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# EVALUATION OF POTENTIAL RESERVOIR DEFICIENCY DUE TO CLIMATE CHANGE, KESEM KEBENA DAM, ETHIOPIA

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**Abstract**

Flood is an excess inundation of water on a surface and difficult to manage. The flood occurred in previous decades of Afar region of Ethiopia, consequently, leads to the death of human beings, destruction of infrastructures, an annihilation of massive hydraulic structures, and downstream properties. The main responsible factors for the flood incidences of the region are climate change, global warming, deforestation, and desertification. Climate change, however, is the foremost reason of increasing flood hazard. To coincide with this, hydraulic structures are designed based on the previously recorded flow data of a river. In Ethiopia, numerous earthen dams are constructed. The water storage capacity of dams is determined by the appraised flood of the upstream catchment: however, when the catchment flood increases due to climate extremes, the constructed structures cannot carry and going to demolish. The extra water that rises due to climate change from the catchment has to be removed before joins to the reservoir. This study has evaluated the potential reservoir deficiency of Kesem Kebena dam due to climate change. The study has comprehended different methods based on scientific criteria and selects the appropriate measure. As per the research output, the excess water that will arise from the catchment and add to the reservoir can be controlled by diversion floodways (Emergency spillways). The study has determined the amount of excess flood join to the reservoir for the excess rainfall incident month (August) for 100 years return period. Its magnitude is 85.76m$^3$/s. The emergency spillway is the best means to divert such unwanted water before joining to the reservoir. Its hydraulic design is discussed in the study.

**Keywords:** Climate change, Kesem Kebena Dam, Reservoir, Prioritization, Emergency Spillway

## INTRODUCTION

A flood is an overflow of a large volume of water on normally dry land beyond its normal limits (Salas et al., 2014). It is a natural phenomenon and nobody can preclude (Shaw, 2005). The floods on a catchment join to streams, channels, and rivers. The flow of these courses are recorded and documented for a certain year (Chow et al., 1988). Then, the documented and forecasted flood data are expedient to design hydraulic structure constructs on a river.

Climate change, an uncertainty of flood estimation methods, global warming, deforestation, desertification, data constraint, and soil degradation are the main features for the incident of an excess flood (Onwuka and Ikekpeazu, 2015).

As it is well known, the foremost governing factors used for hydraulic structure design are a maximum flood, project cost, and susceptibility to flooding, intended purpose and location (Botto et al., 2014). The above-mentioned features have prominent influence and shall be considered while designing water structures. Most of the riverine constructions in Ethiopia are planned and built by starved of bearing in mind of these features (Asfaw et al., 2014).

Hydraulic structures like earthen dams are susceptible to overtopping (Garg, 2006). As soon as the reservoir is entirely full it cannot tolerate tallying of extra and unwanted water to the reservoir. This surplus water is going to over top the dam. The extra water endangers the structure and the hydraulic stability of the dam. A dam intends to be stable during construction, end of construction and in its service years (Arora, 2012). Suitable and appropriate measurements and solutions shall be considered in advance before a superfluous flood develops and makes problems.

Ethiopia is one of the largest developing countries in East Africa. Its topographical characteristics have made the country pretty vulnerable to floods (Abaya, 2008). The flood occurrence in different regions of the country leads to destruction of infrastructures system and damage to life. As per the Abaya's 2008 climate change study report, climate change is the major development challenge of the country. It has a significant impact on the incident of excess water (Abaya, 2008).

For several years, floods have occurred in different areas of the country. 2007 in Dire Dawa and South Omo, 2014 in Kemisse and 2017 in Meteka were the dangerous flood incidents which caused the deaths of dozens of people (Haile et al., 2013). In particular, the Meteka flood was the near year event and affected the displacement of more than 3,000 people from their home. The incident was captured as a photo as shown in Fig. 1 a) and b). It is located downstream of the study area.

Enormous water construction projects have been completed in different areas of the country (WWDSE, 2006). Most of them are multi-purpose dams and are vulnerable to flooding. Among these, Kesem Kebena dam project was designed to supply irrigation water for a 20,000 ha land. In 2008 the Kesem Kebena Dam upstream catchment flood hazard demolished a 35m high dam at Kesem River. The total cost of the dam was two million US dollars by the time.

*Fig. 1* a) Flash flood devastating Meteka town of afar region of Ethiopia in July 2017, b) the communities were displaced from their village

Effect of climate change for flood intensification at the research area was not scientifically studied before: however, scholars have investigated and quantified climate change influence on other similar catchments. As stated by Wobus, et al., it has a significant effect to make an excess flooding. Climate change consequences a rise of 25% flood magnitude for 10 and less years return periods. It also makes 50% rise for 15-30 years return period and 67% flood magnitude increments for 100 years return periods (Wobus et al., 2017). Climate change is, even, worthy on the augmentation of floods for longer return periods.

Structures built across rivers are especially vulnerable to floods (Ranghunath, 2006). Potential damage can be decreased by structural and non-structural, hydraulic measures (Suykens et al., 2016). Fundamental structural hydraulic measures are: confining flood banks, river bed character improvement, flood diversion through flood-ways, reservoir storage improvement and cascade dams (Hudson and Harding, 2004). Whereas, the non-structural hydraulic measures include performing land use practice and soil conservation on flood plains, proclaim dam safety guidelines, adaptation of a flood warning system, community educations and geophysical information system (Hudson and Harding, 2004). These two itemized methods and their lists are aid to control both expected and excessive floods. It is unlikely to use all of these measures for a specific site. Therefore, the prioritization of measures and scientific studies are very vital.

There are many hydraulic flood controlling methods. All of them are not necessarily significant for a specific site. Prioritization of measures for a dam site is very important. The question of when and where the measures appropriateness is answered by observing and assessing previously studied substantial scientific papers.

The study discusses intended hydraulic measures and set its ultimate solution. Measures are appraised and discussed based on precise criteria. The criteria are implementation cost, construction simplicity, appropriateness to control flooding, durability, efficiency, and the place where the measures are located with reference to the structure (Stephens, 2012). The detail

*Table 1* Structural flood controlling methods evaluation and selection

| Measures | Advantages | Disadvantages | Economic Issues |
|---|---|---|---|
| Confining the flow between high banks | Important for protecting an area from over bank floods | It doesn't intend to decrease the due surplus water joins to the reservoir | Costly |
| River bed character improvement | Retard channel flood during its tide.<br>It signifies flood by reducing its speed and increasing its storage volume | Changes the existing ecosystem and ecology of the river.<br>It is not critically important to protect a downstream structure from excess water. | Less significant |
| Diversion floodways | Important to preserve the dam from overtopping and demolishing | Needs appropriate saddle point to be effective | Moderate |
| Improve reservoir storage capacity | It helps during dam construction | Its use is inhibited for full reservoir condition. | Costly |
| Cascade dams | The measure constructs at the upstream side of the flood prone area. | Constructing a dam for protecting other dam from flood hazard alone is illogical. | Costly |
| Adopting Soil Conservation | When the upstream catchment is conserved, the amount of flood becomes retarded. | The upstream catchment of the study area is not ominously important and not significant to soil conservation. | Less significant |

measures appraisal and selection is done based on the listed out parameters of Table 1. The evaluation is done qualitatively for each measure's advantage, disadvantage and economic issues. From the mentioned measures in Table 1; diversion of a flood through floodways, channel character improvement and soil conservation did not need more construction times, resources and crews. The remaining measures, i.e. confining the flow between high banks, providing a temporary storage reservoir, and improve the storage characteristics of the dam reservoir; however, needs large crews, resources and times. If the intention is to reduce certain percentage of flood these laterally mentioned methods are not significantly important.

The prioritized flood controlling measures at the dam reservoir is the first mentioned methods. But, the last two are not significantly important, i.e. river bed character improvement and soil conservation. Terrace and planting of trees conservation measure were there at the reservoir upstream catchment but the flood occurred and demolished the 35m high dam. From this, it is understood that even if the measure is already exercised, it was not critically significant. River bed character improvement has little significant and it has a negative impact in changing the ecosystem and ecology of the river.

As per the above explanations, all measures have specific aptness and snags. Therefore, thinking ahead about climate changes and propose diversion floodways is very important. Eventually, diversions of a portion of flood through floodways are the best prioritized flood controlling measures to protect earthen dams from excess flood (Cowin and Bardini, 2011).

This study evaluated the potential deficiency of the reservoir of Kesem Kebena dam due to climate change and designed appropriate structural hydraulic measures for controlling surplus flood water. In general, the research targeted to protect constructed earthen dams from excessive and unconsidered flood hazard throughout its service years.

## STUDY AREA

The study focused on the Kesem Kebena Dam site (Fig. 2). The site is located in Kesem catchment (Fig. 2 c)), which is a sub-catchment of Awash Basin (Fig. 2 a)) and b)) and located between altitudes of almost 3,471m to 870m above sea level (Fig. 2 b)). Its latitudinal and longitudinal directions are within $9^0$05'18"N $39^0$08'26"E to $9^0$08'56"N $39^0$53'03"E. The upstream catchment to dam site covers about 3,135km$^2$ (Fig. 2 c)). The length of the river up to dam axis is 230km (Fig. 2 c)).

The dam site experiences a typically tropical semi-arid climate with rainfall range of 350mm to 600mm per annum. Temperature varies from mean minima of 15ºC and 21ºC to mean maxima of 23ºC and 38ºC in December and June respectively. Mean relative humidity is lowest in January, 36% and highest in August 58%. Mean daily sunshine reported on an annual basis is 8.5hours.

The catchment experiences from cold to hot weather conditions at its lowland and highland areas respectively. Its rain range falls between 350mm in lowland arid areas to 1,500mm per annum at highlands. The land use condition of the catchment mainly includes: cultivated agricultural land, bare land, grassland, forest land, and rural and urban settlements. The lad use condition of the catchment percentage is shown in Figure 3. The most common soil types are 12% lithosols, 20% cambisols and 68% gypsisols (Paulose, 1989).

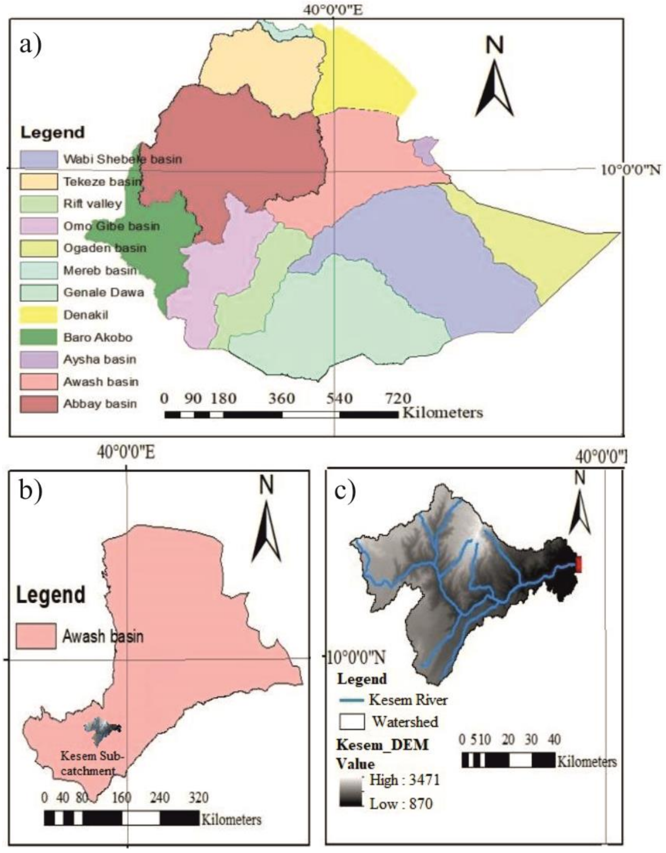

*Fig. 2* a) Ethiopia River basins, b) Awash basin, c) Kesem sub-catchment

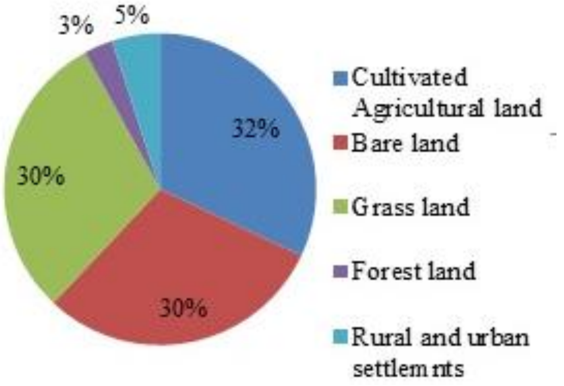

*Fig.3* Land use condition of the catchment

## DATA AND METHODS

### Meteorological data collection

In this study 14 meteorological stations located in and around Kesem catchment were considered. The data of Sheno, Shola Gebeya, Balchi, Chefa Donsa and Alaltu were studied more intensively as they fell within the catchment upstream of the reservoir.

Thus, except July, August and September, as shown in Table 2, rainfall is highly variable. These dates are the last 52 years monthly average rainfalls, shown in Table 2, (1966 to 2017) and higher than the 34 years monthly average data that the dam was initially designed, shown in Table 3, (1966 to 1999). It indicated and proved that there is a rainfall increment and the difference in percentage is expressed in Table 4.

### *Reservoir and spillway*

The dam is zoned and constructed from earthen materials. Its structural height is 43m. The approximate reservoir capacity at its full supply level is 500 million $m^3$ (WWDSE, 2006). Its fetch distance is 8,000m (WWDSE, 2006). The site has a concrete spillway, to spill the excess water from the reservoir, separated from the body of the dam. It is located at the right side of the dam reservoir. It has 1.5m effective discharge head (WWDSE, 2006).

The water discharges from the reservoir to the downstream command area is by 5m diameter tunnel. It is the water outlet for both downstream ecosystem and irrigation area. Hence, the average outflow from the dam pass through the tunnel is $11.74m^3/s$ (WWDSE, 2006).

### *Maximum monthly rainfall*

For this study a 52-years monthly average rainfall data was taken from Ethiopian metrological agency nearby stations and used to estimate the maximum extreme rainfall magnitude. To make the research reliable, 100 years return period is considered. The Gumbel’s method of extreme hydrologic event (Chow et al., 1988) is considered for maximum monthly rainfall scenarios. The method applicable to extreme hydrologic event is expressed as:

$$X_T = U + a\, Y_T \quad \text{(Eq.1)}$$

$$U = X^- - 0.5772*a \quad \text{(Eq.2)}$$

$$a = 0.7797*S \quad \text{(Eq.3)}$$

$$Y_T = -\ln(\ln(T/(T-1))) \quad \text{(Eq.4)}$$

where U = mode of distribution; $Y_T$ = reduced variate; $X^-$ = mean of the samples (Table 3); S = Standard deviation, $K_T$ = frequency factors, T = return period, $X_T$ = maximum rainfall magnitude for T years return period

Then the estimated maximum rainfall magnitude is probably happened in August because it is the maximum rainfall month as the climatological data shows. The remaining months maximum rainfall data were taken by taking the rainfall incremental percentage between the maximum monthly data from Table 2 and the computed maximum rainfall magnitude of August.

### *Peak inflow discharge*

The rational method is used to estimate the peak runoff volume of the catchment. It is the inflow volume of the reservoir. The rainfall volume (in a million cubic meters), was computed using the following equation:

$$V = 1{,}000*CIA \quad \text{(Eq.5)}$$

Where; the rainfall volume (V) is expressed in a million $m^3$, C is the average runoff coefficient, I = $X_T$ is the computed maximum monthly rainfall of 100 years return period in mm, and A is the catchment area in $km^2$ (3,135).

The extreme rainfall magnitude is the rainfall record that will happen in a month. It is difficult and uncertain at what time and day it will happen within the month. So the appropriate and best scenario is keeping this maximum rainfall magnitude for the determination of monthly inflow discharge. That is why the research was conducted by assuming the rainfall magnitude at the maximum level throughout the month. The maximum inflow will happen at August as the rainfall trends indicated in Table 2 and 3.

The average runoff coefficient of the catchment has been taken from the topographic nature of the runoff surface (0.497). The land use and land cover of the catchment helps to know its runoff coefficient. The catchment has different types of land covers. Then, its average runoff coefficient is estimated by taking the weighted average of more than 30 small watershed land use of the upstream catchment with their corresponding runoff coefficient and area cover.

$$C = \sum_{i=1}^{n} \frac{(C_i*A_i)}{(A_1+A_2+\ldots+A_n)} \quad \text{(Eq. 6)}$$

*Table 2* Monthly Average rainfall data of the 14 rain gauge stations in the period of 1966-2017 (Source: Ethiopia Metrological Agency)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF (mm) | 12.1 | 28.2 | 47.2 | 5.7 | 45.8 | 63.1 | 242.5 | 261.4 | 99.3 | 25.1 | 9.9 | 5.7 |

*Table 3* Monthly Average rainfall data of the 14 rain gauge stations in the period of 1966-1999) (Source: Ethiopia Metrological Agency)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF (mm) | 10.8 | 26.7 | 47 | 5.6 | 43.1 | 60 | 221.5 | 230.9 | 94.6 | 24.7 | 10 | 5.7 |

*Table 4* Monthly Average rainfall data increment of the 14 rain gauge stations between the two investigated periods (1966-1999, 1966-2017) (Source: Ethiopia Metrological Agency)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF increment (%) | 12% | 6% | 0% | 2% | 6% | 5% | 9% | 13% | 5% | 2% | 0% | 0% |

*Monthly outflow volume*

The outflow volume of the dam arises from its bottom outlet and/or main spillway. The spillway has effective length and height. Its maximum discharge is estimated by considering the full effective length, height and velocity (WWDSE, 2006). They are secondary data obtained from the hydrologic design report of the Kesem Kebena dam. The bottom outlet is also considered constant and taking the full flow through the 5m diameter tunnel. The research is done by taking the secondary data from hydrologic design report of Kesem Kebena dam report (WWDSE, 2006).

*Monthly excess water volume*

The monthly excess water joined to the reservoir is computed by considering the outflow from both the spillway and the bottom outlet (tunnel), inflow from the catchment and storage from the reservoir. The computation is made for each month starting from August. The calculation is assumed that the dam is full at the end of July before the start of the computation i.e. August. As the previous experience shows most of the Ethiopian earthen dams have been fully filled at the end of July. So it is better to start the simulation by assuming the dam is initially full.

$$Vm=I+S-O \qquad \text{(Eq.7)}$$

where: Vm: Monthly excess water volume, I: Inflow, S: storage, O= outflow

The spillway outflow volume is considered when the difference of monthly inflow and storage of the dam is greater than the total capacity of the reservoir and its bottom outlet. The maximum effective storage volume of the reservoir is 500 million cubic meters (secondary data from WWDSE) and its spillway design discharge is equal to 106.61m$^3$/s (secondary data from WWSDE).

The computation is made for 100 years return period because the other lower years discharge cannot exceed the discharge due to 100 years return period.

*Emergency spillway design*

These are spillways which provided for additional safeties of the dam, which not contemplated by normal design assumptions. The research site (dam) is already completed and providing its service. So, the researcher couldn't modify the main spillway design. Then, the proposing solution is diverting the excess water at the entrance of the reservoir using emergency spillway. Its crest is set at the maximum design water level of the dam. Its main purpose is to protect the dam against overtopping due to extreme flood conditions.

*Spillway design computations*

The height of the spillway above the ground level is the total height from the normal spillway level to its crest (2m). The surplus water volume is computed from the inflow, outflow, and storage simulation. The design discharge of the emergency spillway is computed using equation (8) and its effective length is computed by the equation (9).

$$Q = C*Le*He^{3/2} \qquad \text{(Eq.8)}$$

Where: - Q is discharge in m$^3$/s, C is the coefficient of discharge (1.8), Le is the effective length of the crest of the spillway (m), He is the actual effective head including the head due to the velocity of approach

$$Le = L - 2*(N*kp + ka)*He \qquad \text{(Eq.9)}$$

where: Le is crest effective length, L is net length of crest which is equal to the sum of the clear spans of the gate bays between piers, He is a total head on crest, including velocity head, N is number of piers, KP (0.01) is a pier contraction coefficient and Ka (0.1) is an abutment contraction coefficient (Arora, 2012).

*Ogee crest design*

The shape of an ogee spillway depends upon a number of factors such as head over the crest, height of the spillway above the bed of the entrance channel and the inclination of the u/s face of the spillway (Garg, 2006). Several standard ogee shapes have been developed by a United States army corps of engineers and the vertical shaped ogee is most familiar and has the following set out (Fig. 4).

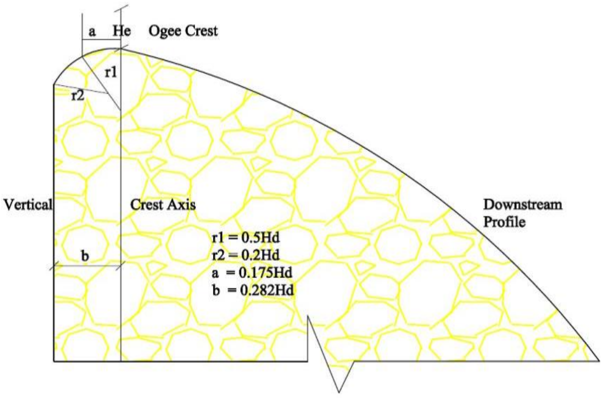

*Fig. 4* Ogee spillway cross sectional profile

The downstream profile is drawn by the equation, $X^n = kH_d^{n-1}y$. Where: x and y are the coordinates of the points on the crest profile with the origin at the highest point called the apex, Hd: Design head excluding the head due to velocity of approach and k & n are constants which depend on the inclination of the upstream face whereas the upstream profile is drawn by using the parameters a, b, $r_1$ and $r_2$. The spillway is uncontrolled at its crest.

## RESULTS AND DISCUSSION

*Maximum monthly rainfall*

According to Equation 1 to 4 and Table 2, U = 30.65; a = 69.5, $Y_T$ = 4.6. Then $X_T$ = 350.35mm, it is the maximum monthly rainfall magnitude as per Gumbel's method of extreme event distribution and will happen in August. The percentage increment of the 52 years average rainfall and the newly computed extreme event magnitude of August is 34.02%. This increment will help to arbitrarily fix the other months increment for inflow-outflow tabulation.

*Computing excess flood volume*

To obtain the monthly excess flood magnitudes, the monthly average rainfall data of 14 rain gauges were taken. As the result of the study shown in Table 5 and 6, the dam cannot tolerate to carry the whole volume of water added to the reservoir in July and August. There is extra water in these months joins to the reservoir. The surprising thing, here, is that the dam, even, could not carry the volume of water in July and August produced by the current rain fall magnitudes (Table 5). It is a shock situation.

The dam was in danger at the end of July 2018 due to the symptom of overtopping since the dam was extremely full. The government decided and diverted a portion of water at the upstream side of the dam and it made the dam stable. The result of the study is an approval of that situation.

The situation is even grave when the 100 years return period extreme climate change conditions are considered. The surplus water for this return period is much extreme and immediate action is needed to control the condition.

As it is shown from Table 5 and 6, unwanted extra water is added to the reservoir in July and August. The designed emergency spillway benefits to remove this extra water from the reservoir. Plus, the spillway is designed by using the maximum surplus water originated in August. The study was conducted by assuming, this extra flood discharge will occur in certain days within the month. It is difficult to know the exact days of the month and the study has been conducted considering the maximum discharge throughout the month.

The maximum surplus design discharge (water volume) which is obtained by taking the current rainfall magnitude is 34.03m$^3$/s (91.15*10$^6$ m$^3$/ month). In the same procedure, the 100 years return period maximum surplus design discharge is 85.76m$^3$/s (229.70*10$^6$ m$^3$/month) respectively. The computation is a yearly based simulation.

### *Ogee profile and hydraulic design*

The provided extra spillway is vertical upstream face and ogee shaped. Its initial effective length was 18m. The maximum 100 years return period design discharge of the spillway is 85.76m$^3$/s. The central pier which equally divides the spillway and carries the bridge is 1m thick and square in cross section. The adjusted coefficient of discharge of the spillway is 2.15. The coefficient is adjusted with effect of approach depth, head ratio, upstream face slope and downstream apron interference.

The spillway effective length and the head is computed using equation 1 and 2. Hence, its effective length (Le) considering abutment and pier contraction effect is 16.6m and the effective head including the velocity head, He, is 1.76m. The velocity head of the spillway is 0.08m and small. So, $H_d$ is 1.68m. The supposed spillway is vertical upstream face and n = 1.85 and k = 2.00. $X^{1.85} = 2H_d^{0.85}y$ and $H_d$ is 1.68m, Then, $X^{1.85} = 3.11y$. The maximum value of y is equal

*Table 5* The monthly inflow, outflow, storage and surplus water volume in million cubic meters for current rainfall magnitudes

| Month | RF (mm) | Inflow | Available storage | Dam outlet | Main spillway | Temporary total available water* | Spill out water | Net available water** | Surplus |
|---|---|---|---|---|---|---|---|---|---|
| Aug | 261.40 | 407.29 | 500.00 | 31.54 | 284.60 | 875.75 | 284.60 | 591.15 | 91.15 |
| Sep | 99.30 | 154.72 | 500.00 | 30.52 | 275.42 | 624.20 | 124.20 | 500.00 | |
| Oct | 25.10 | 39.11 | 500.00 | 31.54 | 284.60 | 507.57 | 7.57 | 500.00 | |
| Nov | 9.90 | 15.43 | 500.00 | 30.52 | 275.42 | 484.91 | - | 484.91 | |
| Dec | 5.70 | 8.88 | 484.91 | 31.54 | 284.60 | 462.25 | - | 462.25 | |
| Jan | 12.10 | 18.85 | 462.25 | 31.54 | 284.60 | 449.56 | - | 449.56 | |
| Feb | 28.20 | 43.94 | 449.56 | 28.49 | 257.06 | 465.01 | - | 465.01 | |
| Mar | 47.20 | 73.54 | 465.01 | 31.54 | 284.60 | 507.01 | 7.01 | 500.00 | |
| Apr | 5.70 | 8.88 | 500.00 | 30.52 | 275.42 | 478.36 | - | 478.36 | |
| May | 45.80 | 71.36 | 478.36 | 31.54 | 284.60 | 518.18 | 18.18 | 500.00 | |
| Jun | 63.10 | 98.32 | 500.00 | 30.52 | 275.42 | 567.80 | 67.80 | 500.00 | |
| Jul | 242.50 | 377.84 | 500.00 | 31.54 | 284.60 | 846.30 | 284.60 | 561.70 | 61.70 |

*inflow+available storage–dam outlet; **temporary total available water of the dam–spill out water

*Table 6* The maximum monthly inflow, outflow, storage and surplus water volume in million cubic meters of 100 years return period rain fall incidents

| Month | RF (mm) | Inflow | Available Storage | Dam outlet | Main spillway | Temporary total available water* | Spill out water | Net available water** | Surplus |
|---|---|---|---|---|---|---|---|---|---|
| Aug | 350.33 | 545.84 | 500.00 | 31.54 | 284.60 | 1,014.30 | 284.60 | 729.70 | 229.70 |
| Sep | 133.08 | 207.35 | 500.00 | 30.52 | 275.42 | 676.83 | 176.83 | 500.00 | |
| Oct | 33.64 | 52.41 | 500.00 | 31.54 | 284.60 | 520.87 | 20.87 | 500.00 | |
| Nov | 13.27 | 20.67 | 500.00 | 30.52 | 275.42 | 490.15 | - | 490.15 | |
| Dec | 7.64 | 11.90 | 490.15 | 31.54 | 284.60 | 470.52 | - | 470.52 | |
| Jan | 16.22 | 25.27 | 470.52 | 31.54 | 284.60 | 464.24 | - | 464.24 | |
| Feb | 37.79 | 58.89 | 464.24 | 28.49 | 257.06 | 494.64 | - | 494.64 | |
| Mar | 63.26 | 98.56 | 494.64 | 31.54 | 284.60 | 561.66 | 61.66 | 500.00 | |
| Apr | 7.64 | 11.90 | 500.00 | 30.52 | 275.42 | 481.38 | - | 481.38 | |
| May | 61.38 | 95.64 | 481.38 | 31.54 | 284.60 | 545.48 | 45.48 | 500.00 | |
| Jun | 84.57 | 131.76 | 500.00 | 30.52 | 275.42 | 601.24 | 101.24 | 500.00 | |
| Jul | 325.00 | 506.38 | 500.00 | 31.54 | 284.60 | 974.84 | 284.60 | 690.24 | 190.24 |

*inflow+available storage–dam outlet; **temporary total available water of the dam–spill out water to the spillway height (2m). The necessary values of x and y for drawing the spill way cross-sections are tabulated in Table 7. The upstream ogee profile parameters: a is equal to 0.29m, b is equal to 0.47m, $r_1$ is equal to 0.84m and $r_2$ is equal to 0.34m. The cross-sectional profile of the emergency spill way is shown in Fig. 5.

*Table 7* The downstream ogee profile design (m)

| Y | 0 | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 |
|---|---|---|---|---|---|---|---|---|---|
| X | 0 | 0.87 | 1.27 | 1.58 | 1.85 | 2.08 | 2.30 | 2.50 | 2.69 |

## CONCLUSION

Climate changes are aggravated conditions for excess flood incidence in a catchment. Their impact studies by different researchers and shivering in flood increment for longer return periods. Hence, the study has shown its discharge augmentation amount. The flood that occurred at Kesem catchment in 2008 was a flash flood. The catchment is very susceptible to flooding and in danger for the stability of the dam. It is impossible to prevent such floods whereas the flood can reduce their effect by providing control structures.

The design flood of a hydraulic structure constructs in a river can be estimated by analysis of stream flow data and/or rainfall based methods. But, there is no stream flow measuring devices at the river of the research site. So, the rainfall based flow estimation is the concurrent and the only means to estimate the river design flood. The average rational method provides an appropriate and reliable result for such scenarios from the rainfall based analysis methods since the others provide either exaggerated or less result.

The assessment of inflow-storage-outflow volume simulation by considering the current and future climate change impact is very important to know the situation of the reservoir. According to this, the study shows that the reservoir cannot tolerate the surplus water for the coming 100 years. Therefore, the foremost thing that shall be done at the site level is implementing the prioritized flood control structure immediately.

All excess flood controlling structures are not necessarily important for a specific site. Then, it has to be scientifically priorities to select the best measure for a specific site. From numerous flood controlling structures, flood diversion through floodways is the best-prioritized flood control structures in the study area. Thus, the researcher selected emergency spillway for immediate action and the safety of the dam.

The emergency spillway has helped to remove excess water from the reservoir and safely save the dam from a hazard. The spillway is designed based on surplus water from the inflow-storage-outflow simulation of the reservoir. However, the study did not include its geotechnical and structural design.

The proposed structural flood controlling measure for Kesem Kebena dam is the best solution for the current risky flood conditions of the reservoir site. It is crucial to protect structures especially the main dam, which is mostly constructed from earthen materials, from the superfluous water. Then, the measure will protect it from an excessive flood. The provision of these bypass structures uses to pass flood at saddle points. Meanwhile, numerous saddle points are situated along the reservoir entrance. Fortunately, there is neither population nor as such vast properties found at the downstream side of the saddle point. The method is also appropriate for earthen dams which are susceptible to the flood.

The researcher concludes by recommending to conduct further modeling studies of the inflow-storage-outflow of the reservoir by taking different flood estimation methods. In addition to this, during the 100 years' service time of the dam, the sediment impact is not as such tolerable. So, further researches have to be conducted because it will reduce the effective storage of the reservoir.

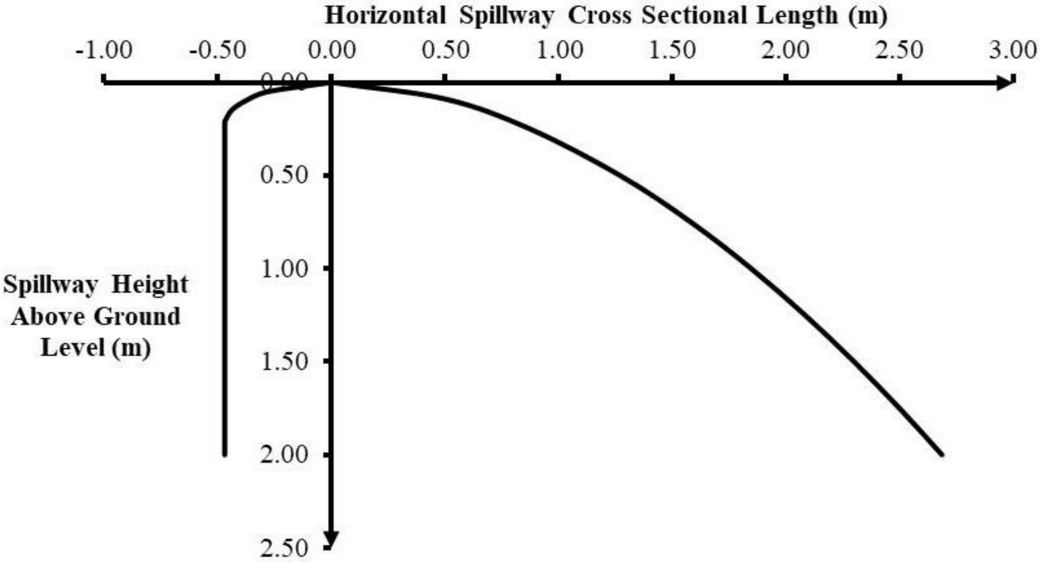

*Fig. 5* The designed emergency spillway cross-sectional profile

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