malappuram Dist.). The project aims to generate about 1000 kW of hydro power from a fall having a head of 20 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

#### **3.7.1 Environmental impact on land**

Total area of catchment is about 27 square kilometres of land in Kanjirappuzha. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi evergreen and deciduous. The land on left bank of stream is owned by private persons and the right bank is forest land. Stream sections are mostly rocky and large sized boulders are plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

#### **3.7.2 Environmental impact on water**

The Kanjirappuzha, which drains to Chaliyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.0283 hectare. No forest land will be submerged. Above all, this accounts for only 0.0283ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **3.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **3.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 850kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **4 . ADAKKAKUNDU**

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**District : Malappuram**

**Panchayath : Kalikavu**

**Head : 33 m.**

**Flow : Seasonal**

**Suggested  
Capacity : 100 kW / 125 kW**

## **4.1 GENERAL**

### **4.1.1 The site**

Adakkakundu water fall is situated in the 7<sup>th</sup> ward of Kalikavu Grama Panchayath in Malappuram district. The site is at a distance of 25 km. from Nilambur. There is bus route from Nilambur to Kalikavu. From there, Jeep services are available to Adakkakundu. The road ends nearly 500m before the site. The nearest 11 KV line is about 3 km away from site.

The water fall is located at 76° 21'20" E longitude and 11° 10' 33" N latitude. The catchment area measured from topo sheet is **6.78 sq.km**. The fall is situated at an elevation of 100m from MSL in Adakkakundu stream which begins at an elevation of 1000m from MSL. After the fall, the stream joins to the Kottapuzha and finally drains to Chaliyar. The location map of the site is shown in **Fig.No.4.1**

### **4.1.2 Topography**

Topography of any site means the description of geographic details of the site. The site is situated in private land. The land is having moderate slope in this area. There is no possibility of land slide and the chances for soil erosion are negligible. The bed of the stream is rocky and boulders are available at the site. The site is a seasonal one while the number of rainy days exceeds 50% in its catchment.

## **4.2 FIELD INVESTIGATION**

### **4.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. The total head of the site was found to be 33 m. A possible location for diversion structure and power house are identified and the details were taken using tacheometric method of surveying.

### **4.2.2 Catchment area**

The catchment of Adakkakundu fall (Chempuzha) was located using the toposheet. It is shown in **Fig.No. 4.2**. The area is measured and it comes to **6.78 sq km**. The catchment area having almost moderate slope but some portions are very steep. The upstream portion of the catchment area is the part of western ghats and the area nearby the site is mainly cultivated lands. The

possibility of land slide exists at the upstream side of the catchment.

### 4.2.3 Contour map

The tacheometric survey details were plotted on a sheet of paper at a scale of 1:200. The undulations on the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.4**.

### 4.2.4 River flow data

For a period of 12 months (November 97 to November 98) the water level observations were taken every week. A suitable location was located on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of that point were noted for calculating the stream discharge. A measuring gauge was fixed at that point to measure the peak flow. Using the collected data (**Table 4.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 4.3**.

### 4.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 4.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 4.2**. These data are used for calculating energy potential and Selection of unit sizes in **section 4.4**.

The flow duration curve for the year 1998 is shown in **Fig.4.4**. The curve was obtained by plotting discharge against percentage exceedence. The details are given in **Table 4.2**.

### 4.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 4.3** The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 4.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	108.12	198.99	35.85	282.65

### 4.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 4.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 86% exceedence is only 0.005 cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 1.25 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 33 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 25 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

- P = Power output in kW
- Q = Discharge in cumec
- H = Head in metres
- $\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.01 \times 33 \times 0.75 = \mathbf{25.00 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.14 \times 33 \times 0.75 = \mathbf{35.00 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 0.26 \times 33 \times 0.75 = 65.00 \text{ kW}$ .

### 4.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 25kW power output for 50% of the time (182 days). Power input corresponding to 50% time will be  $(50/100 * 25 * 365 * 24) = 0.11\text{MU}$ . The flow after 50% time can be utilized by providing a small pondage.

The quantity of water available from 50% to 100% time is calculated to be 500774 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.034 MU.

Total amount of energy produced  $= 0.11 \text{ MU} + 0.03 \text{ MU} = 0.14\text{MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 4.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No.4.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 4.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.4.6**.

**Table 4.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	496.5	0	0	0
2	497	33.20	16.60	1
3	498	116.40	91.40	6
4	499	252.40	275.80	19
5	500	473.80	638.90	44
6	501	687.20	1219.40	84
7	502	909.00	2017.50	139
8	503	1163.80	3053.90	210

As the terrain is suitable for storing 3050 m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 200 kWh. If a single 200 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 6.5 m, to create a storage of 3050 m<sup>3</sup> is suggested. As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### **4.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine

tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Adakkakundu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained during an year to the maximum energy that can be obtained from the given installed capacity during an year.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt for X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for these two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 50 kW, which corresponds to about 38.5% flow of exceedence from the chart, the total energy yield is the sum of:  $50 \text{ kW} \times (0.385 \times 8760) = 0.169 \text{ MU}$  at continuous operation for 38.5% time of an year, and 0.066MU, which is the cumulative energy potential from 38.5% to 100% time as obtained from the Chart (Table 4.3)

So total yield =  $0.169\text{MU} + 0.066\text{U} = 0.235 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 0.235 \times 10^8 / (50 \times 8760) = 53.65 \%$$

For a capacity of 100 kW, Total yield =  $(100 \times 0.195 \times 8760) + 207006$

ie,  $0.171 + 0.207 = 0.378 \text{ MU}$ .

$$\text{PCF} = 0.378 \times 10^8 / (100 \times 8760) = 43.15 \%$$

This PCF is approximately equal to the break even value of 40% for a capacity of 100 kW.

*So 100 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 125 kW (for 13.5 % flow of exceedence)

$$\text{PCF} = (393000 / 125 \times 8760) \times 100 = 35.8\%$$

This PCF is very near to the break even value of 33% for a capacity of 125 kW.

*Similarly, 125 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 4.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW

Rs.2.5/Unit	100 kW
Rs.3.00/ Unit	125 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.1MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.1 MW x 1 + 0.025MW x 1).

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

#### 4.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project, only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. A small building of one or two rooms will suffice.

##### 4.5.1 Weir at Adakkakundu

A Gabion weir has been proposed at the site at a bed level of +495.500 metres. The base width of the weir at bed level is 6.5m. The diversion structure is 6.50 m high having a length of 29 m. at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and a typical section of the proposed weir structure is shown in **Fig.No. 4.7.**

##### 4.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.2m. The penstock can carry a maximum flow of .0404 cumec with a velocity of 1.3 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The

longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 147m (**Fig. No. 4.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 8m x 4.5m, to accommodate a 100 kW generator and standardised turbine.

#### **4.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 100 kW. The electricity generated would be connected to the existing power grid system at Adakkakundu by a 3 km. transmission line. A standardised turbine for 33m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 100 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

#### **4.7 ENVIRONMENTAL IMPACTS**

A micro hydel project has been proposed at Adakkakundu (Malappuram Dist.). The project aims to generate about 100 kW of hydro power from a fall having a head of 33 m. Some preliminary environmental impact analysis have been carried out. They are land, water, socio-economic environmental impacts

##### **4.7.1 Environmental impact on land**

Total area of catchment is about 6.78 square kilometres of land in Chempuzha which joins to Valiyapuzha then Kottapuzha and finally drains in to Chaliar. The site is situated in private land. The land is having moderate slope in this area. There is no possibility of land slide and the chances for soil erosion is exists. The bed of the stream is rocky and boulders are available at nearby the site. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

#### **4.7.2 Environmental impact on water**

The Chempuzha which drains to Valiyapuzha is the stream of this fall. It is a 3rd order, structurally controlled stream. The storage structure will create a pond of area 0.116 hectare. No forest land will be submerged. Above all, this accounts for only 1.16 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

#### **4.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 12 months. It require only minimum land acquisition for construction. The acquisition does not need any rehabilitation

### **4.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area. The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 100kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 125kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **5. CHAKKIMALI**

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**District : Idukki**  
**Panchayath : Arakkulam**  
**Head : 33 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 40 kW / 50 kW**

## **5.1 GENERAL**

### **5.1.1 The site**

Chakkimali water fall is situated in IXth ward of Arakkulam Grama Panchayath in Idukki district.

To reach this site, we have to travel nearly 18km distance from Moolamattom to Kulamavu. Two kilometre away from Kulamavu there is a boat station. After 20 minutes journey from Nellikkappara boat station, we will reach Peranikkadavu. From Peranikkadavu a forest footpath of one kilometre stretch exists which leads to the site. From Moolamattom to Urumpallu, there is another route to reach the site. That jeepable route is too long as compared to the early said route.

The water fall is located at  $76^{\circ} 56' 45''$  E longitude and  $9^{\circ} 47' 13''$  N latitude. The catchment area measured from topo sheet is 1.5 sq. km. The falls are situated at an elevation of 720m from MSL in Chakkimali thodu which begins at an elevation of 940m from MSL. After the fall the stream drains to Idukki reservoir. The fall situated just 150m away from reservoir. No existing supply lines are available near by this site. The location map of the site is shown in **Fig.No.5.1**

### **5.1.2 Topography**

Topography of any site means the description of the geographical details of the site. The land is having steep slopes in this area. There is no possibility of land slide and the possibility of soil erosion is negligible. The stream bed is rocky and availability of boulders are less. The number of rainy days exceeds 50% in its catchment.

## **5.2 FIELD INVESTIGATION**

### **5.2.1 Reconnaissance survey**

Before starting the topographical survey we walked through the project area, which gave an overall idea of the site and its principal features. Possible instrument stations were located for the theodolite surveying and conducted a topographical survey for obtaining topographical details of the site. There is one main fall which gives a total head of 33m. The possible location for diversion structure and power house are identified and the details are taken using tacheometric method of surveying.

### 5.2.2 Catchment area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Chakkimali water fall was located using the toposheet. It is shown in the **Fig.No.5.2** and it is measured the area which comes to nearly 1.5 sq.km. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 1 cumec.

### 5.2.3 Contour map

The tacheometric survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.5**.

### 5.2.4 River flow data

For a period of 12 months (January 98 to January 99) the water level observations were taken every week. A suitable location was located on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of that point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 5.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 5.3**.

### 5.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 5.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 5.2**. These data are used for calculating energy potential and selection of unit sizes in **section 5.4**.

### 5.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different

values obtained are shown in **Table 5.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 5.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumec	35.24	53.48	13.23	113.15

### 5.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But, a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 5.3.1 Power potential of the project

From the flow duration curve, the discharge corresponding to 80% of exceedence is only 0.002cubic metre per second. A discharge of 0.002 cubic metre per second can produce only about 0.5W. In order to tap the full potential of the site, with a head of 33 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 15 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (here it is assumed as 0.75)

For 40% exceedence  $P = 10 \times 0.07 \times 33 \times 0.75 = \mathbf{15.00 \text{ kW}}$ .

For 30% exceedence  $P = \mathbf{25 \text{ kW}}$ .

### 5.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 25kW power output for 30% of the time (110 days). The output reduces to 5kW if we take the percentage flow of exceedence as 50% (183 days). The energy input corresponding to 30% flow of exceedence will be  $(30/100 \times 25 \times 365 \times 24) = 0.066 \text{ MU}$ . The flow after 30% time can be utilized by providing a small pondage. The quantity of water available from 30% to 100% time is calculated to be  $575165\text{m}^3$ . Energy obtained from this water is 0.04 MU.

Total amount of energy produced =  $0.066 \text{ MU} + 0.04 \text{ MU} = \mathbf{0.106 \text{ MU}}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 5.3.3 Pondage requirement

From the contour map a plot of surface area vs. elevation is drawn in **Fig.No.5.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 5.4**. From this information, a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.5.6**.

**Table 5.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	499.5	0	0	
2	500	15.72	7.86	1
3	501	166.00	98.72	7
4	502	258.72	311.08	21
5	503	466.4	673.64	46

6	504	891.44	1352.53	100
7	505	1306.8	2451.68	169

As the terrain is suitable for storing 2450 m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 169 kWh. If a single 150 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 5.5 m, to create a storage of 2450 m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### 5.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted*

from a given site.

Let the capital cost of Chakkimali be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

This means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours, PCF =  $(3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 40 kW, which corresponds to about 19.23% flow of exceedence from the chart, the total energy yield is the sum of;

$40 \text{ kW} \times (0.19 \times 8760) = 0.067$  at continuous operation for 19.23% time of an year, and 0.073MU, which is the cumulative energy potential from 19.23% to 100% time as obtained from the Chart (Table 5.3).

Total yield =  $0.067\text{MU} + 0.073\text{MU} = 0.14 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 0.14 \times 10^8 / (40 \times 8760) = 39.9 \%$$

This PCF is equal to the break even value of 40%.

*So 40 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, For 50 kW (for 4% flow of exceedence)

$$\text{PCF} = (156000 / 50 \times 8760) \times 100 = 35.6\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 50 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 5.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	40 kW
Rs.3.00/ Unit	50 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt ( $0.025\text{MW} \times 1 + 0.015 \text{ MW} \times 1$ )

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( $0.05\text{MW} \times 1$ ).

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of

investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## **5.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a storage structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. The excess water during monsoon is allowed to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 3.5m x 5m.

### **5.5.1 Weir at Chakkimali**

A concrete overflow weir has been proposed on the Chakkimali stream, at a bed level of +499.000 metres. The base width of the weir at bed level is 4.25m. The diversion structure is 5.5m high having a length of 33.25m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and typical section of the storage structure are shown in **Fig.No. 5.7**.

### **5.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.36m. The penstock is designed for a maximum flow of 0.1616 cumec with a velocity of 1.6 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 105m (**Fig. No. 5.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards left bank of the stream. The power house is of size 3.5m x 5m to accommodate 40 kW generator and standardised turbine.

## **5.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 40kW. The system is designed as stand alone system and the energy generated shall be given to the near by houses by a separate transmission line. A standardised turbine for 33m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 40kW 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **5.7 ENVIRONMENTAL IMPACTS**

A micro hydel project has been proposed at Chakkimali (Idukki Dist.). The project aims to generate about 40 kW of hydro power from a fall having a head of 33 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **5.7.1. Environmental impact on land**

The catchment area measured from topo sheet comes to be 1.5 sq. km. After the fall the stream drains to Idukki reservoir. The fall is just 150m. away from reservoir. This area is an isolated one because of reservoir. No gridlines are available in this site. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **5.7.2 Water environmental impact on water**

The Chakkimalithodu, which drains to Idukki reservoir is the basin of this fall. The diversion structure will create a pond of area 0.1307 hectare. No forest land will be submerged. Above all, this accounts for only 3.27 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **5.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 6 months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **5.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 40kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 50kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **6 . NELLIKKAPPARA**

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**District** : Pathanamthitta  
**Panchayath** : Aruvappulam  
**Head** : 33 m.  
**Flow** : Seasonal  
**Suggested Capacity** : 100 kW/ 125 kW

## **6.1 GENERAL**

### **6.1.1 The Site**

The Nellikappara water fall is located in the X<sup>th</sup> ward of Aruvappulam Grama Panchayath in Pathanamthitta district. The site is at a distance of 17 km from Konni. Bus services are not available to the site. There is an unmetalled road to the site. Jeep services are available from Konni town except monsoon season. During rainy season there is another route to reach the site. From Konni to Kumannore, bus services are available. From there, jeep services are available to the site. The nearest 11KV transformer is about 12 km. away from the site.

The water fall is located at 76° 59' 3" E longitude and 9° 12' 21" N latitude. The catchment area measured from topo sheet is 0.50 sq.km. The falls are situated at an elevation of 260m from MSL in Kokkathodu stream which is beginning at an elevation of 940m from MSL. The stream flows through steep slopes. After the fall, the stream joins to the Achankovil Aar near Konni. The location map of the site is shown in **Fig.No.6.1**.

### **6.1.2 Topography**

The site is situated outside of the forest. Both sides of the stream is owned by private persons. The land is having medium slope in this area. There is no possibility of land slide and the chance of soil erosion is also negligible. The stream bed is rocky and boulders are available near to site. The number of rainy days exceeds 50% in its catchment.

## **6.2 FIELD INVESTIGATION**

### **6.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is two falls which gives a total head of 33m. The possible location for diversion structure and power house were identified and the details are taken using tacheometric method of surveying.

### **6.2.2 Catchment Area**

The catchment of Nellikappara site was located using the toposheet. It is shown in **Fig.No.6.2**. The total area of catchment is measured and it comes to **0.5 sq. km**. The catchment area having almost moderate slope but some portions are very steep.

### 6.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.6**.

### 6.2.4 River Flow Data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken every week. A suitable location was identified near the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 6.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 6.3**.

### 6.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 6.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 6.2**. These data are used for calculating energy potential and selection of unit sizes in **section 6.4**.

### 6.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 6.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 6.3**

### Peak Flow Determination

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	15.46	18.63	6.36	27.92

## 6.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But, a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated after consulting various agencies.

### 6.3.1 Power Potential of the Project

From the flow duration curve the discharge corresponding to 80% exceedence is only 0.006 cubic metre per second. A discharge of 0.006 cubic metre per second can produce only about 2 kW. In order to tap the full potential of the site, with a head of 33m., the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 43kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence P =  $10 \times 0.12 \times 33 \times 0.75 = 30 \text{ kW}$ .

For 40% exceedence P =  $10 \times 0.18 \times 33 \times 0.75 = 44.5 \text{ kW}$ .

For 30% exceedence  $P = 10 \times 0.3 \times 33 \times 0.75 = 75 \text{ kW}$ .

### 6.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 75 kW power output for 30% of the time (110 days). The output reduces to 25kW if we take the percentage flow of exceedence as 60%. The energy input corresponding to 30% flow of exceedence will be  $(30/100 \times 75 \times 365 \times 24) = 0.197 \text{ MU}$ . The flow after 30% time can be utilised by providing a small pondage. The quantity of water available from 30% to 100% time is calculated to be  $1634170 \text{ m}^3$ . Energy obtained from this water is  $0.112 \text{ MU}$ .

Total amount of energy produced  $= 0.197 \text{ MU} + 0.112 \text{ MU} = 0.309 \text{ MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 6.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 6.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 6.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 6.6**

**Table 6.4**  
**Pondage area details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	147.50	0	0	
2	148	8.00	2.00	0.1
3	149	52.00	32.00	2
4	150	133.00	124.50	9
5	151	330.00	353.00	24
6	152	562.00	802.00	55

As the terrain is suitable for storing  $802 \text{ m}^3$ , it follows that, at full storage, the energy capacity is only about  $55 \text{ kWh}$ . If a single  $50 \text{ kW}$  machine is installed, it can be operated for only one hour

at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4.5 m, to create a storage of 802 m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### 6.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even plant capacity factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Nellikappara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,  
 per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25  
 per Mega Watt revenue = 1000 kW x Rs. 2.5 x X  
 Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$   
 $X = 3,500 \text{ hrs.}$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$ .

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 100kW, which corresponds to about 11.5% flow of exceedence from the chart, the total energy yield is the sum of:

$100 \text{ kW} \times (0.115 \times 8760) = 0.10\text{MU}$  at continuous operation for 11.5% time of an year, and 0.26MU, which is the cumulative energy potential from 11.5% to 100% time as obtained from the Chart (**Table 6.3**).

Total yield =  $0.1\text{MU} + 0.26\text{MU} = 0.36\text{MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$PCF = 0.36 \times 10^8 / (550 \times 8760) = 41 \%$

This PCF is equal to the break even value of 40%.

*So 100 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, For 125 kW (for 5% flow of exceedence)

$$PCF = (3750000 / 125 \times 8760) \times 100 = 34.25\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 125 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 6.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Selected Units for Rs.3.5 Crores/MW
Rs.2.5/Unit	100 kW
Rs.3.00/ Unit	125 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.1MW x 1) or (0.05 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.1 MW x 1 + 0.025MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## 6.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake

structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of dimensions 10m x 5.5m.

### **6.5.1 Weir at Nellikappara**

A concrete weir has been proposed on the Kokkathodu stream, at a bed level of +147.50 metres. The base width of the weir at bed level is 3.7m. The diversion structure is 2.8m high having a length of 19.75m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and typical section of diversion structure are shown in **Fig.No. 6.7**.

### **6.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.54m. The penstock can carry a maximum flow of 0.404 cumec with a velocity of 1.76 metre per second. The possible alignment for the penstock is located on the right bank of the stream.

The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 141m (**Fig. No. 6.8**).

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is moderate. The power house proposed at this site is 10m x 5.5m, to accommodate 100 kW generator and standardised turbine.

## **6.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 100 kW. The electricity generated would be supplied to the near by houses by a separate distribution system. A standardised turbine for 33m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate a 11kV, three phases, 50Hz shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **6.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Nellikappara (Pathanamthitta Dist.) The project aims to generate about 100kW of hydro power from a fall having a head of 33m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **6.7.1 Environmental Impact on Land**

Total area of catchment is about 0.5 square kilometres of land at Kokkathodu. The stream flows through steep slopes. After the fall, the stream joins to the Achankovil Aar near to Konni.

The site is situated out side of forest. Both the banks of the stream are private land. One side is rubber plantation and other is habitation. The land is having medium slopes in this area. There is no possibility of land slide and the chances of soil erosion are also negligible. The stream bed is rocky and boulders are available near to site. The number of rainy days exceeds more than 50 % of the time.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **6.7.2 Environmental Impact on Water**

The Kokkathodu which joins Achankovil Aar is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.056 hectare. No forest land will be submerged. Above all, this accounts for only 0.56 ha/MW. This diversion structure which also

acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **6.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of twelve months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **6.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse effect is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 100kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 125kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **7. UPPUTHODU KUTHU**

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**District : Idukki**  
**Panchayath : Mariyapuram**  
**Head : 33 m.**  
**Flow : Perennial**  
**Suggested Capacity : 750 kW/ 1 MW**

## **7.1 GENERAL**

### **7.1.1 The Site**

Upputhodukuthu water fall is situated in the II<sup>nd</sup> ward of Mariyapuram Grama Panchayath in Idukki district. The site is at a distance of nearly 6km. from Karimban which is one of the main junction in Kothamangalam- Kumali route. There is bus route from Karimban to Murikkassery. To reach the site we have to get down at Chali city in this route. From there we have to travel nearly 1km distance to reach the site through a motorable unmetalled road going to Koomankandam. The nearest 11KV transformer is just 100 m. away from the site.

The water fall is located at 77° 0' 10" E longitude and 9° 53' 0" N latitude. The catchment area measured from topo sheet is 15 sq. km. The falls are situated at an elevation of 560m from MSL in Upputhodu stream which begins at an elevation of 900m from MSL. It is flowing almost straight through the fern shaped catchment area. After the fall, the stream joins to the Ponnazhikuthu which then drains into Periyar river. The location map of the site is shown in **Fig.No.7.1.**

### **7.1.2 Topography**

The site is situated out side the forest. Both banks of this stream is rubber plantation. The land is having moderate slopes in this area. There is no possibility of land slide in this area and possibility of soil erosion is negligible. The site gets heavy rainfall more than half of the year. The sides of the stream is mainly of loose earth.

## **7.2 FIELD INVESTIGATION**

### **7.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 33m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **7.2.2 Catchment Area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Upputhodukuthu was located using the toposheet. It is shown in the **Fig.No. 7.2**

and measured the area which comes nearly **15 sq.km**. The catchment area having almost moderate slopes but some portions are very steep.

### **7.2.3 Contour Map**

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.7**.

### **7.2.4 River Flow Data**

For a period of 12 months (April 1998 to April 1999) the water level observations were taken every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 7.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 7.3**.

### **7.2.5 Flow Duration Curve**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 7.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 7.2**. These data are used for calculating energy potential and selection of unit sizes in **section 7.4**.

### **7.2.6 Peak Flow Determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 7.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design.

**Table 7.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	198.17	366.08	61.43	533.78

### 7.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated after consulting various agencies.

#### 7.3.1 Power Potential of the Project

From the flow duration curve the discharge corresponding to 90% exceedence is only 0.02 cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 5kW. In order to tap the full potential of the site, with a head of 33 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 450 kW with a dependability of 40%. This is done because by 60% time, the power drastically reduces to 15kW.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 1 \times 33 \times 0.75 = 250 \text{ kW}$ .

For 40% exceedence  $P = 10 \times 1.82 \times 33 \times 0.75 = 450 \text{ kW}$ .

For 30% exceedence  $P = 10 \times 2.16 \times 33 \times 0.75 = 535 \text{ kW}$ .

### 7.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 500kW power output for 30% time (110 days) which drastically reduces to 20 kW by 60% time. The energy input corresponding to 30% time will be  $(30/100 \times 500 \times 365 \times 24) = 1.314 \text{ MU}$ . The flow after 30% time can be utilized by providing a small pondage. The quantity of water available from 30% to 100% time is calculated to be  $11998022 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.825 \text{ MU}$ .

Total amount of energy produced =  $1.314 \text{ MU} + 0.825 \text{ MU} = 2.139 \text{ MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 7.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No.7.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 7.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 7.6**.

**Table 7.4**  
**Pondage Area Details**

Sl. No.	Elevation(m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	497.50	0	0	0
2	498	28.00	7.00	0.48
3	499	203.00	122.50	8
4	500	390.00	419.10	29
5	501	662.00	945.00	65
6	502	796.00	1674.00	115

As the terrain is suitable for storing  $1674\text{m}^3$ , it follows that, at full storage, the energy capacity is

only about 115kWh. If a single 100 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4.5 m, to create a storage of 1674m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### 7.4 SELECTION OF PLANT CAPACITY UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Upputhodukuthu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

This means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during the same year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 750 kW, which corresponds to about 15% flow of exceedence from the chart, the total energy yield is the sum of:  $750 \text{ kW} \times (0.15 \times 8760) = 0.986$  at continuous operation for 15% time of an year, and 1.67MU, which is the cumulative energy potential from 15% to 100% time as obtained from the Chart (**Table7.3**).

Total yield = 0.986MU + 1.67 MU = 2.67 MU.

The plant capacity factor, corresponding to this yield is given by :

$$PCF = 2.67 \times 10^8 / (550 \times 8760) = 40.6 \%$$

*This PCF is equal to the break even value of 40%.*

*So 750 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, For 1000 kW (for 5% flow of exceedence)

$$PCF = (2860000 / 1000 \times 8760) \times 100 = 32.6\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 1000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 7.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Units size for Rs.3.5 Crores/MW
Rs.2.5/Unit	750 kW
Rs.3.00/ Unit	1000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MW x 1 + 0.25MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.5MWx2) or (0.5MWx1+0.25 x 2).

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## **7.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a diversion weir, intake structure, penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 7m x 5m.

### **7.5.1 Weir at Upputhodukuthu**

A concrete weir has been proposed on the Upputhodu stream, at a bed level of +497.75metres. The base width of the weir at bed level is 6.2 m. The diversion structure is 2.00m high having a length of 15.50m at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site and typical section of the diversion structures are shown in **Fig.No.7.7**.

### **7.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided on the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 1.3m. The penstock can carry a maximum flow of 3.03 cumec with a velocity of 2.28 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 147m (**Fig.No.7.8**).

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is moderate. The power house is of size 7m x 5m, to accommodate 750 kW generator and standardised turbine.

## **7.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 750 kW. The electricity generated would be connected to the existing power grid system at Chalicity by a 1km transmission line. A standardised turbine for 33m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 750kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **7.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Upputhodukuthu (Idukki Dist). The project aims to generate about 750 kW of hydro power from a fall having a head of 33m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **7.7.1 Environmental Impact on Land**

Total area of catchment is about 15 square kilometres of land at Upputhodu. After the fall, the stream joins to the Ponnazhikuthu then drains into Periyar river. The site is situated out of forest. Both banks of this stream is rubber plantation. The land is having moderate slope in this area. There is no possibility of land slide in this area and chances of soil erosion is also negligible. The site gets heavy rainfall more than half of the year. The sides of the stream is mainly of loose soil. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **7.7.2 Environmental Impact on Water**

The Upputhodu kuthu which finally drains to Periyar river is the stream of this fall. The diversion structure will create a pond of area 0.0796 hectare. No forest land will be submerged. Above all, this

accounts for only 0.105 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **7.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of eighteen months. It require only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **7.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse impacts anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 750kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **8 . URUMPALLU**

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**District : Idukki**  
**Panchayath : Arakkulam**  
**Head : 33 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 450 kW/ 750 kW**

## 8.1 GENERAL

### 8.1.1 The Site

Urumpallu water fall is situated in the IXth ward of Aarakkulam Grama Panchayath in Idukki district. To reach this site we have to travel 18km from Moolamattom to Kulamavu. Two kilometres away from Kulamavu there is a boat station. This route is a motorable, unmetalled road. After 20 minutes journey from Nellikappara boat station we will reach Peraanikkadavu. From Peraanikkadavu there exists a three kilometre long forest footpath which leads to the site. Also there is another route to reach the site. That is from Moolamattom to Urumpallu which is a lengthy jeepable route.

The water fall is located at  $76^{\circ} 56' 17''$  E longitude and  $9^{\circ} 46' 27''$  N latitude. The catchment area measured from topo sheet is 0.75 sq. km The falls are situated at an elevation of 760m from MSL, in Urumpallu stream which begins at an elevation of 1100m from MSL. After the fall the stream drains to Idukki reservoir. The location map of the site is shown in **Fig.No. 8.1**

### 8.1.2 Topography

The left bank of the stream is owned by private person and the right bank is forest. The land is having steep slopes in this area. There is no possibilities of land slide at this site but the chances of soil erosion exists. The site is perennial and number of rainy days exceeds 50% in its catchment.

## 8.2 FIELD INVESTIGATION

### 8.2.1 Reconnaissance Survey

A topographical survey was conducted for obtaining topographical details of the site. There are two falls which gives a total head of 33m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 8.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Urumpallu site was located using the toposheet. It is shown in **Fig.No.8.2**. The total area of catchment is measured and it comes to nearly **0.75 sq.km**. The catchment area is

having almost moderate slope but some portions are very steep.

### 8.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A. 8.**

### 8.2.4 River Flow Data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 8.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 8.3.**

### 8.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 8.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 8.2**. These data are used for calculating energy potential and selection of unit sizes in **section 8.4.**

### 8.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 8.3** The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 8.3**  
**Peak Flow Determination**

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Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	20.95	27.63	8.34	41.22

### 8.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But, a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated after consulting various agencies.

#### 8.3.1 Power Potential of the Project

The discharge corresponding to 90% of exceedence is only 0.014 cubic metre per second. A discharge of 0.014 cubic metre per second can produce only about 3 kW. However it seen that much higher flows are available during 40% of the time with a discharge of 1.41m<sup>3</sup>/s. In order to tap the full potential of the site, with a head of 33m, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 290 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 0.54 \times 33 \times 0.75 = 135 \text{ kW.}$

For 40% exceedence  $P = 10 \times 1.18 \times 33 \times 0.75 = 290 \text{ kW.}$

For 30% exceedence  $P = 10 \times 1.18 \times 33 \times 0.75 = 325 \text{ kW.}$

### 8.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 350kW power output for 25% of the time (92days). The output reduces to 30kW if we take the percentage flow of exceedence as 60% (219 days). The energy input corresponding to 25% time will be  $(25/100 * 350 * 365 * 24) = 0.767$  MU. The flow after 25% time can be utilized by providing a small pondage. The quantity of water available from 25% to 100% time is calculated to be 10265270 m<sup>3</sup>. Energy obtained from this water is 0.71 MU.

Total amount of energy produced = 0.767 MU + 0.71 MU = **1.48 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 8.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 8.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 8.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.8.6**.

**Table 8.4**  
**Pondage area details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	132.5	0	0	0
2	133	38.52	9.63	0.66
3	134	150.20	103.99	7
4	135	410.60	384.39	26
5	136	580.00	879.99	61
6	137	728.72	1534.35	105

As the terrain is suitable for storing 1500m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 105kWh. If a single 100 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4.5 m, to create a storage of 1500m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### 8.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan Repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Urumpallu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

$$\text{per Mega Watt revenue} = 1000 \text{ kW} \times \text{Rs. } 2.5 \times X$$

$$\text{Equating the two, we get } 3,50,00,000 \times 0.2.5 = X \times 1000 \times 2.5$$

$$X = 3,500 \text{ hrs.}$$

This means that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during the same year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $\text{PCF} = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where  $X=2916$  hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 450 kW, which corresponds to about 23% flow of exceedence from the chart, the total energy yield is the sum of:

$450 \text{ kW} \times (0.23 \times 8760) = 0.91\text{MU}$  at continuous operation for 23% time of an year, and 0.77MU, which is the cumulative energy potential from 23% to 100% time as obtained from the Chart (Table 8.3).

Total yield =  $1.53\text{MU} + 0.77\text{MU} = 1.68 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 1.68 \times 10^8 / (550 \times 8760) = 42.6 \%$$

This PCF is equal to the break even value of 40%.

*So 450 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, For 750 kW (for 16% flow of exceedence)

$$\text{PCF} = (2150000 / 750 \times 8760) \times 100 = 32.7\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 750 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 8.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	450 kW
Rs.3.00/ Unit	750 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt ( 0.25 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.50 MW x 1 + 0.25 x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## 8.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment.

### **8.5.1 Weir at Urumpallu**

A gabion weir has been proposed on the Urumpallu stream, at a bed level of +132.5 metres. The base width of the weir at bed level is 5m. The gabion structure is 4.10m high having a length of 14.50m at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site and typical section of diversion structure are shown in **Fig.No. 8.7.**

### **8.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 1.03m. The penstock can carry a maximum flow of 1.818 cumec with a velocity of 2.20 metre per second. The possible alignment for the penstock is located on the *right bank* of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and was calculated the length, which came to be 110m (**Fig.No.8.8**).

A surface power house is proposed on the *right bank* of the stream. The slope at the proposed site is moderate but increases up the hill towards south. The power house is of size 10m x 6.5m to accommodate 450 kW generator and standardised turbine.

## **8.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 450 kW. The system is designed as stand alone system and the energy generated would be given to the near by houses by a separate transmission line. A standardised turbine for 33m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety

devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 450kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **8.7 Environmental Impacts**

A small hydro project has been proposed at Urumpallu (Idukki Dist.) The project aims to generate about 450 kW of hydro power from a fall having a head of 33m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **8.7.1. Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 0.75 sq. km. After the fall the Urumpallu stream drains to Idukki reservoir. The land is having steep slopes in this area. There is no possibilities of land slide but chances of soil erosion exists a little. The sides of the stream has loose earth. The site is perennial and number of rainy days exceeds 50% in its catchment. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for this project.

### **8.7.2 Environmental Impact on Water**

The Urumpallu stream, which drains to Idukki reservoir is the stream of this fall. The diversion structure will create a pond of area 0.073 hectare. No forest land will be submerged. Above all, this accounts for only 0.162 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **8.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of one year. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **8.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 450kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 750kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of people's participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **9 . MADATHARUVI**

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**District : Pathanamthitta**

**Panchayath : Ranni**

**Head : 50 m.**

**Flow : Seasonal**

**Suggested  
Capacity : 75 kW/ 150 kW**

## **9.1 GENERAL**

### **9.1.1 The site**

Madatharuvi water fall is situated in 9th ward of Ranni Grama Panchayath in Pathanamthitta District. The site is a distance of 7 km from Ranni. There is a bus route from Ranni to Mandamaruthy. From Mandamaruthy, there is no bus service to the site. There is a road leading to a private rubber plantation through the upstream side of the fall. There is another way to reach the down stream side of the site. From Ranni to Chellakkad, bus services are available. From there jeep services are available to Madatharuvi. The stream is seasonal and the head comes near to 50m. The nearest 11kV transformer is about 0.5km from the site.

The water fall is located at  $76^{\circ} 48' 53''$  E longitude and  $9^{\circ} 25' 30''$  N latitude. The catchment area measured from topo sheet is 4.31sq. km The falls are situated at an elevation of 80m from MSL in Madatharuvi stream which begins at an elevation of 287 m. from MSL. The stream falls through moderate slope on the upstream side and gentle after the fall. The site contains two small falls and one moderate. After the fall, the stream joins the Pampa river. The upstream of the fall is rubber plantation. **(Fig. 9.1).**

### **9.1.2 Topography**

The site is situated in private land. One side is owned by Rubber Board and other side by private persons. The land is having moderate slope in this area. There is no land slide occurred in this area on past time and the possibility also very less. The chances of soil erosion are negligible. The bed of the stream is rocky and the boulders are available in plenty at the site. The number of rainy days exceeds 50% in its catchment.

## **9.2 FIELD INVESTIGATION**

### **9.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying. There is 3 main falls which gives a total head of

50m.

### 9.2.2 Catchment area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Madatharuvi site was located using the toposheet. It is shown in **Fig.No.9.2**. The total area of catchment is measured and it comes to nearly **4.31sq.km**. The catchment area is having almost moderate slope but some portions are very steep.

### 9.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:400. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.9**.

### 9.2.4 River flow data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken every week. A suitable location was identified on the downstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for the calculating stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 9.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. 9.3**.

### 9.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 9.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 9.2**. These data are used for calculating energy potential and selection of unit sizes in **section 9.4**.

### 9.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 9.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 9.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	77.81	138.29	26.76	196.75

### 9.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But, a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 9.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 70% is only 0.001 cubic metre per second. A discharge of 0.001cubic metre per second can produce only about 0.325 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 43 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 75 kW with a dependability of 24% (88 days).

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;  $P =$  Power output in kW

$Q =$  Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 24% exceedence  $P = 10 \times 0.215 \times 43 \times 0.75 = 75 \text{ kW.}$

For 50% exceedence  $P = 10 \times 0.054 \times 43 \times 0.75 = 17 \text{ kW.}$

For 40% exceedence  $P = 10 \times 0.102 \times 43 \times 0.75 = 35 \text{ kW.}$

For 30% exceedence  $P = 10 \times 0.192 \times 43 \times 0.75 = 60 \text{ kW.}$

### 9.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 75 kW power output for 24% of the time (88days) which drastically reduces to 15kW by 60% time. The energy input corresponding to 24% time will be  $(24/100 \times 75 \times 365 \times 24) = 0.1577 \text{ MU}$ . The flow after 24% time will be efficiently utilized by providing a small pondage. The quantity of water available from 24% to 100% time is calculated to be  $1335701 \text{ m}^3$ . Energy obtained from this water is calculated to be 0.12 MU

Total amount of energy produced =  $0.1577 \text{ MU} + 0.12 \text{ MU} = 0.277 \text{ MU}$ .

It may be noted that, this much amount of energy can generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 9.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No.9.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 9.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.9.6**.

**Table 9.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	98.50	0	0	0
2	99	4.0625	2.60	0.27
3	100	141.875	189.40	20

As the terrain is suitable for storing 190m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 140kWh. If a single 100 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 1.5 m, to create a storage of 190m<sup>3</sup> is suggested.

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

#### **9.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation

per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Madatharuvi be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs.2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%.**

For an installed capacity of 75 kW, which corresponds to about 24% flow of exceedence from the chart, the total energy yield is the sum of:

$75\text{kW} \times (0.24 \times 8760) = 0.1577$  at continuous operation for 24% time of an year, and 0.12MU, which is the cumulative energy potential from 24% to 100% time as obtained from the Chart (Table 3.3).

Total yield =  $0.1577\text{MU} + 0.12\text{MU} = 0.278 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 0.278 \times 10^8 / (75 \times 8760) = 42.3 \%$$

This PCF is equal to the break even value of 40%.

*So 75 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, For 150 kW (for 19% flow of exceedence)

$$\text{PCF} = (430000 / 150 \times 8760) \times 100 = 32.72\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 150 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 9.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit sizes for Rs.3.5 Crores/MW
Rs.2.5/Unit	75 kW
Rs.3.00/ Unit	150 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.025 MW x 3) or (0.05 MW x 1 + 0.025 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.025 MW x 2 + 0.05MW x 2) or (0.1MW x 1 + 0.05 MW x 1).

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## **9.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 6m x 5m.

### **9.5.1 Weir at Madatharuvi**

A gabion has been proposed on the Madatharuvi stream, at a bed level of +98.000metres. The base width of the weir at bed level is 5.2 m. The diversion structure is 1.5m high having a length of 10m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. 9.7**.

### **9.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided on the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.41m and the thickness of the penstock is found as 6mm. The penstock is designed for a maximum flow of 0.233 cumec with a velocity of 1.77 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which comes to 249m (**Fig. No. 9.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site

is moderate but increases up the hill towards north east direction. The power house is of size 6m x 5m, to accommodate 75kW, generator and standardised turbine.

## **9.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 75 kW. The electricity generated would be connected to the existing power grid system at Mandamaruthi by a 500m transmission line. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 75kW, 11kV three phases, 50 Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **9.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Madatharuvi (Pathanamthitta Dist.). The project aims to generate about 75 kW of hydro power from a fall having a head of 43 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **9.7.1 Environmental impact on land**

The catchment area measured from toposheet comes to be 4.31sq. km. The stream falls through moderate slope on the upstream side and gentle after the fall. The site contains two small falls and one moderate fall. After the fall, the stream joins to the Pampa river. The upstream side of the fall is rubber plantation. The site is situated in private land. One side is owned by Rubber Board and other side by private persons. The land is having moderate slope in this area. There is no land slide occurred in this area on past time and the possibility also very less. The chances of soil erosion is negligible. The bed of the stream is rocky and the boulders are available in plenty at the site. The number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **9.7.2 Environmental impact on water**

The Kanjirappuzha, which drains to Pampa river is the stream of this fall. The diversion structure will create a pond of area 0.0142ha. No forest land will be submerged. Above all, this accounts for only 0.19 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **9.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **9.8 CONCLUSION**

The environmental impact of that small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area. The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 75 kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 150kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **10. KALLIMALI**

**District : Idukki**  
**Panchayath : Rajakkad**  
**Head : 43 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 200 kW/ 450 kW**

## **10.1 GENERAL**

### **10.1.1 The site**

Kallimali water fall is situated in the 3rd ward of Rajakkad Grama Panchayath in Idukki district. The site is at a distance of 3.5 km from Rajakkad. There is a bus route from Rajakkad to Ambalakkavala stop (2km from Rajakkad) on the Rajakkad-Adimali main road. From Ambalakkavala 1.5km motorable road exists up to the upstream of the fall. 11kV transformer is at 1.5km. away from the site.

The water fall is located at  $77^{\circ} 5' 26''$  E longitude and  $9^{\circ} 6' 42''$  N latitude. The catchment area measured from topo sheet is 4.75 sq.km. The falls are situated at an elevation of 920m from MSL in Kallimali stream which is beginning at an elevation of 1060 from MSL. The upstream side of the fall is paddy field. The stream falls vertically and flows through steep sloped terrain and drains to the Ponmudi reservoir. The location map of the site is shown in **Fig .10.1**.

### **10.1.2 Topography**

The site is situated outside the forest area. The land is having gentle slope at the upstream side and steep slopes towards downstream. Possibility for land slide and soil erosion is negligible. The bed of the stream is rocky on the upstream side of the fall. The number of rainy days exceeds 50% in its catchment.

## **10.2 FIELD INVESTIGATION**

### **10.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 50m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **10.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Kallimali was located using the toposheet. It is shown in the **Fig.No.10.2**. The

total area of catchment is having almost moderate slope but some portions are very steep and its area found to be 4.75 sq.km.

### 10.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A 10**.

### 10.2.4 River flow data

For a period of 12 months (March 1997 to April 1998) the water level observations were taken every week. A suitable location was identified on the downstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for the calculating stream discharge. We fixed a measuring gauge at that point to measure the peak flow.

Using the collected data (**Table 10.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. 10.3**.

### 10.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 10.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 10.2**. These data are used for calculating energy potential and selection of unit sizes in **section 10.4**.

### 10.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 10.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 10.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	83.6	150.1	28.54	213.32

### 10.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project. But a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 10.3.1 Power potential of the project

The discharge corresponding to 80% exceedence is only 0.015 cubic metre per second. A discharge of 0.015 cubic metre per second can produce only about 5 kW. In order to tap the full potential of the site, with a head of 43 metre, the project is designed to generate higher output with lower dependability. The site can be designed as a run of the river project, which can produce 300 kW for with a dependability of 25%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.075 \times 43 \times 0.75 = 24 \text{ kW}$

For 40% exceedence  $P = 10 \times 0.245 \times 43 \times 0.75 = 75 \text{ kW}$

For 30% exceedence  $P = 10 \times 0.73 \times 43 \times 0.75 = 235 \text{ kW}$

#### 10.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 300kW power output for 25% of the time (91days). The output reduces to 16kW if we take the percentage flow of exceedence as 60% (219 days). The energy input corresponding to 25% flow of exceedence will be  $(25/100*300*365*24) = 0.657$  MU. The flow after 25% time can be utilized by providing a small pondage. The quantity of water available from 25% to 100% time is calculated to be 3734640 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.334 MU.

Total amount of energy produced = 0.657 MU + 0.334 MU = **0.991 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 10.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 10.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 10.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.10.6**.

**Table 10.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	495.50	0	0	0
2	496	3.48	0.87	0.07
3	497	13.00	9.11	1
4	498	44.00	37.61	3
5	499	259.92	189.57	17

As the terrain is suitable for storing 190m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 15kWh. If a single 15 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 3.5 m, to create a storage of 190m<sup>3</sup> is suggested.

#### 10.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Kallimali kuthu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue  $= 1000 \text{ kW} \times \text{Rs. } 2.5 \times X$

Equating the two, we get  $3,50,00,000 \times 0.2.5 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $\text{PCF} = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where  $X=2916$  hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%.**

For an installed capacity of 300 kW, which corresponds to about 24% flow of exceedence from the chart, the total energy yield is the sum of:

$200 \text{ kW} \times (0.3 \times 8760) = 0.526$  at continuous operation for 30% time of an year, and 0.203MU, which is the cumulative energy potential from 30% to 100% time as obtained from the Chart (Table 10.3).

Total yield =  $0.526\text{MU} + 0.203\text{MU} = 0.73 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 0.73 \times 10^8 / (200 \times 8760) = 41.7 \%$$

This PCF is equal to the break even value of 40%.

*So 200 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, For 450 kW (for 21% flow of exceedence)

$$\text{PCF} = (1300000 / 450 \times 8760) \times 100 = 32.9\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 450 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 10.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	200 kW
Rs.3.00/ Unit	450 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.05MW x 4) or ( 0.1 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.20 MW x 2 + 0.05MW x 1) or (0.250MW x 2)

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 10.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 6m x 3.5m.

### 10.5.1 Weir at Kallimali

A concrete weir has been proposed on the Kallimali stream, at a bed level of +496.000metres. The base width of the weir at bed level is 3.5m. The structure is 1.5m high having a length of 11.25m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and a typical section of the structure are shown in **Fig. No. 10.7.**

### 10.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.63 m. The penstock can carry a maximum flow of 0.62 cumec with a velocity of 2 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which comes to 127.5m (**Fig.No.10.10**). A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 6 m x 3.5 m, to accommodate 200 kW, generator and standardised turbine.

## 10.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 200kW. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 200kW, 11kV three

phases, 50 Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **10.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Kallimalikkuthu (Idukki Dist.). The project aims to generate about 200 kW of hydro power from a fall having a head of 43 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **10.7.1 Environmental impact on land**

The catchment area measured from topo sheet comes to be 4.75 sq. km. The upstream side of the fall is paddy field. The stream falls vertically and flows through steep slopes. After the fall, the stream joins to the Ponnudi reservoir. The site is situated outside the forest. The land is having gentle slope at the upstream side and steep slopes towards downstream. Possibility for land slide and soil erosion is negligible. The bed of the stream is rocky on the upstream side of the fall. The number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house will not take away any forest land. So no forest clearance is required for the project.

### **10.7.2 Environmental impact on water**

The Kallimali, which drains to Ponnudi Reservoir is the stream of this fall. The diversion structure will create a pond of area 0.026 hectare. No forest land will be submerged. Above all, this accounts for only 0.13 ha/MW.

### **10.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 12 months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **10.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 200kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 450kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **11 .GANDHI SMARAKAPPADY**

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**District : Idukki**  
**Panchayath : Kanjikkuzhy**  
**Head : 43 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 150 kW/ 250 kW**

## **11.1 GENERAL**

### **11.1.1 The site**

Idukki district is blessed with a number of water falls. Most of them are potential sites for small hydropower generation. The Gandhi Smarakappady water fall is in the 4th ward of Kanjikkuzhy Grama Panchayath in Idukki district. The site is at a distance of nearly 1.5 km from Chelachuvadu which is nearly 16 km. away from Cheruthony in Kumali-Kothamangalam route. The nearest 11KV line is just 1km from the site.

The water fall is located at 76° 57' 37" E longitude and 9° 55' 0" N latitude. The catchment area measured from toposheet is 1.13 sq.km. The falls are situated at an elevation of 480m from mean sea level (MSL) in Gandhi Smarakppady stream which begins at an elevation of 700m from MSL. After the fall, the stream joins to the Churulythodu and then draining to the Periyar river. The location map of the site is shown in **Fig.No.11.1**.

### **11.1.2 Topography**

The site is situated outside the forest. The land is having steep slopes in this area. From the previous history of site, it is clear that there is no possibility of land slide and the chances for soil erosion is negligible. The bed of the stream is rocky, there is a gross head of 43m. The number of rainy days exceeds 50% in its catchment.

## **11.2 FIELD INVESTIGATION**

### **11.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 50m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **11.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Gandhi Smarakappady was located using the toposheet. It is shown in the **Fig No. 11.2** and the area measured comes to nearly 1.13 sq.km. The catchment area is having almost

moderate slopes but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about **3.10 cumec**

### **11.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The prepared contour map is shown in **Annexure A.11**. The location of the weir, alignment of the penstock and location of the power house were determined using this contour map.

### **11.2.4 River flow data**

For a period of 12 months (December 1997 - December 1998) the water level observations were taken in every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 11.1**) the weekly discharge hydrograph of the site is prepared by plotting number of weeks against discharge. The graph is shown in **Fig. No. 11.3**.

### **11.2.5 Flow duration curve**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No.11.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 11.2**. These data are used for calculating energy potential and selection of unit sizes in **section 11.4**.

### **11.2.6 Peak flow determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 11.3** The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion

structure.

**Table 11.3**  
**Peak Flow Determination**

Parameters	Dicker=s method	Inglif=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	28.40	40.76	10.93	60.23

### 11.3 SALIENT DESIGN FEATURES

Design of any hydel projects means a detailed design of Civil works along with Electrical and Mechanical installation works. Usually for a small hydro scheme, the design is less complicated and easy. A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project. A typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated, after consulting various agencies.

#### 11.3.1 Power potential of the project

The discharge corresponding to 80% exceedence is only 0.005 cubic metre per second. A discharge of 0.005 cubic metre per second can produce only about 2 kW. In order to tap the full potential of the site, with a head of 43 metre, the project is designed to generate higher out put with lower dependability. This site can be designed as a run of the river project which can produce 50 kW with a dependability of 50 % and 100 kW with a dependability of 30 %. So we can use two 50kW machines for the site.

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;  $P =$  Power output in kW

$Q =$  Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.144 \times 50 \times 0.75 = \mathbf{50.00 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.257 \times 50 \times 0.75 = \mathbf{80 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 0.373 \times 50 \times 0.75 = \mathbf{120 \text{ kW}}$ .

### 11.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 100kW power output for 30% of the time (110 days) which reduces to 50kW by 50% time (183 days). The energy input corresponding to 30% time will be  $(30/100 \times 100 \times 365 \times 24) = 0.263 \text{ MU}$ . The energy input corresponding to 50% time will be  $((50-30)/100 \times 50 \times 365 \times 24) = 0.088 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $796547 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.0714 \text{ MU}$ .

Total amount of energy produced =  $0.263 \text{ MU} + 0.088 \text{ MU} + 0.0714 \text{ MU} = \mathbf{0.4224 \text{ MU}}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 11.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 11.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 11.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.11.6**.

**Table 11.4**  
**Pondage Area Details**

Sl. No.	Elevation(m)	Area (m <sup>2</sup> )	Capacity(m <sup>3</sup> )	Energy (kWh)
1	499	0	0	
2	500	57.00	28.60	3
3	501	140.00	127.80	11
4	502	223.00	308.50	28
5	503	329.00	384.30	34

As the terrain is suitable for storing 385 m<sup>3</sup>, it follows that at full storage, the energy capacity is only about 34 kWh. If a single 34 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4m, to create a storage of 385 m<sup>3</sup> is suggested.

#### **11.4 SELECTION OF PLANT CAPACITY AND UNIT SIZE**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine

tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Gandhi Smarakappadi be Rs.3.5 crores/MW. The annual rate is 25%.  
Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,  
per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25  
per Mega Watt revenue = 1000 kW x Rs. 2.5 x X  
Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$   
 $X = 3,500$  hrs.

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of ***Plant Capacity Factor***, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 550 kW, which corresponds to about 8% flow of exceedence from the chart, the total energy yield is the sum of:

$150 \text{ kW} \times (0.2 \times 8760) = 0.263 \text{ MU}$  at continuous operation for 20% time of an year, and 0.28MU, which is the cumulative energy potential from 20% to 100% time as obtained from the Chart (Table 11.3).

Total yield =  $0.263\text{MU} + 0.28\text{MU} = 0.543 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 0.543 \times 10^8 / (150 \times 8760) = 41.3 \%$$

This PCF is equal to the break even value of 40%.

*So 150 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 40%**

Similarly, For 250 kW (for 15% flow of exceedence)

$$\text{PCF} = (700000/250 \times 8760) \times 100 = 32\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 250 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 11.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	150 kW
Rs.3.00/ Unit	250 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.1MW x 1 + .05MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.1MW x 2+ 0.05 MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 11.5 CIVIL ENGINEERING WORKS

The important Civil Engineering structures required for the project are a diversion weir, an intake structure, a penstock and a power house. For this project which is designed as a run off the river system, only a diversion weir is proposed. This allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. A penstock made of steel is proposed for this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of one or two rooms.

### 11.5.1 Weir at Gandhi Smarakappady

A concrete weir has been proposed on the Gandhi Smarakappady stream, at a bed level of +499.000 metres. The diversion structure is 2m high having a length of 9.70m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and a typical section of the structure is shown in **Fig.No. 11.7**.

### 11.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided on the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.55m. The penstock can withstand a maximum flow of 0.465 cumec with a velocity of 1.95 metre per second. The possible alignment for the penstock is decided to be on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which comes to 113m. It is shown in **Fig. No. 11.8**.

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is gentle. The power house of size 10m x 6m is proposed to accommodate two numbers of 150 kW generator and standardised turbine.

## **11.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 150 kW. The electricity generated would be connected to the existing power grid system at Chelachuvadu by a 300m transmission line. A standardised turbine for 43m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 150 kW, 11 kV three phases having a frequency of 50 Hz and will be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment along with parallel operation equipment .

## **11.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Gandhi Smarakappadi (Idukki Dist). The project aims to generate about 150 kW of hydro power from a fall having a head of 43m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **11.7.1 Environmental impact on land**

Total area of catchment is about 1.13 square kilometres of land in Gandhi Smarakppady stream. The falls are situated in Gandhi Smarakppady stream which is beginning at an elevation of 700m from MSL. After the fall, the stream joins to the Churulythodu and finally draining to the Periyar river.

The site is situated out side of forest. The land is having steep slope in this area. From the previous history of site, it is clear that there is no possibility of land slide and the chances for soil erosion is negligible. The bed of the stream is rocky. There is an overall head of 43m. The number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **11.7.2 Environmental impact on water**

The Gandhi Smarakppady stream, which drains to Periyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.033 hectare. No forest land will be submerged. Above all, this accounts for only 0.22 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **11.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 12 months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **11.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area. The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 150kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 250kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **12. PATHINARAMKANDAM**

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<b>District</b>	<b>:Idukki</b>
<b>Panchayath</b>	<b>:Vathikudi</b>
<b>Head</b>	<b>: 43 m.</b>
<b>Flow</b>	<b>: Perennial</b>
<b>Suggested Capacity</b>	<b>: 350 kW/ 450 kW</b>

## **12.1 GENERAL**

### **12.1.1 The Site**

Idukki district is blessed with a number of water falls. Most of them are potential sites for small hydro power generation. The Pathinaramkandam water fall is situated in the Ist ward of Vathikudi Grama Panchayath in Idukki district. The site is at a distance of 2.50 km from Murikkassery. Bus services as well as jeep services are available to Murikkassery from Karimban. From Murikkassery, there is a jeepable road to Pathinaramkandam. The stream is perennial and it is situated outside of forest. The head available is about 43 m.

The water fall is located at 76° 59' 33" E longitude and 9°54' 30" N latitude. The catchment area measured from topo sheet is 15.56 sq. km. The falls are situated at an elevation of 560 m from MSL in Murikkassery thodu which is beginning at an elevation of 900 m from MSL. This is only one main fall in the stream. The upstream side of fall has moderate slope and it continues after the fall also. There is another fall on the upstream side of the stream which is known as Murikkasserikuthu. After the fall, the stream joins the Periyar river. The location map of the site is shown in **Fig.No.12.1**.

### **12.1.2 Topography**

Topography of any site means the description of the geographical details of the site. The site is situated outside the forest area. The land is having moderate slope in this area. There is no possibility of land slide in this area and the possibility of soil erosion is negligible. The bed of the stream is rocky and boulders are available near the site. The number of rainy days exceeds 50% in its catchment.

## **12.2 FIELD INVESTIGATION**

### **12.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 43m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 12.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Pathinaramkandam was located using the toposheet. It is shown in **Fig.No. 12.2** and its area was found to be 15.56 sq.km. The catchment area has moderate slopes.

### 12.2.3 Contour Map

The survey details were plotted on a sheet of paper to a scale of 1:500. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this contour map. The prepared contour map has been shown in **Annexure A.12**.

### 12.2.4 River Flow Data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken in every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point. Cross sectional details of the area were measured for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 12.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 12.3**.

### 12.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 12.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 12.2**. These data are used for calculating energy potential and selection of unit sizes in **section 12.4**.

### 12.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 12.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design.

**Table 12.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	203.72	375.67	62.96	548.94

### 12.3 DESIGN OF SMALL HYDEL PROJECT

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 12.3.1 Power Potential of the Project

From the flow duration curve the discharge corresponding to 100% is only 0.10 cubic metre per second. A discharge of 0.10 cubic metre per second can produce only about 35 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 43 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 150 kW with a dependability of 48%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times e$

Where;  $P =$  Power output in kW

$Q =$  Discharge in cumec

$H =$  Head in metres

$e =$  Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.44 \times 43 \times 0.75 \sim \mathbf{150 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.51 \times 43 \times 0.75 \simeq \mathbf{165 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 0.54 \times 43 \times 0.75 \simeq 175 \text{ kW}$ .

### 12.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 150kW power output for 48% of the time (175 days). The energy input corresponding to 48% time can be calculated to be  $(48/100 \times 150 \times 365 \times 24) = 0.631 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be  $3878928 \text{ m}^3$ . Energy obtained from this water is calculated to be 0.35 MU.

Total amount of energy produced =  $0.631 \text{ MU} + 0.35 \text{ MU} = 0.981 \text{ MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 12.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 12.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 12.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.12.6**.

**Table 12.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	600.25	0	0	0
2	601	183.60	68.85	6
3	602	388.80	355.05	32
4	603	718.60	908.75	81

As the terrain is suitable for storing  $900 \text{ m}^3$ , it follows that, at full storage, the energy capacity is only about 80 kWh. If a single 80 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 3m, to create a storage of  $900 \text{ m}^3$  is suggested.

## 12.4 SELECTION OF PLANT CAPACITY AND UNIT SIZE

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Pathinaramkandam be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours

can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs.3.5 Crores per Mega Watt where  $X=2916$  hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 350 kW, which corresponds to about 5% flow of exceedence from the chart, the total energy yield is the sum of  $350 \text{ kW} \times (0.05 \times 8760) = 0.153\text{MU}$  at continuous operation for 5% time of an year, and 1.16MU, which is the cumulative energy potential from 5% to 100% time as obtained from the Chart (Table 12.3).

Total yield =  $0.153\text{MU} + 1.16\text{MU} = 1.313 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 1.313 \times 10^8 / (350 \times 8760) = 42.8 \%$$

This PCF is equal to the break even value of 40%.

*So 350 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

#### **b. Tariff: Rs.3.0/kWh and break even PCF of 40%**

Similarly, For 450 kW (for 4% flow of exceedence)

$$PCF = (1388000 / 450 \times 8760) \times 100 = 35.2\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 450 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 12.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

<b>Tariff</b>	<b>Unit size for Rs.3.5 Crores/MW</b>
Rs.2.5/Unit	350 kW
Rs.3.00/ Unit	450 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.25MW x 1 + 0.1 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.25 MW x 2)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## **12.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 9m x 6m.

### **12.5.1 Weir at Pathinaramkandam**

A gabion weir has been proposed on the Murikkasserri thodu, at a bed level of +600.000 metres.

The diversion structure is 1.20 m high having a length of 6.40 m at the top with a central broad crested free over fall type spill way. The typical section of proposed structure is shown in **Fig.**

**No. 12.7.**

### **12.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.80 m. It is designed for a flow of 1.08 cumec with a velocity of 2.15 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which comes to 188 m (**Fig. No. 12.8**).

A surface power house is proposed on the left bank of stream. The slope at the proposed site is moderate but it increases in the south-east direction.

## **12.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 350 kW. The electricity generated would be connected to the existing power grid system at Pathinaramkandam by an 1 km transmission line. A standardised turbine for 50 m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 350kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **12.7 ENVIRONMENTAL IMPACTS**

A small hydro Project has been proposed at Pathinaramkandam (Idukki Dist). The project aims to generate about 350 kW of hydro power from a fall having a head of 43 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **12.7.1. Environmental Impact on Land**

Total area of catchment is about 15.56 square kilometres of land in Murikkasserythodu. The site is situated outside the forest. The land is having a moderate slope in this area. There is no possibility of land slide in this area and the possibility of soil erosion also negligible. Both banks of the land is owned by private persons. Stream sections are mostly rocky, large sized boulders are available. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **12.7.2 Environmental Impact on Water**

The Murikkasserythodu which drains to Periyar river is the stream of this fall. The diversion structure will create a pond of area 0.0718 hectare. No forest land will be submerged. Above all, this accounts for only 0.205 ha/MW. So no forest clearance is required.

### **12.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 12 months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **12.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 350kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 450kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **13 . THEKKUMTHONI**

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**District : Idukki**  
**Panchayath : Kanjikuzhi**  
**Head : 50 m.**  
**Flow : Perennial**  
**Suggested Capacity : 1MW/ 1.5MW**

## **13.1 GENERAL**

### **13.1.1 The Site**

Thekkumthoni water fall is situated in the 9th ward of Kanjikkuzhi Grama Panchayath in Idukki District. The site is a distance of 3 km from Venmani. There is a bus route from Chelachuvadu to Venmani. Jeep services are also available in the Chelachuvadu- Venmani route from Kanjikkuzhi. The Chelachuvadu is a main junction in Kothamangalam- Idukki route. From Venmani there is a motorable road to Thekkumthoni site. The stream is perennial and the head available is about 50m. There is no power supply to the site. The nearest 11kV line is about 7 km from the site.

The water fall is located at  $76^{\circ} 51' 55''$  E longitude and  $9^{\circ} 57' 26''$  N latitude. The catchment area measured from topo sheet is 22.25 sq. km. The falls are situated at an elevation of 360m from MSL, in Thekkumthoni stream which begins at an elevation of 1192m from MSL. There are two falls which give a total head of 50m. The upstream side of the fall is moderate slope and it is continuous after the fall also. After the fall, the stream joins the Kaliar puzha which drains to Moovattupuzha.

### **13.1.2 Topography**

The site is situated outside the forest area. But one side of the stream is owned by private persons. The forest is very thick. The land has a steep slope in this area. There is no possibility of land slides in this area and the possibility of soil erosion is negligible. The bed of the stream is rocky and boulders are available in plenty at the site. The stream is perennial and the number of rainy days exceeds 50% in its catchment.

## **13.2 FIELD INVESTIGATION**

### **13.2.1 Reconnaissance Survey**

Before starting the topographical survey we walked through the project area, which gave an overall idea of the site and its principal features. Possible instrument stations were located for the theodolite surveying and a topographical survey was conducted for obtaining topographical details of the site. There are two main falls which give a total head of 50m. The possible location for diversion structure and power house were identified and the details were taken using tachometric method of surveying.

### 13.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Thekkumthoni was located using the toposheet. It is shown in the **Fig.No. 13.2**. From the shape it is identified as a fan shaped catchment and its area is found to be 22 25 sq.km. The catchment area having almost moderate slope but some portions are very steep.

### 13.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:500. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.13**.

### 13.2.4 River Flow Data

For a period of 12 months (December 97 to December 98) the water level observations were taken in every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 13.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 13.3**.

### 13.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 13.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 13.2**. These data are used for calculating energy potential and selection of unit sizes in **section 13.4**.

### 13.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different

values obtained are shown in **Table 13.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 13.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	266.36	478.95	79.9	717.38

### 13.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 13.3.1 Power Potential of the Project

The discharge corresponding to 70% exceedence is only 0.017 cubic metre per second. A discharge of 0.017 cubic metre per second can produce only about 6 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 50metre, the project is designed to generate higher output with lower dependability. Moreover, hydroelectric scheme are usually used as peak load station as the Thermal and other types of power plants are not easily shut down or start up. This site can be designed as a peak load station which can produce 500 kW for 3 hours duration of peak load with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

$P$  = Power output in kW

$Q$  = Discharge in cumec

$H$  = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.53 \times 50 \times 0.75 = 200 \text{ kW}$ .

For 40% exceedence  $P = 10 \times 1.4 \times 50 \times 0.75 = 525 \text{ kW}$

For 30% exceedence  $P = 10 \times 1.77 \times 50 \times 0.75 = 665 \text{ kW}$

### 13.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 500kW power output for 40% of the time (146 days) which reduces to 8kW by 70% time (256 days). The energy input corresponding to 40% time will be  $(40/100 * 500 * 365 * 24) = 1.75 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $4632410 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.484 \text{ MU}$ .

Total amount of energy produced =  $1.75 \text{ MU} + 0.484 \text{ MU} = 2.236 \text{ MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 13.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 13.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 13.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.13.6**.

**Table 13.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	476.50	0	0	0
2	477	97.50	24.375	3
3	478	385.00	265.625	28
4	479	1968.75	1442.50	150
5	480	3061.25	3957.60	412
6	481	3836.25	7406.25	771
7	482	4797.5	11723.00	1221
8	483	6647.50	17445.75	1817

As the terrain is suitable for storing 17450m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 1800 kWh. If a single 1800 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 6.5m, to create a storage of 17450m<sup>3</sup> is suggested.

### 13.4 SELECTION OF PLANT CAPACITY AND UNIT SIZE

For optimization of plant capacity, the following parameters were assumed.

- Rate of return on investment - 15%
- Loan repayment period - 10 years
- Average O/M cost - 2.5% of capital cost
- Resulting standard annual cost - 25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

- Tariff (per Unit) - Rs. 2.5 and 3.0 (Two cases)

- Investment cost (Rs.in Crores per MW) - Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Thekkumthoni be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of **Plant Capacity Factor**, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.5/kWh and break even PCF of 40%**

For an installed capacity of 1000 kW, which corresponds to about 20% flow of exceedence from the chart, the total energy yield is the sum of:

$1000 \text{ kW} \times (0.20 \times 8760) = 1.75$  at continuous operation for 20% time of an year, and 1.8MU, which is the cumulative energy potential from 20% to 100% time as obtained from the Chart (Table 13.3).

Total yield =  $1.75\text{MU} + 1.88\text{MU} = 3.55 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 3.55 \times 10^8 / (1000 \times 8760) = 40.5 \%$$

This PCF is equal to the break even value of 40%.

*So 1000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 1500 kW (for 15% flow of exceedence)

$$\text{PCF} = (4240000/1500 \times 8760) \times 100 = 32.25\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 1500 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 13.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

<b>Tariff</b>	<b>Unit size for Rs.3.5 Crores/MW</b>
Rs.2.5/Unit	1000 kW
Rs.3.00/ Unit	1500 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (1MW x 1 + 0.5 MW x 1).

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

### **13.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock is a pressure pipe which carries water to the turbine. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 7mx 4.5m.

#### **13.5.1 Weir at Thekkumthoni**

A concrete weir has been proposed on the Thekkuthoni stream, at a bed level of +476.500 metres. The base width of the weir at bed level is 5.55m. The structure is 2m high having a length of 1.50m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. No. 13.7**.

### **13.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 1.14m. The penstock is designed for a maximum flow of 2.67 cumec with a velocity of 1.38 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 216m (**Fig. No. 13.8**).

### **13.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 1000kW. The electricity generated would be connected to the existing power grid system at Kanjikkuzhi by a 300m transmission line. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 1000kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **13.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Thekkumthoni (Idukki Dist). The project aims to generate about 1000 kW of hydro power from a fall having a head of 50 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

#### **13.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 22.25 sq. km. The falls are situated in Thekkumthoni stream. There is two falls which gives a total head of 50m. The upstream side of the fall is moderate slope and it continuous after fall also. After the fall, the stream joins to the Kaliar puzha which drains to Moovattupuzha.

The site is situated in forest. But one side of the stream is owned by private persons. The forest is very thick. The land is having steeply sloping in this area. There is no possibility of land slides in this area and the possibility of soil erosion is also very less and is negligible. The bed of the stream is rocky and boulders are available in plenty at site. The site is perennial and number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **13.7.2 Environmental Impact on Water**

The Thekkumthoni stream which drains to Moovattupuzha is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.6647ha. No forest land will be submerged. Above all, this accounts for only 0.6647ha/MW this diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **13.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 50 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **13.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 1000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1500kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **14 . CHENGARA**

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**District : Pathanamthitta**

**Panchayath : Konni**

**Head : 50 m.**

**Flow : Seasonal**

**Suggested  
Capacity : 90 kW/ 100 kW**

## **14.1 GENERAL**

### **14.1.1 The site**

The Chengara water fall is situated in the 10th ward of Konni Grama Panchayath in Pathanamthitta district. The site is at a distance of 10 km from Pathanamthitta. There is bus service from Pathanamthitta to Chengara occasionally. The site is only about 400m from Chengara junction. We can reach there by walking 400 m. through a rubber plantation. The plantation is owned by R.P.G. Enterprises, Harrisons Malayalam Ltd. The nearest 11kV transformer is about 0.50km from the site.

The water fall is located at 76° 40' 47" E longitude and 9° 16' 18" N latitude. The catchment area measured from topo sheet is 0.88 sq. km. The falls are situated at an elevation of 60 m above MSL in Chengarathodu which is beginning at an elevation of 160m. above MSL. After the fall, the stream joins the Achankovil Aar. The location map of the site is shown in **Fig No.14.1.**

### **14.1.2 Topography**

The site is situated in private land is having medium slopes in this area. The possibility for land slide and chances of soil erosion are negligible. The bed of the stream is rocky in this area and the boulders are available near the site. The number of rainy days exceeds 50% on its catchment.

## **14.2 FIELD INVESTIGATION**

### **14.2.1 Reconnaissance survey**

A topographic al survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 50m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **14.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The

catchment of Chengara was located using the toposheet. It is shown in the **Fig.No.14.2** and the area found to be 0.88 sq.km. The catchment area is having almost moderate slope but some portions are very steep.

### 14.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.14**.

### 14.2.4 River flow data

For a period of 12 months (February 1998 to February 1999) the water level observations were taken in every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 14.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 14.3**.

### 14.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 14.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 14.2**. These data are used for calculating energy potential and selection of unit sizes in **section 14.4**.

### 14.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 14.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design.

**Table 14.3**  
**Peak Flow Determination**

Parameters	Dicken=s	Ingli=s	Ryve=s	Nawab Jung
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	method	formula	formula	Bahadur formula
Peak flow in cumecs	23.52	32.05	9.24	47.67

### 14.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated, after consulting various agencies.

#### 14.3.1 Power potential of the project

The discharge corresponding to 60% exceedence is only 0.008 cubic metre per second. A discharge of 0.008 cubic metre per second can produce only about 3kW. In order to tap the full potential of the site, with a head of 50metre, the project can be designed to generate higher output with lower dependability. This site is designed as a peak load station which can produce 50kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence P =  $10 \times 0.07 \times 50 \times 0.75 = 26 \text{ kW}$ .

For 40% exceedence P =  $10 \times 0.16 \times 50 \times 0.75 = 60 \text{ kW}$ .

For 30% exceedence P =  $10 \times 0.2 \times 50 \times 0.75 = 75 \text{ kW}$ .

#### 14.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 50kW power output for 40% of the

time (146 days) which reduces to 3kW by 60% time (219 days). The energy input corresponding to 40% time will be  $(40/100 * 50 * 365 * 24) = 0.175$  MU. The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $414015\text{m}^3$ . Energy obtained from this water is calculated to be 0.0858 MU.

Total amount of energy produced =  $0.175 \text{ MU} + 0.0858 \text{ MU} = \mathbf{0.261 \text{ MU}}$ .

It may be noted that, this much amount of energy can generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 14.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 14.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 14.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.14.6**.

**Table 14.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	199	0	0	
2	200	58.20	29.10	3
3	201	330.48	484.44	50
4	202	586.64	943.00	98
5	203	963.38	1718.01	179
6	204	1464.80	2832.10	295

As the terrain is suitable for storing 2830m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 300 kWh. If a single 300 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 5m, to create a storage of 2830m<sup>3</sup> is suggested.

#### 14.4 SELECTION OF PLANT CAPACITY AND UNIT SIZE

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even plant capacity factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Chengara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3/ unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 90 kW, which corresponds to about 11% flow of exceedence from the chart, the total energy yield is the sum of:

$90 \text{ kW} \times (0.11 \times 8760) = 0.0867$  at continuous operation for 11% time of an year, and 0.25MU, which is the cumulative energy potential from 11% to 100% time as obtained from the Chart (Table 14.3).

Total yield =  $0.087\text{MU} + 0.25\text{MU} = 0.332 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 0.332 \times 10^8 / (90 \times 8760) = 42.11 \%$$

This PCF is equal to the break even value of 40%.

*So 90 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 100kW (for 2% flow of exceedence)

$$PCF = (340000 / 100 \times 8760) \times 100 = 36.96\%$$

This PCF is not near to the break even value of 33%.

*Similarly, 100 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 14.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	90 kW
Rs.3.00/ Unit	100 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.05MW x 2 )

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.05 MW x 2)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 14.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of one or two rooms.

### 14.5.1 Weir at Chengara

A gabion weir has been proposed on the Chengara stream, at a bed level of +199.100 metres. The base width of the weir at bed level is 2.65 m. The structure is 5m high having a length of 22.50m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site and typical section are shown in **Fig.No. 14.7**.

### 14.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.41m. The penstock is designed for a maximum flow of 0.24 cumec with a velocity of 1.82 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated which came to 154m (**Fig. No. 14.8**). A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 5m\*4m, to accommodate 90kW, generator and standardised turbine.

## 14.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 90 kW. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 90 kW, 11kV three

phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **14.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Chengara (Pathanamthitta Dist). The project aims to generate about 90kW of hydro power from a fall having a gross head of 50 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **14.7.1 Environmental impact on land**

Total area of catchment is about 0.88 square kilometres of land at Chengarathodu. The site is situated in private land owned by Harrison Malayalam Ltd. and is having medium slopes in this area. The possibility for land slide and chances of soil erosion are negligible. The bed of the stream is rocky in this area and the boulders are available near the site. The number of rainy days exceeds 50% on its catchment. After the fall, the stream joins to the Achankovil Aar near to Konni.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **14.7.2 Environmental impact on water**

The Chengarathodu which joins Achankovil Aaris the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a water spread area of 0.1465 hectare. No forest land will be submerged. Above all, this accounts for only 1.63ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **14.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of nearly 12 months. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **14.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a merge area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 90kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 100kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial

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## **15. MURIKKASSERI**

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**District** : **Idukki**  
**Panchayath** : **Vathikkudi**  
**Head** : **50 m.**  
**Flow** : **Perennial**  
**Suggested Capacity** : **550 kW/ 650 kW**

## **15.1 GENERAL**

### **15.1.1 The Site**

Idukki District is blessed with a number of waterfalls. Most of them are promising sites for small hydel programme. Murikkassery water fall is a good one in 3<sup>rd</sup> ward of Vathikkudi Grama Panchayath in Idukki District. The site is at a distance of 1 km before Murikkassery town in the Murikkassery - Karimban route. Bus service as well as jeep services are available from Karimban to Murikkassery. The stream is perennial and it is situated outside the forest. The head available is about 50m.

The water fall is located at 77° 0' 13" E longitude and 9° 54' 19" N latitude. The catchment area measured from toposheet is 12 sq. km. The falls are situated at an elevation of 680m from Mean Sea Level (MSL) in Murikkasseri stream which is beginning at an elevation of 900m. This is one of the main falls in the stream. The upstream side of fall has gentle slope and it continues after the fall also. There is another fall on the downstream side which is known as Pathinaramkandom. There is a culvert on the upstream side of the fall. After the fall, the stream joins the Periyar river (**Fig.15.1**)

### **15.1.2 Topography of the Site**

From the topography it is inferred that the site is situated in private land. The land is having gentle slope in this area. The possibility of soil erosion are negligible. The bed of the stream is rocky and boulders are available in plenty at the site. The flow get through out the year. The site is perennial and number of rainy days exceeds 50% in its catchment.

## **15.2 FIELD INVESTIGATION**

### **15.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 50m. The possible location for diversion structure and power house were identified. The details were taken using tacheometric method of surveying.

### **15.2.2 Catchment Area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India . The

catchment of Murikkasseri was located using the toposheet. It is shown in the **Fig.No.15.2**. From the shape its catchment is identified as fan shaped and its area was found to be 12 sq.km. The catchment area is having an almost moderate slope but some portions are very steep.

### **15.2.3 Contour Map**

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.15**.

### **15.2.4 River Flow Data**

The water level observations were taken every week for a period of 12 months (January 98 to January 99). A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point. Cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 15.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 15.3**.

### **15.2.5 Flow Duration Curve**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 15.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 15.2**. These data are used for calculating energy potential and selection of unit sizes in **section 15.4**.

### 15.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 15.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 15.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	167.63	311.86	52.94	449.62

### 15.3 SALIENT DESIGN FEATURES

Design of any hydel projects means a detailed design of Civil works along with Electrical and Mechanical installation works. Usually for a small hydro scheme, the design is less complicated and easy. It has not been carried out in this report as it does not come under the purview of the project. A typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 15.3.1 Power Potential of the Project

The discharge corresponding to 98% exceedence is only 0.12 cubic metre per second. A discharge of 0.12cubic metre per second can produce only about 45kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 50 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project scheme which can produce 150kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.45 \times 50 \times 0.75 = \mathbf{150 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.51 \times 50 \times 0.75 = \mathbf{190 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 0.54 \times 50 \times 0.75 = \mathbf{200 \text{ kW}}$ .

### 15.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 150kW power output for 50% of the time (183 days) which drastically reduces to 60kW by 80% time (292 days). The energy input corresponding to 50% time will be  $(50/100 * 150 * 365 * 24) / = 0.723 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be 3130474 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.33 MU.

Total amount of energy produced = 0.723 MU + 0.33 MU = **1.05 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 15.3.3 Pondage Requirement

The site is very near to the main road. So the storage is not feasible for the site. As the terrain is not suitable for storage the structure proposed at this site is only for diverting water. Here we are proposing a run of the river system without any pondage.

## 15.4 SELECTION OF PLANT CAPACITY AND UNIT SIZE

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Murikkasseri be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of ***Plant Capacity Factor***, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 550 kW, which corresponds to about 8% flow of exceedence from the chart, the total energy yield is the sum of:

550 kW x (0.08 x 8760) = 0.3854 at continuous operation for 8% time of an year, and 1.53MU, which is the cumulative energy potential from 8% to 100% time as obtained from the Chart (Table 15.3).

Total yield = 1.53MU + 0.3854MU = 1.92 MU.

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 1.92 \times 10^8 / (550 \times 8760) = 40 \%$$

This PCF is equal to the break even value of 40%.

*So 550 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 650 kW (for 4% flow of exceedence)

$$\text{PCF} = (1950000/650 \times 8760) \times 100 = 34.25\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 650 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 15.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

<b>Tariff</b>	<b>Unit size for Rs.3.5 Crores/MW</b>
Rs.2.5/Unit	550 kW
Rs.3.00/ Unit	650 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MW x 1 + 0.05 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.5 MW x 1 + 0.1MW x 1 + 0.05 x1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs. 3.0/Unit.

## **15.5 CIVIL ENGINEERING WORKS**

The important structures required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. A penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 12.5m x 6.5m.

### **15.5.1 Weir at Murikkasseri**

A concrete weir has been proposed at the Murikkasseri stream, at a bed level of +697.500 metres. The base width of the weir at bed level is 5.55m. The structure is 2.00m high having a length of 5m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No. 15.6**.

### **15.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.65m and the thickness of the penstock is found as 6 mm. The penstock can withstand a maximum flow of 0.46 cumec with a velocity of 1.39 metres per second. The possible alignment for the penstock can be made on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to around 147m (**Fig. No. 15.7**).

A surface power house is proposed on the left bank of stream. The slope at the proposed site is moderate increasing upwards in the east direction. The power house is of size 12.5m\* 6.5 m to accommodate one 550 kW generator and standardised turbine.

### **15.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 550 kW. The electricity generated would be connected to the existing power grid system at Murikkassery by a 500m transmission line. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system and shall be rated to generate 550kW, 11kV three phases with a frequency of 50Hz and shall be suitable for coupling with turbine as described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **15.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Murikkasseri (Idukki Dist). The project aims to generate about 550 kW of hydro power from a fall having a head of 50 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **15.7.1 Environmental Impact on Land**

The catchment area measured from toposheet comes to be 12 sq. km. The falls are situated in Murikkasseri stream. This is one of the main falls in the stream. The upstream side of fall has gentle slope and it continues after the fall also. There is another fall on the downstream side which is known as Pathinaramkandom. There is a culvert on the upstream side of the fall. After the fall, the stream joins to the Periyar river.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **15.7.2 Environmental Impact on Water**

The Murikkasseri stream which drains to Periyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 1.0125 hectare. No forest land will be submerged. Above all, this accounts for only 0.34ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **15.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 25 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **15.8 CONCLUSION**

The environmental impact of small hydel project is negligible. No serious adverse impact is

anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 550kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 650kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## **16 . MANPILAVU**

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**District : Pathanamthitta**

**Panchayath : Chittar**

**Head** : **50 m.**

**Flow** : **Seasonal**

**Suggested  
Capacity** : **250 kW/ 400 kW**

## **16.1 GENERAL**

### **16.1.1 The site**

Monpilavu water fall is situated in the 6th ward of Chittar Grama Panchayath in Pathanamthitta District. The site is at a distance of 10km from Chittar. There is a bus route from Chittar to Vyattupuzha. From there jeep service are available to Monpilavu. Jeep service will get from Chittar also. The fall is 100m away from main road. The 11 kV transformer is about 1 km from site.

The water fall is located at  $76^{\circ} 56' 47''$  E longitude and  $9^{\circ} 17' 57''$  N latitude. The catchment area measured from toposheet is 3.25 sq. km. The falls are situated at an elevation of 200m from MSL, in Meenthalaruvi stream which begins at an elevation of 700m from MSL. The stream flows through steeply sloping on the upstream side of the fall and it contains two falls. After that the stream is flowing through gentle slope. After the fall, the stream joins the Pampa river (Fig.16.1)

### **16.1.2 Topography**

The site is situated in Chittar reserved forest. But one side of the fall is owned by private persons. The forest is very thick. The land is having moderate slope in this area. There is no possibility of land slide is very less. The chances of soil erosion are negligible. The bed of the stream is rocky in this area. Boulders are available in plenty at site. The number of rainy days exceeds 50% in its catchment.

## **16.2 FIELD INVESTIGATION**

### **16.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is two straight fall which gives a total head of 50m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **16.2.2 Catchment area**

The survey details were plotted on a sheet of paper at a scale of 1:200. The catchment of Manpilavu was located using the toposheet. It is shown in the Fig.No. 16.2. From the shape it is identified as a fern shaped catchment and its area was found to be 3.50 sq. km. The catchment

area is having almost moderate slope but some portions are very steep.

### 16.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.16**.

### 16.2.4 River flow data

For a period of 12 months (March 98 to March 99) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 16.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 16.3**.

### 16.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 16.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 16.2**. These data are used for calculating energy potential and selection of unit sizes in **section 16.4**.

### 16.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 16.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 16.3**

### Peak Flow Determination

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	62.93	108.20	22.16	154.79

## 16.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

### 16.3.1 Power potential of the project

The discharge corresponding to 76% exceedence is only 0.002 cubic metre per second. A discharge of 0.002cubic metre per second can produce only about 2 kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 50metre, the project is designed to generate higher output with lower dependability. This site can be designed as a peak load station which can produce 60 kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.167 \times 50 \times 0.75 = \mathbf{60 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.24 \times 50 \times 0.75 = \mathbf{90 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 0.39 \times 50 \times 0.75 = 145 \text{ kW}$ .

### 16.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 100kW power output for 35% of the time (128 days) which reduces to 8kW by 70% time (256 days). The energy input corresponding to 35% time will be  $(35/100 \times 100 \times 365 \times 24) = 0.307$  MU. The flow after 35% time can be utilized by providing a small pondage. The quantity of water available from 35% to 100% time is calculated to be 1629936 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.17MU.

Total amount of energy produced = 0.307 MU + 0.17 MU = **0.477 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 16.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 16.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 16.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No.16.6**.

**Table 16.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	294.5	0	0	0
2	295	3.08	0.77	0.08
3	296	15.8	10.21	1
4	297	86.4	196.01	20
5	298	183.00	196.01	20

As the terrain is suitable for storing 196m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 20 kWh. If a single 20 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean

months, this kind of operation practice is acceptable. Hence, a weir height of 3.5m, to create a storage of 196m<sup>3</sup> is suggested.

#### 16.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Manpilavu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.2.5 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where  $X=2916$  hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 250 kW, which corresponds to about 25% flow of exceedence from the chart, the total energy yield is the sum of:

$250 \text{ kW} \times (0.25 \times 8760) = 0.5475$  at continuous operation for 25% time of an year, and 0.314MU, which is the cumulative energy potential from 25% to 100% time as obtained from the Chart (Table 16.3).

$$\text{Total yield} = 0.5475\text{MU} + 0.314\text{MU} = 0.8615\text{MU.}$$

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 0.8615 \times 10^8 / (250 \times 8760) = 39.33 \%$$

This PCF is equal to the break even value of 40%.

*So 250 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 400 kW (for 19.5% flow of exceedence)

$$\text{PCF} = (1168000 / 400 \times 8760) \times 100 = 33.3\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 400 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 16.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	250 kW
Rs.3.00/ Unit	400 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.25MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.1 MW x 1 + 0.25MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores / MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 16.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 10m x 6.5m..

### **16.5.1 Weir at Manpilavu**

A concrete weir has been proposed on the Meenthalaruvi stream, at a bed level of +294.750 metres. The structure is 3.5m high having a length of 2.95m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. No. 16.7**.

### **16.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.63 m. The penstock is designed for a maximum flow of 0.667 cumec with a velocity of 0.85 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and the length was calculated, which came to 216m (**Fig. No. 16.8**).

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is gentle. The power house is of size 10m x 6.5m, to accommodate 250 kW, generator and standardised turbine.

## **16.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 250 kW. The electricity generated would be connected to the existing power grid system at Manpilavu by a 300m transmission line. A standardised turbine for 50m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 250kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **16.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Manpilavu (Pathanamthitta Dist.). The project aims to generate about 250 kW of hydro power from a fall having a head of 50 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **16.7.1 Environmental impact on land**

The catchment area measured from toposheet comes to be 3.25 sq. km. The stream flows through steep slopes on the upstream side of the fall and it contains two falls. After that the stream is flowing through gentle slope. After the fall, the stream joins to the Pampa river. The site is situated in Chittar reserved forest. But one side of the fall is owned by private persons. The forest is very thick. The land is having moderate slope in this area. There is no possibility of land slide is very less. the chances for soil erosion is very less and it is negligible. The bed of the stream is rocky in this area. Boulders are available in plenty at site. The number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **16.7.2 Environmental impact on water**

The Meenthalaruvi stream which drains to Pampa river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.0183hectare. No forest land will be submerged. Above all, this accounts for only 0.073 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **16.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of nearly 10 months. The peak labour strength is 25 skilled and 50 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

### **16.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No regions adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 250kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 400kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## 17. MUKKALI

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**District** : Palakkad  
**Panchayath** : Agali  
**Head** : 90 m.  
**Flow** : Seasonal  
**Suggested Capacity** : 650 kW/ 750 kW

## **17.1 GENERAL**

### **17.1.1 The Site**

Palakkad district has quite a number of water falls. Most of them are potential sites for small hydro power generation. Mukkaali water fall is situated in the 13th ward of Agali Grama Panchayath in Palakkad District. The site is a distance of 2 km before Mukkali on the way to Mannarkkad-Mukkaali road. There is a bus route from Mannarkkad to Aanakkatti through Mukkaali. The site is about 16 km away from Mannarkkad. The site is owned by forest department and it can be seen from the main road.

The water fall is located at  $75^{\circ} 32' 26''$  E longitude and  $11^{\circ} 2' 36''$  N latitude. The catchment area measured from topo sheet is 2.75 sq. km. The falls are situated at an elevation of 320m from MSL, in mukkali stream which is beginning at an elevation 700m. After the fall the stream flows through steeply sloping terrain and joins the Nellipuzha river which is drains to the Bharathapuzha (Fig 17.1).

### **17.1.2 Topography**

The site is situated in Mannarkkad reserved forest. The forest is very thick. The land is having moderate slope in this area. There is no possibilities for land slides in this area and the chances of soil erosion are negligible. The bed of stream is rocky and boulders are available in plenty at site. The site is perennial and number of rainy days exceeds 50% in its catchment.

## **17.2 FIELD INVESTIGATION**

### **17.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. Total head of the fall is 90m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 17.2.2 Catchment Area

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of Mukkali was located using the toposheet. It is shown in the **Fig.No. 17.2**. From the shape it is identified as a fan shaped catchment and it is measured which comes to nearly 2.75sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 2 cumec.

### 17.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:250. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.17**.

### 17.2.4 River Flow Data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 17.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 17.3**.

### 17.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 17.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 17.2**. These data are used for calculating energy potential and selection of unit sizes in **section 17.4**.

### 17.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 17.3**. The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 17.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	55.52	93.28	19.82	134.03

### 17.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 17.3.1 Power Potential of the Project

The discharge corresponding to 80% exceedence is only 0.05 cubic metre per second. A discharge of 0.05 cubic metre per second can produce only about 35 kW. However it seen that much higher flows are available during 40% of the time. In order to tap the full potential of the site, with a head of 90 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project, which can produce 350 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.42 \times 90 \times 0.75 = 285 \text{ kW}$ .

For 40% exceedence  $P = 10 \times 0.52 \times 90 \times 0.75 = 350 \text{ kW}$ .

For 30% exceedence  $P = 10 \times 0.65 \times 90 \times 0.75 = 445 \text{ kW}$ .

### 17.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 350kW power output for 40% of the time (146 days) which reduces to 27kW by 80% time (292 days). The energy input corresponding to 40% time will be  $(40/100 \times 350 \times 365 \times 24) = 1.226 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $1349900 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.256 \text{ MU}$ .

Total amount of energy produced =  $1.226 \text{ MU} + 0.256 \text{ MU} = 1.48 \text{ MU}$ .

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 17.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 17.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 17.4**. From this information, a capacity Vs elevation curve of the pondage is prepared and is shown in **Fig.No.17.6**.

**Table 17.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	499.50	0	0	0
2	500	86.80	21.70	4
3	501	192.40	161.30	30
4	502	294.00	404.50	76
5	503	365.60	734.25	138
6	504	433.00	1133.55	213
7	505	499.80	1599.95	300

As the terrain is suitable for storing 1600m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 300 kWh. If a single 300 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 5.5m, to create a storage of 1600m<sup>3</sup> is suggested.

#### 17.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Mukkali be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours, PCF =  $(3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per unit and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 650 kW, which corresponds to about 8% flow of exceedence from the chart, the total energy yield is the sum of.

$650 \text{ kW} \times (0.09 \times 8760) = 0.512$  at continuous operation for 8% time of an year, and 1.76MU, which is the cumulative energy potential from 9% to 100% time as obtained from the Chart (Table 17.3).

Total yield = 1.76MU + 0.512MU = 2.272 MU.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 2.272 \times 10^8 / (650 \times 8760) = 39.9 \%$$

This PCF is equal to the break even value of 40%.

*So 650 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, For 750 kW (for 4% flow of exceedence)

$$PCF = (2263000/650 \times 8760) \times 100 = 34.4\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 750 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 17.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	650 kW
Rs.3.00/ Unit	750 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MW x 1 + 0.1MW x 1 + 0.05 MWx1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 0.25 MW x 3)

Among these two categories, the first one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 17.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, intake structure, penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 15m x 8m

### 17.5.1 Weir at Mukkali

A concrete weir has been proposed on the Mukkali stream, at a bed level of +500.000 metres. The base width of the weir at bed level is 3.05m. The structure is 2.50m high having a length of 18.25m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No. 17.7**.

### 17.5.2 Intake Structure, Penstock and Power House

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.68m. The penstock can carry a maximum flow of 0.963 cumec with a velocity of 2.7 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 315m (**Fig. No. 17.8**).

A surface power house is proposed on the bank of the stream. The slope at the proposed site is gentle but increased upwards in the east direction. The power house is of size 15m\*8m, to accommodate 650kW generator and standardised turbine.

## 17.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 650 kW. The electricity generated would be connected to the existing power grid system at Mukkali by a 500m transmission line. A standardised turbine for 90m gross head is proposed for this particular site.

The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 650 kW, 11 kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **17.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Mukkali (Palakkad Dist). The project aims to generate about 650 kW of hydro power from a fall having a head of 90 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio - economical environmental impacts.

#### **17.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 2.75 square km. The falls are situated in Mukkali stream. After the fall the stream flows through steep sloped terrain and joins to the Nellipuzha river which is drains to the Bharathapuzha.

The site is situated in Mannarkkad reserved forest. The forest is very thick. The land is having moderate slope in this area. There is no possibilities for land slides in this area and the chances for soil erosion is very less and it is negligible. The bed of stream is rocky and boulders are available in plenty at site. The site is perennial and number of rainy days exceeds 50% in its catchment.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So o forest clearance is required for the project.

### **17.7.2 Environmental Impact on Water**

The Mukkali stream which joins to the Nellipuzha river which is drains to the Bharathapuzha is the stream of this fall. The diversion structure will create a pond of area 0.05 hectare. No forest land will be submerged. Above all, this accounts for only 0.077 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **17.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of nearly 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **17.8 CONCLUSION**

The environmental impact of the small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 650kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 750kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **18. ELAPPILLY**

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**District : Idukki**  
**Panchayath : Arakkulam**  
**Head : 90 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 850 kW/ 1 MW**

## **18.1 GENERAL**

### **18.1.1 The site**

The project site is at Elappilly, which is in the 2nd ward of Arakkulam Grama Panchayath in Idukki District. The site is a distance of 18 km from Moolamattom. Bus services are available to the site occasionally. The site is near by the road. The stream has nearly 10 months flow and the head is about 90m. The 11kV transformer is available at a distance of 2 km from the site.

The water fall is located at 76° 52' 0" E longitude and 9° 46' 38" N latitude. The catchment area measured from topo sheet is 3.88 sq.km. The falls are situated at an elevation of 160m from MSL, in Elappilly stream which is beginning at an elevation of 900m. This is one of the main fall in this stream. The down stream of the fall has steep slope and it contains so many small falls. After the fall the stream joins the Thodupuzha river which drains to the Moovattupuzha river (Fig.No. 18.1)

### **18.1.2 Topography of the site**

The site is situated in private land. The land has moderate slope in this area. The possibility of land slide is more in this area and the possibility of soil erosion is less in stream. The bed of the stream is rocky and boulders are available in plenty at site. The stream is a seasonal one and it has a head of 90m.

## **18.2 FIELD INVESTIGATION**

### **18.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. The total head of the site was found to be 85m. The position of the diversion structure and power house were identified and tacheometric method is used for surveying work.

### **18.2.2 Catchment area**

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of Elappilly was located using the toposheet. It is shown in the Fig.No.18.2. From the figure it is identified as a fan shaped catchment and it comes to nearly 3.88 sq.km. Peak value of flood will be less for this basin as the difference between concentration time and time at

which flow starts will be large. The volume of flow will be distributed through a larger length of time.

### 18.2.3 Contour map

The survey details were plotted on a sheet of paper at a scale of 1:200 (**Annexure A.18.**). The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and marked in the above map, along with the contours of the area.

### 18.2.4 River flow data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point and engaged a local person for taking weekly flow data, we also visited the site once in every month for collecting the data from the local person. From the collected data the weekly discharge is collected and make it into tabular form (**Table 18.1**) for weekly discharge graph preparation. The graph was shown in **Fig.No. 18.3**

### 18.2.5 Flow duration curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 18.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 18.2**. These data are used for calculating energy potential and selection of unit sizes in **section 18.4**.

### 18.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 18.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 18.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Inglis formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	71.81	126.16	24.92	179.79

### 18.3 SALIENT DESIGN FEATURES

The design of any hydro electric project can be divided into two. viz. Civil Engineering Works and Electrical & Mechanical Works. The design of civil engineering work in detail is presented in this chapter. A detailed design of Electrical and Mechanical work has not been carried out as it does not come under preview of the project. However, for the sake of cost estimation, required details are collected from various agencies.

#### 18.3.1 Power potential of the project

From the flow duration curve the discharge it is clear that flow corresponding to 80% is only 0.017 cubic metre per second. A discharge of 0.017 cubic metre per second can produce a power of only 11 kW. However it seen that much higher flows are available during 36.5% of the time. In order to tap the full potential of the site, with a head of 90 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 500 kW with a dependability of 36.5%.

The output power was computed using the formula,  **$P = 10 \times Q \times H \times h$**

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.22 \times 90 \times 0.75 = \mathbf{150 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.67 \times 90 \times 0.75 = \mathbf{445 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 1 \times 90 \times 0.75 = \mathbf{675 \text{ kW}}$ .

### 18.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 500kW power output for 38.5% of the time (133 days) which reduces to 8kW by 80% time (292 days). The energy input corresponding to 38.5% time will be  $(38.5/100 \times 500 \times 365 \times 24) = 1.69 \text{ MU}$ . The flow after 38.5% time can be utilized by providing a small pondage. The quantity of water available from 38.5% to 100% time is calculated to be  $2616365 \text{ m}^3$ . Energy obtained from this water is calculated to be 0.49 MU.

Total amount of energy produced =  $1.69 \text{ MU} + 0.49 \text{ MU} = \mathbf{2.18 \text{ MU}}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 18.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in (Fig.No. 18.5). These are corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in Table 18.4. From this information a capacity elevation curve of the pondage is prepared and is shown in Fig. 18.6. The height of weir was chosen based on the following considerations.

**Table No. 18.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	500.00	0	0	0
2	501	111.56	27.89	5
3	502	240.36	203.85	38
4	503	333.76	490.91	92
5	504	527.52	921.55	173
6	505	774.52	1572.57	295
7	506	1006.40	2463.03	462
8	507	1250.40	3591.43	673
9	508	1481.6	4957.43	930

As the terrain is suitable for storing 4950m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 900 kWh. If a single 900 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 8m, to create a storage of 4950m<sup>3</sup> is suggested.

#### **18.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine

tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Elappilly be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,  
 per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25  
 per Mega Watt revenue = 1000 kW x Rs. 2.5 x X  
 Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$   
 $X = 3,500$  hrs.

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.5/kWh and break even PCF of 40%**

For an installed capacity of 550 kW, which corresponds to about 8% flow of exceedence from the chart, the total energy yield is the sum of:

850 kW x (0.13 x 8760) = 0.97 at continuous operation for 13% time of an year, and 2.1MU, which is the cumulative energy potential from 13% to 100% time as obtained from the Chart (Table 17.3).

Total yield = 1.53MU + 2.1MU = **3.07 MU**.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 3.07 \times 10^8 / (550 \times 8760) = 41.2 \%$$

This PCF is equal to the break even value of 40%.

*So 850 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, For 1000 kW (for 4% flow of exceedence)

$$PCF = (3050000 / 650 \times 8760) \times 100 = 34.8\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 1000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 18.5**

**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	850 kW
Rs.3.00/ Unit	1000 kW

The units selected can be one of the following combinations:

For Rs.3.5Crores/MW and Rs.2.5/Unit we can opt (0.5MWx1 + 0.25MW x 1 + 0.1MWx1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.5MW x 1 + 0.25 MW x 2)

Among these two categories, the first one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## **18.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock is a pressure pipe which carries water to the turbine. It can be made of steel, cast iron, plastics (Poly Vinyl Chloride, High Density Poly Ethylene) and concrete. In this project a steel penstock is used. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of size 12.5mx 6m .

### **18.5.1 Weir at Elappilly**

A Gabion weir has been proposed on the Kanjirappuzha stream, at a bed level of +495.500 metres. The base width of the weir at bed level is 7.5 m. The structure is 4.50 m high having a length of 60 m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **(Fig. No. 18.7)**.

### **18.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.76m and the penstock can carry a maximum flow of 1.26 cumec with a velocity of 1.67 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 147m **(Fig. No. 18.8)**.

A surface power house is proposed on the left bank of the stream. The slope at the proposed site

is moderate but increases up the hill towards north east direction. The power house is of size 12.5 m x 6.5m to accommodate 850 kW, generator and standardised turbine.

### **18.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 850 kW. The electricity generated would be connected to the existing power grid system by a 300m transmission line. A standardised turbine for 90m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 850kW 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **18.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Elappilly (Idukki Dist.). The project aims to generate about 850 kW of hydro power from a fall having a head of 90 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

#### **18.7.1 Environmental impact on land**

The catchment area measured from toposheet comes to be 3.88sq.km. The falls are in Elappilly stream. This is one of the main fall in this stream. The down stream side of the fall has steep slope and it contains so many small falls. After the fall the stream joins to the Thodupuzha river which drains to the Moovattupuzha river. The site is situated in private land. The land has moderate slope in this area. The possibility of land slide is more in this area and the possibility of soil erosion is less in stream. The bed of the stream is rocky and boulders are available in plenty at site. The stream is a seasonal one and it has a head of 90m.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **18.7.2 Environmental impact on water**

The Elappilly stream, which finally drains to Moovattupuzha river is the stream of this fall. The diversion structure will create a pond of area 0.1481hectare. No forest land will be submerged. Above all, this accounts for only 0.174 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **18.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **18.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 850kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **19. VALARA**

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**District : Idukki**  
**Panchayath : Adimali**  
**Head : 90 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 7MW/ 10MW**

## **19.1 GENERAL**

### **19.1.1 The Site**

Valarakuthu is a scenic water fall situated in the 1st ward of Adimali (Mannamkandom) Grama Panchayath in Idukki District. The site is at a distance of 18 km before Adimali in Kothamangalam-Adimali route. There is a bus route from Kothamangalam to Adimali through Valara. The site is near to the main road. It can be see from the road. The stream is a seasonal one, but it has more discharge in rainy season because of its large catchment.

The water fall is located at 76° 50' 25" E longitude and 10° 2' 44" N latitude. The catchment area measured from topo sheet is 63.00 sq.km The falls are situated at an elevation of 460m from MSL, in Deviar stream which is beginning at an elevation of 1000m from MSL. This is one of the main fall in this stream. The stream has more falls on its upstream side. The head comes to 90m nearly. The stream flows through medium slopes on the up stream as well as down stream of the fall. After the fall, the stream joins the Periyar river (**Fig.19.1**).

### **19.1.2 Topography**

The site is situated in forest. The land is having steep slopes in this area. The possibility of land slide is more in this site. Land slides are occurred in monsoon seasons. Soil erosion is also high in this stream. The bed of the stream is rocky and boulders are available in plenty at site. The stream has nearly 10 months flow and the head of the stream has 90m. The number of rainy days exceeds 50% in its catchment.

## **19.2 FIELD INVESTIGATION**

### **19.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 90m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 19.2.2 Catchment Area

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of Valarakuthu was located using the toposheet. It is shown in the **Fig.No.19.2**. From the shape it is identified as a fan shaped catchment and it comes to 63.00 sq.km. The catchment area is having almost steep slopes. Maximum flood discharge measured at this site during 1998 is about 40.16 cumec.

### 19.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.19**.

### 19.2.4 River Flow Data

For a period of 12 months (January 98 to January 99) the water level observations were taken every week. A suitable location was identified on the up stream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 19.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 19.3**.

### 19.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 19.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 19.2**. These data are used for calculating energy potential and selection of unit sizes in **section 19.4**.

### 19.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 19.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion

structure.

**Table 19.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	581.4	904.48	159.91	1494.59

### 19.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 19.3.1 Power Potential of the Project

The discharge corresponding to 80% exceedence is only 0.009cubic metre per second. A discharge of 0.009cubic metre per second can produce only about 6 kW. However it seen that higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 90metre, the project is designed to generate higher output with lower dependability. This site can be designed a s a run of the river project which can produce 3400kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence

$$P = 10 \times 1.87 \times 90 \times 0.75 = \mathbf{1250 \text{ kW.}}$$

For 40% exceedence  $P = 10 \times 5.08 \times 90 \times 0.75 = 3400 \text{ kW}$ .

For 30% exceedence  $P = 10 \times 8.7 \times 90 \times 0.75 = 5500 \text{ kW}$ .

### 19.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 3400kW power output for 40% of the time (146 days) which reduces to 3kW by 80% time (292 days). The energy input corresponding to 40% time will be  $(40/100 \times 3400 \times 365 \times 24) = 11.91 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 35% to 100% time is calculated to be  $6825336 \text{ m}^3$ . Energy obtained from this water is calculated to be  $1.28 \text{ MU}$ .

Total amount of energy produced =  $11.91 \text{ MU} + 1.28 \text{ MU} = 13.2 \text{ MU}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 19.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 19.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 19.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.19.6**.

**Table 19.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	743.50	0	0	0
2	744	257.19	64.2975	12
3	745	628.44	507.1125	95
4	746	1136.88	1389.7725	261
5	747	2286.88	3998.76	750

As the terrain is suitable for storing 4000m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 750 kWh. If a single 750 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 3.5m, to create a storage of 4000m<sup>3</sup> is suggested.

#### 19.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Valara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,  
 per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25  
 per Mega Watt revenue = 1000 kW x Rs. 2.5 x X  
 Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$   
 $X = 3,500$  hrs.

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 7000 kW, which corresponds to about 25% flow of exceedence from the chart, the total energy yield is the sum of:

$7000 \text{ kW} \times (0.25 \times 8760) = 0.3854$  at continuous operation for 25% time of an year, and 1.53MU, which is the cumulative energy potential from 25% to 100% time as obtained from the Chart (Table 19.3).

Total yield = 15.33MU + 10.06MU = **25.4 MU**.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 25.4 \times 10^8 / (7000 \times 8760) = 41.4 \%$$

This PCF is equal to the break even value of 40%.

*So 550 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 10000 kW (for 13.5% flow of exceedence)

$$PCF = (30130000/10000 \times 8760) \times 100 = 34.4\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 650 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 19.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	7000 kW
Rs.3.00/ Unit	10000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (5MW x 1 + 1 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (5MW x 1 + 2 MW x 2 + 1MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## 19.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 12.5m x 8m.

### **19.5.1 Weir at Valarakuthu**

A concrete weir has been proposed on the Deviar stream, at a bed level of +742.600 metres. The base width of the weir at bed level is 6.35m. The structure is 3m high having a length of 40m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No. 19.7**.

### **19.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 1.9m and the thickness of the penstock is found as 8mm. The penstock can carry a maximum flow of 10.37 cumec with a velocity of 3.66 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 259m (**Fig. No. 19.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 12.5 mx 8m to accommodate 7000 kW generator and standardised turbine.

## **19.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 7000 kW. The electricity generated would be connected to the existing power grid system at Valara by a 300m transmission line. A standardised turbine for 90m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 7000kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **19.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Valara (Idukki Dist.). The project aims to generate about 3400 kW of hydro power from a fall having a head of 90 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **19.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 63.00 sq.km. The falls are situated in Deviar stream. This is one of the main falls in this stream. The stream has more falls on its upstream side. The head comes to 90m nearly. The stream flows through medium slopes on the upstream as well as downstream side of the fall. After the fall, the stream joins to the Periyar river.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no Forest clearance is required for the project.

### **19.7.2 Environmental Impact on Water**

The Deviar stream which drains to Periyar river is the stream of this fall. The diversion structure will create a pond of area 0.2286 hectare. No forest land will be submerged. Above all, this accounts for only 0.033 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **19.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak

labour strength is 100 skilled and 250 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## 19.8 CONCLUSION

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 7000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 10000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## 20 . VALARA

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**District** : **Thrissur**  
**Panchayath** : **Athirappilly**  
**Head** : **90 m.**  
**Flow** : **Seasonal**  
**Suggested Capacity** : **2.5MW/ 3MW**

## **20.1 GENERAL**

### **20.1.1 The Site**

The Valarakuthu is a scenic waterfall is situated in Aroormuzhi, which is in the 2nd ward of Athirappilly Grama Panchayath in Thrissur District. The site is at a distance of 22 km from Chalakkudy. There is a bus route from Chalakkudy to Athirappilly through Aroormuzhi. From there through a forest foot path of nearly 4 km long we can reach the site. The site is in forest land. The nearest 11kV line is at Aroormuzhi 4 km away from site. The site contains two falls which gives a head of 90m.

The water fall is located at  $76^{\circ} 29' 30''$  E longitude and  $10^{\circ} 17' 30''$  N latitude. The catchment area measured from topo sheet is 0.88sq.km. The falls are situated at an elevation of 200m from MSL, in Aroormuzhithodu which is beginning at an elevation of 500m. There is two falls in the site . The upstream side of the fall has gentle slope while the down stream has moderate slope. After the fall the stream joins the Chalakkudy puzha near to Aroormuzhi, which drains to the Periyar river (Fig.No.20.1).

### **20.1.2 Topography**

The site is situated in Valara reserved forest. The forest is very thick. The land is having steeply sloping in this area. There is no possibility for land slides in this area and chances for soil erosion are negligible. Boulders are available in plenty at site and the bed of stream is rocky. The number of rainy days exceeds 50% in its catchment.

## **20.2 FIELD INVESTIGATION**

### **20.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 90m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 20.2.2 Catchment Area

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of valarathodu was located using the toposheet. It is shown in the **Fig.No.20.2**. From the shape it is identified as a fan shaped catchment and its area is measured as 0.88sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 5.85 cumec.

### 20.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.20**.

### 20.2.4 River Flow Data

For a period of 12 months (March 98 to March 99) the water level observations were taken every week. A suitable location was identified on the down stream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 20.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 20.3**.

### 20.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 20.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 20.2**. These data are used for calculating energy potential and selection of unit sizes in **section 20.4**.

### 20.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 20.3**. The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design.

**Table 20.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	23.52	32.05	9.24	47.67

### 20.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 20.3.1 Power Potential of the Project

The discharge corresponding to 80% exceedence is only 0.02cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 14kW. However it seen that much higher flows are available during 50% of the time. In order to tap the full potential of the site, with a head of 90 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 1000kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

- P = Power output in kW
- Q = Discharge in cumec
- H = Head in metres
- $\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 1.5 \times 90 \times 0.75 = \mathbf{1000 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 2.04 \times 90 \times 0.75 = \mathbf{1350 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 2.4 \times 90 \times 0.75 = 1600 \text{ kW}$ .

### 20.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 1000kW power output for 50% of the time (183days) which reduces to 13kW by 80% time (292 days). The energy input corresponding to 50% time will be  $(50/100 * 1000 * 365 * 24) = 4.38 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be 2516888 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.4724 MU.

Total amount of energy produced = 4.38 MU + 0.4724 MU = **4.85 MU**

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 20.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 20.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 20.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.20.6**.

**Table 20.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	296.50	0	0	0
2	297	54.60	13.65	3
3	298	166.20	124.05	23
4	299	232.60	323.45	61
5	300	347.60	713.55	134
6	301	858.00	1416.35	266

7	302	1450.00	2570.35	482
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As the terrain is suitable for storing 2550m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 450 kWh. If a single 450 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 3.5m, to create a storage of 2550m<sup>3</sup> is suggested.

#### 20.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Valara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 2500 kW, which corresponds to about 10% flow of exceedence from the chart, the total energy yield is the sum of:

$2500 \text{ kW} \times (0.1 \times 8760) = 0.3854$  at continuous operation for 10% time of an year, and 6.5MU, which is the cumulative energy potential from 10% to 100% time as obtained from the

Chart (Table 20.3).

Total yield = 2.2MU + 6.5MU = **8.7 MU**.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 8.7 \times 10^8 / (2500 \times 8760) = 39.70 \%$$

This PCF is equal to the break even value of 40%.

*So 2500 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 3000 kW (for 4% flow of exceedence)

$$PCF = (9050000/3000 \times 8760) \times 100 = 34.4\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 3000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 20.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	2500 kW
Rs.3.00/ Unit	3000 kW

The units selected can be one of the following combinations:

For Rs. 3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 2 + 0.5 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (1 MW x 3)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 20.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of size 12.5m x 8m.

### 20.5.1 Weir at Valarakuthu

A gabion weir has been proposed on the Aroormuzhi thodu, at a bed level of +296.000 metres. The base width of the weir at bed level is 2.95m. The structure is 3m high having a length of 23.50m at the top with a central broad crested free over fall type spill way. the cross sectional details of the proposed diversion site is shown in **Fig.No. 20.7**.

### 20.5.2 Intake Structure, Penstock and Power House

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 1.22m and the thickness of the penstock is found as 10mm. The penstock can carry a maximum flow of 3.7 cumec with a velocity of 3.16 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 210m (**Fig. No. 20.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 12.5m x 8m to accommodate 2500 kW, generator and standardised turbine.

## 20.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 2500 kW. The electricity generated would be connected to the existing power grid system at Aroormuzhi by a 300m transmission line. A standardised turbine for 90m gross head is proposed for this particular site. The

turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 2500kW 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **20.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Valara (Thrissur Dist). The project aims to generate about 2500 kW of hydro power from a fall having a head of 90m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **20.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 0.88sq.km. The falls are situated in Aroormuzhithodu. There are two falls in the site. The upstream side of the fall has a gentle slope while the downstream has a moderate slope. After the fall, the stream joins the Chalakkudi puzha near Aroormuzhi, which drains to the Periyar river.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **20.7.2 Environmental Impact on Water**

The Aroormuzhithodu, which finally drains to the Periyar river is the stream of this fall. The diversion structure will create a pond of area 0.145 hectare. No forest land will be submerged. Above all, this accounts for only 0.058ha/MW. This diversion structure, which also acts as a check dam, can increase the height of the water table level at the site. The impounded water will also change the soil moisture regime in adjacent forest land.

### **20.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

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## 20.8 CONCLUSION

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 2500kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 3000 kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of people's participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## 21 . POOMALA

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**District : Idukki**  
**Panchayath : Velliamattom**  
**Head : 90 m.**  
**Flow : Perennial**  
**Suggested Capacity : 850 kW/ 1.1 MW**

## **21.1 GENERAL**

### **21.1.1 The Site**

The Njandirukki water fall is situated in Poomala, which is in the 7th ward of Velliamattom Grama Panchayath in Idukki District. The site is at a distance of 3 km from Poomala near to Velliamattom Grama Panchayath. There is bus service from Thodupuzha to Poomala. From there jeeps are available to the upstream side of the fall. The 11 KV transformer is at a distance of 1 km from the site.

The water fall is located at  $76^{\circ} 52' 0''$  E longitude and  $9^{\circ} 50' 33''$  N latitude. The catchment area measured from topo sheet is 0.63 sq. km. The falls are situated at an elevation of 260m from MSL, in Njandirukki stream which is beginning at an elevation of 550m. The site contains 3 falls which gives a total head of 90m. After the fall, the stream joins to the Thodupuzha river which drains to Moovattupuzha (**Fig.No.21.1**).

### **21.1.2 Topography**

Topography of any site means the description of the geographical details of the site. The site is situated in private land. The land is having steep slopes in this area. There is no possibility of landslide in this area and the chances for soil erosion is less and it is negligible. The bed of the stream is rocky and boulders are available in site. The site is perennial and number of rainy days exceeds 50% in its catchment.

## **21.2 FIELD INVESTIGATION**

### **21.2.1 Reconnaissance Survey**

A topographical survey for obtaining topographical details of the site. There is one main fall which gives a total head of 20m. The possible location for diversion structure and power house are identified and the details are taken using tacheometric method of surveying.

### 21.2.2 Catchment Area

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of Poomala-Njandirukki was located using the toposheet. It is shown in the **Fig.No.21.2**. From the shape it is identified as a fan shaped catchment and it comes to 0.63m. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 1.87 cumec.

### 21.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house was also determined using this and the prepared contour map has been shown in **Annexure A.21**.

### 21.2.4 River Flow Data

For a period of 12 months (November 98 to November 99) the water level observations were taken in every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating discharge of stream. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 21.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 21.3**.

### 21.2.5 Flow Duration Curve

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 21.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 21.2**. These data are used for calculating energy potential and selection of unit sizes in **section 21.4**.

### 21.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 21.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 21.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	18.28	23.15	7.38	34.64

## 21.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, Mechanical work have not been carried out in this report as it is does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost are fixed consulting various agencies.

### 21.3.1 Power Potential of the Project

The discharge corresponding to 80% of exceedence is only 0.023 cubic metre per second. A discharge of 0.023cubic metre per second can produce only about 15 KW. In order to tap the full potential of the site, with a head of 90 metre, the project is designed to generate higher output with lower dependability. This site can be designed as run off the river which can produce 200 kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;                      P = Power output in kW  
   Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 0.19 \times 90 \times 0.75 = \mathbf{125 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.319 \times 90 \times 0.75 = \mathbf{200 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 1.3 \times 90 \times 0.75 = \mathbf{875 \text{ kW}}$ .

### 21.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 200kW power output for 40% of the time (146 days) which reduces to 15kW by 80% time (292 days). The energy input corresponding to 40% time will be  $(40/100 \times 200 \times 365 \times 24) = 0.7 \text{ MU}$ . The flow after 40% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $1009572 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.187 \text{ MU}$ .

Total amount of energy produced =  $0.70 \text{ MU} + 0.187 \text{ MU} = \mathbf{0.887 \text{ MU}}$

### 21.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 21.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 21.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 21.6**.

**Table 21.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	192.75	0	0	0
2	196	43.4	70.53	1
3	199	185.2	413.13	8
4	201	512.2	1110.5	21

5	202	697	1715	32
6	204	1060.2	3472	65

As the terrain is suitable for storing 3450m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 65kWh. If a single 65kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 11.25m, to create a storage of 3450m<sup>3</sup> is suggested.

#### 20.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Poomala be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 850 kW, which corresponds to about 25% flow of exceedence from the chart, the total energy yield is the sum of:

$850 \text{ kW} \times (0.25 \times 8760) = 0.3854$  at continuous operation for 25% time of an year, and 1.11MU, which is the cumulative energy potential from 25% to 100% time as obtained from the Chart (Table 21.3).

Total yield = 1.86MU + 1.1MU = **3 MU.**

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 3 \times 10^8 / (550 \times 8760) = 40.29 \%$$

This PCF is equal to the break even value of 40%.

*So 850 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 1100 kW (for 8% flow of exceedence)

$$PCF = (3270000 / 1100 \times 8760) \times 100 = 33.9\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 1100 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 21.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	850 kW
Rs.3.00/ Unit	1100 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MWx1+0.25 MW x 1 + 0.1MWx1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.5 MW x 2 + 0.1MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 21.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 10mx 5.5m.

### 21.5.1 Weir at Poomala

A gabion weir has been proposed on the Njandirukki stream, at a bed level of +193.90 metres. The base width of the weir at bed level is 14m. The structure is 9.60m high having a length of 8m at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. No. 21.7**.

### 21.5.2 Intake Structure, Penstock and Power House

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.76m. The penstock can carry a maximum flow of 1.26 cumec with a velocity of 2.78 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 160m (**Fig.No.21.8**). A surface power house is proposed

on the right bank of stream The slope at the proposed site is moderate. The power house is of size 10mx 5.5m, to accommodate 850 kW, generator and standardised turbine.

## **21.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 850 kW. The electricity generated would be connected to the existing power grid system at Poomala by a 2km transmission line. A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 850kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **21.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Njandirukki-Poomala (Idukki Dist.). The project aims to generate about 850 kW of hydro power from a fall having a head of 90m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **21.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 0.63 sq. km. The falls are situated in Njandirukki stream. The site contains 3 falls which gives a total head of 90m. After the fall, the stream joins to the Thodupuzha river which drains to Moovattupuzha.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **21.7.2 Environmental Impact on Water**

The Njandirukki stream, which drains to Moovattupuzha river is the stream of this fall. The diversion structure will create a pond of area 0.106 hectare. No forest land will be submerged. Above all, this accounts for only **0.125 ha/MW**. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **21.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **21.8 CONCLUSION**

The environmental impact of small hydel project is negligible compared to large hydel projects. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 850kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1100kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **22. KALKANDY**

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**District** : Palakkad  
**Panchayath** : Agali  
**Head** : 90 m.  
**Flow** : Perennial  
**Suggested Capacity** : 950 kW/ 1.25 MW

## **22.1 GENERAL**

### **22.1.1 The site**

Kalkandy Mandompotty water fall is situated in Chellekkad near Kalkandy, which is in the 12th ward of Agali Grama Panchayath in Palakkad district. The site is at a distance of 22 km. from Mannaarkkad. Kalkandy is a main stop in Mannarkkad- Aanakkatti route. Bus services are available from Mannaarkkad. From Kalkandy there is about 3 km. to the site. The site is in forest land. The nearest 11 KV line is 2 km away from the site.

The water fall is located at 75° 32' 34" E longitude and 11° 4' 37" N latitude. The catchment area measured from toposheet is 9.50 sq.km. The fall is situated at an elevation of 300m. from MSL, in Kalkandy thodu which is beginning at an elevation of 700m from MSL. After the fall the stream is flowing through moderate slopes. The stream is joins to the Nellipuzha river which is drains to the Bharathapuzha. The upstream side of the fall is sloped steep (**Fig.No.22.1**)

### **22.1.2 Topography**

The site is situated in Mannarkkad reserved forest. The forest is very thick. The land is having steep slope in this area. There is no possibility of land slide and the chances for soil erosion is very less. Boulders are available in plenty at site. The number of rainy days exceeds 50% in its catchment.

## **22.2 FIELD INVESTIGATION**

### **22.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 90m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 22.2.2 Catchment area

Topographical survey sheets to a scale of 1: 50,000 are available from the Survey of India. The catchment of Kalkandy site was located using the toposheet. It is shown in **Fig.No.22.2**. The area is measured and its comes to 9.75 sq km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 4.5 cumec.

### 22.2.3 Contour map

The data collected by survey were used to calculate the horizontal distance, vertical distance and the reduced level of various points on the ground. The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.22**.

### 22.2.4 River flow data

For a period of 12 months (January 98 to January 1999) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at that point to measure the peak flow. Using the collected data (**Table 22.1**) the weekly discharge hydrograph of the site was prepared. The graph is shown in **Fig. No. 22.3**.

### 22.2.5 Flow duration curves

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 22.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 22.2**. These data are used for calculating energy potential and selection of unit sizes in **section 22.4**.

### 22.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 22.3**. The value obtained by Dicken=s formula which is

commonly used in western ghats region has been used for the structural design.

**Table 22.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumec	140.69	261.94	45.3	374.4

## 22.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated, after consulting various agencies.

### 22.3.1 Power potential of the project

The discharge corresponding to 90% of exceedence is only 0.002 cubic metre per second. A discharge of 0.002 cubic metre per seconds can produce only about 1 kW. In order to tap the full potential of the site, with a head of 90m, the project is designed to generate higher output with lower dependability. This site can be designed as run off the river which can produce 200 kW with a dependability of 50%.

The output power can be computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence	$P = 10 \times 0.29 \times 90 \times 0.75 = \mathbf{200 \text{ kW.}}$
For 40% exceedence	$P = 10 \times 0.36 \times 90 \times 0.75 = \mathbf{240 \text{ kW.}}$
For 30% exceedence	$P = 10 \times 0.8 \times 90 \times 0.75 = \mathbf{550 \text{ kW.}}$

### 22.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 200kW power output for 50% of the time (146 days) which reduces to 15kW by 80% time (292 days). The energy input corresponding to 50% time will be  $(50/100 * 200 * 365 * 24) = 0.876 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be  $2202682 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.413 \text{ MU}$ .

Total amount of energy produced =  $0.876 \text{ MU} + 0.413 \text{ MU} = \mathbf{1.289 \text{ MU}}$

### 22.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 22.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 22.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 22.6**.

**Table 22.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	497.5	0	0	0
2	498.0	145.31	36.33	1
3	499.0	439.06	328.52	6
4	500.0	698.44	897.27	17
5	501.0	811.00	1652.00	31
6	502.0	1281.25	2698.00	51

As the terrain is suitable for storing  $2698\text{m}^3$  it follows that, at full storage, the energy capacity is

only about 50kWh. If a single 50kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 4.5m, to create a storage of 3450m<sup>3</sup> is suggested.

## 22.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Kalkandy be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can be work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 950 kW, which corresponds to about 21% flow of exceedence from the chart, the total energy yield is the sum of:

$950 \text{ kW} \times (0.21 \times 8760) = 1.75 \text{ MU}$  at continuous operation for 21% time of an year, and 1.576MU, which is the cumulative energy potential from 21% to 100% time as obtained from the Chart (Table 22.3).

Total yield =  $1.86\text{MU} + 1.1\text{MU} = \mathbf{3.326 \text{ MU}}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 3.326 \times 10^8 / (950 \times 8760) = 39.9 \%$$

This PCF is equal to the break even value of 40%.

*So 950 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 40%**

Similarly, for 1250 kW (for 16% flow of exceedence)

$$PCF = (3750000 / 1250 \times 8760) \times 100 = 34.24\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 1250 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 22.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	950 kW
Rs.3.00/ Unit	1250 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.5MW x 1 + 0.25 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.5 MW x 2 + 0.025MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 22.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed,

which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 12.5m x 6.5m.

### **22.5.1 Weir at Kalkandy**

A Gabion weir has been proposed on the Kanjirappuzha stream, at a bed level of +498.500 metres. The base width of the weir at bed level is 4.25m. The structure is 4.50m. high having a length of 60 m. at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No. 22.7**.

### **22.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.803 m. The penstock can carry a maximum flow of 1.41 cumec with a velocity of 2.76 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 147m (**Fig.No.22.8**). A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 12.5m x 6.5m., to accommodate 950 kW, generator and standardised turbine.

## **22.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 950 kW. The electricity generated would be connected to the existing power grid system at Agali by a 300m transmission line.

A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 950 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **22.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Kalkandy (Palakkad Dist). The project aims to generate about 950 kW of hydro power from a fall having a head of 90 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **22.7.1 Environmental impact on land**

Total area of catchment is about 9.75 square kilometres of land in Kalkandy thodu. The upper catchment is rocky and with little vegetation cover. The forest in their sector is semi evergreen and deciduous. Both bank of the land is owned by private persons. Stream sections are mostly rocky large sized boulders are plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **22.7.2 Environmental impact on water**

The Kalkandy thodu, which drains to Nellippuzha river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.13ha. No forest land will be submerged. Above all, this accounts for only 0.137ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **22.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months.. The peak

labour strength is 75 skilled and 100 unskilled labour. It require only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## 22.8 CONCLUSION

The environmental impact of the small hydel project is negligible. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 950kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 1750kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## 23. VELLACHATTAPARA

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**District : Palakkad**  
**Panchayath : Alanallur**  
**Head : 125 m.**  
**Flow : Seasonal**  
**Suggested Capacity : 2MW/ 2.75MW**

## **23.1 GENERAL**

### **23.1.1 The Site**

Vellachattappara, which is in the 1st ward of Alanallur Grama Panchayath is in Palakkad District. The site is at a distance of 43 km from Mannarkkad. There is a bus route to Edathanattukara (Kottappallom) from Mannarkkad. From Kottappallom bus service are available to Uppukulam occasionally. From there jeep service are available to Ponpara. From Ponpara the site is 4 km away.

The water fall is located at  $75^{\circ} 36' 28''$  E longitude and  $8^{\circ} 9' 9''$  N latitude. The catchment area measured from topo sheet is 2.50sq. km. The falls are situated at an elevation of 220m from MSL, in Vellachattappara stream which is beginning at an elevation of 1050m. After the fall, the stream joins the Pulayanthodu which flows to Velli Aar that finally drains to Kunthi Ppuzha (Fig.No.23.1.).

### **23.1.2 Topography**

The site is situated in Mannarkkad reserved forest. The forest is very thick. The land is having moderate slope in this area. There is no possibility of land slides any where near the site, and the chances for soil erosion are negligible. The number of rainy days exceeds 50% in its catchment.

## **23.2 FIELD INVESTIGATION**

### **23.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 125m. The possible location for diversion structure and power house are identified and the details are taken using tacheometric method of surveying.

### 23.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Vellachattappara was located using the toposheet. It is shown in the **Fig.No. 23.2**

From the shape it is identified as a fan shaped catchment and its area comes to nearly 2.50 sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998-99 is about 5.63cumec.

### 23.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:400. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.23**.

### 23.2.4 River Flow Data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 23.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 23.3**.

### 23.2.5 Flow Duration Curves

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 23.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 23.2**. These data are used for calculating energy potential and selection of unit sizes in **section 23.4**.

### 23.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 23.3**. The value obtained by Dicken=s formula which is commonly used in western ghats region has been used for the structural design.

**Table 23.3**  
**Peak Flow Determination**

Parameters	Dicken= s method	Ingli= s formula	Ryve= s formula	Nawab Jung Bahadur formula
Peak flow in cumec	51.69	85.62	18.6	123.36

### 23.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 23.3.1 Power Potential of the Project

The discharge corresponding to 80% of exceedence is only 0.04cubic metre per second. A discharge of 0.04cubic metre per second can produce only about 35 kW. In order to tap the full potential of the site, with a head of 125 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 700kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where; P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.58 \times 125 \times 0.75 = \mathbf{540 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.74 \times 125 \times 0.75 = \mathbf{700 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 1.24 \times 125 \times 0.75 = 1200 \text{ kW}$ .

### 23.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 675kW power output for 40% of the time (146 days) which reduces to 8.5kW by 80% time (292 days). The energy input corresponding to 40% time will be  $(40/100 \times 675 \times 365 \times 24) = 2.19 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 35% to 100% time is calculated to be 969732 m<sup>3</sup>. Energy obtained from this water is calculated to be 0.969 MU.

Total amount of energy produced = 2.19 MU + 0.657 MU = **2.85 MU**

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 23.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 23.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 23.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 23.6**.

**Table 23.4**  
**Pondage Area Details**

Sl. No.	Elevation (metre)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy(kWh)
1	493.25	0	0	0
2	494	109.60	41.10	1
3	495	190.94	191.27	5
4	497	344	725.02	19
5	499	609.12	1678.18	44
6	501	883.84	3171.14	83

As the terrain is suitable for storing 3150m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 80 kWh. If a single 50 kW machine is installed, it can be operated for only one and half hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 3.5m, to create a storage of 3150m<sup>3</sup> is suggested.

### 23.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Vellachattappara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 2000 kW, which corresponds to about 21% flow of exceedence from the chart, the total energy yield is the sum of:

$2000 \text{ kW} \times (0.21 \times 8760) = 3.7\text{MU}$  at continuous operation for 21% time of an year, and 3.15MU, which is the cumulative energy potential from 21% to 100% time as obtained from the Chart (Table 3.3).

Total yield =  $1.53\text{MU} + 3.15\text{MU} = \mathbf{6.85 \text{ MU}}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 6.85 \times 10^8 / (2000 \times 8760) = 39 \%$$

This PCF is equal to the break even value of 40%.

*So 2000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 2750 kW (for 11.5% flow of exceedence)

$$PCF = (8080000 / 2750 \times 8760) \times 100 = 33.5\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 2750 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 23.5**

**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	2000 kW
Rs.3.00/ Unit	2750 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 3 + 0.5 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (2MWx1 + 0.5 MW x 1 + 0.25MW x1)

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

### 23.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure

takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 10m x 6.5m.

### **23.5.1 Weir at Vellachattappara**

A Gabion weir has been proposed on the Vellachattappara stream, at a bed level of +492.750 metres. The base width of the weir at bed level is 5.50m. The structure is 4.10m high having a length of 13m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No. 23.7**.

### **23.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.91m and the thickness of the penstock is found as 8 mm. The penstock can carry a maximum flow of 2.13 cumec with a velocity of 3.3 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 521m (**Fig. No. 23.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 10m x 6.5m, to accommodate 2000 kW, generator and standardised turbine. A typical section of the intake structure and silt extruder also shown in **Fig.No.23.9**.

## **23.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 2000 kW. The electricity generated would be connected to the existing power grid system at Ponpara by a 2km transmission line. A standardised turbine for 125m gross head is proposed for this particular site.

The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 2000 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **23.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Vellachattappara (Palakkad Dist.). The project aims to generate about 2000 kW of hydro power from a fall having a head of 125 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **23.7.1. Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 2.50sq. km. The falls are situated in Vellachattappara stream. After the fall, the stream joins to the Pulayanthodu which flows to Velli Aar that finally drains to Kadalundi Puzha.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **23.7.2 Environmental Impact on Water**

The Vellachattappara stream which drains to Kadalundi puzha is the stream of this fall. The diversion structure will create a pond of area 0.088hectare. No forest land will be submerged. Above all, this accounts for only 0.131 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **23.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## 23.8 CONCLUSION

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 2000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 2750kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## 24. KOZHIVALKUTHU

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**District** : **Idukki**  
**Panchayath** : **Munnar**  
**Head** : **125 m.**  
**Flow** : **Perennial**  
**Suggested Capacity** : **13 MW/ 16 MW**

## **24.1 GENERAL**

### **24.1.1 The site**

The scenic fall Kozhivalkuthu, which is in the 10th ward of Munnar Grama Panchayath is in Idukki District. The site is at a distance of 36 km from Adimali. There is a bus route from Adimali to Kallaar on the Adimali-Munnar state highway. Mankulam is about 16 km away from Kallar. The road is tarred up to 6km and remaining is unmetalled road. Jeep services are available from Adimali to Mankulam. The site is at a distance of 1.5km. from Mankulam. The nearest 11KV line is about 16 km. away from site.

The water fall is located at 76° 0' 58" E longitude and 10° 6' 35" N latitude. The catchment area measured from topo sheet is 2.25 sq. km The falls are situated at an elevation of 300m from MSL, in Mankulam stream which is beginning at an elevation of 1500m from MSL. The stream flows through a gentle slope at the upstream side and the flows through steep sloped area. The fall is almost vertical. After the fall, the stream joins to the Karinthiripuzha which drains to the Periyar river (**Fig.No.24.1**).

### **24.1.2 Topography of the site**

The left bank of the stream is forest land and right bank is owned by private persons. The land is having gentle slope in this area. There is no possibility of land slide and the chances for soil erosion is very less and it is negligible. The bed of this stream is rocky and boulders are available in plenty at site. The total head of the site comes nearly 125m. The stream is a perennial one and rainfall is getting more than half of the year in its catchment.

## **24.2 FIELD INVESTIGATION**

### **24.2.1 Reconnaissance survey**

A contour survey for obtaining topographical details of the site. There is three main falls in the stream which gives a total head of 125m. The position of the diversion structure and power

house are identified and details of the proposed location was collected using tacheometric survey.

### **24.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Kozhivalkuthu was located using the toposheet. It is shown in the **Fig.No. 24.2**. From the shape it is identified as a feather shaped catchment and its area comes nearly 2.25 sq.km. The catchment area having almost moderate slope and the stream get flooded soon after the rain, but the width of the stream is much enough to carry the flood discharge with in the bank.

### **24.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:500. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.24**.

### **24.2.4 River flow data**

For a period of 12 months (December 1997 to December 1998) the water level observations were taken in every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating discharge of stream. We fixed a measuring gauge at this point and engaged a local person for taking weekly flow data, we also visited the site once in every month for collecting the data from the local person. From the collected data (**Table.24.1**). The weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig.No.24.3**.

### **24.2.5 Flow duration curves**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 24.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 24.2**. These data are used for calculating energy potential and selection of unit sizes in **section 24.4**.

#### 24.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 24.3**. The value obtained by Dickens method which is commonly used in western ghats region has been used for the structural design.

**Table 24.3**  
**Peak Flow Determination**

Parameters	Dickens method	Inglis formula	Ryve's formula	Nawab Jung Bahadur formula
Peak flow in cumec	47.77	77.81	17.34	112.48

### 24.3 SALIENT DESIGN FEATURES

The design of any hydro electric project can be divided into two. viz. Civil Engineering Works and Electrical & Mechanical Works in this chapter. A detailed design of Civil, Electrical and Mechanical work have not been carried out in this report, as it does not come under preview of the project, but a typical section of the proposed diversion structure is given here. The stability of the section and economic diameter of the penstock was carried out as part of preliminary design. The capacity and number of unit, type and specification of turbine, generator and its cost is fixed by consulting various agencies. However, for the sake of cost estimation, required details are collected from various agencies.

#### 24.3.1 Power potential of the project

From the flow duration curve the discharge corresponding to 100 % of exceedence is only 0.2 cubic metre per second. A discharge of 0.21 cubic metre per second can produce only about 180 kW of power. However it is seen that higher flow are available during 50 % of the time. In order to tap the full potential of the site, with a head of 125 metre, the project is designed to

generate higher output with lower dependability.

The out put power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power out put in KW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50 % exceedence,  $P = 10 \times 3.49 \times 125 \times 0.75 = 3250 \text{ kW}$ .

For 40 % exceedence,  $P = 10 \times 8.2 \times 125 \times 0.75 = 7500 \text{ kW}$ .

For 30 % exceedence,  $P = 10 \times 10.7 \times 125 \times 0.75 = 10,000 \text{ kW}$ .

### 24.3.2 Energy potential

3 MW capacity needs a discharge of 3.22. metre cube per second, which has a dependability of 50%. ie. there is sufficient flow available to produce 3 MW during 50% of time. So, the energy output corresponding to this period is equal to  $50/100 \times 3000 \times 365 \times 24 = 13.14$  million units. From 50% to 100%, the site has a cumulative discharge of 15303859 m<sup>3</sup> by which we can generate 4 MU .

So total energy that can be produced = 13.17 MU + 4 MU = **17.17 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 24.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 24.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 24.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 24.6**.

**Table 24.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	497.750	0	0	0
2	498.000	55.00	6.875	0
3	499.000	2166.25	1117.500	29.00
4	500.000	5172.50	4786.875	124.66
5	501.000	8123.75	11435.000	297.80
6	502.000	10243.75	20618.750	537.00
7	503.000	12366.25	31923.750	831.00

As the terrain is suitable for storing 32000m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 800 kWh. If a single 500 kW machine is installed, it can be operated for only one and half hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 5m, to create a storage of 32000m<sup>3</sup> is suggested.

#### **24.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Kozhivalkuthu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of ***Plant Capacity Factor***, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per Mega Watt where X=2916

hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 13000 kW, which corresponds to about 13.5% flow of exceedence from the chart, the total energy yield is the sum of:

13000 kW x (0.135 x 8760) = 15.4MU at continuous operation for 13.5% time of an year, and 32.88MU, which is the cumulative energy potential from 13.5% to 100% time as obtained from the Chart (Table 24.3).

Total yield = 13.5MU + 33MU = **46.5 MU**.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 46.5 \times 10^8 / (13000 \times 8760) = 40.8 \%$$

This PCF is equal to the break even value of 40%. *So 13000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 16000 kW (for 6% flow of exceedence)

$$PCF = (49000000 / 160000 \times 8760) \times 100 = 35\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 16000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 25.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	13000 kW

Rs.3.00/ Unit	16000 kW
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The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (5MW x 2 + 1MW x 3)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (5 MW x 3 + 1 MW x 1)

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## **24.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock is a pressure pipe which carries water to the turbine. It can be made of steel, cast iron, plastics (Poly Vinyl Chloride, High Density Poly Ethylene) and concrete. In this project a steel penstock is used. A power houses constructed for the purpose of housing the electro mechanical equipment. It is usually small building of one or two rooms.

### **24.5.1 Weir at Kozhivalkuthu**

A gabion weir has been proposed on the Mankulam stream, at a bed level of +497.750 metres. The gabion structure is 6.6 metre height having a length of 57m at the top with a central board crested free over fall type spill way. A gravity dam is a structure which is designed in a such a way that its own weight resists the external forces. The preliminary analysis of the proposed structure has been carried out and a typical section of the structure is shown in **Fig.No.24.7**.

### **24.5.2 Intake Structure, Penstock and Power House**

A simple box type direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth. The pen stock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is the diameter for which the annual cost which includes the cost of power lost due to friction and changes for amortization of construction, cost, maintenance, operation etc., is the minimum. The economic diameter is calculated as 2 m.

The steel penstock of 2 m inner diameter takes off from the intake structure. The penstock can carry a maximum flow of 13.87 cumec with a velocity of 4.4 m/sec. The possible alignment for the penstock was located on the left bank of the Kozhival stream. The longitudinal section of the proposed penstock line was drawn and calculated the length of the penstock, which comes to be 342 m. (Fig.No.24.8). A surface power house is proposed on the left bank of stream. The slope at the proposed site is moderate but it increases up the hill towards upstream. The power house is of size 24m x 12m. to accommodate 13 MW generator and the standardised turbine.

## **24.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 13 MW. The electricity generated would be connected with the existing power grid system at by a 6 Km transmission line.

A standardised turbine for 125 m. gross head is proposed for this particular site. The turbine shall be complete with a governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 13MW, at 11KV, three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **24.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Kozhivalkuthu (Idukki District). The project aims to generates about 13000 of hydro power from a fall having a head of 125 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **24.7.1. Environmental impact on land**

The catchment area measured from topo sheet comes to be 2.25sq. km. The falls are situated in Kozhivalkuthu stream. After the fall, the stream joins to the Karinthiripuzha which flows to Periyar river.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **23.7.2 Environmental impact on water**

The Kozhivalkuthu stream which drains to Karinthripuzha is the stream of this fall. The diversion structure will create a pond of area 1.2ha. No forest land will be submerged. Above all, this accounts for only 0.092 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **23.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 250 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **24.8 CONCLUSION**

The environmental impact of small hydel project is negligible compared to large hydel projects. Moreover, deforestation owing to the indentation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 13000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 16000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayat in this effort is crucial.

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## 25 . PAMBLE

<b>District</b>	<b>: Idukki</b>
<b>Panchayath</b>	<b>: Kanjikuzhi</b>
<b>Head</b>	<b>: 140 m.</b>
<b>Flow</b>	<b>: Perennial</b>
<b>Suggested Capacity</b>	<b>: 2.5 MW/ 4MW</b>

### 25.1 GENERAL

#### 25.1.1 The Site

Idukki district is blessed with a number of water falls. Most of them are potential sites for small hydro power generation. The Pamble water fall is situated in the 11th ward of Kanjikkuzhi Grama Panchayath in Idukki district. The site is at a distance of 1.5 km from Kanjikkuzhi town. There is bus route from Kothamangalam to Kattappana. Kanjikuzhi is at a distance of 7 km. from Chelachuvadu which is a major stop in the Kothamangalam -Kattappana route. From Kanjikkuzhi there is a jeepable road to the site. Nearest 11 kV transformer is at a distance of 1km. from the site.

The water fall is located at 76056'40" E longitude and 90057'30" N latitude. The catchment area measured from toposheet is 17.75 sq.km. The falls are situated at an elevation of 480 m from MSL in Pazhayarithodu which begins at an elevation of 825 m from MSL. The stream flows through steeply sloping areas. There are a number of falls in this stream other than Pamble. Another main fall is located at the upstream side of the Pamble named Vattompara. After the fall, the stream joins the Periyar river. The joining point of the stream is just down stream of the Lower Periyar Dam. (**Fig. No. 25.1**).

### 25.1.2 Topography

The site is situated outside forest area. Both sides of the stream are owned by private persons. The land has a moderate slope in this area. There is no possibility of land slide and the chances of soil erosion are negligible. The bed of the stream is rocky and boulders are available in plenty at site. The number of rainy days exceeds 50% in its catchment.

## 25.2 FIELD INVESTIGATION

### 25.2.1 Reconnaissance Survey

A topographical survey was conducted for obtaining topographical details of the site. The total head of the site was found to be 125 m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 25.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Pamble water fall was located using the toposheet. It is shown in the **Fig.25.2** and the area measured comes to nearly 17.75 sq.km. The catchment area is having mostly moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 17.56 cumec.

### 25.2.3 Contour Map

The tacheometric survey details were plotted on a sheet of paper at a scale of 1:500 (**Annexure A.25**). The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and marked in the above map, along with the contours of the area.

### 25.2.4 River Flow Data

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified at the upstream of the fall, where the discharge will be identical. The cross sectional details of the point were measured for calculating the stream discharge. We fixed a measuring gauge at this point. The peak flow was also recorded. Using the collected data (**Table. 25.1**) the weekly discharge hydrograph of the site was prepared (**Fig. 25.3**).

### 25.2.5 Flow Duration Curves

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. 25.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 25.2**. These data are used for calculating energy potential and selection of unit sizes in **section 25.4**.

### 25.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 25.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design.

**Table 25.3**

#### Peak Flow Determination

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	224.84	411.49	68.73	606.30

### 25.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical, and Mechanical work has not been carried out in this report as it does not come under the scope of this work, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and their cost have been estimated, after consulting various agencies.

#### 25.3.1 Power Potential of the Project

The discharge corresponding to 90% exceedence is only 0.02 cubic metre/second. A discharge of 0.02 cubic metre/second can produce only about 25 kW. However it is seen 0.33 cumec is available for 50% of the time and 0.68 for 40%. In order to tap the optimum full potential of the site, the project is designed to generate higher output with lower dependability.

The output power can be computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW.

Q = Discharge in cumec.

H = Head available in metres

$\eta$  = Overall Efficiency (Here it is assumed as 75%)

For 50% of exceedence  $P = 10 \times 0.33 \times 140 \times 0.75 = 345 \text{ kW}$

For 40% of exceedence  $P = 10 \times 0.68 \times 140 \times 0.75 = 700 \text{ kW}$

For 30% of exceedence  $P = 10 \times 2.45 \times 140 \times 0.75 = 2500 \text{ kW}$

#### 25.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 750kW power output for 39% of the time (147 days) or 350kW for 50% time (183 days). The energy output corresponding to 39% time will be  $(39/100 \times 750 \times 365 \times 24) = 2.56 \text{ MU}$ . The flow after 40% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time (ie, 23 rd week to 52 nd week) is calculated to be 3418934 m<sup>3</sup> (Table 25.2). Energy obtained from this water is calculated to be 0.997 MU.

Total amount of energy produced = 2.56 MU + 0.997 MU = **3.56 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### **25.3.3 Pondage Requirement**

From the contour map prepared for the weir site, a plot of surface area Vs. elevation is drawn in **Fig.25.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 25.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.25.6**. The height of weir was chosen based on the following considerations.

**Table 25.4**  
**Pondage Area Details**

Sl. No. Elevation (m.) Area (m<sup>2</sup>) Capacity (m<sup>3</sup>) Energy (kWh) 1 501.50 0 0 0 2 502 15.75 7.875 2  
3 503 56.75 44.125 13 4 504 207.50 176.250 51 5 505 352.50 456.250 133 6 506 446.25  
855.625 249 7 507 525.00 1341.250 391 8 508 648.75 1928.125 562 9 509 922.50 2713.750  
791

As the terrain is suitable for only storing about 2700m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 791 kWh. If a single 750kW machine is operated at full capacity, it will last only for about an hour. However, if a 250kW unit is also installed, this is sufficient for about 3 hours of generation, during peak time. Since this pondage becomes critical only during the lean months, this kind of an operating practice is acceptable. Hence a weir height of 7.5m, to create a pondage of 2713m<sup>3</sup> is suggested.

## 25.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Preamble be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get 3,50,00,000 x 0.25 = X x 1000 x 2.5

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can

deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of **Plant Capacity Factor**, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where  $X=2916$  hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 2500 kW, which corresponds to about 30% flow of exceedence from the chart, the total energy yield is the sum of:

$2500 \text{ kW} \times (0.3 \times 8760) = 6.6\text{MU}$  at continuous operation for 30% time of an year, and 2.04MU, which is the cumulative energy potential from 30% to 100% time as obtained from the Chart (Table 25.3).

Total yield =  $6.6\text{MU} + 2.04\text{MU} = 8.64 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$PCF = 8.64 \times 108 / (2500 \times 8760) = 39.5\%$

This PCF is equal to the break even value of 40%.

*So 2500 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, for 4000 kW (for 18% flow of exceedence)

$PCF = (12000000/4000 \times 8760) \times 100 = 34.2\%$

This PCF is very near to the break even value of 33%.

*Similarly, 4000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 25.5**

**Economically Viable Maximum Capacity at Different Costs and Tariff**

**Tariff Unit size for Rs.3.5 Crores/MW Rs.2.5/Unit 2500 kW Rs.3.00/ Unit 4000 kW**

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 2 + 0.5 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (2 MW x 1 + 1 MW x 2).

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

## **25.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. A small building of one or two rooms will suffice.

### **25.5.1 Weir at Pamble**

A concrete weir has been proposed on the Pazhayarithod, at a bed level of 501.500 metres. The base width of the weir at bed level is 5.10 m. The structure is 7.50 m high having a length of 35m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed site is shown in **Fig.No. 25.7**

### **25.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the structure. The economic diameter of the penstock is calculated as 0.69 m and the thickness of the penstock is found as 6 mm. The penstock can carry a maximum flow of 0.476 cumec with a velocity of 1.27 metre per second. The possible alignment for the penstock is located on the left bank of the stream.

The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 366 m(**Fig. No. 25.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house building is of size 12.5m x 8m to accommodate a 2.5 MW and 2.5 MW generator and standardised turbine.

## **25.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 2.5 MW. Using an 1 kM transmission line, power generated will be connected to the existing power grid system at Kanjikkuzhi.

They will be equipped with governor, control equipment and safety devices. There will be three corresponding generators with brushless excitation system. They will have regulation equipment, parallel operation equipment etc. A 11 kV, three phase line with a frequency of 50Hz will be

satisfactory for us.

## **25.7 ENVIRONMENTAL IMPACTS**

A small hydro project is being proposed at Pamble (Idukki Dist). The project aims to generate about 2.5 MW of hydro power from a fall having a head of 140 m. Some preliminary environmental impact analysis has been carried out. They are land, water and socio-economical environmental impacts.

### **25.7.1 Environmental Impact on Land**

Total area of catchment is about 17.75 square kilometres of land in Pazhayarithodu. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi evergreen and deciduous. Both banks of the land is owned by private persons. Stream sections are mostly rocky and large sized boulders are available in plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the Project. The inundated land (922 m<sup>2</sup>) is mostly river bed and low lying banks.

### **25.7.2 Environmental Impact on Water**

The Pazhayarithodu, which drains to Periyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.0922 hectare. No forest land will be submerged. Above all, this accounts for only 0.037 ha/MW. The diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land. So, in ecological point of view, the diversion structure not only helps to hold the rain water, but also causes a positive effect.

### **25.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation. Not even a single family needs to be rehabilitated.

## **25.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 2500kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 4000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **26 . VATTOMPARA**

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**District : Idukki**  
**Panchayath : Kanjikuzhi**  
**Head : 140 m.**  
**Flow : Perennial**  
**Suggested Capacity : 2.5MW/ 4MW**

## **26.1 GENERAL**

### **26.1.1 The Site**

The Vattompara water fall is situated in the 11th ward of Kanjikkuzhi Grama Panchayath in Idukki district. The site is at a distance of 1.3 km from Kanjikkuzhi town. There is a bus route from Kothamangalam to Kattappana. Kanjikkuzhi is at a distance of 7 km. from Chelachuvadu which is a major stop in the above said route. Jeep services are also available to Kanjikkuzhi from Chelachuvadu. From Kanjikkuzhi there is a jeepable road to the site. Nearest 11 kV transformer is at a distance of 1km. from the site.

The water fall is located at 76° 56' 10" E longitude and 9° 57' 40" N latitude. The catchment area measured from topo sheet is 12.63sq. km. The falls are situated at an elevation of 680m, in Pazhayarithodu which is beginning at an elevation of 820m. The stream flows through steeply sloping areas. There are a number of falls in this stream other than Vattompara. Another main fall is located at the downstream side of the Vattompara named Pamble. After the fall, the stream joins the Periyar river. The joining point of the stream is just dam stream of the Lower Periyar Dam (**Fig.No.26.1**)

### **26.1.2 Topography**

The site is situated in forest area owned by Revenue Department. Both sides of the stream is almost steep slope. There is no possibility for land slide in this are and the chances of soil erosion are negligible. The bed of this stream is rocky and boulder are available in plenty at site. The number of rainy days exceeds 50% in its catchment.

## **26.2 FIELD INVESTIGATION**

### **26.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is one main fall which gives a total head of 20m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### 26.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Vattompara falls was located using the toposheet. It is shown in the **Fig.No.26.2**. From the shape it is identified as a fan shaped catchment and its area comes to nearly 12.63km. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998-99 is about 17.56 cumec.

### 26.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:500. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.26.**

### 26.2.4 River Flow Data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken every week. A suitable location was identified on the upstream of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 26.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 26.3**.

### 26.2.5 Flow Duration Curves

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 1.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 1.2**. These data are used for calculating energy potential and selection of unit sizes in **section 1.4**.

### 26.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 26.3** The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design.

**Table 26.3**  
**Peak Flow Determination**

Parameters	Dicken= s method	Ingli= s formula	Ryve = s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	174.14	323.62	54.76	467.65

### 26.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated, after consulting various agencies.

#### 26.3.1 Power Potential of the Project

The discharge corresponding to 90% exceedence is only 0.02 cubic metre/second. A discharge of 0.02 cubic metre/second can produce only about 25 kW. However it is seen 0.33 cumec is available for 50% of the time and 0.68 for 40%. In order to tap the optimum full potential of the site, the project is designed to generate higher output with lower dependability.

The output power can be computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;  $P$  = Power output in kW .

$Q$  = Discharge in cumec.

$H$  = Head available in metres

$\eta$  = Overall Efficiency (Here it is assumed as 75%)

For 50% of exceedence  $P = 10 \times 0.33 \times 140 \times 0.75 = 345 \text{ kW}$

For 40% of exceedence  $P = 10 \times 0.68 \times 140 \times 0.75 = 700 \text{ kW}$

For 30% of exceedence  $P = 10 \times 2.45 \times 140 \times 0.75 = 2500 \text{ kW}$

### 26.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 750kW power output for 39% of the time (147 days) or 350kW for 50% time (183 days). The energy output corresponding to 39% time will be  $(39/100 \times 750 \times 365 \times 24) = 2.56$  MU. The flow after 40% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time (ie, 23<sup>rd</sup> week to 52<sup>nd</sup> week) is calculated to be 3418934 m<sup>3</sup> (Table 25.2). Energy obtained from this water is calculated to be 0.997 MU.

Total amount of energy produced = 2.56 MU + 0.997 MU = **3.56 MU**.

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 26.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No. 26.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 26.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 26.6**.

**Table 26.4**  
**Pondage Area Details**

Sl. No.	Elevation (m.)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	797.50	0	0	0
2	798	39.25	9.8125	0.3
3	799	183.00	120.9375	3.5
4	800	501.25	463.9625	13.5

As the terrain is suitable for only storing about 460m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 13 kWh. If a single 10kW machine is operated at full capacity, it will last only for about an hour. As the terrain is not suitable for creating a pondage, here we opt for a run of the river system.

## 26.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.

Let the capital cost of Vattompara be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs.2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where  $X=2916$  hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 2500 kW, which corresponds to about 30% flow of exceedence from the chart, the total energy yield is the sum of:

$2500 \text{ kW} \times (0.3 \times 8760) = 6.6\text{MU}$  at continuous operation for 30% time of an year, and 2.04MU, which is the cumulative energy potential from 30% to 100% time as obtained from the Chart (Table 26.3).

Total yield =  $6.6\text{MU} + 2.04\text{MU} = \mathbf{8.64 \text{ MU}}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 8.64 \times 10^8 / (2500 \times 8760) = 39.5\%$$

This PCF is equal to the break even value of 40%.

*So 2500 kW will be the optimum choice for the site, if the overall project cost is below*

*Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.0/kWh and break even PCF of 33.3%**

Similarly, For 4000 kW (for 18% flow of exceedence)

$$PCF = (12000000/4000 \times 8760) \times 100 = 34.2\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 4000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 26.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	2500 kW
Rs.3.00/ Unit	4000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt ( 1MW x 2 + 0.5 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt ( 2MW x 1 + 1MW x 2).

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 26.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock made of steel is proposed

in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 12.5mx 8m

### **26.5.1 Weir at Vattompara**

A concrete weir has been proposed on the Pazhayarithodu, at a bed level of +797.000 metres. The base width of the weir at bed level is 5.15m. The structure is 2.50m high having a length of 10.50 m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed site is shown in **Fig.No. 26.7**.

### **26.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.69m. The penstock can carry a maximum flow of 0.76 cumec with a velocity of 1.27 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 507m (**Fig. No. 26.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 12.5m x 8m, to accommodate 2500 kW, generator and standardised turbine.

## **26.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 2500 kW. The electricity generated would be connected to the existing power grid system at Kanjikkuzhi by a 500m transmission line. A standardised turbine for 140m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 2500 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **26.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Vattompara (Idukki Dist). The project aims to generate about 2500 kW of hydro power from a fall having a head of 140 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **26.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 12.63sq. km. The falls are situated in Pazhayarithodu. The stream flows through steep slope areas. There are a number of falls in this stream other than Vattompara. Another main fall is located at the downstream side of the Vattompara named Pamble. After the fall, the stream joins to the Periyar river. The joining point of the stream is just dam stream side of the Lower Periyar Dam.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **26.7.2 Environmental Impact on Water**

The Pazhayarithodu, which drains to Periyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.05 hectare. No forest land will be submerged. Above all, this accounts for only 0.02ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **26.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 100 unskilled labour. It require only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

### **26.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 2500kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 4000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **27. CHEMBUKATTY**

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**District : Palakkad**  
**Panchayath : Agali**  
**Head : 140m.**  
**Flow : Seasonal**  
**Suggested Capacity : 4 MW/6MW**

## **27.1 GENERAL**

### **27.1.1 The site**

Chembukatty water fall is situated in Kottoppadam Grama Panchayath in Palakkad district. The site is at a distance of 69 km from Palakkad. There is a bus route from Mannarkkaad to Thiruvizhamkunnu. From there, local bus services are available occasionally to Ambalappaara. Jeep services are available to Chembukatti from Ambalappaara. From there we have to walk 3 km to reach the site. The nearest 11kV transformer is at a distance of 5km. away from the site.

The water fall is located at  $76^{\circ} 22' 21''$  E longitude and  $11^{\circ} 1' 12''$  N latitude. The catchment area measured from toposheet is 11.875 sq. km. The falls are situated at an elevation of 40 m from MSL in Chembukatti stream which is beginning at an elevation of 954 m from MSL. After the fall, the stream joins the Palakkuzhipuzha which drains to Chaliyar River (**Fig.No.27.1**).

### **27.1.2 Topography**

The site is situated in forest. The forest is very thick. The land is having steeply sloping in this area. The possibility of land slide is very less and chances of soil erosion are negligible. The bed of the stream is rocky and boulders are available in plenty at the site. The number of rainy days exceeds 50% in its catchment.

## **27.2 FIELD INVESTIGATION**

### **27.2.1 Reconnaissance survey**

A topographical survey was conducted for obtaining topographical details of the site. The total head of the site is 140 m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **27.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Chembukatty falls was located using the toposheet. It is shown in the **Fig.No. 27.2**. From the shape it is identified as a fan shaped catchment and its area comes to nearly 11.875 sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 17.72 cumec.

### **27.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:500. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.27**.

### **27.2.4 River flow data**

For a period of 12 months (December 97 to December 98) the water level observations were taken every week. A suitable location was identified on the downstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 27.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 27.3**.

### **27.2.5 Flow duration curves**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 27.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 27.2**. These data are used for calculating energy potential and selection of unit sizes in **section 27.4**.

### **27.2.6 Peak flow determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 27.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design.

**Table 27.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	166.32	309.48	52.57	445.98

### 27.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and it=s cost have been estimated, after consulting various agencies.

#### 27.3.1 Power potential of the project

The discharge corresponding to 100% exceedence is only 0.008 cubic metre per second. A discharge of 0.008 cubic metre per second can produce only about 8 kW. In order to tap the full potential of the site, with a head of 140 metre., the project is designed to generate higher output with lower dependability. This site can be designed as a run of the river project which can produce 1500 kW for 3 hours duration of peak load with a dependability of 40%.

The output power was computed using the formula ,  **$P = 10 \times Q \times H \times \eta$**

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Efficiency taken as 0.75

For 50% exceedence  **$P = 10 \times 0.68 \times 140 \times 0.75 = 700 \text{ kW.}$**

For 40% exceedence  **$P = 10 \times 1.5 \times 140 \times 0.75 = 1500 \text{ kW.}$**

For 30% exceedence  $P = 10 \times 3.15 \times 140 \times 0.75 = 3250 \text{ kW}$ .

### 27.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 1543kW power output for 40% of the time (146 days) which reduces to 210kW by 60% time (219 days). The energy input corresponding to 40% time will be  $(40/100 \times 1500 \times 365 \times 24) = 5.26 \text{ MU}$ . The flow after 40% time can be utilized by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $4394962\text{m}^3$ . Energy obtained from this water is calculated to be 1.28 MU.

Total amount of energy produced =  $5.26 \text{ MU} + 1.28 \text{ MU} = 6.54 \text{ MU}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 27.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No.27.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 27.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No.27.6**.

**Table 27.4**  
**Pondage Area Details**

Sl. No.	Elevation (m.)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	497.50	0	0	0
2	498	238.00	119.00	3.5
3	499	283.80	379.90	11

As the terrain is not suitable for storage the structure proposed at this site is only for diverting water.

## 27.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Chembukatty be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.5/kWh and break even PCF of 40%**

For an installed capacity of 4000 kW, which corresponds to about 25% flow of exceedence from the chart, the total energy yield is the sum of:

$4000 \text{ kW} \times (0.25 \times 8760) = 8.76 \text{ MU}$  at continuous operation for 25% time of an year, and 5.14MU, which is the cumulative energy potential from 25% to 100% time as obtained from the Chart (Table 27.3).

Total yield =  $8.76\text{MU} + 5.14\text{MU} = 14 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 14 \times 10^8 / (4000 \times 8760) = 39.9 \%$$

This PCF is equal to the break even value of 40%.

*So 4000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 6000 kW (for 19.23% flow of exceedence)

$$\text{PCF} = (17700000 / 6000 \times 8760) \times 100 = 33.6\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 6000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 27.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	4000 kW
Rs.3.00/ Unit	6000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (2MW x 1 + 1 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (1MW x 2 + 2MW x 2)

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

**27.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure

takes water from the weir and leads it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 12.5m x 8m.

### **27.5.1 Weir at Chembukatty**

A gabion weir has been proposed on the Chembukatti stream, at a bed level of +444.500 metres. The base width of the weir at bed level is 10 m. The structure is 6.50 m high having a length of 30.50 m at the top with a central broad crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig. No. 27.7**

### **27.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.69 m and the thickness of the penstock is found as 8 mm. The penstock can carry a maximum flow of 0.476 cumec with a velocity of 1.27 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 807 m (**Fig. No. 27.8**). A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate. The power house is of size 12.5m x 8m, to accommodate 1500kW, generator and standardised turbine.

## **27.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 4000 kW. The electricity generated would be connected to the existing power grid system at Thiruvizhamkunnu by a 2 km transmission line. A standardised turbine for 140 m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 4000kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **27.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Chembukatty (Palakkad Dist.). The project aims to generate about 4000 kW of hydro power from a fall having a head of 140 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **27.7.1 Environmental impact on land**

The catchment area measured from topo sheet comes to be 11.875 sq. km. The falls are situated in Chembukatti stream. After the fall, the stream joins to the Palakkuzhi puzha which drains to Chaliyar River.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **27.7.2 Environmental impact on water**

The Palakkuzhi puzha, which drains to Chaliyar river is the stream of this fall. The diversion structure will create a pond of area 0.0284 hectare. No forest land will be submerged. Above all, this accounts for only 0.007 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **27.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 250 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## 27.8 CONCLUSION

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 4000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 6000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## 28. THENDILLAM

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**District : Palakkad**

**Panchayath : Kizhakkanchery**

**Head : 140 m.**

**Flow : Seasonal**

**Suggested  
Capacity : 2MW/ 3MW**

## **28.1 GENERAL**

### **28.1.1 The Site**

The Thendillam water fall is situated in the 10th ward of Kizhakkanchery Grama Panchayath in Palakkad District. The site is at a distance of 10 km from Vadakkanchery. From Vadakkanchery there is jeep service to Palakkuzhy which is on the upstream side of the fall. There is only 0.50km. to the site from Palakkuzhy.

The water fall is located at  $76^{\circ} 29' 0''$  E longitude and  $10^{\circ} 30' 26''$  N latitude. The catchment area measured from topo sheet is 5.50sq. km. The falls are situated at an elevation of 360m from MSL, in Palakkuzhi stream which is beginning at an elevation of 928m from MSL (**Fig.No.28.1**).

### **28.1.2 Topography**

The site is situated in private land. The land is having steep slope in this area. There is no possibility for land slide and the chances of soil erosion are negligible. The bed of the stream is rocky and boulders are available from the site. The total head comes nearly 140m. The number of rainy days exceeds 50% in its catchment.

## **28.2 FIELD INVESTIGATION**

### **28.2.1 Reconnaissance Survey**

A topographical survey was conducted for obtaining topographical details of the site. There is

one main fall which gives a total head of 20m. The possible location for diversion structure and power house were identified and the details were taken using tacheometric method of surveying.

### **28.2.2 Catchment Area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Thendillam was located using the toposheet. It is shown in the **Fig.No. 28.2**. From the shape it is identified as a fan shaped catchment and its area comes to nearly 5.50 sq.km. The catchment area is having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998 is about 10.85 cumec.

### **28.2.3 Contour Map**

The survey details were plotted on a sheet of paper at a scale of 1:300. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and the prepared contour map has been shown in **Annexure A.28**.

### **28.2.4 River Flow Data**

For a period of 12 months (November 1997 to November 1998) the water level observations were taken every week. A suitable location was identified on the upstream side of the fall, where the whole water is flowing through that point, cross sectional details of the point were noted for calculating the stream discharge. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 28.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 28.3**.

### **28.2.5 Flow Duration Curves**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 28.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 28.2**. These data are used for calculating energy potential and selection of unit sizes in **section 28.4**.

### **28.2.6 Peak Flow Determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 28.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 28.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	93.38	169.66	31.47	240.87

### 28.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical & Mechanical work has not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost have been estimated, after consulting various agencies.

#### 28.3.1 Power Potential of the Project

The discharge corresponding to 76% exceedence is only 0.003 cubic metre per second. A discharge of 0.003cubic metre per second can produce only about 3.15kW. In order to tap the full potential of the site, with a head of 140 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a peak load station which can produce 700kW with a dependability of 40%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;       $P$  = Power output in kW  
                    $Q$  = Discharge in cumec  
                    $H$  = Head in metres  
                    $\eta$  = Efficiency taken as 0.75

For 50% exceedence  $P = 10 \times 0.34 \times 140 \times 0.75 = 350 \text{ kW}$ .

For 40% exceedence  $P = 10 \times 0.78 \times 140 \times 0.75 = 800 \text{ kW}$ .

For 30% exceedence  $P = 10 \times 1.42 \times 140 \times 0.75 = 1500 \text{ kW}$ .

### 28.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 700kW power output for 40% of the time (146 days) which reduces to 42kW by 70% time. The energy input corresponding to 40% time will be  $(40/100 \times 700 \times 365 \times 24) = 2.45 \text{ MU}$ . The flow after 40% time can be utilised by providing a small pondage. The quantity of water available from 40% to 100% time is calculated to be  $4119128\text{m}^3$ . Energy obtained from this water is calculated to be 1.14 MU.

Total amount of energy produced =  $2.45 \text{ MU} + 1.14 \text{ MU} = 3.59 \text{ MU}$ .

It may be noted that this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 28.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 28.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details are shown in **Table 28.4**. From this information a capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 28.6**.

**Table 28.4**  
**Pondage Area Details**

Sl. No.	Elevation (m.)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	496.500	0	0	0
2	497	63.00	31.50	1
3	499	279.90	374.40	11
3	501	901.80	1336.10	39
5	503	1746.90	4204.80	123
6	505	2560.05	8511.75	248
7	506	2912.40	13984.20	408

As the terrain is suitable for storing 14000m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 400 kWh. If a single 400 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 9.5m, to create a storage of 32000m<sup>3</sup> is suggested.

#### **28.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES**

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
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Investment cost (Rs. in Crores per MW) - Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Thendillam be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of **Plant Capacity Factor**, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.5/kWh and break even PCF of 40%**

For an installed capacity of 2000 kW, which corresponds to about 25% flow of exceedence from the chart, the total energy yield is the sum of:

2000 kW x (0.25 x 8760) = 4.4 MU at continuous operation for 25% time of an year, and 2.5MU, which is the cumulative energy potential from 25% to 100% time as obtained from the Chart (Table 28.3).

Total yield = 4.4 MU + 2.5 MU = **7 MU**.

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 7 \times 10^8 / (2000 \times 8760) = 39.9 \%$$

This PCF is equal to the break even value of 40%.

*So 2000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 3000 kW (for 17.3% flow of exceedence)

$$PCF = (8700000/3000 \times 8760) \times 100 = 33.1\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 3000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 28.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for
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	<b>Rs.3.5 Crores/MW</b>
Rs.2.5/Unit	2000 kW
Rs.3.00/ Unit	3000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (1MW x 1 + 0.5 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (2MW x 1 + 1MW x 1).

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## **28.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and leads it to the penstock. The penstock is a pressure pipe which carries water to the turbine. It can be made of steel, cast iron, plastics (Poly Vinyl Chloride, High Density Poly Ethylene) and concrete. In this project a steel penstock is used. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of A detailed design of the civil works are given below.

### **28.5.1 Weir at Thendillam**

A gabion weir has been proposed on the Thendillam stream, at a bed level of +496.000 metres. The base width of the weir at bed level is 7.5m. The gabion structure is 7.1m. high having a length of 21.5m. at the top. The cross sectional details of the proposed diversion site is shown in **Fig. No. 28.7.**

### **28.5.2 Intake Structure, Penstock and Power House**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.94m. The penstock can carry a maximum flow of 1.00 cumec with a velocity of 1.44 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from the contour map and the length was calculated, which came to 147m (**Fig. No. 28.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 12.5m. x 8 m, to accommodate 2000 kW, generator and standardised turbine.

## **28.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 2000 kW. The electricity generated would be connected to the existing power grid system at Nilambur by a 300m transmission line. A standardised turbine for 140m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 2000 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **28.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Thendillam (Palakkad Dist.). The project aims to generate about 2000 kW of hydro power from a fall having a head of 140 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **28.7.1 Environmental Impact on Land**

The catchment area measured from topo sheet comes to be 5.50sq. km The falls are situated in Palakkuzhi stream. The site is situated in private land. The land is having steep slope in this area. There is no possibility for land slide and the chances for soil erosion is very less and it is negligible. The bed of the stream is rocky and boulders are available from the site. The total head comes nearly 140m. The number of rainy days exceeds 50% in its catchment. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land. So no forest clearance is required for the project.

### **28.7.2 Environmental Impact on Water**

The fall which drains to Palakkuzhy stream is the stream of this fall. *It is a 3rd order, structurally controlled stream.* The diversion structure will create a pond of 0.2912 ha. No forest land will be submerged. Above all, this accounts for only 0.1456ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **28.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 75 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **28.8 CONCLUSION**

The environmental impact of this small hydel project is negligible. No serious adverse impact is anticipated. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 2000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 3000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **29. PANAMKUDANTHA**

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**District** : Pathanamthitta  
**Panchayath** : Narayanamoozhi  
**Head** : 140 m.  
**Flow** : Seasonal  
**Suggested Capacity** : 450 kW/ 650 kW

## **29.1 GENERAL**

### **29.1.1 The Site**

The Panamkudantha water fall is situated in the 2nd ward of Naranammoozhi Grama Panchayath in Pathanamthitta district. The site at a distance of 15km from Ranni. There is bus route from Ranni to Athikkayam. A jeepable road starts from Athikkayam and ends near the site. There is also another way to reach the site. From Pathanamthitta to Vechuchira, bus services are available. The site is 3 km away from there . The stream is a seasonal one and the flow is available for 4 months. The head is nearly 140m. The nearest 11KV transformer is available at Perinthenaruvi which is about 4km away from the site.

The water fall is located at  $76^{\circ} 54' 39''$  E longitude and  $9^{\circ} 23' 51''$  N latitude. The catchment area measured from topo sheet is 3.57sq. km. The falls are situated at an elevation of 200 m from MSL in Panamkudantha stream. The stream flows through steep slope. After the fall, the stream joins to the Pampa River near Panamkudantha (**Fig.No.29.1**)

### **29.1.2 Topography**

The site is situated in Kannamala Forest Station Limit. The forest is very thick. The land is having steep slopes in this area. There is no possibility for land slide in this area and chances for soil erosion is less and it is negligible. The bed of the stream is rocky and boulders are available in plenty in this area. The rainfall intensity is high in its catchment. The number of rainy days exceeds 50% in its catchment.

## **29.2 FIELD INVESTIGATION**

### **29.2.1 Reconnaissance Survey**

A topographical survey for obtaining topographical details of the site. There is two main fall and two moderate falls which gives a total head of 140m. The possible location for diversion structure and power house are identified and the details are taken using tacheometric method of surveying.

### 29.2.2 Catchment Area

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Panamkudantha was located using the toposheet. It is shown in the **Fig.No. 29.2**. From the shape it is identified as a fern shaped catchment and its area comes nearly 3.50km. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998-99 is about 4.48 cumec.

### 29.2.3 Contour Map

The survey details were plotted on a sheet of paper at a scale of 1:200. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house was also determined using this and the prepared contour map has been shown in **Annexure A.29**.

### 29.2.4 River Flow Data

For a period of 12 months (January 1998 to January 1999) the water level observations were taken in every week. A suitable location was identified on the down stream of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating discharge of stream. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 29.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 29.3**.

### 29.2.5 Flow Duration Curves

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 29.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 29.2**. These data are used for calculating energy potential and selection of unit sizes in section 29.4.

### 29.2.6 Peak Flow Determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 29.3**. The value obtained by Dicken=s formula, which is

commonly used in western ghats region has been used for the structural design.

**Table 29.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve =s formula	Nawab Jung Bahadur formula
Peak flow in cumecs	66.53	115.57	23.28	164.96

### 29.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work have not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost are fixed consulting various agencies

#### 29.3.1 Power Potential of the Project

The discharge corresponding to 75% of exceedence is only 0.009 cubic metre per second. A discharge of 0.009 cubic metre per second can produce only about 8 KW. In order to tap the full potential of the site, with a head of 140 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a peak load station which can produce 100 kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

- P = Power output in kW
- Q = Discharge in cumec
- H = Head in metres
- $\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 0.095 \times 140 \times 0.75 = \mathbf{100 \text{ kW}}$ .

For 40% exceedence  $P = 10 \times 0.095 \times 140 \times 0.75 = \mathbf{200 \text{ kW}}$ .

For 30% exceedence  $P = 10 \times 1 \times 140 \times 0.75 = 550 \text{ kW}$ .

### 29.3.2 Energy Potential

At this site, sufficient flow is there so that we can obtain 100kW power output for 50% of the time (183 days) which reduces to 10kW by 60% time (219 days). The energy input corresponding to 50% time will be  $(50/100 * 100 * 365 * 24) = 0.438 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be  $316516 \text{ m}^3$ . Energy obtained from this water is calculated to be  $0.092 \text{ MU}$ .

Total amount of energy produced =  $0.438 \text{ MU} + 0.092 \text{ MU} = 0.53 \text{ MU}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 29.3.3 Pondage Requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 29.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 29.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 29.6**.

**Table 29.4**  
**Pondage Area Details**

Sl. No.	Elevation (m.)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	298.50	0	0	0
2	299	96.20	48.10	1.4
3	300	188.80	190.60	505
4	301	386.20	478.10	14
5	303	666.00	1530.30	44.5
6	305	975.00	3171.30	92.5

As the terrain is suitable for storing 3000m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 600 kWh. If a single 600 kW machine is installed, it can be operated for only one hour at full capacity (during peak time). Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 6.5 m, to create a storage of 3000 m<sup>3</sup> is suggested.

## 29.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs. in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Panamkudantha be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs.2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 450 kW, which corresponds to about 33% flow of exceedence from the chart, the total energy yield is the sum of:

$450 \text{ kW} \times (0.33 \times 8760) = 1.3 \text{ MU}$  at continuous operation for 33% time of an year, and 0.3MU, which is the cumulative energy potential from 33% to 100% time as obtained from the Chart (Table 29.3).

Total yield =  $1.3\text{MU} + 0.3\text{MU} = 1.6 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$PCF = 1.6 \times 10^8 / (450 \times 8760) = 40.5 \%$$

This PCF is equal to the break even value of 40%.

*So 450 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 650 kW (for 21% flow of exceedence)

$$PCF = (2000000 / 650 \times 8760) \times 100 = 35\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 650 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 29.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	450 kW
Rs.3.00/ Unit	650 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (0.25 MW x 2)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (0.5 MW x 1 + 0.1MW x 1 +0.05 x1)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

## 29.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 7.5m x 5m.

### 29.5.1 Weir at Panamkudantha

A concrete weir has been proposed on the Panamkudantha stream, at a bed level of +198.000 metres. The base width of the weir at bed level is 6.00 m. The structure is 4.60 m high having a length of 25m. at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No.29.7**.

### 29.5.2 Intake Structure, Penstock and Power House

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 0.45m. The penstock can carry a maximum flow of 0.43 cumec with a velocity of 0.93 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 126m (**Fig. No. 29.8**).

A surface power house is proposed on the right bank of the stream. The slope at the proposed site is moderate. The power house is of size 7.5m x 5m to accommodate 450kW, generator and standardised turbine.

## 29.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 100 kW. The electricity generated would be connected to the existing power grid system at Vechuchira by a 900 m transmission line. A standardised turbine for 140m gross head is proposed for this

particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 450 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

## **29.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Panamkudantha (Pathanamthitta Dist.). The project aims to generate about 450 kW of hydro power from a fall having a head of 140m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

### **29.7.1 Environmental Impact on Land**

Total area of catchment is about 28.5 square kilometres of land in Kanjirappuzha. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi evergreen and deciduous. The land at left bank of stream is owned by private persons and the right bank is forest land. Stream sections are mostly rocky large sized boulders are plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **29.7.2 Environmental Impact on Water**

The Kanjirappuzha, which drains to Chaliyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.0975ha. No forest land will be submerged. Above all, this accounts for only 0.22 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **29.7.3 Socio-economic Impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **29.8 CONCLUSION**

The environmental impact of small hydel project is negligible compared to large hydel projects. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 450kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 650kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **30 . KEEZHARKUTHU**

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**District : Idukki**

**Panchayath : Kanjikuzhi**

**Head : 180 m.**

**Flow : Perennial**

**Suggested Capacity : 10.5 MW/ 13 MW**



## **30.1 GENERAL**

### **30.1.1 The site**

The Keezharkuthu water fall is situated in the 10th ward of Kanjikkuzhi Grama Panchayath in Idukki district. The site is at a distance of 30km. from Kanjikkuzhi. There is a bus route from Kanjikkuzhi to Thadiyampadam which is 5km. away from Kanjikkuzhi. From Thadiyampadam, there are occasional bus services to Maniyarkkudy. From Maniyarkkudy which is at 10km. from Thadiyampadam, there is a jeepable road to Kaithappara. From there, we have to travel 3km. through dense forest to reach the site. There is another bus route from Thodupuzha to Kaithappara through Udumbannoore. But it is very lengthy and not convenient for transport.

The water fall is located at  $76^{\circ} 52' 30''$  E longitude and  $9^{\circ} 54' 20''$  N latitude. The catchment area measured from topo sheet is 17sq. km. The falls are situated at an elevation of 770m from MSL in Keezhar stream which is beginning at an elevation of 1034m. It is flowing almost strate through the fern shaped catchment area. After the fall, the stream joins the Velur Puzha which in turn is draining into Kaliyar a tributery of Muvattupuzha (**Fig.No.30.1**).

### **30.1.2 Topography**

The site is situated in Thodupuzha Reserved Forest . This is a dense forest. The land is having steep slopes in this area. There is no possibility for land slide in this area and chances for soil erosion is less and it is negligible. The bed of the stream is rocky and boulders are available in plenty in this area. The rainfall intensity is high in its catchment. The number of rainy days exceeds 50% in its catchment. The fall is located almost 200m. high before the stream starts flowing horizontally.

## **30.2 FIELD INVESTIGATION**

### **30.2.1 Reconnaissance survey**

A topographical survey for obtaining topographical details of the site. There is two main fall and two moderate falls which gives a total head of 180m. The possible location for diversion structure and power house are identified and the details are taken using tacheometric method of

surveying.

### **30.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Keezharkuthu was located using the toposheet. It is shown in the **Fig.No.30.2**. From the shape it is identified as a fern shaped catchment and its area comes nearly 3.50km. The catchment area having almost moderate slope but some portions are very steep. Maximum flood discharge measured at this site during 1998-99 is about 12 cumec.

### **30.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:400. The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house was also determined using this and the prepared contour map has been shown in **Annexure A.30**.

### **30.2.4 River flow data**

For a period of 12 months (November 1997 to 1998) the water level observations were taken in every week. A suitable location was identified on the down stream of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating discharge of stream. We fixed a measuring gauge at this point to measure the peak flow. Using the collected data (**Table 30.1**) the weekly discharge hydrograph of the site is prepared. The graph is shown in **Fig. No. 30.3**.

### **30.2.5 Flow duration curves**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 30.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 30.2**. These data are used for calculating energy potential and selection of unit sizes in **section 30.4**.

### **30.2.6 Peak flow determination**

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 30.3**. The value obtained by Dickens formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 30.3**  
**Peak Flow Determination**

Parameters	Dickens method	Inglis formula	Ryve's formula	Nawab Jung Bahadur formula
Peak flow in cumec	217.68	399.44	66.77	259.87

### 30.3 SALIENT DESIGN FEATURES

A detailed design of Civil, Electrical and Mechanical work have not been carried out in this report as it does not come under the purview of the project, but a typical section of the proposed diversion structure is given here. The stability analysis of the section and economic diameter of the penstock was carried out as part of preliminary design. The capability and number of units, type and specification of turbine, generator and its cost are fixed consulting various agencies

#### 30.3.1 Power potential of the project

The discharge corresponding to 100% of exceedence is only 0.02 cubic metre per second. A discharge of 0.02 cubic metre per second can produce only about 27 kW. In order to tap the full potential of the site, with a head of 180 metre, the project is designed to generate higher output with lower dependability. This site can be designed as a peak load station which can produce 2500 kW with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times \eta$

Where;

P = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 1.85 \times 180 \times 0.75 = 2500 \text{ kW}$

For 40% exceedence  $P = 10 \times 4 \times 180 \times 0.75 = 5400 \text{ kW}$

For 30% exceedence  $P = 10 \times 5.88 \times 180 \times 0.75 = 8000 \text{ kW}$

### 30.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 2500kW power output for 50% of the time (183 days) which reduces to 10kW by 60% time (219 days). The energy input corresponding to 50% time will be  $(50/100 \times 2500 \times 365 \times 24) = 11\text{MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be  $8416699 \text{ m}^3$ . Energy obtained from this water is calculated to be 3.16 MU.

Total amount of energy produced =  $11 \text{ MU} + 3.16 \text{ MU} = 14.16 \text{ MU}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 30.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig. No. 30.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 30.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 30.6**.

**Table 30.4**  
**Pondage Area Details**

Sl. No.	Elevation (m.)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	93.0	804.80	201.120	7.5
2	93.5	1301.40	757.590	27.3
3	94.0	1917.28	1532.26	57.5
4	94.5	2506.14	2638.121	99
5	95.0	3173.76	4058.098	152
6	95.5	3680.22	5771.593	216
7	96.0	4224.16	7747.880	291
8	96.5	4819.95	10008.710	375
9	97.0	5455.00	12577.466	472

As the terrain is suitable for storing 12500m<sup>3</sup>, it follows that, at full storage, the energy capacity is only about 450 kWh. If a single 450 kW machine is installed, it can be operated for only one hour at full capacity during peak time. Fortunately, pondage becomes critical only during lean months, this kind of operation practice is acceptable. Hence, a weir height of 6m. to create a storage of 12500 m<sup>3</sup> is suggested.

### 30.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Keezharkuthu be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$   $X = 3,500$  hrs.

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of *Plant Capacity Factor*, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of  $X = 3500$  hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per mega watt where  $X=2916$  hours is 33.3%.

Now we shall check various capacities of turbine size which are suitable for this two conditions.

#### **a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 10500 kW, which corresponds to about 12% flow of exceedence from the chart, the total energy yield is the sum of:

$10500 \text{ kW} \times (0.12 \times 8760) = 11\text{MU}$  at continuous operation for 12% time of an year, and 27.5 MU, which is the cumulative energy potential from 12% to 100% time as obtained from the Chart (Table 30.3).

Total yield =  $11\text{MU} + 27.5\text{MU} = 38.5 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$PCF = 38.5 \times 10^8 / (10500 \times 8760) = 41.8 \%$

This PCF is equal to the break even value of 40%.

*So 10500 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, for 13000 kW (for 5.5% flow of exceedence)

$$\text{PCF} = (40260000 / 13000 \times 8760) \times 100 = 35.3\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 13000 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 30.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	10500 kW
Rs.3.00/ Unit	13000 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (5 MW x 2 + 0.5 MW x 1)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (5 MW x 2 + 1MW x 3)

Among these two categories, the second one seems to be less viable since it is bulky with units.

We have restricted ourselves to the more realistic combination of Rs. 3.5 Crores/MW of investment cost and two tariff choices of Rs.2.5/Unit and Rs.3.0/Unit.

### 30.5 CIVIL ENGINEERING WORKS

The important Civil Engineering Works required for the project are a diversion weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project only a diversion weir is proposed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock made of steel is proposed in this site. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 10m x 8m.

#### 30.5.1 Weir at Keezharkuthu

A concrete weir has been proposed on the Keezharkuthu stream, at a bed level of +198.000 metres. The base width of the weir at bed level is 6.00 m. The structure is 4.60 m high having a length of 25m. at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No.30.7**.

#### 30.5.2 Intake Structure, Penstock and Power house

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 1.5m. The penstock can carry a maximum flow of 7.78 cumec with a velocity of 4.4 metre per second. The possible alignment for the penstock is located on the right bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 404.5m (**Fig. No. 30.8**). A surface power house is proposed on the right bank of the stream. The slope at the proposed site is moderate. The power house is of size 10m x 8m to accommodate 10500kW, generator and standardised turbine.

### 30.6 ELECTRICAL AND MECHANICAL EQUIPMENTS

The power house proposed in the scheme will have an installed capacity of 10500 kW. The electricity generated would be connected to the existing power grid system at Vechuchira by a 900 m transmission line. A standardised turbine for 180m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety

devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 10500 kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **30.7 ENVIRONMENTAL IMPACTS**

A small hydro project has been proposed at Keezharkuthu (Idukki Dist.). The project aims to generate about 450 kW of hydro power from a fall having a head of 140 m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

#### **30.7.1 Environmental impact on land**

Total area of catchment is about 28.5 square kilometres of land in Kanjirappuzha. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi evergreen and deciduous. The land at left bank of stream is owned by private persons and the right bank is forest land. Stream sections are mostly rocky large sized boulders are plenty. The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

### **30.7.2 Environmental impact on water**

The Kanjirappuzha, which drains to Chaliyar river is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.0975ha. No forest land will be submerged. Above all, this accounts for only 0.22 ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **30.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 50 skilled and 100 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **30.8 CONCLUSION**

The environmental impact of small hydel project is negligible compared to large hydel projects. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 10500kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 13000kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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## **31 . ATTALA**

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**District : Palakkad**  
**Panchayath : Karimba**  
**Head : 180 m.**  
**Flow : Perennial**  
**Suggested Capacity : 6 MW / 7.5 MW**

## **31.1 GENERAL**

### **31.1.1 The site**

The Attala is a scenic water fall situated in the 8th ward of Karimba Grama Panchayath in Palakkad district. The site is at a distance of 11 km from Kalladikkode. There is bus service from Mannarkkad to Munnekkar through Kalladikkode. From Munnekkar, there is an unmetalled jeepable road nearly 3 km. to reach the site. The nearest 11KV transformer is at a distance of 3km. away from site.

The water fall is located at  $77^{\circ} 25' 49''$  E longitude and  $10^{\circ} 56' 30''$  N latitude. The catchment area measured from topo sheet is **4.5 sq. km**. The falls are situated at an elevation of 620m, in Karimpuzha stream which is beginning at an elevation of 1924m. After the fall, the stream joins to the Karimbuzha which drains to the Bharathapuzha (**Fig.No.31.1**).

### **31.1.2 Topography**

The site is situated in Karimala reserved forest. The forest is very thick. The land is having steep slope in this area. There is no possibility for land slide in this area and the chances for soil erosion is very less and it is negligible. The bed of the stream is rocky and boulders are available in plenty at site.

## **31.2 FIELD INVESTIGATION**

### **31.2.1 Reconnaissance survey**

A topographical survey for obtaining topographical details of the site. The site contains five falls which gives a total head of 210m. The position of the diversion structure and power house are identified and tacheometric method is used for surveying work.

### **31.2.2 Catchment area**

Topographical survey sheets to a scale of 1:50,000 are available from the Survey of India. The catchment of Attala water fall was located using the toposheet. It is shown in the **Fig.No.31.2**. From the shape it is identified as a fan shaped catchment and its area comes nearly 4.75 sq.km. Peak value of flood will be less for this basin as the difference between concentration time and time at which flow starts will be large. The volume of flow will be distributed through a larger length of time.

### **31.2.3 Contour map**

The survey details were plotted on a sheet of paper at a scale of 1:200 (**Annexure A.31**). The undulations of the site, the location of the falls and other topographical features were identified from the contour map. The location of the weir, the alignment of the penstock and location of the power house were also determined using this and marked in the above map, along with the contours of the area.

### **31.2.4 River flow data**

For a period of 12 months (January 1997 to January 1998) the water level observations were taken in every week. A suitable location was identified on the downstream of the fall, where the whole water is flowing through that point, cross sectional details of the point was noted for calculating discharge of stream. We fixed a measuring gauge at this point and engaged a local person for taking weekly flow data, we also visited the site once in every month for collecting the data from the local person. From the collected data the weekly discharge is collected and make it into tabular form (**Table No.31.1**) for weekly discharge graph preparation. The graph is shown in **Fig.No.31.3**

### **31.2.5 Flow duration curves**

Using weekly discharge hydro graph, percentage flow of exceedence was calculated. From this, the flow duration curve was plotted (**Fig. No. 31.4**). The same curve also functions as percentage flow of exceedence graph. This river flow data is recalculated in tabular form, giving the corresponding energy potential in weekly and cumulative mode is given in **Table 31.2**. These data are used for calculating energy potential and selection of unit sizes in **section 31.4**.

### 31.2.6 Peak flow determination

There are various empirical methods for calculating the maximum flood discharge. The different values obtained are shown in **Table 31.3**. The value obtained by Dicken=s formula, which is commonly used in western ghats region has been used for the structural design of diversion structure.

**Table 31.3**  
**Peak Flow Determination**

Parameters	Dicken=s method	Ingli=s formula	Ryve=s formula	Nawab Jung Bahadur formula
Peak flow in cumec	83.66	150.1	28.52	213.37

### 31.3 SALIENT DESIGN FEATURES

The design of any hydro electric project can be divided into two. viz. Civil Engineering Works and Electrical & Mechanical Works. The design of civil engineering work in detail is presented in this chapter. A detailed design of Electrical and Mechanical work have not been carried out as it does not come under preview of the project. However, for the sake of cost estimation, required details are collected from various agencies.

#### 31.3.1 Power potential of the project

The discharge corresponding to 100% of exceedence is only 0.1 cubic metre per second. A discharge of 1.03 cubic metre per second can produce only about 135 KW. However it seen that higher flow are available during 50% of the time. In order to tap the full potential of the site, with a head of 180 m. the project is designed to generate higher output with lower dependability. Moreover, hydroelectric scheme are usually used as peak load station as the Thermal and other types of power plants are not easily shut down or start up. This site can be designed as a peak load station which can produce 1250kW for 3 hours duration of peak load with a dependability of 50%.

The output power was computed using the formula,  $P = 10 \times Q \times H \times h$

Where;  $P$  = Power output in kW

Q = Discharge in cumec

H = Head in metres

$\eta$  = Overall efficiency (Here it is assumed as 0.75)

For 50% exceedence  $P = 10 \times 1.03 \times 180 \times 0.75 = \mathbf{1250 \text{ kW}}$

For 40% exceedence  $P = 10 \times 2.57 \times 180 \times 0.75 = \mathbf{3500 \text{ kW}}$

For 30% exceedence  $P = 10 \times 3.67 \times 180 \times 0.75 = \mathbf{5000 \text{ kW}}$

### 31.3.2 Energy potential

At this site, sufficient flow is there so that we can obtain 1250kW power output for 50% of the time (183 days) which reduces to 100kW by 90% time (328 days). The energy input corresponding to 50% time will be  $(50/100 * 1250 * 365 * 24) = 5.5 \text{ MU}$ . The flow after 50% time can be utilized by providing a small pondage. The quantity of water available from 50% to 100% time is calculated to be  $5676048 \text{ m}^3$ . Energy obtained from this water is calculated to be 2.12 MU.

Total amount of energy produced =  $5.5 \text{ MU} + 2.12 \text{ MU} = \mathbf{7.6 \text{ MU}}$

It may be noted that, this much amount of energy can be generated for the particular year. If higher flows are available during any year, it will enable higher production and vice versa.

### 31.3.3 Pondage requirement

From the contour map a plot of surface area Vs. elevation is drawn in **Fig.No.31.5**. The areas corresponding to each elevation is used to find the volume of water that can be stored in each elevation and the details is shown in **Table 31.4**. From this information capacity elevation curve of the pondage is prepared and is shown in **Fig.No. 31.6**.

**Table 31.4**  
**Pondage Area Details**

Sl. No.	Elevation (m)	Area (m <sup>2</sup> )	Capacity (m <sup>3</sup> )	Energy (kWh)
1	500.5	0	0	0
2	501.0	46	23.00	0.86
3	502.0	151.76	121.88	4.50
4	503.0	255.80	325.66	12.00
5	504.0	413.00	660.00	25.00
6	505.0	538.50	1135.80	43.00
7	506.0	732.20	1771.20	66.00
8	507.0	928.00	2601.30	97.50
9	508.0	1060.00	3595.30	135.00

### 31.4 SELECTION OF PLANT CAPACITY AND UNIT SIZES

For optimization of plant capacity, the following parameters were assumed.

Rate of return on investment	-	15%
Loan repayment period	-	10 years
Average O/M cost	-	2.5% of capital cost
Resulting standard annual cost	-	25%

(This consists of 2.5% O & M costs, 15% return on 25% equity, 15% interest on 75% loan and repayment of loan in 10 annual instalments)

Tariff (per Unit)	-	Rs. 2.5 and 3.0 (Two cases)
Investment cost (Rs.in Crores per MW)	-	Rs. 3.5 (Two cases)

Since manufacturers were not in a position to quote exact figures, no attempt was made to fine tune the cost in relation to site specific conditions. Only ranges could be indicated. Each combination of tariff and capital cost selected above, will demand a minimum annual generation per kW installed. This can be taken to be the break even Plant Capacity Factor (PCF) for the site under the specified conditions.

*Lower the cost/MW and higher the price for energy, the larger will be the economically viable installed capacity and the quantity of energy that can be economically extracted from a given site.*

Let the capital cost of Attala be Rs.3.5 crores/MW. The annual rate is 25%. Let the unit rate of tariff offered by K.S.E.B be Rs. 2.5/kWh.

If X be the number of hours of operation at full load capacity,

per Mega Watt annual cost, at the rate of 25% on investment = Rs. 3.5 Crores x 0.25

per Mega Watt revenue = 1000 kW x Rs. 2.5 x X

Equating the two, we get  $3,50,00,000 \times 0.25 = X \times 1000 \times 2.5$

$$X = 3,500 \text{ hrs.}$$

It follows that, any combination of machines, that can work at full capacity for over 3500 hours can deliver a profit, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.

This can be explained better in terms of **Plant Capacity Factor**, which is defined as the ratio of actual amount of energy obtained to the maximum energy that can be obtained from the given installed capacity during an year, to the actual amount of energy obtained.

In this case, for the value of X = 3500 hours,  $PCF = (3500 / 8760) \times 100 = 40\%$

That is, a maximum capacity, which yields a PCF of 40% is economically viable for this site.

Similarly, break even PCF for Rs.3.0 per and Rs. 3.5 Crores per Mega Watt where X=2916 hours is 33.3%

Now we shall check various capacities of turbine size which are suitable for this two conditions.

**a. Tariff: Rs.2.50/kWh and break even PCF of 40%**

For an installed capacity of 6000 kW, which corresponds to about 10% flow of exceedence from the chart, the total energy yield is the sum of:

$6000 \text{ kW} \times (0.1 \times 8760) = 5.26\text{MU}$  at continuous operation for 10% time of an year, and 17MU, which is the cumulative energy potential from 10% to 100% time as obtained from the Chart (Table 31.3).

Total yield =  $5.26\text{MU} + 17\text{MU} = 22.26 \text{ MU}$ .

The Plant Capacity Factor, corresponding to this yield is given by :

$$\text{PCF} = 22.26 \times 10^8 / (6000 \times 8760) = 42.4 \%$$

This PCF is equal to the break even value of 40%.

*So 6000 kW will be the optimum choice for the site, if the overall project cost is below Rs.3.5 crores/MW and tariff is Rs. 2.5 per kilo Watt hour.*

**b. Tariff: Rs.3.00/kWh and break even PCF of 33.3%**

Similarly, For 7500 kW (for 1.5% flow of exceedence)

$$\text{PCF} = (23500000 / 7500 \times 8760) \times 100 = 35.5\%$$

This PCF is very near to the break even value of 33%.

*Similarly, 7500 kW will be the optimum choice for the site, if the overall project cost is below Rs. 3.5 crores/MW and tariff is Rs. 3.0 per kilo Watt hour.*

**Table 31.5**  
**Economically Viable Maximum Capacity at Different Costs and Tariff**

Tariff	Unit size for Rs.3.5 Crores/MW
Rs.2.5/Unit	6000 kW
Rs.3.00/ Unit	7500 kW

The units selected can be one of the following combinations:

For Rs.3.5 Crores/MW and Rs.2.5/Unit we can opt (2 MW x 3)

For Rs.3.5 Crores/MW and Rs.3.0/Unit we can opt (5 MW x 1 + 2MW x 1 + 0.5 x 1).

Among these two categories, the second one seems to be less viable since it is bulky with units. We have restricted ourselves to the more realistic combination of Rs.3.5 Crores/MW of investment cost and two tariff choices of Rs. 2.5/Unit and Rs. 3.0/Unit.

### **31.5 CIVIL ENGINEERING WORKS**

The important Civil Engineering Works required for the project are a weir, an intake structure, a penstock and a power house. A weir is constructed to have a small storage and to divert the water from stream to the intake. For this project an overflow weir is to be constructed, which allows the excess water to flow over the weir to the downstream. The intake structure takes water from the weir and lead it to the penstock. The penstock is a pressure pipe which carries water to the turbine. It can be made of steel, cast iron, plastics (Poly Vinyl Chloride, High Density Poly Ethylene) and concrete. In this project a steel penstock is used. A power house is constructed for the purpose of housing the electro mechanical equipment. It is usually a small building of 20m.x 10m. A detailed design of the civil works are given below.

#### **31.5.1 Weir at Attala**

A gabion weir has been proposed on the Attala stream, at a bed level of +500.500 metres. The base width of the weir at bed level is 4.2m. The structure is 7m. high having a length of 15m. at the top with a central board crested free over fall type spill way. The cross sectional details of the proposed diversion site is shown in **Fig.No.31.7**.

#### **31.5.2 Intake Structure, Penstock and Power house**

A simple box type, direct intake structure of reinforced cement concrete is provided on the stream bed. A trash rack is provided at the intake mouth, the penstock entrance starts from the wall of intake box near the gabion. The economic diameter of the penstock is calculated as 1.2m. The penstock can carry a maximum flow of 4.44 cumec with a velocity of 4 metre per second. The possible alignment for the penstock is located on the left bank of the stream. The longitudinal section of the proposed penstock line was drawn from contour map and calculated the length, which comes to 147m (**Fig. No. 31.8**).

A surface power house is proposed on the left bank of the stream. The slope at the proposed site is moderate but increases up the hill towards north east direction. The power house is of size 20m x 10m, to accommodate 6000 kW, generator and standardised turbine.

### **31.6 ELECTRICAL AND MECHANICAL EQUIPMENTS**

The power house proposed in the scheme will have an installed capacity of 6000 kW. The electricity generated would be connected to the existing power grid system at Munnekkar by a 500m transmission line. A standardised turbine for 20m gross head is proposed for this particular site. The turbine shall be complete with governor, control equipment and safety devices. The generator would be synchronous with a brushless excitation system shall be rated to generate 6000kW, 11kV three phases, 50Hz and shall be suitable for coupling with turbine described above. The generator shall have voltage regulation equipment, parallel operation equipment etc.

### **31.7 ENVIRONMENTAL IMPACT**

A small hydro project has been proposed at Attala (Palakkad Dist.). The project aims to generate about 6000 kW of hydro power from a fall having a head of 180m. Some preliminary environmental impact analysis have been carried out. They are land, water and socio-economical environmental impacts.

#### **31.7.1 Environmental impact on land**

Total area of catchment is about 4.75 sq. km. of land in Karimbuzha. The upper catchment is rocky and with little vegetation cover. The forest in this sector is semi evergreen and deciduous. The land at left bank of stream is owned by private persons and the right bank is forest land. Stream sections are mostly rocky large sized boulders are plenty.

The most significant thing is that, due to impoundment, no forest land will be submerged. The construction of weir, penstock, power house, tailrace and temporary road will not take away any forest land.

#### **31.7.2 Environmental impact on water**

The Karimpuzha, which drains to Bharathapuzha is the stream of this fall. It is a 3rd order, structurally controlled stream. The diversion structure will create a pond of area 0.106ha. No forest land will be submerged. Above all, this accounts for only 0.0177ha/MW. This diversion structure which also acts as a check dam can increase the height of water table level at the site. The impounded water will also change soil moisture regime in adjacent forest land.

### **31.7.3 Socio-economic impact**

The construction phase would create employment opportunities for a period of 18 months. The peak labour strength is 100 skilled and 150 unskilled labour. It requires only minimum land acquisition for construction. The acquisition does not need any rehabilitation.

## **31.8 CONCLUSION**

The environmental impact of small hydel project is negligible compared to large hydel projects. Moreover, deforestation owing to the inundation will be a meagre area.

The economic size of installed capacity depends upon the permissible tariff as well as the capital cost. It was found that the project is financially viable for an installed capacity of 6000kW at a project cost of Rs. 3.5 Crores per MW and a tariff rate of Rs.2.5 per unit of electricity. Alternatively, if the tariff is raised to Rs.3.00 per unit, an installed capacity of 7500kW would become economically viable.

Cost effective methods of construction, like the use of gabion weirs, can be used to reduce the capital costs. A methodology for implementing the project with a maximum of peoples= participation should also be devised. The role of the Grama Panchayath in this effort is crucial.

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