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API Renewable Energy LLC

Combining the Energy of Human Hope with New Greener Economy

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

API

2011

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EXECUTIVE SUMMARY

The feasibility analysis of Mitano 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 Mitano River, which eventually pours its waters into Lake Edward, in Rukungiri district in western Uganda. The proposed project site is on River Mitano which lies in Rukungiri District.

Initial site investigations were carried out during the months of January 2011 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, forebay 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 Mitano.

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 MITANO MINI HYDRO PROJECT SITE

Figure 1: Map of Uganda showing the position of Rukungiri district (River Mitano Hydro Project Site)

Table 1: SALIENT FEATURES: MITANO RIVER, RUKUNGIRI DISTRICT

Location	
East	: 814000 to 815000 Eastings
South	: 9914000 to 9917000 Northings
River	: Mitano
Type of project	: Mini Hydro
Hydrology	
Catchment area	: 1200 square kilometers
Design flow	: 12m³/sec
Head	
Net head	: 35.0m
Weir	
Type	: Clear overflow
Length	: 20 m
Height	:1.8 m
Concrete canal	
Type	: Trapezoidal
Length	: 2.7 Km
Top Width	: 4.65 m
Bottom Width	: 2.40 m
Height	: 1.93 m
Forebay	
Length	: 19.5 m
Width	; 6.0 m
Height	: 7.0 m
Penstock	
Type	: Steel Pipes
Length	: 100 m
Thickness	: 8.0 mm
Diameter	: 2000 mm
Power and energy	
Installed capacity	: 2.8 MW
Turbine	
Type	: Francis

Number of unit	: 4
Rated capacity	: 1,500 trs/min
Generator	
Type	: Synchronous
Number of unit	: 4
Rated capacity	: 1,500 trs/min
Power transformer	
Type	: Outdoor, oil cooled
Number of unit	: 1
Rated capacity	: 0.40KV/33KV
Financial parameters	
Project cost, USD$	: 8,150,800 (excluding VAT)
Annual energy produced, KWh	: 92,053,000
Development Cost p/KWh	: $2,811
Financial Project NPV	: $8,675,753
Financial Project IRR	: 13.97%
Economic Return Rate (Annualized)	: 14.28%
Project Payback	: 7
Recommendation	: Proceed; Commercial format; Grid-tied

SALIENT FEATURES: INFRASTRUCTURE

Power house

Type : Stone masonry
Floor size : 30x10m

Access road

Rehabilitation of existing road : N/A
New access : 2.25 Km

Substation
Type : Compact
No of cellule : 7

Transmission line 30 KV **:** 18

1.0. HYDROLOGICAL REPORT ON MITANO 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 hydrologic parameters necessary for the design of hydropower plant at River Mitano, which eventually pours its waters into Lake Edward, in Rukungiri district in western Uganda.

This 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 Mitano, which borders Rukungiri and Kanungu districts in South West Uganda and eventually pours its waters into Lake Edward. The project is proposed to cover about 4Km downstream from the Nengo Bridge.The river, just like its name suggests in the local dialect, serves as a boundary to a number of villages, parishes, sub counties, counties as well as districts. In light of that background, the proposed site is located at the boundary of Rukungiri and Kanungu districts. Both districts are in the South Western part of Uganda. The map in figure 3.1 below shows the geographical location of the project area.

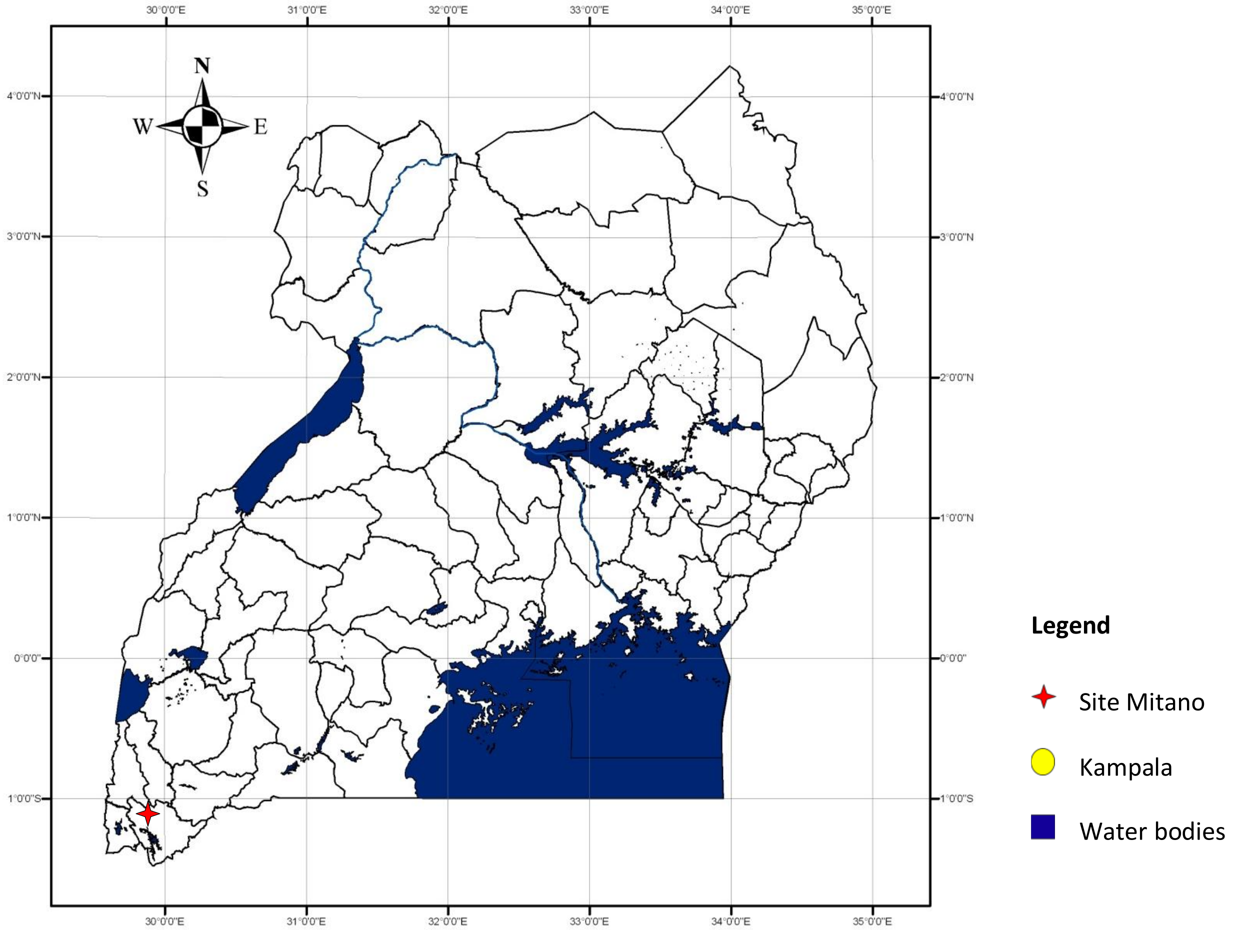


Figure 2: Map showing Mitano Site

1.2.2. River description

River Mitano 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, although it has a brown color, which comes as a result of having quite a number of large swamps within its catchment area. 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, the river width varies between 10 and 12 meters while the depth is normally around 0.7 and 1.2 meters.
While on site, a flood plain of 4 meters width on either side of the banks, with flood marks at an average height of 0.8 meters were observed.

1.2.3. Description of catchment

The catchment of River Mitano generally has deep fertile soils with a large amount of green vegetation. In addition to this, the catchment is characterized with a number of swamps, which also contribute to the flow of the river.
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.
The catchment can also be described as one with a rather steep gradient, where in some areas, it curves its way through gorges. The pictures below give an impression of the catchment.
River Mitano has a very large catchment area, with a number of smaller rivers joining it on its way to Lake Edward. The catchment area according to the Directorate of Water Resources Management (DWRM) was estimated at 1200 square kilometers (up to the proposed site)

Figure 3: Picture showing the catchment area of River Mitano

Figure 4: Picture showing River Mitano (from Nengo Bridge)

1.3. AVAILABLE DATA

1.3.1. 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 Kanungu district and at station 90290020, the available data is from 1945 to 1978, although data for the years: 1958, 1959, and 1962 to 1973 is missing. Station 90290030 has records from 1949 to 1956, with data for the year 1958 missing. Data obtained from station 90290040 shows rainfall records from 1950 to 1984, although there are gaps in the data for the years: 1953, 1956, 1957, 1959, 1960, 1967 and 1968.

With regard to temperature, the River Mitano catchment is influenced by a range of temperatures which cut across its catchment (since it has a huge catchment area). From the records available at the meteorological department, only weather stations in Kabale and Mbarara had temperature data that could be used for this catchment. Records at the Kabale station were available from 1961 to 2009, while Mbarara had records from 1963 to 2009.

1.3.2. River gauging data

There is gauged data on River Mitano at the Directorate of Water Resources Management (DWRM). However, the data available is from a gauging station situated very far away from the proposed intake. Therefore, the data from DWRM will be used for verification of the flow duration curve obtained using the meteorological data.

1.3.3. Topographic maps

Topographic maps of the area at scale 1:50000 are available and have been obtained from the lands and surveys department.

1.4. DATA ANALYSIS

1.4.1. 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

Table 2: Showing average temperature in Kabale

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVERAGE
Daily mean maximum temperature [C]	26.8737	27.73074	27.90701	26.41983	26.19533	26.73767	27.27378	27.43084	27.20528	26.22357	25.60387	295.6016	26.87287472
Daily mean minimum temperature [C]	13.94638	14.24498	14.59044	14.41933	14.4511	13.56631	13.4265	14.25628	14.38373	14.47542	14.46597	156.2264	13.01886897
Average [C]	20.41004	20.98786	21.24872	20.41958	20.32322	20.15199	20.35014	20.84356	20.7945	20.34949	20.03492	225.914	19.94587185

Table 3: Showing average temperature in catchment area

Having obtained the above analysis, an average of 18.7 degrees was obtained and used for determining the rate of evapotranspiration in the area.

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

STATION	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
90290020	1945	54	11	102	87	137	144	91	100	162	177	86	24	1173
90290020	1946	82	66	106	217	241	45	114	183	148	94	125	109	1531
90290020	1947	144	122	123	190	153	95	121	143	190	105	159	37	1582
90290020	1948	64	96	108	188	195	156	55	111	211	98	113	36	1431
90290020	1949	23	59	69	174	206	38	149	225	208	54	101	93	1399
90290020	1950	24	28	154	52	99	71	147	165	198	250	83	32	1302
90290020	1951	45	30	144	264	97	41	51	94	112	213	280	196	1567
90290020	1952	36	14	46	239	179	5	16	102	147	107	149	71	1110
90290020	1953	141	50	234	255	38	192	21	56	220	123	195	29	1555
90290020	1954	0	59	202	109	197	203	90	250	150	347	123	224	1952
90290020	1955	91	123	107	105	85	45	99	195	231	147	125	101	1452
90290020	1956	47	84	74	172	85	44	33	108	180	247	16	83	1174
90290020	1957	1	52	154	165	199	19	19	78	62	105	165	64	1081
90290030	1949	69	57	86	195	149	69	83	179	265	160	108	87	1506
90290030	1950	49	20	133	172	130	135	80	282	227	215	69	64	1576
90290030	1951	21	47	188	452	241	69	30	131	296	255	274	199	2204
90290030	1952	7	3	69	222	313	13	57	166	180	192	95	6	1321
90290030	1953	86	54	108	370	140	424	268	219	290	360	447	117	2883
90290030	1954	0	100	358	126	297	178	231	79	211	371	128	143	2221
90290030	1955	84	51	195	127	94	58	144	182	516	254	83	312	2099
90290030	1956	71	94	191	409	237	63	93	179	292	426	174	151	2379
90290030	1957	51	63	202	268	240	108	52	128	118	110	136	69	1546
90290040	1961	55	69	95	199	46	4	41	68	202	129	259	92	1258
90290040	1962	133	28	148	81	171	76	11	121	219	224	140	79	1431
90290040	1963	142	117	154	244	106	38	11	114	119	80	188	202	1515
90290040	1964	173	118	147	91	32	39	53	76	174	77	148	166	1293
90290040	1965	31	42	46	69	138	8	0	42	63	154	197	110	898
90290040	1966	107	69	47	61	3	21	38	130	107	113	89	90	875
Mean monthly rainfall		65.39286	61.64286	135.3571	189.3929	151.7143	85.75	78.5	139.5	196.3571	185.25	151.9643	106.6429	1546.928571

Table 4: Showing rainfall analysis results for stations in Kanungu district

From the above analysis, an average annual rainfall figure of 1546.9 mm was obtained.

1.5. 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 Mitano catchment has deep soils and a large amount of vegetation cover, hence, a lower level of evapotranspiration is expected. Below is the analysis leading to the flow duration curve.

Mean Temperature[C]	18.7	Percentage Exceedance	No. of days of the year	Empiric coefficients	Discharge (l/s)	Standard Deviation	+'/'-' (l/s)
Mean Annual Rainfall [mm]	1546.9	5%	18	1.77	26485.188	0.32	4788.3
Catchment Area [Sq. km]	1200	10%	37	1.48	22145.807	0.3	4489.0
L	1094.46	20%	73	1.19	17806.426	0.12	1795.6
Annual Evapo-transpiration [mm]	1153.662	30%	110	1.04	15561.918	0.09	1400.6
Annual Run-off [mm]	393.2377	40%	146	0.96	14364.848	0.08	1149.2
Mean discharge [l/s]	14963.38	50%	183	0.87	13018.143	0.08	1197.1
		60%	219	0.79	11821.073	0.08	1197.1
		70%	256	0.7	10474.368	0.09	1346.7
		80%	292	0.63	9426.9313	0.09	1346.7
		90%	329	0.57	8529.1283	0.09	1346.7
		100%	365	0.26	3890.4796	0.09	1346.7

Table 5: Flow duration curve analysis table

1.6. VERIFICATION OF THE OBTAINED FLOW DURATION CURVE

In order to fully validate the obtained hydrological analysis / flow duration curve, spot measurements (averaged) have been carried out using the salt dilution method. The following are the results that have been obtained so far:

Period Of Mesurments	**Average Flow Mesured (l/s)**	**Mean Monthly rainfall (mm)**
Nov- December 2010	9257.0	129.28
Jan – Feb 2011	7519.0	63.52
March – Apr 2011	11234.0	189

Table 6: Spot measurements using the salt dilution method.

The FDC for river has been analyzed as shown in figure 3.8 below, with the averaged spot measurements at the proposed intake, and find that, the data correlates with the annual precipitation derivations.

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

2.1 INTRODUCTION

The Geotechnical feasibility assessment is targeted at a section of river Mitano 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 Mitano 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 seismic history of the area was assessed to give a good understanding of the risk factor to potential earthquake phenomenon.

The Mitano river is located in South 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. The structural set up indicates a dense network of fault lines which are seismically inactive. The only seismic activity recorded from Earthquakes is approximately 50 km away with magnitudes of 3.0 – 4.0 on the Richter scale whose consequence on structures is very minimal.
The distribution of earthquakes in the region from records of the National seismological center is relatively low and poses no major threat to project structures. The general shear on undisturbed samples posted allowable bearing capacities at the site ranging from 205 kPa to 265 kPa.
The geotechnical investigation of the proposed Mitano Mini-hydro power project is important in the design of civil and mechanical structures. River Mitano is located in western Uganda approximately 14 kilometers from Rukungiri township. The proposed Mini-hydropower project is expected to have a considerable structural footprint on the area. All proposed infrastructure have 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.

2.1.1 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 Mitano 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 Mitano river catchment and vicinity are generally steep slopes areas with the exception of the forebay and power house area. Regionally the area has numerous fault lines which have correlate to the wide valleys and massive gully 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 Nile.

At the In-take area, insitu rocks and floats cover most of the near surface area. A network of trees hold the rock floats and soils in place, a phenomenon which should be maintained or even improved to minimize siltation of the river. The proposed forebay and power house is located along steep slope with an elevation difference between the two of approximately 40 – 50m equivalent to the head. The penstock route is described as rocky with boulders and floats.

Topographical Map showing River Mitano

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	16.30	0	0	39	28
2	0.80	1.0	18.00	0	0	35	25

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

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	25.8	14.7	10.9	265	3	88
2	20.7	10.7	6.8	205	3	68

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

Where: $q_o = \gamma D$

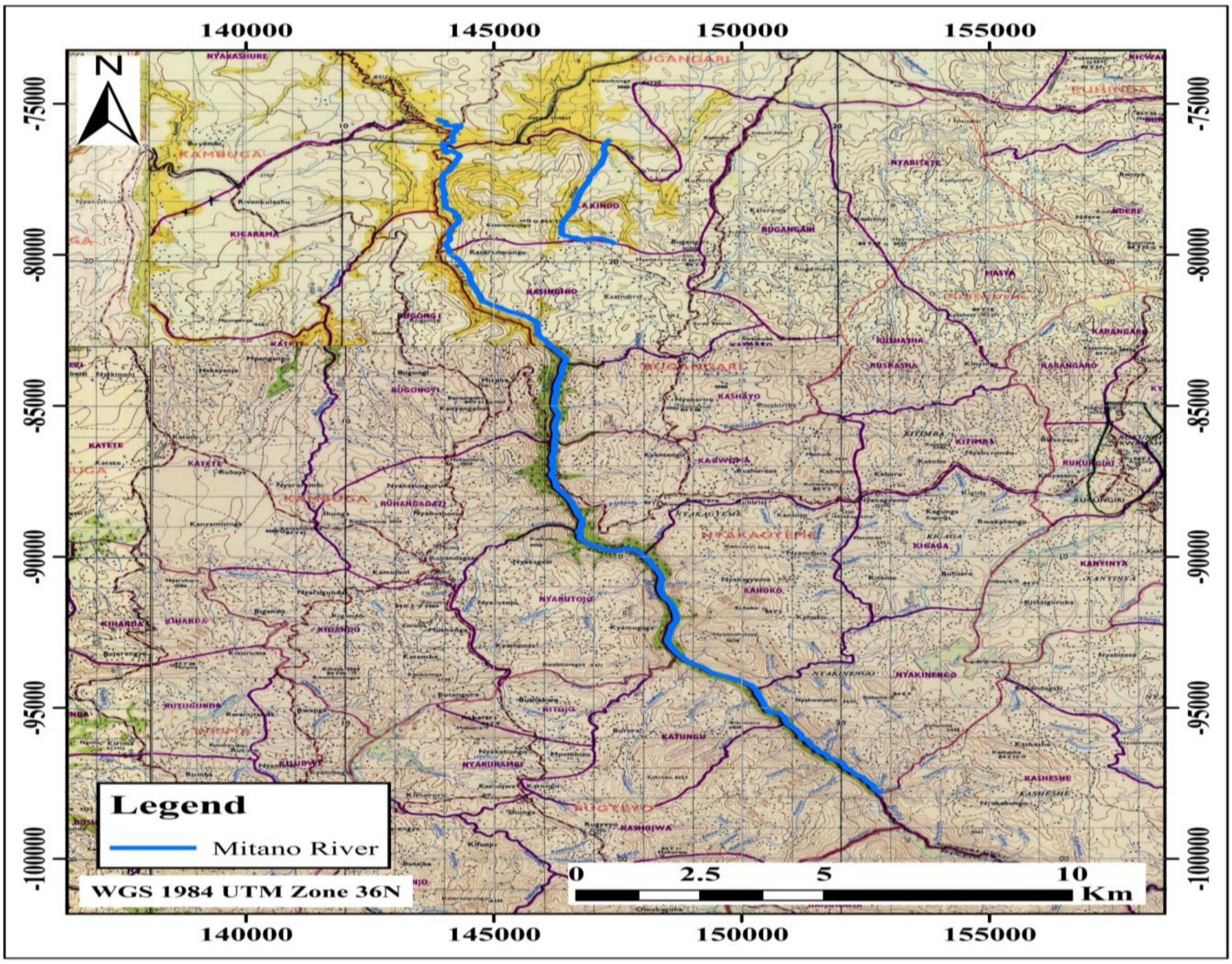
$\varphi' = \tan^{-1}(0.67 \tan \varphi)$

$C' = 0.67C$

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

2.4 LOCAL GEOLOGY AND SOIL PROFILE

The project area comprises of sandstones quartzitic sandstones ana gneisses of the Karagwe-Ankolean 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 Locations

According to preliminary designs on the survey drawing, three locations were sited as possible intake to the channel. The merits and demerits of these locations in view of ground conditions are given here below.

2.4.2 Intake Area 1

- The location is within a river bed and potential flood plain of the river and is filled with sand and silt. This poses a danger to the structures at this location.
- Although the area is relatively flat, there is a huge cost of establishing a firm foundation of the in-take structures.
- Water table is at an average depth of one meter (1.0m)

2.4.3 Intake Area 2

- At this location, the soil profile gives a more favorable surface for laying upon foundation structures. A top 1.0m profile composed of sandy loam soil with an ultimate bearing capacity of 265 and a rock base at 1.8 m.
- Area is relatively flat and construction structures are easy to erect at the location.

2.5 SEISMICITY OF THE AREA

TP 1 (In-take 2) - Water Table; Not encountered in the test pit

TP 1 (In-take 2) Water Table Not encountered in the test pit

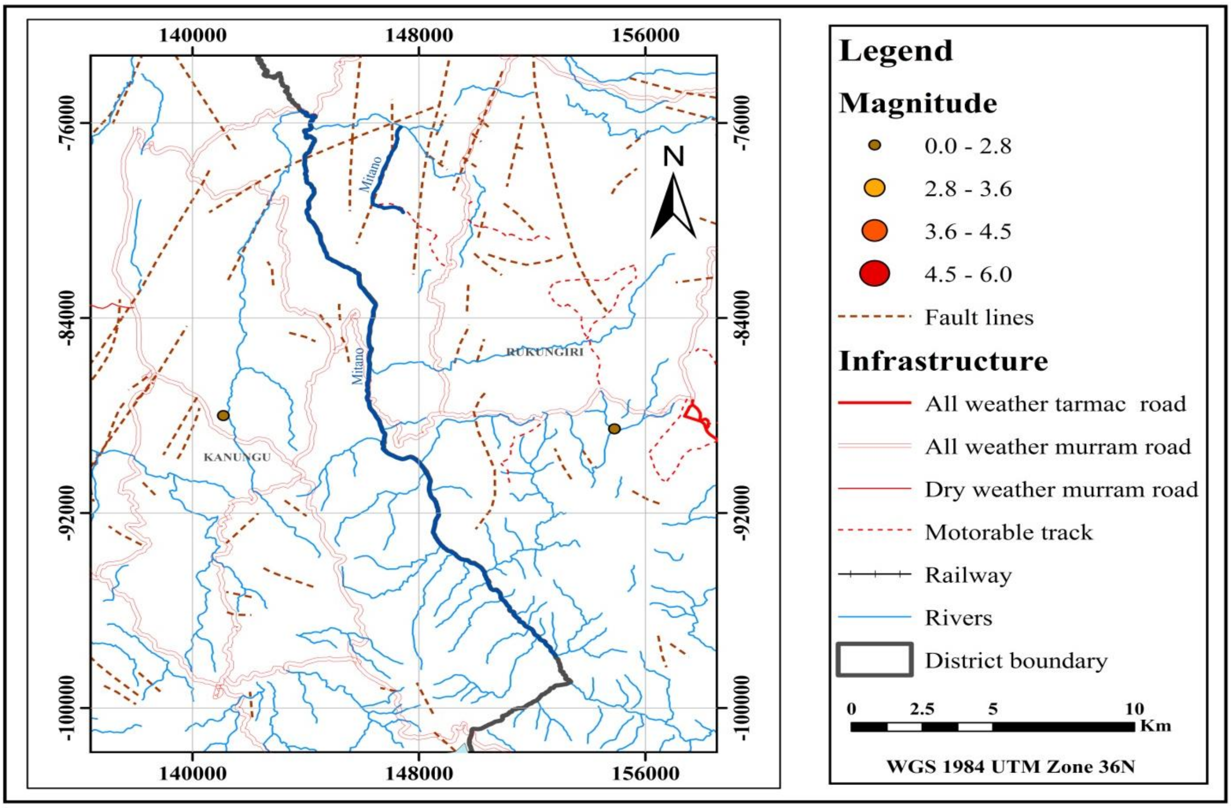
DEPTH (m) 0.00	LOG*	SOIL DESCRIPTION	REMARKS
1.0	= =	Brown sandy Loam soil	Moderately dense
0.8	* ** * * * *	grey - brown clayey sand	Medium dense Consolidated
(Rock surface)	/////		

LOG*: Expression of ground Profile with depth

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 can be seen to have numerous fault lines which seem to be inactive in terms of seismic activity (this is clearly shown by the number of events recorded over a period of more than 40 years). The lack of a dense network of stations to cover the whole country and the big distances between the existing stations has led to numerous un-locatable events as majority are recorded on less than three stations.

Epicentral Map of Part of South Western Uganda



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 and unlikely. The few events so far recorded are of a very low magnitude and pose no danger to structures.

2.6 KEY CONCLUSIONS ON ENGINEERING PROPERTIES OF SOIL

1. The site was investigated by excavating 3 No. test pits to a maximum depth of 1.8 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 2.0 – 4.0 meters along the channel route.
3. The key index properties of the soil samples from the test pits investigated ranged from: LL = 30%,. The Natural Moisture Content ranged from 8% to 15%. (See Appendix 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 at the site ranging from 205 kPa to 265 kPa at 2.0 depths as per Table 2.0;
5. Compaction tests revealed that the MDD ranged from 1.631 to 1.796 Mg/m^3 whereas the OMC ranged from 17 to 25%. The least MDD value was obtained from TP 2 at 1.80m depth and the highest value from TP 3 at 0.6m depth.
6. The permeability (k) of the soils ranged from 2.24×10^{-6} cm/sec to 6.93×10^{-6} cm/sec implying that it is low permeability. Details are presented in Appendix 1.
7. The area has numerous fault lines which are seismically inactive. The two seismic events recorded are of magnitudes less than 2.8 which pose no serious threat to the proposed Mini-hydropower structures.

3.0 CONCEPTUAL AND STRUCTURAL DESIGN, SITE LAYOUT, DESIGN FLOW RATE

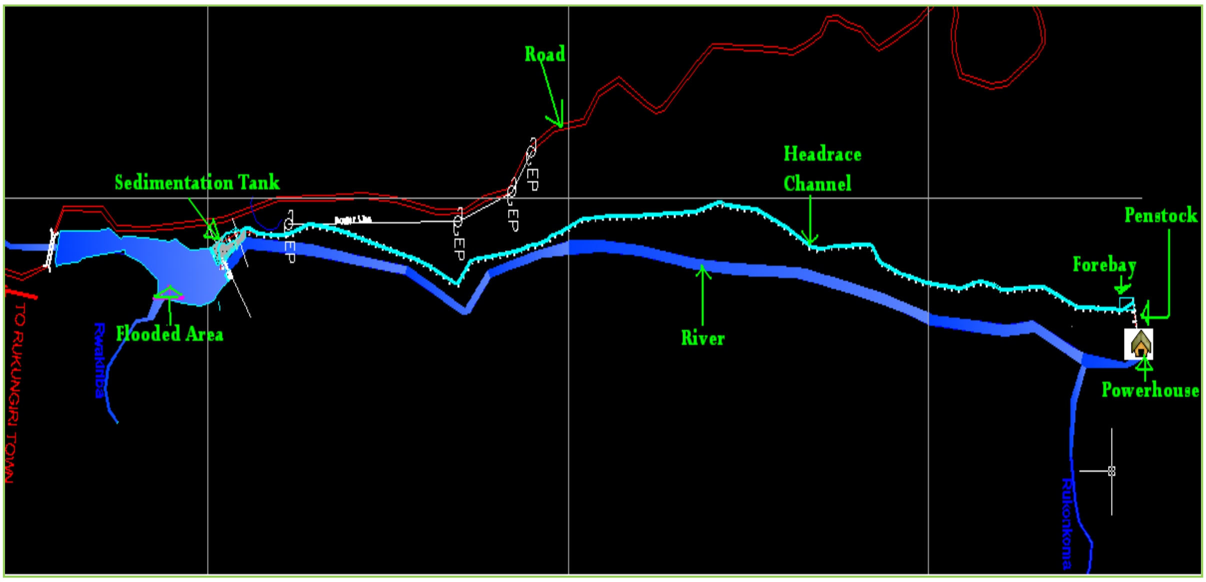


Figure 5: Site layout

ANALYSIS OF THE FDC VALUES

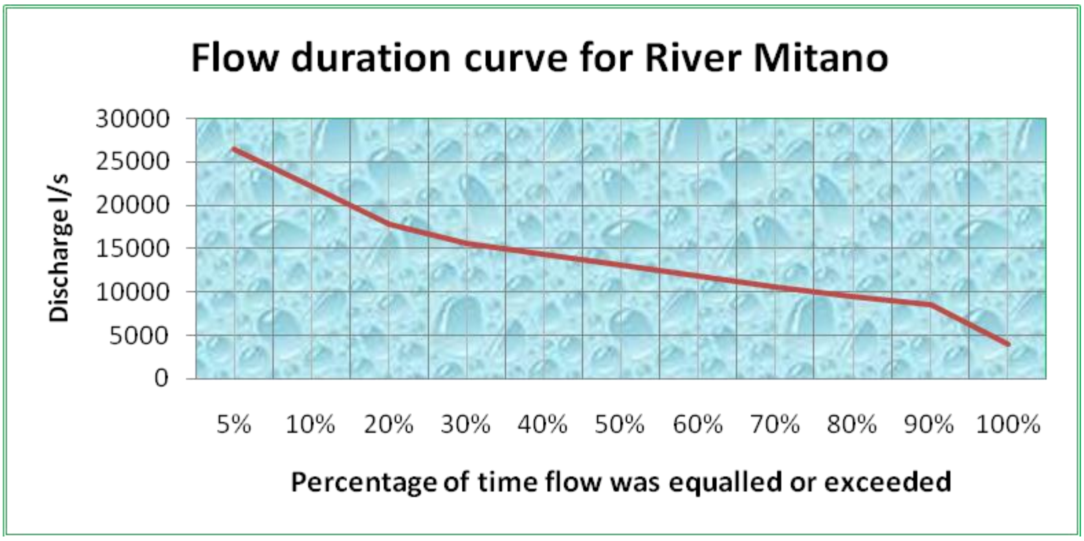


Figure 6: Flow Duration Curve

- Mitano river flows the all year round and it never dries out
- River flow rates ranges from 30,000l/s to about 4000l/s.
- We can also see that for the most part of the year, the variance in the river flow is gradual.

TYPE OF THE SCHEME

Mitano Micro hydropower scheme will be a run-of-river scheme. This means that power generation is only done when the water is available and provided by the river.

Damming is not possible due to the following:

1 The topography of the area consists of wide gorges with loose soils, hence a deterrent to damming.

1. The envisaged dam has got to be high and wide if one is to attain the advantage of increment in head and a guaranteed flow in the dry periods; this would in turn lead to flooding of large farm area upstream.
2. There is a Mini-hydroelectric plant which has been planned downstream which requires damming. An additional damming on this site would grievously affect the environment.

DESIGN FLOW RATE

The considered maximum design flows of 12000l/s corresponds to 60% exceedance on the FDC curve. This means that this flow is guaranteed at least 7 months of the year. The selected turbine-generator set is envisaged to work at up to 50% the designed flow (6000l/s), guaranteeing energy supply for 11.5 months in year.

It is important to note that this design flow is subject to the minimum required environment flow (in between the intake and the tailrace) of 1000l/s as recommended by the Environmentalist. The spilled water over the weir crest and sedimentation tank spillway shall supplement the environment release. In the case of river discharges greater than 8000l/s, the intake screen shall spill the water downstream.

Table 7: Design flow rate

Type of scheme	Run-of-river
Design flow	12000l/s
Minimum Environmental release	1000l/s

3.1 INTAKE

A Tyrolean screen intake and round overflow weir intakes were considered. The pros and cons of both were studied and the round overflow weir intake was chosen.

3.1.1 A TYROLEAN SCREEN INTAKE

The Tyrolean intake also known as a Coanda screen comprises of a collecting channel across the river covered by a screen or a perforated plate. Tyrolean intakes are often used to divert river with steep longitudinal slope, supercritical flow regime and in which the transport capacity is great. The intake screen is designed to work as a self-cleaning screen.

3.1.2 DESIGN OF A TYROLEAN SCREEN

Consider;

- Diverted discharge to the turbine, Q (m^3/s)
- Intake's width across the river, B (m)
- Inclination of the rack, α(º)
- Spacing between the rack bars, e (m)
- Bar's cross section length, L

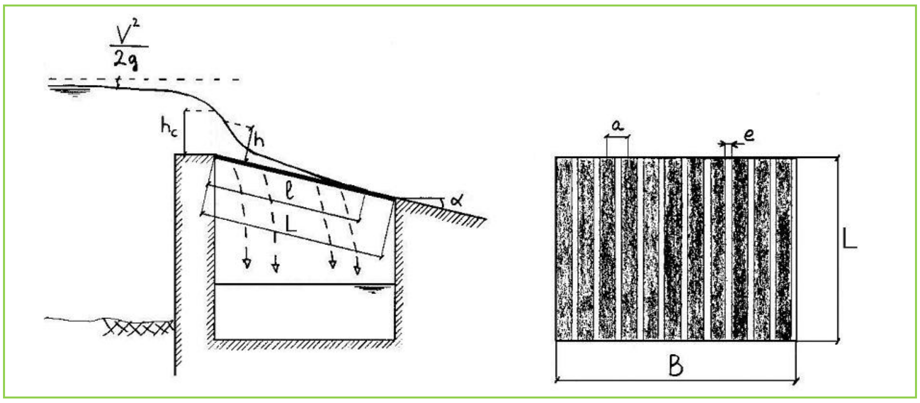


Figure 7: Tyrolean Weir design

Table 8: Tyrolean Weir Design Parameters

Input Parameters	value
Diverted flow Q, m^3/s	12
Width of the River B, m	20
Angle of Inclination α, °	20
Spacing between Bars e, mm	15
Distance between the middle of two bars a, mm	30
Output Parameters	
Construction Ratio Ψ	0.50
Unit discharge q	0.60
Upstream critical depth h_c, m	0.33
Reduction factor *x*	0.837
Water depth upstream of the rack h, m	0.28
Contraction coefficient m	0.673
Discharge coefficient λ	1.45
Minimum Length of trash rack in flow direction *l*, m	2.01
True length L, m	2.62

$$m = 0.8052 \times \Psi^{-0.16} \times \left(\frac{a}{h}\right)^{0.13}$$

$$h_c = \sqrt[3]{\frac{q^2}{g}}$$

$$\lambda = \Psi \cdot m \cdot \sqrt{2 \cdot g \cdot \cos\alpha}$$

$$\Psi = \frac{e}{a}$$

$$2\cos\alpha \cdot x^3 - 3 \cdot x^2 + 1 = 0$$

$$h = x \cdot h_c \quad l = 2.561 \cdot \frac{q}{\lambda \cdot \sqrt{h}}$$

$$q = \frac{Q}{B}$$

$$L = l \cdot c \text{ where } c = 1.3$$

3.1.3 COLLECT
3.1.4 ING CHANNEL

Under the trash rack is a channel which leads the water to a settling basin. The collecting channel must have sufficient capacity to transport the required flow. The length and the width of the channel are usually defined by the size of the trash rack. The water depth at the downstream end of the channel is known (1.8m, which is the required water level in the power canal), therefore the water level can be computed towards upstream. Using Chow's equation

$\frac{dy}{dx}$ = Change of water depth, *y*, in the longitudinal direction of the channel, *x*

S_o = bed slope

S_f = energy line, computed with Manning's formula

Q = discharge in the section of the collecting channel, which is considered (m^3/s)

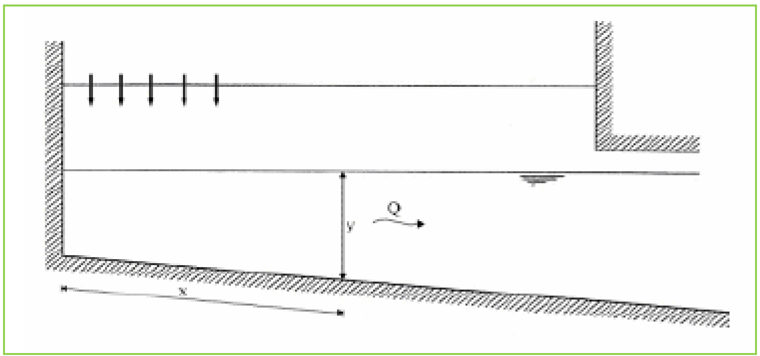


Figure 8: Tyrolean Intake collecting Channel

Table 9: Tyrolean Intake collecting Channel Parameters

Depth of Water at the extreme depth downstream, y	1.60
Depth of Water at the extreme upstream depth, y	0.3
Flow Q, m^3/s	12
S_f	0
S_o	0.065
g ,m^2/s	9.81
Inclination Angle	0.065
Minimum Width of the collecting channel, m	2.5

Distance from the Extreme end of the channel X, m	20
Horizontal Length from the extreme end B, m	20
Change in unit discharge q, m^2/s	0.60
Vertical water depth y at X, m	1.6
Cross sectional Area at y and X, m^2	3.931

$$\frac{dy}{dx} = \frac{S_o - S_f - \frac{2Qq}{gA^2}}{1 - \frac{Q^2}{gA^2 y}}$$

3.1.5 ROUND OVERFLOW WEIR INTAKE

A weir is intended to aid water extraction from the river. In this particular design, the weir helps to raise the water to a convenient 'depth' at which sufficient, reliable and regulated amounts of water will be extracted.

In this design, the weir is a clear-overflow type masonry mass. It is designed as a gravity type dam (according to design criteria recommended for the Design of small dams United State Bureau of Reclamation - USBR), therefore ensuring that it will resist exerted forces with its own self-weight.

This type of design is widely recognized as the most durable, and it requires minimum maintenance. As the ground condition on the foot of the weir is of firm bedrock, the weir will be constructed on the natural bedrock as its foundation material is strong enough to bear the weight of the structure. The environmental flow shall be taken care of by the use of a UPVC pipe built close to the foot of the weir

Table 10: Round Weir Specifications

Parameter	Value	Unit
Maximum flood, Q_{flood}	136	m^3/s
Weir Breadth, B	20	m
Weir Height, Y	1.8	m
Design Head, Hw	0.42	m
River average Velocity, V	2	m/s
Velocity Head, h_v	0.2	m
Total head, H	0.62	m
Silt Flushing Head	1	m
Silt Flushing Width	1	m
Maximum flood weir head, $h_{overtop}$	2.12	m
Height of barrier wall, $h_{barrier}$	3.92	m
Environmental release head, h_φ	1.0	m
Environmental release Diameter, φ	0.69	m
Weir discharge Coefficient, C_v	2.2	

$$C_d = 0.564 + 0.0846 \frac{H_w}{Y}$$

$$Q = C_d b \sqrt{g} H^{3/2}$$

$$H_v = \frac{V^2}{2g}$$

COMPARISON OF THE INTAKE TYPES

Table 11: Comparing Weirs

INTAKE TYPE	PROS	CONS
Tyrolean screen intake	Self cleansing	Too much silt in the intake water
	No flooding of the upstream land due to intake features	A steep slope is required for the collecting channel leading a 2m loss of head.
	A short weir is required (0.3m high)	Excavation and construction of the channel between the sedimentation tank and collecting channel will be hard since the water table level is only 1.5m below the ground
	Easy to construct the minimum environmental release orifice	
Round overflow weir	Raises the water to 1.8m, so there is an increase in the intake head	The area up to 320m upstream of the weir is prone to be affected by floods (1 in 50yr flood)
	The silt entering the intake channel can be easily controlled	

From the reasons given above for the suitability or inapplicability of the two intake types, the round overflow weir was chosen. This is because a 35m of gross head obtained with the round overflow weir and also the intake channel will be easily constructed contrary to 33m of the Tyrolean intake coupled with the construction hardships envisaged.

3.1.6 WEIR STRUCTURAL ANALYSIS

The weir is constructed 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.

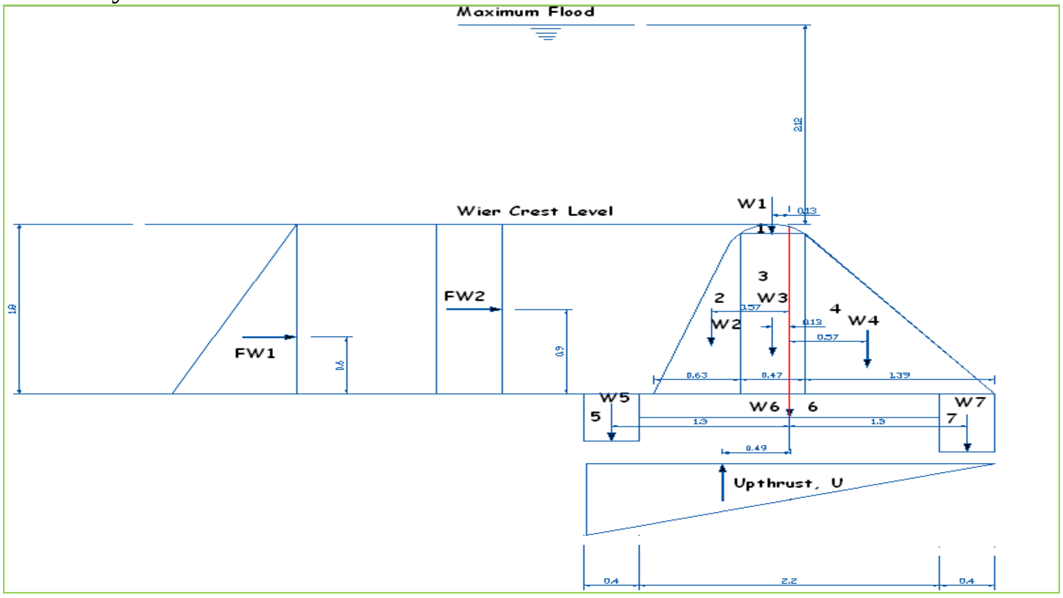


Figure 9: Round Weir Structural Analysis

The Overturning moments are taken about the centre of the base.

Table 12: Round Weir Structural Analysis

Force	Volume per m	Force Magnitude		Lever Arm	Moment about centre of base
		Vertical	Horizontal		
	m^3/m	KN	KN	m	KNm
W1	0.031	0.806		-0.13	-0.10
W2	0.566	14.716		-0.57	-8.39
W3	0.801	20.826		-0.13	-2.71
W4	1.183	30.758		0.57	17.53
W5	0.2	5.2		-1.3	-6.76
W6	0.55	14.3		0	0.00
W7	0.246	6.396		1.3	8.31
FW1	0.822		8.22	0.6	0.00
FW2	0.855		8.55	0.9	0.00
U	1.138	-11.38		0.49	5.58
		81.622	**16.77**		**13.46**

Resultant Moment	13.46KNm
Direct stress at base	27.2 KN/m^2
Bending Stress at the extreme fibres	18.22KN/$m^2$and 36.17 KN/m^2

3.1.7 INTAKE CHANNEL

The intake channel is designed to be a direct-intake rectangular section capable of transporting a maximum of 12m^3/s. it is fixed with a screen to deter big stones and boulders from entering the power canal, and it has a sluice gate to ‘cut’ off flow in case of routine maintenance or emergencies.

Table 13: Intake Channel Parameters

Channel flow (Q_{gross})	12	m^3/s
Length of the Channel, L	25	m
Velocity	2.5	m/s
Side slope, N	0	
Manning's, n	0.015	
Freeboard allowance, F	1.3	
Cross-sectional area, A	6	m^2
Side slope index, X	2.000	
Channel Height, H	1.77	m
Water depth, Hw	1.56	m
Freeboard Head	0.20	m
Bed width, B	3.5	m
Top width, T	3.5	m
Wetted perimeter, P	7.065	m
Hydraulic mean radius, R	0.883	m
Slope, S	0.166%	
Head Loss, HL	0.041	m
Type of Channel	Rectangular	

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

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

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

$$B = H \times X$$

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

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

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

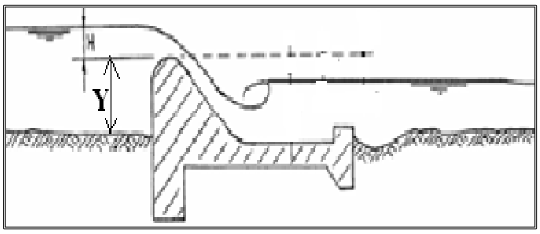
$$HL = L \times S$$

Since the weir height is already designed to be 1.8m, the channel height H will be 1.95m, so as to 'run' with a 0.15m of freeboard.

3.1.8 WING WALL HEIGHT AT THE WEIR

Table 14: Weir Parameters

Weir Parameters		
Design flow rate, Q	**12**	m^3/s
Worst flood Design flood, Q_{flood}	**136**	m^3/s
Weir Length	**20**	m
Weir Height, Y	**1.8**	m
Weir discharge coefficient, C_V	**2.2**	
Maximum Weir head, $h_{overtop}$	2.12	m
Height of the barrier wall, $h_{barrier}$	3.92	m
Head under design flow	0.42	m



$$h_{overtop} = \left(\frac{Q_{flood}}{(C_w . L_{weir})}\right)^{1/1.5}$$

From the hydrological report, the designed flood is considered to be 4.5 times the maximum flow shown on the FDC. This gives a flood flow of $136 m^3/s$.

The wing wall is designed to retain the river water from flooding the adjacent intake structures e.g. the sedimentation tank, headrace canal etc.

The wing wall height is given by the sum of the maximum weir head and weir height.

3.1.9 BACKWATER ANALYSIS EFFECT

In 475m distance from the weir, there is a bridge 4m high. This analysis is meant to assess the impact of the weir on the upstream bridge during the worst flood. The direct step method has been used to compute the river water profile. The river has been assumed to be trapezoidal in shape.

- Depth of water at the weir at normal flow = $y_0 = 2.12+1.8 = 3.92$m
- Type of flow is subcritical since $y_0 > y_c$ since the critical depth, y_c=1.68m
- The normal depth, y_n=3.26m. Therefore, $y_0 > y_n > y_c$ indicating that the backwater curve away from the weir profile (upstream) has got a positive gradient.

Table 15: Backwater effect analysis

Name	Symbol	Unit	Value
Bridge Height	y	m	4
Weir Head at Max. flood	Hw	m	2.12
Weir Height	H	m	2.5
flood flow rate	Q_{flood}	m^3/s	136
Weir crest length	B	m	20
The river slope S	S	%	0.02
Manning's constant n	n		0.035
Total head at the weir	m	m	0.8
Critical depth	yc	m	1.68
Normal depth	yn, m	m	3.26
Water depth at weir, m		m	3.92
River specifications			
River Bottom Width		m	20
River Bed slope, So	So		0.02
Change in water profile in respect to x	dy	m	0.15

$$y_c = \left(\frac{Q^2}{b^2 g}\right)^{1/3}$$

$$\frac{dy}{dx} = \frac{S_o - S_f}{1 - Fr^2}$$

$$Q = \frac{b y_n R_n^{\frac{2}{3}} S_o^{1/2}}{n}$$

$$S_f = \frac{n^2 Q^2 P^{4/3}}{A^{10/3}} \text{ and } Fr^2 = \frac{Q^2 b}{g A^3}$$

Plotting dy/dx against the upstream distance from the weir to the bridge;

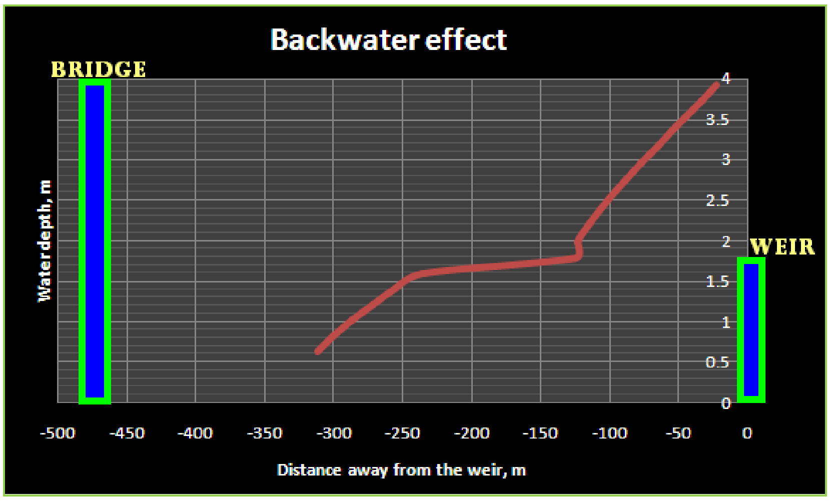


Figure 10: Backwater Effect

The water profile above shows the flood characteristic as influenced by the constructed weir. It can be seen that the bridge is not in any way affected by the weir as the flood dies out before reaching the bridge.

3.1.10 MINIMUM ENVIRONMENTAL WATER RELEASE STRUCTURE

A minimum flow of 1000l/s will be released by the 'out let' structure built into the weir. This will be supplemented by the spill water at the weir crest. The structure is a circular orifice that will operate at 1m head, elevated at 0.3m from the foot of the weir.

Table 16: Environmental Release Orifice Parameters

Minimum Environmental release	1.00	m^3/s
Submerged head, H	1.00	m
Jet Velocity, V_{jet}	2.66	m/s
Orifice Diameter, D	692	mm
Orifice coefficient, C_v	0.6	

$$Q = A_{jet}V_{jet} = \frac{\pi D^2}{4} C_v \sqrt{2gH}$$

3.1.11 SILT FLUSHING STRUCTURE AT THE WEIR

River Mitano has a high silt load so a silt mitigation structure is designed to alleviate the problem of silt accumulation at the intake and weir area.
A steel breast wall type roller gate 0.75m wide and 0.75 m long will be built into the weir to allow flushing. This will be operated during de-silting.

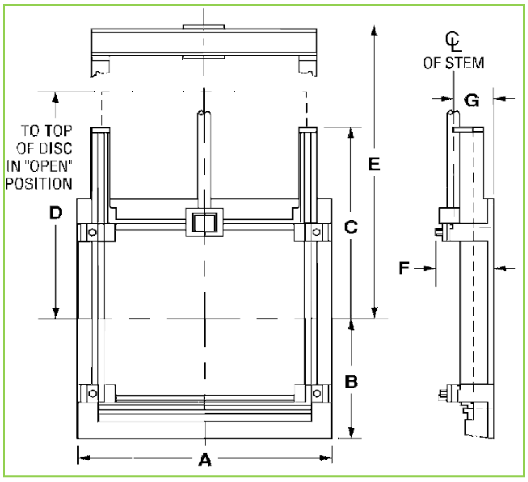


Figure 11: Silt Flushing Gate

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.

Table 17: Silt Flushing Gate Parameters

Width × Height	Max. Design Head	A	B	C	D	E	F	G
mm	m	mm						
750×750	18.3	1016	508	813	1295	1480	235	159

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

3.2 SEDIMENTATION TANK DIMENSIONS

The sedimentation tank is designed in a way to remove all particles bigger than 0.2mm.

Table 18: Sedimentation tank specification

Sedimentation tank specification		
Flow rate, Q	12	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	3	m
Settling Length, L	34.46	m
Transition Angle, α	37.0	o
Settling time, t_d	175	s
Settling Breadth, B	20.3	m
Incoming Channel width, B'	3.53	m
Transition Length, I	11.1	m

$$V_d = \frac{\left(44\sqrt{D}\right)}{100}$$

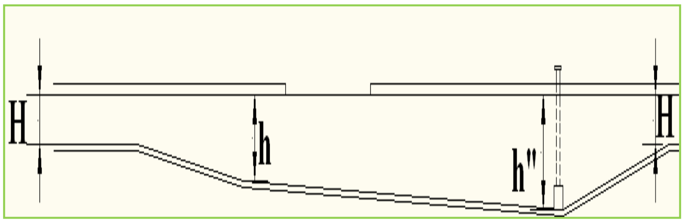
$$L = \frac{V_d \cdot h}{V_s - 0.04V_d}$$

$$B = \frac{Q \cdot t_d}{L \cdot h}$$

$$t_d = \frac{L}{V_d}$$

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

Design Parameters		
Exit Width, B'''	4.73	m
Exit Transition length, I'	11.1	m
Water depth in the channel, H	1.7	m
Exit depth, h''	4	m
h	3	m
L	34.5	m
B	20.3	m
I	11.1	m
B'	3.5	m

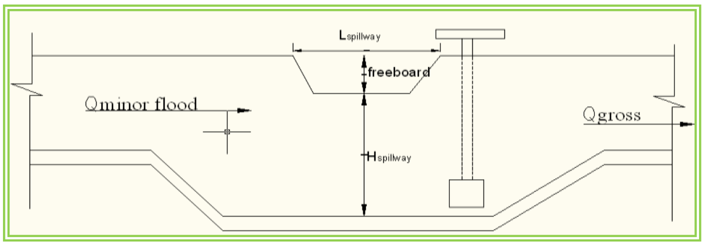


3.3 SPILLWAY MINIMUM DIMENSIONS

In case of more water is diverted, the overflow-like notch in the side of the sedimentation tank will spill the excess water back to the river.

Table 19: Spillway Dimensions

Spillway dimensions		
gross	12.000	m^3/s
Hspillway	4.000	m
Weir constant, Cw	1.600	
Qminor flood	13.800	m^3/s
Q spillway	1.800	m^3/s
hminor flood	4.400	m
Minimum Lspillway	4.447	m
minimum freeboard	0.400	m



The required freeboard is more than that calculated in the intake canal. Therefore, the spillway length will be increased to 8m so as to maintain a freeboard of 0.15m.

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

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

$$L_{spillway} = \frac{Q_{min\,orflow} - Q_{gross}}{C_w \left(h_{min\,orflood} - h_{spillway}\right)^{1.5}}$$ And minimum freeboard $= h_{minorflood} - h_{spillway}$

3.4 HEADRACE CHANNEL

This channel is different from that which joins the intake to the sedimentation tank, this joins sedimentation tank to the forebay. The selected channel is a trapezoidal section which is designed to offer optimal channel functioning while minimizing the construction costs.

Table 20: Headrace Design

Parameter	**Value**	**Units**
Channel flow (Qgross)	12	m^3/s
Length of the Channel, L	2700	m
Velocity	2.15	m/s
Side slope, N	0.58	
Manning's n	0.015	
Freeboard allowance, F	1.3	
Cross-sectional area, A	7	m^2
Side slope index, X	1.152	
Channel Height, H	2.05	m
Water depth, Hw	1.77	m
Freeboard Head	0.28	m
Bed width B	2.4	m
Top width T	4.73	m
Wetted perimeter, P	7.090	m
Hydraulic mean radius, R	1.023	m
Slope S	0.10%	
Head Loss HL	2.723	m
Type of Channel	**Trapezoidal**	

These parameters are calculated with the same formulas of the intake canal.
In order to achieve optimal dimensions for efficient canal functionality, the Top width T and Channel Height H have been changed (from those calculated) to be 4.65m and 1.95m respectively. These dimensions will guarantee a flow of 12 m^3/s and a freeboard of 0.15m.

The channel slope and the dimensions selected ensure that the water moves at a velocity that prevents concrete scour and the same time permits no sedimentation along the channel. A 'small' slope was considered in order to avoid loss of head and hence optimizing gross head for power generation.

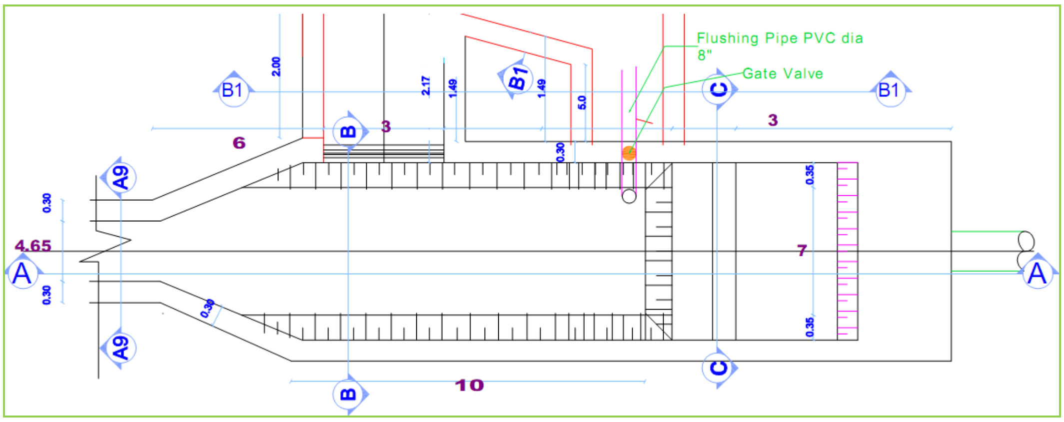
Note: At an interval of 500m of the headrace channel, a spill notch shall be created in the channel to control water levels in the channel especially during rainy seasons.

3.5 FOREBAY DIMENSIONS

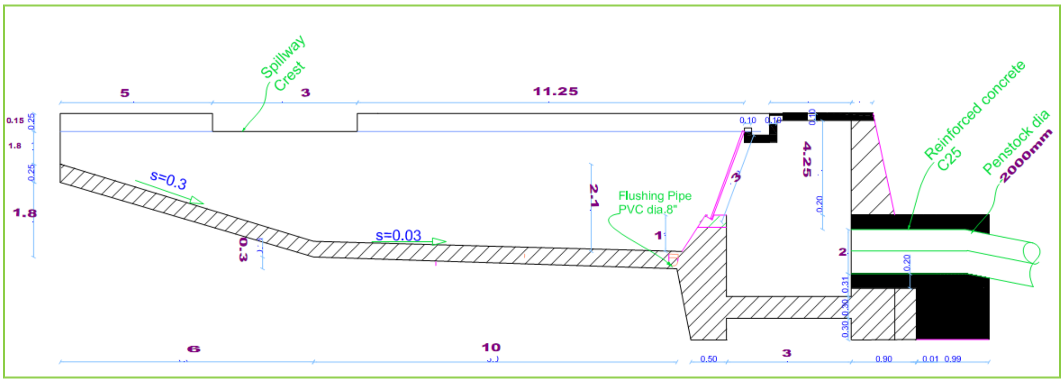
Since the de-silting will be done 25m from the intake and the channel is 'too' long, the forebay will not be made as large as the de-silting tank. That said though, the purpose of the forebay will be to settle and trap 'foreign bodies' intruded into the channel e.g. leaves, stones, grass etc. Secondly 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>3.82m, therefore S will be set to 4m. A storage depth is provided for possible silt deposition. A trash rack inclined at 70^{o} and dimensioned in a way to stop relatively big particles from accessing the turbine whereas letting through adequate flow. A dead storage of 0.31m was considered to allow for silt accumulation.

Figure 12: Forebay



All dimensions are in m



4.0 ELECTRO MECHANICAL EQUIPMENTS

4.1 Introduction

The electromechanical equipment consists of the penstock and the equipment in the Power House. The penstock conveys water under pressure from the fore-bay into the turbine. The penstock must withstand the pressures, minimize the head loss and be of reasonable cost.

4.2 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.

4.3 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 35m, and the available flow is $8.0m^3/s$. The expected power generation for this site is 2900KW. The optimum size of a single penstock to meet these condition has been determined as steel with a diameter of 2000mm with a thickness of 7.5mm.

4.4 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 equipment 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.

4.5 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.

4.6 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 a butterfly valves are provided to regulate the flow to each turbine, and isolate it when necessary.

4.7 Generating Plant

4.7.1 General

The available flow is 8.0m3/s for at least 9 months. The available head is 35m. It is proposed to use 4 turbines in the Power House by dividing the incoming flow equally into 4 streams. This is done in a manifold just outside the Power House. The division has the following objectives:

- To ensure that even at the lowest flows in the year some power can be generated by using the number of turbine suitable for the available water.
- To have manageable physical sizes of turbines, generators and valves considering that this is a remote site over difficult terrain and site handling equipment will be difficult to access.

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 8.0m3/hr, the river is not left dry and will have some flow to satisfy environmental requirements.

4.7.2 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

4.8 Turbines

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

4.8.1 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.

4.8.2 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.

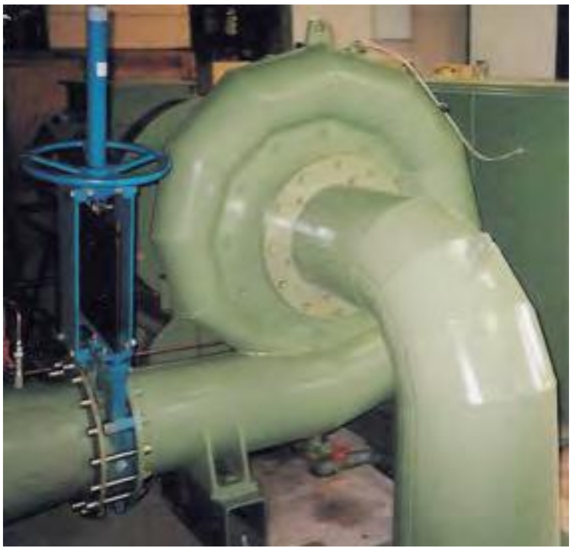


Figure 13: Horizontal Francis Turbine

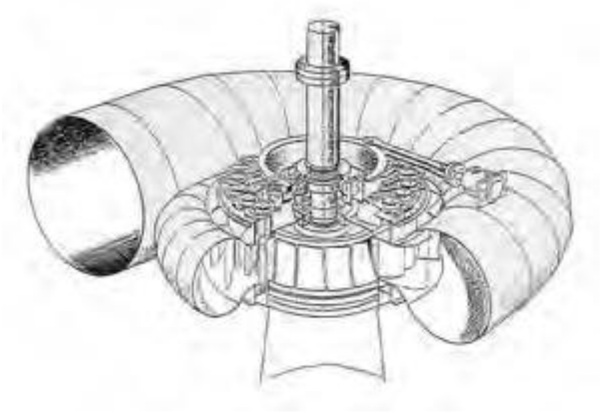


Figure 14: Vertical Francis Turbine

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.

4.8.3 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.

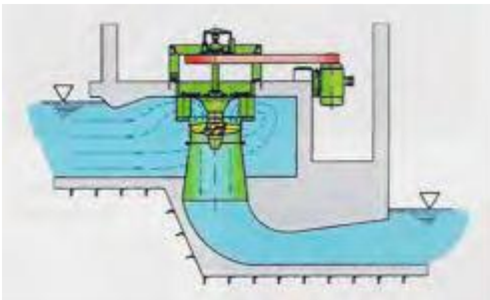


Figure 15: Kaplan Turbine

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.

4.8.4 Pelton turbine

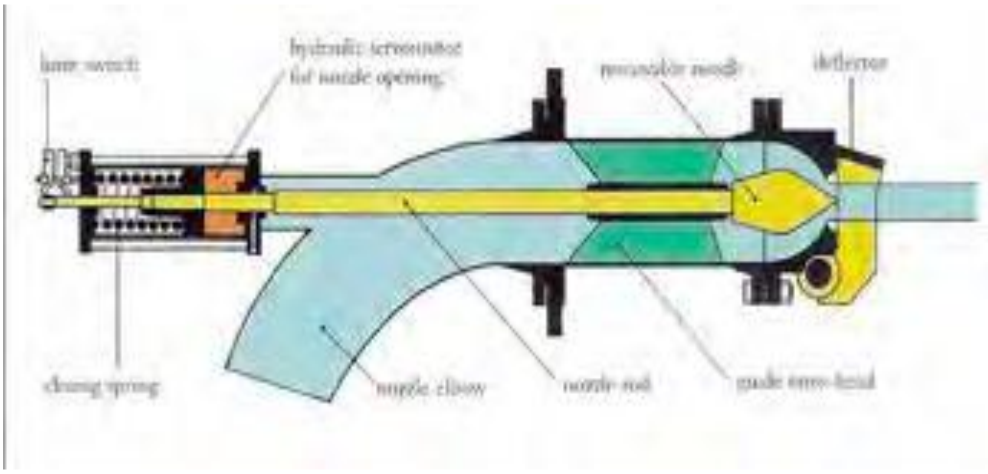
Pelton turbines are impulse turbines where one or more jets impinge on a wheel carrying on its periphery a large number of buckets. Each jet issues water through a nozzle with a needle valve to control the flow (figure 1.2). They are suitable for high heads from 60 m to more than 1,000 m. The axes of 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).

Figure 16: 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.

Figure 1.5: Pelton Turbine Inlet Nozzle with Needle Control



4.8.5 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.

4.9 Selection of Turbine

The available head is about 35m and the available flow is 8.0m3/s. This gives the available power of about 2800KW.

Therefore our main parameters for the turbine are as follows:

Quantity	:	4No
Power	:	700KW
Head	:	35m
Flow	:	2.0m^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.

4.10 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 Kanungu. There are two possible kinds of generators namely: Asynchronous and Synchronous

4.10.1 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

4.10.2 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 700KVA at 0.8pf apparent Power to match the turbine output. The selected voltage is 4500Volts, 3 phase. This voltage will give a current of about 200A. This voltage is selected in order to minimize the current. Since this is a non-standard voltage, suppliers will be asked to indicate their preferred voltage and all the supplied equipment to conform.

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 : 4No.

Flow Rate : 2.0m3/s

Head : 35m

Power : 700 KW

Speed : 1500 RPM

Runway Speed :2700 RPM

Orientation : Horizontal

Efficiency : >85% for flow rate 50% to 110%

Governor : Electronic

Generator Type: Synchronous

Quantity : 4No

Power :700KVA

Voltage :4500Volts, 3phase

Frequency : 50Hz

Speed : 1500 RPM

Loading : Continuous

4.11 Network Configuration.

There are 4no 700KVA generators connected to a step up transformer rated at 4500V/33KV 50Hz. The transmission voltage selected is 33KV to minimize losses and voltage drops on the Transmission line which is 22km long.

4.12. Overhead Transmission Line.

The overhead line is of flat formation configuration. The line conductor size is $100mm^{2,}$ All Aluminum Alloy Conductor (AAAC) with a current carrying capacity of 200A. The total loss when carrying 2800 KVA is about 80KW which is about 2.5%.

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.

4.13. Station Supply at Mitano.

The station supply at Mitano is derived from the generator output bus at 4500V through a 100KVA, 4500/415V step-down station transformer. 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 100KVA 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.

4.14 Power Sub-Station at Kanungu.

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

4.15 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 Mitano and at the bulk supply point at Kanungu. Group Control at Mitano will include the local station equipment plus the transmission line, and all the equipment at Kanungu.

Similarly Group Control at Kanungu will mean control of all the local equipment in Kanungu plus control of the transmission line and the equipment in the Power Station at Mitano. 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 Mitano and the other at Kanungu 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.

4.16 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:-

- generator transformer unit including the turbine
- station supply at Mitano
- (3)33 KV Busbar together with the 33KV overhead line and the 33KV Busbars at Kanungu.
- Load transformer and 33KV Busbar.
- Feeder for load supply

4.17 Operation and Maintenance

4.17.1 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.

4.17.2 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.

4.17.3 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:

1.Operating Schedules

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

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.

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.

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.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.

4.18 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.

4.19 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.

4.20 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.

4.21 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.

4.22 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.

4.23 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.

4.24 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.

4.25 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.

4.25.1 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.

4.25.2 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.

4.26 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.

4.27 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.

4.28 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.

4.29 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.

4.30 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.

4.31 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.

4.32 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 $\pm$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.

4.33 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.

5 ECONOMIC ANALYSIS

MITANO RIVER MINI HYDRO PROJECT SCHEME

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 t 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.

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 Mitano River are as follows:

ELECTRICITY PRODUCTION			
MITANO RIVER MINI HYDRO			
Cost of Project *2	$8,150,800	Loan Interest	5.00%
Head (m)	35	Debt	70%
Plant Factor	75%	Term	20
Tariff *1	$0.100	Loan Amt	$5,705,560
Carbon Credit Price, est.	$15	Equity Amt	$2,445,240
Annual Credits, est.	9,860	Annual O&M *3	$30,000
Design Flow, m^3/s	12	Tax Rate	30%
Installed Capacity, KW	2,900	Carbon credits, yrs	10
Annual Output, KWh	19,053,000		
Annual Revenue *4	$2,053,200		
Main Cost Summary	**$8,150,800**	NPV, Equity	$8,746,715
Preliminaries	$121,700	NPV, Project	$8,675,753
Civil Works	$5,165,716	Project Payback	7
Supervisory	$369,651	IRR, Project	13.97%
Contingencies	$388,133	IRR, Equity	25.70%
Electromechanical	$2,105,600	Install Cost p/KW	$2,811
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 Mitano River Mini Hydro project scheme has a very favorable financial profile when viewed strictly from a traditional financial analysis standpoint. Due to the high levels of free cash flows generated by the project, the payback period is projected at 7 years.

The primary reason for higher amounts of free cash flow of the Mitano mini hydro scheme is because the Mitano River is a non-seasonal river that provides a relative high flow amount throughout the year. Additionally River Mitano has a very large catchment area, with a number of smaller rivers joining it on its way to Lake Edward. The Mitano catchment has deep soils and a large amount of vegetation cover, hence, a lower level of evapotranspiration is experienced.

The technical team visited the site on several occasions and made the determination that the water flows of the Mitano River are adequate and sufficient for the installed capacity of 2,900KW (2.9MW). There was a determination that the water flows are quite high during the rainy seasons and even during the dry season.

Mitano River mini hydro power project scheme is a profitable venture from the viewpoint of a strict financial investment return, as well as when viewed from the broader context of the societal impact and the effects of climate change on poverty reduction. 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 site is not difficult to access, and lends itself for some limited 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.

<u>Avoided Costs Analysis</u>

A typical 2,900KW Diesel Powered Generator, operating at approximately 70%-75% efficiency, as shown below will consume approximately 420 liters (110 gallons) of fuel per hour at 75% load. If this machine runs for the equivalent amount of hours per year as the proposed 2.9MW mini hydro scheme at Mitano River, of approximately 6,570 hours (at a conservative 75% plant factor capacity), it will consume approximately 2,759,400 liters (726,157 gallons) of diesel fuel per year. With the current diesel prices in Uganda at approximately UGX 3,000 per liter(i.e. UGX 11,400 p/gallon), then utilizing the generator at equivalent usage would result in a cost of UGX (2,759,400 * 3,000) = 8,278,200,000. This is equivalent to an annual cost of approximately USD$3,762,818 (at USD$1:UGX2,200).

Over a twenty year equivalent period, it is USD$75,256,363. On a discounted basis to compute into present value, this is equivalent to $46,893,000 if the gain was to be realized in the current time frame (i.e. “today”). 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 2.76 Million litres of diesel fuel annually for the generator.

DIESEL GENERATOR SET

Image shown may not reflect actual package

PRIME

2260 ekW 2825 kVA
50 Hz 1500 rpm 11000 Volts

Caterpillar is leading the power generation Market place with Power Solutions engineered to deliver unmatched flexibility, expandability, reliability, and cost-effectiveness.

PRIME 2260 ekW 2825 kVA

50 Hz 1500 rpm 11000 Volts

CAT®

TECHNICAL DATA

Open Generator Set - 1500 rpm/50 Hz/11000 Volts	PRIME DM8726	
Package Performance		
Power rating	2260 ekW	
Power rating @ 0.8 pf	2825 kVA	
Fuel Consumption		
100% load with fan	553.4 L/hr	146.2 Gal/hr
75% load with fan	419.4 L/hr	110.7 Gal/hr
50% load with fan	293.0 L/hr	77.4 Gal/hr
Cooling System*		
Coolant to aftercooler temp max	48° C at 30° C ambient	
	118° C at 86° F ambient	
Inlet Air		
Combustion air inlet flow rate	174.0 m^3/min	6148.2 cfm
Exhaust System		
Exhaust stack gas temperature	475.7 °C	888.2 °F
Exhaust gas flow rate	451.8 m^3/min	15963.4 cfm
Exhaust flange size (internal diameter)	150 mm	6 in
Exhaust system backpressure (maximum allowable)	6.7 kPa	26.9 in. water
Heat Rejection		
Heat rejection to coolant (total)	1034.7 kW	58857 Btu/min
Heat rejection to exhaust (total)	2024.4 kW	115156 Btu/min
Heat rejection to aftercooler	184.8 kW	10512 Btu/min
Heat rejection to atmosphere from engine	252.6 kW	14368 Btu/min
Heat rejection to atmosphere from generator	139.1 kW	7910 Btu/min
Alternator**		
Motor starting capability @ 30% voltage dip	7645 SKVA	
Frame	3044	
Temperature Rise	80°C	144 °F
Lube System		
Lube oil refill volume with filter change for standard sump	540 L	142.6 US Gal
Emissions (Nominal)***		
NO_x g/hp-hr	8.31 g/hp-hr	
CO g/hp-hr	0.27 g/hp-hr	
HC g/hp-hr	0.20 g/hp-hr	
PM g/hp-hr	0.05 g/hp-hr	

Note: This generator set package is not offered with an engine driven radiator.
The addition of an engine driven fan will reduce the output below the nameplate rating.

* For ambient and altitude capabilities consult your Cat dealer. Air flow restriction (system) is added to existing restriction from factory.
** UL 2200 Listed packages may have oversized generators with a different temperature rise and motor starting characteristics. Generator temperature rise is based on a 40 degree C ambient per NEMA MG1-32.
*** 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, NO_x. 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.

<u>Sensitivity Analysis</u>

The Mitano River mini hydro project scheme is a moderate sized project in comparison to the other schemes in this engagement. It is a project whose benefits would best achieved by connection to the national electricity grid of Uganda.

The project is located in an easily accessible position the result of which is the installation costs are a relatively ordinary $2,811 p/KW, in as fas as mini hydro project costs go. Within the context of conducting a sensitivity analysis, the project already exhibited quite a favorable financial profile that it was felt that there were no obstacles of particular significance to the development of this project.

Sensitivity Subsidy Amt	Project Cost with subsidy	Installed Cost p/KW	Project NPV	Project IRR
50%	$4,075,400	$1,405	$12,557,087	26.28%
40%	$4,890,480	$1,686	$11,780,820	22.50%
30%	$5,705,560	$1,967	$11,004,553	19.64%
0%	$8,150,800	$2,811	$8,675,753	13.97%

As can be seen from the above sensitivity matrix, the project has a positive Net Present Value (NPV) at the currently estimated project cost of USD$8,150,800.

It is recommended that this project be offered for development to any interested private sector enterprise for connection to the national grid.

<u>Conclusion & Recommendation</u>

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

#	Benefits	Annual	20 years
1.	Project Direct Revenues	$2,053,200	$ 39,585,000
2.	Construction Period Revenues	$250,000	$250,000
3.	Worker Labor/Employment	$491,150	$491,150
4.	Misc Other, post construction	$ 100,000	$ 2,000,000
5.	Avoided Fuel Costs (Savings)	$ 3,762,818	$ 75,256,360
6.	**Total**	**$6,657,168**	**$117,582,510**

Project Cost: $8,150,800
Economic Benefits: $117,582,510
Gross Economic Return: 1,343%
Annualized Economic Return: 14.28%

<u>Notes:</u>

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 ($369,650) per BOQ.
4. (726,157 gallons *UGX11,400 p/gal) * 20

The above results demonstrate the favorable financial profile of the Mitano River mini hydro scheme. It should be noted that the above computed "Gross Economic Return" is not a very meaningful result, and only becomes meaningful when interpreted within the context of the "Annualized" return, which is the actual meaningful metric to pay attention to.

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:

#	Benefits	Annual	20 years
1.	Electricity Revenues	$1,905,300	$ 23,744,249
2.	Carbon Credit Revenues	$147,900	$1,142,045
3.	Construction Period Revenues	$ 250,000	$ 238,095
4.	Worker Labor/Employment	$ 491,150	$ 467,762
5.	Misc Other, post construction	$ 100,000	$ 1,246,221
	Avoided Fuel Costs (Savings)	$3,762,818	$ 46,893,029
6.	**Total**	**$6,657,168**	**$73,731,402**

Current Project Cost: $8,150,800
Present Value of Economic Benefits: $73,731,402
Net Economic Benefits: $65,580,602

Note:

1. The construction period and worker employment benefits are only computed for the estimated 12-18 month construction period.

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 Ministry of Energy to identify a capable private sector developer to undertake the development of this project under a private sector initiative. The Ministry already has an existing process under which it lists projects available for development in Uganda. It is not recommended for the Ministry to undertake development of this project under its own banner for the basic reasons that i) the project has a very favorable financial and economic profile that will support private development; and ii) the Ministry should focus more on policy and regulatory functions rather than take on direct operations of projects.

It is further recommended that this project be developed as a grid connected project to serve the national grid. It has the potential to generate adequate supply that will have immediate impact to the current deficit in electricity generation in Uganda.

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

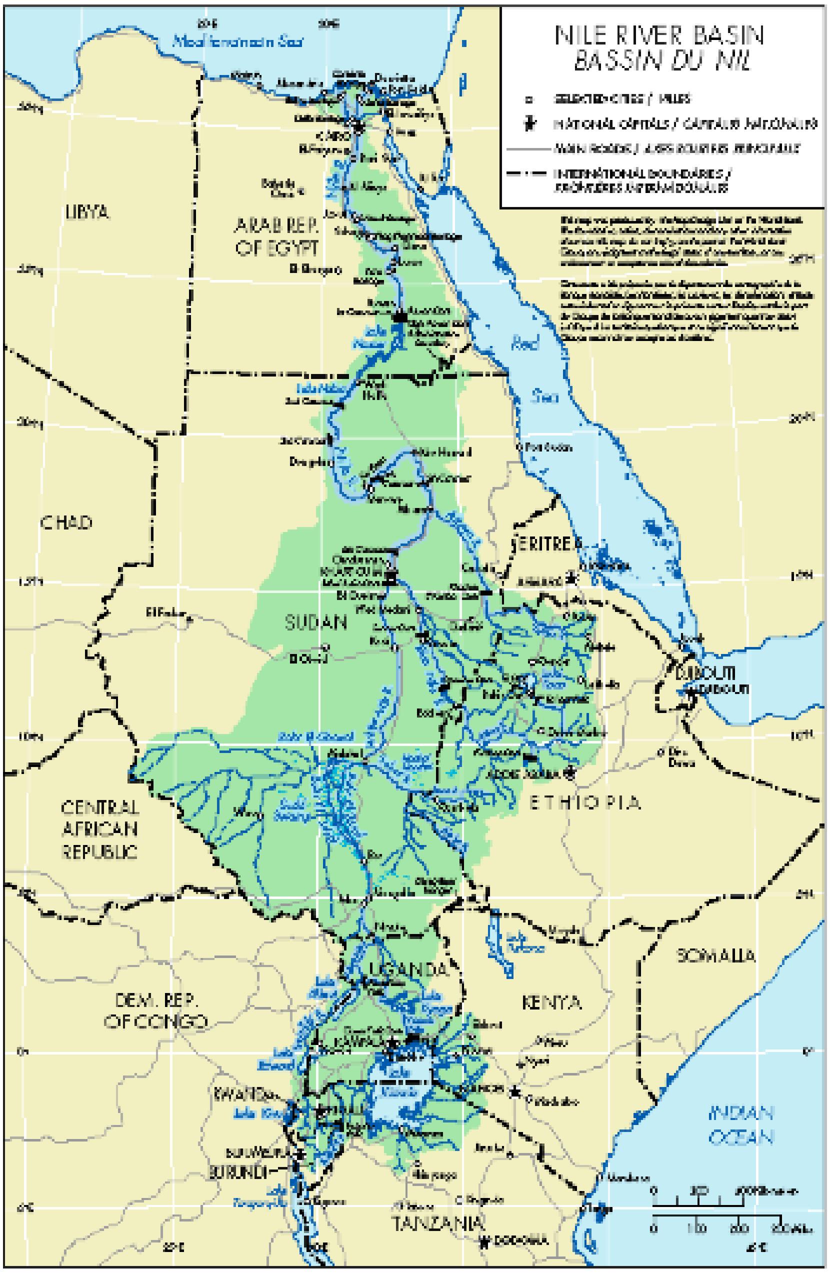
At the currently estimated electricity production rate, the Mitano River mini hydro power scheme can receive approximately $147,900 per year for 10 years of carbon credit revenues. This estimate is based on receipt of approximately 9,860 credits, priced at roughy $15 per credit ton offset, per year. This amounts to an estimated amount of USD$1,479,000 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$1,142,045 (by discounting USD$147,900 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.

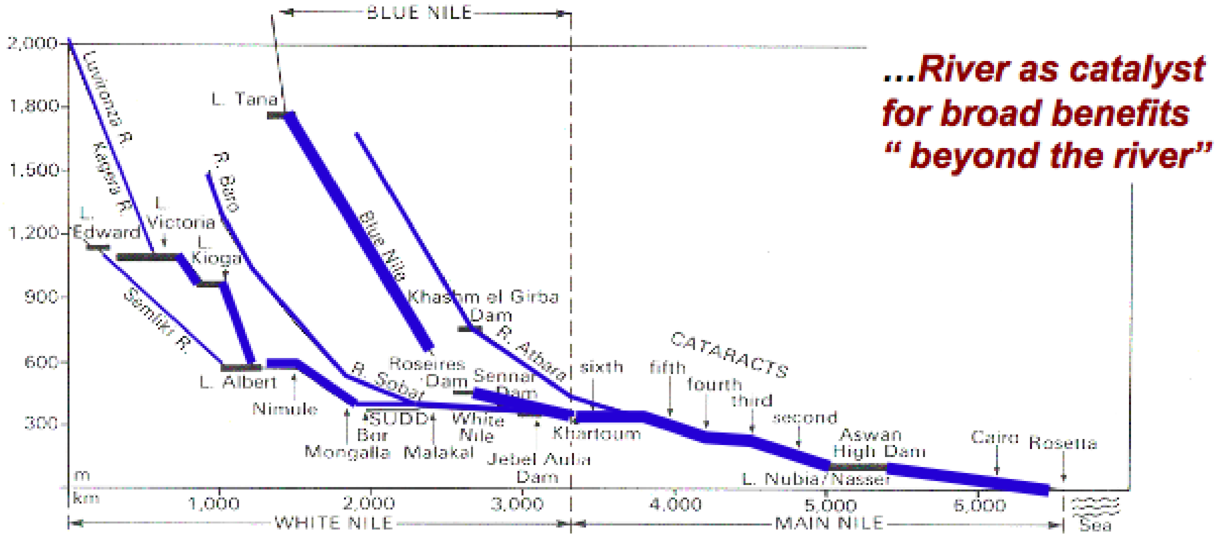
Mitano River mini hydro scheme can therefore take advantage of this situation by leveraging the scheme's renewable energy credentials in exchange for financial benefits under the carbon credit market initiative.

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 Mitano River project is very close to the border with Rwanda and 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 Mitano 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.

APPENDICES

APPENDIX 1: BILL OF QUANTITIES

1.1: 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 USD55,000(Fifty Five Thousand United States Dollars) for demobilisation of works	PS	1.00	55,000.00	55,000.00
	Total Amount to be carried to Item 1.1 of BOQ No. 1				55,000.00

1.2: 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 50,000(Fifty Thousand United States Dollars) for demobilisation of works	PS	1.00	50,000.00	50,000.00
	Total Amount to be carried to Item 1.1 of BOQ No. 1				50,000.00

1.3: 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	55,000.00	55,000.00
					-
B	Demobilization Carried from Appendix 2	LS	1.00	50,000.00	50,000.00
					-
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					121,700.00

1.4: 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	52,513	1.00	52,513.28
				-	-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	52,513	1.20	63,015.94
				-	-
C	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	1,800.00	1,800.00
D	Allow for keeping the whole of the excavation free from general water.	ITEM	1	1,800.00	1,800.00
				-	-
	CART AWAY AND FILLING			-	-
				-	-
E	filling with stablised marrum to make up levels in layers of 250mm thick including compacting	CM	86,784	10.00	867,837.90
F	cut to reduce levels to formation level of the diversion	CM	23,099	6.25	144,371.34
G	Extra over excavation for excavating in rock.	CM	7,700	50.00	384,990.25
	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**	942	83.33	78,500.00
I	Ditto : girth 600 - 900mm girth.	**NO**	236	125.00	29,500.00
				-	-
	CHANEL FOUNDATION AND MASONRY WALLS			-	-

J	provide and place stone masonary works to foundations of the chanel average thickness 400mm in cement sand mortar mix 1:4	CM	3,002	83.33	250,203.73
K	masonry stone work to bases and walls in cement sand mortar mix 1:4	CM	8,976	83.33	748,000.00
				-	-
	PLASER TO CHANEL WALLS AND BOTTOMS			-	-
L	12mm thick cement sand plaser to masonry surfaces of chanel walls and bottoms mix 1:4	SM	22,440	6.25	140,250.00
Total for Element No. 1 Carried to collection					2,762,782.44
					2/1/1
	GABIONS				-
M	Provide and place galvanised gabion boxes, size 2x1x1 inclusive of rockfill as specified or directed by the Engineer	CM	9,326	5.00	46,632.45
	FENCING			-	-
N	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	5,651	7.50	42,384.96
				-	-
O	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	200	20.83	4,166.67
				-	-
P	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	1,800	18.75	33,750.00
	TRASH SCREEN				-
Q	supply and install steel trash screen for the intake shaft complete including all embedded parts and all requirements as per engineer's drawings	SM	2	400.00	876.00
					-

Total for Element No. 1 Carried to collection					127,810.08
	Element 1. collection				
	Page No. 2/1/1				2,762,782.44
	Page No. 2/1/2				127,810.08
	Allow a provisional sum od USD200,000 (Two Hundred Thousand United States Dollar) for installation of other un measured facilities along the channel	SUM	1	200000	200,000.00
Total for Element No. 1 Carried to Bill ! Summary					3,090,592.52
					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	39,000	1.00	39,000.00
					-
B	Excavate average 200mm deep to remove top soil: remove from site	SM	39,000	1.20	46,800.00
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	2,800.00	2,800.00

F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	2,800.00	2,800.00
					-
	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	25	83.33	2,083.33
I	Ditto : girth 600 - 900mm girth.	NO	18	125.00	2,250.00
	WEIR FOUNDATION				-
J	provide and place stone masonary works to foundations of the weir and abutments average thickness 400mm in cement sand mortar mix 1:4	CM	34	125.00	4,198.00
	WING WALL FOUNDATION				-
K	Supply all materials placing and finishing of C25 reinforced concrete for wing wall foundations	CM	122	187.50	22,804.88
	WING WALL				-
L	Supply all materials placing and finishing of C25 reinforced concrete for wing wall	CM	104	187.50	19,462.78
Total for Element No. 2 Carried to collection					143,965.52
					2/2/3
	STEEL REINFORCEMENT				
	high tensile steel reinforrcement in wing wall footings and walls to structural engineer's detail in:				
M	R10 mm Dia	KG	6,504	1.67	10,839.73
N	Y12 mm Dia	KG	8,976	1.67	14,960.77
	MASONRY WEIR				-
P	masonry stone work to weir bases in cement sand mortar mix 1:4	CM	110	83.33	9,166.67
Q	Ditto to weir	CM	196	83.33	16,316.67

	GABIONS				-
R	Provide and place galvanised gabion boxes, size 2x1x1 inclusive of rockfill as specified or directed by the Engineer	CM	973	5.00	4,864.00
	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
	CART AWAY AND FILLING			-	-
				-	-
T	filling with approved material in 150mm thick layer to make up levels including compacting	CM	3,405	10.42	35,466.67
	Total for Element No. 2 Carried to collection				92,222.50
					2/2/4
					-
	PLASER TO WEIR & ABUTMENT				-
U	12mm thick cement sand plaser to masonry surfaces of weir and abutments mix 1:4	SM	576	6.25	3,597.03
	FENCING				-
V	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	7,200	104.17	750,000.00
					-
W	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
					-
X	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				-
Y	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	6,000.00	6,000.00
Z	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	6,000.00	6,000.00
	ENVIRONMENTAL REALEASE PIPE				-
AA	supply and install environmental release pipe including all necissarry fittings and valves as specified	LM	120	35.00	4,200.00
					-
Total for Element No. 2 Carried to summary					770,880.36
	Element 2. collection				
	Page No. 2/2/3				92,222.50
	Page No. 2/2/4				92,222.50
	Page No. 2/2/5				770,880.36
Total for Element No. 2 Carried to Bill 1 Summary					955,325.36
					2/2/5
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	3,339	1.00	3,338.80
B	Excavate average 200mm deep to remove top soil: remove from site	SM	3,339	1.20	4,006.56
C	Mass excavation to reduce levels not exceeding 2.0m commencing from stripped level; deposit in spoil heaps where directed on site	CM	1,669	6.25	10,433.75
D	Extra over excavation for excavating in rock.	CM	835	50.00	41,735.00
					-
E	Allow for maintaining and upholding sides of excavation : clear off all fallen material, rubbish.	ITEM	1	2,800.00	2,800.00
F	Allow for keeping the whole of the excavation free from general water.	ITEM	1	2,800.00	2,800.00
	CART AWAY AND FILLING				-
G	Load from spoil heaps and cart away excavated material from site.	CM	2,504	6.25	15,650.63
H	filling with stablised marrum to make up levels in layers of 250mm thick including compacting	CM	5,303	10.00	53,028.15
	CUTTING TREES				-
I	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
J	Ditto : girth 600 - 900mm girth.	NO	7	125.00	875.00
	TANK FOUNDATION AND MASONRY WALLS				-
J	Supply all materials placing and finishing of C25 reinforced concrete for Disilting tank base including all reinforcement bars	CM	442	320.00	141,300.48
K	Ditto to walls	CM	134	320.00	42,758.40
	PLASER TO DISILTING TANK				-
M	12mm thick cement sand plaser to masonry surfaces mix 1:4	SM	445	6.25	2,783.75
Total for Element No. 3 Carried to collection					322,510.52
					2/3/6

	FLUSHING PIPE				-
N	supply and install 900mm Dia. PVC flushing pipe including all necissarry fittings and valves	LM	5	210.00	1,050.00
	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	262	104.17	27,291.67
					-
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	12	20.83	250.00
					-
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

1.5: SUMMARY OF CIVIL WORKS BILLS OF QUANTITIES

ELEMENT	*DESCRIPTION*	*PAGE NO.*	*AMOUNT (USD)*
	BILL NO. 2		
	CIVIL WORKS		
1	DIVERSION AND ACCESS ROADS	2/1/2	3,090,592.52
2	WEIR AND ABUTMENTS	2/2/5	955,325.36
3	DISILTING TANK	2/3/7	352,735.52
4	FOREBAY	2/4/9	75,500.02
5	PENSTOCK	2/5/11	327,637.62
6	SPILLWAY	2/6/12	11,924.85
7	POWER HOUSE	2/7/14	352,000.00
	TOTAL BILL NO.3 CARRIED TO MAIN SUMMARY		**5,165,715.89**

1.6: BILL NO. 3. ELECTROMECHANICAL

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 700KW, Speed 1500 RPM, Head 35m, flow rate 2.0m3/s with efficiency of >85% for flows between 50% and 110% complete with all accessories.	No.	4	175,000	700,000.00
B	Turbine Governor including dummy load.	No.	4	15,350	61,400.00
C	Flywheel	No.	4	4,850	19,400.00
D	**Generator**				-
	Horizontal shaft, three phase AC Synchronous Generator, 4 pole, speed 1500 RPM, Frequency 50Hz, capacity 700KVA, rated voltage 4.5KV, rated current 200A, Efficiency 91% (minimum), power factor 0.8, Air cooled, with self exciter and brushless.	No.	4	95,000	380,000.00
E	Lightning Protection	No.	1	3,000	3,000.00
F	Earthing	No.	1	800	800.00
G	**Control Panel**				-
	Generator control panel including a synchronising unit for the four generators free standing.	No.	1	125,000	125,000.00
H	Governor control panel	No.	4	15,000	60,000.00
I	**Substation Equipment**				-
	Outdoor substation equipment.	No.	1	115,000	115,000.00
J	Battery charging and DC equipment.	No.	1	15,000	15,000.00
K	Step up Transformer 3200KVA, 4.5KV/33KV, 50Hz, Dyn11	No.	1	45,000	45,000.00
L	100KVA 4500/415V 50Hz Dyn11 station transformer complete with associated switchgear and all accessories.	No.	1	29,500	29,500.00
	100KVA standby generator	No.	1		

				35,500	35,500.00
M	Overhead electric crane with X, Y, and Z movement to carry 2000kg complete with controls and all accessories.	No.	1	18,500	18,500.00
N	Wiring and electrical accessories for Power house	No.	1	7,500	7,500.00
	Spares and Tools	Item	1	85,000	85,000.00
Total for Bill No.3 Carried to collection					1,700,600.00
					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	360,000.00
P	Step down Transformer 3200KVA, 33KV/11KV/415V, 50Hz, Dyn11	No.	1	45,000	45,000.00
Total for Bill No.3 Carried to collection					405,000.00
	Element 6. collection				
	Page No. 3/1/1				1,700,600.00
	Page No. 3/S				405,000.00
Total BILL NO.3 Carried to MAIN Summary					2,105,600.00

1.7: MAIN SUMMARY

BILL NO.	DESCRIPTION	AMOUNT (USD.)
	CIVIL WORKS	
1	PRELIMINARIES	121,700.00
2	CIVIL WORKS	5,165,715.89
3	ELECTROMECHANICAL	2,105,600.00
		7,393,015.89
	ADD **5% supervisory costs**	**369,650.79**
	SUB-TOTAL (USD.)	**7,762,666.68**
	ADD: 5% CONTINGENCIES	388,133.33
	SUB-TOTAL (USD.)	**8,150,800.02**
	ADD: 18% VAT	1,467,144.00
	TOTAL AMOUNT (USD.)	**9,617,944.02**

APPENDIX 2: SITE GPS CO-ORDINATES

Point	Name on the map	Position	Point	Name on the map	Position	Point	Name on the map	Position
Intake	Intake	35 M 814211 9913737	Channel Point	52	35 M 814141 9913902	Rock out crop	Rock	35 M 814155 9915535
Channel Point	2	35 M 814208 9915595	Channel Point	53	35 M 814119 9913987	Rock out crop	Rock Area	35 M 814141 9915425
Channel Point	3	35 M 814218 9915620	Channel Point	54	35 M 814121 9914023	Rock out crop	Rock	35 M 814286 9915718
Channel Point	4	35 M 814180 9915561	Channel Point	55	35 M 814131 9913926	Rock out crop	Rocky	35 M 814069 9914782
Channel Point	5	35 M 814197 9915568	Channel Point	56	35 M 814131 9913945	Rock out crop	Rocky	35 M 814081 9914842
Channel Point	6	35 M 814231 9915654	Channel Point	57	35 M 814101 9914901	Rock out crop	Rocky Area	35 M 814128 9914061
Channel Point	7	35 M 814246 9915799	Channel Point	58	35 M 814096 9914959	Rock out crop	Rocky :	35 M 814225 9915390
Channel Point	8	35 M 814236 9915831	Channel Point	59	35 M 814103 9914798	River joint	RUK-MIT	35 M 814388 9916165
Channel Point	9	35 M 814245 9915703	Channel Point	60	35 M 814102 9914844	Spring	Spring	35 M 814160 9915542
Channel Point	10	35 M 814248 9915753	Channel Point	61	35 M 814095 9915014	Gully	Wide Gully 1	35 M 814133 9914704
Channel Point	11	35 M 814166 9915418	Channel Point	62	35 M 814082 9915160	Gully	Wide Gully 2	35 M 814092 9914739

Channel Point	12	35 M 814156 9915442
Channel Point	13	35 M 814138 9915330
Channel Point	14	35 M 814169 9915387
Channel Point	15	35 M 814138 9915459
Channel Point	16	35 M 814158 9915527
Channel Point	17	35 M 814164 9915549
Channel Point	18	35 M 814146 9915486
Channel Point	19	35 M 814152 9915506
Channel Point	29	35 M 814249 9915943
Channel Point	30	35 M 814244 9915993
Channel Point	31	35 M 814237 9915862
Channel Point	32	35 M 814247 9915890

Channel Point	63	35 M 814087 9915221
Channel Point	64	35 M 814085 9915083
Channel Point	65	35 M 814068 9915121
Channel Point	66	35 M 814180 9914501
Channel Point	67	35 M 814175 9914539
Channel Point	68	35 M 814198 9914420
Channel Point	69	35 M 814186 9914464
Channel Point	70	35 M 814168 9914574
Channel Point	71	35 M 814126 9914695
Channel Point	72	35 M 814108 9914749
Channel Point	73	35 M 814159 9914609
Channel Point	74	35 M 814138 9914655

Gully	Wide Gully 3	35 M 814057 9915102
Gully	Wide Gully 4	35 M 814120 9915509

Channel Point	33	35 M 814251 9916034	Channel Point	99	35 M 814136 9913821
Channel Point	34	35 M 814291 9916212	Channel Point	151	35 M 814137 9913860
Channel Point	36	35 M 814279 9916096	Channel Point	152	35 M 814136 9913872
Channel Point	37	35 M 814285 9916141	Channel Point	153	35 M 814305 9916271
Channel Point	38	35 M 814110 9915273	Channel Point	154	35 M 814340 9916278
Channel Point	39	35 M 814147 9914132	BRIDGE	BRIDGE	35 M 814164 9913264
Channel Point	40	35 M 814162 9914187	Gully	Gully 1	35 M 814148 9914662
Channel Point	41	35 M 814130 9914065	Gully	Gully 1 end	35 M 814141 9914686
Channel Point	42	35 M 814140 9914102	Gully	Gully 2	35 M 814105 9914712
Channel Point	43	35 M 814173 9914232	Gully	Gully 2 end	35 M 814094 9914715
Channel Point	44	35 M 814223 9914364	Gully	GULLY 3	35 M 814080 9914881
Channel Point	45	35 M 814222 9914400	Gully	Gully 3 end	35 M 814068 9914895

Channel Point	46	35 M 814191 9914287		Forebay	Forebay	35 M 814279 9916268
Channel Point	47	35 M 814211 9914335		Power House	PH	35 M 814382 9916288
Channel Point	50	35 M 814164 9913748		River Joint	Ram Mit	35 M 814176 9913596
Channel Point	51	35 M 814153 9913772		Rock out crop	Rock	35 M 814070 9915048

APPENDIX 3: GEOLOGY

a) **COMPACTION & PERMEABILITY TEST RESULTS**

Label	Depth (m)	Compaction BS Light		Permeabilty on remolded specimen at 95% MDD: OMC			
		MDD (mg/m3)	OMC (%)	Bulk Density (mg/m3)	MC (%) at casting	Coefficient, k cm/sec	MC (%) after test
TP 1	0.8	1.72	15	1.631	15	$2.24x10^{-6}$	25
TP 2	0.8	1.89	8	1.796	8	$6.93x10^{-6}$	17
TP $_P$	0.8						

b) : CLASSIFICATION TEST RESULTS

Label	Depth (m)	PERCENTAGE PASSING Sieve (mm)													Atterberg limits		
		37.5	28.0	20.0	10.0	6.3	5.0	2.0	0.600	0.425	0.300	0.212	0.150	0.075	LL %	PL %	PI %
TP 1	0.8					100	99	98	94	93	89	80	70	60	30	NP	_
TP 2	0.8		100	96	91	84	83	81	76	71	62	48	39	38	31	NP	_
TP P	0.8								100	99	85	56	43	41	30	NP	_

c) : FIELD PHOTOS

TP 1 – Proposed Intake 2

TP 2 – Proposed Forebay

TP_p - Proposed Power house