Connections Between Recent Water Level Drops in Lake Victoria, Dam Operations and Drought

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Summary
The past 2-3 years have seen sharp decreases in Lake Victoria’s water level, currently more than 1.1 m below the 10-year average. In the past year it has been claimed that the dams at Owen Falls (Nalubaale and Kiira) are responsible for a portion of the lake’s drop, while others insist that the drop is due only to recent droughts.

This study sought to determine what factors have contributed to what extent to recent drops in Lake Victoria. Data has for some time been kept out of the public eye, but recently released reports as well as on-line resources allowed for rough analyses of the situation. At the same time, the implications for the designs and benefits of the Owen Falls and Bujagali Dams of recent level and outflow changes of Lake Victoria, as well as past observed hydrology, was analysed.

The major conclusions of the study are:
1. Recent severe drops in Lake Victoria (2004-2005) are approximately 45% due to drought and 55% due to over-releases from the Owen Falls Dams (Nalubaale and Kiira).
2. The Owen Falls Dams have not been adhering to the Agreed Curve for operations, releasing more water than dictated.
3. Based on the current Lake Victoria hydrology, as well as observations from the past 100+ years, the Owen Falls Dams are likely over-dimensioned.
4. The current hydrology, long-term observations and non-adherence to the Agreed Curve for Owen Falls Dam operations must be considered in the cost-benefit analysis of the proposed Bujagali Dam.
5. The lack of public information on dam releases, dam operations and river flows is disturbing and makes it difficult for outsiders to soundly judge implemented and proposed hydroelectric projects on the Victoria Nile.

Future climates, which will likely involve “drier conditions, lower lake levels… and lower downstream river flows” (WREM, 2005a), will exacerbate conclusions 3 and 4, making it increasingly more difficult for Victoria Nile dams to produce their projected power, and thus challenge hydropower on the Victoria Nile as a viable energy alternative for Uganda.

February, 2006
1. The Problem: Recent Severe Drops in Lake Victoria Level
Since late 2003, Lake Victoria’s water level has dropped over 1.1 m from its 10-year average (Figure 1). As of December 27, 2005, it was approximately 10.69 m, reaching the lowest level since 1951 (USDA, 2005).

Historical Water Level Elevations for Lake Victoria

![Historical Water Level Elevations for Lake Victoria](image)

**Figure 1:** Recent Lake Victoria water level drops (from USDA (2005)).

It should be noted that all Lake Victoria water levels in this report are given in reference to the Jinja gage. Reported water levels are thus not elevations. The 0 m, or datum, of the Jinja gage is 1122.86 m above sea level, such that the actual elevation above sea level of the lake can be computed by adding 1122.86 to the Jinja gage value (WREM, 2005b). For instance, a lake level of 11 m is equal to \(11 + 1122.86 = 1133.86\) m above sea level.
2. Nalubaale Dam: Turning Lake Victoria into a Reservoir
Since 1959, the outflow of Lake Victoria – the second largest freshwater lake in the world – has been under human control, through the Nalubaale Dam (originally called Owen Falls Dam), located at Jinja, Uganda. The construction of this hydropower dam effectively transformed Lake Victoria from a natural lake to a reservoir, controlling the lake’s outflow to the Victoria Nile (which eventually becomes the White Nile.

Originally, the outflow of Lake Victoria, while driven by inflow from tributaries, rainfall on the lake, and evaporation from the lake, was controlled “hydraulically” by Ripon Falls. Ripon Falls acted as a natural weir and constriction, allowing a certain flow of water to exit the lake depending on the level of water in the lake. The Nalubaale Dam submerged Ripon Falls, which were also excavated in preparation for the Dam, thus assuming hydraulic control over the lake.

3. Agreed Curve Mimics Natural Flows
An “Agreed Curve” (based on agreements in 1949, 1953 and again in 1991 between Uganda and Egypt) was developed for the operation of Nalubaale Dam to dictate how much water should be released from Lake Victoria, based on the water level in the lake, shown in Figure 2. This operating rule was developed in a way to retain the original (natural) pre-Nalubaale Dam relationship between lake level and outflow. Dam operators adjust the outflow based on a water balance of the lake computed every ten days (World Bank, 2002).

![Agreed Curve for the Release of Water at Owen Falls](image)

**Figure 2:** The “Agreed Curve” dictating how the Owen Falls dams are operated.

By developing such an Agreed Curve, the Nalubaale Dam’s operators acknowledged the importance of keeping Lake Victoria levels in sync with hydrologic developments and natural conditions. Allowing the lake level to dictate the outflow meant that fluctuations in rainfall and evaporation determined how much water would flow out of the lake, as would occur in a natural state. In effect, hydropower demands took a back seat to the requirement of mimicking natural conditions.

Figure 3 shows observed water levels in Lake Victoria since 1800. It can be seen that from the late 1800’s to about 1960, lake levels averaged between 11 and 12 m, indicating on the Agreed Curve in Figure 2 an average outflow range of 600-1100
m$^3$/s. However since about 1961, water levels and thus outflow has maintained a higher level than before.

Figure 3: Historical water levels of Lake Victoria (from Nicholson et al (2000)).

The Agreed Curve is not considered to be a significant factor in determining lake level (World Bank, 2002), meaning that by mimicking the natural system, when the dams are operated according to the Agreed Curve, they allow nature to “run its course.” In this way, lake inputs (direct rainfall and tributary flows) and outputs (evaporation and “natural” outflow) determine the lake level, as they would have in the natural state without the dams. This implies, since the historical data used to develop the Agreed Curve included previous droughts, dam operations according to the Agreed Curve would not lead to unnatural extreme drops in lake levels.

4. Kiira Dam: Extending the Owen Falls Hydropower Complex

Not all the water being released by Nalubaale was being utilised for hydropower production. Water release management at Nalubaale, with the aim of adhering to the Agreed Curve, involved balancing turbine and sluice gate flows, with only the sluices providing direct control. Some of the water flowed through the dam’s turbines, while some flowed through the sluice gates down a spillway. By regulating spillway flow, the sluice gates also determined how much water passed through the turbines.

The need for more power in Uganda resulted in a second dam being added one kilometer from the existing Nalubaale dam. The Owen Falls Extension, called Kiira, was built to utilise the “excess” water being spilled by the sluices of Nalubaale, thus generating more electricity. Work started on the Kiira project in 1993 and major construction was completed in 1999. In July 2000 the first 2 turbine and generator units (officially “Units 11 and 12”, continuing from the original 10 turbines at Nalubaale), were commissioned. The 3rd Kiira turbine, Unit 13, was commissioned in 2002. Design and project management was by Acres International (now Hatch Acres) of Canada.

The turbines of Kiira Dam are a few meters lower than those of Nalubaale, therefore utilizing the same "head" (water drop) from Lake Victoria plus some additional head, resulting in increased relative energy capacity. A 1.3 km canal above Nalubaale diverts water to Kiira in such a way that the two dams now in combination control the Lake Victoria water level and outflow. Figure 4 shows a map of the two dams.
With the opening of Kiira’s turbines, the aforementioned balancing of turbine and sluice gate flows at Nalubaale to adhere to the Agreed Curve has become more difficult, if not impossible, as additional water is released through the new dam (Wamaniala, 2002).

5. **What is the Cause of Recent Severe Drops in Lake Victoria?**

In order to estimate what the impacts of both drought and dam operations are on Lake Victoria’s water levels, the annual water balance of the lake was analysed under different scenarios. Two average annual water balances, provided in Yin and Nicholson (1998) and World Bank (1996) (from UNEP, 2005), were averaged in order to obtain a “consensus” water balance.

A non-drought year was analysed along with mild, strong and severe drought year scenarios. Table 1 shows the assumptions used to develop the drought scenarios, with 100% values equalling average annual direct rainfall, tributary flows and evaporation.

<table>
<thead>
<tr>
<th></th>
<th>No drought</th>
<th>Mild drought</th>
<th>Strong drought</th>
<th>Severe drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct rain &amp; tributary flows</td>
<td>100%</td>
<td>90%</td>
<td>80%</td>
<td>70%</td>
</tr>
<tr>
<td>Evaporation</td>
<td>100%</td>
<td>105%</td>
<td>110%</td>
<td>115%</td>
</tr>
</tbody>
</table>

**Table 1:** Drought scenarios used for lake water balance analysis.

A reduction by 10% of annual rainfall and tributary flow may not appear to be much of a drought. It must be considered, however, that if all of the missing rainfall was concentrated during the March-May wet season, it would represent a loss of 25% of the rains for those 3 months. If it were concentrated in the December-February dry season, it would represent a 55% rainfall deficiency for the season. The additional assumption of increased evaporation, based on the premise that during a drought there are less clouds and thus higher radiation and evaporation, further strengthens the drought scenarios. As a major component of the water balance, a 5% increase in

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1 A water balance represents the relationship between the lake’s input (direct rainfall and tributary flows), output (evaporation and outflow), and the resultant change in water stored in the lake and thus change in lake level for a given period of time.
annual evaporation is equivalent to a 3.6% decrease in annual lake input (rainfall and tributary flow).

The water balance and resultant changes in lake level were computed under five assumptions of Nalubaale and Kiira combined dam operations: according to the Agreed Curve and average annual releases of 700, 900, 1100 and 1300 m³/s. It was assumed that the lake level at the beginning of the year was equal to the recent 10-year average. The results are show in Figure 5.

**1-Year Drought and Dam Operations Effects on Lake Levels**

*Beginning Lake Level = 11.79 m (recent 10-year average)*

![Graph showing the impact of droughts and dam operations on Lake Victoria levels.](image)

**Figure 5:** *The impact of droughts and dam operations on Lake Victoria levels.*

It can be seen in Figure 5 that both drought and dam operations have strong impacts on lake levels. Under the mild drought scenario, operations according to the Agreed Curve would result in about half the lake level drop caused by average releases of 1300 m³/s. The dynamic nature of the Agreed Curve can also be seen – as drought intensity increases, less water is released, reducing the relative drop in lake level as compared to the steady release scenarios. If the analysis were to assume a lower starting lake level (as is the case today), the Agreed Curve would further dampen the impact of the drought relative to the steady releases.

Using the same water balance model, recent changes in the level of Lake Victoria were simulated. 2004 and 2005 were analyzed by estimating departures from average monthly rainfall to compute yearly difference from average rainfall in the Lake Victoria basin, based on data and graphics from NOAA (2006) and FEWS NET (2006a). Despite some periods of less than normal rainfall, for example April-July 2004 and the last months of 2005, the rough estimates of total departure from average annual rainfall are -10% for 2004 and -15% for 2005.

Recent reports indicate that for the period of October 2005 to 25 January 2006, rainfall in parts of the Lake Victoria Basin were 45-70% of normal (FEWS NET, 2006b). This is equivalent to 8-14% of annual rainfall, indicating that the -15% estimate used for the 2005 analysis is well within range. Owing to a lack of data, it was assumed that evaporation was 10% greater than normal for both years.
The analysis assumed that dam operations adhered to the Agreed Curve. As it represents the natural hydrologic functioning of the lake, any lake drop occurring with Agreed Curve operations represents natural drought effects. Therefore, any observed drops in lake level in excess of that expected from the Agreed Curve were caused by an additional factor. Results are given in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Observed Lake Level² (m)</th>
<th>Lake Drop (m)</th>
<th>Cause of Lake Level Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Begin</td>
<td>End</td>
<td>Drop</td>
</tr>
<tr>
<td>2004</td>
<td>11.59</td>
<td>11.13</td>
<td>0.46</td>
</tr>
<tr>
<td>2005</td>
<td>11.13</td>
<td>10.69</td>
<td>0.44</td>
</tr>
</tbody>
</table>

*Table 2: Water balance simulation results for 2004 and 2005.*

It can be seen that although the droughts of 2004 and 2005 contributed to the lowering of the lake level, if dam operations had adhered to the Agreed Curve, today’s lake levels would be around 50 cm higher. There has obviously been an additional factor in the reduction of the lake level.

Assuming this additional factor was dam releases not in adherence to the Agreed Curve, an analysis was performed to estimate what the average annual combined (both dams) releases would have had to have been in order for the observed drop to occur, shown in Table 3. The Agreed Curve annual average flows shown in Table 3 are computed based on the observed lake level at the beginning of 2004, followed by Average Curve releases for the two years. This assumption results in the lake level being about 0.45 m higher than observed at the end of 2005. This differs slightly from the expected lake drops shown in Table 2 (0.41 m) because these were computed individually per year, while the computations in Table 3 utilise the cumulative impacts of two years of non-Agreed Curve operations.

<table>
<thead>
<tr>
<th></th>
<th>Agreed Curve Average Flow (m³/s)</th>
<th>Needed for Observed Drop Average Flow (m³/s)</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>857</td>
<td>1387</td>
<td>162%</td>
</tr>
<tr>
<td>2005</td>
<td>752</td>
<td>1114</td>
<td>148%</td>
</tr>
</tbody>
</table>

*Table 3: Estimated average annual combined releases prescribed by the Agreed Curve, verses those necessary for the observed lake drop.*

It can be seen that for 2004 and 2005, more than 50% over the prescribed Agreed Curve flow has been released from Nalubaale and Kiira. If the two years are analysed separately, thus using the observed water level at the beginning of 2005 as opposed to the higher water level that would have resulted from Agreed Curve flows in 2004, the expected Agreed Curve flows for 2005 average 646 m³/s, such that the over-release approaches 75% of the prescribed flow for that year. Based on the results of this analysis (Tables 2 and 3), it must be concluded that the severe Lake Victoria drops occurring in 2004 and 2005 were about 45% due to drought, and 55% due to over-releases from Nalubaale and Kiira.

² USDA, 2005
Anecdotal evidence supports this conclusion: a dry period from June-September 2004 was followed by heavy rain during October to December of the same year. Experts assured that this wet period would raise the lake level “back to normal,” but this did not occur (Onek, 2005).

6. Sample Analysis Shows Dam Releases Far Above the Agreed Curve

Technical Report 7 of the Study on Water Management of Lake Victoria reviews a study on the river hydraulics between Lake Victoria and Nalubaale and Kiira (WREM, 2005b). It investigates primarily the impacts of the river channel and Lake Victoria levels on hydropower production.

Table 1 of Technical Report 7 lists the Nalubaale and Kiira outflows for August 19-21, 2004. These are provided to indicate the data used for the calibration and validation of a numerical simulation model. Dam operations data is otherwise not publicly available. Monthly flow data is available from the Global Runoff Data Centre for 1946-1970 and 1973-1982, but no recent or higher resolution (daily, hourly, etc.) data is publicly available. In many other countries such data is public domain, which is appropriate considering water and thus major lakes and rivers are public goods. The secrecy of hydrologic and dam operations data for Lake Victoria and the Victoria Nile is worrying.

During the 3 days of provided data, the estimated lake level at Jinja was about 11.24 m (USDA, 2005). According to the Agreed Curve, when the lake is at this level, about 740 m$^3$/s should be released. Although fluctuating between 530 and 882 m$^3$/s over the three days, Nalubaale was releasing an average 712 m$^3$/s, which is not far from the prescribed 740 m$^3$/s. These fluctuations are somewhat surprising, as the levels of Lake Victoria, which as discussed according to the Agreed Curve should dictate the dam outflows, cannot change so quickly.

But in addition to this 712 m$^3$/s from Nalubaale, during that same time, Kiira was releasing an average 658 m$^3$/s, such that for the lake level of 11.24 m, a total of average 1370 m$^3$/s was being released. This is a full 630 m$^3$/s over the Agreed Curve (an over-release of 85%). In other words, this is almost double the prescribed release for the given lake level. This over-release is very close to the average annual flow of 1387 m$^3$/s estimated in Section 5 of this study for 2004, further supporting the conclusion that over-releases have contributed to lake level drops.

On March 1, 2005, a Ugandan engineer, Hilary Onek (who is also an MP for Lamwo County, Kitgum) claimed that over 1400 m$^3$/s was being released from Nalubaale and Kiira combined (Onek, 2005). On that date, the observed lake level was about 11.05 m (USDA, 2005), which according to the Agreed Curve, requires an outflow of 653 m$^3$/s. The total releases from the dams were thus on this day more than double the agreed release for the observed lake level.

The Lake Victoria Policy Brief December 2005, as quoted in Mugabe and Kisambira (2006), indicates that during November 2005 the average combined dam releases were about 1100 m$^3$/s. During that month, the average Lake Victoria level was approximately 10.8 m (USDA, 2005), indicating an Agreed Curve prescribed release

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3 http://grdc.bafg.de
of about 550 m$^3$/s. During November, 2005, combined Nalubaale and Kiira dam releases were thus about double the prescribed releases, and are again extremely close to the average estimated for 2005 (1114 m$^3$/s) in Section 5 of this report.

It is clear that at least for some of the time since Kiira has come on-line, the combined outflows from Nalubaale and Kiira have been far above that prescribed by the Agreed Curve. Dam operations have therefore no longer been mimicking natural Lake Victoria outflows.

According to the WREM Hydraulic Model Study (2005b), at lake levels around 11.1 m, combined (both dams) maximum hydropower production would result in total outflow of about 1460 m$^3$/s. It would thus appear, based on the analysed flow data for August 2004, March 2005 and November 2005, that dam operators have been maximizing hydropower production, which is in violation of Uganda’s agreement with Egypt.

7. Mixed Messages on Plans and Operations

The East African media (in Uganda and Kenya, primarily) have had conflicting messages in recent weeks about this controversy. Numerous articles have made reference to the lake level dropping because of drought. But a few articles have stated that the lake's level is being negatively affected because of the operation of the dams.

For example, an article in The Sunday Vision on 4 Jan. 2006 states that "The (Study on Water Management of Lake Victoria) report heaped the blame for the continued falling water levels on the over leasing of water to generate electricity at the two existing dams, Kiira and Nalubaale" (Tenywa, 2006).

In this same article, Dr. Frank Sebbowa of the Electricity Regulation Authority denied the dams were at fault, blaming instead global warming. He said: “The new dam (Kiira) is supposed to replace the old dam (Nalubaale), which has become obsolete” (Tenywa, 2006). The article reports that the sluice gates at Nalubaale had been closed, and all flows were now going through Kiira, “which then rules out the arguments of over leasing of water.”

This is a mis-representation: the reality is that Nalubaale is still releasing water through its turbines, but the water that used to pass through its sluice gates (thus not producing electricity) is now passing through Kiira. On 5 January 2006, Maj. Gen. Kahinda Òtafire, Minister of Water, Lands and Environment, is reported to have said that the Government is considering closing one of the dams in order to maintain water levels (Nyanzi and Nandutu, 2006). This indeed confirms that both Nalubaale and Kiira have been in operation.

Dr. Sebbowa’s statements are also in conflict with the goal of Kiira to utilise the spare hydro capacity being spilled by the sluices of Nalubaale. If Kiira has been designed to replace Nalubaale, as Dr. Sebbowa stated, it can be assumed that reference to this would have been made in World Bank Project Appraisal Documents for the Uganda 4th Power Project, which is not the case (World Bank, 2001). Indeed, references to Uganda’s future hydropower generation include inputs from both Nalubaale and Kiira.
8. Disputed Hydrology
The hydrology of Lake Victoria, especially the outflow into the Victoria Nile, has long been a topic of disagreement among hydrologists and engineers. Between 1960-1964, Lake Victoria experienced a massive 2.5 m increase in lake level, which many experts have attributed to a period of excessive rainfall, but the precise cause of which is not agreed.

Computed averages for lake outflow depend greatly on the period of record used. Since the 1960-1964 rises in lake level, outflow has been greater than before 1960. Table 4 shows some of the many different computed values for average annual flow from Lake Victoria.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Flow (m$^3$/s)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 1960</td>
<td>600</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>1946-1982*</td>
<td>985</td>
<td>author’s analysis</td>
</tr>
<tr>
<td>“average flow”</td>
<td>1004</td>
<td>World Bank (2001)</td>
</tr>
<tr>
<td>1960-1982*</td>
<td>1218</td>
<td>author’s analysis</td>
</tr>
</tbody>
</table>


Table 4: Average outflow from Lake Victoria into the Victoria Nile at Jinja.

The impact of the period of record used to compute average flow is quite apparent in Table 4. Those using data only after 1960 are of the opinion that the higher water levels and thus outflows from 1960 are relatively permanent, representing the modern state of the lake.

Surface water modelling is based on stochastic hydrology, and the longest available and sound period of record should always be used for hydrologic statistical analysis. The longer the time-series of observations, the better dynamic physical processes, natural cycles, extremes and changes are captured. “As the number of samples grows, the accuracy typically improves” (Maidment, 1993).

This has been recognised by the World Bank: “The river is susceptible to some hydrological cycles but these are included within the available record length of 100 years” (World Bank and IFC, 2001).
9. Implications for the Owen Falls Complex

The original Kiira design and cost-benefit analysis were based on the higher average flows experienced after 1961. Acres International assumed a 99% probability for the continuation of the higher flows (thus implying a 1% probability for reversion to earlier low flows) for their investment risk analysis. This assumption was supported by a break-even analysis that showed that only a 61% probability for the high flows to continue was needed for Kiira to produce a net benefit. It was acknowledged that Kiira would not be economic if the low-flow observed before 1961 returned and continued (World Bank, 1991).

The World Bank again later recognised the challenges that Lake Victoria outflows and levels could pose to the viability of the proposed additional Kiira Units 14 and 15, admitting the flows were a function of an “uncertain hydrological regime.” It was, however, determined that the flow “available in the short-term (in particular during 2003-5) was the most critical” (World Bank, 2001).

The design therefore emphasized the higher flows of 1965-1998, neglecting the extremely high 1961-64 flow, which resulted in an average flow of 1004 m$^3$/s. The higher starting level of the lake (as observed since 1961) and the assumption that “from a hydrological viewpoint it is more likely that the higher post 1965 inflow pattern will continue as opposed to a reversion to the older lower flows” are given as reasons for this decision (World Bank, 2001).

It is unclear what hydrological viewpoint, when taken in context of the full hydrologic record and the inherent variability of climate and hydrology, would assume a high likelihood of continued high lake levels and flows. Although by omitting the 1961-1964 flows, the utilised flow is lower than figures computed for 1960–2000, it can still be considered optimistic in relation to the full historical record, and particularly with today’s new reality.

The situation has now changed, with the water level dropping severely and outflow reduced. In 2002 the World Bank’s Investigation Panel drew a conclusion that is beginning to ring true in light of the current situation: “If (average flow is) 650 (m$^3$/s), then the Owen Falls complex (Nalubaale and Kiira) is over-designed and incapable of full capacity” (World Bank, 2002).

Figure 20a of the Hydraulic Model Study of the Study on Water Management of Lake Victoria (WREM, 2005b) shows the combined maximum power generation capacity of the two dams. It can be seen that at current water levels of about 10.69 m (corresponding to an elevation of 1133.55 m), proposed turbines 14 and 15 would be useless.

Section 3.3 of the USER Manual: Lake Victoria Decision Support Tool (LVDST) of the Study on Water Management of Lake Victoria (WREM, 2005c) shows the turbine power curves of the 10 original Nalubaale units. For the full 180 MW of Nalubaale to be realised, a flow of at least 850 m$^3$/s is needed, depending on the lake level.

Section 4.5.2 of WREM (2005c) shows that at lake water elevation of 1134.0 m (equivalent to Jinja gage of 11.14 m), in order to produce combined (both Nalubaale
and Kiira operating) 200 MW of power, a lake outflow of about 1130 m$^3$/s is needed. This assumes optimising Kiira’s turbines as a priority over Nalubaale turbines, as the newer units are more efficient. This optimised combination (lake level 11.14 m, total outflow 1130 m$^3$/s), is much removed from the Agreed Curve, which dictates a total flow of 694 m$^3$/s for this lake elevation. The same figure shows that even flow only through Kiira, at about 800 m$^3$/s, is above the Agreed Curve, and produces just over 144 MW. Table 5 summarises the scant data available on minimum flow and lake level needed for hydropower generation as extracted from WREM (2005c).

<table>
<thead>
<tr>
<th>Minimum Condition</th>
<th>Dam Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flow (m$^3$/s)</td>
</tr>
<tr>
<td>800</td>
<td>11.14</td>
</tr>
<tr>
<td>850</td>
<td>all</td>
</tr>
<tr>
<td>1130</td>
<td>11.14</td>
</tr>
</tbody>
</table>

Table 5: Flow and lake level needed for power production found in WREM (2005c).

It can be concluded that under today’s and the long-term averaged (100+ years) lake level and flow conditions (for instance a flow of 838 m$^3$/s, as defined in World Bank (2002)), the average power capacity for the Owen Falls complex under sustainable operations is somewhere below 200 MW. It thus appears that the original Nalubaale plant, with its expansion to 180 MW, was well designed to capture the hydroelectric potential of the Owen Falls site in a sustainable manner.

Considering that the project target capacity of the Owen Falls complex is 380 MW, with so far 300 MW having been installed, it must be concluded that the complex, especially Kiira, has been over-designed. This scenario was noted in the project documents: “The only significant risk to economic feasibility would arise if low hydrologic regime flows of the magnitude of the pre-1961 streamflow data set were to occur. In this case, the extension would not be economic.” (World Bank, 1991).

Recent technical reports further support this conclusion: “The full installed capacity of the (existing and proposed) Kiira units (208 MW) cannot be utilized until 1137 meters lake level, which, of course, is undesirable from a lake level management standpoint.” (WREM, 2005b).

10. Implications for Bujagali Dam
The prospect of the flow and thus hydropower output of Bujagali Dam meeting cost-benefit expectations is a bit more positive, as the project design appears to have been based on the full hydrologic record (World Bank and IFC, 2001).

It is interesting to note, however, that hydrologists from the dam’s proponents, Acres International (also involved in the Kiira projects), disagreed with hydrologists from the Institute of Hydrology (IOH - United Kingdom), Electricité de France (EdF) and Knight Piesold (United Kingdom). The Acres' hydrologists believed that the pre-1960 data was not reliable, such that the long term mean flow would be about 1100 m$^3$/sec. The IOH, EdF and Knight Piesold hydrologists believed the 1925-1960 data to be reliable, such that their estimate of long-term mean flow was 870 m$^3$/s, and that “lake outflow conditions similar to the pre-1960 low flow sequence could occur again in the design life of a hydraulic structure” (World Bank and IFC, 2001).
One can assume that Acres’ optimistic view of the hydrology was biased, especially when considering they were disagreeing with professional hydrologists from the internationally renowned IOH (as opposed to engineers performing hydrology “on the side”, as is often the case in engineering firms), in a situation where such a disagreement benefitted the viability of their project.

Bujagali was designed assuming the flow released from Lake Victoria through the Owen Falls complex would be in accordance with the Agreed Curve (World Bank and IFC, 2001). As it is clear now that the Agreed Curve is no longer being respected and the Victoria Nile flow regime has changed, the original long-term energy output assessment for Bujagali is no longer valid.

11. Conclusions
Because of uncertainty a “cautious and incremental approach to the extension of Owen Falls capacity has been adopted” (World Bank, 2001). Unfortunately, it would seem that there has been no similar caution in recent Nalubaale and Kiira Dam operations. The Agreed Curve is no longer being adhered to, and the resultant over-release of water from Nalubaale and Kiira is contributing to the severe drop in water level in Lake Victoria.

The drops in Lake Victoria threaten the future performance of the Owens Falls dams, as well as to a lesser degree the proposed Bujagali Dam. “It is clear that future climates imply drier conditions, lower lake levels… and lower downstream river flows” (WREM, 2005a). It is unknown if Lake Victoria will recharge to the high levels and outflow experienced during 1961-2000, and if such a recharge could occur, whether it would be in the next years or only in 100 years. Viable non-hydro, or at least hydro not on the Victoria Nile, power generating alternatives must therefore be considered for Uganda.

It is ironic that some years of what appears to be optimised hydropower and thus benefit production since Kiira opened have now resulted in the economic viability of Kiira being challenged. This would appear to be a case of environmental and economic sustainability ignored!

12. References


Lahmeyer International (2004). *Owen Falls Extension (Completion of Kiira Station)* 


Monitor*, Kampala, Uganda, 6 January.

Water Balance Model to Infer Rainfall: An Example from Lake Victoria.” 
*Hydrological Sciences Journal*, no. 1, vol. 45, February pp. 75-95.

Climatology (CPC ARC).* National Weather Service, Climate Prediction Center, 
Camp Springs, MD, USA, 
http://www.cpc.ncep.noaa.gov/products/fews/AFR_CLIM/afr_clim.html

Section, Kampala, Uganda, 1 March.

Roskar, J (2000). *Assessing the Water Resources Potential of the Nile River Based on 
Data, Available at the Nile Forecasting Centre in Cairo.* Republic of Slovenia 
Ministry of the Environment and Spatial Planning, Hydrometeorological 
Institute of Slovenia, UDC: 556.53(282.263.1), COBISS: 1.01.

of climate change on Lake Victoria Basin, Africa.” *People-Centred Approaches 
to Water and Environmental Sanitation*, 30th WEDC International Conference, 
Vientiane, Lao PDR.

Kampala, Uganda, 4 January.

Outlook.* UNEP, Pan African START Secretariat (PASS), Nairobi, Kenya.

Resources in Uganda.” *Hydro Power Resources Development and Management 
Course*, Trondheim, Norway, 3-20 June.

29, Washington, D.C.

World Bank (1996). *Staff Appraisal Report for the Lake Victoria Environmental 
Management Project,* Report no. 15429-AFR, Washington, D.C.


