Hydrology of the major water sources of Lake Bosomtwe in Ghana

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Abstract

The paper seeks to identify the major inflows of Lake Bosomtwe, the meteoritic lake sited in the Ashanti Region of Ghana. It seeks to establish major annual flows as against the lake evaporation in an attempt to establish the water balance of the lake with a view to understanding the factors that are critical to the sustainability of the lake. The average annual rainfall observed in the catchment was estimated to be 350 mm. This is far lower than the average long-term rainfall recorded in the area, of 1,565.9 mm for the period 1950-1971 or that of 1,263.4 mm for the period 1971 to 1991. Even though there appears to be a decline in the two periods, indicating reduction in rainfall amounts with time, the recorded rainfall is not representative. Based on the recorded rainfall and stream flow data, an estimated annual inflow of 0.14027 km^3 was derived, with the major inflows being direct rainfall onto the lake surface (99.81%), Nana Abrewa stream (0.15%), Abono bɔ stream (0.04%) and Atafram stream (0.00% insignificant). In view of the reduced flows as a result of lower rainfalls, it is prudent to both conserve and adapt measures to ensure the lake is sustainably managed.

Introduction

The Lake Bosomtwe Project sought to identify and institute remedial measures aimed at ensuring the sustainable management of the lake and its environment for the benefit of the catchment communities and the environment. Some environmental concerns, including overfishing, new developments, depletion of the forest cover through bush burning and tree harvesting for construction and canoe ("padua") making, and inadequate farming methods were raised by the communities during the inception of the project.

These issues have become important due to increasing population and the use of the water and other resources of the lake especially for agricultural and leisure related needs. Rainfall in the catchment is not uniform with some areas receiving so little rainfall that the vegetation is mainly grass with a few scattered trees. Rainfall events rarely cover the entire catchment so that whilst it is raining in parts of the catchment, the remaining can be entirely dry. The population is increasing and this is putting more pressure on fish and other resources from the catchment. Recently, demand for fish from nearby Kumasi, the capital of the region, and its environs have put more pressure on the fish resource and therefore calls for improved aquaculture technology in the lake. The locals, due to reduced fish catches, have resorted to increased agriculture on the steep slopes of the impact crater. As more and more of the hills are converted into farmland, exposing the surface to the impacts of torrential rainfalls, soil erosion is expected to have a greater impact on siltation of the lake. Additionally, waste disposal is becoming a problem with its subsequent impact on the quality of the lake water. Being the main inland water body in the Ashanti Region, the lake environment is rapidly gaining popularity as a tourist centre. This has led to increased recreational activities that have the tendency of putting more pressure with regard to sanitation, demand for fish and pollution of the lake.

These issues were to be investigated in order

to assist in putting in place a sustainable management plan for the lake by the communities and local government offices represented by the district assemblies.

Lake Bosomtwe is a meteoritic impact lake believed to have been created in the Pleistocene period (World Lakes, 2012). The name Bosomtwe is derived from two Akan names, "bosom" meaning god or deity and "ɔtwe" meaning antelope. Thus, Bosomtwe means antelope god. It is a sacred environment for the communities because of the folk tales associated with the area. Sacrifices are performed occasionally for the lake god and though Christianity thrives, residents still resort to traditional methods of healing that have links to the lake.

The lake is replenished by direct rainfall, surface runoff and seepage from the hill slopes. It is the only inland lake in Ghana and has no drainage outlet apart from evaporation from the lake surface, abstraction for domestic use by the communities and deep percolation into the aquifer.

Most of the catchment of the lake is forested with patches of agricultural activity scattered on the hill slopes.

This paper seeks to identify and document sources of water into the lake and their seasonality with emphasis on catchment hydrology. Specifically, the paper seeks to undertake the following assignments;

- undertake reconnaissance survey of the catchment and conduct literature review of previously undertaken works and research
- conduct hydrological investigation, identify and document flow sources within the catchment including measurement of flow sources and sediment sampling
- conduct baseline research and analyses required for the creation and adoption of community-based water conservation approaches

This paper seeks to document the climatic and hydrological observations made and their implication for the sustainability of the lake.

Study Area

Lake Bosomtwe is located in the Ashanti Region of Ghana within latitudes 6° 28' 15.11" N and 6° 32' 28.53" N and longitudes 1° 24' 24.06" W and 1° 26' 46.30" W (Figure 1). It is the only closed (endorheic) lake in Ghana

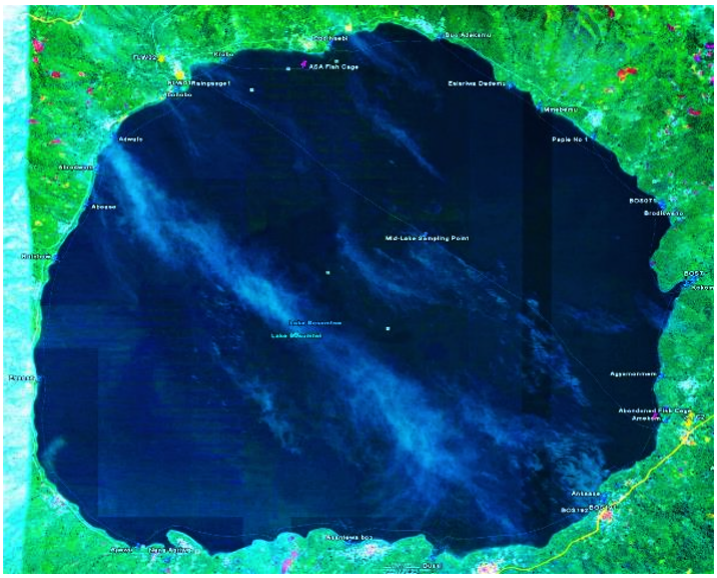

Figure 1 Study Area showing location of communities

and Africa, and the third largest closed lake in the world. The lake is enclosed within two administrative districts, Bosomtwe District and the newly created Bosome-Freho District, all within Ashanti Region of Ghana. The lake has the following characteristics.

The elevation of the lake surface is currently at 97 m above MSL (assumed to be 0.0 m). The surrounding crater rises to heights above 350 m with varying slopes all of which are rather steep. It lies in the deciduous forest agro-ecological zone of Ghana with average annual rainfall of 1,260 mm as shown in Table 1

All the communities in the selected catchment areas are fishing and agricultural communities. Abono, Ankaase and Abrodwom are major tourist centres within the catchment area, but Abono and Ankaase are the largest centres for tourist visits. One of the problems with water protection is the pollution of the lake due to human activities. As more and more people move into the area, a number of factors are likely to cause pollution. The quality of the lake water is often a good indicator of the way of life within a community through which it has its source. It is also an indicator of the socio-economic conditions, environmental awareness and attitude of the users around the lake.

Hydrology And Water Resources

The lake recharges mainly by rainfall falling directly into the lake and through its runoff from the slopes of the crater. Over forty-four stream channels release runoff water into the

TABLE 1
Characteristics of Lake Bosomtwe

Location	Ashanti Region, Ghana
Coordinates	6°30.3′ N, 1°24.5′ W
Lake Type	Impact Crater Lake
Primary Inflows	Rainfall, overland flows
Primary Outflows	none
Catchment Area	400 km²
Basin Countries	Ghana
Max Length	8.6 km
Max Width	8.1 km
Lake Surface Area	49 km²
Average Depth	45 m
Max Depth	81 m
Surface Elevation	150 m

TABLE 2
Trend of Rainfall depression due to Climate Change Impacts

	Annual Rainfall	
	1st Period	2nd Period
	(1950-1971)	(1971-1991)
Mean (mm)	1,565.9	1,263.4
Max (mm)	2,270.3	1,696.4
Min(mm)	1,140.5	864.8
CV	0.2	0.2

Source: Gyau-Boakye P, (2012)

lake during rainfall events and most of them run only temporarily through flash flows. The topographic outlay of the lake environment, showing the pattern of inflow channels and location of the communities, situated mostly around the rim of the lake is shown in Figure 2.

The slopes of the channels range from 4° to 20°. More than 75% of the catchment has slopes around 20° with the lower slopes being about 8°. Flows from the streams are therefore very fast and have the potential to erode the soil if vegetation is removed from the catchment. Fortunately, the steep slopes and the small catchment size coupled with the occurrence of rocks in the flow channels, does not allow the flows to progress for significant durations and hence the channels are not heavily developed but are still narrow in width and mostly shallow in depth.

Climate

The districts, in which the lake lies, have a wet semi-equatorial climatic regime and experience tropical rainfall with a bi-modal rainfall pattern. The rainfall period lasts from March to July and from September to November.

Lake Bosomtwe lies within the Interior Forest climate zone of Ghana. The mean annual long-term rainfall and evapotranspiration (Figure 3) data recorded from 1956 to 1995 were 1,419.8 mm and 1,454.3 mm respectively indicating significant humid periods within each year. This is in spite of the downward trend in annual rainfall receipts. The periods mid-April to July and September to October are relatively humid with rainfall satisfying evapotranspiration rates from a minimum of 71% to a maximum of 197%. A significant amount of rainwater runoff over the land occurs in these months. Monthly mean temperatures range from 30ºC in March to about 24ºC in August and relative humidity varies from 90% to 95% in the rainy season to 75% to 80% in the dry season. Rainfall deficits occur in the region because of the high evapotranspiration rates that occur in November to March.

Temperatures range between 20°C in August to 32°C in March. Relative humidity is moderate but quite high during rainy seasons and in the early mornings. The fairly even distribution of temperature and rainfall enhances the cultivation of many food and

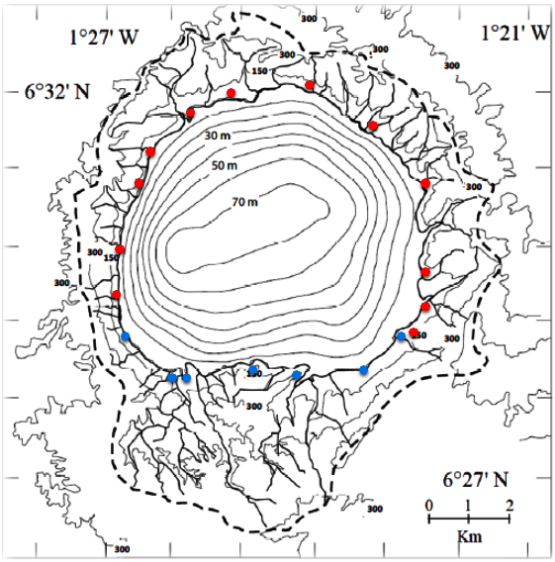

Figure 2 Distribution of stream channels and communities within the catchment
Source: Modified from Otu, 2010; Bosomtwe District Community, Bosome-Freho Community

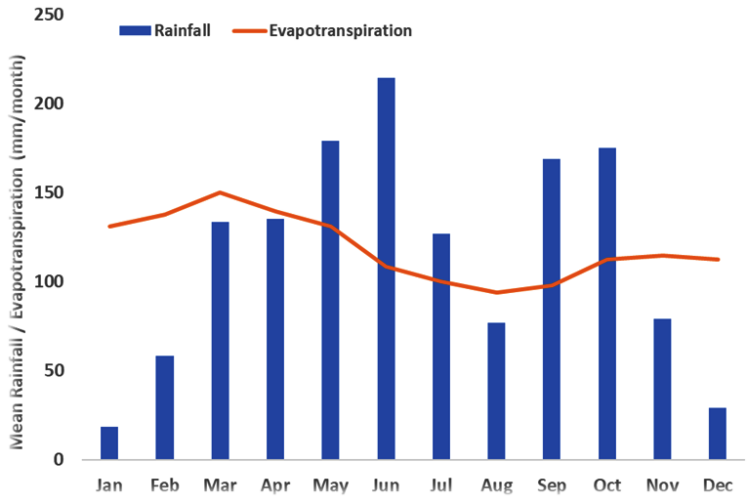

Figure 3 Mean Monthly Rainfall and Evapotranspiration of project site (1956 – 1995)

cash crops including, cocoa, plantain, cassava, cocoyam, maize and vegetables including pepper, tomatoes, okra and garden eggs.

During the period of the study, rainfall data was collected at five locations surrounding the lake (Table 3). Initially, two automatic rainfall recorders were installed at Abono and Amekom. Monthly totals of readings from these two stations are shown in Figure 4 below.

In addition, five semi-automatic rainfall gauges were installed at Apewu, Esaase, Abono, Amekom and Dompa. Several challenges were encountered with collecting rainfall data from the stations because of interference from unauthorised persons who tampered with the equipment. Long-term rainfall data was obtained from the web-based tool CRU CL 2.0 of the Climate Research Centre of the University of East Anglia (New *et al.*, 2002).

TABLE 3
Locations and altitudes of rainfall gauges and loggers around Lake Bosomtwe

Location	Latitude (°)	Longitude (°)	Altitude (m MSL)
Abono	6.53178396	-1.429379191	96
Amekom	6.48899183	-1.374760112	102
Esaase	6.49401418	-1.445605466	106
Apewu	6.47274728	-1.434629699	100
Dompa	6.47138069	-1.40054117	98

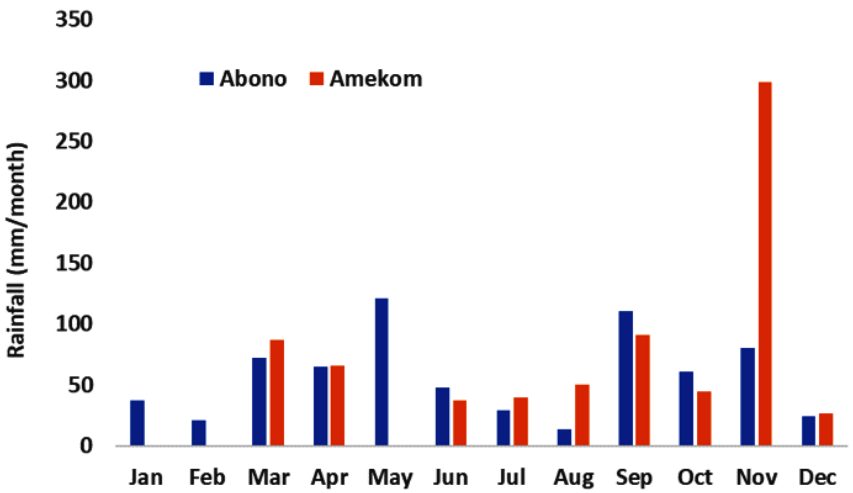

Figure 4 Monthly rainfall values recorded at Abono and Amekom

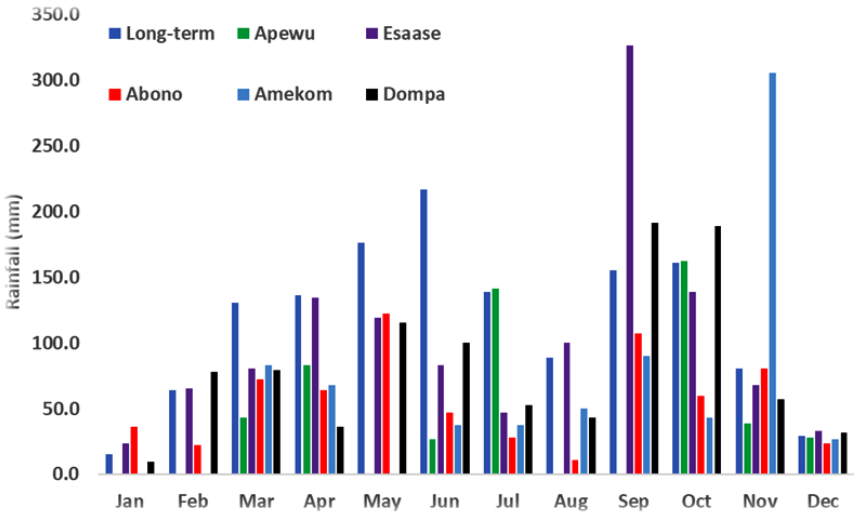

Figure 5 Recorded rainfall values in relation to long-term values (CRU CL 2.0)

Total monthly rainfall values collected from these stations and compared with the long-term data, are shown in Figure 5.

A comparison of total rainfall during the period for the stations (Figure 4, Figure 5 and Figure 6), indicate significant variations in rainfall amounts and variability. Several instances of malfunction of the rainfall gauges were observed due to tampering by unauthorised persons including tourists who visited the sites for recreational purposes. Even then, it is clear that variations in rainfall activity exist in the catchment. On several occasions, rainfall was observed in three separate locations around the lake without as much as a single drop occurring in the other locations.

An average rainfall of 350 mm, much less than is observed in the region, was recorded. As indicated, interruptions in the proper functioning of the rain gauges may have been the cause. It is also probable that it could be due a general decline in rainfall across the country. Using the average recorded rainfall over the catchment, total rainfall volume contribution into the lake environment is in the order of 0.14 km^3 per annum.

Hydrology

Only three streams were identified that contributed significantly to lake inflows. These include Nana Abrewa situated between the twin settlements of Apewu and Banso in the

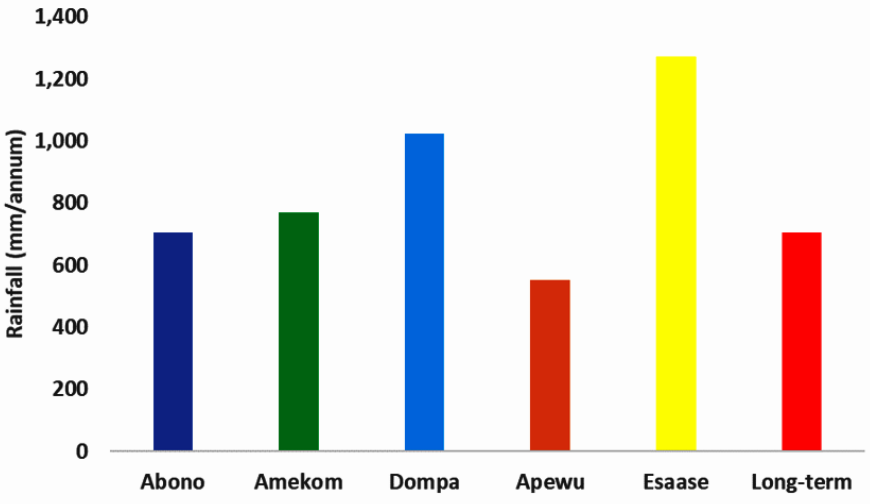

Figure 6 Total rainfall volumes (compared to long-term) recorded during the period

Bosome Freho district, Abono bɔ located at Abono in the Bosomtwe district, and Atafram at Atafram in the Bososme Freho district. Of these, Nana Abrewa rarely runs dry. Abono bɔ contributes more into the lake than Atafram though it runs dry earlier than Atafram. During rainfall, most of the flows, even for the small stream channels, are rapid and take place over a short period, as long as the rain is falling. After that, most of the flows cease with the three main streams showing some flows. It is almost difficult to manually measure flows during rainfall and requires constant presence at each location to be able to take measurements. For reliability, automatic flow measurement is recommended. Flow measurements were done by the floating method because the flows were too shallow (about 30 mm at Abono and about 26 cm at Nana Abriwa) to use a flow metre. The channels were also too wide (about 6 m at Abono) or with insufficient side slope to use a weir to measure the flows. The floating method was used to determine the velocities beneath the flow surface. The channel width was divided into several sections to get the various depths at different points. The surface velocity was measured with a stopwatch and small floats for six or more times (small enough to ensure that their movement was not affected by wind, e.g., dried leaves). A survey tape was used to measure the river/stream width and the distance travelled by the float. The time taken for the floating object to traverse the marked distance was noted and used to estimate the volume of water flowing through the channel. Average discharge measurements taken from the Abono bɔ and Nana Abrewa streams are respectively 6.3905m^3/hr. and 24.3652 m^3/hr. This translates to 56,019 m^3 and 213,585 m^3 of annual inflows respectively. It must be noted that sufficient data has not been collected to make conclusive statements about the generality of inflows of the streams into the lake.

The stream channel widths are rather narrow ranging from 20 cm in parts, to about 2 m at Nana Abriwa. Abono bɔ however is exceptionally wide and, in sections of its channel, widths can reach about 4 m. Depths of channels are also not deep and vary between a few centimetres at Abease, Assase, Apewu and about 1.5 m at Duase, Atafram and Ɔbo. These differences can be attributed to the soils in the areas. The relatively shallow stream channels

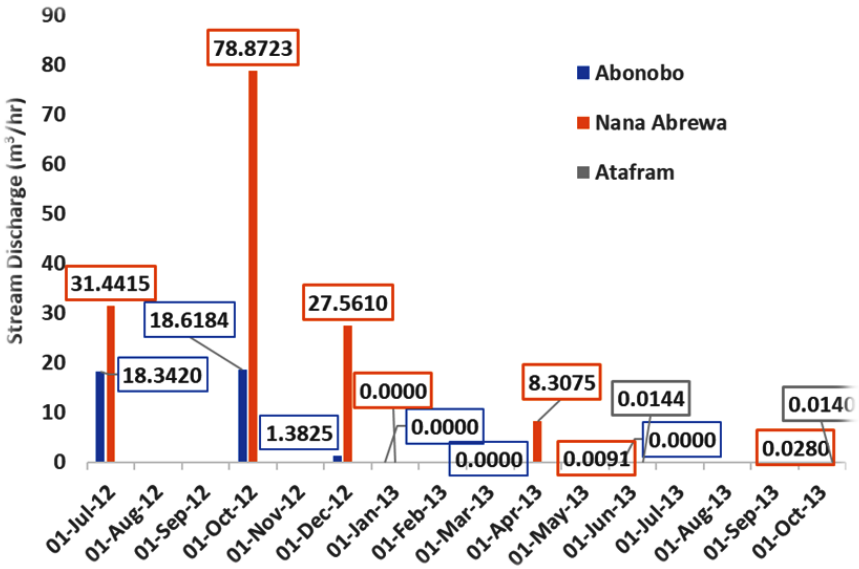

Figure 7 Discharge data of three streams recharging Lake Bosomtwe

have predominantly stony soil conditions as opposed to the silty clay conditions found at the locations with deeper channels at Ankaase (Figure 8). Erosion is therefore more apparent at places like Dompa, Duase, Amekom, Atafram, Ankaase, Agyamanmu, Old Brodekwano and Abono. Locations around Detieso, Esaase, Abrodwom, have less erosive conditions except close to the shore line due to the lack of the stony conditions of the beaches.

Figure 8 Narrow and dry channel at Ankaase (left) that feed the Lake Bosomtwe (right)

Discussion

It was observed during the three years of study, that variations in rainfall amounts occurred from year to year. Additionally, rainfall did not uniformly occur within the lake catchment, occurring in localised portions of the catchment during most events. Rarely did rainfall occur across the entire catchment simultaneously. A section of the catchment was actually observed to be in a rain shadow for most parts of the year as evidenced by the predominantly grassy nature of the slopes as against the lush greenery on the other sections of the catchment. Direct rainfall falling on the lake surface was estimated from the data collected to be in the order of 0.14 km^3 per annum. This is based on the recorded rainfall values for the three years of the study and is far lower than the average recorded rainfall for the periods, 1950-1971 (1,565.9 mm) and 1971-1991 (1,263.4 mm). Even though this suggests a reduction in rainfall, the challenges encountered in collecting data as well as a lack of sufficient spread in the siting of rain gauges does not justify the reduced annual rainfall of 350 mm. Evapotranspiration within the catchment exceeds rainfall for about seven months of the year. However, the annual amounts are not significant over the rainfall amounts. This has therefore led to lush vegetation in the catchment in spite of the steep slopes which promote runoff as against infiltration of rainfall. The climatic trend as observed shows a potential reduction in annual rainfall amounts which could mean an increasing deficit in rainfall that could affect the inflows into the lake.

Of the over forty inflow systems, only three streams were capable of observation and data collection. The others were so temporal in their flows, making them very difficult to monitor. Nana Abrewa flowed most of the year whilst Abono bɔ was perennial in nature. Atafram on the other hand was mostly submerged and rarely flowed on the surface, making it difficult to monitor. The residents in the community however dug in sections of

the stream to obtain water for agriculture and for domestic water supply. The data indicated that Nana Abrewa contributed most to the inflows into the lake, followed by Abono bɔ and Atafram in the order of 1716:450:1. The estimated average flow from these three streams is calculated from the observed data to be 0.00027 km^3 per annum.

The average inflows into the lake is thus estimated to be at least 0.14027 km^3 per annum, not considering seepage flows due to possible springs in the lake as well as submerged flows from some of the streams as occurred with the Atafram stream.

Conclusions

The study gives some insight into the inflow regime of Lake Bosomtwe with major inflow contributions coming from direct rainfall into the lake surface. The steep slopes of the depressed catchment of the lake is littered with over forty stream channels which are rather narrow, ranging from a few centimetres to about six metres in some sections of the Abono bɔ stream. Depths are even shallower, ranging from about 20 cm to about 1.5 m. Though rainfall and flow measurements were fraught with some challenges in the functionality of equipment, the spread/ coverage of the equipment and also difficulty in taking measurements especially for flows in the majority of the channels, the data obtained show that rainfall is the major contributor to lake inflows with direct rainfall into the lake being the largest contributor. The steep slopes of the catchment promote runoff instead of infiltration however the relatively short runs of the runoff water have not produced deep and wide channels even though erosion is observed to be prominent in the channels. The rocky nature of some sections of the catchment slopes, account for lack of prominent channel depths.

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