OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

API Renewable Energy LLC

Combining the Energy of Human Hope with New Greener Economy

UNIDO PROJECT: TF/UGA/08/004

CONTRACT NUMBER: 16002124/RE

FEASIBILITY STUDY FOR NDUGUTU RIVER MINIHYDRO POWER PLANTS TO REDUCE THE VULNERABILITY OF THE POOR POPULATION TO CLIMATE CHANGE IMPACTS BY PROVIDING ECONOMIC EMPOWERMENT

API

2011

API RENEWABLE ENERGY (UGANDA)

PLOT 696/679, BUNGA, GABA ROAD

P.O. BOX 14299, KAMPALA, UGANDA TEL: +256 414 66 2547

FAX: +256 414 66 2548

MOBILE: +256 715 911 600

Email: info@api.co.ug

BS 8110 HAS BEEN USED FOR ALL CIVIL ENGINEERING STRUCTURAL DESIGN CALCULATIONS

USBR STANDARDS USED FOR HYDRAULIC DESIGN COMPUTATIONS

API 1104 STANDARD IS USED FOR PENSTOCK AND OTHER STEEL STRUCTURAL DESIGNS AND DESIGN VERIFICATIONS

ASME CODE IS USED FOR ELECTRO-MECHANICAL INSTALLATIONS

THE GEOGRAPHICAL POSITIONING ELEVATIONS ARE SHOWN ON THE FLAT PLAN OF THE GENERAL ARRANGEMENT DRAWING. THESE VALUES ARE BASED ON MEAN SEA LEVEL (MSL) IN METERS.

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

The feasibility analysis of Ndugutu River hydro power projects have been prepared to provide the status of detailed analysis on the viability of the project including the geographical, geological and hydrological analysis. Upon which its construction methodologies will be assessed and designs has to be carried out and finally the project feasibility will be determined by the project financial analysis.
The proposed mini hydropower projects are intended to take water from Ndugutu River, which lies in Bundibugyo District in the Western part of Uganda, bordering the Democratic Republic of Congo and at the foot of Rwenzori Mountains. The proposed project site is on River Ndugutu which lies in Bundibugyo District.

Initial site investigations were carried out during the months of January 2010 and April 2011, followed by desk calculations, laboratory investigations, modeling etc prior to the compilation of first draft report. Basic outline of the project includes a diversion weir, headrace channel, fore bay tank, penstock, power house with electro-mechanical equipments, transmission and distribution network. The hydrological study on the river flows has been carried out based on rainfall figures obtained from rain gauging stations located within the catchments of river Ndugutu.

A comprehensive geological study has been carried out by a professional geologist, based on the data from field investigations and resulted with observation of the existence of most stable formation of an alternation of granite and gneiss tics granite. This geological study reveals the suitability of the site for the project and recommendations have been provided in order to increase the stability of the soil. A detailed investigation on the catchments erosion and silting has been carried out as river water contain considerable amount of silt due to upstream catchments erosion.

RIVER NDUGUTU MINI HYDRO PROJECT SITE

Fig 1: Map of Uganda showing the position of Bundibugyo district (River Ndugutu Hydro Project Site)

1.0 SALIENT FEATURES: NDUGUTU RIVER, BUNDIBUGYO DISTRICT

East	: 165000 to 165700
South	: 66000 to 67200
River	: Ndugutu
Type of project	: Mini Hydro
Hydrology	
Catchment area	: 42.5sq.km
Design flow	: 0.55 m³/sec
Head	
Net head	: 82.5 m
Weir	
Type	: Clear overflow
Length	: 8m
Height	: 3 m
Concrete canal	
Type	: Rectangular
Length	:1.2 Km
Width	:1.2 m
Height	:0.6 m
Forebay	
Length	:10.70 m
Width	: 3 m
Height	: 3 m
Penstock	
Type	: Steel Pipes
Length	: 250 m
Thickness	: 6.0 mm
Diameter	: 560 mm
Power and energy	
Installed capacity	: 320 KW
Turbine	
Type	: Francis
Number of unit	: 1

Rated capacity	: 1,500 trs/min
Generator	
Type	: Synchronous
Number of unit	: 1
Rated capacity	: 1,500 trs/min
Power transformer	
Type	: Outdoor, oil cooled
Number of unit	: 1
Rated capacity	: 315KVA, 415KV/33KV
Financial parameters	
Project cost, USD$	: 3,099,194 (excluding VAT)
Annual energy produced, KWh	: 2,102,400
Development Cost p/KWh	: $9,685
Financial Project NPV	: ($662,074)
Financial Project IRR	: 2.47%
Economic Return Rate (Annualized)	: 10.70%
Project Payback	: 16
Recommendation	: Proceed; Co-op format; Off-grid

SALIENT FEATURES: INFRASTRUCTURE

Power house	
Type	Stone masonry
Floor size	$96m^2$
Access road	
Rehabilitation of existing road	N/A
New access	N/A
Substation	
Type	Compact
No of cellule	7
Transmission line 30 KV	4 km

1.0 HYDROLOGICAL REPORT ON NDUGUTU RIVER MINI HYDRO PROJECT

1.1 INTRODUCTION

1.1.1 Background

The amount electrical energy that can be generated with a hydropower plant is directly proportional to the product of flow and available hydraulic head. This makes the knowledge of river discharge, its annual distribution and long term variability very essential for the planning and design of a hydropower plant. The long term river discharge records are especially very vital for the selection of the design discharge. These discharge records are not always available, however most of the time long term rainfall records may be available within and/or around the catchment of interest. Hydrology present opportunities for modeling the possible river discharge using rainfall records. The modeled discharges can be presented in a form of Flow Duration Curves (FDC) which in turn can be used in selection of the design discharge.

Hydrologic systems are sometimes impacted by extreme events, such as severe storms, floods, and droughts. The magnitude on an extreme event is inversely related to its frequency of occurrence. In general very severe events occur less frequently than more moderate events. The knowledge of flood flow frequency are use for the technical and economic design of engineering structures such dams, weirs, bridges, culverts, flood control structures etc. The design of a hydropower plant requires the construction of dam and/or weir. One of the basic requirements for the design of dams and weirs is the knowledge of flow exceedence probability that is the maximum flood with which the structure is designed. Hydraulics structures such as dams and weirs are expected to work efficiently without problem of failure or damage for a flood less than or equal to the design flood. In the event of a flood that exceeds the design flow the probability of failure or damage of the structure is possible. The maximum floods that can be expected in a river in the absent of river flow data when the long term rainfall records is available can also be modeled using hydrologic methods. Depending on the method to be use the modeling hydrologic respond of a watershed at the absent of river flow data may require some of the followings: catchment area, rainfall, topography, soil data, and use and land cover etc.

1.1.2 Objective

This study was carried out with the main objective of determining the basic hydrological parameters necessary for the design of hydropower plant at River Ndugutu, which lies in Bundibugyo District in Western part of Uganda, bordering the Democratic Republic of Congo and at the foot of Rwenzori Mountains. Thais includes the determination of the followings:

a) Analyzing climate and precipitation data

b) Flow measurements

c) Determining the size of the catchment area and assessing its characteristics

d) Analyzing flood patterns

e) Correlating the meteorological data with flow data

f) Obtaining the flow duration curve

g) Investigating the amount of water required for purposes such as irrigation

h) Estimation of the design flow

1.2 DESCRIPTION OF THE PROJECT AREA

1.2.1 Location

The proposed project site is on River Ndugutu which lies in Bundibugyo District in the Western part of Uganda, bordering the Democratic Republic of Congo and at the foot of Rwenzori Mountains.

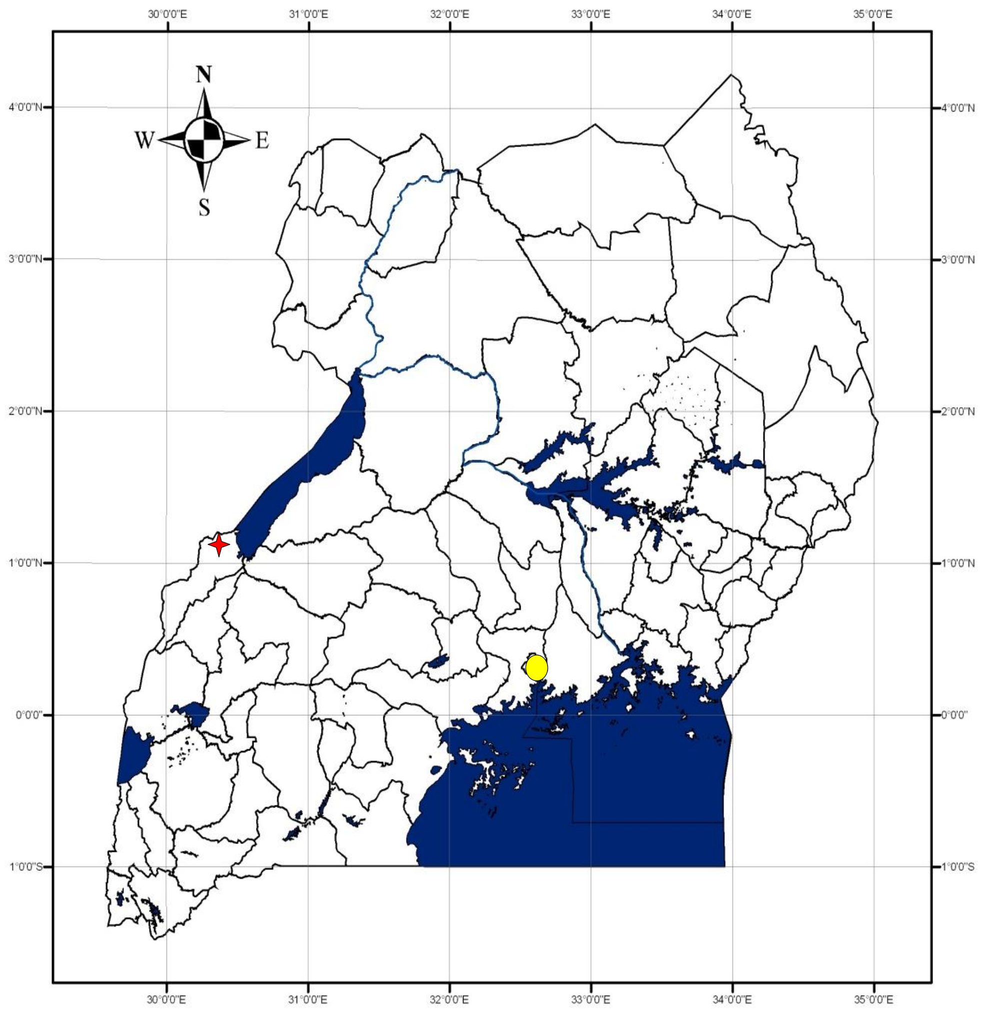


Fig 2: Geographical location of Ndugutu HPP project area

Legend

- Site Ndugutu
- Kampala
- Water bodies
- River Nile

1.3 RIVER DESCRIPTION

River Ndugutu is a non-seasonal river. It has flow variations between the wet and dry seasons although it still maintains a rather high flow during the dry season. According to information gathered from the locals, the river swells to almost twice the size it normally projects in the dry season.

The water carried in the river can be described as clean water. Silt is not prevalent during the dry season, although, due to the extensive cultivation of the banks, it is generally expected during the rains.

In the proposed section for development, that is, between the proposed intake and tailrace, together with the dam area, the river width varies between 4 and 7 meters while the depth is normally around 0.3 and 0.8 meters.

While on site, a flood plain of 4 meter width on either side of the banks, with flood marks at an average height of 1 meter were observed.

1.4 DESCRIPTION OF CATCHMENT

The catchment of River Ndugutu generally has deep fertile soils with a large amount of green vegetation. In addition to this, the catchment is characterized with a possibility of glaciers, since it originates from a mountainous area.

Such catchment characteristics ensure a high level of water retention and therefore high levels of ground water storage. When such a scenario prevails, the river generally has replenishment from ground water sources. Vegetation also ensures low ground water evaporation levels.

The catchment can also be described as one with a rather steep gradient, where in some areas, it curves its way through gorges and gullies.

Fig 3: Ndugutu catchment area

1.5 AVAILABLE DATA

1.5.1 Rainfall and temperature data

Rainfall data has been obtained from the meteorology department and it is important to note that although some data is available, there are some years where gaps have been noted. There are three weather stations in Bundibugyo district and at station 89300000, the available data is from 1943 to 1960, although data for the years: 1944, 1949, and 1953 to 1958 is missing.

Station 89300010 has records from 1944 to 1959, with data for the years 1953 to 1958 missing. Data obtained from station 89300020 shows rainfall records from 1944 to 1971, without any missing information.

In order to get a clear picture of the rainfall situation, correlation of the obtained records will be done with data from the neighboring district of Kabarole at a station in Rwimi. Records from Rwimi are available from 1964 up to 1998 with gaps for the years 1978 to 1980 and 1984 to 1990.

There is no temperature data for Bundibugyo or Kabarole district, hence, the meteorology officers advised the use of temperature for Kabale, since both areas experience similar climatic trends.

1.5.2 River gauging data

There is no gauged data on River Ndugutu at the Directorate of Water Resources Management.

1.5.3 Topographic maps

Topographic maps of the area at scale 1:50,000 are available and have been obtained from the lands and surveys department.

1.6 DATA ANALYSIS

1.6.1 Rainfall and temperature data

Records of the daily maximum and minimum temperature were analyzed. The following average values were obtained for the project area.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVERAGE
Daily mean maximum temperature [C]	24.0358	24.39451	24.15923	23.52153	23.33215	23.66588	24.04691	24.2448	24.67094	24.07523	23.42102	23.59713	23.93042628
Daily mean minimum temperature [C]	10.81225	10.96115	11.05774	11.78545	11.8807	9.924741	9.322096	10.18875	10.70557	11.08035	11.49351	10.78708	10.83328245
Average [C]	17.42402	17.67783	17.60849	17.65349	17.60642	16.79531	16.6845	17.21677	17.68825	17.57779	17.45726	17.1921	17.38185437

Fig 4: Table showing average temperature in Kabale

Having done the above analysis, 17.4 [C] was used for calculating the evapotranspiration.

Analysis of rainfall data of the area yielded the following results;

		Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Totals
1	89300020	1943	4	121	130	244	141	37	36	90	184	187	m	125	m
2	89300020	1944	51	57	230	182	129	58	21	164	122	171	221	50	1453
3	89300020	1945	48	6	81	103	145	68	94	72	221	180	115	27	1160
4	89300020	1946	11	4	53	158	240	92	67	165	183	254	119	77	1424
5	89300020	1947	103	175	184	273	159	119	110	132	103	68	136	77	1638
6	89300020	1948	7	97	71	130	153	150	47	126	212	268	273	68	1603
7	89300020	1949	14	53	90	186	241	95	73	141	271	243	94	58	1559
8	89300020	1950	3	32	147	169	92	74	84	121	206	170	176	107	1381
9	89300020	1951	11	132	276	265	93	66	37	112	212	288	233	177	1903
10	89300020	1952	22	46	102	282	198	28	79	111	112	182	107	36	1304
11	89300020	1953	79	79	147	170	106	253	53	77	186	202	230	82	1661
12	89300020	1954	16	55	121	211	252	210	127	157	346	335	187	99	2115
13	89300020	1955	103	48	159	133	80	62	107	89	148	202	106	214	1451
14	89300020	1956	30	86	88	157	111	19	49	129	119	243	86	106	1223
15	89300020	1957	50	23	162	230	99	105	47	78	94	245	139	152	1425
16	89300020	1958	17	24	132	163	161	67	79	122	140	207	95	119	1326
17	89300020	1959	78	30	108	241	151	91	56	81	160	211	271	84	1561
18	89300020	1960	47	149	83	137	124	41	45	100	141	274	228	26	1396
19	89300020	1961	57	81	100	208	231	93	89	135	308	243	253	154	1952
20	89300020	1962	37	51	107	143	140	84	63	142	314	196	202	138	1617
21	89300020	1963	88	123	136	342	208	42	79	71	109	279	187	142	1805
22	89300020	1964	6	52	240	150	56	68	51	147	146	331	156	150	1553
23	89300020	1965	32	19	235	174	120	68	14	127	160	207	191	53	1400
24	89300020	1966	78	132	133	353	124	83	38	203	130	271	159	92	1796
25	89300020	1967	6	18	79	217	185	65	100	61	149	274	216	38	1409
26	89300020	1968	32	86	190	218	68	71	40	83	127	148	213	124	1401
27	89300020	1969	125	52	158	100	113	75	29	159	147	126	172	120	1376
28	89300020	1970	43	33	264	283	96	82	78	178	219	274	94	37	1681
29	89300020	1971	60	37	122	195	113	56	122	144	160	198	158	11	1376
Mean Monthly Rainfall			43.37931	65.55172	142.3448	200.5862	142.3793	83.51724	66	121.2759	176.8621	223.3448	172.0357	94.58621	1533.892857

Fig 5: Table showing rainfall analysis results for the project area

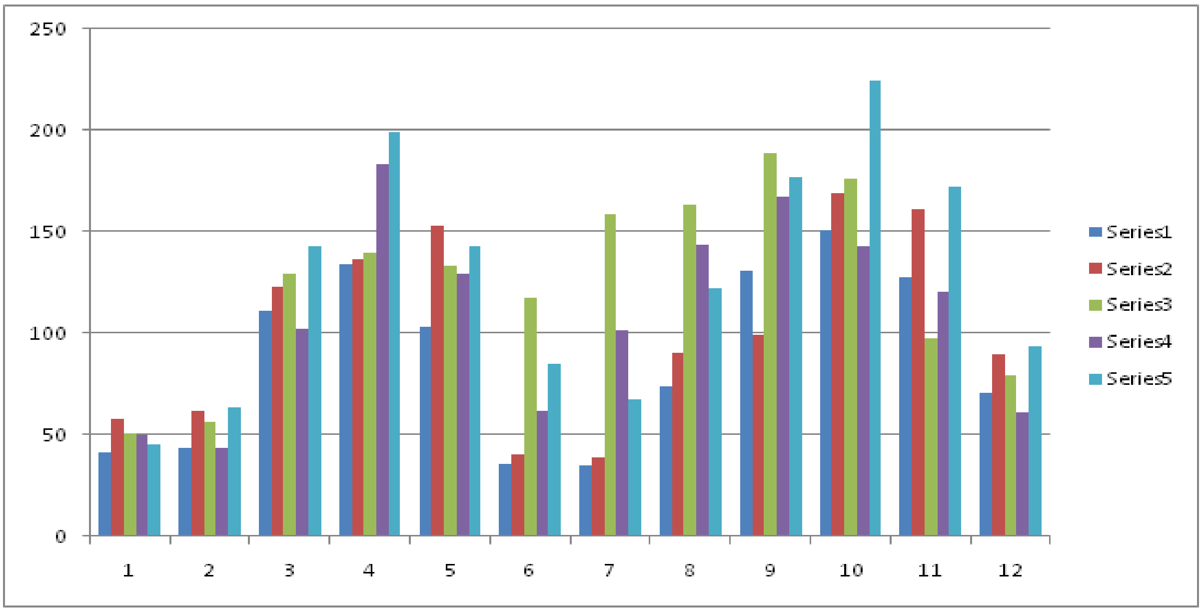


Fig 6: Graph showing rainfall analysis results for the project area

From the above analysis, 1533.9 mm of rainfall were obtained.

1.6.2 Derivation of the flow duration curve

Having obtained the annual precipitation, the actual annual run off was then derived. However, as stated earlier, the annual run–off is heavily affected by the rate of evapotranspiration and the ground characteristics of the area. The evapotranspiration is heavily dependent on the plant cover, as well as the prevailing temperature in the area. Run-off on the other hand depends on the nature of soils as well as the activities being carried out in the area – urban areas tend to have high levels of run-off due to the high construction levels.

In light of the above explanation, the Ndugutu catchment, like Mitano has deep soils and a large amount of vegetation cover, hence, a low level of evapotranspiration is expected. Below is the analysis leading to the flow duration curve.

Mean Temperature [C]	17.4	Percentage Exceedance	No. of days of the year	Empiric coefficients	Discharge (l/s)	Standard Deviation	+'/'-' (l/s)
Mean Annual Rainfall [mm]	1533.9	5%	18	1.77	1148.5379	0.32	207.65
Catchment Area [Sq. km]	42.5	10%	37	1.48	960.35936	0.3	194.67
L	998.4012	20%	73	1.19	772.18083	0.12	77.87
Annual Evapo-transpiration [mm]	1052.407	30%	110	1.04	674.84712	0.09	60.74
Annual Run-off [mm]	481.4927	40%	146	0.96	622.9358	0.08	49.83
Mean discharge [l/s]	648.8915	50%	183	0.87	564.53557	0.08	51.91
		60%	219	0.79	512.62425	0.08	51.91
		70%	256	0.7	454.22402	0.09	58.40
		80%	292	0.63	408.80162	0.09	58.40
		90%	329	0.57	369.86813	0.09	58.40
		100%	365	0.26	168.71178	0.09	58.40

Fig 7: Flow duration curve analysis table

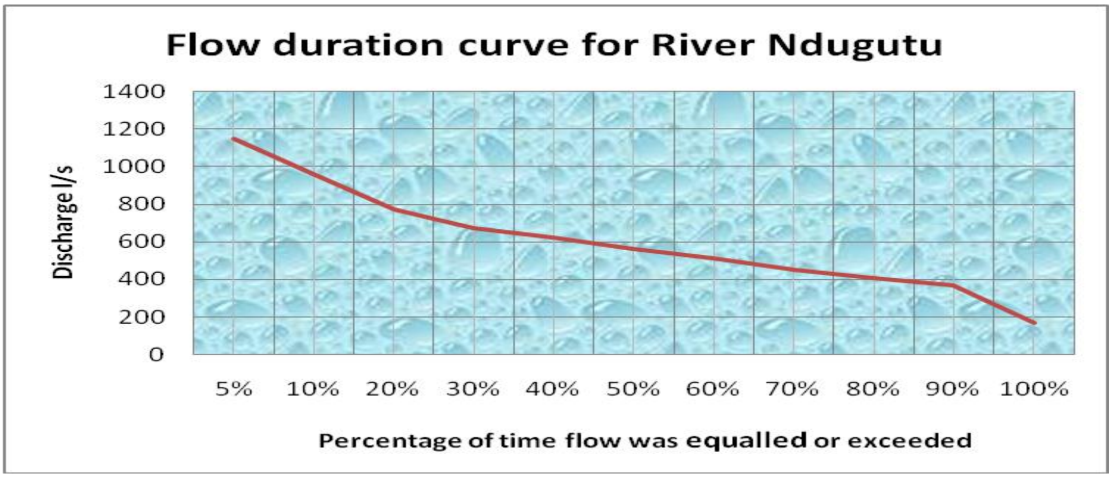


Fig 8: Flow duration curve for River Ndugutu

1.6.3 Spot measurements

In order to fully validate the obtained hydrological analysis flow duration curve, averaged spot measurements have been carried out using the salt dilution method in the period November 2010 to April 2011. The following are the results that have been obtained so far:

Period of measurements	Average Flow measured (l/s)	Mean monthly rain fall
Nov- Dec 2010	603.1	133.31
Jan – Feb 2011	487.3	54.19
March – April 2011	774.0	171.0

Fig 9: Spot measurements using the salt dilution method**.**

Since spot measurements were carried for half year; further measurements should be carried consistently throughout the year to establish the flows for the entire period.

2.0 GEOLOGY

EXECUTIVE SUMMARY

The Geotechnical feasibility assessment is targeted at a section of river Ndugutu identified as suitable for setting up a mini-hydro power station. The major object of the study was to explore the ground characteristics and profile at the various locations of the proposed mini-hydro power structures along the Ndugutu River namely the In-take area, channel route, forebay, penstock and power house. The soil and rock composition of the project site was a key area although other physical features such as valleys, gullies, rock outcrops and extent of the potential flood plain were important aspects in this study.

The Ndugutu River is located in western Uganda in the district of Rukungiri. Its water source originates from mountain ranges within the region and from the Ruwenzori mountain ranges. The topography indicates that most of area is occupied by steep slopes in nature with narrow valleys. The river course is characterized by several short intervals of twists and curves. The soils are black/brown clayey sandy of relatively low permeability and are highly susceptible to transportation by run-off. Siltation has created a sand filled river bank.

An integrated approach to the geotechnical study was adopted with a desktop review of datasets and other relevant information relating to the area including topography, soils, geology, and geomorphology. A field study was then followed up with appraisal of the actual site parameters, observation of physical landscape and sampling of soils for laboratory testing of its engineering properties. Therefore, all structures constructed in this area have to be laid at/on rock interface foundation. Major rock types in the area are quartzites, granite gneisses and granites of the Karagwe- Ankolean system. There are intervals of quartz veins which intrude the country rocks.

Bundibugyo district is one of the seismically active areas of the western arm of the east African Rift. The particular project area has fault lines that are partially active and the magnitude of previous events will be used a baseline design threshold for structures to be set-up at the site.

The general shear on undisturbed samples posted allowable bearing capacity at the proposed forebay of 203 kPa.

2.1 INTRODUCTION

The geotechnical investigation of the proposed Ndugutu Mini-hydro power project is vital in the design of civil and mechanical structures. River Ndugutu is located in western Uganda approximately 16 kilometers from Bundibugyo Township. The proposed Mini-hydropower project is expected to impact the hilly terrain of the area. All proposed infrastructure has to be designed bearing in mind the soil properties, rock types, depth to the bedrock among other vital parameters. It is therefore important to critically assess the soil engineering properties, profile, potential risks and mitigation measures to be undertaken during design and implementation of project structures. Samples of soils were collected and forwarded to the laboratory for testing of material properties. Locations near or along the project site with suitable construction materials were proposed to avail options to the construction team.

2.2.1 Objective of Geotechnical Study

The major object of the feasibility study was to investigate the ground characteristics at the various locations of the proposed mini-hydro power structures along the Ndugutu River namely the proposed earth dam site, channel route, forebay, penstock and power house. The soil and rock composition of the project site was a key aspect although other surface phenomenon such as valleys, gullies; seasonal streams and surface deposition were investigated. A review of the seismic history of the area was accomplished during the project.

2.2 TOPOGRAPHICAL AND PHYSIOGRAPHICAL ASSESSMENT

The Ndugutu River is surrounded steep slopes with narrow valleys areas which continuously drain their waters into the river. Regionally the area has numerous fault lines which are linked to the narrow valleys structures observed in the field. The deposition of erosion material gradually increases from the source towards the direction where it drains its waters in the river Semliki.

At the In-take area, in-situ rocks and floats cover most of the near surface area. The project area is partly cultivated land and the other areas are bush and marshland. The proposed forebay and power house is located along a rather gentle slope with an elevation difference between the two of approximately 30 – 60 m equivalent to the head. The penstock route is described as rocky with boulders and floats.

TOPOGRAPHICAL MAP SHOWING RIVER NDUGUTU

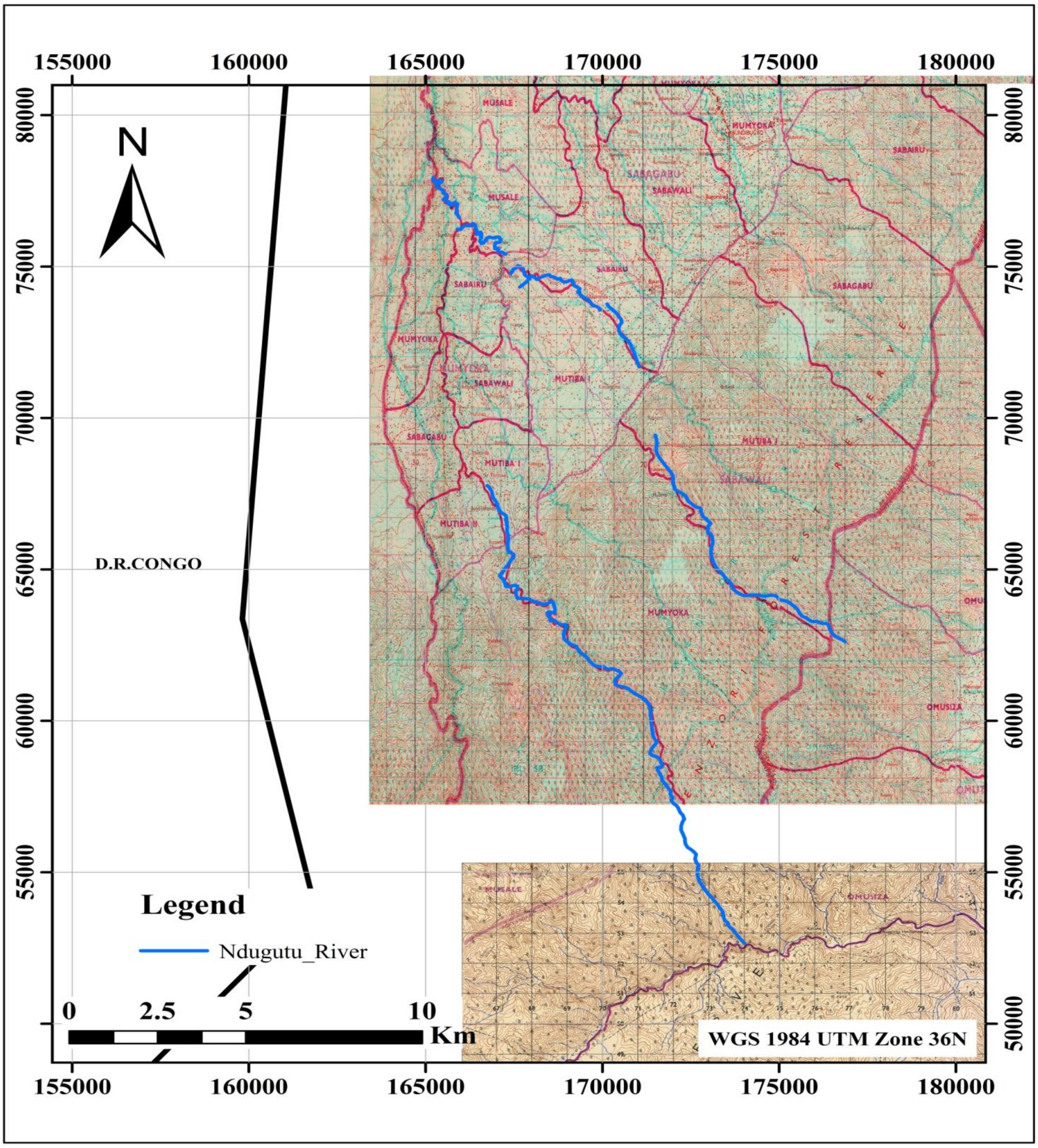


Fig 10: Topographical Map Showing River Ndugutu

2.3 LABORATORY TEST RESULTS

2.3.1 Classification test results

Laboratory analysis of the samples indicated that the soils at the site are generally clayey sands (SC). This classification is based on the Unified Soil Classification System. The key index properties of the material were as summarized in Table 1 & 2 below:

Using Terzaghi's model, the bearing capacity was determined for the two test pits at the proposed In-take and forebay locations.

Table 1: Angle of Friction at local shear failure

TP	DEPTH, D	WIDTH, B	BULK DENSITY, g	COHESION	COHESION	ANGLE OF FRICTION	MODIFIED ANGLE OF FRICTION
No.	(m)	(m)	(Mg/m^3)x10	C (KPa)	C' (KPa)	f(Degrees)	f' (Degrees)
1	0.80	1.0	16.90	3	2	33	23

N.B: Evaluation of bearing capacity based on terzaghi's model for 1.0m square footing (local shear failure)

TP 1 (Forebay): Water Table not encountered in the test pit

DEPTH	LOG*	SOIL DESCRIPTION	REMARKS
0.8	= =	Brown sandy soil Rock	Moderately dense Highly consolidated
	/////		

LOG*: Expression of ground Profile with depth

Table 2: Bearing Capacity factors at Local shear failure

Test Pit (TP)	BEARING CAPACITY FACTORS			ULTIMATE BEARING CAPACITY	SAFETY FACTOR	ALLOWABLE BEARING CAPACITY
	Nc	Nq	N_g	q_{ult} (KPa)	(F)	q_{all} (KPa)
1	18.1	8.7	4.9	203	3	68

$q_{ult} = 1.3C^{'}N_C + q_oN_q + 0.4\gamma BN_\gamma$

Where: $q_o = \gamma D$

$\varphi^{'} = \tan^{-1}(0.67 \tan \varphi)$

$C^{'} = 0.67C$

$q_{all} = q_{ult}/F$

2.4 LOCAL GEOLOGY AND SOIL PROFILE

The project area comprises of sandstones quartzitic sandstones and gneisses of the Buganda-Tororo rock group. In most locations, quartzitic sandstones and gneisses are massive have outcrops with few joints. The process of weathering has given rise to other intermediates such as quartzitic sandstones and sandstones. Continuous erosion and transportation of material has resulted in the accumulation of alluvium in several locations along the project site as well as at the banks of the river.

2.4.1 Proposed Intake Location

According to preliminary designs on the survey drawing, indicated an intake area in the upstream region of the river. The area has the following characteristics:

2.4.2 Intake Area

- The location is within a potential flood plain of the river and is covered with rocky outcrops and boulders. This will provide a firm foundation for erecting intake structures.

- The area is located in a potential flood plain of the river. In the event of flooding, the need to be protected against high water pressure and flows.

2.5 SEISMICITY OF THE AREA

The Uganda National Seismological Network (UNSN) currently consists of four stations located at Entebbe, Kilembe, Hoima and Kyahi. The network has continued to execute its role of monitoring earthquakes and the data collected is analyzed at Entebbe using Seisan software. The most prone districts to earthquake hazard are located in the west and they include Kabarole, Kasese, Bundibugyo and Hoima districts. These districts have experienced moderate earthquakes some of which have caused damage or destructions to some of the buildings, death to humans and earthquake induced ground failures.

The area of interest is seen to have some fault lines which seem to be partly active in terms of seismic activity (this is clearly shown by the number of events recorded over a period of more than 40 years). The number of events can also be attributed to the location of the area in the western arm of the rift valley which is known to be more seismically active than the eastern arm.

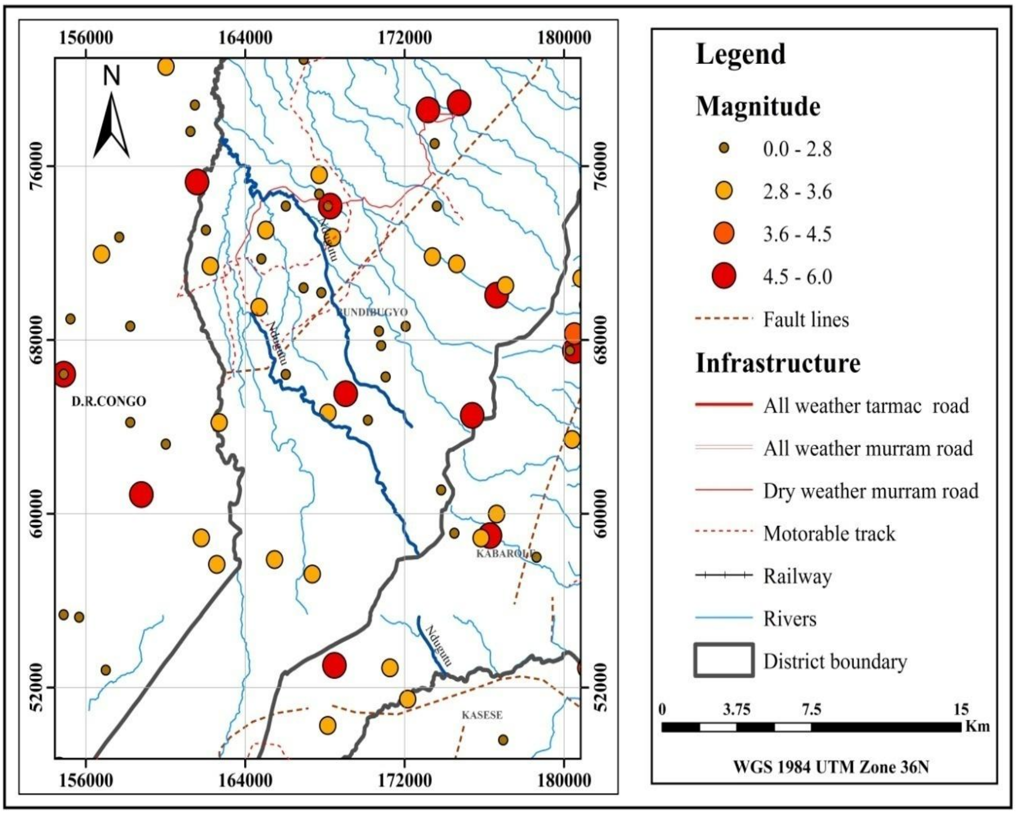


Fig 11: Epicentral Map of Part of Western Uganda (Buundibugyo & Kabarole district)

From the data and map of earthquake phenomenon, it is clear that the risk of occurrence of disturbance due to ground movement resulting from earthquake induced hazards is very low high and likely. The numerous seismic events in the which include earthquakes magnitudes of > 4.5 on the Richter scale poses a high risk factor to project structures.

Therefore all foundations structures for the proposed mini-hydropower project have to be designed to withstand ground movement and vibrations resulting from earthquakes of between 4.0 and 7.0 magnitude measured on the Richter scale. The project should liaise with the National Seismological Centre in Entebbe for update and prediction of seismic activity in the area.

2.6 KEY CONCLUSIONS ON ENGINEERING PROPERTIES OF SOIL

1) The site was investigated by excavating one (1) test pit to a depth of 0.8 m; and sampling disturbed samples (2 No. in each) for laboratory testing;

2) Ground water table was not encountered in any of the test pits; The average depth to water table was determined at 6.0 – 9.0 meters along the channel route.

3) The key index properties of the soil samples from the test pits investigated ranged from: LL = 34%,. The Natural Moisture Content ranged from 11% to 22%. (See Appendix 1 & 2) for detailed laboratory test results);

4) Evaluation of bearing capacity based on laboratory tests (General Shear Failure) on undisturbed samples posted allowable bearing capacities of 203 kPa.

5) Compaction tests revealed that the MDD 1.86 mg/m³ corresponding to an OMC of 11%.

6) The permeability (k) of the soils from TP 1 are 2.26 x 10^{-6} ^{c}m/sec implying that it is low permeability..

7) The area has fault lines which are partially seismically inactive. The many seismic events recorded in the region. Foundations structures must be able to withstand seismic events of the order raging from 4.0 -7.0 on the Richter scale.

2.7 MATERIALS FOR INFILL AND CONSTRUCTION

Along the channel route, the project site has a number of locations with high grade lateritic gravel (murram) that is suitable for use as infill material, construction of project access roads, bridge construction and compaction of weak zones.

Fig 12 A section of excavated ground showing lateritic gravel

3.0 CONCEPTUAL AND STRUCTURAL DESIGN

3.1 SCHEME LAY-OUT

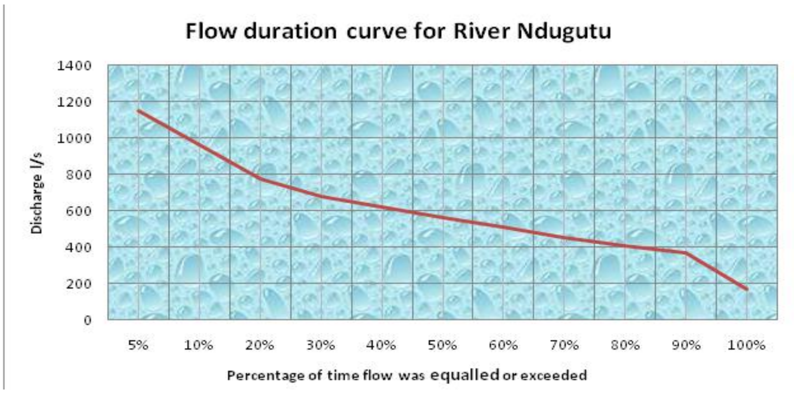
Table 1: Weir and River specifications

Parameter	Value	Unit
Maximum Flood, Q_{flood}	24	M^3/s
Weir Breadth, b	8	m
Weir Height, Y	3	m
Weir head, Hw	0.075	m
Design Head, H_w	1.5	m
Velocity Head, H_v	0.011	m
Total Head	1.586	m
Silt Flashing head	3	m
Slit Flashing Width	0.5	m
Environmental release head	2	m
Environmental release Diameter,$Ø_1$	0.175	m
C_v	0.6	
River Average velocity	0.45	m/s
Weir Coefficient	0.567	
Maximum Flood overtop head	1.23	m
Type of weir	Round Overflow	

$$Q = C_d b \sqrt{g} H^{3/2} \qquad C_d = 0.564 + 0.0846 \frac{H_w}{Y} \qquad H_v = \frac{V^2}{2g}$$

3.2 DESIGN FLOW RATE

3.2.1 Analysis of the FDC Values



I. Ndugutu River is a permanent River; it runs the all year round. The least flow computed by the Hydrologist was 180l/s and maximum being 1200l/s.

II. The large flow rates (780l/s to 1200l/s) lie on the steeper part of the curve (upper 20% of the exceedence curve) meaning that they are only experienced for two and half months per annum.

III. 550l/s is guaranteed for at least six months of the year.

IV. 380l/s is almost guaranteed 11 months of the year.

3.3 TYPE OF THE SCHEME

The scheme is designed to be a run-of-river scheme. This means that power generation is only done when the water is available and provided by the river.

Ndugutu River is relatively steep and narrow (≈8m), therefore a relatively high weir (3m) will be built without causing harmful flooding upstream. The weir shall raise the water level at the intake and enable the construction of the intake channel. The weir has been designed in such a way that the resulting flood does not affect the existing water supply intake pipe. This pipeline is part of the gravity water supplying neighboring villages. Any hydropower intake upstream from the water supply intake would affect the scheme.

3.4 DESIGN FLOW RATE

The scheme is designed to provide the maximum plausible output using the maximum obtainable head (85m) and the average flow rate (550l/s). This design flow corresponds to 50% exceedence on the FDC curve and translates into six months' occupancy of which the scheme will provide maximum design output.

It is important to note that this design flow is subject to the minimum required environment release of 100l/s as recommended by the Environmentalist. The spill water over the crest of the weir shall supplement the environment release. In the case of discharges greater than 550l/s, the weir shall spill the water downstream.

Table: Design flow rate

TYPE OF SCHEME	**RUN-OF-RIVER**
flow	550l/s
Minimum Environmental release	100l/s

3.5 WEIR

In this design the main water retaining structure is a barrage with a clear overflow type of spillway. The barrage is designed as a gravity type dam (according to design criteria recommended for the Design of small dams United State Bureau of Reclamation - USBR). In general this type of a dam is designed to resist external forces with its own self-weight. However, it is widely recognized that gravity type dams are the most durable, and solid structures that requires minimum maintenance. Since this water-retaining structure is at isolated locations, with difficult access, a dam that requires minimum maintenance is the most suitable. Therefore this barrage is designed as a stone masonry gravity type structure with straight axis. As the ground condition on the barrage axis is of firm bedrock, it is assumed that the structure is constructed on the natural bedrock as its foundation material is strong enough to bear the weight of the structure. An environmental orifice has been inbuilt to offer an environmental flow.

With the abundant availability of sound rocks of granite gneiss, it is recommended that the dam is constructed using stones in 1:4 cement sand mortar. The density of this mass has been taken as 25KN/m^3. This type of construction will offer employment to the locals since its execution is simple and well known.

The proposed weir is designed to divert only the needed flow and let out the river permanent flow rate as recommended by the Environmentalist. The proposed length is enough to discharge the flood corresponding to that of return periods of 50 years i.e. $24m^3/s$.

The weir is laid on sound rock foundation of granite gneisses and granites of the basement complex of Uganda. The distribution of earth quakes in the project area obtained from the records of National Seismological center is relatively low and possess no significant threat to the project structures. Therefore, Seismic analysis on the weir is not necessary.

3.5.1 Seismic Consideration

Through a study on the geology of the area, the geologist advises that all foundations for the proposed mini-hydropower project have to be designed to withstand ground movement and vibrations resulting from earthquakes. The US 319: 2003 Uganda Standards Seismic Code of Practice for Structural Designs by the Uganda National Bureau of Standards is referred for relevant seismic data.

3.5.2 Horizontal and Vertical Seismic Coefficients

The calculation of the horizontal seismic Coefficient has been calculated as:

$$\alpha_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where:

α_h= Horizontal seismic Coefficient

Z=Seismic Zone factor which is taken as 0.36 for seismic Zone V

I= Important factor which is taken as 1.00 for the retaining wall.

R= Response reduction factor taken as 1.50 for unreinforced concrete wall

$\frac{S_a}{g}$ = Spectral acceleration coefficient or flexibility factor

The solid retaining wall is almost rigid and no differential displacement shall take place in the wall during seismic acceleration. Hence the wall is taken as zero period structure and the spectral acceleration coefficient of the wall is taken as 1.00. Putting the values we have

$$\alpha_h = \frac{1}{2} \times \frac{1.00}{1.50} \times 1.00 = 0.33$$

The vertical acceleration coefficient $\alpha_v = \frac{2}{3} \times 0.33 = 0.22$

3.5.3 Active Pressure Coefficient under Seismic Condition

Adopting the method in IS 1893: 1984, the dynamic coefficient is given by the equation

$$C_a = \frac{(1 \pm \alpha_v)\cos^2(\emptyset - \lambda - \alpha)}{\cos\lambda \cos^2\alpha \cos(\delta + \alpha + \lambda)} \times \left[\frac{1}{1 + \left\{ \frac{\sin(\phi + \delta)\sin(\phi - \iota - \lambda)}{\cos(\alpha - \iota)\cos(\delta + \alpha + \lambda)} \right\}^{\frac{1}{2}}} \right]^2$$

Two values shall be calculated from the above equation, one for 1+ α_v and the other for 1-α_v and maximum of the two shall be the design values. The values of the notations shall be taken as below:

α_v = vertical seismic coefficient- its direction being taken consistently throughout the stability analysis of wall and equal to

φ = angle of internal friction of the soil

λ = $\tan^{-1}\frac{\alpha_h}{1 \pm \alpha_v}$

α = angle which the earth face of the wall makes with the vertical

i = slope of the earth fill

δ = angle of friction between the wall and the earth fill

α_h = horizontal seismic coefficient

3.5.4 Overturning Moments

Sl.No.	Description	Areas	Vertical Weight	Horizintal Force	Lever Arm from the base of Weir	Overturning Moment
			[KN]	[KN]	[m]	[KNm]
	Static Condition					
1	FW1			45	1	45
2	FW2			36.9	1.5	55.35
3	U	6	-60		0.67	40.2
	Seismic Condition					
4	W1	0.735	18.375	6.13	0.5	3.06
5	W2	2.027	50.675	16.89	1.425	24.07
6	W3	2.355	58.875	19.63	0.95	18.64
7	W4	0.683	17.075	5.69	1.617	9.20
8	W5	0.073	1.825	0.61	2.9	1.76
9	W6	0.2	5	1.67	0.25	0.42
10	W7	0.801	20.025	0.33	0.35	0.12
11	W8	0.247	6.175	2.06	0.25	0.51
	Total			**134.90**		**198.34**

Fig 13: Overturning Moments on the weir

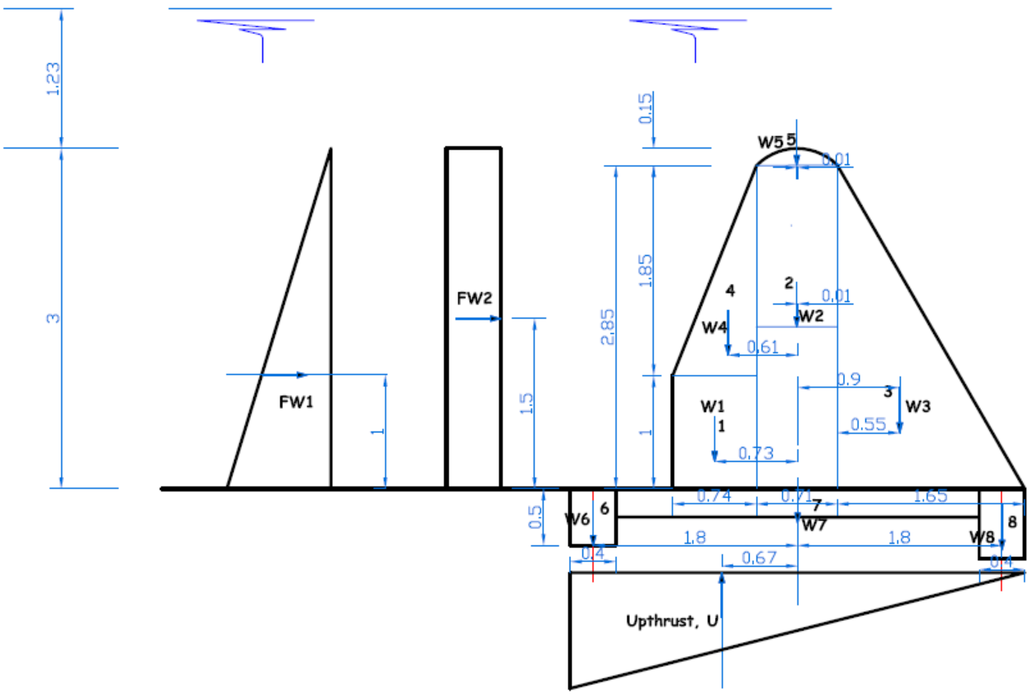


Fig 14: Force analysis on the weir

3.5.5 Restoring Moments About The Toe Of Weir

SL No.	Description	Areas	Vertical Weight	Lever Arm from the base of Weir	Restoring Moment
			[KN]	[m]	KNm
	Static Condition				
1	W1	0.735	18.375	2.73	50.16375
2	W2	2.027	50.675	2.01	101.85675
3	W3	2.355	58.875	1.45	85.36875
4	W4	0.683	17.075	2.61	44.56575
5	W5	0.073	1.825	2.01	3.66825
6	W6	0.2	5	3.8	19
7	W7	0.801	20.025	2	40.05
8	W8	0.801	20.025	2	40.05
11	U	6	-60	0.2	0
	Total		**131.875**		**384.72325**

Fig 15: Force analysis on the weir

Factor of Safety against overturning = 1.94 > 1.2 OK

Net Moment = 186.38KNm

Vertical Load = 131.88KN

Eccentricity = 0.59m

Base Pressure f_{max} = 61.98KN/m^2

f_{min} = 3.96 KN/m^2 No tension exists hence OK

3.6 CALCULATING THE WEIR FLOOD FLOW

Weir parameters

Weir crest length =8m

Y=Weir height

H=Weir head

b=Weir breadth Using Poleni formula the weir discharge for different crest shapes and for free-flow or submerged conditions can be obtained;

Table: Weir flood Head

Maximum flow rate from FDC	1.2	m^3/s
Worst flood Design flood	24.0	m^3/s
c	1.000	
μ	0.75	
b	8.00	m
g(Gravitational unit force)	9.81	m/s^2
h (Head at maximum flood)	1.22	m

The designed flood is considered to be 20 times the maximum measured flow.

c is the correction factor for submerged orifice and in this case it will be 1

μ is the weir coefficient which vary from 0.49 to 0.79 depending on the cross-sectional shape of the weir.

3.7 WING WALL HEIGHT AT THE WEIR

The wing wall is designed to retain the river water from flooding the adjacent intake structure.

The maximum flow computed approximates to $1.2m^3/s$. using the Hydrologist's recommendation; we can say that the worst flood will be $24m^3/s$

Table 6: Wing wall height

Weir Parameters		
Design flow rate, Q	0.55	m^3/s
Weir Length,b	8	m
Weir Height, hweir	3	m
Weir discharge coefficient	2.2	
Maximum Weir head, $h_{overtop}$	1.23	m
Height of the barrier wall, $h_{barrier}$	4.23	m
Head under design flow	0.10	m

3.8 DESIGN OF THE WING WALLS

3.8.1 Reinforced Concrete Wing Wall:

Wing walls are constructed for the following purpose:

- To retain the water so that the right level is obtained and prevent flood water from damaging the structures at the intake – Reinforced Concrete wall and Gabion wall
- To support the intake structures e.g. orifice structure, Intake and flushing gates – Reinforced Concrete Wall
- To act as an embankment for the created reservoir

A trapezoidal masonry wall, 4.3m high was found to be more economical than a reinforced concrete wall. The design is made such that there is nowhere in the wall that experiences any tensional forces.

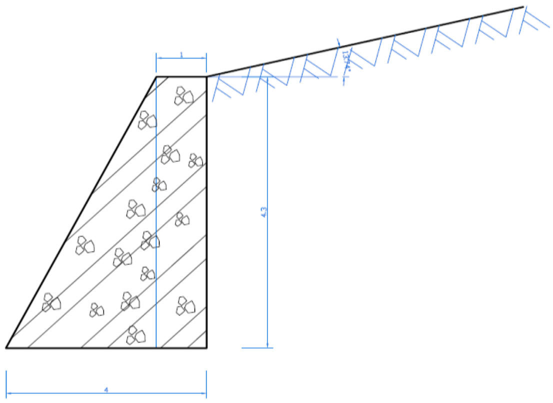


Fig 16: Wing wall design

Active Pressure Coefficient under Seismic Condition

Adopting the method in IS1893: 1984, the dynamic coefficient is given by the equation

Height of Wall	=	4.8	m
Density of backfill	=	18.6	KN/m^3
Density of wall mansonry	=	25	KN/m^3

Seismic Zone	Z	=	1			
Impontance factor	I	=	1	$\alpha_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$	=	0.33
Response Reduction Factor	R	=	1.5			
Flexibility Factor	S_a/g	=	1			

α_v	α_h	ϕ	λ_1	λ_2	α	δ	i	$1+\alpha_v$	$1-\alpha_v$
0.22	0.33	33	0.27	1.53	0	20	10	1.22	0.78

cos(ϕ-λ-α)	=	0.952423
Cos(λ)	=	0.964764
cos(α)	=	1
cos(δ+λ+α)	=	0.81659
Sin(ϕ+δ)	=	0.798636
Sin(ϕ-*i*-λ)	=	0.30035
Cos(α-i)	=	0.984808
Cos(δ+α+λ)	=	0.81659

$$\frac{(1\pm\alpha_v)\cos^2(\phi-\lambda-\alpha)}{\cos\lambda\cos^2\alpha\cos(\delta+\alpha+\lambda)} = \mathbf{1.41}$$

$$1+\left\{\frac{\sin(\phi+\delta)\sin(\phi-\imath-\lambda}{\cos(\alpha-\imath)\cos(\delta+\alpha+\lambda)}\right\}^{\frac{1}{2}} = \mathbf{1.55}$$

$$C_a = \frac{(1\pm\alpha_v)\cos^2(\emptyset-\lambda-\alpha)}{\cos\lambda\cos^2\alpha\cos(\delta+\alpha+\lambda)} \times \left[\frac{1}{1+\left\{\frac{\sin(\phi+\delta)\sin(\phi-\imath-\lambda)}{\cos(\alpha-\imath)\cos(\delta+\alpha+\lambda)}\right\}^{\frac{1}{2}}}\right]^2 = \mathbf{0.59}$$

Static Coefficient of Earth Pressure (K_a)

α_v	α_h	ϕ	λ_1	λ_2	α	δ	i	$1+\alpha_v$	$1-\alpha_v$
0	0	33	0	0	0	20	10	1	1

cos(ϕ-λ-α)	=	0.84
Cos(λ)	=	1
cos(α)	=	1
cos(δ+λ+α)	=	0.939693
Sin(ϕ+δ)	=	0.80
Sin(ϕ-*i*-λ)	=	0.54
Cos(α-i)	=	0.984808
Cos(δ+α+λ)	=	0.939693

$$\frac{(1\pm\alpha_v)\cos^2(\phi-\lambda-\alpha)}{\cos\lambda\cos^2\alpha\cos(\delta+\alpha+\lambda)} = \mathbf{0.75}$$

$$1+\left\{\frac{\sin(\phi+\delta)\sin(\phi-\imath-\lambda}{\cos(\alpha-\imath)\cos(\delta+\alpha+\lambda)}\right\}^{\frac{1}{2}} = \mathbf{1.69}$$

$$C_a = \frac{(1\pm\alpha_v)\cos^2(\phi-\lambda-\alpha)}{\cos\lambda\cos^2\alpha\cos(\delta+\alpha+\lambda)} \times \left[\frac{1}{1+\left\{\frac{\sin(\phi+\delta)\sin(\phi-\imath-\lambda}{\cos(\alpha-\imath)\cos(\delta+\alpha+\lambda)}\right\}^{\frac{1}{2}}}\right]^2 = \mathbf{0.26}$$

Imperical Method

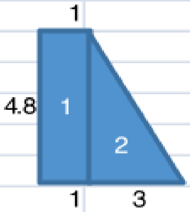
Imperically, the dynamic pressure increment of pressure is 0.75 times the horizontal seisimic coefficient

$C_a = K_a + \frac{3}{4}k_h$ = 0.51 (The values are comparable)

Calculation of Earth Pressure:

Active Pressure	=	23.52	KN/m
Height of action from base of wall	=	1.60	m
Dynamic Pressure	=	52.56	KN/m
Dynamic increment [ΔE]	=	29.04	KN/m
Height of action from the base of the wall (0.5H)	=	2.4	m

Self weight of Wall



Section I	=	120	KN/m
Section II	=	180	KN/m

Stability Analysis

Calculation of overtuning moments

Sl.No.	Description	Vertical Weight	Horizintal Force	Lever Arm from the base of wall	Overturning Moment
		[KN]	[KN]	[m]	[KNm]
	Static Condition				
1	Active Pressure		23.52	1.6	37.63
	Seismic Condition				
2	Section 1	120	40.00	2.4	96.00
3	Section 2	180	60.00	1.6	96.00
4	Dynamic Pressure		29.04	2.4	69.69
	Total	**300**	**152.56**		**299.32**

Sl.No.	Description	Vertical Weight	Lever Arm from toe of wall	Restoring Moment
		[KN]	[m]	[KNm]
	Static Condition			
2	Section 1	120	3.5	420.00
3	Section 2	180	2.0	360.00
	Total	**300**	**5.50**	**780.00**

Factor of Safety against overturning				2.605889	>	1.20
Coefficient of friction of soil and wall at base		=	tan 30 =	0.65	say	0.5
Factor of Safety against sliding		=		**1.28**	**>**	**1.10**
Net Moment		=	480.68	KNm		
Vertical Load		=	300	KN/m		
Eccentricity (e)		=	0.40	m		
Base Pressure	f_{max}	=	119.75	KN/m^2		
	f_{min}	=	30.25	KN/m^2	[No tension exists hence OK]	

3.9 MINIMUM ENVIRONMENTAL WATER RELEASE STRUCTURE

A minimum flow of 100l/s will be released by the 'out let' structure built in the weir. This will be supplemented by the spill water at the weir crest. The structure is a circular orifice shall operate at a head of 2.5m from the crest of the weir. As a guarantee for continual environmental minimum flow release, the 'environmental' release orifice has been located below the intake orifice.

From the flow through orifice equation $Q = A_{jet}V_{jet} = \frac{\pi D^2}{4} C_v \sqrt{2gH}$, C_v taken to be 0.6

Minimum Environmental release	0.1	m^3/s
Submerged head, H	2.50	m
Cv	0.6	
Jet Velocity	4.2	m/s
Orifice Diameter	174	mm

With the silt flushing gate operating below the orifice, orifice being 0.5m from the foot of the weir and with water velocity of 4.2m/s, the orifice will stay clear of any silt and tiny particle blockages.

3.10 SILT FLUSHING STRUCTURE AT THE WEIR

Ndugutu River has a low silt load and the water is clear but since people cultivate near the river, during heavy rains the river banks are eroded and the ‘soil’ end up in the river. A silt trap alone cannot be reliable and secondly silt accumulation might renders blockage of the environment release. Therefore a steel breast wall type roller gate 0.5m wide and 0.5 m long will be built into the weir to allow flushing. This will be operated during de-silting.

The gate dimensions are dependent on the operational head and the design head.

The specifications presented in the table below are from Rodney Hunt company brochure, a Massachusetts’ sluice gate manufacturer.

Width × Height	Maximum Design Head	A	B	C	D	E	F	G
Mm	m	mm						
500×500	30	762	381	533	908	1054	216	152

The gate of a much higher design head (than what is needed) is used in order to have a bigger flushing area

3.11 INTAKE STRUCTURE

The structure used to take the water from the river into the mini hydropower structure should be able to divert the designed flow, flood flow and also stay clear of any blockage or sedimentation. The intake incorporates a rectangular orifice side intake and a rectangular channel section transporting water into the sedimentation tank.

The intake channel is designed in to transport water at a higher speed hence avoiding sedimentation before the sedimentation tanks. This is done by using a relatively high slope, though caution is made that there is no loss of much head.

$$Q = A_i V_i = A_i c_d \sqrt{2g(h_r - h_h)}$$

$$V_i = C_d \sqrt{2g(h_r - h_h)}$$

$$W_h = \frac{Q_{gross}}{v_h h_{h(normal)}}$$

$$S = \left(\frac{n \times v_h}{R^{0.667}}\right)^2$$

$$R = \frac{W_h d}{W_h + 2d}$$

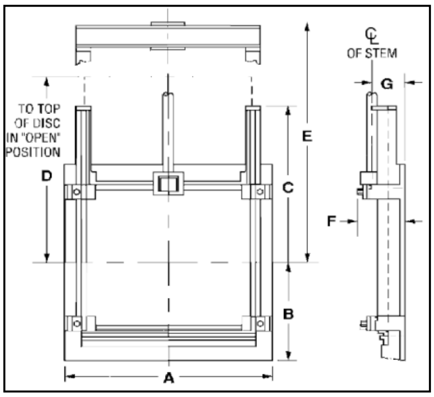


Table: Intake orifice and channel dimensions

Length of the weir $L_{weir,}$, m	8
Height of the Weir h_{weir},m	3
Orifice constant, C_w	1.6
Head upstream of the weir h_r,m	1.5
Head during flooding $h_{overtop}$, m	1.23
Height of barrier wall $h_{barrier}$, m	4.2
Orifice coefficient of discharge, C_d	0.6
Orifice depth d,m	0.6
Water depth under normal flow h_h, m	0.6
Orifice velocity V_i, m/s	2.52
Orifice width W, m	0.4
Intake channel velocity V_h, m/s	2
Intake channel width W_h, m	0.6
Intake channel Hydraulic radius R	0.166
Intake channel slope	0.6%
Water depth under flood flow h_h, m	0.1
Design intake channel depth ,m	1.2

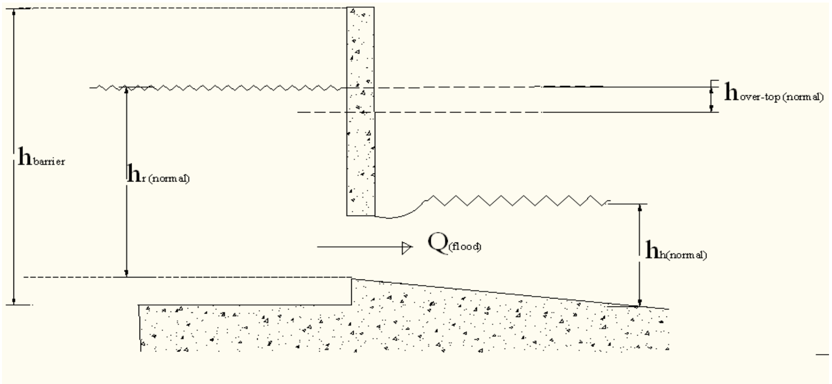


Fig 17 Intake Orifice and Intake channel

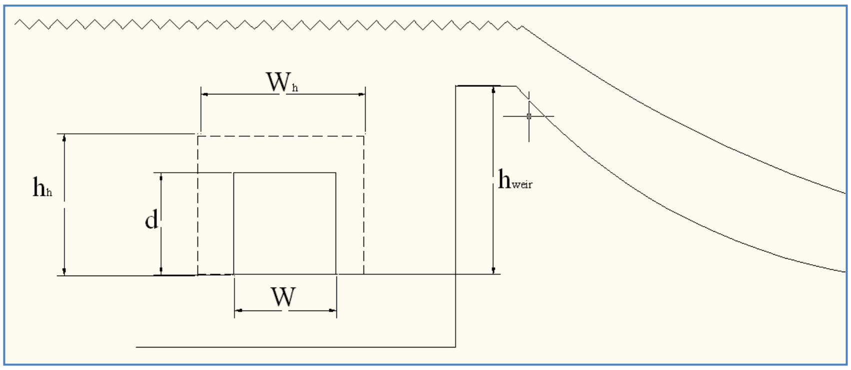


Fig 18 Intake Channel

For a sharp-edged, roughly finished intake, C_d=0.6 is suitable.

The surface of the water depth in the headrace channel during normal flow conditions is assumed to be at the same level as the upper edge of the intake orifice, then $h_{h(normal)}$=d(the depth of the intake mouth. d is set at 0.5m

Finding the width of the intake mouth, w

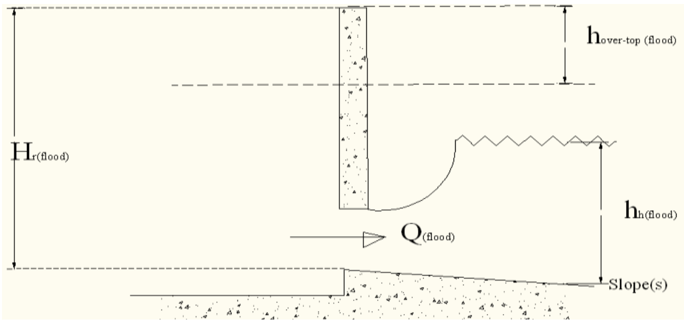


Fig 19: Intake channel under flood flow

Headrace flood flow

The water depth in the intake headrace channel will increase during the flood conditions. We use two equations, discharge orifice equation and the manning's equation. The correct depth is known when both the equations give approximately the same value.

Equation 1

$$Q_{1\,flood} = d \times w \times c_d \sqrt{2g\left(h_{r(flood)} - h_{h(flood)}\right)}$$

Equation 2

$$Q_{2\,flood} = h_{h(flood)} \times w_h \times \frac{S^{0.5}}{n} \times \left(\frac{w_h h_{h(flood)}}{w_h + 2h_{h(flood)}} \right)^{0.667}$$

By assuming several values of h_{hflood}, a value is reached where $Q_{1flood} = Q_{2flood}$

h_{hflood}=1.04m at Q_{flood}=1.0m^3/s

In order to contain the flood flow of 1.04m depth, the channel walls need to be 1.2m high.

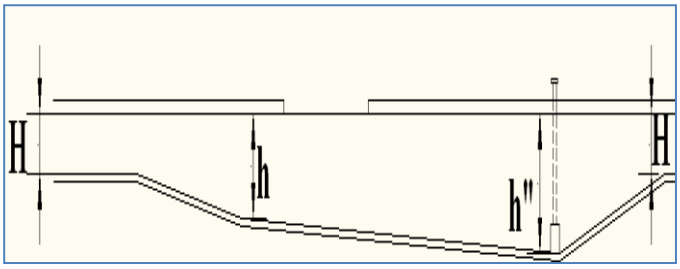
3.12 SEDIMENTATION TANK DIMENSIONS

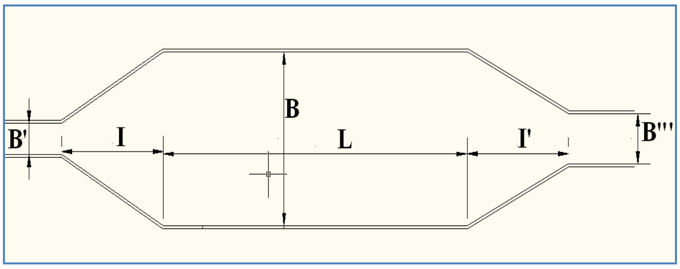
The sedimentation tank is designed to sink all particles bigger than 0.2mm. Since the maximum intake at worst flood conditions is approximately 1m^3/s, the sedimentation tank is designed to handle 1m^3/s instead of 0.55 m^3/s, though the inflow into the power canal will be constrained to 0.55 m^3/s by the use of the spillway.

PARAMETERS	CALCULATED VALUE	UNITS
Flow rate	1	m^3/s
Particle size, d	0.2	mm
Flows velocity, V_d	0.20	m/s
Sinking Velocity, V_s	0.025	m/s
Settling depth, h	2.2	m
Settling Length, L	25.27	m
Transition Angle, α	8.0	^{o}
Settling time, t_d	128	s
Settling Breadth, B	2.3	m
Incoming Channel width, B'	0.60	m

Some sedimentation tank calculated parameters are altered for construction convenience vis-à-vis the site ground conditions.

Transition Length, I	6.1		m
Design Parameters			
Parameters	Calculated Value	Design Value	units
Exit Width, B'''	1.20	**1.20**	m
Exit Transition length, I'	6.0	**3**	m
Channel depth at entrance, H	1.2	**1.2**	
Channel depth at exit, H	0.5	**0.7**	m
Exit depth, h''	2.5	**2.5**	m
H	2.2	**2.2**	m
L	25	**15**	m
B	2.3	**4**	m
I	6	**6**	m
B'	0.6	**0.6**	m





The Design values have been chosen basing on the intake area topography and the ease to cut or fill.

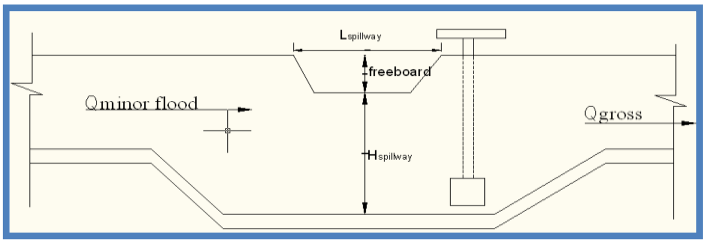
It should be noted that the percentage removal of particles, X_R is:

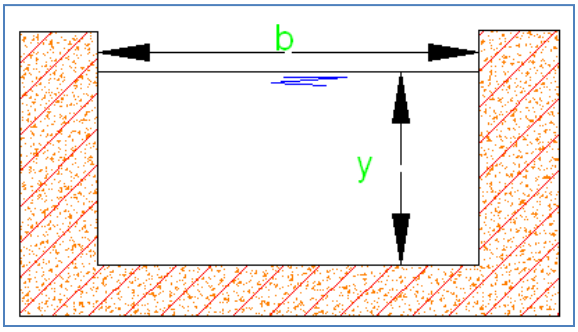
$$X_R = \frac{0.025}{1/15x4} = 1.5 = 150\% > 100\%$$

$$X_R = \frac{v_s'}{Q/A}$$

In this design,

This shows that all particles bigger than 0.2mm will be removed.





Parameters	Calculated values	Design values
Channel flow (Qgross), m^3/s	0.55	
Length of the Channel, L, m	1313	
Velocity v, m/s	1	
Side slope, N	0	
Manning's n	0.015	
Freeboard allowance, F	1.3	

3.13 SPILLWAY MINIMUM DIMENSIONS

SPILLWAY DIMENSIONS		
Q gross	1.000	m^3/s
Hspillway	2.000	m
Weir constant	1.600	
Qminor flood	1.150	m^3/s
Q spillway	0.150	m^3/s
hminor flood	2.200	M
Minimum Lspillway	1.048	M
Freeboard	0.200	M

Cross-sectional area, A, m^2	1	
Side slope index, X	2.000	
Channel Height, H, m	0.60	0.7
Freeboard Head, m	0.09	0.2
Water depth, y, m	0.5	
Bed width b, m	1.20	
Top width T, m	1.20	
Wetted perimeter, P, m	2.392	
Hydraulic mean radius, R, m	0.299	
Slope S	0.113%	
Head Loss HL, m	1.479	

The minor flood is assumed to be 1.15 the gross flow and also

$H_{minor\ flood} = 1.15 * H_{spillway}$

$$L_{spillway} = \frac{Q_{\min orflow} - Q_{gross}}{C_w \left(h_{\min orflood} - h_{spillway}\right)^{.5}}$$ And minimum freeboard = $h_{minorflood} - h_{spillway}$

The minimum freeboard is adjusted to 0.15m and the $L_{spillway}$ to 3m

$$I = \frac{B - B'}{2 Tan\alpha}$$

3.14 HEADRACE CHANNEL

This channel is different from that which links the intake orifice to the sedimentation tank; this links the sedimentation tank to the forebay. A 1085m contour is used as a guide route for the channel. Moving in the vicinity of a single contour path to will minimize the excavations during construction.

3.14.1 Headrace channel design

The channel slope and the dimensions selected ensure that the water moves at a velocity that prevents concrete scouring and the same time permits no sedimentation along the channel. The slope of 0.1% was chosen to avoid immense loss of head and hence optimizing gross head for power generation.

$$A = \frac{(Q \times F)}{v}$$

$$X = 2 \times \sqrt{(1 + N^2)} - (2 \times N)$$

$$H = \sqrt{\frac{A}{(X + N)}}$$

$$b = H \times X$$

$$T = b + (2 \times H \times N)$$

$$P = b + \left(2 \times H\sqrt{1 + N^2}\right)$$

$$S = \left(\frac{n \times v}{R^{0.667}}\right)^2$$

$$HL = L \times S$$

3.14.2 Gabion Retaining Structures along the Headrace Channel

Gabions shall be used to retain the fill material along the headrace channel. The basis of the design of the gabion base should be such that the pressure at the base is less than the anticipated bearing capacity of the material under it. A fill shall be placed behind the gabions and compacted in layers of 150mm thick.

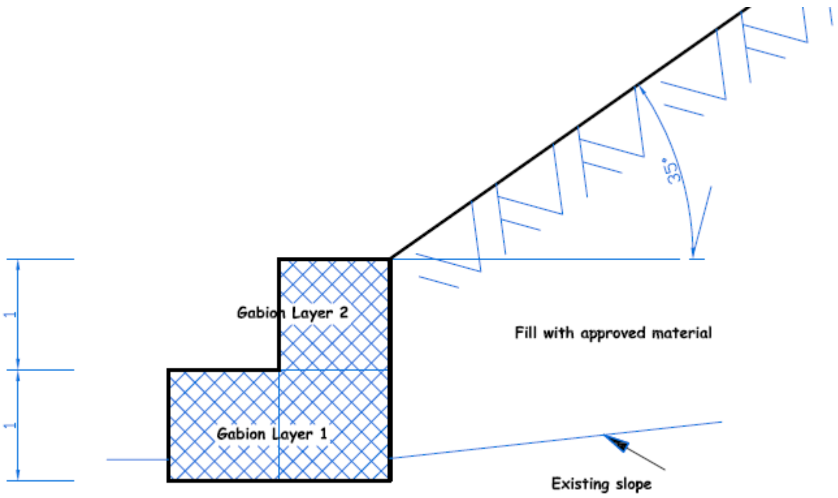


Fig 20: Embankment Specifications

Description	symbols	Amount	units	Notes
Backfill Slope angle	β	35	°	
Angle of Internal Friction	ϕ	35	°	
Angle of wall friction	δ	0	°	
Inclination angle to vertical plane	ω	0	°	
cohesion	c	0	KN/m^2	Ignore Cohesion
Surcharge	q	7	KN/m^2	
Soil Density of fill	γ	18	KN/m^3	
Gabion Density	γ_g	28	KN/m^3	
Height of Wall	H	2	m	
Width of base	B	2	m	
Embedment	d	0.3	m	
Allowable Soil Bearing capacity	q_a	200	KN/m^3	See Geotechnical Report
Active Earth Pressure coefficient	K_a	0.67		Coulumb's Theory

Below are calculations to check

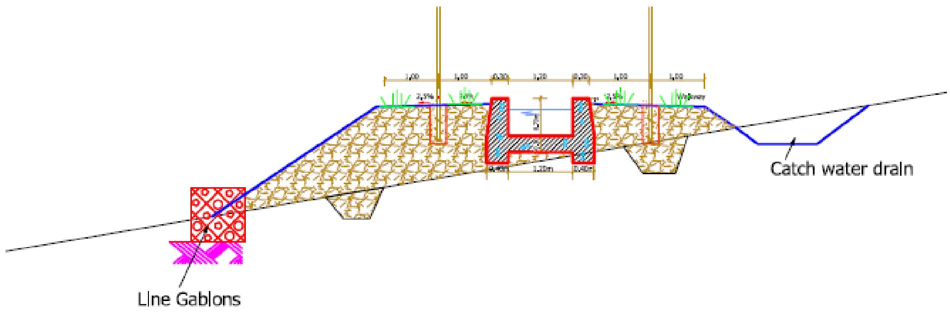
1. Overturning in which the factor of safety should be greater than 2
2. Sliding where the factor of safety should be greater than 1.5
3. Eccentricity of Resultant Force should be within the middle 3rd of the base

Table 9: Embankment structural analysis

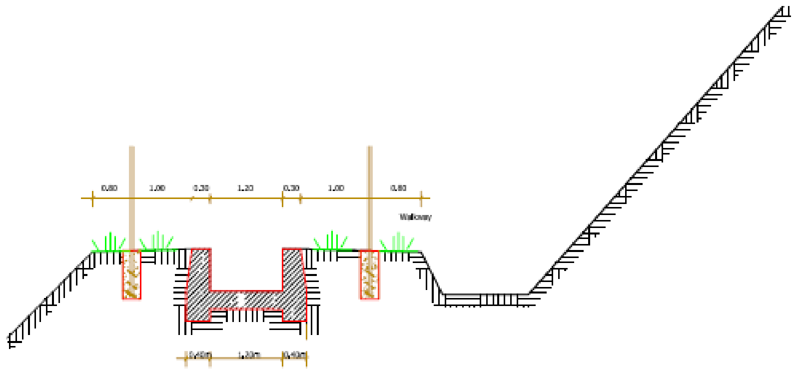
Gabion Row #	Width	Height	Offset from mid base	Offset from toe	Area	Weight	Moment	Moment 2
2	1	1	0	1.5	1	25	-	37.5
1	2	1	0	1	2	50	-	50
Resisting moment						75	-	87.5
Overturning moment								
Description	Force	Amount	Moment arm				Moment	
Soil Fill	F_h	24.16	0.67				16.10	
Water	F_w	20.00	0.67				13.33	
Surcharge Force	Q_h	9.394141	1				9.39	
Total overtuning moment							38.83	
Factor of Safety against overturning							2.25	

Gabion Row #	Width	Height	Offset from mid base	Offset from toe	Area	Weight	Moment	Moment 2
2	1	1	0	1.5	1	25	-	37.5
1	2	1	0	1	2	50	-	50
Resisting moment (M_R)						**75**	**-**	**87.5**
Overturning moment								
Description	Force	Amount	Moment arm					Moment
Soil Fill	F_h	24.16	0.67					16.10
Water	W_h	20	0.67					13.33
Surcharge Force	Q_h	9.394141	1					9.39
Total overtuning moment (M_o)								**38.83**
Factor of Safety against overturning								**2.25**

Sliding			
Total vertical weight		75.00	KN/m
Frictional Force		52.52	W.tanΦ
Total horizontal Force		33.55	KN/m
Sliding Factor of Safety		1.57	Ok
Checking The Excentricity of Resultant Force			
Eccentricity (e)	-0.51776		$\frac{\sum M_R - M_o}{\sum W}$
B/6	0.75		



TYPICAL FILL



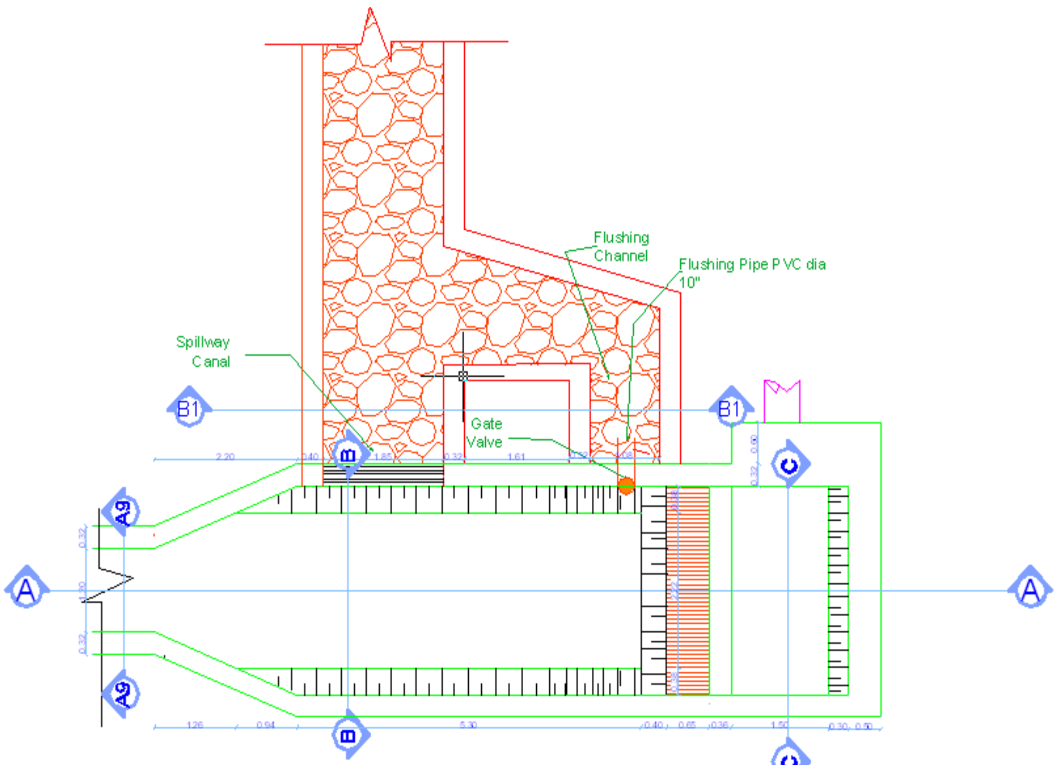
TYPICAL CUT

It should be noted, however, that where the cut slope is steep and characterized by loose stones, gabion mats may be used to retain any loose material. Further analysis may however be required to establish the stability of such slopes.

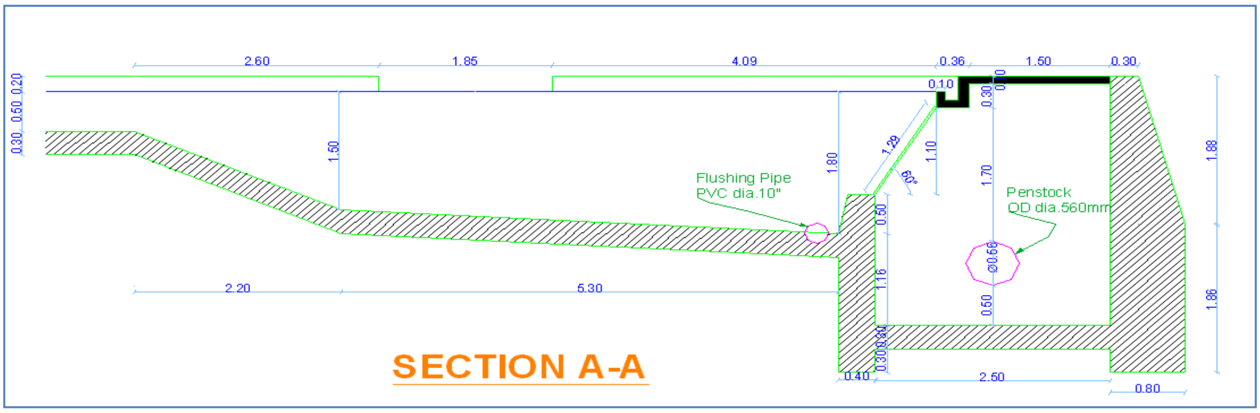
3.15 FOREBAY DIMENSIONS

That said though, the purpose of the forebay will be to settle and trap 'foreign bodies' intruded into the channel e.g. leaves, stones, grass etc. Secondly the forebay shall provide water to the penstock while eliminating the possibility of vortices' formation at the penstock intake.

The pipe minimum submergence S that ensures elimination of vortices is given by $S > 0.7 \times V \times \sqrt{d}$ Solving for S, S>1.21m, therefore S will be set to 1.5m. A storage depth is provided for possible silt deposition. A trash rack inclined at 60^{o} and dimensioned in a way to stop relatively big particles from accessing the turbine whereas letting through adequate flow. A dead storage of 0.5m was considered to allow for silt accumulation.



PLAN VIEW


2.60
1.85
4.09
0.36
1.50
0.30
0.10
0.30
1.50
1.80
1.29
1.10
1.70
1.88
Flushing Pipe
PVC dia.10"
Penstock
OD dia.560mm
0.50
1.16
0.50
1.86
2.20
5.30
0.40
2.50
0.80

SECTION A-A

4.0 ELECTRO MECHANICAL EQUIPMENTS

4.1 PROJECT OUTLINE

The project outline is as follows:

Construct a flow abstraction weir.

Construct settling chamber adjacent to the weir structure.

Provide a low pressure water conveyance system from the weir to a location which results in the shortest length of penstock.

Provide 1No penstock to the power house.

Construct a powerhouse complete with all the required plant and equipment.

Provide a transmission line from the power site to Kanungu town.

Provide the plant and equipment to connect up into the existing distribution system.

4.2 PENSTOCK

The upper diameter of the penstock is set by the power output required and the pressure rating of the pipe. The pipe materials available for the penstock are steel, polyethelene (PE), and PVC. These are available in the range of sizes required for this project.

The available head is 85m, and the available flow is $0.55m^3/s$. The expected power generation for this site is 320KW. The optimum size of a single penstock to meet these condition has been determined as steel with a diameter of 550mm with a thickness of 6mm.

4.3 POWER HOUSE

The role of the powerhouse is to protect the electromechanical equipment that convert the potential energy of water into electricity, from the weather hardships.

The following equipmentS will be found in the powerhouse:

Inlet gate or valve

Turbines

Gearbox if required

Generators

Control system

Switchgear

Protection systems

DC emergency supply

Power and current transformers

The power house will be set 1.2m above the highest flood marks, but the floor is sunk to 0.5m above the high flood level.

4.3 SITE ACCESS

There is no existing access road to the proposed power site. This will have to be provided under the project.

Only a low grade gravel road will be provided to afford access to regular off road vehicles, and the occasional delivery trucks.

In the process of laying the pipes and building the channels, the contractor will provide a rough access for his equipment. This access will be maintained for the operation and maintenance staff.

4.4 FLOW CONTROL

The main control for flow into the generation system is at the intake via the penstock valves at the inlet to the stilling basin. Thereafter, the flow is free up to the power house. Bar screens will be provided at the entry from the open channel to the pressure pipe. This will exclude large objects from gaining access to the pipe.

The inlet chamber into the penstock is provided with a large overflow, and an open channel to lead the flow back to the river. It is expected that when this chamber begins to overflow into the water channel, then the control valves at the abstraction weir should be throttled to reduce flow into the system.

The final control is within the power house where butterfly valves are provided to regulate the flow to each turbine, and isolate it when necessary.

4.5 GENERATING PLANT

4.5.1 General

The available flow is 0.55m3/s for at least 9 months. The available head is 85m. It is proposed to use 1 turbine in the Power House.

It is also important to select a turbine and generator with a good guaranteed efficiency curve for the range of available water flow. A generator has been selected which can operate down to 40% of the flow. By abstracting 0.55m3/hr, the river is not left dry and will have some flow to satisfy environmental requirements.

4.5.2 Selection of Turbine Size and Type.

The purpose of a hydraulic turbine is to transform the water potential energy to mechanical rotational energy.

The potential energy in water is converted into mechanical energy in the turbine, by two basically different mechanisms:

- The water pressure can apply a force on the face of the runner blades, which decreases as it proceeds through the turbine. Turbines that operate in this way are called **reaction turbines**. The turbine casing, with the runner fully immersed in water, must be strong enough to withstand the operating pressure. Francis and Kaplan turbines belong to this category.
- The water pressure is converted into kinetic energy before entering the runner. The kinetic energy is in the form of a high-speed jet that strikes the buckets, mounted on the periphery of the runner. The jet is formed by reducing the diameter of the penstock drastically before it enters the Turbine. Turbines that operate in this way are called **impulse turbines**. The most usual impulse turbine is the Pelton.

The hydraulic power at output of the turbine is given by:

P_h = $\rho Q.gH$ [W]

Where:

ρQ = mass flow rate [kg/s]

ρ = water specific density [kg/m3]

Q = Discharge [m3/s]

gH = specific hydraulic energy of machine [J/kg]

g = acceleration due to gravity [m/s2]

H = "net head" [m]

The mechanical output of the turbine is given by:

P_{mec} = P_h ŋmec [W]

ŋ = turbine efficiency

4.5.3 Turbines

There are several hydraulic turbines available and below is a discussion of some of them.

CrossFlow Turbine

This impulse turbine, also known as Banki-Michell is used for a wide range of heads overlapping those of Kaplan, Francis and Pelton. It can operate with heads between 5 and 200 m.

Water enters the turbine, directed by one or more guide-vanes located upstream of the runner and crosses it two times before leaving the turbine. This simple design makes it cheap and easy to repair in case of runner breaks due to mechanical stresses.

The Cross-flow turbines have low efficiency compared to other turbines and the important loss of head due to the clearance between the runner and the downstream level should be taken into consideration when dealing with low and medium heads. Moreover, high head cross-flow runners may have some troubles with reliability due to high mechanical stress. It is an interesting alternative when one has enough water, defined power needs and low investment possibilities, such as for rural electrification programs.

The Crossflow Turbine has a wide range of operation for small turbines of less than 2.0MW with heads from 1m to 200m and flows of 0.03m^3/s to 10m^3/s.

The Crossflow turbines have a relatively constant efficiency characteristic over a wide range of flows, but a peak efficiency of around 85%. This Turbine is only available in the horizontal arrangement.

The major disadvantage of a Crossflow Turbine is its relatively fragile blades and small case/runner clearances which can be easily damaged by floating debris such as sticks and maize cobs. Good trash racks and silt control is essential therefore.

Francis Turbine

Francis turbines are reaction turbines, with fixed runner blades and adjustable guide vanes, used for medium heads. In this turbine the admission is always radial but the outlet is axial. Figure 1.3 shows a horizontal axis Francis turbine. The Francis Turbines is a medium head, medium flow Turbine for heads of less than 200m and flows of more than 0.1m^3/s.

This is an inward radial flow reaction turbine. The high speed Francis Turbine is suitable for heads up to 200m. It is the mostly widely used turbine in the world.

This turbine is available in the horizontal configuration for small sizes and vertical configurations in large sizes.

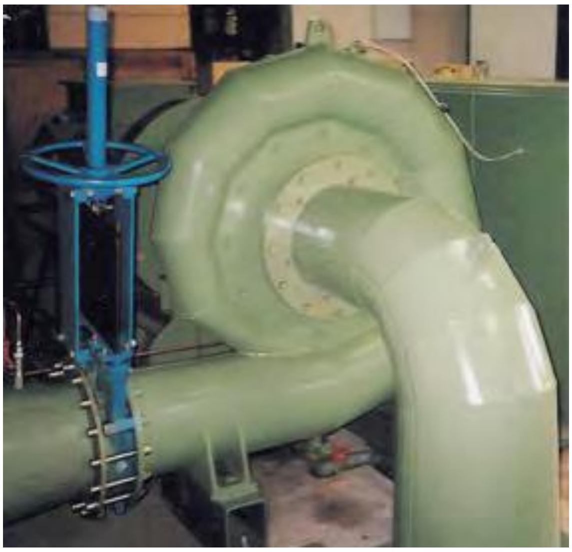


Fig 22: Horizontal Francis Turbine

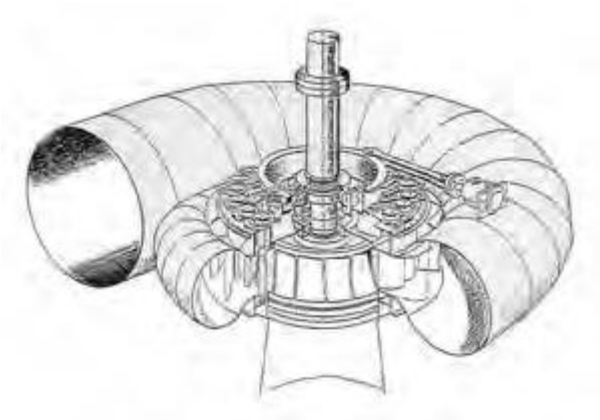


Fig 23: Vertical Francis Turbine

Disadvantages

- Limited operating range – for flows less than 75% of the rated flow, the efficiency drops vary rapidly.
- Turbulent hydraulic flow means low efficiency.
- Debris tends to accumulate – the Francis turbine unlike the Crossflow Turbine is unable to clear itself. Cleaning the turbine means complete shutdown.
- Regulation is achieved by means of wicket gates which require a complicated hydraulic system.

Kaplan Turbine

Kaplan and propeller turbines are axial-flow reaction turbines; generally used for low heads from 2 to 40 m. The Kaplan turbine has adjustable runner blades and may or may not have adjustable guide- vanes. If both blades and guide-vanes are adjustable it is described as "double-regulated". If the guide-vanes are fixed it is "single-regulated". Fixed runner blade Kaplan turbines are called propeller turbines. They are used when both flow and head remain practically constant, which is a characteristic that makes them unusual in small hydropower schemes.

The Kaplan Turbine is always vertically mounted and is suitable for low heads and large flows. It has a dual regulation mechanism using adjustable propeller blades and guide vanes. Its efficiency curve is very flat. However this advantage must be weighed against the high capital cost due to the complicated construction. Further, in small Kaplans, the guide vanes tend to collect debris.

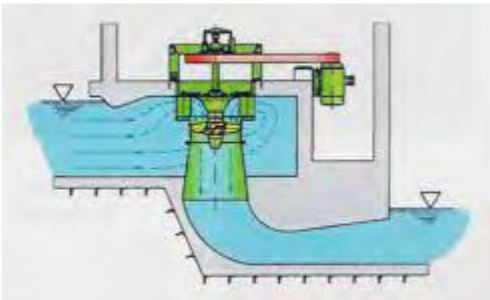


Fig 24: Kaplan Turbine

The Kaplan should actually be used for heads less than 10m and flows of more than $5m^3/s$ and therefore does not come into contention in our proposed scheme.

Pelton turbine

Pelton turbines are impulse turbines where one or more jets impinge on a wheel carrying on its periphery a large number of buckets. Each jet issues water through a nozzle with a needle valve to control the flow (figure 26). They are suitable for high heads from 60 m to more than 1,000 m. The axes of the nozzles are in the plane of the runner. In case of an emergency stop of the turbine (e.g. in case of load rejection), the jet may be diverted by a deflector so that it does not impinge on the buckets and the runner cannot reach runaway speed. In this way the needle valve can be closed very slowly, so that overpressure surge in the pipeline is kept to an acceptable level (max 1.15 static pressure).

Fig 25: Pelton Turbine

The regulating equipment is also expensive.

For low heads, the buckets would be too big. It is therefore suitable for heads lager than 50m and it is an excellent choice for heads larger than 200m.

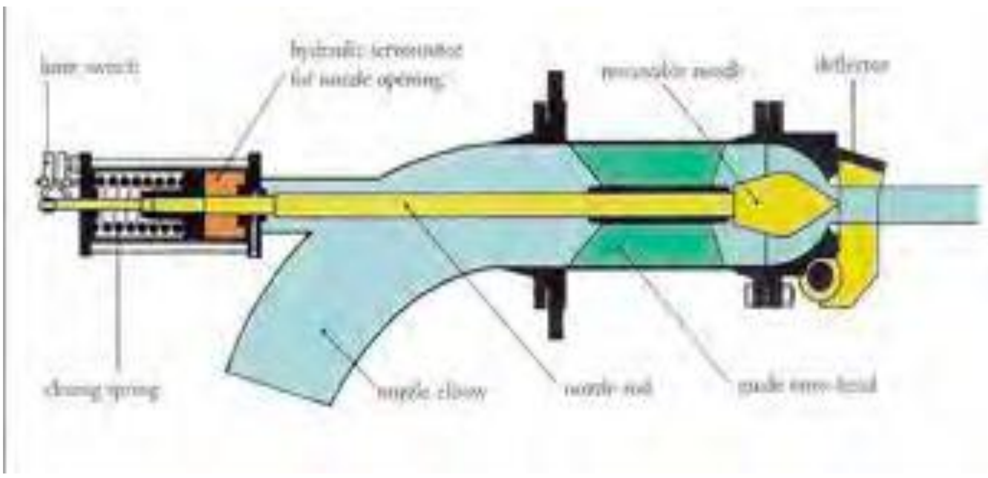


Fig 26: Pelton Turbine Inlet Nozzle with Needle Control

Turgo turbines

The Turgo turbine is also an Impulse turbine and can operate under a head in the range of 50-250 m. Its buckets however are shaped differently from the Pelton and the jet of water strikes the plane of its runner at an angle of 20º. Water enters the runner through one side of the runner disk and emerges from the other side. It can operate between 20% and 100% of the maximal design flow.

The efficiency is lower than for the Pelton and Francis turbines. Compared to the Pelton, a Turgo turbine has a higher rotational speed for the same flow and head. A Turgo can be an alternative to the Francis when the flow strongly varies or in case of long penstocks, as the deflector allows avoidance of runaway speed in the case of load rejection and the resulting water hammer that can occur with a Francis.

4.6 SELECTION OF TURBINE

The available head is about 85m and the available flow is 0.550m3/s. This gives the available power of about 320KW.

Therefore our main parameters for the turbine are as follows:

Quantity	:	1No
Power		:320KW
Head	:	82.5m
Flow	:	0.550m^3/s

For this size of turbines the choice is between the Francis Turbine and the Cross-flow Turbine.

The Cross-flow turbine would be the preferred choice but other factors to take into account are the availability in the preferred source markets. We shall therefore keep our options open for the choice between the two.

4.7 SELECTION OF GENERATOR

The proposed Power System is going to work either as a standalone unit or in parallel to the existing National Grid at Bundibugyo. There are two possible kinds of generators namely: Asynchronous and Synchronous

Synchronous generator

They are equipped with a DC electric or permanent magnet excitation system (rotating or static) associated with a voltage regulator to control the output voltage before the generator is connected to the grid or load. They supply the reactive energy required by the power system when the generator is connected to the grid. Synchronous generators can run isolated from the grid and produce power since excitation is not grid-dependent

Asynchronous generator

They are simple squirrel-cage induction motors with no possibility of voltage regulation and running at a speed directly related to system frequency. They draw their excitation current from the grid, absorbing reactive energy by their own magnetism. Adding a bank of capacitors can compensate for the absorbed reactive energy. They cannot normally generate when disconnected from the grid because they are incapable of providing their own excitation current.

However, they are used in very small stand-alone applications as a cheap solution when the required quality of the electricity supply is not very high. In this case the excitation current is supplied from a bank of capacitors.

Below 1 MW, synchronous generators are more expensive than asynchronous generators.

The efficiency of asynchronous generators can be about 95 % for a 100 kW machine and can increase to 97% towards an output power of 1MW. Efficiencies of synchronous generators are slightly higher. In general, when the power exceeds some MVA a synchronous generator is indicated.

We have therefore selected the Synchronous generator which is suitable for both isolated operation and operation in parallel with other systems.

The selected frequency is 50Hz which is the standard frequency in Uganda and will allow connection to the grid. The selected power output for each generator is 320KVA at 0.8pf apparent Power to match the turbine output. The selected voltage is 415Volts, 3 phase. This voltage will give a current of about 556A. This voltage is selected as a commonly available Voltage.

The rated speed is selected at 1500 RPM which is deemed reasonable but will also depend on the speed of the Turbine. A direct coupling between the generator and turbine shafts is preferred but in case of a lower turbine speed, a gear box drive will be accepted.

Therefore the following is a specification of the Turbine and Generator:

Turbine Type	:Francis or Cross-Flow
Quantity	:1
Flow Rate	:0.550m3/s
Head	:82.5m
Power	:320 KW
Speed	:1500 RPM
Runway Speed	:2700 RPM
Orientation	:Horizontal
Efficiency	:>85% for flow rate 50% to 110%
Governor	:Electronic
Generator Type	:Synchronous
Quantity	:1
Power	:320KVA
Voltage	:415Volts, 3phase
Frequency	:50Hz
Speed	:1500 RPM
Loading	:Continuous

4.7.1 Network Configuration.

There is one 320KVA generator connected to a step up transformer rated at 315KVA, 415V/33KV 50Hz. The transmission voltage selected is 33KV to minimize losses and voltage drops on the Transmission line which is 22km long.

4.7.2 Overhead Transmission Line.

The overhead line is of flat formation configuration. The line conductor size is $50mm^{2,}$ All Aluminum Alloy Conductor (AAAC) with a current carrying capacity of 200A. The total loss when carrying 320 KVA is about 16KW which is about 5%.

The distance between poles will be an average of 110m as used by the UMEME. Appropriate corner poles will be used at all changes of line direction. Off-load dis-connectors shall be installed at each end of the line.

4.7.3 Station Supply at NDUGUTU.

The station supply at Ndugutu is derived from the generator output bus at 415V by direct connection to the output buses. The station supply provides power to all auxiliaries of the generator and turbine, battery charging, control and monitoring, protection, power supply and lighting for the Power House.

A 50KVA emergency diesel electric generator will also be provided to maintain the station supply in case of total shut down of the station. The last line of defense is a battery supply which will maintain basic control and monitoring functions in case of total failure.

4.7.4 Power Sub-Station at Bundibugyo

At Bundibugyo there is a 33KV Sub-Station into which the Ndugutu Plant will connect. A 33KV connection bay will be required.

4.7.5 Control and Monitoring System

Control and Monitoring System will be a Computer based two level hierarchical system, consisting of the station control level and the group level control.

There will be a local station control at the Generating Station at Ndugutu and at the bulk supply point at Bundibugyo. Group Control at Ndugutu will include the local station equipment plus the transmission line, and all the equipment at Bundibugyo.

Similarly Group Control at Bundibugyo will mean control of all the local equipment in Bundibugyo plus control of the transmission line and the equipment in the Power Station at Ndugutu. The operation mode shall be either manual, automatic. There will be a provision for SCADA connection to the UETCL Central Control at Lugogo in Kampala

The quantities to be monitored shall include, power, voltage and current of the generator, voltage and frequency of 33KV Busbars and the power, voltage and current in the feeder, Positions of circuit Breakers in the Systems, Status of each generator unit, turbine and alarm conditions.

Two microcomputers one at Ndugutu and the other at Bundibugyo will be used to operate the system. Communication between the two systems will be by Power Line Carrier (PLC) system using the 33KV line.

Voice communication will also be carried on this system.

4.7.6 Protection

The aim of protection is to isolate a fault on the system causing the minimum of disruption to the supply. A good protection system is simple robust easy to operate and maintain, quick to operate and economic to install.

For purposes of protection, the system has been divided into the following units:-

i. generator transformer unit including the turbine
ii. station supply at Ndugutu
iii. 33 KV Busbar together with the 33KV overhead line and the 33KV Busbars at Bundibugyo.
iv. Load transformer and 33KV Busbar.

5.0 OPERATION AND MAINTENANCE

5.1 INTRODUCTION

The implementation of this scheme will involve a large capital commitment. In order to repay this investment the scheme needs to run efficiently and continuously throughout its design life (more than 25 years). Efficient and continuous running will only be possible with skilled operation of the scheme and a well planned maintenance programme.

If operation and maintenance (O&M) schedules are not followed carefully the scheme will run into problems. The occurrence of regular breakdowns will result in complaints from the client and both the contractor and the installation will be perceived badly.

O&M procedures must be planned and put into action in the initial stages of the scheme to prevent breakdowns and their ramifications.

Safety in the place of work is also a major consideration. The mechanic or operator should know what is dangerous in terms of materials, conditions and equipment. The correct tools and also correct or recommended spare parts should be used for both the safety of the plant and also the people.

5.2 RESPONSIBILITIES

The designer, Contractor and user all have important parts to play in the O & M of a small hydro scheme.

At the design stage we must have O & M in mind throughout the design process. The design must take into account the skill levels, motivation, availability and costs of O & M staff.

Failure to take sufficient account of O & M considerations, can lead to long downtimes. We have to select equipment with good spares availability to achieve good reliability.

The Contractor will have tightly supervised specifications to work to and continuous supervision during construction. The Contractor will produce as built drawings and will be responsible for training operators.

Operation and maintenance of a modern micro-hydro can be a monotonous job – in many cases involving long periods of inactivity. Motivation can be a problem, as can the costs of continuous supervision of a small plant. The users also have to implement the O&M schedule and make sure that spares are stocked and replaced in time. O & M staff need to be recruited, trained and perhaps periodically retrained during the life of the plant.

5.3 Levels of Maintenance

It is important to decide which maintenance jobs can be done by the operators and which have to be referred elsewhere. There are usually three "level" of maintenance – by the operators, by local workshops/mechanics and by specialists.

It is then necessary to establish which companies will undertake which jobs. For example, a local workshop may be able to change turbine and alternator bearings. The workshops will need written information on this procedure to avoid mistakes being made.

More complex repairs – say repairs to a runner – will need to be done by the manufacturer.

The maintenance schedules then must make clear which jobs are for which level.

A structured system for O & M is very important. This will take the form of a number of documents as listed below:

5.3.1 Operating Schedules

This is the basic operating instructions – start-up, maximum loads, descriptions of meters, trips etc. This corresponds to the user manual.

5.3.2 Manuals

Copies of all manuals must be readily available in the right language. Typically, manuals are available for turbines, alternators, switches, belts, couplings, governors and so on. These correspond to the workshop manual.

5.3.3 Design Documents

These cover any equipment not covered by the manuals; for example, the penstock and the powerhouse. These documents should give drawings, dimensions, design information and O+M schedules.

5.3.4 Maintenance Schedule

This corresponds to the Service Record Book, and describes in detail the various maintenance tasks and when they should be carried out. Typical items will be greasing bearings and emptying silt basins.

5.3.5 Log book

This is a formal record book which can be checked and countersigned by a supervisor. It is an essential document for continuity and monitoring of O&M activity. Without a log book, for example, oil changes might be missed or the fact that a certain bearing fails far too often might not be noticed.

Maintenance of the civil works can be carried out on a regular basis, as indicated in the following schedule. It is also important to remember that most problems will occur during times of heavy rainfall and more frequent inspection may be necessary during the rainy season. Repair work on the other had is more easily carried out during the dry season. The maintenance of the civil works therefore should take account of the seasonal variations.

5.4 WEIRS

The weir is the concrete structure across the river where the water for the turbine is taken. This will need very little maintenance other than during heavy rains as this will bring in large stones or vegetation, which may stop the water from entering the channel. It may also be necessary to remove silt from behind the weir. However, it is not necessary to remove all the silt as in most cases it helps to keep a good seal and prevents leaks on the weir.

If there are leaks on the weir they will show up during the dry periods of the year. It is during this time of year that it is necessary to get as much water into the channel as is available in the stream. If there are leaks on the weir this will not be possible. A temporary measure is to block the leak with sand bags.

The dry periods of the year are also the best to inspect the weir for cracks and carry out repairs where required. The repairs may take the form of patching broken or cracked pieces or more major repairs. Flood water can erode the banks if the wing walls are damaged, and erosion of the banks could have serious implications on the working of the hydro plant.

5.5 INTAKES

The intake is the point where the water leaves the stream and enters the channel. It is necessary to inspect this area at least daily, especially during the wet periods of the year. This is because, during the rainy season, the stream will carry more debris and silt which could block the intake. The trash racks need clearing on a daily basis.

5.6 OVERFLOWS AND SPILLWAYS

Excess water entering the channel will be put back into the stream in a spillway which leads the back into the stream.

Overflows and spillways should be inspect periodically like the rest of the civil works for various damages which may happen with time, e.g. cracks. These should be promptly repaired or the damage will extend and will be more expensive to repair later.

5.7 CHANNEL

During daily maintenance, the channel should be inspected and any stones or vegetation removed from it. If there is silt in the channel it should be moved into the silt tank and removed from there.

General maintenance of a channel should prevent leak and repair any damage as soon as it appears. If leaks are not attended to, they get worse and sometimes wash away the ground that holds the channel

Drains to carry rainwater away from the channel should always be inspected and cleaned or repaired as necessary.

In some places where the channel has to cross a valley pipes are used. These will the low pressure pipes. As far as maintenance is concerned these pipes may get blocked occasionally and need to be cleaned. The inspection of these pipes should take into account the supports and joints along the pipe. The ground both above and below the pipes should be carefully looked at, as stones falling onto a pipe from above can damage it.

5.8 SILT TANKS, FOREBAY TANKS AND RESERVOIRS

Silt tanks form an important part of small scale hydro scheme as it is the silt tank that determines the wear on the turbines The silt collects in the silt tank because the speed of the water is reduced here, allowing the silt to fall to the bottom of the tank. The collected silt should be removed daily through the flushing gate; if not it will collect up to its limit and any excess will be passed into the turbine. During rainy periods the tank will have to be emptied as there will be more silt in the water.

Other than cleaning the silt out daily, the tank needs very little maintenance. The occasional masonry repair can be carried out during the dry period of the year. Flushing valves may need attention as there are moving parts which need to be lubricated about once a week. Care should be taken over the water leaving the flushing valve; this should be taken back to the stream without causing any erosion to the soil under the silt tank.

The forebay tank consists of a trash rack, an overflow or spillway and a sluice gate to shut off the water to the turbine.

The trash rack will need daily maintenance or cleaning, as it is here that all the water borne vegetation and debris is prevented from entering the turbine. The trash rack should be cleaned as often as possible and during rainy periods it may be necessary to clean it twice daily.

It is very important that only water gets past the trash rack as anything else could reduce the output of the turbine or could damage the turbine. Keeping this in mind it is important to inspect and repair the trash rack as often as necessary. When repairs are carried out on trash racks, they should be done in such a way that cleaning is easy. To make cleaning easier, suitable rakes should also be made.

5.9 PENSTOCKS

Penstocks carry the water from the forebay tank to the turbine.

The proposed penstock is mild steel coated with bitumen inside and outside. It is very important to keep this bitumen coat in good repair all the time by regular inspection and repair.

Penstock support should be inspected as often as possible and any damage should be repaired immediately, as neglecting this could cause extensive damage to the penstock itself. If the supports are broken or damaged, the pipe is unable to support itself, and breaks under its own weight. It becomes very difficult to repair or replace such a broken pipe as it is sometimes difficult to obtain such pipes. If the correct pipes are not available it is then necessary to replace them with similar pipes which should be rated to take up the same pressure.

The drainage around penstock supports should be such that the water is moved away from the supports, as running water will erode the foundation of the supports. It has been seen of some hydro schemes that bad drainage has caused a few pipe lengths to move from its original position due to earth slips. Penstocks can easily be damaged by falling rocks and wherever possible these rocks should be removed from above the penstock.

5.10 VALVES

Valves are used in the penstock and the turbine. Valves generally tend to leak with time which is not a major problem. Water leaks into the powerhouse can be stopped by repairing the sealing arrangement on the valve, but if the valve does not shut off the water completely, it is a skilled job to repair it.

Most gate valves have felt “stuffing box” seals. The felt needs to be moist to prevent deterioration. The amount of leakage through the seal is usually adjusted by two bolts. These should be adjusted to allow a slight seepage, to keep the felt moist, and checked periodically.

Valves need occasional lubrication. Sometimes large valves are provided with a small bypass valve which is installed to make the opening of the large valve easy. The bypass valve removes the pressure on the large valve and also reduces the wear and tear on it while it is being opened or closed.

Valves installed on the penstock should be fully opened while in operation and should not be used as flow control valves which work differently. These flow control valves are generally installed in the turbine.

5.11 TURBINE

In this project we are proposing either Francis or the Cross-flow turbine. The turbine is new and the manufacturer's instructions should be followed during maintenance and operation.

The Turbine will need very little maintenance as long as the water course is kept clean. However, if things do get in to the turbine it is necessary to open the inspection covers in the case of the Francis turbines. These foreign objects should be removed for the best performance of the machines.

Many turbines have some type of mechanical link to the governor for speed control and these links should be greased and their nuts and bolts should be checked to see that they are tight.

Bearings on these machines should be kept dry and in most cased the bearings are placed a few inches a way from the castings. There is sometimes a hole at the bottom, where the bearing is mounted, to drain any water which may come towards these bearings. A common mistake is to over-grease bearings (they should only be half full of grease). The excess grease can then block the drains and, unless cleaned, can cause water to enter the bearing.

For these turbines it is important to keep the tailrace clean, as otherwise water leaving the turbine will find it difficult to move out and will ultimately flood the casing, which should not happen.

Francis turbines

Silt in the water is a major problem in this type of turbine as it wears out the internal parts of the machine. Therefore it is important to keep the water clean by having a very effective silt tank.

The Francis turbine tends to get blocked with vegetation, and this will reduce the kilowatt Output of the machine. When the machine gets blocked in this manner the vegetation which collects inside the turbine must be removed by opening the inspection plate which is generally provided on the casing.

Francis turbines tend to leak along the shafts that are connected to the guide vanes. To a certain extent this leak is allowable as the water acts as a coolant for the seals. However, if these points leak to much the seals could be tightened.

The draught tube is an integral part of the Francis turbine and its open end should be immersed in water during operation. In some Francis turbines and air vents included and this is used to remove the air from inside the casing during start-up.

Cross-flow turbines

Cross-flow turbines can be catastrophically damaged by sticks because of the relatively fragile blades, and small case/runner clearances. Good trash racks are essential. Some turbines are provided with inspection plates on the nozzle which helps to remove any dirt collected in this area.

Crossflow are more affected by erosion that Peltons because of the relatively thin blades often fabricated from mild steel. Good silt control and regular inspection of the runner are therefore important.

5.12 DRIVES, BEARINGS AND BELTS

The drives consist of shafts, couplings, belts and bearings. The turbine may also be directly connected to the alternator and this type of drive is known as direct drive. This type of drive needs very little maintenance, only the occasional inspection to check that the nuts and bolts are tight. On some couplings there are leather or rubber pieces which need inspection and to be changed when necessary.

5.13 GOVERNORS

The function of the governor is to keep the turbine speed constant over the wide range of output loads.

Mechanical governors are generally connected to the turbine shaft directly or with a set of belts. These governors control the flow of water into the turbine through a set of mechanical levers. The governors should be inspected daily to check that the belts are in good conditions and the link mechanism is well lubricated. The governors have various adjustments and springs, which should be adjusted only after reference to the manufacturer's literature or by a competent person. Any adjustment to these links or springs will change the operation of the turbine and will most probably make the machine run at a different speed.

5.14 ALTERNATORS

This should be kept clean and free from dust, moisture and oil. The alternator should be inspected frequently, as dust can have a harmful effect if it is allowed to settle on the windings, to enter the bearings, or to collect in the ventilating passages. A blower can be used to remove dust from inside the alternator and should be done every six months at least depending on the site conditions. Chemical solvents should not be used as these can damage the insulation of the windings.

Electrical connections should be checked at the alternator and should be tightened when necessary, as loose connections will cause these points to get hot. The frame of the alternator should be earthed and this connection should also be checked.

Ventilation should be very good as a flow of air through the alternator is necessary to keep it cool while in operation.

5.15 ELECTRICAL EQUIPMENT AND TRANSMISSION LINES

Wire connections should be tight as loose connections cause heating and damage to the switches. Switches also get hot when the contacts are worn out and in this case the contacts must be replaced.

Meters and other instruments on the switchboard should be working as these give an indication of the rest of the condition of the plant. Trips and protection devices should be tested periodically.

Overhead transmission lines should be inspected frequently and any trees or branches touching the line should be cleared. The connections along the overhead lines should be checked and tightened if necessary.

This installation has transformers and high voltage transmission lines. A competent engineer familiar with such work should attend to the maintenance of the system. The

Engineer should inspect the overhead line and transformer from time to time and clear the vegetation that may touch the lines. In the case of the transformer the Engineer should inspect the oil level and the desiccator both of which are visible from the outside.

5.16 RECOMMENDED SPARE PARTS

This is a vital and often neglected part of maintenance. The penalty for not having the right bearing or the right tool in stock will be typically one month downtime.

One complete set of spares and essential tools has been specified to be supplied by the contractor to the client.

Spares should be kept in a cool, dry and clean place. Bearings should be stored in the original packing, or if this is not available they should be coated with grease to prevent rust and stored in a dry place. Electrical spare parts should be packed, labeled and stored away from moisture.

Oil and grease should be protected from contamination by moisture and dirt.

5.17 TOOLS

Good quality tools are essential for good maintenance. Cheap, poor quality tools will break and will be expensive in the long run. Poor quality tools will also tend to damage the equipment that is to be maintained. The tools shall be ordered along with the equipment. This has been taken care of by including a comprehensive list of tools.

5.18 OPERATION

In general the water supply to the machines should be checked before the plant is put into operation. For this, it is necessary to inspect the channel, regulating valves, silt tank, forebay tank, and trash racks, to see that they are clean and the required amount or water is flowing in the channel.

Before the turbine is started it is good practice to rotate the shaft by hand to see whether it is free to rotate, and check the bearings, belts, nuts and bolts, etc. The pressure gauge on the turbine should indicate the maximum static value.

The turbine should be started gradually and brought up to speed. The operator should observe the pressure gauge and the revolution meter as the turbine comes up to speed. If the pressure drops below its normal running value it is possible that there is not enough water or there is something blocking the penstock. If the speed exceeds the rated value then it may be that the governor is not working properly. At rated speed the voltage also should reach the nominal value or if set at a higher or lower value, should be in the range of ±5%.

If the turbine is now operating at its rated value then it is possible to load the machine. This is done by switching the hydro power into the switchboard.

Periodically the turbine should be inspected. Bearing and alternator temperatures should be checked. If they rise to a high value, the meters should be examined to see if the machine is overloaded, if not then the machine should be stopped and checked.

5.19 STAFFING

Once consumers acquire electrical services, they quickly come to rely on its quality and continuity. For this reason, the hydro power plant must be operated and maintained by properly trained and experienced personnel.

On the job training for future plant operators should ideally start from the moment of ground breaking. The procedure of recruiting plant operators after the plant is already completed is therefore undesirable since for the power plant, the crucial step include commissioning, carrying out the various tests and making the necessary adjustments. The absence of the operator at this stage of the project can cause problems in the long run. When the plant is ready for operation, all the staff in charge of its technical and financial management must be in place and ready.

6.0 ECONOMIC ANALYSIS

NDUGUTU RIVER MINI HYDRO PROJECT SCHEME

6.1 ECONOMIC RATE OF RETURN (ERR)

The Economic Rate of Return (ERR) is defined as the net benefit to the society as a whole, with respect to the cost and benefit of an investment. It is a broader term than the more narrowly defined term of Financial Internal Rate of Return, that is more widely utilized in traditional financial analysis.

In the case of this particular engagement, Africa Power Initiative Limited has been asked to analyze and review the wider economic benefits of developing and implementing the mini hydro electric power schemes within the context of climate change and its effect on poverty reduction. Therefore, in addition to analyzing the strict financial returns of the three mini hydro schemes, we have also done a broader review of the societal economic impacts and thereafter proceeded to give our recommendations.

The three mini hydro schemes under this engagement were deemed to have differing financial profiles. However, they all did share a central theme in their importance towards alleviating the grinding poverty that is prevalent in the rural Uganda households within which these schemes would be implemented. Specifically, the additional benefits that would accrue to the larger society as a result of these projects include, but are not limited to:

1. Employment opportunities to the local population during the construction as well as post-construction period: During the construction period, there will be the possibility for unskilled as well skilled labor, both manual and technical on the job site. There could also be an additional opportunity for provision of services to the job site employees by the adjacent population. these may include provision of food, shelter, transportation and other related services.

2. Post-construction opportunities include the on-going maintenance and operations of the installed equipment; site security and landscaping maintenance; and any resultant benefits from dual use of the newly installed and operational scheme. Here we have in mind the possibility of having farming activities arising from the potential of site damming, if such a path selected.

It is estimated that just provision of meals to the construction workers during the construction period of approximately 18 months, could result in an additional revenue generation at the local of close to $80-$100,000.

6.2 NET PRESENT VALUE ANALYSIS

Taking an estimated rate of interest (discount) of 5%, a term of 20 years, and a debt/equity ration of 70/30, the results for Ndugutu River are as follows:

ELECTRICITY PRODUCTION			
NDUGUTU RIVER MINI HYDRO			
Cost of Project *2	$3,099,194	Loan Interest	5.00%
Head (m)	82.5	Debt	70%
Plant Factor	75%	Term	20
Tariff *1	$0.109	Loan Amt	$2,169,436
Carbon Credit Price	$15	Equity Amt	$929,758
Est. Annual Credits	1,088	Annual O&M *3	$12,000
Design Flow, m^3/s	0.55	Tax Rate	30%
Installed Capacity, KW	320	Carbon credits, yrs	10
Annual Output, KWh	2,102,400		
Annual Revenue *4	$245,482		
Main Cost Summary	**$3,099,194**	NPV, Equity	($251,541)
Preliminaries	$101,700	NPV, Project	($662,074)
Civil Works	$1,953,361	Project Payback	16
Supervisory	$140,553	IRR, Project	2.47%
Contingencies	$147,581	IRR, Equity	2.04%
Electromechanical	$756,000	Install Cost p/KW	$9,685
Notes:			
*1	Uganda REFiT may not apply to projects under 500Kw capacity.		
	if applicable, it is estimated at USD$0.109		
*2	Excludes VAT		
*3	O&M escalates at annually	7.08%	
*4	Includes estimated Carbon Credit sales for 10 years.		

As can be seen from the above, the Ndugutu River Mini Hydro project scheme does not have a favorable financial profile when viewed strictly from a traditional financial analysis standpoint. Due to the low levels of free cash flows generated by the project, the payback period is rather a long way out, at 16 years.

The main reason for lower free cash flow of the Ndugutu mini hydro scheme is due to the location and the accessibility of the project site. Our technical team visited the site on several occasions and made the determination that the water flows of the Ndugutu River are adequate and sufficient for the installed capacity of 320KW. There was a determination that the water flows are quite high during the rainy seasons and still acceptable even during the dry season.

The project site is in a very difficult to access location. It is in a very steep ravine that was extremely challenging to the technical team during our several visits. Therefore, the capital costs associated with accessing and properly installing equipment on this site have an escalating effect on project costs.

Viewed from the broader context of the societal impact and the effects of climate change on poverty reduction, a different and much more favorable view emerges. If the installation costs are viewed within the context of the resulting benefits to the local community in the area, then the implementation of the project will result in avoided costs for:

i) Utilization of local biomass such as trees for domestic, and to a limited extend, commercial electrification;

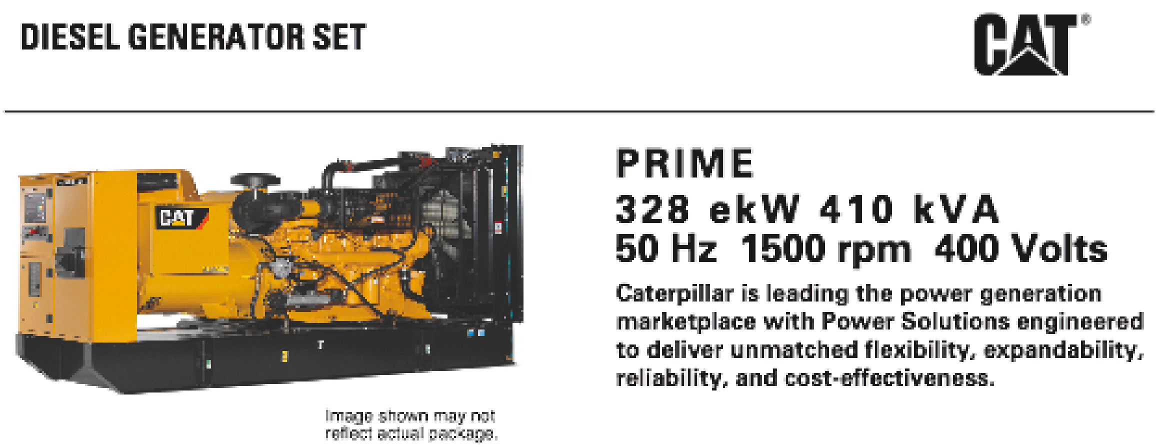
ii) Saved foreign exchange that would have had to be spent on the equivalent production of diesel powered generators; and with sound planning,

iii) The location is in a very steep ravine, which will require a higher wier. While the site is difficult to access, it also lends itself somewhat well for damming. However, as a general matter, any damming to regulate the river flow has to pay attention not to harm the local indigenous fauna and flora. The additional damming may also provide a potential for local farming activities, whose effects will benefit the environment and help to mitigate the effects of climate change; while any resulting farming produce will go a long way towards reducing poverty.

6.3 AVOIDED COSTS ANALYSIS

A typical 320KW Diesel Powered Generator, as shown below will consume approximately 85.5 litres (22.7 gallons) of fuel per hour at full load. If this machine runs for the equivalent amount of hours per year as the proposed 320KW mini hydro scheme at Ndugutu River, of approximately 6,570 hours (at a conservative 75% plant factor capacity), it will consume approximately 561,735 litres (147,825 gallons) of diesel fuel per year. With the current diesel prices in Uganda at approximately UGX 2,500-3,000 per litre (i.e. UGX 11,400 p/gallon), then utilizing the generator at equivalent usage would result in a cost of UGX (147,825 * 11,400) = 1,685,205,000. This is equivalent to an annual cost of approximately USD$766,000 (at USD$1:UGX2,200). Over a twenty year equivalent period, this adds up to USD$15,320,045. There are also the additional avoided emissions of harmful CO2 into the atmosphere by running the diesel powered generator for this amount of time per year.

Equally important is the savings of valuable foreign exchange in purchasing 561,735 litres of diesel fuel annually for the generator.



PRIME 328 ekW 410 kVA

50 Hz 1500 rpm 400 Volts

TECHNICAL DATA

Open Generator Set - - 1500 rpm/50 Hz/400 Volts	DM8486	
Low BSFC		
Generator Set Package Performance		
Genset Power rating @ 0.8 pf	410 kVA	
Genset Power rating with fan	328 ekW	
Fuel Consumption		
100% load with fan	85.9 L/hr	22.7 Gal/hr
75% load with fan	64.7 L/hr	17.1 Gal/hr
50% load with fan	46.6 L/hr	12.3 Gal/hr
Cooling System[1]		
Air flow restriction (system)	0.12 kPa	0.48 in. water
Air flow (max @ rated speed for radiator arrangement)	558 m^3/min	19706 cfm
Engine Coolant capacity with radiator/exp. tank	57.8 L	15.3 gal
Engine coolant capacity	20.8 L	5.5 gal
Radiator coolant capacity	37.0 L	9.8 gal
Inlet Air		
Combustion air inlet flow rate	23.7 m^3/min	837.0 cfm
Exhaust System		
Exhaust stack gas temperature	519.7 ° C	967.5 ° F
Exhaust gas flow rate	66.7 m^3/min	2355.5 cfm
Exhaust flange size (internal diameter)	152.4 mm	6.0 in
Exhaust system backpressure (maximum allowable)	6.8 kPa	27.3 in. water
Heat Rejection		
Heat rejection to coolant (total)	130 kW	7393 Btu/min
Heat rejection to exhaust (total)	302 kW	17175 Btu/min
Heat rejection to atmosphere from engine	64 kW	3640 Btu/min
Heat rejection to atmosphere from generator	20.6 kW	1171.5 Btu/min
Alternator[2]		
Motor starting capability @ 30% voltage dip	923 skVA	
Frame	LC6114D	
Temperature Rise	105 ° C	189 ° F
Lube System		
Sump refill with filter	60.0 L	15.9 gal
Emissions (Nominal)[3]		
NOx mg/nm3	3397.8 mg/nm^3	
CO mg/nm3	144.9 mg/nm^3	
HC mg/nm3	10.3 mg/nm^3	
PM mg/nm3	10.3 mg/nm^3	

[1] For ambient and altitude capabilities consult your Cat dealer. Air flow restriction (system) is added to existing restriction from factory.
[2] Generator temperature rise is based on a 40° C (104° F) ambient per NEMA MG1-32. Some packages may have oversized generators with a different temperature rise and motor starting characteristics.
[3] Emissions data measurement procedures are consistent with those described in EPA CFR 40 Part 89, Subpart D & E and ISO8178-1 for measuring HC, CO, PM, NOx. Data shown is based on steady state operating conditions of 77°F, 28.42 in HG and number 2 diesel fuel with 35° API and LHV of 18,390 btu/lb. The nominal emissions data shown is subject to instrumentation, measurement, facility and engine to engine variations. Emissions data is based on 100% load and thus cannot be used to compare to EPA regulations which use values based on a weighted cycle.

6.4 SENSITIVITY ANALYSIS

The Ndugutu River mini hydro project scheme is a small project whose main benefits would likely accrue to the local community. The project is located in a very challenging position which will have an upward impact on the project costing. Within the context of conducting a sensitivity analysis, it was felt that the biggest obstacle to the development of this project is most likely going to be the installation cost. However, it is also our opinion that the nearby community will be well served if this project is developed, which will necessitate some external financial intervention. This is what is termed within the body of this analysis as the "construction subsidy".

Sensitivity Subsidy Amt	Project Cost with subsidy	Installed Cost p/KW	Project NPV	Project IRR
50%	$1,549,597	$4,842	$813,733	10.17%
40%	$1,859,517	$5,811	$518,572	7.88%
30%	$2,169,436	$6,779	$223,410	6.11%
20%	$2,479,355	$7,748	($71,751)	4.68%
10%	$2,789,275	$8,716	($366,913)	3.49%
0%	$3,099,194	$9,685	($662,074)	2.47%

As can be seen from the above sensitivity matrix, the project has a negative Net Present Value (NPV) at the currently estimated project cost of USD$3,099,194. However, with a subsidy of approximately 25% of the project costs, the NPV turns positive, and the project assumes a more favorable financial profile. It is also at this point where the project IRR also gains equivalence with the discount rate.

It is thus recommended that a two step process be pursued in order to lower the installation costs. The first would be for some value engineering on the existing project BOQ (Bill of Quantities). Then, after this exercise, it is suggested that the proposed construction subsidy be applied towards the value engineered BOQ, to the point of achieving a positive NPV.

6.5 CONCLUSION & RECOMMENDATIONS

A quick overview of the overall societal benefits reveals the following:

	Annual	20 Years
1. Project Direct Revenues *1	$245,482	$ 4,746,440
2. Construction Period Revenues *2	$250,000	$ 250,000
3. Worker Labor/Employment *3	$262,053	$ 262,053
4. Misc Other, post construction	$100,000	$ 2,000,000
5. Avoided Fuel Costs (Savings) *4	$766,000	$ 15,320,000
Total		**$20,578,493**

Project Cost:	$ 3,099,194
Economic Benefits:	$20,578,493
Gross Economic Return:	664%
Annualized Economic Return:	10.70%

Notes:

*1: Carbon credit revenue is only for 10 years

*2: Consists of potential provision of meals, transportation and other directly consumable services during construction.

*3: $15 p/day; 15 workers; 18 months ($121,500), plus, Supervisory costs ($140,553) per BOQ.

*4: (147,825 gallons *UGX11,400 p/gal) * 20

Alternate Scenario:

We can also view the economic benefits that would accrue over a 20 year period in current dollar value, i.e. present value. This is computed by discounting to today's value the future accumulation of the economic benefits. Therefore:

	Annual	PV of 20 Years
1. Project Electricity Revenues	$229,162	$3,059,248
2. Project Carbon Credits Revenues	$16,320	$ 126,019
3. Construction Period Revenues	$250,000	$250,000
4. Worker Labor/Employment	$262,053	$262,053
5. Misc Other, post construction	$100,000	$1,246,221
6. Avoided Fuel Costs (Savings)	$766,000	$9,546,053
Total		**$13,774,158**

Current Project Cost:	$ 3,099,194
Present Value of Economic Benefits:	$13,774,158
Net Economic Benefits:	**$10,674,964**

Within the above contextual ERR analysis, it is recommended that the project be implemented and developed.

The recommended form of development for this project is for the community in the area to formulate a joint and mutually agreeable approach and form a cooperative entity that will take the role of project developer. It must be noted, however, that this project site is located in a very challenging position that could have a significant impact on the development costs of the project. The technical project team observed evidence of attempts by previous parties to visit and/or consider developing the project, but to date nothing seems to have transpired.

The costs of maintaining the status quo and not developing this project are outweighed by the benefits of development. This is clearly demonstrated by the Net Economic Benefits as shown above. If the project is developed as an off-grid application for the benefit of the local community’s needs, then the more traditional financial analytical approach would have less of a decision making bearing on the best course of action for this project. Further, the sensitivity analysis also gives guidance on quantifying the amount of "soft" investment (or subsidy) that would be beneficial for the project.

As an added alternative, it could also be considered that this project be developed as an off-grid project to serve the immediate community within which it is located. This will likely result in a higher benefit from Carbon Credit sales, thus a greater community economic return.

6.6 CARBON MARKET INITIATIVE

This project would benefit greatly from the utilization of the Carbon Market Initiative (CMI). In Uganda there is an incumbent organization named the "Uganda Carbon Bureau" which the project developer is highly recommended to make contact with. They can be reached at +256 414 200988 Plot 47 Lubowa Estate, Clocktower, Kampala, Uganda. Their web site is: www.ugandacarbon.org

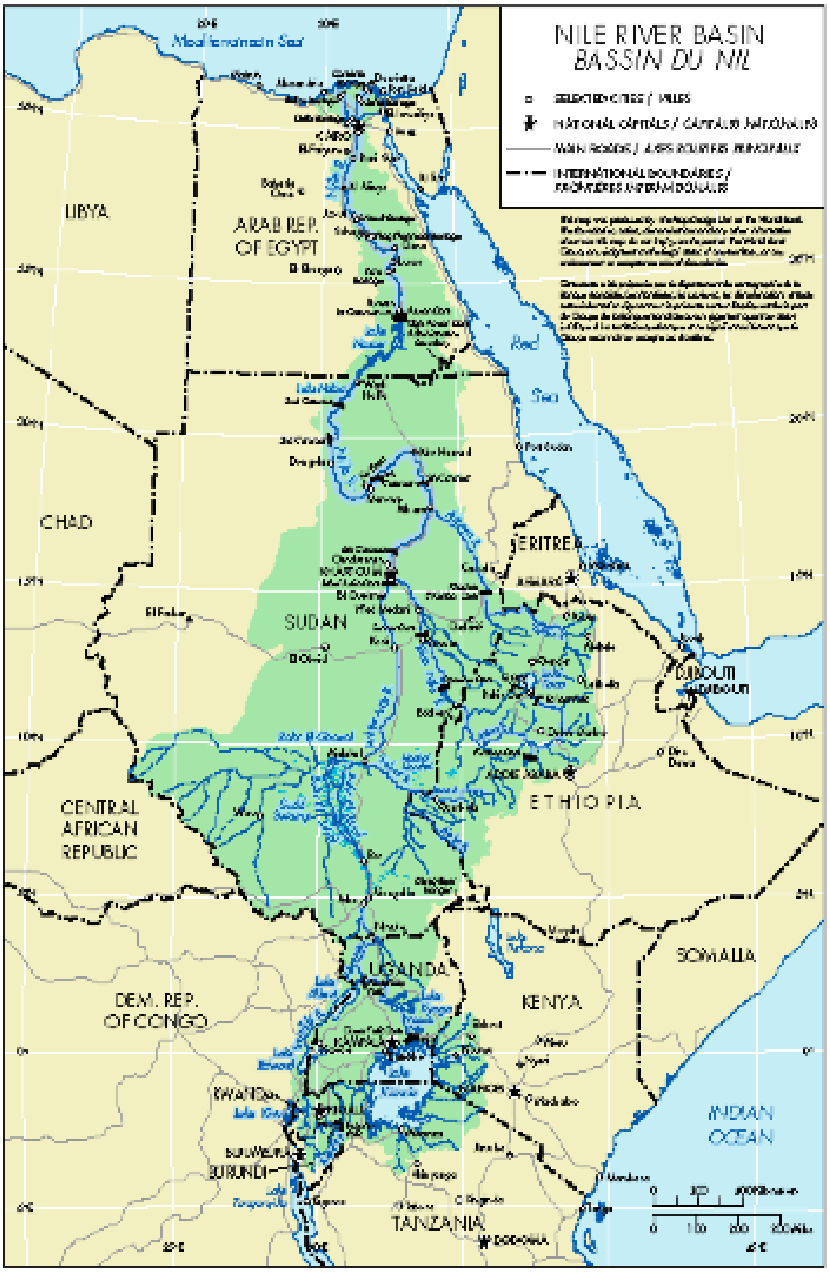
At the currently estimated electricity production rate, the Ndugutu River mini hydro power scheme can receive approximately $16,320 per year for 10 years of carbon credit revenues. This estimate is based on receipt of approximately 1,088 credits, priced at roughy $15 per credit ton offset, per year. This amounts to an estimated amount of USD$163,200 over 10 years, which can be utilized towards project development costs. In present value dollars, this is equivalent to receiving an upfront payment of approximately USD$126,000 (by discounting USD$163,200, by 5%, over 10 years).

In addition, several of the multilateral agency donors with offices in Uganda have recently began staffing their local secretariats with renewable energy experts, whose function is to disseminate and identify projects in which their governments can invest in. This is driven primarily by the desire of these "carbon credit buyers" to off-set their polluting industrial complexes in their home nations.

Ndugutu River mini hydro scheme can therefore take advantage of this situation by leveraging the scheme's renewable energy credentials in exchange for financial benefits under the carbon credit market initiative.

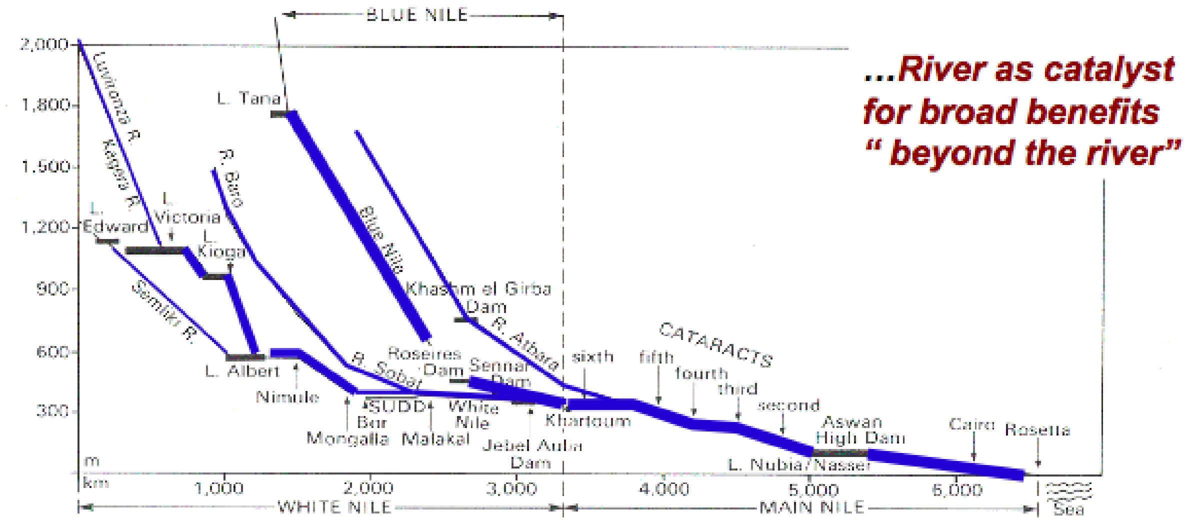
6.7 NILE BASIN INITIATIVE

According to the publicly available information, the Nile Basin Initiative (NBI) is an inter-governmental organization dedicated to equitable and sustainable management and development of the shared water resources of the Nile Basin. NBI Member States include Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. Eritrea is as an observer.



The NBI was established on February 22, 1999 in Dar es Salaam, by Ministers responsible for Water Affairs of each of the nine Member States. The Nile Council of

Ministers (Nile-COM) agreed on a Shared Vision which states: ‘to achieve sustainable socio-economic development through the equitable utilization of and benefit from the common Nile Basin water resources’.



The NBI also has an investment arm named the ‘Subsidiary Action Program’ (SAP) to guide Nile cooperation. The SAP is the investment arm of NBI focusing on preparation of investment projects that are trans-boundary in nature.

Due to the fact the Ndugutu River project is very close to the border with the Democratic Republic of Congo (DRC), the eventual project developer is advised to liaise with the NBI secretariat in Entebbe in order to explore the potential to be included among the selected project by NBI for further investment review. If the Ndugutu project can further offset its cost structure with non-debt, public sector financing, then the project’s impact at the local level will be greatly beneficial.

7.0 APPENDICES

7.1 APPENDIX1 BILL OF QUANTITIES

a) MOBILIZATION

MOBILIZATION					
This includes the mobilization of all forces and equipment during the period of the Contract, except for the mobilization of forces and equipment for Foundation Drilling and Grouting they will be compensated for under grouting works Bid Items. The contractor shall include in this appendix full breakdown and details of this item along with price details , if this appendix left blank , this cost of mobilization is deemed to be included in the contract amount . and no separate payment will be made to the contractor in this respect .					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
A	allow a provisional sum of USD45,000(Forty Five Thousand United States Dollars) for demobilisation of works	PS	1.00	45,000.00	45,000.00
	Total Amount to be carried to Item 1.1 of BOQ No. 1				45,000.00

b) **DEMOBILIZATION**

DEMOBILIZATION					
This includes the demobilization of all forces and equipment during the period of the Contract, except for the demobilization of forces and equipment for Foundation Drilling and Grouting they will be compensated for under grouting works Bid items. The contractor shall include in this appendix full breakdown and details of this item along with price details , if this appendix left blank , this cost of demobilization is deemed to be included in the contract amount . and no separate payment will be made to the contractor in this respect					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
A	allow a provisional sum of USD 40,000(Forty Thousand United States Dollars) for demobilisation of works	PS	1.00	40,000.00	40,000.00
	Total Amount to be carried to Item 1.1 of BOQ No. 1				40,000.00

c) **BILL NO. 1 : PREPARATORY WORKS AND FACILITIES**

BILL NO. 1 : Preparatory Works and Facilities					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 1				
	PRELIMINARIES				
	-				
	-				
A	Mobilization Carried from Appendix 1	LS	1.00	45,000.00	45,000.00
					-
B	Demobilization Carried from Appendix 2	LS	1.00	40,000.00	40,000.00
					-
C	Construction Surveys and setting out	LS	1.00	5,000.00	5,000.00
					-
D	Supply erection and maintenance of a permanent building for the field office (300 m2)and laboratory (400 m2) including all equipment and furniture	LS	1.00	6,250.00	6,250.00
					-
E	Supply, Installation and complete chain link fence for the office and laboratory site	LM	60.00	7.50	450.00
					-
F	Contractor’s Quality Control	LS	1.00	5,000.00	5,000.00
Total for Bill No. 1 Carried to summary					101,700.00

d) **BILL NO. 2 DIVERSION AND ACCESS ROADS**

BILL NO. 2 DIVERSION AND ACCESS ROADS					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.1				
	DIVERSION AND ACCESS ROADS				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	8,125	1.00	8,125.00
				-	-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	8,125	1.20	9,750.00
				-	-
C	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00
D	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,500.00	1,500.00
				-	-
	CART AWAY AND FILLING			-	-
				-	-
E	filling with stablised marrum to make up levels in layers of 250mm thick including compacting	CM	35,916	10.00	359,156.11
F	cut to reduce levels to formation level of the diversion	CM	11,917	6.25	74,483.35
G	Extra over excavation	CM	3,972	50.00	

	for excavating in rock.				198,622.28
	CUTTING TREES			-	-
H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	**NO**	280	83.33	23,333.33
I	Ditto : girth 600 - 900mm girth.	**NO**	95	125.00	11,875.00
	CHANEL FOUNDATION AND MASONRY WALLS			-	-
J	provide and place stone masonary works to foundations of the headrace and intake chanel average thickness 400mm in cement sand mortar mix 1:4	CM	1,545	83.33	128,781.33
K	masonry stone work to headrace and intake chanel bases and walls in cement sand mortar mix 1:4	CM	3,136	83.33	261,333.33
	PLASER TO CHANEL WALLS AND BOTTOMS			-	-
L	12mm thick cement sand plaser to masonry surfaces of headrace and intake chanel walls and bottoms mix 1:4	SM	22,440	6.25	140,250.00
Total for Element No. 1 Carried to collection					1,218,709.74
					2/1/1
	FENCING			-	-
M	barbed wire fencing 2000mm high comprising 65mm x 65mm x 6mm angle line poles, straining poles and corner poles all cast in concrete bases, barbed wire guage 10 in three lines at 600mm c/c including foundation	LM	2,800	7.50	21,000.00

	excavation and back filling. Fenced on either sides of the channel				
				-	-
N	Extra for corner posts with 2no. 65 x65mm x6mm straining posts 3240mm long on including 65x65x6mm angle struts including concrete grade 25 on bases	No	88	20.83	1,833.33
				-	-
O	Extra for intermidiate posts with 2no. 65 x65mm x6mm straining posts 3240mm long on including 65x65x6mm angle struts including concrete grade 25 on bases	No	1,200	18.75	22,500.00
	TRASH SCREEN				-
P	supply and install steel trash screen for the intake shaft complete including all embedded parts and all requirements as per engineer's drawings	SM	1	400.00	400.00
					-
Total for Element No. 1 Carried to collection					45,733.33
	Element 1. collection				
	Page No. 2/1/1				1,218,709.74
	Page No. 2/1/2				45,733.33

	Allow a provisional sum od USD150,000 (One Hundred FiveThousand United States Dollar) for installation of other un measured facilities along the channel	SUM	1	150000	150,000.00
Total for Element No. 1 Carried to Bill ! Summary					1,414,443.07
					2/1/2
BILL NO. 3. The Weir and the Aburtments					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.2				
	WEIR AND ABUTMENTS				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	444	1.00	444.00
					-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	444	1.20	532.80
C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	46	6.25	288.41
D	Extra over excavation for excavating in rock.	CM	21	50.00	1,057.51
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00

F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,500.00	1,500.00
					-
	CART AWAY AND FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	67	6.25	420.60
					-
	CUTTING TREES				-
H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	NO	19	83.33	1,583.33
I	Ditto : girth 600 - 900mm girth.	NO	12	125.00	1,500.00
	WEIR FOUNDATION				-
J	provide and place stone masonary works to foundations of the weir and Wing walls average thickness 400mm in cement sand mortar mix 1:4	CM	12	85.00	1,054.00
	MASONARY WING WALL FOUNDATION				-
K	provide and place stone masonary works to foundations of the Wing Walls average thickness 400mm in cement sand mortar mix 1:4	CM	39	85.00	3,315.00
	WING WALLS				-
L	Supply all materials placing and finishing of C25 reinforced concrete for wing wall	CM	120	187.50	22,481.25
M	masonry stone work to Trapezoidal Wing walls in cement sand mortar mix 1:4	CM	407	85.00	34,595.00

Total for Element No. 2 Carried to collection					70,271.91
					2/2/3
	STEEL REINFORCEMENT				
	high tensile steel reinforrcement in wing wall footings and walls to structural engineer's detail in:				
N	R10 mm Dia	KG	176	1.67	293.33
O	Y10 mm Dia	KG	2,602	1.67	4,336.67
P	Y12 mm Dia	KG	4,318	1.67	7,196.67
	MASONRY WEIR				-
Q	masonry stone work to weir in cement sand mortar mix 1:4	CM	54	83.33	4,533.33
	PLASER TO WEIR & ABUTMENT				-
R	12mm thick cement sand plaser to masonry surfaces of weir and abutments mix 1:4	SM	594	6.25	3,711.72
	WATER PROOFING				
S	provide and place 50mm thick water proofing material as approved by the Engineer between gabions and the fill material	SM	486	1.25	608.00
	FENCING				-
T	2400mm high steel grill built around the weir structure including the abutments comprising of pointed tops in steel hollow sections of 50x 50mm welded and built into boundary wall pre painted before brought to site	LM	120	104.17	12,500.00

U	Extra for corner posts with 2no. 65 x65mm x6mm straining posts 3240mm long on including 65x65x6mm angle struts including concrete grade 25 on bases	No	12	20.83	250.00
V	Mild steel gate size2000mm wide X 2400mm high overall comprising steel hollow section frame and 16mm steel rails spaced at 150mm centre to centre including covering bottom half with ironmongery and painting all exposed steel surfaces.	No	1	833.33	833.33
	GATES				-
W	allow a provisional sum of US$ 5,000 (Five Thousand US Dollars) for supply and install intake gate facility including all necessary accessories as specified	SUM	1	5,000.00	5,000.00
X	allow a provisional sum of US$ 5,000 (Five Thousand US Dollars) for supply and install Flushing gate facility including all necessary accessories as specified	SUM	1	5,000.00	5,000.00
	ENVIRONMENTAL REALEASE PIPE				-
T	supply and install environmental release pipe including all necissarry fittings and valves as specified	LM	6	35.00	210.00
Total for Element No. 2 Carried to summary					44,473.05
	Element 2. collection				
	Page No. 2/2/3				70,271.91
	Page No. 2/2/4				44,473.05

	Total for Element No. 2 Carried to Bill 1 Summary				114,744.96
					2/2/4
	BILL NO. DISILTING TANK				
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.3				
	DISILTING TANK				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	414	1.00	414.00
B	Excavate average 200mm deep to remove top soil: remove from site	SM	414	1.20	496.80
C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	207	6.25	1,293.75
D	Extra over excavation for excavating in rock.	CM	104	50.00	5,175.00
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00
F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,500.00	1,500.00
	CART AWAY AND FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	311	6.25	1,940.63
	CUTTING TREES				-

H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	NO	12	83.33	1,000.00
I	Ditto : girth 600 - 900mm girth.	NO	7	125.00	875.00
	TANK FOUNDATION AND MASONRY WALLS				-
J	provide and place stone masonary works to foundations of the disilting tank average thickness 400mm in cement sand mortar mix 1:4	CM	39	85.00	3,298.00
K	Ditto to walls	CM	332	85.00	28,217.96
	PLASER TO DISILTING TANK				-
M	12mm thick cement sand plaser to masonry surfaces mix 1:4	SM	87	6.25	544.00
Total for Element No. 3 Carried to collection					46,255.14
					2/3/5
	FLUSHING PIPE				-
N	supply and install 200mm Dia. PVC flushing pipe including all necissarry fittings and valves	LM	4	210.00	840.00
	FENCING				-
O	2400mm high steel grill built around the weir structure including the abutments comprising of pointed tops in steel hollow sections of 50x 50mm welded and built into boundary wall pre painted before brought to site	LM	85	104.17	8,854.17

					-
P	Extra for corner posts with 2no. 65 x65mm x6mm straining posts 3240mm long on including 65x65x6mm angle struts including concrete grade 25 on bases	No	4	20.83	83.33
					-
Q	Mild steel gate size2000mm wide X 2400mm high overall comprising steel hollow section frame and 16mm steel rails spaced at 150mm centre to centre including covering bottom half with ironmongery and painting all exposed steel surfaces.	No	1	833.33	833.33
	TRASH SCREEN				-
R	supply and install steel trash screen for the intake shaft complete including all embedded parts and all requirements as per engineer's drawingings	SM	2	400.00	800.00
Total for Element No. 3 Carried to summary					11,410.83
	Element 3. collection				
	Page No. 2/3/5				46,255.14
	Page No. 2/3/6				11,410.83

	Total for Element No. 3 Carried to Bill 1 Summary				57,665.97
					2/3/6
	BILL NO. FOREBAY				
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.4				
	FOREBAY				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	369	1.00	369.00
					-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	369	1.20	442.80
					-
C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	185	6.25	1,153.13
					-
D	Extra over excavation for excavating in rock.	CM	92	50.00	4,612.50
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00
F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,500.00	1,500.00
					-
	CART AWAY AND				

	FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	277	6.25	1,729.69
					-
	CUTTING TREES				-
H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	NO	12	83.33	1,000.00
I	Ditto : girth 600 - 900mm girth.	NO	8	125.00	1,000.00
	FOREBAY FOUNDATION AND MASONRY WALLS				-
J	provide and place stone masonary works to foundations of the Forebay average thickness 400mm in cement sand mortar mix 1:4	CM	18	85.00	1,530.00
K	Ditto to walls	CM	18	85.00	1,501.44
	PLASER TO FOREBAY WALLS AND BASE				-
L	12mm thick cement sand plaser to masonry surfaces mix 1:4	SM	30	6.25	186.88
Total for Element No. 4 Carried to collection					16,525.43
					2/4/7
	FENCING				-
M	2400mm high steel grill built around the weir structure including the abutments comprising of pointed tops in steel hollow sections of 50x 50mm welded and built into boundary wall pre painted before brought to	LM	55	104.17	5,729.17

	site				
					-
N	Extra for corner posts with 2no. 65 x65mm x6mm straining posts 3240mm long on including 65x65x6mm angle struts including concrete grade 25 on bases	No	4	20.83	83.33
					-
O	Mild steel gate size2000mm wide X 2400mm high overall comprising steel hollow section frame and 16mm steel rails spaced at 150mm centre to centre including covering bottom half with ironmongery and painting all exposed steel surfaces.	No	1	833.33	833.33
	TRASH SCREEN				-
P	supply and install steel trash screen for the intake shaft complete including all embedded parts and all requirements as per engineer's drawingings	SM	3	400.00	1,280.00
	FLUSHING PIPE				-
Q	supply and install 250mm Dia. PVC flushing pipe including all necissarry fittings and valves	LM	5	35.00	175.00
Total for Element No. 4 Carried to summary					8,100.83
	Element 4. collection				

	Page No. 2/4/8				16,525.43
	Page No. 2/4/9				8,100.83
Total for Element No. 4 Carried to Bill 1 Summary					24,626.26
					2/4/8
BILL NO. 3. The Penstock					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.5				
	PENSTOCK				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	317	1.00	316.80
B	Excavate average 200mm deep to remove top soil: remove from site	SM	317	1.20	380.16
					-
C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	130	6.25	810.00
					-
D	Extra over excavation for excavating in rock.	CM	54	50.00	2,700.00
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00
F	Allow for keeping the whole of the excavation	ITEM	1	1,500.00	1,500.00

	free from general water.				
	CART AWAY AND FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	184	6.25	1,147.50
					-
	CUTTING TREES				-
H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	NO	28	83.33	2,333.33
I	Ditto : girth 600 - 900mm girth.	NO	15	125.00	1,875.00
	PENSTOCK FOUNDATION AND PIPE WORK				-
K	DN550 6mm thick spiral welded steel pipe epoxy lined complete in 6m lengths	No	44	930	40,920.00
L	Jointing	No	42	520	21,840.00
M	Flexible joint	No	4	1,600	6,400.00
N	Anchor blocks	No	4	1,800	7,200.00
O	Support Blocks	No	40	550	22,000.00
Total for Element No. 5 Carried to collection					110,922.79
					2/5/9
P	Penstock valve at input to penstock	No	1	4,500	4,500.00
Q	DN600 PN16 all flanged Butterfly valve	No	1	2,200	2,200.00
R	DN550 to DN600 all flanged steel tapper	No	2	1,200	2,400.00
S	DN550 to DN400 all flanged steel tapper	No	1	1,200	1,200.00
T	DN550 all flanged steel pipe piece not exceeding 2000mm	No	1	1,500	1,500.00

U	DN550 all flanged steel pipe piece not exceeding 1000mm	No	1	1,200	1,200.00
V	DN200 PN16 all flanged Gate valve	No	1	220	220.00
W	DN200 all flanged steel pipe piece not exceeding 1000mm	No	1	600	600.00
X	DN200 all flanged 90degree steel bend	No	1	300	300.00
Y	DN200 all flanged steel pipe piece not exceeding 3500mm	No	1	900	900.00
Z	DN200 all flanged steel pipe piece not exceeding 2000mm	No	1	700	700.00
	PAINTINTING TO PENSTOCK PIPE				-
AA	prepare and apply three coats of specified gloss pait to penstock pipe and stands as per engineers recommendations	SM	83	3.75	310.46
	FENCING			-	-
AB	barbed wire fencing 2000mm high comprising 65mm x 65mm x 6mm angle line poles, straining poles and corner poles all cast in concrete bases, barbed wire guage 10 in three lines at 600mm c/c including foundation excavation and back filling. Fenced on either sides of the channel	LM	528	7.50	3,960.00
					-
					-
					-
					-
					-

					-
					-
					-
Total for Element No. 5 Carried to summary					19,990.46
	Element 5. collection				
	Page No. 2/5/10				110,922.79
	Page No. 2/5/11				19,990.46
Total for Element No. 5 Carried to Bill 1 Summary					130,913.26
					2/5/10
BILL NO. 3. The Spillway Canal from forebay and Disilting Tank					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.6				
	SPILLWAY				
	Earth works and site clearance				
A	Clear site of all trees, bushes, shrubs and under growth including grubbing up roots and removing away from site	SM	665	1.00	665.00
					-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	665	1.20	798.00
					-

C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	266	6.25	1,662.50
					-
D	Extra over excavation for excavating in rock.	CM	166	50.00	8,312.50
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,500.00	1,500.00
F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,500.00	1,500.00
					-
	CART AWAY AND FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	432	6.25	2,701.56
					-
	CUTTING TREES				-
H	Cut down trees and grub up roots and chop-up and remove all arising from site : large trees girth not exceeding 600mm girth	NO	25	83.33	2,083.33
I	Ditto : girth 600 - 900mm girth.	NO	12	125.00	1,500.00
	FOUNDATION				-
J	provide and place stone masonary works to foundations average thickness 400mm in cement sand mortar mix 1:4	CM	160	120.00	19,152.00
	FOUNDATION AND MASONRY WALLS				-

K	provide and place stone masonary works to foundations average thickness 400mm in cement sand mortar mix 1:4	CM	160	120.00	19,152.00
L	masonry stone work to walls in cement sand mortar mix 1:4	CM	13	120.00	1,584.00
Total for Element No. 6 Carried to collection					60,610.90
					2/6/11
					-
	PLASER TO SPILLWAY BASE AND WALLS				-
M	12mm thick cement sand plaster to masonry surfaces mix 1:4	SM	57	6.25	356.25
					-
Total for Element No. 6 Carried to collection					356.25
	Element 6. collection				
	Page No. 2/6/11				60,610.90
	Page No. 2/6/12				356.25
Total for Element No. 6 Carried to Bill 1Summary					60,967.15
					2/6/12
BILL NO. 4. Power House					
ITEM	**DESCRIPTION**	**UNIT**	**QTY**	**RATE (USD)**	**AMOUNT (USD)**
	BILL NO. 2				
	CIVIL WORKS				
	ELEMENT NO.7				
	POWER HOUSE				

A	allow a provisional sum of USD 150,000 (One Hundred Fifty Thousand United States Dollars) for construction of the Power House as designed by the Engineer in concrete, overall size 12x8m 4m high complete with IT4 Steel roof and all accessories.	No	1	150,000.00	150,000.00
Total forElement No. 7 Carried to Bill 1Summary					150,000.00

e) SUMMARY OF CIVIL WORKS BILL OF QUANTITIES

ELEMENT	*DESCRIPTION*	*PAGE NO.*	*AMOUNT (USD)*
	BILL NO. 2		
	CIVIL WORKS		
1	DIVERSION AND ACCESS ROADS	2/1/2	1,414,443.07
2	WEIR AND ABUTMENTS	2/2/4	114,744.96
3	DISILTING TANK	2/3/6	57,665.97
4	FOREBAY	2/4/8	24,626.26
5	PENSTOCK	2/5/10	130,913.26
6	SPILLWAY	2/6/12	60,967.15
7	POWER HOUSE	2/7/13	150,000.00
	TOTAL BILL NO.3 CARRIED TO MAIN SUMMARY		**1,953,360.66**

f) SUMMARY OF BILLS OF QUANTITIES FOR ELECTRO-MECHANICAL WORKS

BILL NO. 3. ELECTROMECHANICAL					
ITEM	***DESCRIPTION***	***UNIT***	***QTY***	***RATE (USD)***	***AMOUNT (USD)***
	BILL NO. 3				
	ELECTROMECHANICAL				
	Turbine				
A	Mini-hydro turbine of the Francis Horizontal type, rated at 320KW, Speed 1500 RPM, Head 82.5m, flow rate 0.55m3/s with efficiency of >80% for flows between 50% and 110% complete with all accessories.	No.	1	115,000.00	115,000.00
B	Turbine Governor including dummy load.	No.	1	11,350.00	11,350.00
C	Flywheel	No.	1	2,850.00	2,850.00
D	**Generator**				-
	Horizontal shaft, three phase AC Synchronous Generator, 4 pole, speed 1500 RPM, Frequency 50Hz, capacity 320KVA, rated voltage 415V, rated current 557A, Efficiency 90% (minimum), power factor 0.8, Air cooled, with self exciter and brushless.	No.	1	75,000.00	75,000.00
E	Lightning Protection	No.	1	3,000.00	3,000.00
F	Earthing	No.	1	800.00	800.00
G	**Control Panel**				-
	Generator control panel including a synchronising unit for the grid.	No.	1	45,000.00	45,000.00
H	Governor control panel	No.	1	7,500.00	7,500.00
I	**Substation Equipment**				-
	Outdoor substation equipment.	No.	1	45,000.00	45,000.00
J	Battery charging and DC equipment.	No.	1	9,000.00	9,000.00
K	Step up Transformer 315KVA, 415KV/33KV, 50Hz, Dyn11	No.	1	25,000.00	25,000.00
L	50KVA standby generator	No.	1	15,500.00	

					15,500.00
	Overhead electric crane with X, Y, and Z movement to carry 500kg complete with controls and all accessories.	No.	1	8,500.00	8,500.00
M	Wiring and electrical accessories for Power house	No.	1	7,500.00	7,500.00
N	Spares and Tools	Item	1	25,000.00	25,000.00
Total for Bill No.3 Carried to collection					396,000.00
					3/1/2
O	**Transmission Line**				-
	33KV Overhead transmission line with 3nox50mm2 AAAC flat formation conductors complete with GS cross-arms, pin type insulators and all accessories.	km	20	18,000.00	360,000.00
Total for Bill No.3 Carried to collection					360,000.00
	Element 6. collection				
	Page No. 3/1/1				396,000.00
	Page No. 3/S				360,000.00
Total BILL NO.3 Carried to MAIN Summary					756,000.00

g) MAIN SUMMARY OF BILL OF QUANTITIES

BILL NO.	DESCRIPTION	AMOUNT (USD.)
	CIVIL WORKS	
1	PRELIMINARIES	101,700.00
2	CIVIL WORKS	1,953,360.66
3	ELECTROMECHANICAL	756,000.00
		2,811,060.66
	ADD	
	5% supervisory costs	**140,553.03**
	SUB-TOTAL (USD.)	**2,951,613.70**
	ADD: 5% CONTINGENCIES	147,580.68
	SUB-TOTAL (USD.)	**3,099,194.38**
	ADD: 18% VAT	557,854.99
	TOTAL AMOUNT (USD.)	**3,657,049.37**

APPENDIX 2: SITE GPS CO-ORDINATES

Grid	UTM	
Datum	ARC 1960	
Name	Name on the map	Coordinate
Channel Point	44	35 N 833551 67114
Channel Point	45	35 N 833552 67080
Channel Point	46	35 N 833553 67050
Channel Point	47	35 N 833561 67013
Channel Point	49	35 N 833561 66986
Channel Point	51	35 N 833561 66986
Channel Point	52	35 N 833536 66958
Channel Point	53	35 N 833508 66928
Channel Point	54	35 N 833484 66903
Channel Point	55	35 N 833459 66866
Channel Point	56	35 N 833446 66834
Channel Point	57	35 N 833451 66799
Channel Point	58	35 N 833458 66772
Channel Point	59	35 N 833469 66732
Channel Point	60	35 N 833453 66706
Channel Point	61	35 N 833417 66685
Channel Point	62	35 N 833389 66674
Channel Point	63	35 N 833357 66664
Channel Point	64	35 N 833324 66641
Channel Point	65	35 N 833304 66613
Channel Point	66	35 N 833300 66584
Channel Point	68	35 N 833300 66549
Channel Point	69	35 N 833303 66520
Channel Point	70	35 N 833307 66483
Channel Point	71	35 N 833300 66446
Channel Point	72	35 N 833279 66423
Channel Point	73	35 N 833253 66408
Channel Point	74	35 N 833248 66370
Channel Point	75	35 N 833277 66348
Channel Point	76	35 N 833300 66326
Channel Point	77	35 N 833310 66304
Channel Point	78	35 N 833298 66274
Channel Point	79	35 N 833324 66257
Channel Point	80	35 N 833333 66221
Forebay	Forebay	35 N 833511 67210
Intake	Intake	35 N 833342 66178
Powerhouse	Powehouse	35 N 833261 67271

APPENDIX 3: GEOLOGY

a) Compaction & Permeability test results

Label	Depth	Compaction BS Light		Permeabilty on remolded specimen at 95% MDD: OMC			
	(m)	MDD (mg/m3)	OMC (%)	Bulk Density (mg/m3)	MC (%) at casting	Coefficient, k cm/sec	MC (%) after test
TP 1	0.8	1.86	11	1.773	11	$2.66x10^{-6}$	22

b) : Classification Test results

Label	Depth	PERCENTAGE PASSING													Atterberg limits		
	(m)	Sieve 37.5 mm	Sieve 28.0mm	Sieve 20.0 mm	Sieve 10.0 mm	Sieve 6.3 mm	Sieve 5.0 mm	Sieve 2.0 mm	Sieve 0.600 mm	Sieve 0.425 mm	Sieve 0.300 mm	Sieve 0.212 mm	Sieve 0.150 mm	Sieve 0.075 mm	LL %	PL %	PI %
TP 1	0.8			100	98	96	95	90	74	68	61	52	44	43	34	18	16

c) : Field photos