RESERVOIR SEDIMENTATION: CAUSES, EFFECTS AND MITIGATION

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ABSTRACT

The world's reservoirs are used for many purposes, among them are to provide reliable water supply, hydropower and flood mitigation. Sustainable hydropower requires dealing with the important issue of reservoir sedimentation. Sedimentation is a process whereby soil particles are eroded and transported by flowing water or other transporting media and deposited as layers of solid particles in water bodies such as reservoirs and rivers. Reservoir sedimentation therefore is filling of the reservoir behind a dam with sediment carried into the reservoir by streams. This paper therefore describes sedimentation processes, identifies key causes, effects and mitigations of sedimentation on reservoir facilities and presents techniques that can be used to address these. Generally, soil erosion is the major cause of reservoir sedimentation and subsequent sedimentation of reservoirs is a complex process dependent upon a number of natural and anthropogenic factors. The causes are classified into two with respect to the factors, namely; Natural Causes and Anthropogenic Causes. Sedimentation can affect hydropower production due to loss of reservoir storage and/or damage to the facility's mechanical components. Sediments deposited in reservoirs may affect the safety of dams and, without proper management, negatively impact the environment. Methods of managing sediment fall under three general categories: those that divert sediment around or through the reservoir, those that remove deposited sediments, and those that minimize the amount of sediment reaching the facility in the first place. A variety of sediment management strategies have been used around the world, with many successful implementations documented. The paper highlights the need for appropriate sediment management at hydropower facilities and shows how this can be achieved through consideration of sediment concerns from the earliest design phase through to construction and operation. In order to curb erosion and sedimentation in rivers and reservoirs, there is need to develop and implement an integrated water resources management plan by all stakeholders.

Keywords: Reservoir, Sedimentation, Hydropower, Soil Erosion and Desilting.

1.0 INTRODUCTION

Sedimentation is a process whereby soil particles are eroded and transported by flowing water or other transporting media and deposited as layers of solid particles in water bodies such as reservoirs and rivers (Tundu et al., 2019). It is a complex process that varies with watershed sediment yield, rate of transportation and mode of deposition (Ezugwu, 2013). Sediment deposition reduces the storage capacity and life span of reservoirs as well as river flows (Eroglu et al., 2010).

Sedimentation continues to be one of the most important threats to river eco-systems around the world. A study was done on the world's 145 major rivers with consistency long term sediment records and the results show that about 50% of the rivers have statistically a significantly downward flow trend due to sedimentation (Walling & Fang, 2003). Sumi & Hirose (2009) reported that the global reservoir gross storage capacity is about 6000 km^3 and annual reservoir sedimentation rates are about 31 km^3 (0.52 %). This suggests that at this sedimentation rate, the global reservoir storage capacity will be reduced to 50% by year 2100.
Reservoir sedimentation therefore is filling of the reservoir behind a dam with sediment carried into the reservoir by streams. The flow of water from the catchment upstream of a reservoir is capable of eroding the catchment area and of depositing material either upstream of the reservoir, or in the still water of the reservoir. The nature of the material in the catchment area and the slope of the catchment area and the inlet streams are a factor, as is the nature of the ground cover. The deposition of sediment will automatically reduce the water storing capacity of the reservoir, and if the process of deposition continues longer, a stage is likely to reach when the whole reservoir may get silted up and become useless (Garg, 2009).

Moreover, with the passage of time, the reservoir capacity will go on reducing. For instance at the time of construction, a reservoir can store 10,000 cubic meters of water, and in five year time, it may be able to store only 8000 cubic meters of water. Therefore, in order to see that the capacity does not fall short of requirement ever during the design period, we must consider silting. The total volume of silt likely to be deposited during the designed life period of dam is therefore estimated and approximately that much of volume is left unused to allow for silting and is known as dead storage. The reminder is known as effective storage or the live storage. The dead storage generally varies between 15 to 25% of the total capacity. All the outlets fetching water from the reservoir are provided above the dead storage level. The importance of this silting can be understood by considering the following example:

Let the total capacity of a reservoir be 30 million cubic meters and the provision of the dead storage be 6 million cubic meters. Let the average volume of the sediment deposition be 0.15 million cubic meters per year. Then it is evident, that the dead storage will be filled up in 6/0.15=40 years, and the total storage in about 30/0.15=200 years. Therefore, the usefulness of the reservoir would start reducing after 40 years and after 200 years it would be nothing but collection of sand and sediment with no water in it (Garg, 2009).

Figure 1: Example of a Dam, the Three Gouges Dam in China (source: ecns.cn)

Figure 2: A typical example of Reservoir sedimentation (Adapted from Pramoda, 2017)

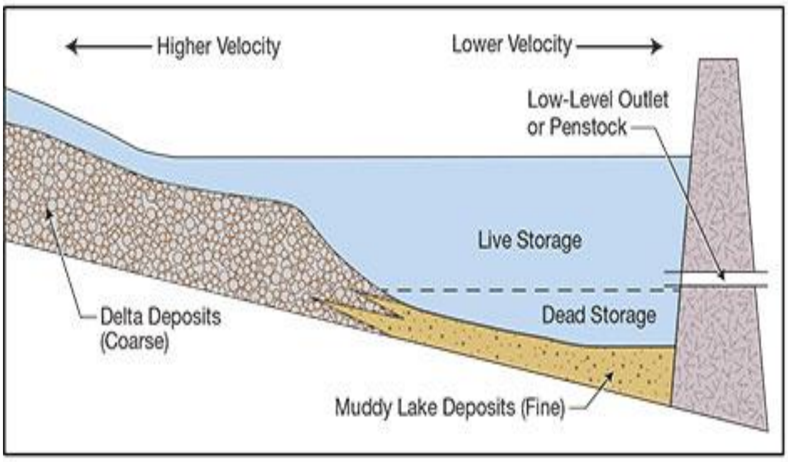

Figure 3: Typical Reservoir Sediment Profile (Adapted from Morris, 1998).

Dams are constructed for many reasons such as flood attenuation, hydropower generation, storage for irrigation, navigation, etc. When a reservoir is relatively small in relation to the mean annual runoff (MAR) (say less than 10%), and the sediment yield is relatively high, there is a high risk that it would silt up in a short period of time. The rate of sedimentation and ultimate storage capacity of small reservoirs can however be controlled by sluicing or flushing of sediment through large low level outlets during floods or the rainy season. If most existing and still to be constructed reservoirs are managed in a sustainable manner, the number of new dams required to maintain reliable water and power supply will decrease. The historical growth in storage capacity up to 2000 and sedimentation is shown in Figure4.

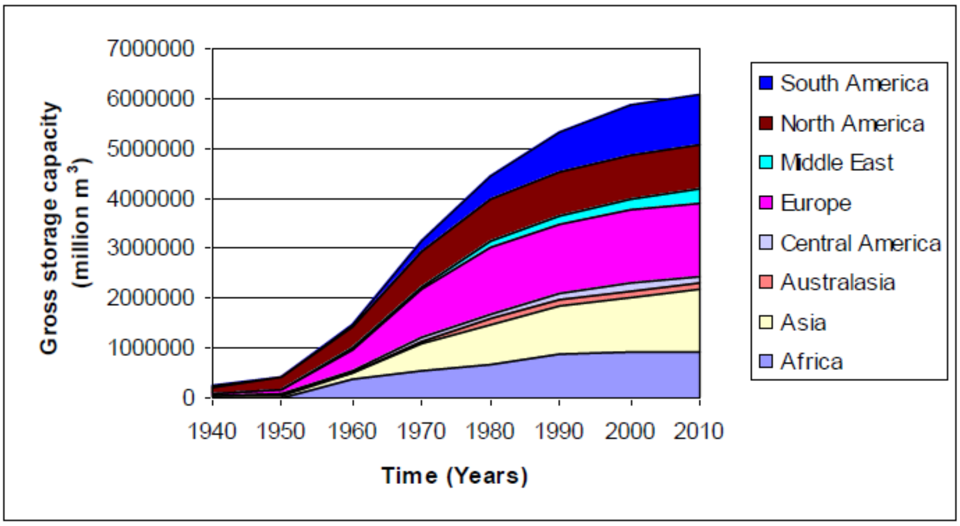

Figure 4: Historical growth in global storage capacity (Basson, 2009).

According to Morris et al. (2008), there are three stages in a reservoir's life: *Continuous and rapidly* occurring sediment accumulation; *Partial sediment balance*, where often fine sediments reach a balance but coarse sediments continue to accumulate; and *Full sediment balance*, with sediment inflow and outflow equal for all particles sizes. Most of the world's reservoirs are in the continuous accumulation stage (Morris et al., 2008). Many were designed by estimating sedimentation rates in order to provide a pool with sufficient volume to achieve a specified design life. However, this design life is typically far less than what is actually achievable. Therefore, managing reservoirs to achieve a full sediment balance is essential in order to maximize their lives. Developing regions of the world that stand to benefit most from hydroelectricity are often those with the highest sediment yields (Grummer, 2009). In these regions, sustainable hydropower development must involve consideration of sediment management techniques during design, construction and operation.

2.0 CAUSES OF RESERVOIR SEDIMENTATION

Generally, soil erosion is the major cause of reservoir sedimentation and subsequent sedimentation of reservoirs is a complex process dependent upon a number of natural and anthropogenic factors. The causes are classified into two with respect to the factors, namely;

i. Natural Causes
ii. Anthropogenic Causes

2.1 Natural Causes

Geomorphology: In geological sense, geomorphology is the configuration of the land surface, and it includes the location, size and shape of such physical features as hills, ridges, valleys, streams and lakes. Topographic maps show these features.

Hydrology: Hydrology is the science relating to water of the earth, its distribution and its phenomena. To be successful, a dam and reservoir project must have an adequate and continuous supply of water suitable for theory intended uses of the reservoir. Hydrologic information and investigation will be required in varying degree, depending upon the size of the project. The annual rainfall, the ratio of watershed area to reservoir area, and the volume of stream of the year must be known.

Hydrogeology: Hydrogeology to determine whether groundwater would contribute to the reservoir or whether the reservoir would lose water to the groundwater system is also essential. The reservoir yield also must be known so that commitments for water will not exceed the quantity of water available.

Geology: It has been said that construction of a dam and reservoir causes more interferences with natural conditions than does any other civil engineering operation. Knowledge of the geological situation is essential as a basis for sound engineering, especially in the investigation of dam and reservoir sites, for an error in geological interpretation or the failure to discover some relatively minor geologic detail may be costly and sometimes hazardous.

Soil Characteristics: The type of soil and its properties such as porosity and permeability can cause or lead to erosion within and around the reservoir.

2.2 Anthropogenic Causes

Tillage practices: Wrong tillage practices can cause loose soil thereby leading to washing away of top soil.

Overgrazing: Too much grazing of vegetation by animals can lead to exposure of the soil in an area thereby causing erosion.

Mining and logging: Mining activities can lead to erosion due to wearing off of the surface through surveys and excavation as well. Logging is the cutting, on-site processing, and loading of tree or logs on trucks. It is a process of cutting trees, processing them, and moving them to a location for transport.

3.0 EFFECTS OF RESERVOIR SEDIMENTATION

The effects of reservoir sedimentation can be found in the following subheadings:

Sediment Impacts on Generation

About 0.5% to 1% of the total volume of 6,800 km^3 of water stored in reservoirs around the world is lost annually as a result of sedimentation (Morris et al., 2008). As a result, global per capita reservoir storage has rapidly decreased since its peak at about 1980. Current storage is equivalent to levels that existed nearly 60 years ago (Morris et al., 2008). Loss of reservoir storage reduces flexibility in generation and affects the reliability of water supply. Without storage, hydropower facilities are entirely dependent on seasonal flows. These flows might not occur when energy is needed, eliminating one of the key benefits that hydropower provides over other renewables.

Sediments discharged from an upstream dam in a cascade system can increase tail water levels, reducing power generation (Morris, 1998). This would impact the generation potential of all plants in the cascade and increase the possibility of powerhouse flooding.

Sediment Impacts on Stability of Dams

Sediment loads are commonly idealized as a static at-rest soil pressure. The U.S. Bureau of Reclamation’s design manual for small dams suggests that sediments be considered equivalent to a fluid with an implied pressure coefficient of about 0.39 and an internal friction coefficient of about 37 degrees.

However, actual reservoir sediment properties can vary considerably. Unconsolidated fine-grained sediments likely have lower shear resistance and a higher at-rest pressure coefficient, while a reservoir filled with coarser sediments may have higher shear strength (Morris, 1998). Published criteria with respect to potential changes in uplift pressures due to sedimentation often neglect the fact that fine-grained sediments may reduce uplift in the same manner as does an engineered upstream blanket. Conversely, in the case where there is a large turbid inflow, higher uplift pressures would be expected until enough particles had settled to form a blanket. During a seismic event, it is likely that liquefied sediments would quickly return close to their original state, resulting in a rapid dissipation of pore pressures. Therefore, it may be questionable to automatically assign higher uplift pressures in this case.

Commonly used design considerations can omit some plausible load cases. For example, an underwater sediment slope failure could cause surface waves, adding additional loading, hydro-dynamic pressure waves and an inertial loading from the dense fluidized soil-water mass. Another phenomena commonly ignored relates to turbidity currents in reservoirs. Such turbid fluid with a sediment load of 100 mg/l could be about 6% heavier than clear water (Morris, 1998).

Submarine landslides are widely studied because of their potential to create tsunami waves. However, designers also need to consider the potential that failure of the steeply sloped deltaic front could increase loading and produce compression waves that may fluidize finer sediments near the toe of the landslide. As the deposition advances toward the dam, the potential for issues progressively increases. It is often assumed that, during an earthquake, sediments fully liquefy, lose all strength and exert a dense fluid hydrostatic load on the dam. However, this degree of fluidization likely is not possible in a reservoir filled with coarse materials. Designers also often assume that the fully fluidized dense fluid contributes to hydro-dynamic pressure loading based on Westergaard's formula, ignoring the physical basis for its derivation. In fact, there is some question about the applicability of Westergaard's formula for hydro-dynamic pressures. Designs also need to consider the degree of saturation of the sediments. There is minimal system damping under dynamic loading when reservoir sediments are fully saturated. However, significant reductions in acceleration occur when sediments are partially saturated (Bougacha & Tassoulas, 1991; Dominguez et al., 1997). For rigid foundations, hydrodynamic pressures decrease slightly at the dam base when sediments are fully saturated but increase when partially saturated. Partial saturation will increase the system's response to horizontal ground movement. Sediment thickness is an important consideration, especially when the sediments are partially saturated (Dominguez et al., 1997). Thin layers result in minimal absorption of horizontal motions, largely due to a relatively high modulus of elasticity and low attenuation coefficient (Hatami, 1997). Over the reservoir life cycle, this changes as sediments continue to accumulate (Gogoi & Maity, 2007). Other important factors are sediment density, compressibility and pore water pressure (Gogoi & Maity, 2007).

This dependence on sediment properties makes a strong case for their measurement and inclusion as part of the design (Bougacha & Tassoulas, 1991). However, designs are performed before sedimentation occurs and the same sediments that are stable under normal conditions and absorb energy at the bottom of the reservoir could liquefy. For this reason, the use of a reservoir bottom reflection coefficient must be logically linked to assessment of the reservoir sediment behavior and ongoing monitoring.

Sediment Impacts on Discharge Capability

Sediments will often block low-level outlets designed to allow for reservoir drawdown (Morris, 1998). As sedimentation continues, clogging of spillway tunnels or other conduits may occur (Morris, 1998). Reduction of spillway capacity can occur as a result of the loss of approach depth when the sediment front reaches the dam. The reservoir becomes a delta-filled valley that takes a meandering course such that a flood wave does not spread out to allow flood routing.

Sediment Impacts on Equipment

Sediment can damage turbines and other mechanical equipment through erosion of the oxide coating on the blades, leading to surface irregularities and more serious material damage (Dorij & Ghomaschi, 2014). Sustained erosion can lead to extended shutdown time for maintenance or replacement (Dorij & Ghomaschi, 2014).

Sediment Impacts on the Environment

Any dam will cause some degree of sediment starvation downstream. Plant and animal species are sensitive to alteration of both the sediment supply and flow regime (Ahmari et al., 2013). Increases in sediment concentration can create turbid waters with a smaller euphotic zone. This decreases plant productivity, negatively impacting fish and bird species (Morris et al., 2008) and causing abrasion of fish gills, thus increasing potential for disease or mortality. Turbidity can also cause visual impairment for predatory fish, affecting their feeding habits. Finally, sediment is a primary carrier of suspended pollutants such as nitrogen, phosphorous and heavy metals (Ahmari et al., 2013). Sediments released as a result of sediment management or a dam breach may have environmental effects that can persist for decades.

Other effects include the following;

i. Reduced storage capacity
ii. Retrogressive deposition
iii. Reduced availability of water for irrigation
iv. Shortening of life of a reservoir

4.0 MITGATION FOR RESERVOIR SEDIMENTATION

Sedimentation of storage reservoirs is a natural process, since large part of the silt eroded from the catchment and transported by the river, gets deposited on the bed of a reservoir. This causes reduction in the live as well as dead storage capacities of the reservoir. Progressive loss of capacity due to sediment accumulation results in reduced benefits and may even cause operational problems. It therefore, becomes necessary to monitor the sedimentation rates in the existing reservoirs at regular interval, to help in planning and executing suitable remedial measures for controlling sedimentation in order to prolong the life of the reservoir and its benefits (Garg, 2009). According to Garg (2009), the following are the mitigation for reservoir sedimentation;

Silting control in a reservoir: In order to increase the life of a reservoir, it is necessary to control the deposition of sediments. Various measures are undertaken in order to achieve this aim. The various methods which are adopted can be divided into two parts:

1. Pre-constructing measures and
2. Post- constructing measures

Pre-constructing measure – They are those measures which are adopted before and during the execution of the project. They are as follows:

a) Selection of Dam Site. The silting depends upon the amount of erosion from the catchment. If the catchment is less erodible, the silting will be less. Hence, the silting can be reduced by choosing the reservoir site in such a way as to exclude the runoff from the easily erodible catchment.
b) Construction of dam in Stages. The design capacity plays an important role in the silting of a reservoir. When the storage capacity is much less than the average annual runoff entering the reservoir, a large amount of water will get out of the reservoir, thereby, reducing the silting rate compared to what it would have been if the entire water would have been stored. Therefore, the life of a reservoir can be prolonged by constructing the dam in stages. In other words, first of all, the dam should be built lower and raised subsequently when some of its capacity gets silted up.

c) Construction of Check Dams. The sediments inflow can be controlled by building check dams across the river streams contributing major sediment load. These are smaller dams and trap large amounts of coarser sediments. They however, prove to be quite expensive.
d) Vegetation screens. This is based on the principle that vegetation trap large amounts of sediment. The vegetation growth is, therefore, promoted at the entrance of the reservoir as well as in the catchment. These vegetative covers, through which flood waters have to pass before entering the reservoirs, are known as vegetation screens and provide a cheap and a good method of silt control.
e) Construction of Under-sluices in the dam below the Dead Storage Level. The dam may be provided with openings or under-sluices below the probable height of deposition of sediment at appropriate levels, so as to remove the more silted water on the downstream side.

The sediment concentration will be more at some levels than at others. Therefore, sluices are located at the levels of higher sediment concentration. The method in itself is not sufficient because the water digs out a channel behind the sluice for movement and leaves most of the sediment undisturbed. Therefore, this is simultaneously supplemented with mechanical loosening and souring of the neighboring sediment in order to increase its effectiveness. But to provide large sluices near the bottom of a dam, is again a structural problem. The use of this method is therefore, limited.

Post-constructing measures. These measures are undertaken during the operation of the project. They are as follows:

a) Removal of Post Flood Water. The sediment content increases just after the floods; therefore, attempts are generally made not to collect this water. Hence, the efforts should be made to remove the water entering the reservoir at this time.
b) Mechanical stirring of the Sediment. The deposited sediment is scoured and disturbed by mechanical means, so as to keep it in a moving state, and thus, help in pushing it towards the sluices.
c) Adopting Erosion Control and Soil Conservation Measures in the Catchment Area. This includes all those general methods which are adopted to reduce erosion of soil and to make it more and more stable. They may include: plantation, control grazing, terracing benching, cover cropping like grassing and contour binding, etc. This method is found to be the most effective method for controlling siltation, because when the soil erosion is reduced, automatically, the sedimentation problem is reduced. But the methods of treating the catchment in order to minimize erosion are very costly (Garg, 2009).

Other mitigation methods are below:

Reduce Sediment Inflow: Sediment delivery to reservoir can be reduced by techniques such as erosion control and upstream sediment trapping.

Figure 5: Using the operation of storing clean water and discharging muddy flow to mitigate reservoir sedimentation (Adapted from Pramoda, 2017)

Route Sediments: Some or the entire inflowing sediment load may be hydraulically routed beyond the storage pool by techniques such as drawdown during sediment-laden floods, off-stream reservoirs, sediment bypass, and venting of turbid density currents.

Sediment Removal: Deposited sediments may be periodically removed by hydraulic flushing, hydraulic dredging or dry excavation.

Figure 6: Sediment Removal, reduction and flushing (Adapted from Pramoda, 2017)

Afforestation: Afforestation for reservoir protection should be carried out in a scientific manner; and to aid in accomplishing this, proper afforestation will not only provide the desirable qualities of watershed protection.

Figure 7: A typical example of afforestation along a reservoir (Adapted from Pramoda, 2017)

Check Dam: Check dam is a small dam which can be either temporary or permanent, built across a micro channel or drainage ditch.

Figure 8: Using water, soil conservation and check dams to reduce sedimentation in reservoirs (Adapted from Pramoda, 2017)

Desilting: Desilting might also be needed when there is a large accumulation of semi-decomposed leaf litter and other organic debris. This material tends to reduce oxygen levels in the pond or lake, and because it often produces acidic conditions, it can reduce the fertility of the pond or lake.

Figure 9: Examples of desilting methods (Adapted from Pramoda, 2017)

Erosion control

Many watersheds experience increased erosion rates due to land use and other human practices. Erosion reduction techniques fall into three categories: structural or mechanical, vegetative and operational (Morris, 1998). Structural or mechanical measures - such as terraces, conveyance channels, check dams and sediment traps (Morris, 1998) decrease overland or channelized flow velocity, increasing surface storage and thereby reducing the sediment load in the runoff. Vegetative erosion control takes advantage of plants' natural ability to limit erosion. Agricultural practices that minimize sediment yield are particularly effective. Operational measures minimize erosion through planning, management and organization. Examples include timing construction work such that erosion is minimized or scheduling timber harvesting to coincide with favorable soil conditions (Morris, 1998). Erosion management is perhaps the most widely recommended but most poorly implemented sediment management technique because land users may not see any direct benefits from controlling sediment yield (Morris et al., 2008).

5.0 CASE HISTORIES

5.1 Case History 1: A Case of Marah Dam in Masvingo Province of Zimbabwe.

There are several direct and indirect causes of degradation in this particular catchment leading to rapid siltation of the dam (Chihombori et al., 2013). Among the direct causes of overgrazing, excessive wood cutting, improper soil and water management, land disturbance and cropping lands that are too erodible. Indirect causes including increase in human and livestock populations, refusal to believe that a problem exists, absence of environmental awareness, lack of knowledge on how to control and prevent land degradation, government policies and greed. Improper soil and water management and cropping are the most important causes in this particular catchment (Chihombori et al., 2013).

Similar studies elsewhere have also been conducted with similar results. Shiyang Reservoir in China had its capacity reduced after 43% of woodland areas within its catchment were turned into agricultural land (Mavima et al., 2011). In Ghana a similar study to assess the impact of land use changes on the Burekese catchment was conducted and the results showed a loss in reservoir storage capacity of 45% due to siltation over a period of six years. The causes for the silting up of the reservoir were attributed to deforestation, population growth and lack of proper education of the communities in catchment management (Mavima et al., 2011).

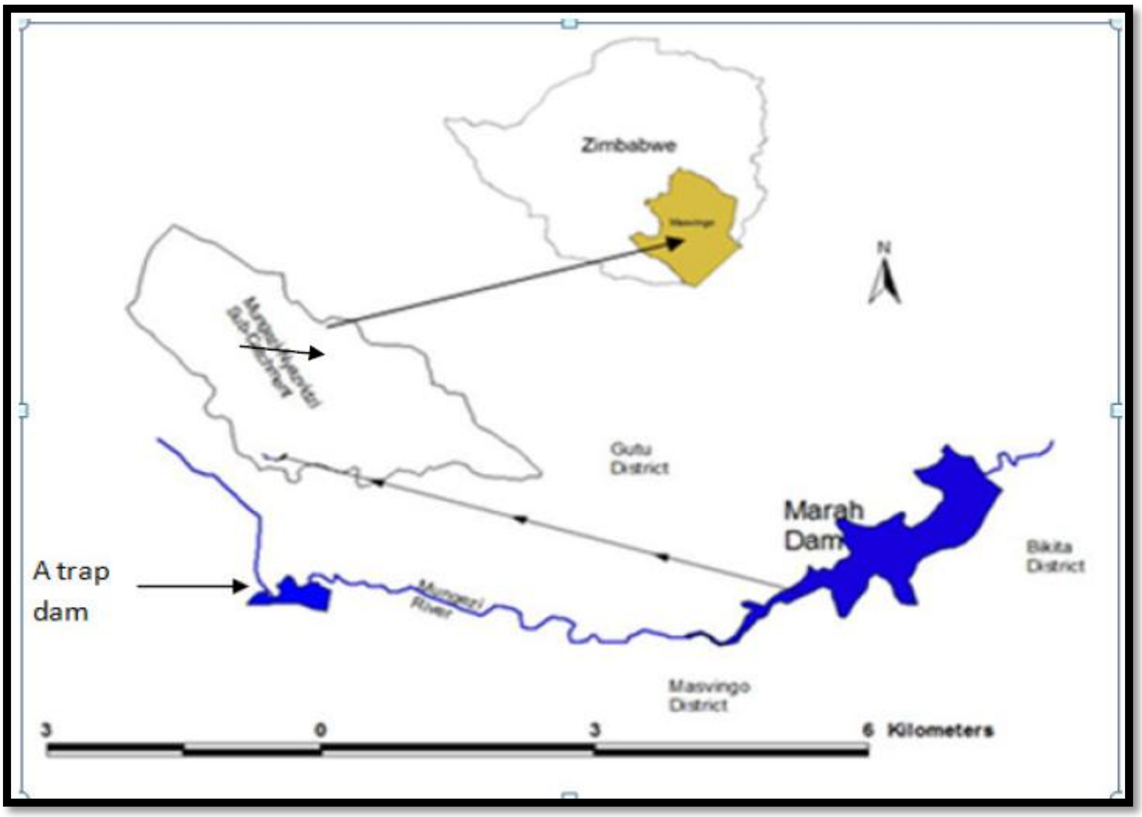

Figure 10: Map showing Marah dam and its catchment area (After Chihombori et al., 2013)

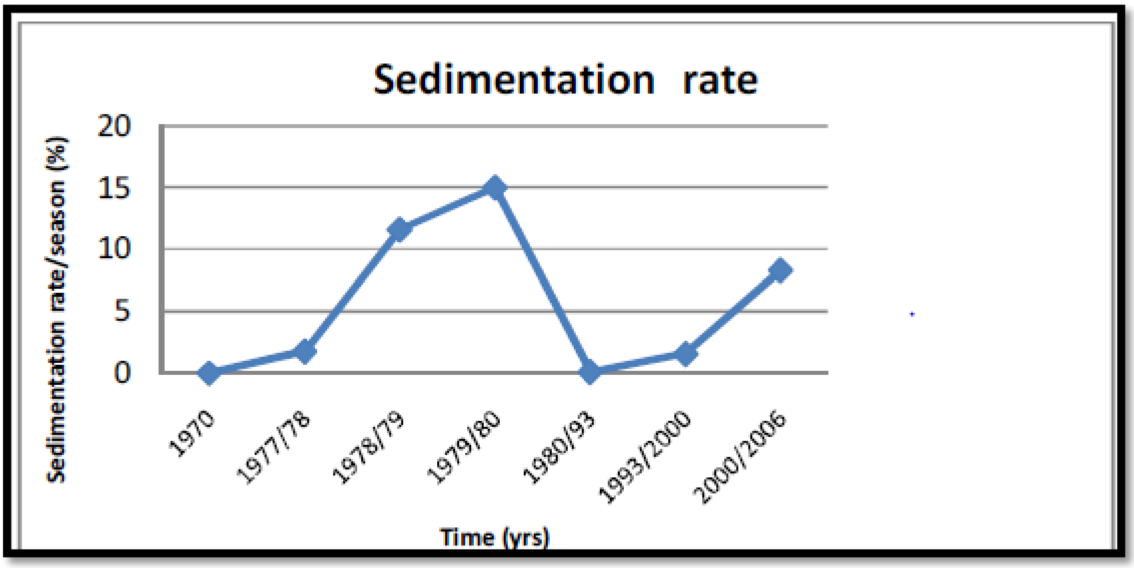

Figure 11: Sedimentation rate of Marah dam (After Chihombori et al., 2013)

5.2 Case History 2: Aswan High Dam, Egypt

The 2,100- MW Aswan High Dam project on the Nile River in Egypt includes a 111 m high dam that impounds a 130 km reservoir (Grummer, 2009). This dam has been controversial, largely due to concerns regarding sediment starvation of the Nile River Delta (Grummer, 2009). Before construction of this dam, the Nile River transported an average of 100 x 106 tons/yr of sediment to the Nile River Delta in the Mediterranean Sea (Milliman & Meade, 1983). Today, with a trapping efficiency of 99%, little sediment reaches the delta (Abd-El Monsef et al., 2015). While the live storage capacity of the Lake Nasser/Nubia reservoir upstream of Aswan High Dam is not expected to be compromised for another 300 to 400 years (Smith,1990), the adverse downstream impacts have been widely reported (Abd-El Monsef et al., 2015). Erosion along the Mediterranean coast of Egypt has been ongoing for centuries, but the sediment trapping has combined with sea-level rise and other factors to exacerbate coastal erosion problems (Abd-El Monsef et al., 2015).

Figure 12: Aswan High Dam in Egypt (Source: face2faceafrica.com)

Figure 13: Aswan High Dam in Egypt (Source: thoughtco.com)

5.3 Case History 3: Kanji Dam, Nigeria

The construction of dam across River Niger at Kainji has impacted on its rate of flow. Prior to dam construction, most natural rivers have a flow rate that varies widely throughout the year in response to varying conditions (Ehigiator et al., 2017). Of course once constructed, the flow rate of the river below a dam is restricted. According to David (2017), the dam itself and the need to control water releases for the various purposes of the particular dam result in a flow rate that has a smaller range of values and peaks that occur at times related to need rather than the dictates of nature.

The impoundment of water behind a dam causes the velocity of the water to drop. Sediment carried by the river is dropped in the still water at the head of the lake. Below the dam, the river water flows from the clear water directly behind the dam (Ehigiator et al., 2017). Because the river no longer carries any sediment, the erosive potential of the river is increased. Erosion of the channel and banks of the river below the dam will ensue. Even further downstream, sediment deprivation affects shoreline processes and biological productivity of coastal regions (David, 2017).

Figure 14: Overview of Kanji Dam (Source: premiumtimesng.com)

Figure 15: Sedimentation in kanji Dam (Source: cometonigeria.com)

Ehigiator et al. (2017) observed from their study that the reduction noticed in the reservoir volume could be attributed to sedimentation and the slight increase in the area was resulted from erosion of the bank by the river Niger.

6.0 CONCLUSION

The world's reservoirs are used for many purposes, among them to provide reliable water supply, hydropower and flood mitigation. Sustainable hydropower requires dealing with the important issue of reservoir sedimentation. This paper therefore describes sedimentation processes, identifies key causes, effects and mitigations of sedimentation on reservoir facilities and presents techniques that can be used to address these. Sedimentation can affect hydropower production due to loss of reservoir storage and/or damage to the facility's mechanical components. Sediments deposited in reservoirs may affect the safety of dams and, without proper management, negatively impact the environment.

Methods of managing reservoir sedimentation problems fall under three general categories: those that divert sediment around or through the reservoir, those that remove deposited sediments, and those that minimize the amount of sediment reaching the facility in the first place (check dam). A variety of sediment management strategies have been used around the world, with many successful implementations documented.

This discussion in essence highlights the need for appropriate sediment management at hydropower facilities and shows how this can be achieved through consideration of sediment concerns from the earliest design phase through to construction and operation. In order to curb erosion and sedimentation in rivers and reservoirs, there is need to develop and implement an integrated water resources management plan by all stakeholders.

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