FEASIBILITY STUDY FOR THE DEVELOPMENT OF A MINI-HYDRO POWER PLANT, IRRIGATION AND GRAVITY WATER SUPPLY SCHEMES FOR THE PEOPLE OF THE FLAT LANDS OF THE WESTERN RIFT VALLEY ALONG THE EASTERN SHORE OF LAKE ALBERT

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ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
ACDI	Agricultural Cooperative Development International
C	Constant Representing the Acceleration of Gravity
DANIDA	Danish International Development Agency
DWD	Directorate of Water Development
EPED	Environmental Protection and Economic Development
FAO	Food and Agriculture Organization
HA	Hectare
HYDATA	United Kingdom Institute of Hydrology's Data Processing System
ITCZ	Inter Tropical Convergence Zone
KVA	Kilovolt-ampere
KW	Kilowatt
M	Meter
ML	Milliliter
MM	Millimeter
MW	Megawatt
NTU	Nephelometric Turbidity Unit
PH	Measure of the Hydrogen Ion Concentration in Water
RPM	Revolution Per Minute
S	Second
UEB	Uganda Electricity Board
UK	United Kingdom
USAID	United States Agency for International Development
VOCA	Volunteers in Overseas Cooperative Assistance

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Finally a note of appreciation to Allen Inversin, for his words of encouragement and assistance prior to the start of this project, and for his book, *Micro-Hydropower Source Book* which provided the necessary background information to carry it out.

EXECUTIVE SUMMARY

This report has been prepared for ACDI/VOCA in collaboration with the Environmental Protection and Economic Development (EPED) Project in Masindi, Uganda. The objective of the feasibility study was to evaluate the potential for constructing a mini-hydro electric plant, a gravity flow water supply system and an irrigation system for the inhabitants living near Butiaba, on the eastern shore of Lake Albert in Uganda.

The assignment was carried out between March 25 and April 24, 1997. It involved the collection, compilation, and evaluation in Uganda of data, maps and reports relevent to these specific areas of interest. In addition to this, considerable time was spent in the field evaluating the actual physical conditions present at the site.

The River Waki, the object of our attention, is a perrinal river that originates east and southeast of Butiaba. From there it flows in a northwesterly direction towards Butiaba, going over the eastern escarpment of the western Rift Valley and entering Lake Albert just south of that village. As it goes over the escarpment into the Rift Valley, it produces a small waterfall, about 30 m high, and the main target of the present investigation.

Stream gauge data from the River Waki, measured several kilometers upstream from the escarpment, indicate that for 95% of the time, this river is capable of producing a flow of at least 1 m/s. This flow rate has therefore been used in this study to calculate the minimum power potential using run-of-the-river schemes for two sites, which have been selected for the possible construction of a 3 m high concrete and rock weir.

The first site (option 1) selected is on the bedrock across a series of rapids, about 300 m upstream from the edge of the escarpment. In this location, it is proposed that a 3 m high weir be constructed which will have a length of about 40 m. This structure will produce a total head of about 42 m (with the power house positioned in the Rift Valley below the escarpment), and a minimum potential power of 226 kW.

The second location for the possible construction of the weir (option 2), is immediately behind the waterfall at the top of the escarpment. At this location, the same 3 m high weir would be only about 20 m wide to span the valley. This structure will produce a total head of about 32 m which will result in a potential power of 173 kW. Any structure higher than the 3 m high weir proposed here, in either of these two locations, would produce correspondingly larger potential energy.

A cost estimate for the construction of option 1(the more expensive of the two) is about $1,300,000. This price includes the cost of all of the civil construction and piping (weir, intake, headrace pipeline, forebay, penstock, power house, etc.) and supply and installation of all of the electro-mechanical equipment (turbine, generator, switches, accessories, etc.). Also included in this price are the costs for constructing the access roads for constructing the weir and power house, and the cost for providing the overhead transmission lines and transformers to the three major load centers of Butiaba, Bugoigo and Biiso.

There are presently three sources of drinking water available to the local inhabitants in this area. The two surface water sources, Lake Albert and River Waki, are both contaminated with varying amounts of coliform bacteria. The third source, deep wells, produce water that the local people dislike to drink because they report the water "tastes salty."

The study unfortunately did not find any protected source (spring) coming out of the escarpment which could be developed for use in gravity flow system. It was therefore decided that the River Waki would be used for this purpose, and that water for this system will come from the same intake structure used for the mini-hydro plant. From there, which will be over 30 m above the valley, the water will be transmitted by pipeline to a water treatment plant, which will be located on the elevated area between the escarpment and Butiaba. From there it will flow to consumers by gravity.

The proposed water treatment plant will be as simple as possible to reduce costs of construction, operations, and maintenance. It will basically consist of a gravity settling tank and a slow sand filter. From the slow sand filter, the finished water could be stored in a clean water ground reservoir at the treatment plant, or alternatively transmitted by gravity to an overhead reservoir which could be constructed somewhat closer to the consumers in Butiaba and Bugoigo. This latter option would allow a slightly smaller sized pipeline to be used from the water treatment plant to the reservoir and then on from there to the consumers. The final decision as to which of the two options will be selected, will depend on a detailed ground survey and donor preferences. DANIDA has already provided $100,000 towards the construction of a gravity flow system.

The section on irrigation is less well defined because the entire concept of irrigated agriculture in this area will require careful development if it is to be sustainable. This is mainly because there seems to be a general lack of visible agricultural activities in the area around Butiaba, and because nearly all of the local inhabitants are engaged in some activity associated with fishing from Lake Albert. Based on experience from other irrigation projects in Uganda and other parts of Africa, some of which are presented in this paper, the study concentrated on utilizing what has been learnt from those experiences to develop a number of parameters which should be taken into account in developing an irrigation program for this area.

The consultant recommends that whatever scheme is ultimately adopted, it should be developed in incremental steps as much as possible. It should include establishing test plots using improved farming techniques, where the local farmers can be encouraged to physically participate and learn by doing. The system should also have a bottom-up approach, with minimal external control, giving the farmers the opportunity to initiatives as they gain confidence in new methods. The farmers need to feel that the irrigation scheme is theirs. The irrigation system should be appropriate, efficient, and one which can be realistically maintained by the local people with minimal recurring costs. The step by step developing scheme should also include provision for providing training for local extension workers, rather than relaying mainly on external experts, and for the providing access of the farmers to tools, improved varieties of seeds, fertilizers, and other inputs.

INTRODUCTION

Background

ACDI/VOCA, through implementing the Environmental Protection and Economic Development (EPED) Project in Masindi, Uganda, commissioned a study in Masindi District to improve the social conditions and economic base of inhabitants living in and around the Butiaba area of Lake Albert. A study into the feasibility of the Project has been funded by USAID and undertaken by Nathaniel R. Richardson, Ph.D., an outside consultant from the United States.

Objective

The study's general objective is to seek ways of harnessing the natural potential of the River Waki, as it flows over the escarpment into the Western Rift Valley. The specific objectives are as follows:

- evaluate the potential for constructing a mini-hydroelectric power plant, indicating recommended technology, possible power output and level of investment required;
- evaluate the possibility of an irrigation scheme for agricultural production in the flat lands of the Rift Valley along the eastern shore of Lake Albert; and
- evaluate the potential for a gravity water supply scheme for safe drinking water for the subsistence population near Lake Albert.

The Study Area

The study area is about 250 kilometers northwest of Kampala, Uganda on the eastern shore of Lake Albert (see Figure 1). The major village in the area is Butiaba which was once an important transit port for the East African Railroad. From this port, steamers were built and carried goods up the White Nile and across the lake into the Democratic Republic of Congo (formerly called Zaire.)

The town was inundated and generally destroyed in the early 1960s by rising water levels in Lake Albert, brought upon by the period of exceptionally high rainfall, which occurred over the entire East African subregion. Most of the physical structures in the town were destroyed, including the landing dock.

This natural disaster, coupled with the rising tide of African independence, caused most of the foreigners living there to leave and abandon the town, which was never rebuilt.

The area was gradually resettled by local people and migrants from up north around the White

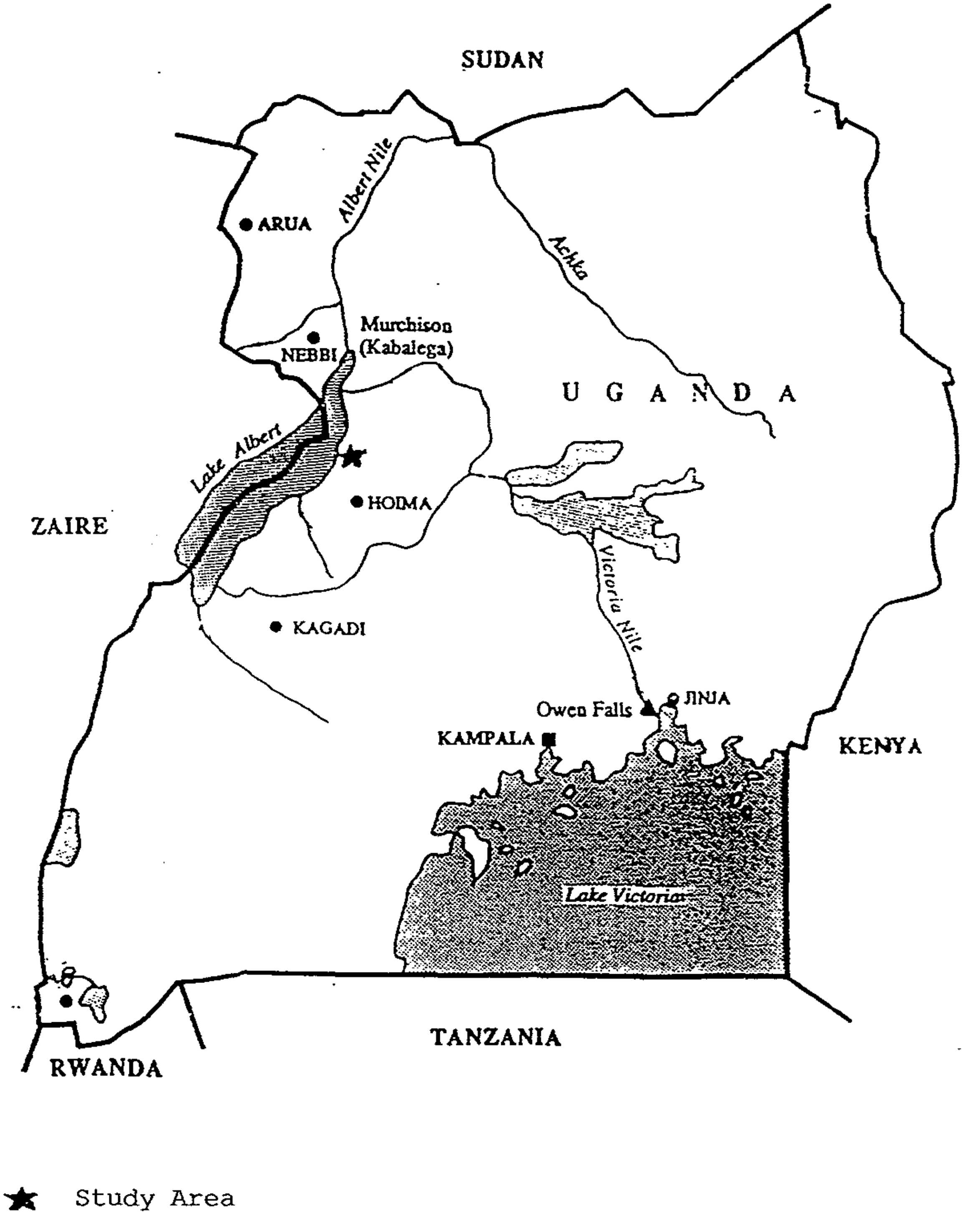


FIGURE 1: Map of Uganda showing our area of interest in Masindi District

Nile, and by Congolese (Zaireans) from across the lake, who had left their country because of insecurity. The major activities in present day Butiaba and the other nearby villages are fishing, some trading across the lake, and limited subsistence farming.

Geographically, the area of interest is bordered by the Wiki river to the south and the Waisoke river to the north. To the west is Lake Albert and to the east is the escarpment of the Western Rift Valley. Between the two rivers (see Figure 2), several villages have been established along the lake, depending almost entirely on the lake for their survival. As one travels towards the north, up the Rift Valley, our study area becomes restricted to the left side of the road going up the valley. On the right side of the road, is an area reserved as part of the Ugandan National Park system. Photo 1, taken near the sharp, hairpin curve in the road at the top of the escarpment (see Figure 2), shows the Rift Valley looking in a northern direction, with Lake Albert in the back ground. The thin line going up the center of the photograph is the road just mentioned. To the right of it is the Bugungu Wildlife Reserve.

Geology

Uganda is underlain by some of the earth's oldest rocks which were formed about 3 billion years ago. A major part of these older rocks have been modified and altered by later deep-seated mountain building movements, which extended throughout the Precambrian era into the beginning of the Cambrian era about 500 million years ago. Later significant rifting took place with the formation of the Western Rift system which runs the entire length of Western Uganda, where it constitutes the Lakes Edward, George, and Albert and the Ruwenzori Mountains horst block (Uganda Geology Map).

In our project area, the rocks west of the escarpment, within the Rift Valley, are collectively classified as the Western Rift Valley sediments. They are Pleistocene to recent in age and are thought to be up to 3000 m thick and consist largely of fine grained lacustrine sediments with lenses of coarser material. Their depositional history are closely associated with the faulting within the Rift Valley.

The rocks of the escarpment and those immediately east of it are collectively classified as undifferentiated gneisses. Lithologically they include biotite gneisses, banded migmatitic and granite gneisses, hornblende and amphibolite gneisses, metaquartizites and some ultra basic rocks. Further to the east, and underlying most of the River Waki catchment area, are rocks of the Bunyoro and Kyoga Series. These rocks are composed mainly of shales, phyllites, tillites, amphibolites with some quartizitic sandstones found in the Kyoga Series.

Seismicity

The Western Rift Valley runs through the western boundary of Uganda and is one of the most seismically active areas in the world. The eastern escarpment of this rift system has produced the waterfalls on the River Waki, which is the object of this investigation. The fault pattern of the

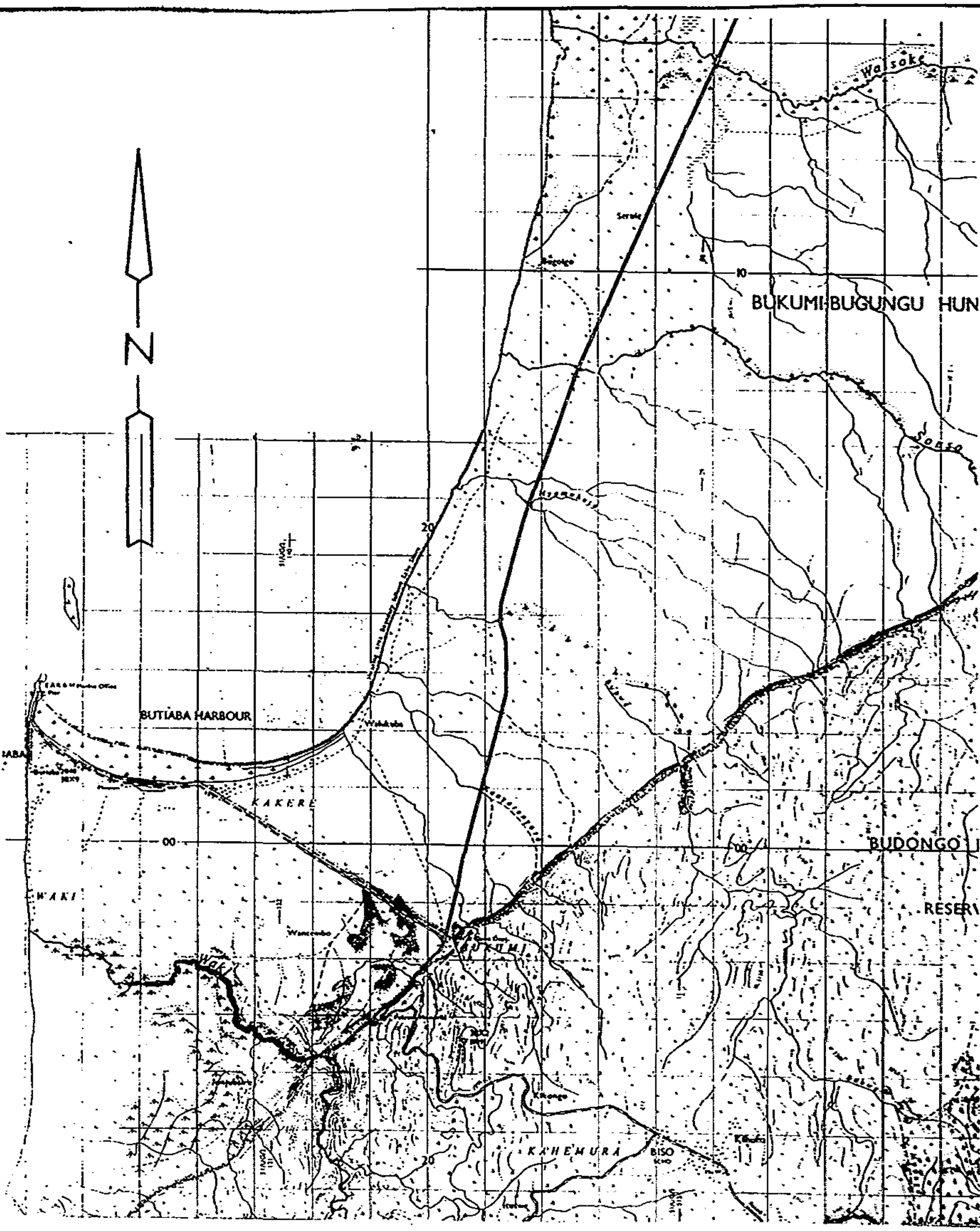


FIGURE 2: Map of the study area showing Butiaba Habour and the other villages along Lake Albert

Rift Valley is complex, especially near the Ruwenzori Mountains, where most earthquakes seem to originate. Although there has been many earthquakes in historical times, the most serious earthquake in Uganda in recent times, occurred in that area, near a place called Bundibugyo in 1966. It had a magnitude of between 6.7 and 7.0.

Near our immediate area of interest however, Maasha (1978), found when comparing the average daily occurrences of micro earthquakes recorded in various districts in Uganda, excluding the low level activities associated with the Kitugata geothermal area, that the Ruwenzori region is the most seismically active, followed perhaps by the Biiso-Masindi area, east of Lake Albert. This may be of significance if a large reservoir is ever contemplated along the River Waki, east of the escarpment, as will be mentioned later in this document.

RAINFALL

Uganda extends from latitude 1.5 degrees South to 4.0 degrees North and therefore experiences a truly equatorial climate. It has very small variations in temperature and humidity. Across the country, the rainfall pattern is generally bimodal, with peaks from March to May and again from August to November. Many regions have a relatively dry season from December to February. The bimodal rainfall pattern over much of Uganda is linked to the double passage of the Inter Tropical Convergence Zone (ITCZ). (Directorate of Water Development, 1995)

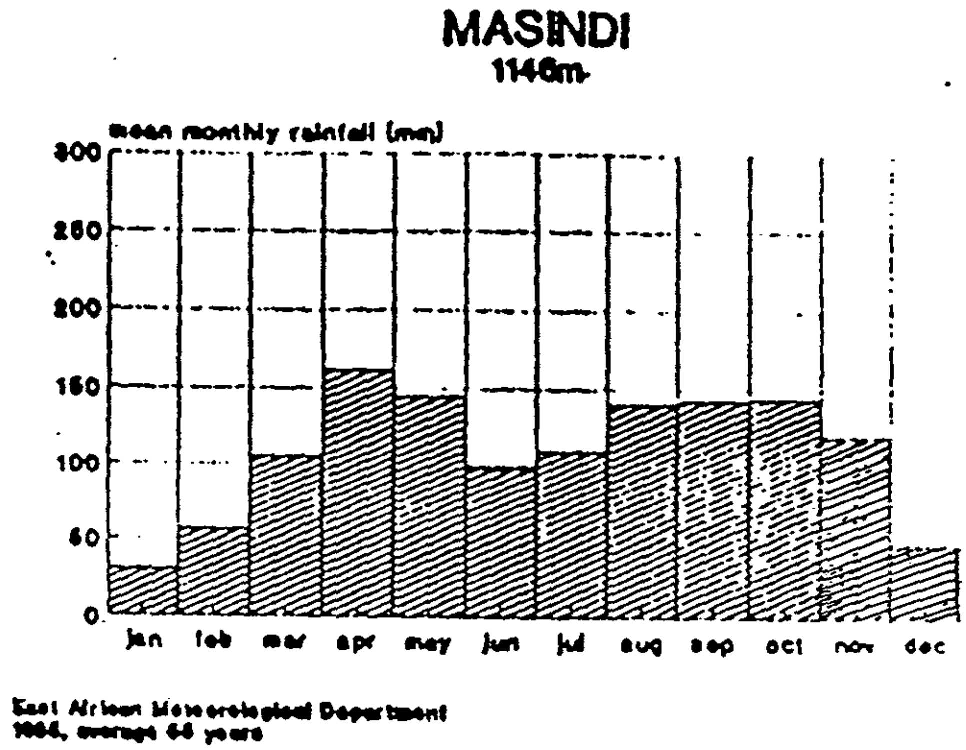
In addition to this, local variations in climate are dominated by topographic influences such as the lakes (Victoria in the south east and Albert to the west), and the mountains (the Ruwenzori range in the west and Mt. Elgon in the east). Generally rainfall is much higher in the south and southwest of the country which is consequently much richer agriculturally.

In our immediate area of interest, rainfall data shown in Figure 3, was obtained for Butiaba (elevation 630 m) which is some 8 km north west of the proposed mini-hydro site, and for Masindi (elevation 1160 m), which is some 40 km east of the site. Rainfall for the River Waki catchment area falls somewhere in the middle of the two probably being closer to that of Masindi than Butiaba. The isohyet (mean annual rainfall) map of the region, illustrated in Figure 4, shows a rather well defined low centered just south of the Butiaba meteorological station on Lake Albert.

HYDROLOGY

Available Records

Historical readings from gauging stations were available across Uganda, from a variety of stations up until the late seventies when the outbreak of civil unrest in the country disrupted the process. In our area of interest, the nearest gauging stations to the proposed intake on the River Waki are the Waki II station No. 85317 and the Waki I station No. 85316. There appears to be some confusion however, as to the exact location of the Waki II station. When we visited the



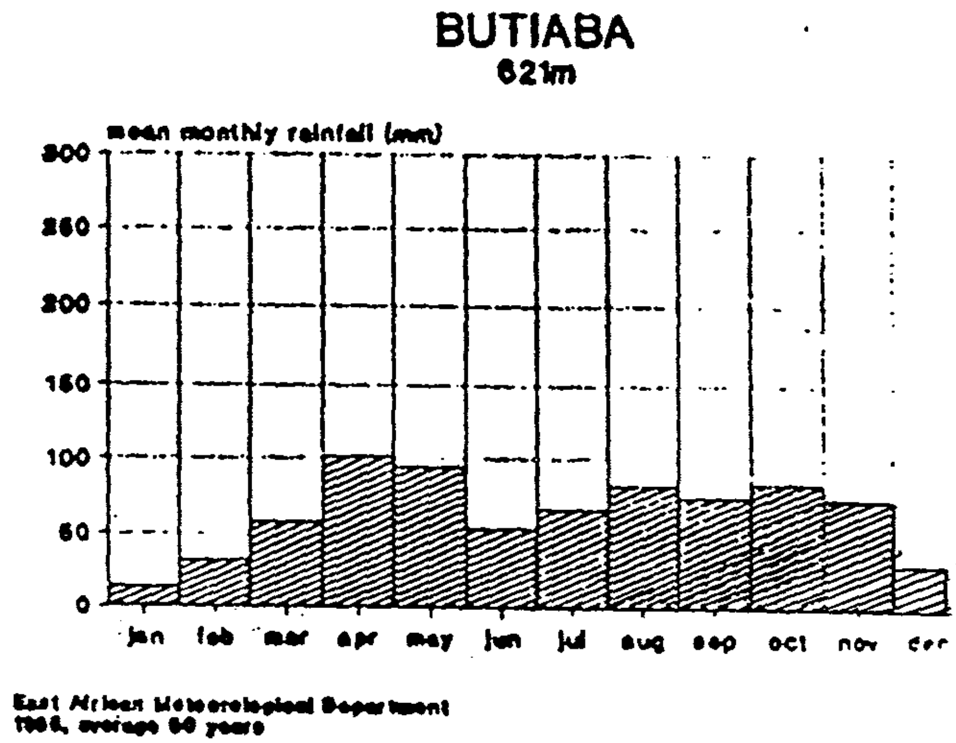


FIGURE 3: Rainfall Data for Masindi and Butiaba

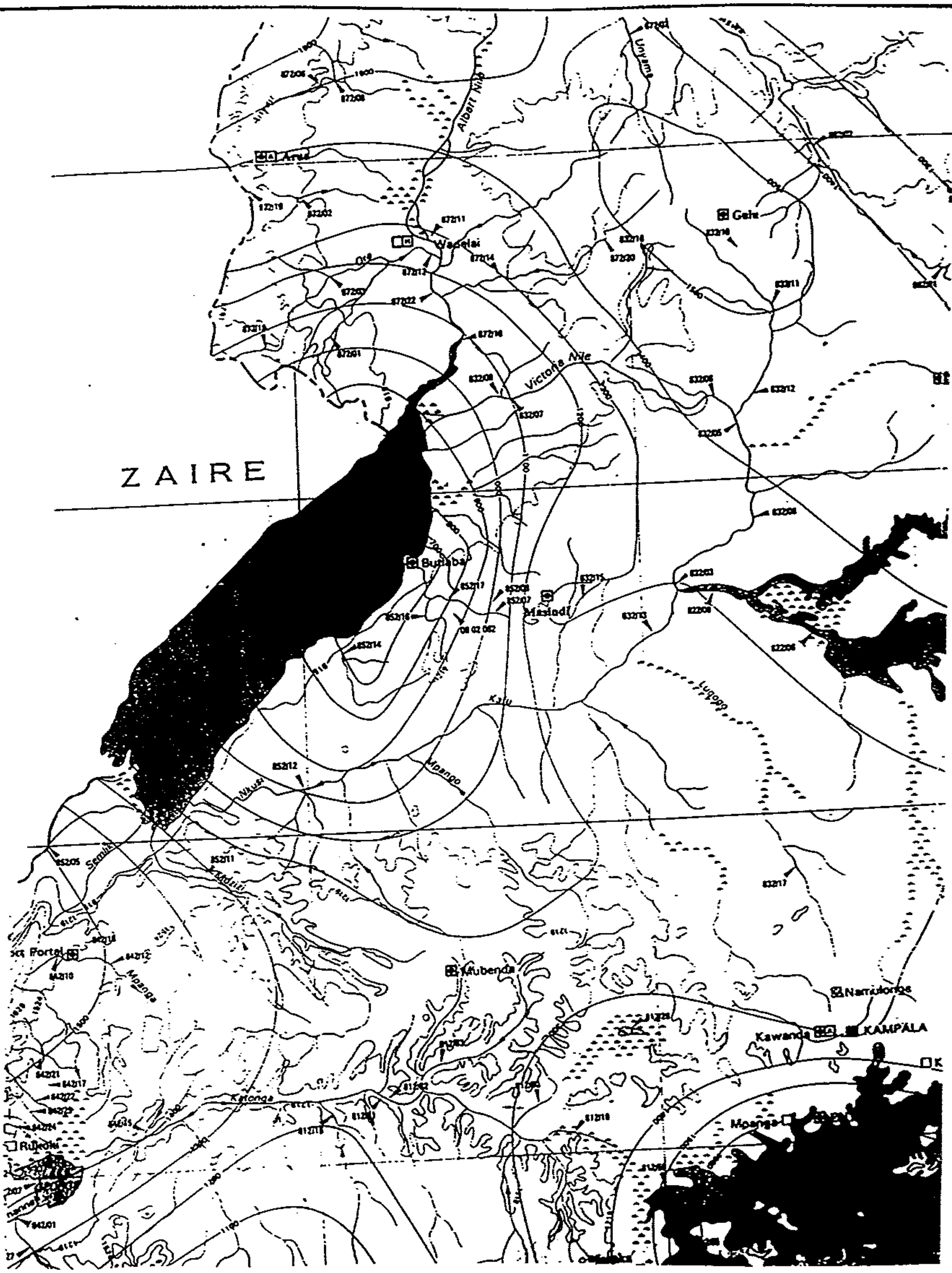


FIGURE 4: Isohyet Map covering the Study Area

station with the district hydrologist to read the gauge, we found that the station is slightly upstream of the bridge on the Hoima-Biiso road. There are no other tributaries joining this river downstream before it goes under the bridge. The Uganda Hydrological network map of 1974 shows that a second tributary on which the Waki I gauging station is located, joins that river before it goes under the bridge. This tributary of the River Waki system appears to originate north of Hoima to the south. In the Uganda Water Action Plan (4), prepared by the Directorate of Water Development(DWD), Waki I gauging station is reported as being in the Siba forest, which would put it to the north east of the bridge and not south as just stated.

Our concern is whether the gauging data recorded at Waki II represents flow from both tributaries as it would appear from on the ground, and hence includes the water from the Waki I catchment; or is the flow from Waki I separate and hence should be added to the flow being measured at Waki II. This latter consideration is important because it would significantly increase the available flow to the River Waki further downstream where we propose to site the intake for the mini-hydro system.

The situation is further confused by the report of Kennedy and Donkin Power Limited *et. al.* (1996), when they appear to completely ignore the flow from Waki II, referring only to Waki I, which is reported as having a catchment area of 238 sq. km. In their work, they used only Waki I in making their projections for a potential hydro electric power plant on the River Waki, some distance down stream below the Hoima-Biiso bridge. The data sheet for daily flow measurements supplied by the Directorate of Water Development indicate that the catchment for Waki II is 523 sq km, about 45% larger than the Waki I catchment.

If this is not confusing enough, if one looks at the approximate location of where Waki II would be located on Figure 4 (1:5000,000), it would appear that Waki II is on the Siba River and not on the River Waki at all. Be it as it may, the River Waki where we intend to construct our intake is a perennial river, with tributaries that originate in the Nyamirima hill area north of Hoima, in the south and southwest of Masindi, just south of the Budongo Forest to the east.

THE RIVER WAKI MINIHYDRO PROJECT

Bringing electricity to rural areas has occupied an almost mythical status in development theories. Some states, for example Bangladesh, have gone as far as providing constitutional guarantees for electric power for each village (Deudney 1981). Yet today only a very small percentage of the people in Third World nations live in areas with electricity. With cost of grid-based systems rising rapidly, this situation is unlikely to change in the foreseeable future.

In Uganda, demand on the existing national grid is extremely high and growing daily, with many extensions planned by the Uganda Electricity Board (UEB). Numerous studies have been commissioned, both public and private, for the expansion of the system and development of smaller or micro hydropower sites. However, it will take decades before the national grid can adequately cover the country, especially those areas at the extremities of the system.

In this light, this feasibility study is being conducted to evaluate the potential for providing power, from the River Waki, for the inhabitants living in the area of Lake Albert near Butiaba. If sufficient power can be generated from the site, other communities will be considered for inclusion in this local network.

Hydropower systems are classified by their power output capacities. Mini-hydros, the subject of the first part of this feasibility study, generally range from 100 kW to 1500 kW (6), which is enough electric power for a medium-sized town or for a whole rural region. Because mini-hydros can produce the same constant-frequency alternating current (AC) electricity as larger electric power systems, they can be interconnected with the larger hydropower system or grids.

One recent study completed in 1996, by Kennedy and Donkin Power Limited et al., attempted to identify all rivers in Uganda with sites capable of producing 50 MW of power. During the study, they worked in conjunction with the Ugandan Directorate of Water Development (DWD), which had earlier entered its entire database onto HYDATA, the UK Institute of Hydrology data processing system, and derived mean annual runoff and flow duration analysis for the entire database.

Using different relationships such as elevation/area/volume which they computed using 1:50,000 scaled topographic maps, and studying total storage volume which could be sustained for 95% of the time, they concluded, among many other things, that the River Waki possesses the requisite high natural head and suitable dam site, to generate a reliable power potential of 17 MW. The location of their proposed dam was indicated as 1 degree, 47 minutes North latitude and 31 degrees, 22 minutes East longitude. The exact location of this site is unclear on the map using these coordinates, however it would appear that it is quite close to the escarpment of the Western Rift.

They suggest that such a dam would be between 83 and 93 meters high. A structure of such size is beyond the scope of this present study, however with the Western Rift being still very much active, one might caution against erecting such a structure so close to an active fault system. As stated earlier, the area near Biiso and Masindi, is quite active seismically. Coupled to this, the relationship observed between mass loading by water and earth quake frequencies shown associated with both Lake Albert and the Aswam dam (see Figure 5 for the Lake Albert example), would suggest that a structure of such magnitude, in that location might not be advisable.

In evaluating a site for hydroelectric power generation, irrespective of its size, the key parameters are head and flow. Head is fixed and is a function of the topography, whereas flow is a continuously changing variable that depend on rainfall patterns and the physical characteristics of the river's catchment.

FLOW, HEAD AND ENERGY ESTIMATES

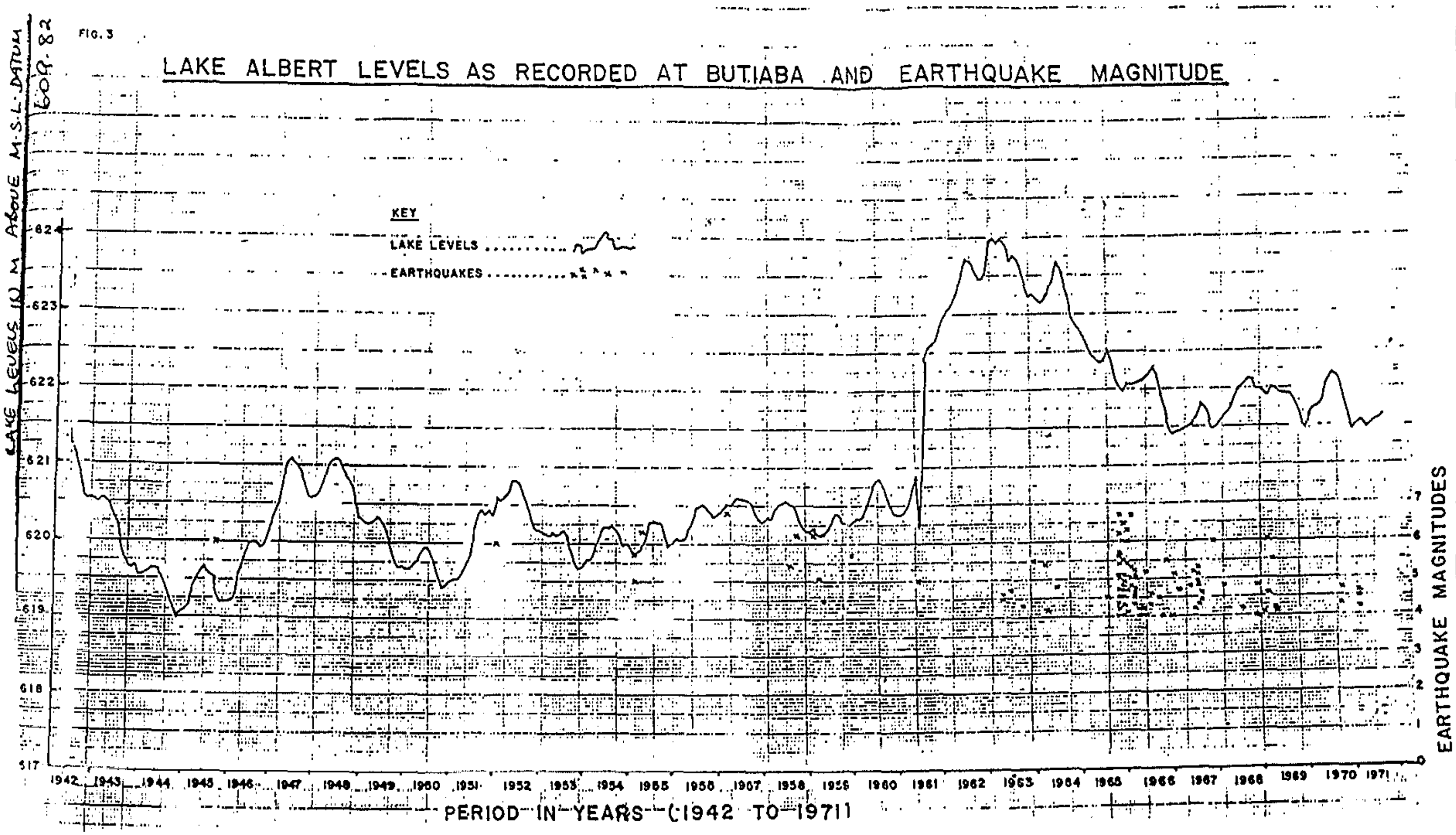


FIGURE 5: Relationship of Earthquake Frequencies to Elevated Water Level in Lake Albert

In carrying out this feasibility study, the assumption is made that Waki II represents the gauging station near the bridge on the Hoima-Biiso road. That station therefore represents the flow from both the Siba river which flows from the Budongo forest in Masindi District, and the River Waki which starts in the Nyamirima hill, north of Hoima. Table 1 is a summary of the annual flow at the Waki II station representing the years 1968 to 1979, which represented the last period of uninterrupted readings at this station. Figure 6 is a bar graph of the numbers indicated in Table 1. The daily flow measurements covering this period are presented in Appendix B, and Figure 7 illustrates the daily flow duration curve calculated from those numbers.

The Waki II station is about 11 km upstream of the proposed intake. The 95% exceedence flow, that is the flow which is exceeded 95% of the time on average, an amount often used in calculating minimum power generating capacity of mini-hydro power systems, is 1 m^3/second. A minimum flow reading of 0.684 m^3/second was measured at this station on February 6, 1997 by the district hydrologist Mr. Waako, who reported that this was the lowest he had seen this river (oral communication).

Because the proposed intake is quite far down stream from the gauging station, it was decided to attempt to determine, what added flow might be available to the river at the intake, as a result of the extra catchment area between the Waki II station and the intake site. The extra catchment area between the Waki II station and the proposed intake was estimated at being only about 35 sq. km, less than 1% of the total Waki II catchment above the bridge. It was decided that very little additional water is added to the river by the time it reaches the area of the proposed intake, therefore the 95% exceedence flow at the Waki II station will be used in the Power Equation in determining the power potential for the site. Using the simple power equation of:

Power (kW) = Gross Head (m) x Flow (m/s) x System Efficiency x C

where C is a constant representing the acceleration of gravity (9.81 if metric units are used).

Overall, system efficiency will range between 42% and 62% with a well-designed system achieving an average efficiency of 55%. The turbine manufacturers will be able to provide a closer estimate of the potential power output for their turbines, given the head and flow condition of our site. For our preliminary estimate however, we will use a figure of 55%.

Photo 2 is taken from the Rift Valley between the water falls and Butiaba on the lake shore and shows the River Waki gorge which has been cut into the eastern flank of the rift escarpment. Photo 3 is taken about 100 meters from the base of the escarpment and shows the waterfalls which have been created by the River Waki as it descends the escarpment. From the base of the lower falls to the upper falls is about 29 meters.

In the present study, two sites have been selected for run-of-the-river schemes. One is to construct a low weir (2-3 m high), about 300 m upstream above the falls on the escarpment.

TABLE 1: SUMMARY OF ANNUAL FLOW MEASUREMENTS FOR THE WAKI 11 GAUGING STATION

Water Development Department
Summary of monthly data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
1967	-	-	-	-	-	-	-	-	-	-	4.636	2.939	-
1968	1.612	1.614	1.310	2.098	4.090	2.519	1.674	2.727	2.602	2.517	2.501	3.257	2.423
1969	2.479	2.237	2.298	1.520	3.661	2.195	1.726	1.588	2.019	2.554	3.455	5.162	2.593
1970	2.227	1.546	2.090	4.275	3.586	2.334	2.410	3.681	3.382	5.435	4.200	2.554	3.193
1971	2.091	1.432	1.498	2.871	3.045	1.988	2.429	2.564	2.717	3.268	2.952	1.670	2.382
1972	1.360	1.191	1.239	-	3.101	2.527	1.358	1.597	2.287	-	7.529	5.223	-
1973	3.019	2.256	1.391	2.267	2.621	2.079	1.549	2.098	2.460	2.695	2.613	1.494	2.261
1974	1.131	.831	1.109	1.733	2.001	2.383	3.432	2.123	3.337	3.292	2.826	1.593	2.155
1975	1.067	.954	.380	2.615	1.537	1.489	-	3.866	6.167	6.716	4.553	2.782	-
1976	1.730	1.497	1.359	2.868	3.217	3.535	4.305	3.867	3.609	2.560	2.768	1.885	2.774
1977	1.682	1.020	1.157	2.873	3.472	2.363	2.405	2.641	3.221	3.389	4.496	2.939	2.645
1978	1.642	1.517	2.384	3.532	4.261	2.272	2.851	3.283	4.019	5.554	8.352	5.085	3.739
1979	4.189	3.942	2.332	3.378	2.973	3.358	1.850	2.374	2.676	3.720	2.659	1.456	2.942
Mean	2.024	1.674	1.729	2.730	3.130	2.420	2.363	2.709	3.250	3.791	4.119	2.926	2.742
Median	1.682	1.497	1.498	2.868	3.101	2.334	2.405	2.564	2.717	3.292	3.455	2.782	
Maximum	4.189	3.942	2.332	4.275	4.261	3.535	4.305	3.867	6.167	6.716	8.352	5.223	
Minimum	1.067	.831	.380	1.520	1.537	1.489	1.358	1.597	2.019	2.517	2.501	1.456	
St. dev.	.883	.847	.534	.812	.793	.556	.893	.803	1.118	1.447	1.981	1.410	
CV	.44	.51	.34	.30	.25	.23	.38	.30	.34	.38	.46	.48	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

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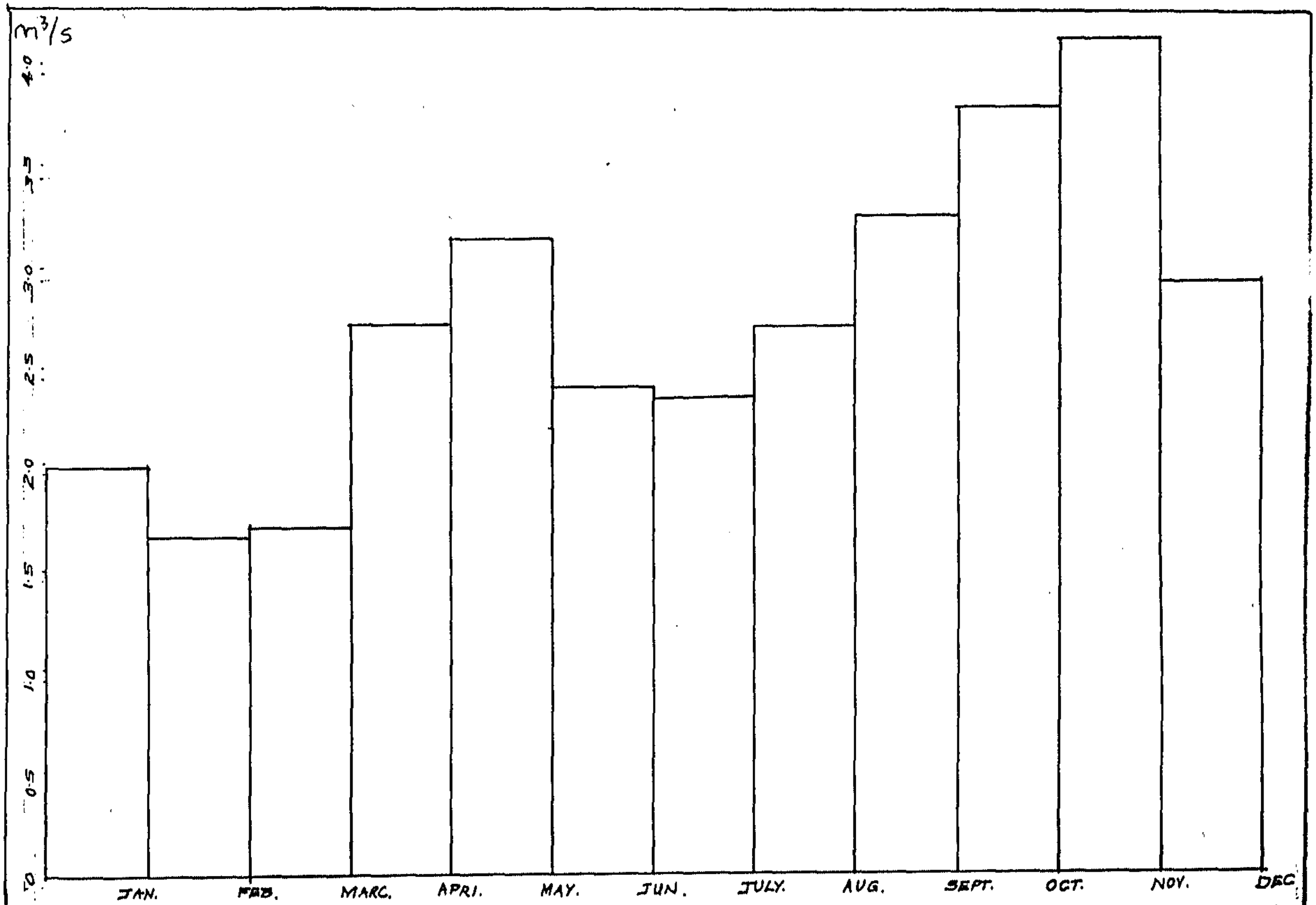


FIGURE 6: Mean Annual Flow Hydrograph

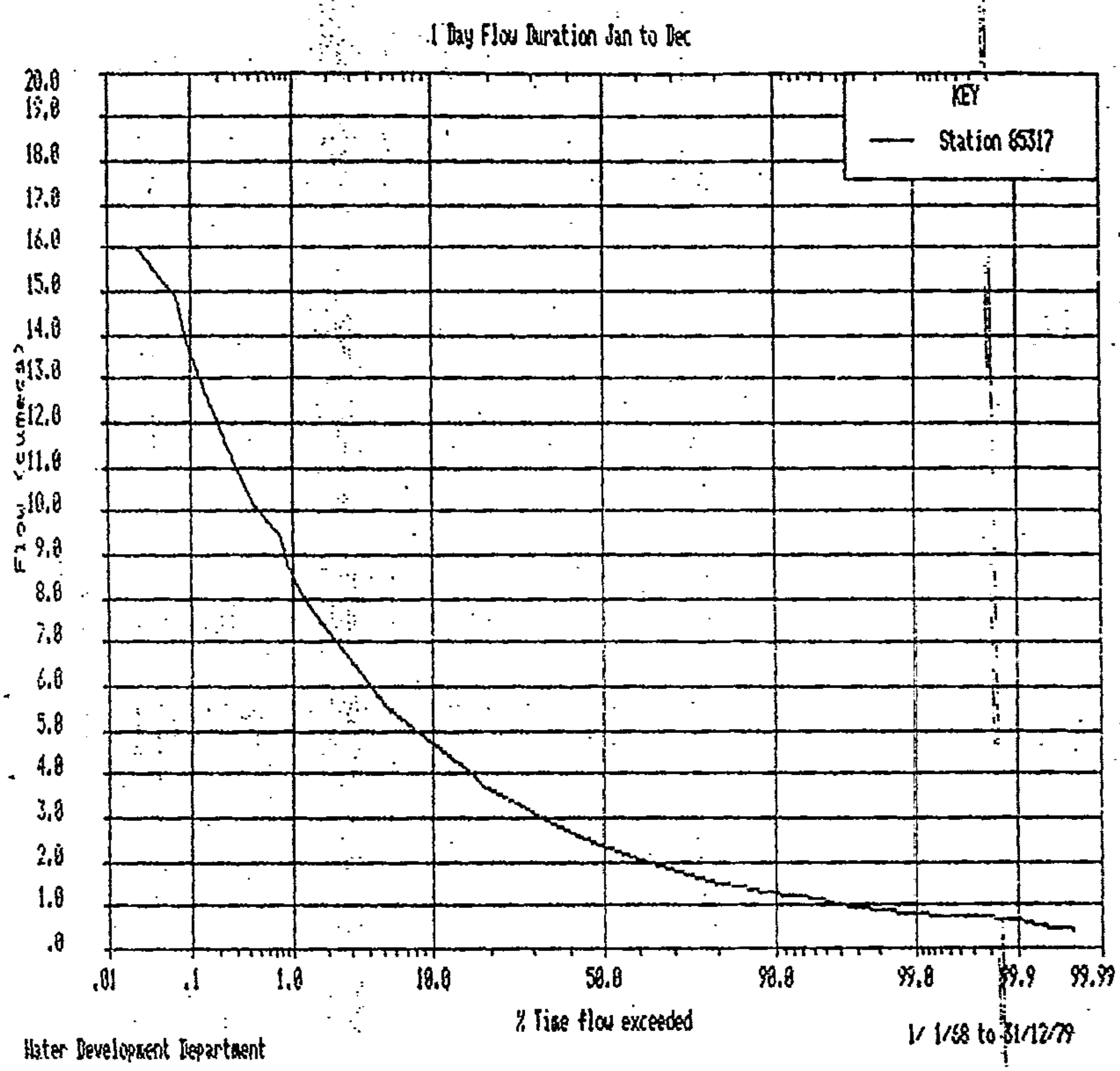


Figure 7: Flow Duration Curve for Waki II Gauging Station

PHOTOGRAPH 1: View of the Rift Valley looking North, taken from the top of the Escarpment

PHOTOGRAPH 2: View of the River Waki gorge looking towards the southwest from the Rift Valley

This structure will be about 40 to 50 m long and will give a head of about 42 m. The other run-of-the-river intake structure would be to construct a similar weir (same height), at a location just behind the upper falls on the escarpment. This structure will give a head of about 32 m. The minimum power levels generated by the two different sites, using a run-of-the river scheme with very little reservoir, and a flow of 1 m/s are presented in Table 2 below. Another possible scenario, is to construct larger structures at the two sites. For example an 8 m high weir at the upper site, and a dam (about 15 m) high at the falls. In both of the latter cases, this will significantly increase the utilization factor of the water, and hence the output power capacity of the systems. It will however carry with them the many environmentally related problems associated with such reservoirs. Either of these two latter options will require considerably more time to get off the ground, therefore except for determining the minimum potential power they could generate, they will not be investigated further in this feasibility study. Table 2 also indicates the potential energy output of these two structures.

The potential storage that the two bigger structures could generate is difficult to determine at the present time because of the lack of an adequately scaled map of the site. Therefore in determining the potential energy outputs for these structures, the mean annual flow measurement of 2.742 cubic meters per sec. rather then the 1 cubic meter per sec. (95% daily exceedence) figure will be used. As with the smaller structures, we can either increase the power by doubling the numbers of turbines or as in the case of a Pelton turbine, we could simply double the number of nuzzles striking the runners (Inversin 1995)

Photo 4 and Photo 5 both show the gorge of the River Waki above the falls. The former is looking upstream from behind the top of the escarpment towards the general location of the upper weir site and the latter is looking downstream towards the escarpment from the same location. The falls are around the corner to the right on Photograph 5.

Table 2 shows possible energy calculations for the different options just stated.

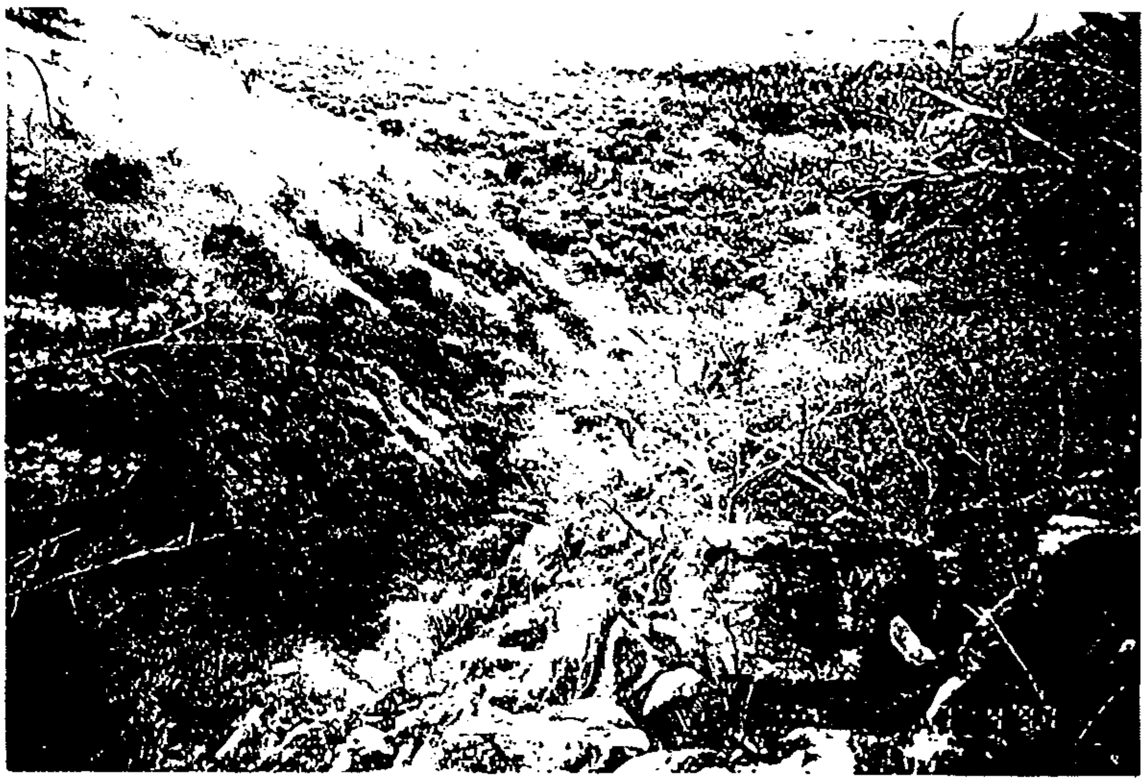
	OPTION			
	Upper weir	Low weir	large weir	Dam
Head (m)	42	32	47	45
Flow (m^3/s)	1.0	1.0	2.742	2.742
Power Output (kW)	226	173	700	650

Table 2: Potential power based on 95% exceedence (1 m^3/s) for the smaller weirs and mean annual flow of 2.742 m^3/s for the larger structures.

All of these energy outputs are probably very conservative because in each case the reservoirs

PHOTOGRAPH 3: View of the River Waki Falls where the river comes over the Escarpment

PHOTOGRAPH 4: River Waki gorge above the Escarpment looking upriver



PHOTOGRAPH 5: River Waki gorge looking down river towards the Escarpment

created by the weir or dam will allow a flow greater then those used in the calculations above. Those numbers may be used as minimum power outputs.

In either of the upper weir construction schemes, a headrace would have to be constructed to run along the north wall of the gorge. Because of the possibility of falling debris or sediment runoff clogging a potential trench which could serve as the headrace, we recommend some type of pipe be used to convey the water from the intake structure to the surge tank or forebay. This will be discussed below.

Because access to this area of the gorge is difficult, an access road from the main Biiso-Butiaba road to the proposed construction site will have to be constructed. This road will probably needed to be put in anyway, even if this scheme (weir) is not ultimately the one selected, because if power is to be supplied to Biiso, as it is being proposed, that road would provide the shortest route there from the power plant below the escarpment. It would then serve as a service road for the power line. This road would also be useful in the construction of the weir or dam at the top of the falls. The alternative is to get to the area of both sites the weir from the valley, in front of the escarpment. In all cases, even for the run-of-the-river schemes, accessibility to either sites will be difficult, especially to the top of the falls.

The different components of the two possible schemes and the approximate costing of the two run-of-the-river schemes are presented below. The exact dimensions, distances, design and costing for either of these schemes will be done during the pre-design and design phase of this project.

COMPONENTS OF THE MINIHYDRO SYSTEM

WEIR AND RESERVOIR

The main option being considered in the run-of-the-river scheme is to construct a weir (2-3 m high) in one of two locations across a section of the River Waki valley. The two sites are across some rapids about 250 to 300 meters away from the escarpment, and immediately behind the top falls at the escarpment. The main function of the weir will be to raise the river water level to the required height in order to hold the flushing device, sand excluder and other components of the intake arrangement. Its secondary function will be to create a very small reservoir which will increase the potential power output and optimize operations during low flow in the river. Its third function is to accommodate an overflow spillway. The weir will be constructed of rock and concrete, to a designed maximum height of 3 meters. It will have at least three flushing gates installed in it to remove sediments that will accumulate behind it from time to time. The weir profile and generalized cross section are shown in the Figures 8a and 8b respectively. Although it has already been mentioned, it is worth repeating that it is very difficult, because of the lack of a detailed map of the river valley in this area, to estimate, with any degree of accuracy, the possible volume of water which might be stored by either of the two structures at those two locations.

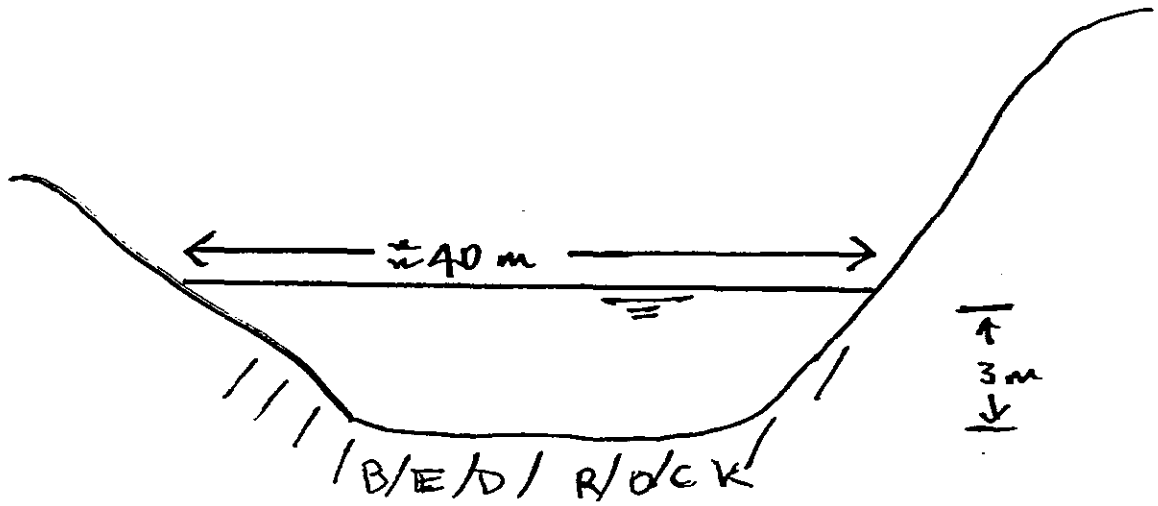


FIGURE 8a: Generalized Weir Profile

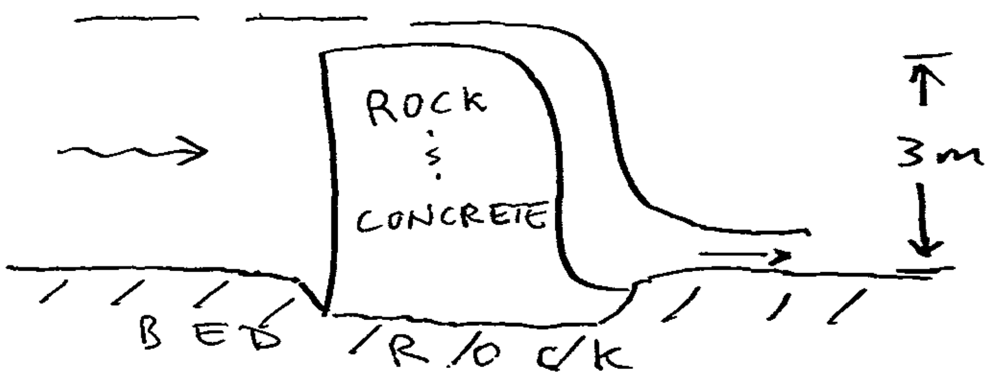


FIGURE 8b: Ogee Crest Type Weir

The shape of the weir will be of the Ogee crest type as illustrated above in Fig.8b. The foundation for the weir will be the bedrock at the small rapids upstream or again on bedrock immediately behind the top falls. Photo 6 shows the small pool just behind the top falls. In this location the valley bottom is only about 15 to 20 meters wide.

The reservoirs created by either of the two small weirs will not be very significant in terms of their environmental impact, however if either of the larger structures are ever contemplated, their impact could be significantly different, possibly having international ramifications. It has been said that, by their very nature, "dams do not contribute to economic development in a net sense unless their benefits are larger than their costs, where costs include environmental damage." (World Bank, 1995) This statement might become appropriate in the future, if it ever becomes desirable to create a larger storage reservoir further up the River Waki, which would then allow the turbines to operate at a greater capacity and generate more peak power throughout the year.

INTAKE, DESANDER AND HEADRACE

For the upper weir, the intake and desander structures will be constructed off the weir on the solid bedrock forming the rapids. From there, the headrace will go along the north valley wall, to an area near and above the location of the upper falls at the escarpment. It will need to follow a height considerably above the falls to take advantage of the extra head which the upper site provides. The conceptual weir, intake and desander is modified from a similar one in a report by Norconsult (9) and is illustrated in Figure 9.

If the site just above the falls is selected, only the intake and desander structure will be constructed off the weir and no headrace will be necessary.

It is not certain how much sediment is carried by this river. Dr. Nick Mandeville, consultant to the Directorate of Water Development (DWD) in Entebbe, does not feel it is a large amount, especially since one of the major tributaries of this river, the Siba, originates in a heavily forested area, which will have the tendency to restrict erosion. During one occasion while we were gauging the River Waki below the escarpment, it started to rain. In a matter of minutes, the river became very angry and appeared to carry a great deal of suspended matter. From that one experience, it is expected that during the rains, the sediment load carried by this river might be significant. If this is the case, it could cause significant silting of the reservoirs. It will probably be necessary at some point in the future to try to determine how much sediment does come down this river during the rainy season, because this can negatively impact the life of the reservoir. The high sediment load will also produce a lot of wear on the pipes, valves and especially the turbines.

To avoid this possibility, a desander (settling basin) will be included in the intake design to remove particles exceeding 0.3 mm in diameter. This unit works simply by letting the water travel at low velocity along the basin, thereby permitting the larger particles to settle to the

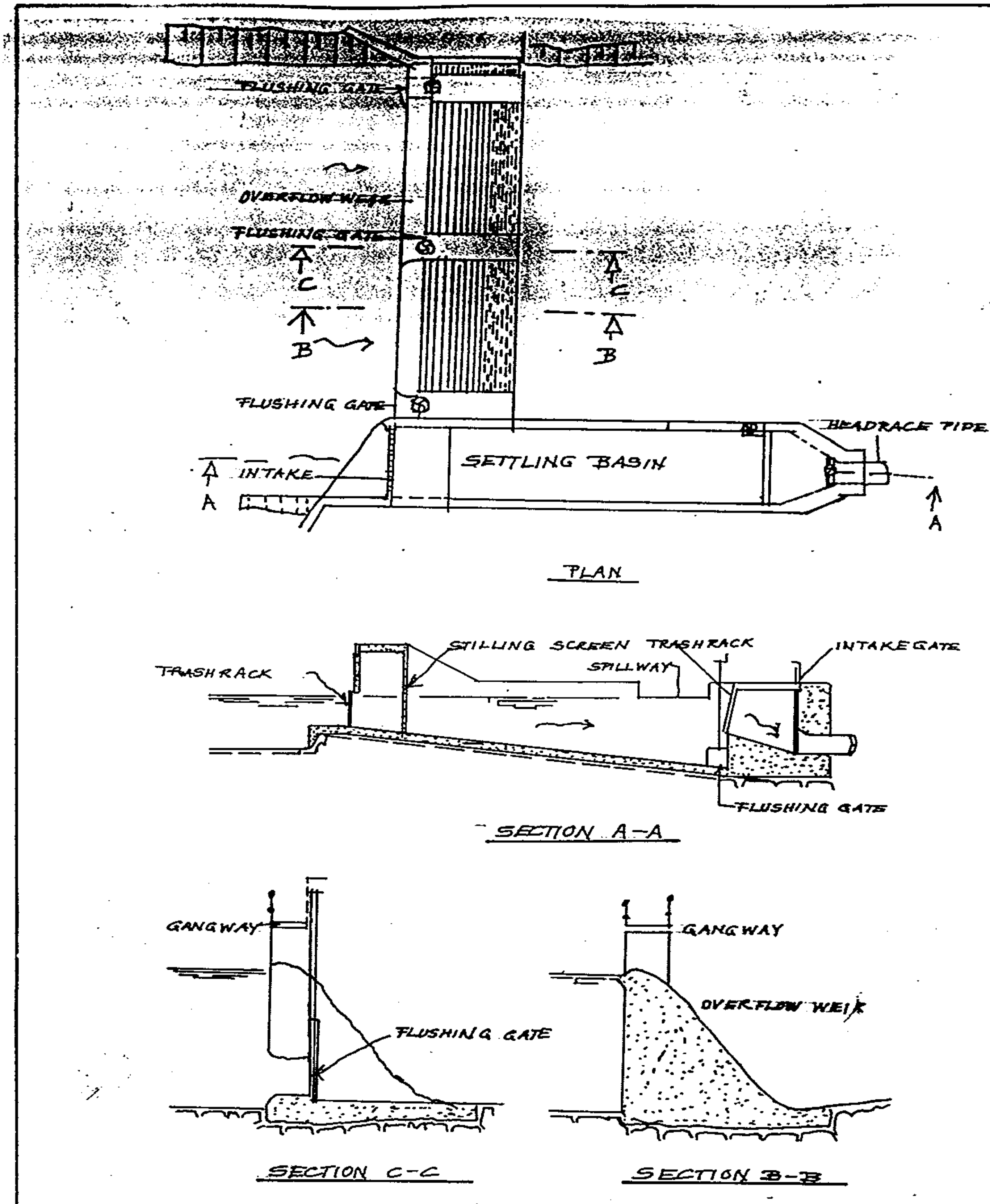


FIGURE 9: Conceptual Intake and Desander Layout

PHOTOGRAPH 6: The small pool at the top of the upper falls

PHOTOGRAPH 7: The River Waki falls indicating the probable location of the proposed Penstock

bottom. A bypass channel could also be designed in the desander to allow for maintenance in the dry season, without having to stop the operation of the system. During the dry season, cleaning of the desander is expected to be required only occasionally.

A movable trash rack will be designed for the intake (slanting downstream) which will prevent floating material from entering and subsequently clogging the channel piping. The trash rack will be designed to withstand the hydrostatic pressures at designed flood levels and floating objects which might come down the river.

Because of the very steep hill sides associated with the river valley in this area, the headrace will be constructed of either a pressurized fiber-glass or metal piping rather than simply an open channel. In this case, a pipe will have the advantage over an open channel which would quickly fill up with debris and sediments from surface erosion. In addition to this, the pipe will eliminate components such as spillways, drop structures and drainage which are usually incorporated in the designs of such canals. It also does not need to be completely level, but can follow the rise and fall of the terrain it traverses. The pipe will be anchored onto concrete monuments which will themselves be anchored into the bedrock along the north wall of the valley. The diameter of the is 900 mm and the length is estimated to be about 300 m. Head loss will be limited as much as possible to pipe friction losses only.

SURGE TANK OR FOREBAY AND PENSTOCK

A surge tank may be incorporated into the system, depending if the final design of the system will permit the use of a lower pressure pipe for the headrace. This will protect such a pipe (low-pressure) above the tank from high internal pressures caused by rapid valve closure. Because it will reduce upstream pressure fluctuations, it will permit the use of lower-cost, low-pressure pipes. It will also limit the immediate change of pressure at the turbine by a sudden stop or start, such as water hammer effects. Depending on the exact location chosen for this unit, and for reasons of cost, it might be designed to be inclined up the valley side (i.e. pipe), rather than be a free standing tank.

Another possibility for this scheme, might be to construct a tunnel through the escarpment, rather than going around it in the area of the falls. The tunnel which would probably be much more expensive, could then exit on the west side of the escarpment, from where it would go directly into the penstock and down into the powerhouse.

Because this project is also expected to provide water for the gravity flow and irrigation systems, it will probably be preferable to construct a forebay instead of a surge tank or surge pipe. The exact location of such a structure will be determined prior to the final design of the system. From the forebay, individual pipes, dedicated to each of the three systems (power, water and irrigation) would then run down the escarpment, to where those respective systems are to be operated (these are discussed in the other two parts of this report). Alternatively, intakes for each system can be taken off the surge tank, which will need to be constructed somewhere above the falls. If the tunnel option is considered, intake for each system would be near where the tunnel exits the escarpment. Regardless of which option is chosen, the headrace pipe will need to be sufficiently sized to bring enough water from the weir along the valley, to adequately supply all three schemes.

The penstock will simply be a pipe to convey the water, under pressure, to the turbine. When the flow of water in the turbine is increased or decreased, an immediate pressure difference is created in the penstock. The elastic pressure wave (water hammer) in the penstock should not exceed 20% of the gross head of the turbine.

The penstock will be constructed of welded steel pipe or pressurized fiber glass, and will run above ground resting on support blocks, down the western face of the escarpment. The blocks will themselves be secured on anchor blocks that are founded on rock. Drainage channels will be provided to protect the support and anchor blocks from erosion. The total length of the pipe will be about 250 m, and will have to span the small dry valley of the seasonal stream which is located below the escarpment in that area. Photo 7 is taken from the south side of the river, and shows roughly where the penstock pipe might run from an area above the upper falls to the right. Figure 10 illustrates, on the topography map of the area, a conceptual layout of the possible scheme that is proposed coming from the top weir to the powerhouse.

POWERHOUSE

The powerhouse will contain the turbine generating plant and the associated mechanical and electrical equipment. The location of the powerhouse is also indicated on Figure 10. Photo 8 is taken from the top of the escarpment and shows the Rift Valley with Lake Albert at the very top of the picture. The powerhouse is to be constructed roughly at the location just below the center of the photograph where the white pickup is. That site for the powerhouse has been chosen for the following reasons:

- It will provide minimum disturbance to the natural river flow by the tailrace, which is planned to be discharged into the small seasonal dry stream valley.
- It will be protected from flooding by both the main river (Waki) and its seasonal tributary.
- It will be protected from the possibility of landslides off the escarpment.
- It will require a minimum amount of clearing and excavation work.
- It will have easy access. A location closer to the escarpment would reduce the length of pipe for the penstock by about 75 m, however it would require that a small bridge be constructed across the seasonal tributary which enters the River Waki just below the falls (see Figure 10).

The powerhouse will be designed to provide enough space for storage, a toilet/wash room, and with sufficient clearance and space for the maintenance of the plant. The superstructure will need to incorporate an overhead crane and gantry and have all of the necessary domestic

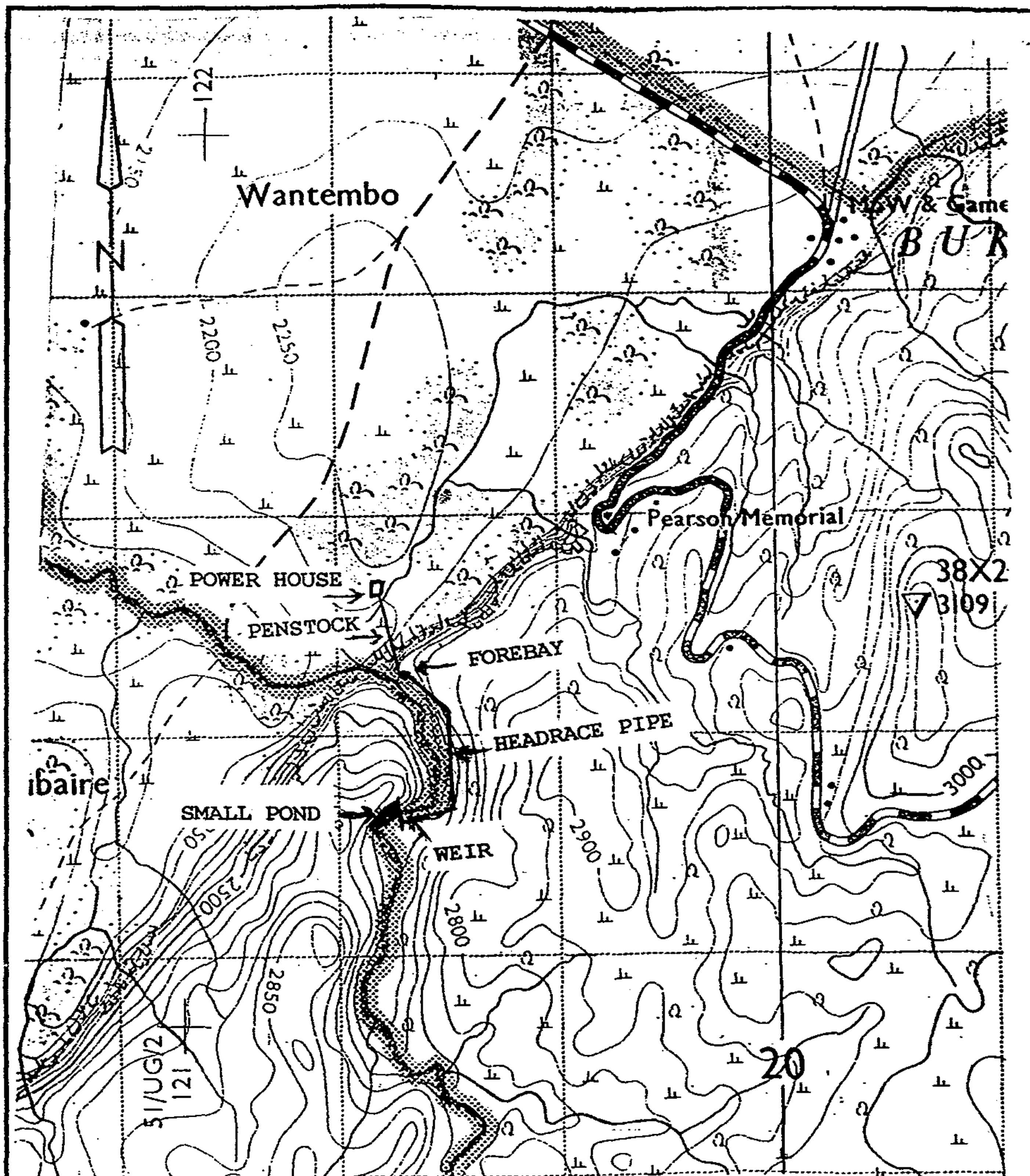


FIGURE 10: Conceptual Layout of the Mini-Hydro Scheme from the Upper Weir to the Power House

electrical wiring. Transformers will be located outside the powerhouse in a small fenced compound.

The design of the powerhouse will also need to include various related features, such as a septic tank, area for parking, a small overhead water tank for washing water and a perimeter fence. All attempts will be made to have the facility blend in with the natural environment.

TAILRACE

The tailrace will return the water from the turbine back into the river via the channel of the seasonal stream. The outfall from the tailrace will be protected against erosion by rip-rap or gabions.

ELECTRO-MECHANICAL EQUIPMENT

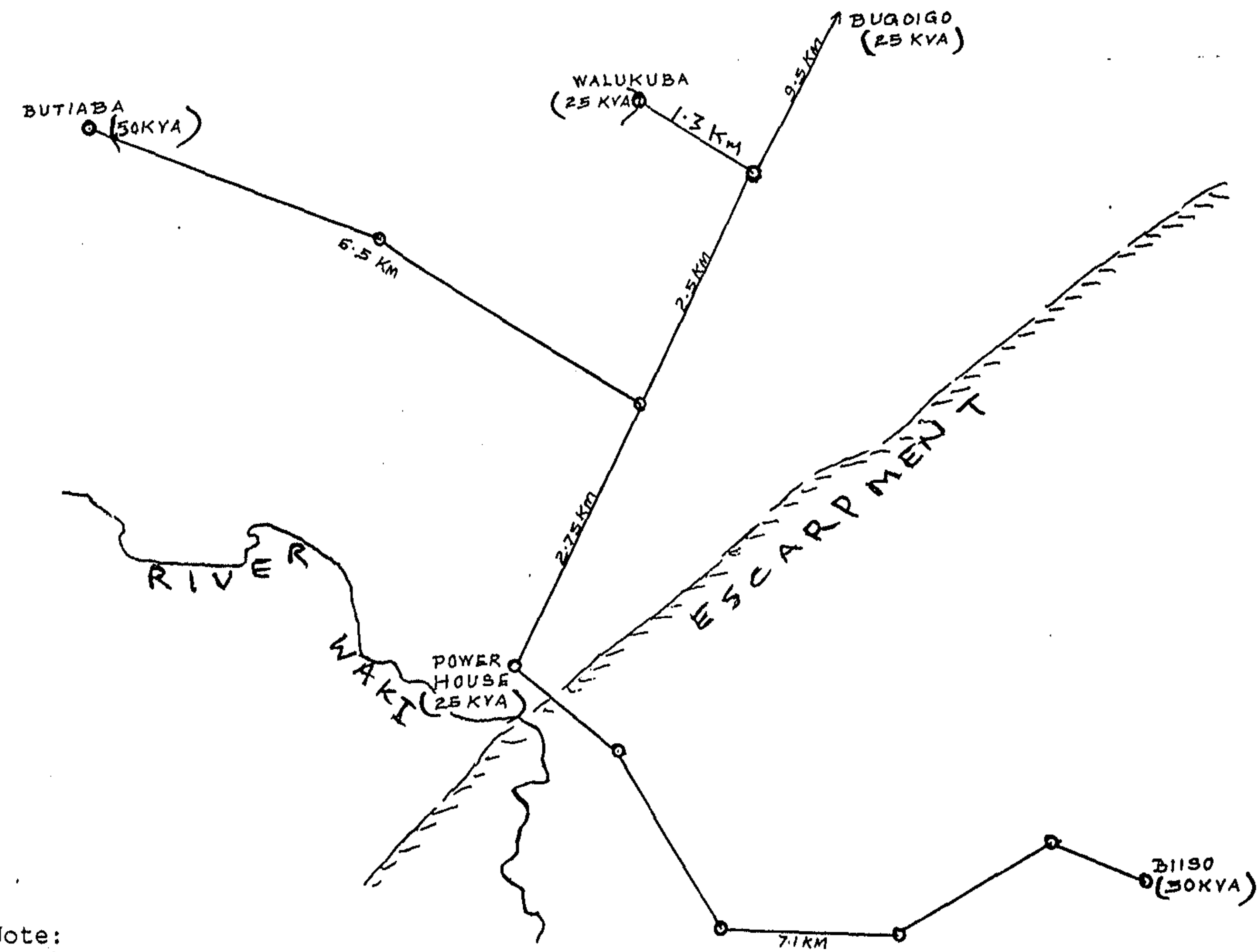
The electro-mechanical equipment recommended for this project is a horizontal shaft Francis turbine rated 280 to 350 kilowatts (depending on the head used) operated at 900 RPM. The unit will have a governor and a synchronous generator with all of the necessary switchgear and control.

POWER DISTRIBUTION

Figure 11 is a sketch of the general project area showing the proposed limited distribution system of the overhead lines from the Waki powerhouse to the main load centers of Butiaba, Bugoigo and Biiso. The line sizing (11 kW) and the loads (50 kVA and 25 kVA) indicated in Fig. 11, were recommended to us by the UEB manager in Masindi, based on rural electrification standards, and potential activities which are likely to occur in those villages when electricity becomes available there. The cost estimate of this distribution system are based on prices supplied by the UEB manage in Masindi, and is included in Table 3 below.

Table 3 - COST ESTIMATES FOR THE MINIHYDRO ELECTRIC POWER SCHEME (calculated for the upper weir)

	Estimated Amount ($)
Civil Works	
Road (from Biiso-Butiaba road to escarpment and to the power plant)	18,000
Weir to Powerhouse (intake structure, desander, headrace pipe, forebed,	270,000



Note:
1. All 11 kV overhead lines
2. Load Figures in Brackets

FIGURE 11. Map of the Waki Power Station showing proposed Load Locations

penstock, power house and
tailrace)

Mechanical and Electrical (Turbine, inlet valves, governor, generator, bedplate, switchgear and accessories)	450,000
Crane	9,000
Overhead power lines (to Butiaba, Bugoigo, and Biiso and transformers)	450,000
Sub Total	1,197,000
Contingency @ 10%	119,700
ESTIMATED COST	**1,316,700**

Note: These prices are only ball park figures, and are based on a list prepared in an earlier report sponsored by the United Nations to evaluate small hydropower sites in Uganda (Engineering & Power, 1988). The prices listed above are currant estimated prices. A firmer quotation must await the pre design investigation, survey, scheme selection and actual design of the minihydro power system. The prices for the overhead power lines were provided by the UEB manager in Masindi, and the cost for putting in the access road was provided by the Ministry of Works' district engineer in Masindi. These prices also do not include the cost of labor or project supervision. Some labor might be provided on a self help basis by the local people, who are expected to benefit from the minihydro project.

GRAVITY WATER SUPPLY SYSTEM

A second part of the current feasibility study was to investigate the possibility of installing a gravity water flow system for the inhabitants in Butiaba and its immediate vicinity. During our first visit to the offices of the district's water department in Masindi, we were informed by the Department Head, Mr. Wabwire, that a proposal to DANIDA for such a system had been submitted by the National Coordinator of the National Gravity System, in Kampala. He informed us further that DANIDA had approved the request for funding and that $100,000 had been made available by them for the project. Material (pipes, fittings etc.) has already been secured in Kampala and the technician to construct the system would be shortly in Masindi to start the work.

In spite of this, the district hydrologist Mr. Waako accompanied us on several occasions as we visited the site of the falls to carry out our investigation. We learnt from the hydrologist that they had planned to build the intake structure at some point near the upper falls at the escarpment.

Frank Turyalunga, EPED Project Director, was informed about this development, and it was subsequently agreed by all parties that we should provide them with what ever assistance we could. In the main time however, we continued to develop our ideas regarding the possible implementation of the gravity scheme within the context of our terms of reference.

Eventually the coordinator of the National Gravity System, Mr. Nebert Wobusobozi came to Masindi and we had a meeting with him in EPED's office. He was happy to learn of EPED's program which included the gravity water system, and upon our detailed briefing, including our recommendations for implementing the system, he has decided to meet the representative of DANIDA in Kampala to possibly incorporate their scheme into ours. However, we have continued to develop our proposal for the system.

That there is a need for providing the local people with clean drinking water is an understatement, because most of the water used by them come directly from Lake Albert, which is quite polluted. Some enterprising individuals go to the mouth of the River Waki, collect water in plastic jerry-cans and transport them to Butiaba by canoe, where each jerry-can is sold for 200 Ugandan shillings (about $0.20). Photo 9 is taken at the mouth of the River Waki where it enters Lake Albert. The woman in the background is getting drinking water. Note the people in the foreground are crossing the river.

In a study of the water and sanitation conditions at Lake Albert, Mourits (1992) found diarrhea, bilharzia and other water related diseases were common with people living along the lake. This condition has probably not changed, it may have gotten worse, as the population there has continued to grow, with more migrants and refugees coming to the area from the former Zaire, across the lake. Without a better source of water in this area, however, the local inhabitants have no alternative but to continue to drink water from the lake and other undesirable sources.

In visiting the villages along this section of the lake, one would hardly know that there is a very serious problem with the availability of potable water, since people appear to be working, and children are going to school. However, Daniels (1982) noted that while major benefits are to be gained from improved rural water supply systems, these tend to appear not all at once, but to build up and become evident over time.

In attempting to provide potable water for the inhabitants in this area, it should be noted that surface sources (lake and river) are contaminated, and water from deep wells are highly mineralized and therefore "taste salty." Unfortunately, there is no such thing as a simple and reliable water treatment process suitable for small community water supply, and it is preferable to choose a source which provides naturally pure water and protect it from pollution, so that treatment is not necessary. Treatment should only be considered if it can be afforded and reliably operated

Earlier in this century when the East African Railway ran the town at Butiaba, the British pumped water from the lake, treated it and supplied it into their houses by pipes. A similar system could now be employed for these communities, however the local economy could not afford or support such a system, nor would they be able to financially maintain it if it were provided for them.

In this light the present system is being proposed, which will be as simple as possible and not very expensive to operate and maintain. The delivery capacity of the proposed system and treatment plant, including finished water storage, needs to be designed to exceed the maximum anticipated demand for a reasonable time period. A sufficient time margin should be allowed for future expansion as the community grows. In this regards, the design being proposed here is to meet all demand 5 years in the future.

WATER DEMAND ESTIMATION

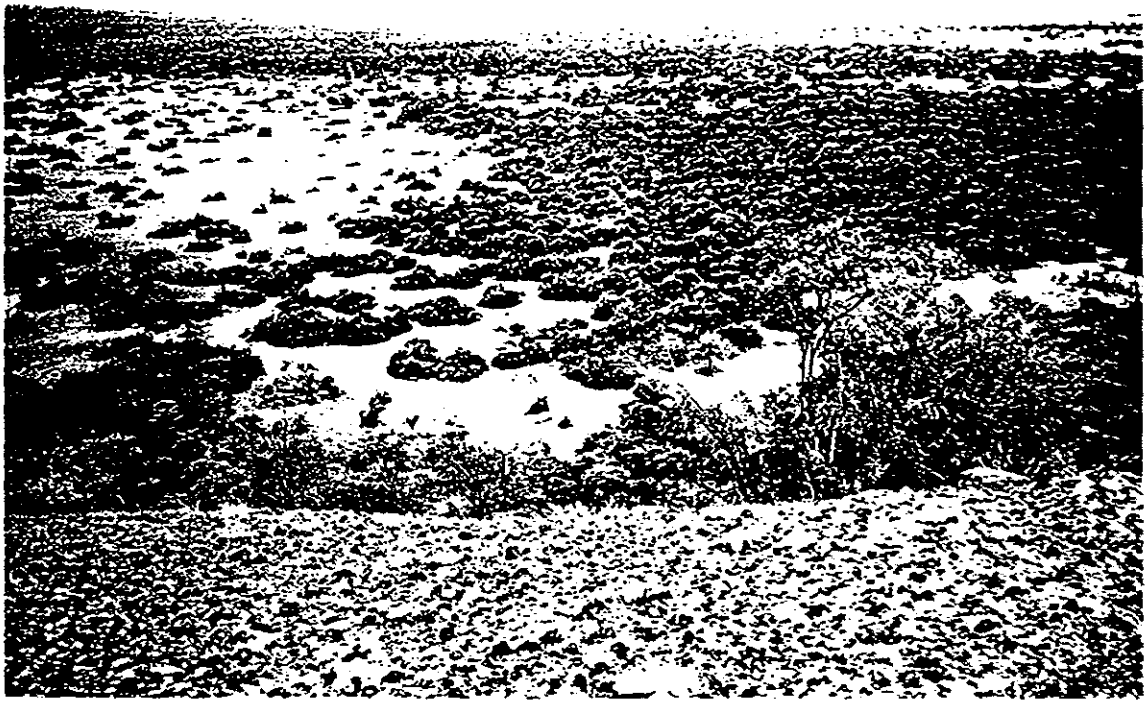
It is estimated that by 2001, the Parish of Butiaba, which includes the following villages, Walukuba, Sigunga, Bugoigo, and Serule, would have 10,175 inhabitants. (Engineering & Power, 1988). If we assume a daily water consumption of 20 liters per person, this will require a minimum daily water supply of 203,500 liters per day, or a source producing a minimum of 2.4 liters per second.

Bugoigo is probably the largest single village in the Parish and also lies on the shore of Lake Albert. Because of the distance of this village from the others, it might be ultimately more desirable to develop another independent source of water for it, rather than attempting to take water there all the way from the River Waki. A good source for such a water system is the River Waisoke which is slightly north of that village and much closer to Bugoigo than the River Waki. This will avoid the very long pipeline (7 to 8 km) which will be necessary to take water there from the treatment plant near the River Waki. To get water that far under pressure, would require piping of sufficient size to overcome the friction which will result in a pipeline that long. Another advantage of an independent water source for Bugoigo is that everyone along the lake will not have to rely on only one source for their water.

In the case of the present investigation, we attempted to find some source of uncontaminated water, possibly a spring coming out of the escarpment, which we could then develop as the source for our gravity water system. Interviews with local inhabitants in the area led us to believe that such a spring does not exist. The local people therefore are forced to get drinking water from one of three sources:

a) the lake;
b) the River Waki; and
c) one or two drilled wells.

None of these sources are satisfactory to the local inhabitants for a variety of reasons, which are well documented in Mourits (1992). Briefly, the lake water is contaminated with bacteria with coliform counts as high as 250 per 100 ml, the River Waki has a significantly lower, but still unacceptable, bacteria count of 42 coliform per 100 ml, and the deep well water, with a pH of



PHOTOGRAPH 8: View of the Rift Valley from atop the Escarpment. The location of the white pickup marks the site of the proposed Powerhouse

PHOTOGRAPH 9: Mouth of the River Waki where it enters Lake Albert showing women getting drinking water

8.2, is reported as "tasting salty". Mourits found that although the water from the drilled wells is initially free from coliform bacteria, it gets contaminated during transportation and storage. This would suggest that even with the proposed gravity supply, there will be a need for some form of corresponding education in handling and storing water. Often times, it is the little children who are sent to get water from wells, and unfortunately they are the ones who are least aware of the need to protect the water. They sometime cup their hands under the tap of the pump in an attempt to help guide the water into the mouth of the jerry-cans.

In making our present proposal for the gravity water flow system for the inhabitants in and around Butiaba, we are taking into account the present quality of the water that the people are drinking, and the area's ability to sustain a system. We are certain that the finished water that will be produced by the proposed system will be a significant improvement over any water that is presently available to anyone in the area. We are not attempting to introduce a technically advanced system, which can not be sustained, and which will send the local inhabitants back to their present unacceptable sources, if that system breaks down or if funds are not available to maintain it. In this regard, our proposed system is not very much different from what is presently in use for the town of Masindi.

WATER INTAKE AND PIPING

As this project is being considered in conjunction with the minihydro project, the intake for the proposed gravity water supply system will be incorporated into the intake structure for the minihydro, the forebay. From this intake, which will be at least 30 m above the base of the lower falls, the water will be conducted via a pressure pipe down to the area of the water treatment facility which is approximately 1000 meters away from the intake as indicated on Figure 13. To avoid vandalism, and damage by fire or wildlife, the pipe will be buried along most of its route to the water treatment plant.

PLANT LOCATION

The treatment plant will be located on a small hill which is located northwest of the intake location. This location, which is indicated in Figure 12, was chosen for a variety of reasons that include:

- It is above any possible flooding.
- It is centrally located and therefore will permit water to be transmitted to other villages along the lake.
- It is relatively close to the powerhouse and along the route of the power line to the main road to Butiaba, which would allow it to receive the necessary security and other operational lighting without much added cost.
- It is uphill from any potential source of runoff and contamination, especially in view of the proposed agricultural activities (i.e. fertilizers, pesticides etc,) which are anticipated for that area, as the result of another part of this feasibility study.
- It offers the best location for natural and emergency drainage (i.e. for removal of

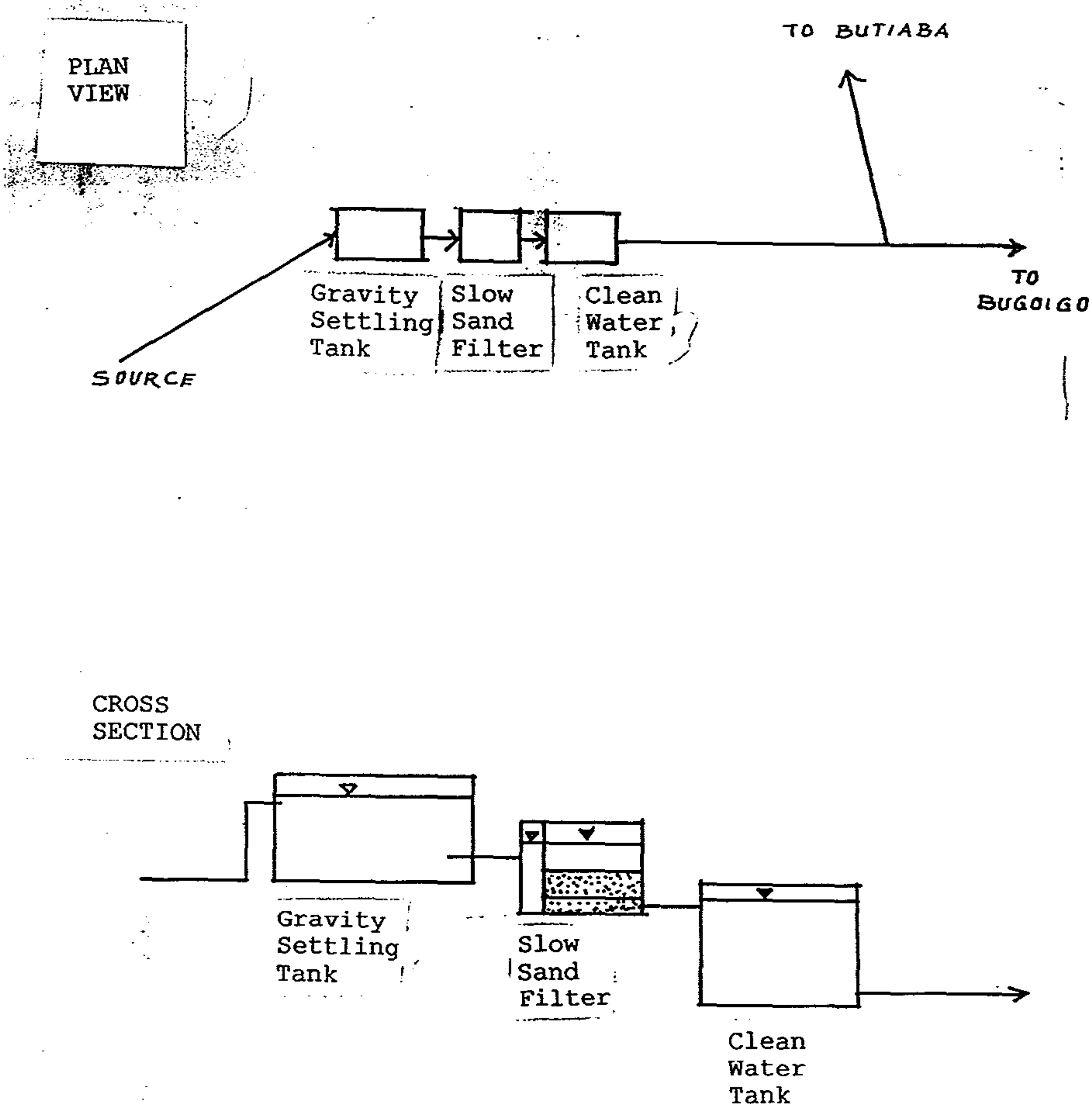


FIGURE 12. Generalized Water System Flow Chart

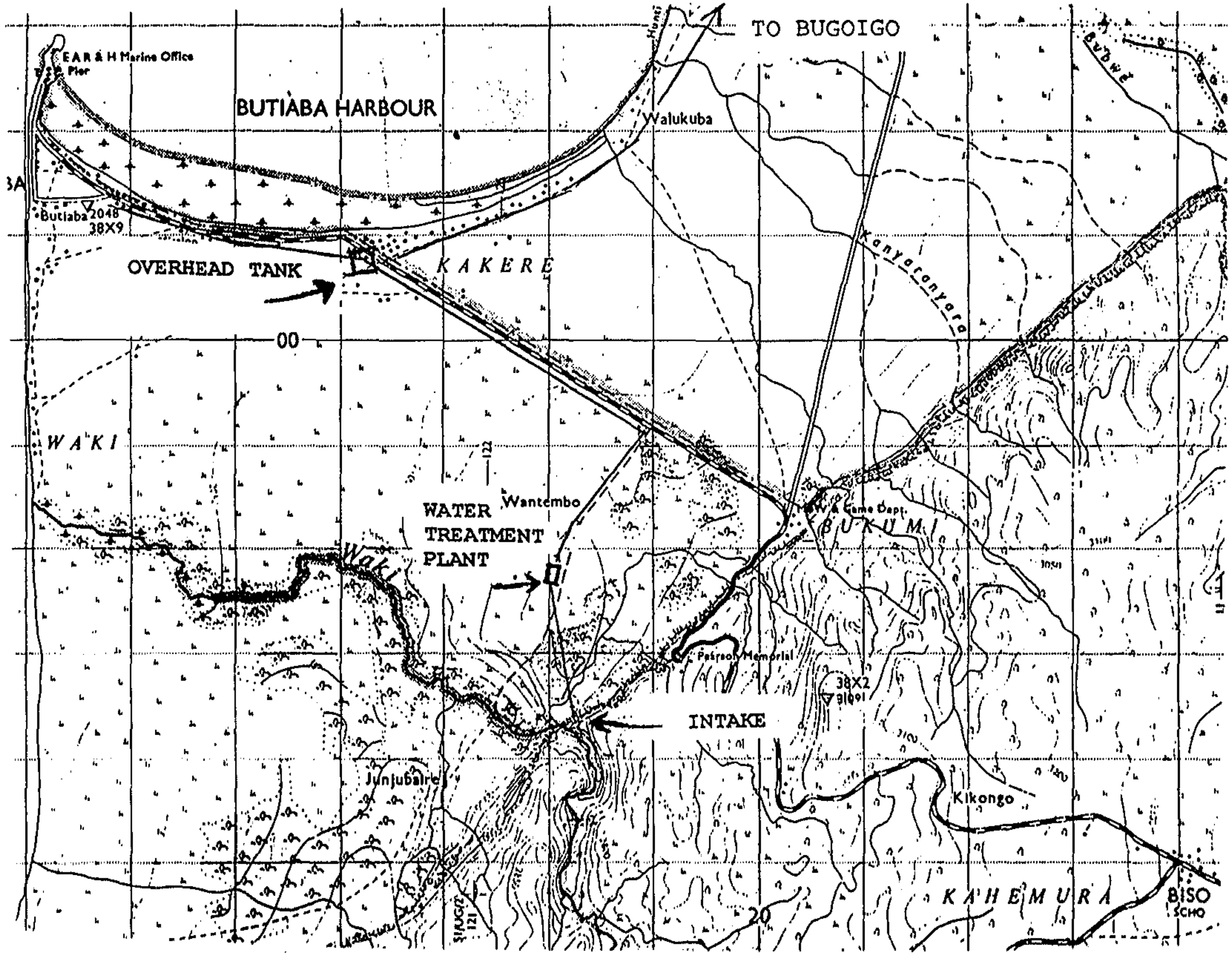


FIGURE 13: General Layout of the water intake to Water Treatment Plant, overhead tower and proposed pipelines

filter wash water, plant wastes and sanitary wastes).

- It provides the best chance for avoiding backflow into the plant from submerged outlets.
- It has easy access by a bush road (the same to be used to the power plant).
- Also, because from there water can be transmitted easily to Butiaba by natural gravity flow due to its elevation above the surrounding area. The 1:50,000 contour map of the area (Butiaba Sheet) indicates that this hill is about 60 m above Butiaba. From the actual ground situation, it is probably somewhat less than that.

STORAGE, COAGULATION and SEDIMENTATION

The simplest method of treatment is storage in a covered tank. If water can be stored for at least two days, it will be free of schistosome larvae and contain considerably fewer bacteria. In general, the quality of water can be improved in a large tank by sedimentation, the process by which silt and other solid material sink to the bottom of a tank. Sedimentation alone however, does not remove many of the harmful organisms from polluted water, but it helps to make silty water clearer. This is particularly useful in our case because we intend to also filter the water which comes from the intake and the silty water will block up the filter in a short time.

Depending on how bad the incoming water is, and also the ability in the future of the end users to maintain and financially support this water treatment plant, it might be possible and necessary to incorporate the process of coagulation and flocculation into the plant's operation. Should this be necessary, it will precede the sedimentation and generally be accomplished by rapid distribution of the coagulating agent, usually alum, followed by gentle agitation which will promote flocculation. Such a modification to the system however will probably not be done in the near future. To do so will require that the sedimentation system will need to be modified, because pretreatment by chemical coagulation is seldom appropriate with slow sand filters, which are being proposed for this system, because floc carryover quickly clogs the filter medium. Sedimentation by itself will not produce completely clear water unless a specially designed tank is used and chemicals are added to the water to help the process. However, Okun and Ernst (1987) suggest that "for rural treatment works, the most simple designs are the most appropriate: horizontal flow, manually cleaned units, with two in parallel so that one can be taken out of service for cleaning without interfering with the plant operation." These horizontal flow units have the following advantages:

- they are more tolerant of shock loading;
- they are more uniform in performance;
- they can handle high silt loads without upset;
- large capacity can be provided at low cost; and
- they are simple to operate and maintain.

FILTRATION

Some kinds of water filters can remove at least 99% of the bacteria and viruses in water if they are correctly operated, as well as other sources of disease such as cysts, ova and schistosome larvae (Ross Bulletin 1986). Sand is the most convenient material for filtering water although other material such as burnt rice husks may be used. "Slow sand filters operate with ungraded sand so their hydraulic capacity is much smaller than rapid sand filters." (Okun and Ernst 1987) These filters are most appropriate for treatment of low-turbidity water, less than 50 NTU, although short periods of higher turbidity may be tolerated.

In an endorsement of these types of filters, Tillman (1981) stated that in rural areas, "no other single process can equal the improvements in the physical, chemical and biological quality of surface water produced by a slow sand or biological filter."

The turbidity level of the water in the River Waki is unknown, however it was observed during low flow stage to be slightly brown, presumably because of the silt it carried. During one rain shower however, the water color turned gray, probably because of the extra runoff sediment. The intake structure at the weir or dam will be designed to remove as much of the coarse material as possible, however it might become necessary at some point in the future if the water is very dirty during the rainy season, to construct another settling tank specifically for the water treatment plant. This extra tank would then be used during high runoff periods. Until then, the present sedimentation tank might simply have to be cleaned more often if a lot of material is coming through.

According to Okun and Ernst, advantages of slow sand filters for rural water supply systems are:

- simple construction and low construction cost;
- simple operation, requiring limited supervision and using unskilled operators;
- material requirements for equipment, pipe and chemical are small;
- less material is required, and if gravity flow is available, power is not required;
- variations in raw water quality can be tolerated; and
- much less water is required for washing the sand than is required for washing the sand for rapid filters.

The major disadvantages are:

- the required area is about five times greater;
- need for covering in freezing climate (not applicable to us); and
- possibility of algae growth that may clog filters.

A slow sand filter basically consists of a large tank containing a bed of sand. The water filters down through the sand bed to a set of drains which take it to an outlet well. The filter does not work by a simple straining process. The sand grains in the top layers of the bed become coated with a sticky deposit in which bacteria and microscopic plants multiply. These form a very fine mat in the topmost few millimeters, as well as killing most other micro-organisms which pass through. (Ross Bulletin)

We are not attempting at this stage to design the different parts of the water system, and pipelines, because a detailed survey of the site and route to the different consumption centers will first have to be carried out. This is understood by the water management people in Masindi who have agreed to do it. We are however providing a few pointers which will assist them when they need to design and build the water treatment plant. We would recommend, using information from Okun and Ernst's book, that the tank walls should rise 2.4 meters above the floor and that the area in plan should be at least 3 square meters for each 400 liters per hour capacity. The sand should be at least 700 mm deep, and its surface should be at least one meter deep under water. The filter sand material should range in size from 0.2 to 1.0 mm. (Okun and Ernst) Sands with an 'effective size' of 0.20 to 0.40 millimeters however work best. (EPA 1991) Between the sand beds and the drains there should be three or four layers of clean gravel, each 75 mm thick. The gravel in each layer should be of uniform size, and about twice as large as the layer above. The drains beneath the gravel can be made of bricks laid down without cement, and they should not be more than 3 meters apart. The drains lead the water to an outlet chamber, a separate compartment which is kept clean. Water collects in the chamber and flows down the collector pipe, whose top should be a little above the level of the top of the sand. There should be a valve in the inlet and outlet pipe, and a drainpipe so that the filter can be emptied when necessary. Figure 12 is a generalized flow chart of the system being proposed here.

If the water being treated is reasonably clear, a slow sand filter may run for weeks or even months without cleaning. "Slow sand filtration has proven to provide a large reduction in bacteria, cloudiness, and organic levels and thereby reduce the need for disinfection and presence of disinfection by-product in the finished water." (EPA) It will become obvious when the slow sand filter requires cleaning, because the flow through the filter will slowly drop to a point where it is not enough for the community's need. It is then cleaned by raking off the top 20 mm of sand from the surface of the sand bed and discarding it. When the sand bed is only 600 mm thick, more sand is needed. The old sand can be washed in a box with water slowly piped in at the bottom. This should continue and the sand disturbed with a shovel until the water overflowing from the box is clean.

CHLORINATION

Chlorine as a disinfectant can kill bacteria, schistosome larvae, some viruses, and in higher doses, amoebic cysts. A chlorination unit may be added the system, but only if some sort of user fee is established, because the chlorine will need to be purchased. When that time comes, the chlorine should be added automatically, prior to water being put into the distribution tank, through some type of a simple chlorinator. To make the system simple however, this may be done manually by the individual chosen by the community to take care of the water supply plant.

AERATION

Another component to a water treatment plant which could be added to the gravity water system at a later date, is an aeration unit. Often in areas with heavy concentration of iron or manganese, the water might have an unpleasant taste to it, and it can give a brownish color to clothes washed in it. Aeration changes the iron and manganese so that they are no longer soluble in water, and therefore form a fine dark sediment which is easily removed. It must be pointed out here that the more components that are added to the simple, sedimentation-filtration system, being proposed for the water system, the more costly it will be to operate, and the more things that can go wrong. The future addition of these other elements to the water system might be needed as the population grows, and as the simple proposed system is being required to handle more and more water over a shorter period of time.

DISTRIBUTION PIPELINE

Water will be distributed from the clean water reservoir tank at the water treatment plant to the different supply centers of Butiaba and possibly to Bugoigo to the north by a pipeline. The size of the pipeline will need to be appropriately sized to ensure that water gets to the end of the line. Another possibility is erecting an overhead water tower at a location closer to these two larger villages. This would allow a smaller diameter pipeline to be used (reduction in cost of the pipe) from the proposed treatment plant to the tower, and then from the tower to the end users in both Butiaba and Bugoigo. The smaller villages along the lake towards Bugoigo could then be supplied by the same pipeline. In this regard, we would recommend that a site near Walukuba be selected for the location of such a tower. Water would then flow from the tower to Butiaba along the main road and to Bugoigo, along the newly built feeder road which connects the smaller villages along the lake. Figure 13 is a generalized layout showing the intake to treatment and proposed pipe layout recommended for this area.

To ensure that the pipes are easily located for future repairs or inspection, a consistent layout system should be adopted; for example, always laying the pipes on the same side of the road. At selected locations along the way, such as at the school, public standposts should be provided for the inhabitants to get water. Standposts are the lowest investment cost for piped service to people, and they should be located at points on the distribution system so as to be no more than a prescribed distance, of about 100 m, from any household. Initially these standposts might be installed along the main road to Butiaba and Bugoigo, and they should be designed to serve a prescribed number of inhabitants.

The standposts can be equipped with one or more taps depending upon the number of households to be served. It should also have a concrete pad designed to collect spillage and conduct it to a drain, which is carried away to a soakage pit. The type of faucet selected should be the type which will stop releasing water once pressure is removed from it. This will avoid the loss of water by someone leaving the faucet on or forgetting to turn it off after they have used it.

This project will probably need some sort of subsidy by the district, because experience has shown that, even though the building of water projects such as this may be in the interest of the national welfare, the costs may not be completely repaid by the direct users of the water. Thus economic analysis differs from financial analysis in that it is concerned with all effects which a project may have on the local or national welfare. Financial evaluation on the other hand is concerned only with the ability of the project to repay with interest the capital invested in development. This statement will also initially apply to the irrigation project which is being contemplated.

In order to effectively manage such a resource, the water used must be metered and some sort of charge, even if nominal, must be levied on the user. The former will help identify if the water is being lost, for example by leaks in the line, and the latter will discourage waste of the water and perhaps most importantly, provide supplemental revenue to run, maintain, and hopefully upgrade the system as the need arises. From experience, once the local inhabitants start to get *running* water, their usage of water will significantly increase. This will subsequently overload the system, thereby affecting its ability to produce a quality product.

It is recommended that an amount of at least 5% of the estimated capital cost be set aside for the maintenance of the system. o this amount can be added the funds which are collected from users of the system. It is also important that this money stays close to where it is collected. One would think this is obvious, however in a neighboring country, revenues collected from such a scheme were initially paid to the Office of the President, and hence was unavailable for basic operation and maintenance of the system. (AID 1980)

In addition, we recommend that a water committee should be established whose function would be to set guidelines for the operation of the system, hire operators, approve purchases for the system, and collect the user fees. It is also important that the payments not be too high as to discourage the use of the water. This has been the case in many areas in Kenya where the operation of the payment system sometimes meant that rural water supplies were simply highly subsidized methods of bringing water to the elite minority.

Before leaving this subject, it is obvious that water supply is generally of higher priority than sanitation for rural communities in developing countries, however it is important that sanitation in this area, for example latrines, not be overlooked when bringing development to this lake shore area. Because as long as the local people use the lake for fishing, bathing, and recreation, if this issue, well discussed by Mourits (1992) is not addressed, the overall desired health benefits of bringing potable water to this area will not be fully realized.

IRRIGATION

In carrying out this part of this feasibility study, we believe a conceptual model for developing irrigated agriculture for the people in the area near Butiaba is what is needed, rather than coming up with a specific physical design for potential farmers to follow. As such, we will attempt to discuss different aspects of African irrigation, with a view of deciding what lessons may be learnt from them. We will then briefly present some of the general components of irrigation systems, followed by a discussion of irrigation in Uganda. The final part of this section on irrigation will be a discussion dealing with irrigation activities in and around Butiaba, including the types of information needed to design and develop an irrigated agriculture program for the people living there. We then conclude with our recommendations for developing a sustainable irrigation program for that area.

The Food and Agriculture Organization of the United Nations (FAO) in 1987, classified irrigation schemes in Africa by size as follows:

1. Very large scale schemes: typically over 10,000 ha. with full water control and under government management. Example are the gravity schemes in the large river basins in Sudan, Morocco and Egypt.

2. Large scale scheme: typically 1,000 to 10,000 ha. with full water control. Generally under government or commercial management, the latter usually less than 5,000 ha. Example are found in Kenya, Tanzania and Somalia.

3. Medium scale schemes: typically 100 to 1,000 ha. with full or partial water control. Examples include government managed schemes, government assisted cooperatives, or commercial estates.

4. Small scale schemes: typically 1 to 100 ha., controlled by farmers' groups, or single farmers. Example are: Kenya, Zimbabwe, Tanzania, Madagascar for simple river diversions; Nigeria (*fadama*) for shallow groundwater, and Kenya and Tanzania for pumping from lakes.

To this list has been added "micro-irrigation" (less than 1 ha) for certain very small traditional systems such as the calabash watered gardens of Mali. (Underhill 1988)

Moris and Thom (1987) reported that an earlier world-wide overview of irrigation by Steinburg, had noted certain circumstances where irrigation investment represented an "inappropriate" policy response. Some of the specific constraints which Steinburg warned against included:

a) when there is an unresolved presence of irrigation failure in the past;

b) if irrigation intrudes into a fragile ecological or social environment;

c) when economic policies or institutions are weak;

d) if irrigation involves massive dislocation of peoples;

e) if it will exacerbate social tensions;

f) if the institutional capacity to manage irrigation has not been demonstrated or if overall management is weak;

g) if a long-term donor commitment is unlikely or if the donor lacks the required disciplinary skills and monitoring capability;

h) if required socio-cultural knowledge is lacking;

I) if the legal basis is clouded or if dispute resolution is likely to be faulty; and

j) where there are poor agricultural pricing policies, ineffective marketing facilities, high transport costs, or the unavailability of required agricultural materials.

Moris and Thom (1987) also noted that a majority of Africa's formal irrigation projects have been implemented under circumstances where several of these constraints were present. They then suggest the main reasons against African irrigation are as follows:

1. Low performance of many existing systems

The first reason given against most African irrigation projects is the low performance of existing scheme. The debate continues regarding the success of some of the larger schemes. The World Bank, which has been involved in most of the larger projects, feel that most of those they have sponsored have been successful. However, African experts drawn upon to formulate the main report on African Irrigation Overview in 1987, did not share the bank's optimism. From most of their field visits and experience, most regarded African irrigation as a source of continuing economic and technological problems, far outweighing the meager benefits which participating farmers obtain from them.

2. Returns to alternative investments

The second reason given by those against African irrigation is simply that returns on investment in rainfed agriculture, or non-formal small-scale irrigation, are higher. This conclusion has come about primarily because much of the larger share of Africa's rice production comes from upland and swamp rice systems, developed by farmers themselves with minimal public assistance. Statistics has shown this to generally be true. The problem has basically been that the return on investment has not covered costs of imported technology, foreign designers and consultants, and high operation and maintenance cost of many of the larger projects.

3. Technical Appropriateness

The third reason given against African irrigation is that in their contemporary form, irrigation technologies are inappropriate. Africa generally lacks the trained staff, at all levels, to manage the schemes, which often are designed and imposed from the outside. Often times many countries have qualified personnel for the design and construction of irrigation projects, but most lack teachers and facilities for education in the field of water management The agricultural teacher working directly with the farmer is in the best position to get improved water management practices into effect on the land. Most of the time however this is inadequately done.

Another negative development which unfortunately has been more apparently related to the larger irrigation schemes then the smaller ones, has been the spread of several debilitating water borne and water related diseases such as malaria, cholera, filariasis and schistosomiasis. The fact that larger schemes bring together greater numbers of people might be the determining factor here.

In the past unfortunately, most irrigation planning at the national level has been concerned with large schemes. Underhill (1988) suggested several reasons for this, one being that planning, design, appraisal, funding construction and finally operation and management are more efficiently done, in terms of cost per hectare for large schemes. The large schemes, he also suggested, have more psychological appeal and prestige value to planners, donors, and politicians than do small schemes.

In addition to this, farmers often feel that because these schemes are imposed from the outside, they are not regarded as *their* schemes, so when things go wrong they see themselves under no obligation to fix them.

On the other hand, self-help schemes, based on indigenous knowledge, with the addition of modern inputs that are perceived by the farmer as useful, have generally succeeded. Another concept which also has not worked, is a combination of the negative aspects of both approaches: high investment, remotely controlled top-down systems, with input requirements which cannot be met, in association with an alienated and uncommitted peasantry. It should come as no surprise that bottom-up projects can be economically efficient, and that projects designed around people can achieve satisfactory production targets as well as human betterment, while projects designed around production often fall short on both counts.

Farmers who are undertaking irrigated agriculture for the first time should be assisted in making such changes in traditional cultural operations as may be needed to obtain the most efficient use of water. With the introduction of irrigation, changes may be required in such operation as cultivating, planting, fertilizing, applying herbicides and insecticides, controlling plant diseases, and harvesting. Without appropriate changes in these practices, particularly in the use of fertilizers, the application of irrigation water may fail to increase crop production.

A permanently successful irrigated agriculture program requires that irrigation and related cultural practices be adapted to local conditions. Experience has shown that a farmer is usually willing to adopt new production ideas if he will benefit, and it is demonstrated that he can carry out the practice on his farm.

Migot-Adholla (1988) of the World Bank said, "the potential for irrigation in Sub-Saharan Africa is somewhat limited and its development is likely to contribute only marginally to the region's agricultural production." He went on to say that "the necessary increase in Africa's agricultural production must, therefore be ultimately sought in improvement in rainfed farming, through better moisture conservation methods and high yielding crop varieties."

As previously stated, the agricultural history in Africa has not been very kind to large scaled, "prestige" type projects, although some elements within the World Bank feel otherwise. The apparent relationship of failed schemes to size, coupled with budgetary crisis and foreign exchange constraints, has forced many African governments and some donor agencies to shift their preference to small-scale irrigation projects, which can be operated and managed by farmers themselves, since they have lighter management structures and tend to be amenable to low cost technology. (Migot-Adholla 1988)

It would appear therefore based on experience, that in planning an irrigated farming program, one might wish to look at smaller scaled schemes. The advantages of such schemes have been summarized by Underhill as follows:

- initiating a development process rather than planning a development action;
- self reliance - technology is based on the farmers existing knowledge;
- sustainability;
- the mobilization of the human resources - local skills;
- flexibility and learning by doing - or step by step approach;
- no migration or resettlement of labor with all of the associated costs;
- reaches rural people where they are and slows urban migration;
- little infrastructure is needed;
- low take off point or success threshold;
- low external inputs; and
- limited investment.

Regarding the last item, investment is less in terms of purchases of machinery and materials, and more in social inputs such as extension training, guidance to farmers' organizations, and credit for use by the farmers.

COMPONENTS OF AN IRRIGATION PROGRAM

In planning an irrigation program, it is desirable to select the irrigation method during the initial project planning stage. There are generally three basic methods by which water can be applied: from above ground, on the ground surface, or below the ground surface. The primary characteristics of the three are as follows:

- Sprinkler (from above the ground) - this form of irrigation involves conveying the water onto the land in pipes under pressure. It is then sprayed into the air through a series of nozzles and falls to the ground in a circular pattern like rain. Sprinklers should be considered when any of the following basic circumstances exist: a limited flow of water, rough topography, soil too shallow for grading, or soil with a high or low infiltration rate.

- Surface method (on the ground surface) - this form of irrigation involves the application of water to the land from a ditch or low pressure pipe system. The land surface is used for the conveyance of the water over the field under varying degree of control. For close growing crops, ones that are sown, drilled or sodded, the entire field is flooded. For row crops or crops in beds, the water is directed down furrows between the rows. (Turner and Anderson, 1988) Three conditions required for successful surface irrigation are a large flow of water, deep medium to fine textured soils, and topography which can be graded at limited cost.

- Subsurface method (below the ground surface) - in this form of irrigation, water is supplied to the root zone of the crop being grown by artificially regulating the ground water table elevation. In this form of irrigation, also known as subirrigation, the water table may be controlled by varying or maintaining water levels in surrounding ditches, using check dams or gates. Necessary conditions for successful subsurface irrigation are a large quantity of good quality water and a subsoil barrier or a high water table.

Proper drainage, either natural or artificial, is as important to a successful irrigation agriculture as is the system of applying water. Excess water may consist of surface and/or subsurface water. Too much water in the root zone of most agricultural plants can be just as harmful as not enough water. Most plants must have air around the root system for proper growth. Lack of air limits the capacity of the plant to take up water and fertilizers.

There are generally two methods for removing damaging water. They are as follows:

- Surface drainage: this type of drainage is accomplished by land grading and/or digging open, shallow ditches in the field to drain off the surface water. The open drains are usually laid out on a gentle slope and are excellent for removing large quantities of water. The initial cost of an open drainage system is usually less than for a covered drain, however maintenance cost are nearly always higher.

- Subsurface drainage: in these types of drains, water is drained through ditches or pipelines which are placed underground. They are usually more expensive to install, require little maintenance and farming operation can be conducted over them without loss of land.

Land grading for surface irrigation is the modification of the land surface so that water can flow and spread evenly across the surface with a minimum of erosion. It is always required to some extent where surface irrigation methods are to be used, even if the area has been previously cultivated. Deep plowing is often necessary to obtain favorable water penetration and retention, and good root development.

A farm system should be constructed so that water can be delivered to all parts of the farm when needed and in sufficient quantities to meet crop demand during peak use periods. When water is delivered on a demand basis, the system should be large enough to allow the delivery of sufficient water in the time allotted.

Water for irrigated agriculture is obtained by building structures ranging from simple divisions to groups of structures for the control of entire river systems. Where drains are used, the main drains should be constructed concurrently with distribution systems, and division structures should be installed where water is to be delivered to several fields at one time. Lined ditches, pipelines, or drop structures may be necessary to prevent erosion and minimize seepage.

Discussion

Following the general information presented above, we would now like to briefly discuss irrigation in Uganda, followed by a discussion on how to possibly develop an irrigation scheme near Butiaba.

IRRIGATION IN UGANDA

Irrigated agriculture has been in effect in different parts of Uganda for several decades. The most successful projects have mainly been run by private agricultural estates.

In a feasibility study carried out in 1955, 100,000 ha. of irrigable land was identified in Uganda. This figure has been upgraded several times over the years from 188,000 ha. in 1964 to 297,000 ha. by 1970, (Macdonald 1980) and more recently in 1987 to 410,000 ha. in a preliminary study by the FAO. (Ogwang 1996).

Uganda, like many other countries in Africa, has been plagued with the failure of most of its large government sponsored irrigation projects. Not unlike elsewhere, the reasons have included, unreliability of the planned water sources, lack of foreign exchange to purchase needed spare parts, poor management, and lack of general maintenance. Looting during episodes of civil unrest in the country has contributed to these problems.

In his briefing paper on Uganda irrigation schemes, Ogwang classified most of Uganda's irrigation schemes which have failed as being top to bottom schemes, which like most of their counterparts elsewhere in Africa, ultimately failed.

DEVELOPING IRRIGATION IN THE AREA OF BUTIABA

In visiting the area around Butiaba, including the area near to the escarpment, when we first arrived in the latter part of March, it becomes evident very early that there is a paucity of agricultural activities being carried out by the local people. No one seem to be doing any farming, and everyone appeared to be engaged in activities related to fishing from Lake Albert. Even along the banks of the River Waki, which is a perennial river, there is almost nothing being cultivated there. We did see some banana and mango trees being grown near the mouth of the river, where it enters the lake, as shown in Photo 10.

Some individuals, obviously not in the fishing business and living away from the lake, were actually seen on several occasions collecting and taking fire wood at the lake to sell, rather than engaging in farming. It was difficult to understand this apparent lack of interest in agriculture, because the large number of individuals engaged in the fishing trade would probably buy all the food stuff that may be grown along the banks of the river.

Our initial thought therefore was to try to see what might be done to first encourage individuals in the area to engage in agriculture, before we attempted to look at a possible irrigation scheme. However, as the rains became more frequent, several of the local people living away from the immediate vicinity of the lake started to grow cassava and some beans near their homes
In 1988, the Uganda Commercial Bank set up a program with the local people in that area to grow cotton on land that the bank had cleared. Apparently the program worked well the first year because of sufficient rainfall, with many individuals getting involved. When the project was tried the second year, the bank had a larger area cleared, however the rains did not come on time, and the project failed. (Mugyengi, personal communication) It does suggest therefore that the local people would engage in more agriculture, if assistance were given to them. In the case of the proposed irrigation system, the lack of water would not be the problem. The fact that they were not growing crops along the river might simply be that they do no irrigation at all; or conversely, because there is quite a lot of wildlife around the area, they might prefer to farm close to their houses where the animals are is less likely to come and destroy what they grow.

Because other hydrological development activities are being simultaneously planned for this area (drinking water and electricity), irrigated agriculture initially does not have to take the center stage, but can be properly developed over time. It is highly likely that with the coming of those other amenities, and the knowledge that water for irrigation is also available, people who are committed to farming, will be attracted to the vast areas of undeveloped and seemingly unclaimed land, between the Butiaba school and the escarpment. If this happens, it would probably expedite the development of an irrigated agriculture program in the area.

PHOTOGRAPH 10: Banana and Mango trees grown near the mouth of the River Waki

In view of what we have seen in the area, we recommend that an incremental, step-by-step approach, with each step accepted before the next is attempted should be used in developing the irrigation in this area. This type of approach (bottom up) is generally impossible with large scale irrigation schemes.

It is often said that effective irrigation development can contribute to food security and enhanced income, thereby improving living standards for the rural people. It can seldom be expected to accomplish both goals at optimum levels at the same time. For example, if the irrigation scheme is to be financially viable, then it might need to concentrate on the production of industrial crops which are grown on fairly large plots, such as cotton. In that case, the immediate contribution to food security may be indirect and the income of only a few individuals and families may be affected.

In this area, it probably is not appropriate to base decisions as to the viability of developing an irrigation project here solely on the use of conventional economics. Often other objectives, such as the food security situation, getting as many families as possible employed, or simply providing economic empowerment of the local inhabitants, thereby diverting them from illicit use of protected area resources, may increase the justification for developing the scheme.

In order for the bottom-up approach to informal irrigation to succeed, external (usually governmental) intervention in the farmers's way of life should initially be as small as possible, giving the farmers themselves the space for taking the initiatives, gaining confidence and adopting new methods. External financing can then be used to develop this program, using some of the points which are presented below.

It is often suggested that cooperatives are the best ways to manage a farm system. Unfortunately for every positive cooperative story there are many negative ones. To some farmers, cooperatives, especially those linked with governments or their structures, mean the misappropriation of funds, confidence tricks, swindling and manipulation.

Migot-Adholla (1988) notes that since farmer-owned agricultural cooperatives are rather widespread in Africa, perhaps their experience can be transferred to irrigation. He cautions however, that the two kinds of activities (for example, collectively selling milk versus managing the day to day regime of operations related to an irrigation project) are clearly different. It might be initially desirable to have only specific needs of the irrigation scheme handled by special cooperatives such as marketing of the produce, or a local credit union which would provide credit, related to agricultural activities, to the farmers participating in the scheme. The example provided by the Grameen Bank of Bangladesh may be considered.

If a credit union is to be established for the farmers to buy tools, seeds, and materials, it is important that one understand that local people worldwide are often suspicious of such organizations, and the program developers must be careful that it does not become simply an extension of the existing village power structure into a new environment. In Bangladesh, credit for many local cooperatives dried up because of this very reason. Apparently the limited credit available within the cooperatives were extended to those with influence, who used their position within the cooperative societies to get loans, and then in many cases not repay them. The subsequently high default rate caused the program to fail (AID 1983)

A checklist of points to be considered in forming farmers' cooperative should include the following:

- Where possible make use of existing forms of cooperation and social control, such as extended family, clan, quarter, or village.
- Let the group elect their own officers, who should change periodically.
- Help people decide on the remuneration system.
- Help people decide on a financial control system.
- Train people from the first project initiation phase in the field of group responsibility.
- Train the local extension officers right from the start of the project initiation phase.
- Train group leaders, and scheme management, in work organization, administration and bookkeeping, and external relations. (Underhill 1988)

We must always remember that the role of women in agriculture is extremely important, not only in agricultural production, but in educating the younger generation and in marketing.

It is important that upon completion of the physical design for developing a water supply and for conveying it to the irrigated area, attention must be given to actions required to ensure the availability of the many complementary inputs and conditions required for successful irrigation development. The costs for providing these inputs and conditions may exceed the cost of the engineering works required to develop the water and land. Therefore it is imperative that in the planning stage, firm plans be made to ensure the availability of the following inputs: production seed, fertilizers, pesticides and farming equipment. Also, necessary conditions for good production must be established by creating or providing favorable land tenure and ownership frameworks, favorable credit, attractive production incentives, and management skills.

In 1983, the European Community sponsored a program to evaluate irrigation projects they had sponsored in six African countries. (van Steekelenburg 1988) The results, which are very instructional here, indicated that it was common practice when designing irrigation schemes not to consult the farming families, instead planners seem to take for granted that every farmer will readily go for irrigation once it is available to him. However, it indicated there was ample evidence to prove that this is only true in situations where hardly any alternatives were left to the farmer. It recommended,"making a study of the existing farming system prior to taking any firm decision on project approval is indispensable." It suggests that such a study should answer the following questions:

- Does the farming family need or wish for additional agricultural production?

- Would irrigation fit into their present system and resource base (in terms of land, labor, finances, relations), and are the proposed modifications to that system acceptable/feasible?

- What is the present orientation/goal of the farmers: substance, safety, surplus, or speculative? Farmers in the first categories might not be very interested in venturing into new, market-oriented irrigation production; those in the second might be, and so on.

- What is the social reality at village level: can mutual cooperation for adequate operation and maintenance of an irrigation system be expected and, if so, under what conditions (leadership, ethnic composition, land tenure) ?

Such a survey in the area around Butiaba would be very instructional because many of the farmers who might move into the area are local tribal people from further north along the lake, whereas man people (farmers), now living in the immediate area where the irrigation is expected to take place, are reported to have settled there from elsewhere, including the former Zaire. Will there be conflict then, which does not now exist

In planning an irrigation scheme such as this, it is very important to carry out investigations into land tenure. The assumption that the land was state owned soon proved wrong during construction of the Gezira irrigation project in the Sudan, when many owners produced written title deeds (Tiffen 1987). Other important issues which must be dealt with in designing the irrigation scheme for the people near Butiaba include:

- Are the settlers (farmers) allowed to maintain off-scheme agricultural interests, for example livestock. This is vital if individuals within the scheme are to have communal responsibilities which might be neglected as they pursue their other interests.

- What are the tenant selection criteria, or can anyone come into the scheme?

- Do tenants have the same size plots or will that depend on family size? In some countries, the size of area assigned to a family is determined by that which can be worked without having to hire laborers.

- What type of management structure will run the place, and how will it be compensated?

- What are the rights and duties of those participating in the program? These will need to be clearly determined before the program starts, as the managers (overseers of the project) will have to define standards and issue instructions to cover such things as:
-- strict control over livestock and grazing areas;
-- construction, maintenance, roads, canals drains and other structures;
-- use of vehicles;
-- prevention and control of pests, diseases, fire and soil erosion;
-- maintenance of boundary beacons;
-- sanitary arrangements and hygiene; and
-- agricultural methods and practices in general.

- Once a person is in the scheme, are there any sanction for non performance; for example, can a family be evicted?

With the bottom up approach being proposed to develop the irrigation project in this area, most of this work requires the participation of the farmers and local organizations. The planning stage therefore of such a project requires the professional contribution of persons with social science training, who should be incorporated into every facet of the project. In addition to this, for the project to be sustainable, the ground rules to guide the project's implementation must be laid down by the local communities themselves during the project design.

In addition to the comments already discussed, arrangements might have to be made for handling the crops, depending on the nature of the program being contemplated, including: harvest equipment, transportation, produce, storage, processing, and marketing facilities. The long term success of such a program will require provisions for good housing, health services and other community facilities, schools, research and agricultural extension. Plans for supplying all of these needs should be an integral part of any irrigation proposal. (FAO 1968)

It is commonly understood that the economics of irrigation development are such that maximum net returns are obtainable, only when the entire irrigable area is intensely cultivated and the full range of complementary inputs is provided. This obviously must be the ultimate goal for the development of the irrigated agricultural program for this area. We believe that based on the unfortunate history of formal irrigation in Africa, including what has happened in Uganda, and what is apparent on the ground near Butiaba, that an incremental, step by step approach would have the best chance of success and sustainability.

The following general recommendations are being forwarded to develop an irrigated agricultural program for this area: Begin developing the project in incremental steps which must include the establishment of pilot test plots, where the local farmers should be encouraged to physically get involved as much as possible. Then choose an appropriate and efficient irrigation technology, including management, and hardware components, which can be realistically maintained and which can minimize recurring costs, especially those requiring foreign exchange. In all of this, involve the local district agricultural officer and the farmers. Let them feel that it is their scheme and its success or failure depends on them, not someone from abroad or Kampala.

As part of the design and construction of the mini-hydro intake, a pipe will be included which will provide the necessary irrigation water down into the valley from above the falls. In addition to this, it will be a very simple matter, as the project expands and when extra water is needed, to construct an intake structure off the tailrace from the powerhouse. This would allow the water being discharged into the river to be pumpe back into the fields.

What is being proposed here is to use irrigated water to supplement the water requirements of the farmers, not to replace rainfed agriculture with a full blown irrigation scheme. Water obtained as the result of the minihydro project will supplement rainwater and ensure that water is available to them all year round. The inclusion of the pilot plots and the involvement of the agricultural extension officer, which are both essential to develop agriculture in this area, is primarily to show the farmers what is possible using modern techniques, improved seeds, and cropping patterns. This area generally gets enough rain during the raining season to carry out rainfed agriculture. We are of the opinion that the step by step approach which includes provision for providing farmers with farming tools, improved varieties of seeds, fertilizers (including compost), and education as to how to improve their yields, will start this area on its way to a sustainable agricultural program in a matter of a few years. Experience has shown that people are generally willing to adapt to new things, if they believe it is in their interest to do so, and working within the pilot project scheme will show them that it is. There are many examples all over Uganda where other well meaning programs have started off with a rush only to fail a few years down the road.

Such a program, even if started small, will require money, which must be available over a number of years, probably five, rather than a lot of it all at once. A donor would probably have to be found who could commit to such a program, because to provide a lot of money all at once, as is often requested, without the necessary social and agricultural framework to support and thereby sustain it, will probably cause this project to go the way of most of its predecessors. The money, once appropriate would then be used to support the incremental development of the irrigated agriculture of the area, through the pilot plot training/participation program, the cooperative program, the improved seed distribution program, and the incremental construction activities.

It will probably be very useful to have the agricultural extension workers for this project visit the other irrigation schemes (success and failures) in Uganda. A significant advantage would also be gained by possibly sending the individuals abroad to neighboring countries. This will be more cost effective then having foreign experts come, spend a short time, use up a lot of the money in foreign exchange, and eventually leave, carrying the knowledge gained on the local project with them.

If a faster growing irrigation program is immediately desired for this area, or as the slower one (being proposed), is being brought along, the entire area below the falls can be divided up, with one side (towards the escarpment), being made available to private growers who would then have immediate access to the water, with the other side towards Butiaba, being left for the slower growing scheme. As an added advantage, because of the natural gradient surrounding the central high ground, distribution of water by gravit is possible, once water is delivered to the higher elevations, which will be possible because of the head generated by the intake to the hydro-power system

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APPENDIX A PERSONS MET IN UGANDA RELATED TO THE PROJECT

Environmental Protection and Economic Development (EPED)

Frank Turyatunga	Project Director
Benson Turamye	Senior Planner

Ministry of Agriculture

John Kalule-Swaali	Deputy Commissioner for Land Resources, Entebbe
J. M. Ogwanga	Irrigation Officer, Entebbe
Peter Watanda	District Agriculture Officer, Masindi

Ministry of Works

Patrick Kamanyire	District Engineer, Masindi

Uganda Electricity Board (UEB)

Emmanuel Nzabanita	Chief Development Manager, Kampala
Eutychno Maholo	Manager (UBE), Masindi

Metrological Department

Phillip Gwange

Geological Survey and Mines Department

Gadi Turyomurugyendo	Senior Geophysicist

Local Official, Masindi

Serimos Mulimba	Local Council 1 Chairman
Wamara Jos	Local Council 5 Chairman
Zededia Karokora	Resident District Commissioner

Directorate of Water Development

Dr. Nick Manderville	Consultant to Directorate of Water Development
Nebert Wobusobozi	National Coordinator of Gravity Flow Systems
Vally R. B. Wabwire	District Water Officer, Masindi
Tom Waako	District Hydrologist
Yesse Kisembo	Water Works Foreman, Masindi

Petroleum Exploration and Production Department

Reuben Kashambuzi	Commissioner

District Land Office

Sam Wakibi	Senior Staff Surveyor

APPENDIX B: DAILY FLOW MEASUREMENTS FOR WAKI 11 GAUGING STATION

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1967

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	4.221	6.449
2	-	-	-	-	-	-	-	-	-	-	4.679	6.309
3	-	-	-	-	-	-	-	-	-	-	5.511	5.819
4	-	-	-	-	-	-	-	-	-	-	4.057	5.042
5	-	-	-	-	-	-	-	-	-	-	3.202	4.548
6	-	-	-	-	-	-	-	-	-	-	3.509	4.176
7	-	-	-	-	-	-	-	-	-	-	3.210	3.891
8	-	-	-	-	-	-	-	-	-	-	3.339	3.385
9	-	-	-	-	-	-	-	-	-	-	4.439	3.082
10	-	-	-	-	-	-	-	-	-	-	3.947	2.843
11	-	-	-	-	-	-	-	-	-	-	3.966	2.592
12	-	-	-	-	-	-	-	-	-	-	4.280	2.476
13	-	-	-	-	-	-	-	-	-	-	4.457	2.404
14	-	-	-	-	-	-	-	-	-	-	6.272	2.304
15	-	-	-	-	-	-	-	-	-	-	5.325	2.228
16	-	-	-	-	-	-	-	-	-	-	5.648	2.199
17	-	-	-	-	-	-	-	-	-	-	6.061	2.154
18	-	-	-	-	-	-	-	-	-	-	6.807	2.435
19	-	-	-	-	-	-	-	-	-	-	5.911	2.440
20	-	-	-	-	-	-	-	-	-	-	4.879	2.298
21	-	-	-	-	-	-	-	-	-	-	4.191	2.199
22	-	-	-	-	-	-	-	-	-	-	3.645	2.148
23	-	-	-	-	-	-	-	-	-	-	3.384	1.941
24	-	-	-	-	-	-	-	-	-	-	3.201	1.881
25	-	-	-	-	-	-	-	-	-	-	3.004	1.865
26	-	-	-	-	-	-	-	-	-	-	3.743	1.897
27	-	-	-	-	-	-	-	-	-	-	4.922	1.908
28	-	-	-	-	-	-	-	-	-	-	5.534	2.160
29	-		-	-	-	-	-	-	-	-	5.232	2.097
30	-		-	-	-	-	-	-	-	-	6.512	1.957
31	-		-		-		-	-		-		1.975
Mean	-	-	-	-	-	-	-	-	-	-	4.6362	2.9388
Maximum	-	-	-	-	-	-	-	-	-	-	6.807	6.449
Minimum	-	-	-	-	-	-	-	-	-	-	3.004	1.865
R/off mm	-	-	-	-	-	-	-	-	-	-	22.977	15.05

Flows in cubic metres per second

Insufficient data for annual statistics

Possible data flags

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Printed on 24/ 3/1997

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1968

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.222	1.464	2.143	1.209	7.901	2.649	1.406	1.958	1.764	2.064	2.562	2.901
2	2.246	1.320	2.764	1.077	7.635	3.681	1.401	2.148	1.644	2.030	2.568	3.568
3	1.964	1.264	2.133	1.064	5.415	3.655	1.459	2.411	1.583	1.860	2.251	3.948
4	1.827	1.260	1.753	.947	4.848	2.841	1.563	2.592	3.699	1.743	2.388	3.475
5	1.795	1.255	1.711	.838	3.322	2.286	1.474	2.293	5.822	1.696	2.666	4.056
6	1.737	1.337	1.871	.898	2.623	2.316	1.488	1.931	2.365	1.867	3.059	5.908
7	1.727	1.614	2.326	.942	2.270	2.699	1.568	1.706	2.909	3.134	3.585	6.127
8	1.706	1.489	3.172	1.151	2.808	2.977	1.604	1.822	3.198	2.665	3.236	6.827
9	1.701	1.320	3.299	1.842	8.547	2.699	1.931	2.496	2.407	2.374	2.786	6.126
10	1.670	1.340	2.480	2.538	9.901	2.715	1.914	2.166	2.058	2.292	2.483	5.500
11	1.670	1.645	1.866	2.605	6.573	2.951	1.650	2.194	1.843	1.993	2.292	4.852
12	1.665	1.639	1.701	1.668	4.342	3.578	1.599	2.368	1.876	1.732	2.097	4.177
13	1.649	1.484	1.702	1.431	4.006	2.958	1.850	2.387	1.915	1.578	1.925	4.245
14	1.696	1.297	2.126	1.260	3.607	2.352	1.895	2.126	2.119	1.649	1.759	3.763
15	1.634	1.424	1.995	1.165	3.019	2.300	1.459	1.979	2.427	1.846	1.696	3.182
16	1.583	1.979	1.796	1.410	2.587	2.979	1.344	2.036	2.327	2.676	1.849	2.887
17	1.603	2.160	1.728	1.378	2.275	3.744	1.325	2.965	1.882	2.545	1.925	2.629
18	1.578	1.760	1.519	1.649	2.153	2.701	1.420	5.465	2.307	2.199	2.249	2.399
19	1.578	1.665	1.702	2.189	2.131	2.512	1.344	5.750	2.604	2.514	2.544	2.228
20	1.553	1.608	1.660	2.440	2.414	2.470	1.246	3.834	2.477	2.876	2.234	2.058
21	1.543	1.504	1.655	2.231	3.547	2.392	1.297	3.322	2.194	3.736	2.040	1.796
22	1.488	1.656	1.548	3.320	4.641	2.482	1.565	3.076	2.380	2.982	2.063	1.723
23	1.430	2.079	1.459	3.271	3.628	2.194	1.769	2.667	2.666	2.513	2.257	1.559
24	1.372	2.329	1.316	2.535	2.830	1.903	1.963	2.581	2.127	2.959	2.751	1.369
25	1.297	2.036	1.183	2.058	2.895	1.769	1.807	2.718	1.849	4.014	3.634	1.744
26	1.316	2.039	1.151	1.847	2.604	1.665	1.660	2.601	2.473	5.403	3.475	1.737
27	1.344	1.706	1.151	3.193	3.585	1.523	1.936	3.245	3.944	3.393	3.036	1.732
28	1.334	1.578	1.121	4.986	4.460	1.548	2.739	3.297	5.069	2.617	2.594	1.732
29	1.270	1.564	1.073	4.342	3.550	1.573	2.206	3.535	3.596	2.464	2.234	1.732
30	1.409		1.267	5.465	3.785	1.464	1.872	2.871	2.546	2.240	2.806	1.850
31	1.377		1.740		2.893		2.137	1.988		2.359		3.124
Mean	1.6124	1.6143	1.81	2.0983	4.0902	2.5192	1.6739	2.7267	2.6023	2.5165	2.5015	3.2566
Maximum	2.246	2.329	3.299	5.465	9.901	3.744	2.739	5.75	5.822	5.403	3.634	6.827
Minimum	1.27	1.255	1.073	.838	2.131	1.464	1.246	1.706	1.583	1.578	1.696	1.369
R/off mm	8.2574	7.7339	9.2696	10.399	20.947	12.485	8.5724	13.964	12.897	12.888	12.397	16.676

Flows in cubic metres per second

Annual statistics

Maximum 9.901 Minimum .838 Mean 2.423 cubic metres per second
Total 76.613 million cubic metres Runoff 146.488 millimetres

Possible data flags

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Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoimà-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1969

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.280	2.437	2.269	1.372	2.180	2.130	1.686	1.655	1.670	1.884	3.482	8.523
2	1.996	2.188	2.058	1.372	3.727	2.046	1.634	1.938	1.838	1.580	4.523	7.558
3	1.924	1.991	1.871	1.363	2.918	1.870	1.640	1.931	1.729	1.521	4.946	7.816
4	1.854	1.897	1.862	1.265	2.405	1.854	1.941	1.764	1.672	1.806	3.977	14.944
5	1.806	1.886	1.518	1.210	2.535	1.801	1.817	1.675	2.075	1.749	2.720	10.452
6	2.061	1.769	1.425	1.183	1.839	1.764	1.838	1.786	2.443	1.419	2.876	12.725
7	2.351	1.706	1.559	1.192	1.849	1.732	1.908	2.609	2.588	1.906	3.043	10.426
8	2.531	1.727	1.764	1.402	2.061	1.748	1.822	2.195	2.609	2.059	2.570	7.588
9	2.352	1.615	1.737	1.377	2.281	1.876	1.675	1.739	2.322	1.848	2.310	6.187
10	2.030	1.538	1.722	1.390	2.969	1.834	1.676	1.271	1.770	3.017	2.980	6.520
11	1.807	1.493	1.608	2.060	4.268	1.457	2.280	1.402	1.717	2.230	3.515	6.240
12	1.737	1.529	1.742	1.766	5.143	1.904	2.230	1.416	1.614	1.958	3.020	5.492
13	1.758	2.390	2.553	1.650	3.973	2.370	1.898	1.325	1.608	1.960	2.208	4.649
14	1.753	2.248	3.024	1.459	2.981	4.193	1.706	1.264	1.670	2.274	2.315	4.102
15	1.930	1.991	3.632	1.320	2.723	4.954	1.603	1.201	1.940	2.304	3.479	3.741
16	1.865	1.903	3.740	1.264	3.894	3.877	1.508	1.147	2.269	2.030	2.936	3.405
17	1.859	1.990	3.358	1.260	2.621	2.768	1.640	1.152	2.544	2.184	2.418	3.195
18	1.849	2.190	2.882	1.514	3.087	2.985	1.508	1.112	2.306	2.592	2.125	2.977
19	1.737	2.610	2.710	2.371	4.896	2.370	1.488	1.174	2.001	2.716	2.092	2.880
20	1.670	2.376	2.370	1.999	5.387	2.069	1.498	1.520	1.903	2.735	2.513	2.747
21	1.645	2.136	2.063	1.727	6.531	1.990	1.598	1.539	1.925	2.933	3.011	2.734
22	2.637	2.159	1.892	1.543	5.848	1.979	1.548	1.500	2.240	3.320	3.821	2.722
23	3.592	2.656	2.927	1.598	6.287	1.865	1.484	1.603	1.948	3.627	3.716	2.622
24	3.877	4.891	3.441	1.603	4.752	1.764	1.416	1.578	2.205	3.726	5.118	2.549
25	3.296	4.228	3.811	1.553	4.862	1.701	1.549	1.625	2.184	4.161	6.759	2.482
26	3.589	2.934	3.023	1.796	6.026	1.644	1.936	2.115	1.686	4.310	4.885	2.470
27	3.561	2.951	2.509	1.461	4.864	1.681	1.738	1.844	2.005	3.927	3.720	2.422
28	4.619	2.594	1.640	1.421	3.245	1.849	1.728	2.714	1.777	3.259	3.119	2.530
29	4.468		1.645	1.377	2.680	1.914	1.968	2.514	1.822	2.655	2.719	2.440
30	3.426		1.479	1.720	2.434	1.860	1.834	2.138	2.497	2.428	6.729	2.380
31	2.991		1.401		2.234		1.696	1.882		3.065		2.519
Mean	2.4791	2.2865	2.2979	1.5196	3.6613	2.195	1.7255	1.688	2.0192	2.5543	3.4548	5.1625
Maximum	4.619	4.891	3.811	2.371	6.531	4.954	2.28	2.714	2.609	4.31	6.759	14.944
Minimum	1.645	1.493	1.401	1.183	1.839	1.457	1.416	1.112	1.608	1.419	2.092	2.38
R/off mm	12.696	10.577	11.768	7.5312	18.75	10.878	8.8368	8.6446	10.007	13.081	17.122	26.438

Flows in cubic metres per second

Annual statistics

Maximum 14.944 Minimum 1.112 Mean 2.593 cubic metres per second
Total 81.761 million cubic metres Runoff 156.331 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1970

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.647	2.239	1.264	4.353	3.867	2.798	3.342	1.963	2.913	3.253	4.457	2.887
2	2.446	2.257	1.339	3.648	5.490	2.691	5.043	1.941	2.772	3.357	4.366	2.810
3	2.304	2.092	1.367	3.039	5.739	2.622	3.238	2.301	2.648	3.922	5.409	2.766
4	2.228	1.833	1.349	2.760	4.578	2.471	2.629	2.345	3.007	4.275	5.050	2.709
5	2.193	1.743	1.325	2.442	4.417	2.351	2.446	2.286	3.609	3.622	4.937	2.797
6	1.704	1.712	1.358	2.385	3.927	2.512	2.333	2.316	2.438	4.515	5.090	2.810
7	1.837	1.376	1.288	3.025	3.402	2.568	2.228	2.148	3.542	3.673	5.424	2.741
8	2.193	1.620	1.242	3.357	2.869	3.043	2.125	2.159	3.147	3.760	5.114	2.691
9	2.187	1.614	1.493	2.886	2.991	3.343	2.057	2.644	4.944	5.438	4.945	2.592
10	2.058	1.558	1.981	2.218	3.043	3.000	1.990	3.800	4.890	5.329	4.594	2.549
11	1.897	1.245	2.171	1.963	2.773	2.167	1.892	3.654	4.031	4.164	4.221	2.549
12	1.865	1.555	2.537	2.480	2.685	2.041	1.764	3.185	5.538	3.502	3.884	2.549
13	1.892	1.523	2.301	2.635	3.313	1.930	1.931	2.881	6.326	4.116	3.522	2.549
14	1.919	1.488	1.893	2.512	3.900	1.930	1.909	4.524	5.904	6.806	3.705	2.549
15	1.919	1.493	1.644	2.476	4.788	2.323	2.097	6.631	5.163	7.687	4.304	2.512
16	1.865	1.538	1.553	2.942	3.894	2.819	2.309	4.577	4.624	7.312	4.378	2.476
17	1.897	1.493	1.588	6.860	3.414	2.774	2.160	4.313	4.102	7.910	4.785	2.462
18	2.063	1.484	1.769	9.443	3.964	2.471	1.930	4.600	3.790	7.984	5.822	2.506
19	2.376	1.435	1.706	7.104	4.811	2.228	1.833	4.099	4.200	7.622	4.437	2.440
20	2.818	1.401	1.564	4.896	3.081	2.068	2.015	3.425	4.312	6.534	3.833	2.404
21	2.880	1.372	1.543	6.060	2.616	2.091	2.582	3.135	3.754	5.482	3.542	2.404
22	3.088	1.372	1.693	5.758	3.094	2.125	2.592	3.934	3.391	5.632	3.445	2.404
23	2.926	1.372	2.041	4.922	2.901	2.085	2.960	4.539	3.459	6.551	3.430	2.428
24	2.623	1.367	2.125	7.159	2.672	1.920	2.958	4.401	3.487	6.989	3.818	2.592
25	2.404	1.292	2.193	8.288	2.482	1.806	3.075	4.205	3.648	6.575	3.536	2.488
26	2.240	1.264	2.271	6.990	2.470	1.827	2.700	5.051	3.488	5.788	3.295	2.530
27	2.187	1.247	3.228	5.311	2.961	1.795	2.042	7.353	3.664	4.986	3.275	2.410
28	2.142	1.297	2.850	3.997	3.621	1.795	1.935	5.711	3.641	4.931	3.268	2.309
29	2.211		4.346	3.331	3.971	1.838	1.965	3.600	3.104	5.401	3.095	2.309
30	2.052		5.312	3.023	4.043	2.578	2.462	3.069	2.920	5.971	2.964	2.488
31	1.986		4.462		3.374		2.159	3.323		5.409		2.446
Mean	2.2273	1.5458	2.0902	4.2754	3.5855	2.3337	2.4097	3.6811	3.8819	5.4354	4.1998	2.5541
Maximum	3.088	2.257	5.312	9.443	5.739	3.343	5.043	7.353	6.326	7.984	5.822	2.887
Minimum	1.704	1.245	1.242	1.963	2.47	1.795	1.764	1.941	2.438	3.253	2.964	2.309
R/off mm	11.407	7.1502	10.704	21.189	18.362	11.566	12.341	18.852	19.239	27.836	20.814	13.08

Flows in cubic metres per second

Annual statistics

Maximum 9.443 Minimum 1.242 Mean 3.193 cubic metres per second
Total 100.698 million cubic metres Runoff 192.539 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 **Name :** R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1971

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.453	1.608	1.201	2.881	3.259	1.696	1.850	2.812	2.416	3.556	3.169	3.614
2	3.166	1.608	1.156	3.103	3.985	1.619	1.691	3.023	2.733	3.579	2.748	2.927
3	3.057	1.608	1.156	2.811	3.152	1.670	1.779	2.736	2.849	3.582	2.441	2.341
4	2.704	1.578	1.196	2.485	2.709	2.028	1.675	2.392	2.543	4.441	2.292	2.014
5	2.482	1.518	1.156	2.306	2.616	2.774	1.899	2.545	2.206	3.763	2.314	1.974
6	2.333	1.488	1.147	2.574	3.283	4.707	2.588	2.220	2.352	3.906	3.942	1.897
7	2.228	1.493	1.103	2.466	3.815	4.670	2.635	1.925	2.836	4.095	4.487	1.849
8	2.131	1.599	1.098	2.940	4.324	2.982	2.339	2.131	2.811	4.213	3.593	1.743
9	2.091	1.583	1.098	2.460	3.975	2.242	2.562	2.170	3.049	3.898	3.578	1.727
10	2.119	1.516	1.098	2.025	3.024	2.030	3.178	2.146	2.698	3.840	3.189	1.670
11	2.085	1.488	1.098	1.881	2.798	1.682	2.892	2.035	2.491	3.701	2.680	1.614
12	1.996	1.488	1.094	2.179	2.673	1.608	2.310	2.159	3.058	2.979	2.537	1.583
13	1.990	1.459	1.051	2.768	3.319	1.578	2.279	2.177	4.679	2.526	3.168	1.598
14	1.990	1.430	1.047	2.861	2.955	1.499	3.064	2.120	4.051	2.304	4.564	1.523
15	1.996	1.401	1.047	2.792	2.726	1.474	2.425	2.526	3.552	2.257	4.433	1.488
16	2.018	1.339	1.064	2.478	2.564	1.642	2.251	2.586	2.850	2.159	3.856	1.459
17	1.990	1.264	1.462	2.812	2.487	2.272	2.375	2.404	2.641	2.024	3.217	1.435
18	2.001	1.260	1.713	2.276	3.250	2.422	2.131	2.149	2.636	1.935	2.811	1.484
19	2.153	1.260	1.373	2.760	2.781	2.099	2.171	2.282	2.464	2.097	2.567	1.459
20	2.188	1.264	1.349	3.716	3.452	1.785	3.735	2.472	2.304	2.423	2.464	1.430
21	2.091	1.316	1.288	4.732	4.213	1.806	3.504	2.491	2.148	2.196	2.298	1.425
22	2.046	1.396	1.260	4.543	4.460	1.655	2.768	2.200	2.182	3.548	2.188	1.406
23	1.930	1.459	1.293	3.088	4.559	1.544	2.512	2.263	2.182	3.291	2.001	1.425
24	1.827	1.454	1.539	2.877	3.135	1.406	2.254	2.306	2.035	2.991	1.897	1.377
25	1.737	1.372	1.749	3.328	2.643	1.344	1.936	3.199	2.008	3.509	1.887	1.372
26	1.732	1.320	2.270	2.780	2.140	1.297	2.102	4.315	2.626	3.379	2.137	1.367
27	1.732	1.306	2.668	3.343	2.310	1.396	2.171	4.164	2.806	3.135	1.930	1.320
28	1.701	1.214	2.728	3.588	2.058	1.469	2.489	3.063	2.410	2.993	2.385	1.316
29	1.639		2.531	2.718	1.958	1.593	2.830	2.710	2.532	4.210	3.638	1.316
30	1.608		2.625	2.531	1.957	1.665	2.466	2.971	3.367	5.214	4.163	1.316
31	1.608		2.772		1.807		2.449	2.801		3.566		1.316
Mean	2.091	1.4318	1.4977	2.8707	3.0447	1.9885	2.4294	2.5644	2.7172	3.2677	2.9525	1.6705
Maximum	3.166	1.608	2.772	4.732	4.559	4.707	3.735	4.315	4.679	5.214	4.564	3.614
Minimum	1.608	1.214	1.047	1.881	1.807	1.297	1.675	1.925	2.008	1.935	1.887	1.316
R/off mm	10.709	6.6231	7.6703	14.227	15.593	9.8549	12.441	13.133	13.466	16.735	14.632	8.5549

Flows in cubic metres per second

Annual statistics

Maximum 5.214 Minimum 1.047 Mean 2.382 cubic metres per second
Total 75.123 million cubic metres Runoff 143.640 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

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Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1972

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.316	1.272	1.543	-	4.599	3.490	1.748	1.344	1.920	-	6.936	7.947
2	1.316	1.228	1.543	-	5.667	2.900	1.722	1.279	1.743	-	5.854	7.322
3	1.316	1.156	1.498	-	6.094	2.697	1.578	1.160	1.743	-	6.478	6.780
4	1.316	1.156	1.543	-	7.429	3.726	1.411	1.169	1.849	-	5.584	6.673
5	1.316	1.205	1.543	-	5.941	6.181	1.316	1.297	1.833	-	6.060	6.163
6	1.316	1.228	1.426	-	5.016	3.887	1.228	1.232	2.539	-	5.150	7.090
7	1.316	1.201	1.251	-	3.714	2.838	1.210	1.210	2.724	-	4.282	7.135
8	1.316	1.156	1.094	-	2.726	2.376	1.237	1.255	2.323	-	3.978	7.172
9	1.311	1.103	1.125	-	2.224	2.009	1.223	1.260	1.987	-	4.333	6.896
10	1.264	1.068	1.142	-	1.870	1.812	1.178	1.237	2.486	-	4.352	6.520
11	1.260	1.042	1.125	-	1.817	1.760	1.156	1.228	3.266	-	6.540	5.677
12	1.260	1.114	1.134	-	1.903	1.980	1.160	1.363	3.030	-	7.414	5.407
13	1.260	1.274	1.174	-	1.743	1.925	1.192	3.156	2.358	-	7.330	5.317
14	1.260	1.246	1.151	-	1.630	1.913	1.073	2.777	2.136	-	7.536	5.114
15	1.260	1.382	1.160	-	1.416	1.854	.955	1.825	2.119	-	7.574	5.211
16	1.260	1.553	1.219	-	1.420	1.850	1.094	1.849	2.125	-	8.158	5.548
17	1.228	1.431	1.276	-	1.455	1.899	1.055	1.914	2.119	-	11.517	5.060
18	1.165	1.316	1.374	-	1.701	2.097	1.121	2.047	2.051	-	9.594	4.236
19	1.196	1.260	1.461	-	1.604	1.935	1.187	1.753	1.892	-	9.932	4.175
20	1.151	1.237	1.925	-	2.186	2.065	1.224	1.600	1.743	-	9.810	4.102
21	1.151	1.197	1.739	-	2.660	2.471	1.156	1.382	1.727	-	10.971	4.124
22	1.233	1.051	1.249	-	2.484	2.767	1.178	1.363	1.644	-	9.914	4.161
23	2.067	1.004	1.099	-	2.465	2.909	1.174	1.260	1.603	-	9.183	4.138
24	1.903	1.017	1.047	-	2.033	2.940	1.259	1.344	1.427	-	7.936	4.087
25	1.622	1.000	1.042	-	1.753	2.853	1.883	1.382	1.613	-	5.432	3.984
26	1.589	1.042	1.004	-	1.854	2.381	2.119	1.320	2.497	-	5.563	3.839
27	1.498	1.047	1.042	-	2.292	2.052	1.939	1.316	3.437	-	8.659	3.716
28	1.513	1.087	1.005	-	4.428	2.176	1.758	1.472	3.483	-	10.082	3.676
29	1.454	1.480	.823	-	4.210	2.114	1.807	1.835	3.571	-	10.225	3.570
30	1.377		.842	-	4.954	1.947	1.388	2.655	3.610	-	9.486	3.563
31	1.344		.807		4.845		1.367	2.220		-		3.493
Mean	1.3598	1.1915	1.2389	-	3.1011	2.5268	1.3579	1.5969	2.2866	-	7.5288	5.2226
Maximum	2.067	1.553	1.925	-	7.429	6.181	2.119	3.156	3.61	-	11.517	7.947
Minimum	1.151	1.0	.807	-	1.416	1.76	.955	1.16	1.427	-	3.978	3.493
R/off mm	6.9639	5.7082	6.3447	-	15.881	12.523	6.9543	8.1781	11.332	-	37.313	26.746

Flows in cubic metres per second

Insufficient data for annual statistics

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 24/ 3/1997

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Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1973

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.487	2.339	2.555	1.732	4.280	2.265	1.242	1.325	1.523	2.316	1.985	2.222
2	3.613	2.298	2.371	1.696	3.535	5.961	1.169	1.311	1.553	2.193	1.946	2.333
3	3.661	2.263	2.187	1.644	3.275	5.905	1.196	1.269	1.598	2.102	1.947	2.199
4	2.486	2.257	2.125	1.665	2.978	2.940	1.206	1.283	1.619	2.096	1.811	2.058
5	3.557	2.199	2.063	1.686	2.471	3.034	1.260	1.260	1.691	2.188	1.737	1.924
6	3.195	2.193	1.985	1.843	2.464	3.066	1.260	1.260	1.655	2.234	1.743	1.859
7	3.161	2.187	1.865	1.795	2.404	2.865	1.260	1.293	1.801	2.369	1.903	1.795
8	3.262	2.125	1.822	1.727	2.465	3.096	1.260	1.599	1.929	2.423	2.067	1.696
9	3.535	2.063	1.737	1.624	3.076	2.403	1.292	1.563	3.220	2.626	3.003	1.553
10	3.377	2.057	1.722	1.665	3.262	1.951	1.363	1.826	3.826	3.176	3.913	1.488
11	3.282	2.131	1.619	1.711	3.605	1.156	1.387	2.405	3.503	3.862	3.805	1.469
12	3.282	2.222	1.619	1.822	3.453	1.541	1.494	2.308	2.907	3.797	2.980	1.499
13	3.322	2.153	1.812	1.854	2.704	1.892	1.330	2.020	2.831	4.095	2.654	1.311
14	3.235	2.068	1.865	1.828	2.489	1.969	1.556	2.497	3.003	3.732	2.422	1.363
15	3.088	2.125	1.796	2.052	2.933	1.604	1.604	3.010	2.996	3.698	2.398	1.344
16	3.075	2.187	1.670	2.322	3.230	1.578	1.578	2.134	2.925	2.947	2.298	1.288
17	3.042	2.193	1.608	2.592	3.144	1.608	1.524	1.770	2.735	2.760	2.120	1.260
18	3.009	2.187	1.603	3.093	2.636	1.608	1.484	1.739	2.555	2.868	1.903	1.260
19	3.003	2.130	1.528	3.942	2.398	1.578	2.414	2.933	2.648	2.900	1.843	1.260
20	3.003	2.125	2.071	3.432	2.188	1.518	2.728	3.753	3.023	3.029	1.991	1.260
21	2.971	2.130	2.768	2.735	2.245	1.459	2.304	3.601	2.891	2.959	2.020	1.260
22	2.913	2.187	2.555	2.945	2.171	1.430	2.252	3.559	2.316	3.529	2.088	1.260
23	2.778	2.165	2.428	2.896	2.112	1.401	1.668	3.551	2.091	3.371	2.293	1.260
24	2.766	2.048	2.537	2.514	2.098	1.339	1.475	3.023	1.952	2.654	2.781	1.260
25	2.703	2.423	2.476	2.333	1.924	1.264	1.548	2.583	2.019	2.176	3.196	1.260
26	2.629	3.211	2.299	2.257	1.903	1.237	1.543	1.851	1.812	2.019	2.969	1.260
27	2.537	2.773	1.892	2.410	1.930	1.246	1.518	1.774	2.196	1.865	4.310	1.260
28	2.410	2.716	1.859	2.660	1.936	1.160	1.523	1.780	2.941	1.865	5.811	1.260
29	2.404		1.822	2.641	2.091	1.151	1.548	1.619	3.270	1.886	4.174	1.260
30	2.404		1.737	2.895	1.941	1.160	1.548	1.603	2.769	1.865	2.424	1.260
31	2.398		1.732		1.919		1.479	1.548		1.957		1.260
Mean	3.019	2.2555	1.9912	2.267	2.6213	2.0795	1.5489	2.0984	2.4599	2.6954	2.618	1.4936
Maximum	3.661	3.211	2.768	3.942	4.28	5.961	2.728	3.753	3.826	4.095	5.811	2.333
Minimum	2.398	2.048	1.528	1.624	1.903	1.151	1.169	1.26	1.523	1.865	1.737	1.26
R/off mm	15.461	10.433	10.198	11.235	13.424	10.306	7.9321	10.746	12.191	13.804	12.975	7.649

Flows in cubic metres per second

Annual statistics

Maximum 5.961 Minimum 1.151 Mean 2.261 cubic metres per second
Total 71.314 million cubic metres Runoff 136.355 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1974

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.260	.897	.838	2.419	.914	1.344	3.579	1.196	2.538	3.818	2.711	2.018
2	1.260	.897	.998	1.707	.862	1.291	3.352	1.262	2.446	3.563	2.551	1.897
3	1.260	.897	1.374	1.519	.967	1.999	4.170	1.548	2.666	3.670	3.389	1.827
4	1.260	.897	1.237	1.344	1.114	1.947	4.508	1.480	2.793	4.479	3.574	1.795
5	1.255	.874	1.121	1.279	1.589	1.696	4.734	1.831	4.418	4.495	4.103	1.769
6	1.210	.846	1.004	1.459	1.588	1.416	4.488	2.570	3.476	3.955	3.298	1.764
7	1.205	.807	.992	1.593	1.615	1.283	4.098	2.616	3.761	3.570	3.176	1.785
8	1.205	.803	.938	1.513	2.194	1.215	3.454	2.543	3.570	3.626	3.718	1.737
9	1.205	.803	1.027	1.349	2.630	1.269	2.805	2.374	3.322	3.457	3.619	1.701
10	1.205	.803	1.402	1.251	3.421	1.349	2.694	2.188	3.095	3.950	3.411	1.665
11	1.205	.803	1.230	1.446	3.556	1.445	3.425	1.963	2.977	3.539	3.255	1.624
12	1.205	.803	1.004	1.989	2.908	1.396	4.548	2.102	2.679	3.122	2.881	1.701
13	1.205	.803	.930	2.256	2.629	1.260	4.795	2.781	2.893	3.142	2.648	1.748
14	1.205	.803	.894	2.744	2.555	1.156	5.042	3.056	2.940	2.856	2.369	1.670
15	1.205	.803	.826	3.158	3.060	1.151	4.571	3.329	3.813	3.601	2.165	1.614
16	1.205	.803	.826	3.690	3.195	1.151	4.051	3.296	3.755	3.677	2.002	1.603
17	1.201	.807	.850	3.482	3.082	1.151	3.704	2.882	2.998	3.641	1.935	1.553
18	1.156	.850	.850	2.669	3.003	1.188	3.833	2.599	3.068	3.447	1.968	1.578
19	1.147	.893	.850	2.019	2.813	2.340	3.310	2.217	4.506	3.072	2.085	1.603
20	1.077	.893	.850	1.914	1.987	3.613	2.888	2.085	4.044	2.966	2.275	1.548
21	1.047	.850	.850	1.631	1.811	4.471	2.424	1.924	3.804	3.473	2.494	1.464
22	1.047	.807	.850	1.251	1.892	3.677	2.726	1.769	3.418	3.276	2.470	1.430
23	1.047	.803	.850	1.340	1.856	3.210	3.446	1.670	3.194	2.900	2.933	1.430
24	1.047	.803	.911	1.109	1.711	2.832	3.411	1.573	3.295	2.629	4.078	1.406
25	1.047	.803	1.293	1.000	1.479	3.128	3.411	1.450	3.181	2.537	3.014	1.420
26	1.021	.803	1.196	.996	1.401	3.679	3.627	1.823	3.255	2.440	2.531	1.349
27	.992	.803	1.246	.996	1.363	5.165	3.091	1.919	3.480	2.555	2.446	1.349
28	.950	.807	1.550	.996	1.265	5.146	2.460	1.924	3.626	2.363	2.748	1.391
29	.942		1.898	.967	1.210	4.921	1.432	1.930	3.507	2.575	2.720	1.320
30	.901		1.828	.905	1.178	4.596	1.160	1.974	3.584	2.810	2.168	1.316
31	.897		1.875		1.169		1.156	1.932		2.849		1.316
Mean	1.1314	.83086	1.1093	1.733	2.0005	2.3828	3.432	2.1228	3.3367	3.2924	2.8262	1.5933
Maximum	1.26	.897	1.898	3.69	3.556	5.165	5.042	3.329	4.506	4.495	4.103	2.018
Minimum	.897	.803	.826	.905	.862	1.151	1.156	1.196	2.446	2.363	1.968	1.316
R/off mm	5.7943	3.8432	5.6809	8.589	10.245	11.809	17.576	10.871	16.537	16.861	14.007	8.1594

Flows in cubic metres per second

Annual statistics

Maximum 5.165 Minimum .803 Mean 2.156 cubic metres per second
Total 67.976 million cubic metres Runoff 129.973 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1975

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.316	1.648	.850	1.771	1.233	1.237	-	1.435	8.592	7.315	5.210	3.049
2	1.316	1.426	.784	2.304	1.361	1.174	-	1.318	8.242	7.311	4.930	3.316
3	1.316	1.297	.735	2.606	1.067	1.090	-	1.565	6.243	7.425	5.026	3.549
4	1.311	1.256	.691	2.766	.942	1.272	-	2.636	5.375	8.966	4.516	3.818
5	1.264	1.125	.666	2.495	1.262	1.609	-	2.190	5.440	9.063	4.228	3.612
6	1.232	1.047	.641	2.456	1.461	1.391	-	2.178	5.673	8.939	3.993	4.047
7	1.205	1.025	.773	2.090	1.210	1.197	-	2.669	5.516	8.601	3.650	3.994
8	1.201	1.021	.953	2.058	1.472	1.031	-	3.216	4.789	7.803	4.215	3.536
9	1.156	.992	.863	1.764	1.548	1.284	-	2.518	4.850	7.045	4.930	3.289
10	1.147	.946	.743	1.931	1.489	1.266	-	3.092	5.171	7.234	4.349	3.154
11	1.081	.901	.713	1.814	1.215	1.581	-	4.676	5.465	8.109	4.524	2.977
12	1.094	.918	.709	1.470	1.223	2.020	-	3.575	5.276	7.565	4.925	2.887
13	1.073	.972	.709	2.499	1.178	2.155	-	2.805	4.859	7.311	6.312	2.798
14	1.047	1.025	.666	3.886	1.360	1.713	-	3.339	4.674	6.657	7.100	2.672
15	1.042	1.017	.634	2.641	1.359	1.440	-	3.031	5.395	5.176	6.285	2.660
16	1.000	.946	.554	1.743	1.288	1.532	-	3.263	4.486	3.161	5.368	2.585
17	.996	.897	.467	1.814	1.538	2.002	-	3.275	4.764	4.922	4.521	2.512
18	.992	.830	1.120	3.745	2.097	1.822	-	2.946	12.505	4.724	4.447	2.470
19	.950	.776	1.720	5.370	1.781	1.559	-	2.716	13.749	4.569	4.258	2.410
20	.946	.713	1.996	3.149	1.549	1.401	-	3.041	10.349	4.554	3.962	2.404
21	.950	.680	1.919	2.410	1.484	1.417	-	3.398	7.554	4.355	3.825	2.398
22	.992	.746	1.676	3.059	1.378	1.828	-	4.622	6.398	4.440	4.102	2.339
23	.971	.717	1.425	5.073	1.242	2.302	-	6.667	5.988	5.302	4.791	2.333
24	.946	.709	1.539	4.619	1.232	1.780	-	5.013	5.507	7.381	4.687	2.292
25	.942	.673	1.280	3.521	1.232	1.411	-	4.780	4.837	9.982	4.289	2.199
26	.901	.695	1.052	2.774	1.461	1.316	-	6.154	4.409	9.731	4.517	2.193
27	.897	.808	.922	2.146	1.969	1.233	-	6.433	4.169	8.296	3.826	2.193
28	.897	.910	.834	1.681	2.609	1.156	-	6.817	4.379	6.209	3.529	2.187
29	.877		.834	1.464	3.398	1.138	-	6.504	4.664	5.465	3.275	2.130
30	.910		.859	1.344	2.556	1.302	-	7.108	5.679	5.457	2.997	2.125
31	1.100		1.049		1.442		-	6.871		5.138		2.119
Mean	1.0667	.95414	.97987	2.6154	1.5366	1.4886	-	3.8662	6.1666	6.7163	4.5529	2.7822
Maximum	1.316	1.648	1.996	5.37	3.398	2.302	-	7.108	13.749	9.982	7.1	4.047
Minimum	.877	.673	.467	1.344	.942	1.031	-	1.318	4.169	3.161	2.997	2.119
R/off mm	5.4629	4.4135	5.0181	12.962	7.8695	7.3777	-	19.739	30.562	34.396	22.564	14.248

Flows in cubic metres per second

Insufficient data for annual statistics

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 24/ 3/1997

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1976

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.063	1.372	1.422	1.219	4.222	5.708	2.452	4.322	2.999	2.660	2.125	2.722
2	2.057	1.372	1.440	1.398	3.496	4.745	2.315	3.797	2.842	2.755	2.046	2.500
3	2.029	1.363	1.484	1.388	3.268	3.892	2.477	3.775	2.753	2.636	2.057	2.536
4	2.051	1.636	1.493	1.584	3.202	3.371	2.877	4.139	2.992	2.458	2.153	2.440
5	2.057	1.894	1.484	1.777	3.044	3.004	3.467	3.607	3.501	2.661	2.340	2.298
6	2.035	1.919	1.435	1.881	2.655	2.887	3.282	3.350	3.711	2.939	2.837	2.193
7	2.085	1.836	1.639	1.892	2.310	3.276	3.336	3.062	4.361	3.600	2.555	2.119
8	2.085	1.493	2.001	1.871	2.159	3.050	3.569	2.887	4.402	3.398	2.660	1.915
9	2.051	1.660	1.542	1.639	2.080	2.649	4.266	2.804	4.065	3.559	2.855	1.903
10	1.990	1.494	1.316	1.459	1.892	2.802	4.243	2.843	4.154	2.846	2.971	1.806
11	1.930	1.382	1.210	1.651	2.087	3.089	4.562	3.502	4.162	2.519	2.678	1.882
12	1.935	1.367	1.151	3.436	2.399	3.227	4.288	4.206	3.836	2.392	2.573	2.125
13	2.040	1.462	1.103	4.450	2.531	3.574	4.410	4.353	3.440	2.269	2.428	1.958
14	1.957	1.472	1.125	4.736	2.081	2.392	5.319	5.220	3.317	2.199	2.216	1.774
15	1.859	1.665	1.166	3.920	2.165	2.195	5.401	4.816	3.113	2.125	2.125	1.701
16	1.795	1.654	1.559	4.023	2.264	3.017	6.568	4.009	3.984	2.057	2.024	1.634
17	1.737	1.498	1.548	4.206	1.936	4.059	7.173	3.508	4.014	1.952	1.963	1.548
18	1.701	1.430	1.446	4.383	1.780	3.040	6.548	3.404	4.524	2.119	2.109	1.493
19	1.670	1.387	1.023	4.736	2.129	2.520	6.005	3.431	4.044	2.333	2.177	1.484
20	1.670	1.339	1.086	3.810	3.198	2.829	5.458	3.545	3.832	2.580	2.791	1.459
21	1.665	1.719	1.026	2.484	2.985	4.817	4.963	4.102	3.351	2.779	3.606	1.323
22	1.614	1.559	.971	2.108	3.680	5.076	4.320	3.706	3.090	2.856	3.979	1.465
23	1.603	1.430	1.001	2.188	4.206	5.384	3.729	3.453	3.908	2.887	3.634	1.559
24	1.553	1.372	1.018	2.264	4.384	5.114	3.184	4.124	4.610	2.697	3.532	2.003
25	1.543	1.320	1.049	3.210	5.090	4.670	3.062	3.791	4.465	2.513	3.742	1.974
26	1.493	1.292	1.325	3.070	4.811	4.069	3.405	4.165	3.008	2.304	3.634	2.074
27	1.488	1.316	1.573	2.874	4.440	3.580	3.418	5.374	3.323	2.193	3.466	1.980
28	1.484	1.367	1.578	3.620	4.065	2.916	3.622	5.474	3.017	2.172	3.507	1.743
29	1.435	1.344	1.780	4.288	4.465	2.555	3.851	4.228	2.747	2.372	3.309	1.644
30	1.425		1.713	4.470	5.231	2.538	6.036	3.370	2.697	2.100	2.939	1.578
31	1.377		1.431		5.482		5.847	3.505		1.919		1.602
Mean	1.7896	1.497	1.3593	2.8678	3.2173	3.5348	4.3049	3.8668	3.6087	2.5596	2.7677	1.885
Maximum	2.085	1.919	2.001	4.736	5.482	5.708	7.173	5.474	4.61	3.6	3.979	2.722
Minimum	1.377	1.292	.971	1.219	1.78	2.195	2.315	2.804	2.697	1.919	1.963	1.323
R/off mm	9.1648	7.172	6.9612	14.213	16.477	17.519	22.047	19.803	17.885	13.109	13.717	9.6535

Flows in cubic metres per second

Annual statistics

Maximum 7.173 Minimum .971 Mean 2.774 cubic metres per second
Total 87.717 million cubic metres Runoff 167.720 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

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Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1977

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.336	1.205	.780	2.090	2.780	2.211	2.165	2.856	3.109	2.252	4.044	4.563
2	2.159	1.178	.761	2.153	3.039	1.985	2.493	2.110	3.010	2.398	3.585	4.095
3	1.996	1.151	.826	1.949	5.490	1.806	2.737	2.290	2.642	2.240	3.551	3.740
4	1.865	1.249	.889	2.154	7.455	1.753	2.616	2.171	2.708	2.159	4.221	3.418
5	1.758	1.383	.850	2.106	4.332	1.614	2.610	2.035	2.230	1.960	3.884	3.242
6	1.644	1.187	.807	2.716	3.083	1.533	2.422	2.637	2.355	2.423	3.740	3.115
7	1.573	1.099	.780	2.768	3.330	1.519	2.208	2.624	2.471	3.372	4.992	3.003
8	1.459	1.042	.701	3.161	3.210	1.558	2.015	2.547	2.635	3.088	5.213	2.925
9	1.372	1.000	.385	3.004	2.606	1.850	2.332	2.606	2.745	2.874	4.432	2.791
10	1.320	.996	.868	3.610	2.281	2.679	2.570	2.861	2.693	2.772	3.920	2.926
11	1.316	.996	.959	7.803	2.211	3.428	3.578	2.874	2.514	2.722	3.501	3.290
12	1.288	.975	1.254	6.667	1.943	2.748	4.571	2.766	2.411	2.722	3.235	3.202
13	1.255	.971	1.383	4.656	2.202	1.917	3.093	2.417	2.272	2.703	2.952	3.328
14	1.210	.992	1.319	4.516	3.229	1.812	2.478	2.120	3.620	2.691	3.036	3.166
15	1.223	.992	.992	5.262	2.908	2.288	2.511	2.284	3.481	3.084	3.162	3.336
16	1.501	.950	.905	4.150	3.409	3.352	2.428	4.798	3.995	3.522	4.033	3.242
17	2.044	.942	.897	3.262	3.175	3.898	2.304	3.069	4.147	3.460	3.963	3.042
18	2.654	.905	.874	3.628	3.232	3.626	2.036	2.649	2.632	3.746	4.296	2.887
19	2.509	.950	.847	2.937	2.364	3.812	1.948	2.404	4.480	3.432	4.146	2.735
20	2.286	1.043	1.403	2.138	2.342	3.279	2.106	2.304	5.051	3.148	4.244	2.586
21	2.119	1.064	1.426	1.718	3.050	2.674	2.030	2.194	4.647	3.610	4.418	2.476
22	1.903	.996	1.161	1.513	4.268	2.226	2.120	2.052	5.198	5.422	4.702	2.368
23	1.972	.950	1.047	1.353	4.537	1.936	2.165	2.126	4.980	5.834	4.804	2.412
24	1.595	.942	.992	1.283	5.718	1.892	2.093	1.974	3.828	5.665	5.474	2.939
25	1.411	.901	.922	1.422	5.541	1.943	2.127	2.074	3.316	4.872	5.203	2.760
26	1.401	.874	1.136	1.555	5.047	2.136	2.172	2.102	3.255	3.973	5.276	2.653
27	1.469	.826	2.217	1.863	4.199	2.327	1.908	2.395	2.933	3.535	6.542	2.454
28	1.538	.803	1.996	1.650	3.298	2.580	2.099	4.085	2.642	3.650	7.908	2.086
29	1.426		1.766	1.604	2.643	2.294	2.200	3.346	2.327	4.438	6.960	2.205
30	1.292		1.966	1.492	2.292	2.216	2.125	3.500	2.304	2.900	5.437	2.048
31	1.255		2.770		2.405		2.300	3.594		4.329		2.091
Mean	1.6822	1.0201	1.1574	2.8728	3.4716	2.3631	2.4052	2.6408	3.221	3.3886	4.4958	2.9395
Maximum	2.654	1.383	2.77	7.803	7.455	3.898	4.571	4.798	5.198	5.834	7.908	4.563
Minimum	1.21	.803	.385	1.283	1.943	1.519	1.908	1.974	2.23	1.96	2.952	2.048
R/off mm	8.6151	4.7185	5.9272	14.237	17.779	11.711	12.317	13.524	15.964	17.354	22.281	15.054

Flows in cubic metres per second

Annual statistics

Maximum 7.908 Minimum .385 Mean 2.645 cubic metres per second
Total 83.409 million cubic metres Runoff 159.482 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 **Name :** R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.001	1.264	2.545	1.584	5.943	1.957	2.154	1.924	3.445	4.725	15.697	6.539
2	2.051	1.255	3.109	1.645	4.900	1.957	2.442	2.061	3.242	4.312	14.409	6.065
3	2.051	1.210	2.991	1.609	5.246	1.892	3.942	2.210	3.069	3.797	12.872	5.757
4	1.990	1.205	2.540	1.459	6.586	1.801	5.134	2.535	3.161	4.278	11.438	5.564
5	1.892	1.201	1.931	1.387	7.130	1.795	3.909	3.142	2.997	4.858	-9.689	5.692
6	1.801	1.156	1.753	1.789	6.441	1.795	3.019	2.971	3.523	4.471	8.086	5.615
7	1.795	1.147	1.965	3.169	6.356	1.806	2.723	3.196	3.433	3.891	6.766	5.539
8	1.795	1.112	1.947	3.769	5.188	2.031	2.411	2.998	3.044	4.306	4.546	5.489
9	1.795	1.237	2.392	4.126	4.766	2.234	2.234	2.755	2.692	4.579	5.902	5.349
10	1.764	1.396	4.047	3.733	5.302	2.068	2.159	2.440	2.929	4.602	5.548	5.342
11	1.727	1.445	4.443	4.451	5.284	2.057	2.085	2.177	3.620	6.027	5.259	5.696
12	1.675	1.372	3.088	4.931	4.820	2.074	1.990	2.229	3.535	8.521	5.065	5.473
13	1.670	1.316	2.874	4.424	4.988	1.946	1.941	2.380	4.158	7.704	5.065	5.350
14	1.665	1.260	2.927	4.088	5.002	2.320	2.064	2.525	5.033	5.934	5.259	4.811
15	1.614	1.210	3.432	3.941	5.195	3.005	2.975	2.716	6.319	5.010	5.440	4.670
16	1.603	1.694	3.249	4.038	5.366	2.697	4.505	2.895	6.153	4.827	5.382	4.538
17	1.553	2.322	2.920	4.164	4.846	2.452	4.501	3.148	5.132	4.305	5.154	4.447
18	1.543	1.933	2.550	3.250	4.023	2.309	4.908	3.208	4.342	4.334	5.337	4.371
19	1.493	1.639	2.200	3.004	3.571	2.453	4.652	3.011	3.744	4.647	6.650	4.431
20	1.528	1.450	1.893	3.304	3.242	2.856	3.231	3.271	3.683	4.462	7.539	4.355
21	1.654	1.454	1.604	4.090	2.851	3.051	2.556	2.798	3.211	4.439	9.082	4.621
22	1.608	1.580	1.624	3.238	2.945	3.564	2.234	2.818	3.471	4.236	9.647	5.691
23	1.523	1.909	1.589	3.627	2.830	2.956	2.002	3.687	3.446	3.662	10.647	5.473
24	1.484	1.706	2.026	3.762	2.722	2.458	2.299	3.632	4.261	3.595	11.191	5.083
25	1.435	1.697	2.211	3.384	2.679	2.304	2.799	3.483	5.034	5.350	9.763	4.470
26	1.430	2.007	2.048	3.245	2.798	2.222	2.704	4.225	5.408	5.498	10.793	4.221
27	1.425	2.041	2.015	3.980	2.489	2.091	2.471	5.573	5.030	5.386	12.034	4.501
28	1.377	2.246	1.634	4.302	2.298	1.968	2.234	6.936	4.589	6.810	9.755	5.091
29	1.344		1.523	5.738	2.193	1.963	2.097	6.052	4.563	7.925	9.272	4.908
30	1.316		1.430	6.727	2.031	2.074	2.024	5.049	4.296	9.602	7.288	4.371
31	1.311		1.391		1.990		1.985	3.735		16.017		4.131
Mean	1.6424	1.5166	2.3836	3.5319	4.2607	2.2719	2.8511	3.2832	4.0188	5.5539	8.3525	5.0854
Maximum	2.051	2.322	4.443	6.727	7.13	3.564	5.134	6.936	6.319	16.017	15.697	6.539
Minimum	1.311	1.112	1.391	1.387	1.99	1.795	1.941	1.924	2.692	3.595	4.546	4.131
R/off mm	8.4109	7.0151	12.207	17.504	21.82	11.259	14.601	16.814	19.917	28.443	41.395	26.043

Flows in cubic metres per second

Annual statistics

Maximum 16.017 Minimum 1.112 Mean 3.739 cubic metres per second
Total 117.900 million cubic metres Runoff 225.430 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Annual summary of daily data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

Year : 1979

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	4.408	4.356	3.318	2.874	3.042	3.539	2.046	2.570	2.206	3.554	1.279	1.506
2	4.232	3.956	2.964	3.052	3.004	4.599	1.914	2.150	2.247	5.064	1.516	1.717
3	3.626	3.578	2.810	2.984	2.631	6.233	1.737	2.954	2.191	6.706	2.343	1.665
4	3.605	3.350	2.666	2.804	1.743	6.727	1.609	3.004	3.020	6.736	2.330	1.614
5	3.521	3.135	2.616	2.726	1.599	5.615	1.474	2.623	4.151	5.614	1.909	1.639
6	3.377	3.202	2.512	2.933	1.933	3.691	1.302	2.258	3.614	4.438	1.764	1.629
7	3.390	3.302	2.404	3.432	2.419	2.887	1.539	1.898	2.948	2.995	1.649	1.498
8	3.288	3.082	2.339	3.384	2.952	2.654	1.378	1.898	2.376	2.654	2.340	1.454
9	3.255	3.290	2.298	3.372	2.736	2.709	1.210	1.671	2.171	2.709	3.546	1.372
10	3.704	3.577	2.263	3.999	2.393	2.555	1.306	1.455	2.818	2.520	3.720	1.316
11	5.208	3.330	2.228	5.746	2.605	2.434	1.855	1.631	3.270	2.349	4.147	1.260
12	5.305	3.115	2.222	5.740	2.928	2.800	1.974	2.232	2.818	2.851	4.245	1.303
13	4.405	3.345	3.110	4.563	3.530	4.224	2.125	2.948	2.712	4.394	4.106	1.445
14	3.761	3.690	4.722	4.640	4.051	4.373	1.979	3.531	2.270	4.032	2.596	1.339
15	3.480	3.474	3.700	4.207	4.402	5.975	2.080	4.083	2.280	5.903	2.153	1.210
16	3.704	2.865	3.913	3.662	3.741	6.215	2.102	3.511	2.526	6.215	1.996	1.139
17	3.697	3.945	3.783	3.170	3.445	4.979	1.807	2.814	2.674	5.108	1.881	1.192
18	3.528	3.833	3.494	2.779	3.255	3.131	1.574	2.549	2.623	4.517	1.645	1.156
19	3.363	3.690	3.316	2.531	3.064	2.617	1.793	2.369	2.334	3.668	1.465	1.134
20	3.241	4.029	3.036	2.530	2.655	2.269	2.103	2.194	2.374	4.031	1.632	1.197
21	3.128	4.403	2.741	2.446	2.359	1.991	2.024	2.046	3.076	4.703	2.662	1.530
22	3.128	5.029	2.489	2.712	3.178	1.898	1.796	2.061	2.804	4.045	4.018	1.769
23	3.289	5.384	2.640	3.374	3.312	2.228	1.940	2.649	2.741	3.482	4.765	1.551
24	4.292	5.581	2.323	3.663	2.875	2.199	2.199	2.191	2.741	3.572	4.411	1.265
25	6.712	5.284	2.263	3.256	2.724	2.125	2.125	2.125	2.477	2.873	3.612	1.377
26	4.950	4.985	2.251	3.010	3.624	1.991	1.991	2.143	2.211	2.347	3.505	1.316
27	5.937	4.444	2.142	2.925	3.854	1.963	1.963	1.892	2.269	2.182	2.799	1.283
28	5.477	5.131	2.211	2.836	3.592	1.844	1.844	1.696	2.663	2.029	2.551	1.732
29	6.390		2.641	2.938	3.111	2.165	2.165	1.705	2.862	1.821	1.737	2.270
30	5.659		3.037	3.065	2.490	2.109	2.199	2.185	2.600	1.026	1.440	1.806
31	4.805		3.326		2.928		2.189	2.545		1.168		1.440
Mean	4.1892	3.9423	2.8315	3.3784	2.9734	3.358	1.8497	2.3736	2.6756	3.7195	2.6594	1.4556
Maximum	6.712	5.581	4.722	5.746	4.402	6.727	2.199	4.083	4.151	6.736	4.765	2.27
Minimum	3.128	2.865	2.142	2.446	1.599	1.844	1.21	1.455	2.171	1.026	1.279	1.134
R/off mm	21.454	18.236	14.501	16.744	15.227	16.642	9.4729	12.156	13.26	19.049	13.18	7.4544

Flows in cubic metres per second

Annual statistics

Maximum 6.736 Minimum 1.026 Mean 2.942 cubic metres per second
Total 92.767 million cubic metres Runoff 177.376 millimetres

Possible data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Water Development Department
Summary of monthly data - Flow

Station number : 85317 Name : R. Waki II at Hoima-Biiso Road

Basin no. : 5 Latitude : 1:43: 0 N Longitude : 31:29: 0 E Altitude : 980.3
Area : 523.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
1967	-	-	-	-	-	-	-	-	-	-	4.636	2.939	-
1968	1.612	1.614	1.810	2.098	4.090	2.519	1.674	2.727	2.602	2.517	2.501	3.257	2.423
1969	2.479	2.287	2.298	1.520	3.661	2.195	1.726	1.688	2.019	2.554	3.455	5.162	2.593
1970	2.227	1.546	2.090	4.275	3.586	2.334	2.410	3.681	3.882	5.435	4.200	2.554	3.193
1971	2.091	1.432	1.498	2.871	3.045	1.988	2.429	2.564	2.717	3.268	2.952	1.670	2.382
1972	1.360	1.191	1.239	-	3.101	2.527	1.358	1.597	2.287	-	7.529	5.223	-
1973	3.019	2.256	1.991	2.267	2.621	2.079	1.549	2.098	2.460	2.695	2.618	1.494	2.261
1974	1.131	.831	1.109	1.733	2.001	2.383	3.432	2.123	3.337	3.292	2.826	1.593	2.155
1975	1.067	.954	.980	2.615	1.537	1.489	-	3.866	6.167	6.716	4.553	2.782	-
1976	1.790	1.497	1.359	2.868	3.217	3.535	4.305	3.867	3.609	2.560	2.768	1.885	2.774
1977	1.682	1.020	1.157	2.873	3.472	2.363	2.405	2.641	3.221	3.389	4.496	2.939	2.645
1978	1.642	1.517	2.384	3.532	4.261	2.272	2.851	3.283	4.019	5.554	8.352	5.085	3.739
1979	4.189	3.942	2.832	3.378	2.973	3.358	1.850	2.374	2.676	3.720	2.659	1.456	2.942
Mean	2.024	1.674	1.729	2.730	3.130	2.420	2.363	2.709	3.250	3.791	4.119	2.926	2.742
Median	1.682	1.497	1.498	2.868	3.101	2.334	2.405	2.564	2.717	3.292	3.455	2.782	
Maximum	4.189	3.942	2.832	4.275	4.261	3.535	4.305	3.867	6.167	6.716	8.352	5.223	
Minimum	1.067	.831	.980	1.520	1.537	1.489	1.358	1.597	2.019	2.517	2.501	1.456	
St. dev.	.883	.847	.594	.812	.793	.556	.893	.803	1.118	1.447	1.881	1.410	
CV	.44	.51	.34	.30	.25	.23	.38	.30	.34	.38	.46	.48	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

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