SHORT-TERM PROFILE MAPPING OF IKPOBA DAM BOTTOM TOPOGRAPHY USING LONGITUDINAL PROFILING TECHNIQUES.

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF SCIENCES {BSCGEM - B.SC. GEOMATICS} DEGREE, IN THE FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

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CERTIFICATION

This is to certify that this project was carried out by MATTHEW GOKEME ANDY with Matriculation Number: ENV1704619 of the Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria.

SUPERVISOR **SURV. S. O. OLADOSU**	**DATE**
HEAD OF DEPARTMENT **SURV. S. O. OLADOSU**	**DATE**
EXTERNAL EXAMINER	**DATE**

DEDICATION

I gratefully dedicate this project to the God almighty, whose grace has illuminated my path. To my parents, MR. AND MRS. MATTHEW ISINNEY, along with my cherished siblings, relatives, friends, and course mates, I extend my heartfelt appreciation for their unwavering support in every facet of my journey. I would also like to convey my sincere thanks to my supervisor, SURV. S. O. OLADOSU. May divine blessings continue to enrich your life. Amen.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to all those who contributed to the successful completion of this final project. Their support, guidance, and assistance were invaluable throughout this journey.

First and foremost, I extend my deepest appreciation to my supervisor, SURV. S. O. OLADOSU, for his mentorship, expertise, and continuous encouragement. His insightful feedback and guidance played a critical role in shaping this project and improving its quality. I am also grateful to the faculty and staff of department of Geomatics, whose knowledge and resources provided a solid foundation for this project. Their dedication to education and research created an environment conducive to academic growth and learning.

A special thanks to my family and friends for their unwavering support and encouragement during this project. Their belief in me and their understanding of the demands of this endeavor were motivating factors that kept me focused and determined.

Lastly, I would like to acknowledge the participants and sources that contributed to the data and information used in this project. Their contributions were fundamental to the project's accuracy and comprehensiveness.

Thank you all for being part of this academic journey and for making this project possible.

ABSTRACT

Ikpoba Dam serves a singular purpose - the provision of potable water to the populace of Benin City. However, the dam's functionality has been adversely affected by acute sedimentation. In response, comprehensive bathymetric surveys were conducted to assess the volume of sediment accumulated during its operational period. This study delves into a thorough investigation employing a longitudinal profiling technique for short-term mapping of Ikpoba Dam's bottom topography. The primary objectives encompass determining short-term variations in the longitudinal profile of the dam's bottom, generating short-term Digital Terrain Models (DTMs) of the dam's bottom topography, and calculating the accumulated sediment volume by leveraging Digital Elevation Models (DEMs) differencing.

The longitudinal profiling technique, known for its precision and accuracy, was instrumental in capturing topographic changes over specific time intervals, providing a nuanced understanding of the dam's evolving features. The findings of this study underscore a significant accumulation of sediment, quantified at 11,392.15303 cubic meters over the study period. These insights are crucial for formulating effective strategies to mitigate sedimentation and optimize the dam's operational efficiency.

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CHAPTER ONE

1.0 Introduction

1.1 Background of the Study

Dams play a crucial role in managing water resources, controlling floods, and generating energy (Smith et al., 2018). However, changes in the bottom topography of dams over time can pose significant threats to their structural integrity and operational efficiency (Varekamp et al., 2016). It is vital to comprehend the dynamics of dam bottom topography for effective management and maintenance of dams (Yang et al., 2019).

Traditional methods of assessing dam bottom topography have involved visual inspections and manual measurements, which are laborious, time-consuming, and may not provide a comprehensive understanding of long-term changes (Hansen et al., 2017). Therefore, advanced surveying technologies are now increasingly being utilized to accurately and efficiently profile dam bottom topography.

Modern techniques such as multibeam echo sounders and bathymetric instruments have revolutionized the field of dam bottom topography profiling (Smith et al., 2020). These tools enable precise data collection and visualization of the elevation of the dam's bottom, facilitating the identification of potential risks and the implementation of appropriate maintenance measures (Jones et al., 2018). The application of these advanced technologies enhances the accuracy and efficiency of dam bottom topography monitoring.

Short-term profiling of dam bottom topography involves conducting frequent surveys at regular intervals to capture changes occurring over relatively short periods (Bianchi et al., 2019). By monitoring the elevation of the dam bottom at regular intervals, engineers and dam operators can promptly identify trends, patterns, and potential risks (Wu et al., 2021). This proactive approach enables timely decision-making regarding maintenance and safety measures.

The data collected from short-term profiling of dam bottom topography provides valuable information for assessing the dam's condition (Duan et al., 2019). It aids in detecting changes like erosion, sedimentation, or settlement, which can jeopardize the structural stability of the dam (Wang et al., 2020). Analyzing this data empowers engineers to make well-informed decisions to ensure the dam's safety and longevity (Chen et al., 2022).

The use of advanced surveying technologies for short-term profiling of dam bottom topography is crucial for the effective management and maintenance of dams. Employing multibeam echo sounders and bathymetric instruments allows for precise data collection and visualization of changes in dam bottom elevation. Through regular monitoring and analysis of the collected data, potential risks and maintenance requirements can be promptly identified, ensuring the safety and stability of dams.

1.2 Statement of the Problem

Increasingly dynamic changes in the bottom topography of dams pose significant threats to both the structural stability and operational efficiency of these vital infrastructures. Traditional inspection methods, such as visual assessments and manual measurements, often fall short in providing a comprehensive understanding of these evolving conditions. Consequently, there is a pressing need for precise and efficient techniques to conduct short-term profiling of the bottom topography of Ikpoba dam. These advanced methods are crucial for proactive monitoring, accurate risk assessment, and strategic maintenance planning, ultimately ensuring the safety and longevity of dams.

1.3 Aim and Objectives

The aim of this study is to examine the short-term variations in Ikpoba dam bottom topography using longitudinal profiling techniques.

The objectives are:

i. To determine the short-term changes in the longitudinal profile of the dam’s bottom topography.

ii. To generate short-term DTMs of the dam bottom topography, and

iii. To calculate the volume of accumulated sediment by performing DEMs differencing.

1.4 Scope and Limitation of the Study

In order to ensure the stability and longevity of a dam, several key steps need to be taken. Firstly, it is crucial to identify the sediment thickness and geological characteristics of the dams subsurface. This involves analyzing the collected data to determine the depth and composition of the sediment layers, as well as gaining insights into the geological features present beneath the dam.

Once the data has been collected and analyzed, the next step is to assess the stability of the dam and evaluate the potential risks associated with sedimentation. This involves a thorough examination of the collected data to understand the factors that may impact the dam's long-term stability. By assessing the sedimentation potential, engineers can identify any areas of concern and develop strategies to address them.

Based on the findings of the study, recommendations can then be provided to enhance the stability of the dam and reduce the risks associated with sedimentation. These recommendations may include measures to mitigate erosion, control sediment movement, and implement strategies for maintaining the stability of the dam. By implementing these recommendations, the overall integrity and functionality of the dam can be improved, ensuring its resilience against sedimentation-related challenges.

Through a comprehensive analysis of the collected data and the implementation of appropriate recommendations, dam engineers can effectively address sedimentation concerns and optimize the stability of the dam, contributing to its long-term success and functionality.

Limitation

i. Hydraulic system and piping were not investigated.
ii. Depth data beyond the dam was be included in the study.
iii. Chemical composition, pollution and biological processes was not be covered.

1.5 Justification of the Study

Ikpoba dam was built primarily for water supply for Edo state which play a crucial role in managing water resources, supplying water for various purposes. However, sedimentation in dam reservoirs can reduce storage capacity, compromise stability, and pose risks to human life and property and the bottom of the dam is a vital component that provides support and stability to the entire structure. Changes in dam bottom topography, such as erosion, sedimentation, or other natural or human-induced factors, can impact the overall stability of the dam and pose safety risks to surrounding areas. Therefore, regular monitoring of dam bottom topography is necessary to ensure safety and stability. Despite the importance of regular monitoring, Ikpoba dams lack adequate or no monitoring, leaving changes in dam bottom topography unnoticed and increasing potential safety risks. Below are reasons to justified this study:

i. Safety: Ensuring the stability of the dam is crucial for the safety of people residing downstream. Sub-bottom profiling provides vital information for understanding sedimentation potential and assessing dam stability, reducing the risk of dam failure.
ii. Water Resource Management: Sedimentation in the dam reservoir can negatively impact water storage capacity, affecting water supply for domestic, agricultural, and industrial purposes. Sub-bottom profiling offers essential data for developing sediment management strategies and enhancing long-term water availability.
iii. Engineering Design: Sub-bottom profiling provides valuable information for engineering design and construction of dams, aiding in ensuring their stability and durability.
iv. Cost-Effectiveness: Recent technological advancements have made sub-bottom profiling more accessible and affordable. This study will explore the feasibility of using sub-bottom profiling for dam investigation and assess potential cost savings associated with the technique.

CHAPTER TWO

2.0 Literature Review

2.1 Concept of Reservoir Bottom Profiling

Reservoir bottom profiling involves the measurement and analysis of the characteristics of the reservoir bed. It aims to understand the topography, sediment distribution, and changes in elevation over time. This information is crucial for various aspects of dam operations and reservoir management. Reservoir bottom profiling plays a significant role in assessing sedimentation patterns within the reservoir. Sedimentation can impact water storage capacity, water quality, and the functioning of associated infrastructure. By understanding the distribution and thickness of sediments, engineers can develop effective strategies for sediment management, including dredging operations and the implementation of sediment diversion structures (Johnston et al., 2018). Moreover, reservoir bottom profiling provides insights into the channelization of water flow. It helps engineers optimize channel geometries to ensure efficient water conveyance and prevent excessive sediment deposition. The data obtained from reservoir bottom profiling assists in identifying potential obstructions or sediment traps within the channel system, allowing for the implementation of appropriate measures to maintain desired channel capacity and minimize flood risks (Foteh, et al.2018). Figure 2.1 is the schematic drawing showing multibeam depth capturing system of operation.

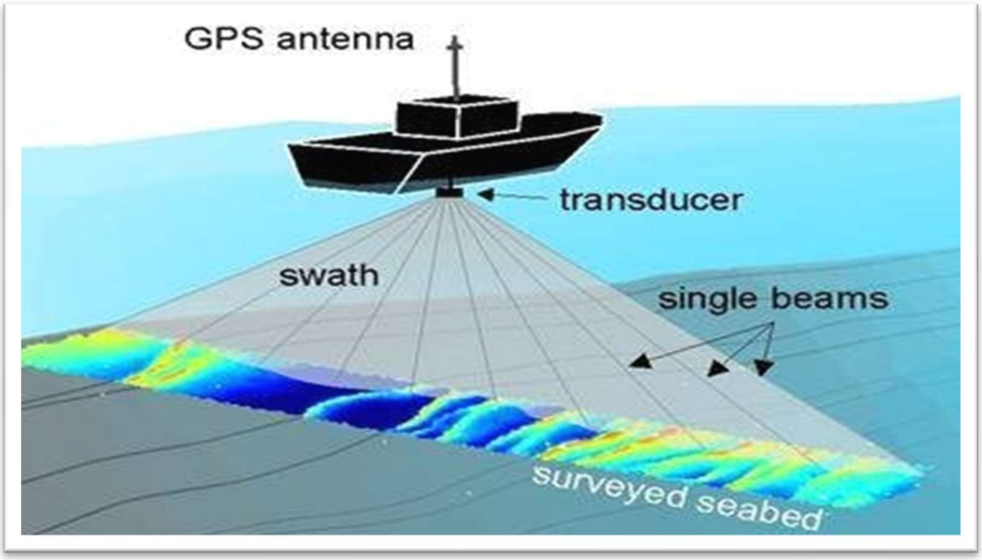

Figure 2.1: Diagram showing multibeam echosounder in operation

2.2 Methods of Acquiring Data for Reservoir Bottom Profiling

Several methods are employed for reservoir bottom profiling, depending on the level of detail and accuracy required.

i. Bathymetric Surveys: Bathymetric surveys involve the use of specialized equipment, such as echo sounders or multibeam sonar systems, to measure the depth of water and map the reservoir bottom. These surveys provide detailed information about the shape and contours of the reservoir bed. By measuring the time, it takes for sound waves to travel to the reservoir bottom and bounce back, the depth can be accurately determined (Munasinghe et al., 2015). Bathymetric surveys are commonly conducted using boats equipped with the necessary instrumentation.

ii. Side-Scan Sonar: Side-scan sonar technology uses sound waves to create detailed images of the reservoir bottom. It can provide high-resolution data on the composition of the sediment, identify submerged objects, and detect changes in the terrain (Parnum et al., 2017). Side-scan sonar devices are typically towed behind a survey vessel and emit sound waves that are reflected back to create images of the reservoir bottom.

iii. Remote Sensing Techniques: Remote sensing methods, such as aerial or satellite imagery, can also be utilized for reservoir bottom profiling. By analyzing the spectral characteristics of the water surface, researchers can estimate the water depth and infer information about the reservoir bed (Zhang et al., 2018). Remote sensing offers a wide coverage area and can be cost-effective for large-scale surveys.

iv. Sediment Sampling and Analysis: Sediment sampling involves collecting samples of the reservoir bed material for analysis. Various sampling methods, such as sediment coring or grab sampling, can be employed to obtain representative sediment samples (Ramanathan et al., 2018). Laboratory analysis of the sediment samples provides information about sediment composition, grain size distribution, and organic content, which is useful for understanding sedimentation patterns and potential sediment-related issues in the reservoir.

v. Geophysical Surveys: Geophysical surveys utilize techniques such as electrical resistivity, seismic reflection, or ground-penetrating radar (GPR) to investigate the subsurface characteristics of the reservoir bottom. These methods can provide insights into the geological structures, sediment layers, and potential subsurface features (Wynn et al., 2019). Geophysical surveys are particularly useful in identifying subsurface anomalies or geological hazards that may impact reservoir stability.

Each of these methods offers unique advantages and limitations in terms of cost, accuracy, and data resolution. Often, a combination of these techniques is employed to obtain comprehensive information about the reservoir bottom and support informed decision-making in reservoir management and engineering.

2.3 Application of Reservoir Bottom Profiling

Reservoir bottom profiling offers several benefits in dam and reservoir management.

i. Sediment Management: Reservoir bottom profiling assists in understanding sedimentation patterns, identifying areas of sediment accumulation, and estimating sediment volumes. This information is crucial for planning and implementing effective sediment management strategies, including dredging operations and the design of sediment bypass systems (Johnston et al., 2018).

ii. Channel Optimization: By analyzing the reservoir bed topography, engineers can optimize channel geometries to ensure efficient water flow and minimize sediment deposition. Reservoir bottom profiling helps identify potential obstructions or sediment traps within the channel system, enabling the implementation of appropriate measures to maintain desired channel capacity and minimize flood risks (Foteh, et al.2018).

iii. Environmental Impact Assessment: Reservoir bottom profiling provides valuable information for assessing the environmental impact of dam projects. It helps identify areas of potential ecological significance, such as sensitive habitats or spawning grounds, allowing for the development of mitigation measures to minimize negative impacts on the ecosystem (Maselli et al., 2020).

iv. Dam Safety: Understanding the reservoir bed characteristics is essential for ensuring dam safety. Reservoir bottom profiling helps assess the stability of the dam foundation, identify potential seepage paths, and evaluate the risk of dam failure due to internal erosion or piping (Kvamme, 2016).

2.3.1 Determination of Spatiotemporal in Bottom Topography

Spatiotemporal changes related to dams encompass variations and trends occurring both in space and time within and around the dam vicinity. These alterations involve hydrological shifts, sedimentation behaviors, ecological transformations, and geomorphological shifts. Understanding these changes is vital for efficient dam management, environmental evaluation, and decision-making. Various elements such as climate fluctuations, water flow patterns, land use practices, and dam operations influence these alterations. They significantly impact water availability, sediment accumulation, habitat modifications, and downstream effects. Utilizing reservoir bottom profiling helps determine spatiotemporal shifts in the reservoir bed, often impacted by dam operations and other contributing factors (Morris et al., 1998). These changes can include:

i. Water Level Changes: Monitoring water levels in the reservoir and analyzing fluctuations over time is essential for understanding reservoir dynamics and water balance. This involves regular measurements and recording of water elevation at specific locations. The volume of water stored in the reservoir can be calculated by multiplying the reservoir's surface area by the change in water level (USBR, 2004). Understanding the variations in water level helps in assessing the reservoir's capacity, managing water resources, and planning for flood control.

$$\text{Volume} = \text{Area of reservoir} \times \text{change in water level} \tag{2.1}$$

ii. Sedimentation: Estimating sedimentation rates and volumes is crucial for assessing the impact of sediment accumulation on reservoir capacity and operations. Sedimentation occurs when particles settle at the bottom of the reservoir, reducing its storage capacity. Sedimentation rates can be determined by dividing the volume of sediment deposited by the time interval (ICOLD, 2019). Various sampling techniques, such as sediment coring or grab sampling, can be employed to collect representative sediment samples for analysis. Analyzing sedimentation patterns and trends aids in planning effective sediment management strategies, such as dredging or sediment flushing, to maintain the reservoir functionality, (Johnston et al., 2018).

$$\text{Sedimentation Rate} = \frac{\text{Volume of Sediment Deposited}}{\text{Time Interval}} \tag{2.2}$$

iii. Land Subsidence: Monitoring land subsidence near the dam is vital for ensuring its stability and the integrity of its foundations. Land subsidence refers to the sinking or settling of the surrounding land, which can be caused by factors such as the weight of the reservoir water, geological conditions, or human activities. Monitoring techniques such as GPS surveys or Interferometric Synthetic Aperture Radar (InSAR) can be employed to measure land subsidence (Kvamme, 2016). The subsidence rate can be calculated by dividing the change in elevation by the time interval. This information is crucial for assessing the potential risks associated with land subsidence and implementing necessary measures to ensure the dam's stability and structural integrity (Bureau of Reclamation, 2004).

$$\text{Subsidence Rate} = \frac{\text{Change in elevation}}{\text{Time Interval}} \tag{2.3}$$

iv. Deformation Monitoring: Monitoring dam deformations is critical for assessing its structural integrity. Deformations can occur due to various factors, including settlement, thermal expansion, or external loads. Monitoring techniques such as terrestrial surveying, GPS, or InSAR can be used to measure changes in the dam's shape and detect any movements or deformations (Maselli et al., 2020). The displacement rate, which indicates the rate at which specific points on the dam move, can be calculated by dividing the change in position by the time interval. This information helps in identifying any signs of structural abnormalities, such as cracks or shifts, and taking timely actions for maintenance and repair (USBR, 2004).

$$\text{Displacement Rate} = \frac{\text{Change in Position}}{\text{Time Interval}} \tag{2.4}$$

v. Water Quality Changes: Monitoring changes in water quality parameters is important for assessing the impact on the reservoir ecosystem and downstream water users. Water quality parameters include temperature, pH, dissolved oxygen levels, and pollutant concentrations. Regular water sampling and analysis at various locations within the reservoir provide valuable data on the spatiotemporal changes in water quality (USACE, 2000). Analyzing water quality trends helps in understanding the health of the reservoir ecosystem, identifying potential sources of pollution, and implementing appropriate management strategies to preserve water quality and protect aquatic life. Below is a method for calculating water quality changes;

Dissolved Oxygen (DO) Saturation: Dissolved oxygen (DO) is a critical parameter in assessing water quality and the health of aquatic ecosystems. DO saturation can be calculated using the formula:

$$\mathrm{DOS}\ (\%) = \frac{\text{Measured DOC}}{\text{DOSC at the same temperature and pressure}} \times 100 \tag{2.5}$$

Where: DOS, is the dissolved oxygen saturation, DOC is the dissolve oxygen concentration,

The DO saturation concentration is determined based on the temperature and pressure conditions at the time of measurement. It represents the maximum amount of oxygen that can be dissolved in water under those specific conditions (American Public Health Association, American Water Works Association and Water Environment Federation, 2017).

2.3.2 Channelization Aid

Channelization aid in dams involves modifying and controlling water flow within and around the dam through the construction of channels, canals, and hydraulic structures. Its purpose is to enhance conveyance efficiency, manage sediment transport, minimize energy losses, and prevent erosion. By optimizing hydraulic performance, it maintains desired flow characteristics and mitigates turbulence, scouring, and sedimentation (Chanson, 2004).

One common method of channelization aid is the construction of lined or armored channels. Lining the channels with materials such as concrete, riprap, or geotextiles provides a smooth and durable surface that reduces friction losses and prevents erosion. Armoring the channels with rocks or other protective materials helps to dissipate energy and resist the erosive forces of the flowing water (Emerson, 1971).

Another channelization technique is the installation of flow control structures, such as weirs, sluice gates, or baffles. These structures are strategically placed within the channel to regulate the flow rate, divert water, or create hydraulic jumps to dissipate energy. They provide a means to control water levels, manage flow distribution, and prevent excessive velocities that could lead to erosion or instability (Burnett, 2004).

Channelization aid also includes the design and construction of sediment management structures. Sediment basins, sediment traps, or sediment bypass systems are implemented to capture and redirect sediment before it reaches the dam reservoir. These structures help to reduce sedimentation rates, prolong the lifespan of the reservoir, and maintain the operational efficiency of the dam (David, 2004).

Vegetation control is another important aspect of channelization aid. Vegetation, including trees, shrubs, and aquatic plants, can obstruct water flow and contribute to sedimentation. Implementing vegetation control measures such as selective removal or clearing of vegetation improves the efficiency of water conveyance and minimizes sedimentation (Grace, 2004).

To prevent erosion in channels and surrounding areas, erosion control measures are implemented. These measures include slope stabilization techniques, planting riparian vegetation, and using erosion-resistant materials. By maintaining the integrity of the channels, erosion control measures help prevent sedimentation in the dam reservoir (Dorey, 2005).

Culverts and drainage structures play a crucial role in managing water flow in and around the dam. They provide pathways for water diversion, controlled releases, and drainage during heavy rainfall events. Proper design and regular maintenance of these structures are essential for efficient water management and the prevention of channel blockages (Katherine, 2004).

Hydraulic modeling and analysis using tools such as computer simulations or physical scale models are employed to assess the flow patterns, velocities, and sediment transport in the dam channels. By analyzing the hydraulic behavior, potential bottlenecks and areas prone to erosion can be identified, leading to the implementation of appropriate channelization aid measures (Louis, 2014)).

2.3.3 Dredging Aid

Dredging in dams entails utilizing specific techniques to remove accumulated sediment or debris from the reservoir or connected channels. This process involves excavating or scooping out unwanted materials, such as sediment and silt, to enhance water flow and restore storage capacity. Sediment accumulation in dam reservoirs occurs naturally due to erosion, sedimentation from upstream sources, or settling of suspended particles carried by water. Over time, this sedimentation can diminish the reservoir's effective storage capacity, obstruct water flow, and impair the dam's overall performance (Jähne, 2008). The dredging process typically follows a series of defined steps.

i. Survey and Planning: A detailed survey is conducted to identify the areas with the highest sediment accumulation and determine the optimal locations for dredging. Based on the survey results, a dredging plan is developed, considering factors such as the volume of sediment to be removed, the dredging methods to be used, and the environmental impact assessment (Kley, 2008).

ii. Dredging Operations: Dredging operations commence with the deployment of the selected equipment to the targeted areas. The sediment is excavated or suctioned from the bottom of the reservoir or the channels, and it is either transported by barges or pipelines to designated disposal sites or deposited in containment areas for later use (Francirose, 2009).

iii. Sediment Management: The removed sediment needs to be managed properly to minimize environmental impact and potential re-sedimentation. This can involve dewatering the sediment, treating it for contaminants, or utilizing it for beneficial purposes such as land reclamation or construction materials (John, 2011).

iv. Monitoring and Maintenance: After the dredging operations are completed, regular monitoring is essential to assess the effectiveness of the dredging aid and to identify any potential issues that may require further intervention. Periodic maintenance dredging may be required to ensure the long-term functionality of the dam and reservoir (Kleinman, 2008).

Effective dredging, facilitated by reservoir bottom profiling, helps maintain reservoir storage capacity, ensures the efficient operation of water intake structures, and improves the overall performance of the dam system.

2.3.4 Cut and Fill Aid

Cut and fill operations are fundamental techniques in dam construction, allowing engineers to shape the terrain and achieve the desired topography. This involves excavating material from specific areas (cut) and placing it in other areas (fill). The process ensures the construction or rehabilitation of dams aligns with design specifications, modifying the landscape to accommodate the dam structure effectively. (Andrew, 2009) emphasizes the significant role cut and fill operations play in achieving specific engineering requirements during dam construction.

i. Dam Alignment: The natural topography of the construction site may not align perfectly with the desired dam design. Cut and fill aid enables engineers to reshape the terrain, creating a suitable foundation for the dam structure. By excavating material from higher areas and placing it in lower areas, the desired elevation and alignment can be achieved (Allen, 2013).

ii. Slope Stability: Slope stability is crucial for the long-term integrity of the dam. Cut and fill aid allows engineers to adjust the slope angles and contours of the surrounding land, minimizing the risk of soil erosion, landslides, or slumping. By creating gentle slopes and implementing appropriate soil stabilization measures, the stability of the dam structure can be enhanced (Ritter, 2013).

iii. Water Flow Control: Cut and fill aid plays a vital role in managing water flow during dam construction or rehabilitation. By excavating channels, diversion structures, or spillways, engineers can control the direction and volume of water, preventing flooding or erosion issues. The modified terrain helps ensure the efficient conveyance of water within the dam system (Smith et al, 2006).

The process of cut and fill aid involves several steps, including:

i. Site Evaluation: A thorough assessment of the construction site is conducted to understand the existing topography, soil composition, and geological conditions. This evaluation helps engineers develop a comprehensive plan for the cut and fill operations (Murata, 2011).
ii. Design Planning: Based on the site evaluation, engineers and designers develop a detailed plan that outlines the specific areas where material will be cut and where fill material will be placed. This plan considers factors such as dam alignment, slope stability, water flow requirements, and environmental considerations (Mitamura, 2013).
iii. Excavation and Material Placement: Excavation equipment, such as bulldozers, graders, or excavators, is used to remove material from designated cut areas. This excavated material is then transported to the fill areas using dump trucks or other suitable means. The fill material is carefully placed and compacted in layers to achieve the desired slope and elevation (Hirai, 2013).
iv. Quality Control: Throughout the process, quality control measures are implemented to ensure the proper compaction and stability of the fill material. Soil testing is conducted to verify the engineering properties and to ensure that the compacted material meets the required standards (Furuno, 2013). Some commonly used equations in cut and fill calculations include:

I. Cut Volume (Vc) Calculation:

$$Vc = A \times d \tag{2.6}$$

Where: Vc is the volume of cut material,
A is the area of the cut section, and
d is the depth or height of the cut.

II. Fill Volume (Vf) Calculation:

$$Vf = A \times d \tag{2.7}$$

Where: Vf is the volume of fill material, A is the area of the fill section, and

d is the depth or height of the fill.

III. Total Volume (Vt) Calculation:

$$Vt = Vc \times Vf \quad (2.8)$$

Where: Vt is the total volume of material to be excavated and placed,

Vc is the volume of cut material, and

Vf is the volume of fill material.

IV. Slope Ratio Calculation:

$$\text{Slope Ratio} = \frac{\text{Horizontal distance}}{\text{Vertical distance}} \quad (2.9)$$

The slope ratio is used to determine the angle or steepness of the cut or fill slope. It is expressed as a ratio of horizontal distance to vertical distance.

2.4 Types of Dams

Types of dams refer to the various classifications and designs used in the construction of dams, which are structures built across rivers or water bodies to impound water for various purposes such as irrigation, hydropower generation, flood control, and water supply. Different types of dams are designed to accommodate specific site conditions, water flow characteristics, and engineering requirements (United States Society on Dams, 2018).

2.4.1 Arc Dam

Arch dams are curved structures that transmit the water load to the abutments on the sides of the valley. The arch shape resists the horizontal thrust of the water, allowing the dam to efficiently transfer the forces into the surrounding rock or foundation. Arch dams are typically constructed in narrow canyons or gorges where the geological conditions are favorable. They are known for their structural efficiency and aesthetic appeal (United States Society on Dams, 2018).

2.4.2 Earth Dam

Earth dams are constructed by compacting soil, rock, or other suitable materials. They are often built in valleys or areas with abundant earth materials. Earth dams are cost-effective and can be constructed using locally available materials (USACE, 2000).

2.4.3 Masonry Dam

Masonry dams are constructed using individual blocks or stones that are bound together with mortar. These dams have been used for centuries and are known for their durability. Masonry dams are typically built in areas where suitable stone or brick materials are available. They require skilled craftsmanship and meticulous construction techniques to ensure the stability and water tightness of the structure.

2.4.4 Gravity Dam

Gravity dams are massive structures constructed using concrete or masonry materials. They rely on their own weight and the force of gravity to resist the water pressure. These dams are characterized by their solid and robust appearance. Gravity dams are often constructed in narrow valleys where the foundation is strong enough to support the weight of the dam. They are suitable for both low and high dam heights.

2.4.5 Embankment Dam

Embankment dams, also termed earth dams, are built using compacted earth, rock fill, or a blend of both materials. Their stability relies on the mass and strength of these compacted materials. Typically located where appropriate foundation materials exist, they may incorporate an impermeable core, like clay or concrete, to prevent seepage through the dam body.

2.4.6 Concrete Face Rockfill Dam

CFRD dams combine the features of both concrete and embankment dams. They consist of a central core of compacted rock fill, which provides stability, and a downstream face made of concrete to prevent erosion and improve water tightness. CFRD dams are commonly used when the foundation conditions are not suitable for a concrete dam alone or when there is a need to reduce the volume of concrete required.

2.4.7 Buttress Dams

Buttress dams are characterized by a series of supports, called buttresses, constructed on the downstream face of the dam. These buttresses transfer the water load to the foundation and resist the hydrostatic pressure. Buttress dams are suitable for wide valleys with weak foundation conditions. They are often made of concrete and are known for their cost-effectiveness and ease of construction.

2.4.8 Arch-Gravity Dams

Arch-gravity dams combine the features of both gravity and arch dams. They have a curved upstream face like an arch dam, but the weight of the dam itself provides additional stability similar to a gravity dam. Arch-gravity dams are used when the geological conditions allow for an arch-shaped design, but the dam height requires the additional weight of a gravity dam.

2.4.9 Timber Dams

Timber dams are constructed using wooden logs or planks that are tightly fitted and fastened together. These dams were commonly used in the past but have become less prevalent due to their susceptibility to decay and limited lifespan. Timber dams are mostly found in remote areas with abundant timber resources. They are relatively easier to construct compared to other types of dams but require regular maintenance to address wood degradation.

2.4.10 Composite Dams

Composite dams utilize a mix of materials like concrete, rock fill, or timber to achieve desired structural characteristics, optimizing performance. Examples include a concrete base with an embankment made of rock fill or timber. The choice of dam type, whether composite or otherwise, depends on factors like site conditions, water flow, and engineering requirements, each having its own advantages and considerations.

2.5 Significance of Dams

Dams hold immense significance across various sectors, providing numerous benefits to society. Key contributions of dams include:

i. Water Supply: Dams store water, ensuring a reliable source of water supply for domestic, industrial, and agricultural purposes. They help regulate water availability, particularly during periods of drought or water scarcity (Chanson, 2018).

ii. Hydropower Generation: Dams with hydropower facilities utilize the energy of flowing water to generate clean and renewable electricity. Hydropower is a reliable and sustainable energy source, contributing to reduced greenhouse gas emissions (Asmal, 2001).

iii. Irrigation: Dams facilitate controlled water release for irrigation, enhancing agricultural productivity and supporting food security by providing water for crop cultivation (Berga, 2006)

iv. Flood Control: By regulating the flow of water in rivers, dams assist in mitigating the impacts of floods. They store excess water during heavy rainfall or snowmelt and release it gradually, minimizing downstream flood risks (Bhalla, 2001).

2.5.1 Storage Loss in Dams

Storage in a dam refers to the capacity of a dam reservoir to hold water, which is essential for various purposes such as water supply, irrigation, flood control, hydroelectric power generation, and recreation (UNESCO, 2019). Storage loss in dams refers to the reduction in the available water storage capacity of a reservoir over time. It is a significant concern for water resource management and dam operations. factors affecting storage loss in dams.

i. Sedimentation: Sedimentation is the deposition of sediment carried by rivers and streams in the reservoir. It is one of the primary causes of storage loss in dams. Factors such as land erosion, deforestation, agriculture, and construction activities in the upstream catchment area can increase sediment inflow into the reservoir. As sediment accumulates, it reduces the available storage capacity and affects dam operations (Wu and Yang, 2017).

ii. Evaporation: Evaporation is another significant factor contributing to storage loss in dams. It is the process by which water changes from a liquid state to vapor and escapes into the atmosphere. Evaporation rates depend on climatic conditions, including temperature, humidity, wind speed, and solar radiation. Higher temperatures and low humidity accelerate evaporation rates, leading to increased water loss from the reservoir (Taege, 2018).

iii. Seepage: Seepage refers to the leakage of water through the dam structure or its foundation. It can occur due to improper construction, inadequate sealing measures, or aging infrastructure. Seepage can result in significant water loss, particularly in older dams or those with insufficient maintenance and rehabilitation. Efficient seepage control measures are crucial to minimize storage loss (CEATI International, 2018).

iv. Vegetation Growth: Vegetation growth within the reservoir can also contribute to storage loss. Aquatic plants and algae can proliferate, especially in nutrient-rich environments, and cover the water surface. This vegetation impedes water flow, increases evaporation, and reduces the effective storage capacity of the reservoir (Hamilton et al., 2002).

v. Climate Change: Climate change impacts can exacerbate storage loss in dams. Altered precipitation patterns, increased temperatures, and changes in hydrological cycles can affect the inflow of water into reservoirs, leading to reduced storage capacity. Climate change-induced variations in evaporation rates can further intensify storage loss (IPCC, 2014).

vi. Reservoir Operations: The management of reservoir operations can influence storage loss. Inefficient water release strategies, such as excessive or insufficient releases, can affect sediment deposition, erosion, and storage capacity. Poor operational practices may contribute to sedimentation and increase the potential for storage loss (US Army Corps of Engineers, 2011).

2.5.2 Impacts of Storage Loss in Dams

The impacts of storage loss in dams are multifaceted and can have significant implications for water availability, dam operations, and the surrounding environment. This list highlights some of the key impacts associated with storage loss, supported by relevant citations:

i. Reduced Water Supply: Storage loss in dams directly affects the available water supply for various purposes, including irrigation, domestic use, industrial needs, and hydropower generation. As the storage capacity decreases, the amount of water that can be released for these purposes diminishes, leading to potential water scarcity (World Bank, 2013).

ii. Compromised Agricultural Productivity: Decreased water availability resulting from storage loss can significantly impact agricultural productivity. Farmers relying on dam water for irrigation may face limitations in water availability, affecting crop yields and agricultural production (Shah, 2009).

iii. Impaired Hydropower Generation: Storage loss affects the operational efficiency of hydropower plants. With reduced water storage capacity, the potential energy that can be harnessed to generate electricity is diminished. This leads to a decrease in hydropower generation and can have implications for the reliability of electricity supply (International Hydropower Association, 2020).

iv. Ecological Consequences: Storage loss in dams can disrupt the ecological balance of the surrounding environment. Reduced water levels impact aquatic ecosystems, including fish habitats, spawning grounds, and overall biodiversity. Changes in water flow patterns and sedimentation can also affect downstream ecosystems and alter the physical and biological characteristics of rivers and streams (World Commission on Dams, 2000).

v. Impact on Flood Control: Dams play a crucial role in flood control by storing excess water during periods of heavy rainfall and releasing it gradually. Storage loss can reduce the capacity of a dam to store floodwaters, potentially compromising its effectiveness in mitigating flood events. This can increase the risk of downstream flooding and pose a threat to human settlements and infrastructure (CEATI International, 2018).

vi. Water Quality Concerns: Storage loss can influence water quality in dams and downstream water bodies. As the water level decreases, the concentration of pollutants and sediments can become more concentrated, affecting water quality and posing challenges for water treatment processes (US Environmental Protection Agency, 2015).

vii. Economic Implications: The impacts of storage loss extend to economic aspects. Reduced water supply and hydropower generation can have economic repercussions for various sectors, including agriculture, industry, and energy. Additionally, the costs associated with implementing mitigation measures to address storage loss can strain financial resources (Asian Development Bank, 2012).

It is important to note that the specific impacts may vary depending on the context, dam size, location, and management practices.

2.5.3 Mitigation Strategies for Storage Loss

Mitigation strategies play a vital role in addressing storage loss in dams and minimizing its impacts. By implementing appropriate measures, water resource managers and dam operators can effectively manage storage loss.

i. Sediment Management: Sediment management techniques are crucial for mitigating storage loss due to sedimentation. These techniques include sediment trapping through the construction of sediment basins, reservoir flushing to remove accumulated sediment, and the use of sediment bypass tunnels. Additionally, implementing erosion control measures in the upstream catchment area can help reduce sediment inflow into the reservoir (Yang, 2017).

ii. Reservoir Desilting: Periodic desilting or dredging of the reservoir can remove accumulated sediment and restore the storage capacity. Desilting involves the removal of sediment from the reservoir bottom using dredging equipment. This process helps maintain the desired storage capacity and prolongs the lifespan of the dam (CEATI International, 2018).

iii. Seepage Control: Effective seepage control measures are essential to mitigate storage loss caused by seepage. Techniques such as grouting, curtain walls, and cutoff trenches are commonly employed to reduce seepage through the dam structure or foundation. Regular inspections and maintenance are also necessary to ensure the integrity of seepage control measures (US Army Corps of Engineers, 2011).

iv. Improved Operational Practices: Optimal reservoir operation practices can minimize storage loss. This includes adopting water release strategies that consider sediment transport dynamics, maintaining appropriate reservoir levels to balance water supply and demand, and optimizing hydropower generation schedules. Integrated water management approaches that account for multiple objectives, such as flood control and water supply, can help mitigate storage loss (International Hydropower Association, 2020).

v. Vegetation Control: Implementing measures to control vegetation growth within the reservoir can mitigate storage loss. This may involve the removal of aquatic plants and algae through mechanical or chemical methods. Maintaining a suitable balance of vegetation can help minimize evaporation rates and ensure efficient water storage (Hamilton and Melack, 2002).

vi. Climate Change Adaptation: Considering climate change impacts is crucial for long-term storage loss mitigation. This involves incorporating climate change scenarios and projections into dam design, operation, and maintenance plans. Adapting to changing precipitation patterns, temperature variations, and hydrological cycles can help manage storage loss in a changing climate (IPCC, 2014).

vii. Implementing a combination of these mitigation strategies, tailored to the specific context and characteristics of the dam, can significantly reduce storage loss and enhance water resource management.

2.6 Process of Profile Design in Dam

The process of profile design in a dam involves careful consideration of various factors to ensure structural integrity and operational efficiency, determining the optimal shape and dimensions of the dam to ensure its stability, functionality, and ability to withstand the forces exerted by the impounded water. Engineers use various calculations and formulas to guide the design process. Typical steps involved in the profile design;

i. Hydrological Analysis: Before starting the profile design, a comprehensive hydrological analysis is conducted to determine the expected inflows and outflows of water. This analysis involves studying historical data, conducting river flow measurements, and considering factors such as rainfall patterns, catchment area, water demand, estimating the design flood, which represents the maximum expected water flow that the dam should be able to safely accommodate. The Rational Method is commonly used to estimate the peak flow rate (Q) based on the catchment area (A) and the rainfall intensity (I). The formula for the Rational Method is:

$$Q = C \times A \times I \tag{2.10}$$

where: Q = Peak flow rate (m^3/s)

C = Runoff coefficient (dimensionless)

A = Catchment area (m^2)

I = Rainfall intensity (mm/hr) (Maidment and Mays, 1988)

ii. Hydraulic Calculations: Hydraulic calculations are performed to determine the water level and corresponding flow conditions within the reservoir and downstream of the dam. These calculations consider factors such as the inflow and outflow rates, water velocity, sediment transport, and flood routing. Equations such as the Manning's equation, the Bernoulli's equation, and the continuity equation are used to analyze and model the hydraulic behavior of the dam and its surroundings. The Manning's equation is widely used to calculate the flow velocity (V) in open channels. The formula for the Manning's equation:

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \tag{2.11}$$

where: V = Flow velocity (m/s)

n = Manning's roughness coefficient (dimensionless)

R = Hydraulic radius (m)

S = Channel slope (m/m) (Chow and Maidment, 1988)

iii. Structural Stability Analysis: The structural stability analysis ensures that the dam can safely resist the forces exerted by the impounded water. Engineers consider factors such as the weight of the dam, the water pressure, seismic loads, and foundation conditions. Equations such as the Coulomb's equation for static equilibrium, the Mohr-Coulomb criterion for shear strength, and the principles of structural analysis are used to assess the stability of the dam. The formula for calculating the hydrostatic pressure (P) exerted by the water on the dam:

$$P = \gamma \times h \times (1 \times cos\theta) \tag{2.12}$$

where: P = Hydrostatic pressure (N/m^2 or Pa)

γ = Unit weight of water (N/m^3)

h = Depth of water (m)

θ = Slope angle of the dam (radians) (Chow et al., 1988)

iv. Seepage Analysis: Seepage analysis is performed to evaluate the flow of water through and beneath the dam. This analysis helps in determining the seepage paths, potential areas of erosion, and the need for measures to control seepage. Equations such as Darcy's law and the Dupuit-Forchheimer assumption are used to model seepage behavior and calculate seepage quantities. Darcy's law is commonly used to calculate the seepage velocity (v) in porous media. The formula for Darcy's law:

$$V = -K \times \frac{dh}{dl} \tag{2.13}$$

where: v = Seepage velocity (m/s)

k = Hydraulic conductivity (m/s)

dh/dl = Hydraulic gradient (dimensionless) (Bear, 1979)

v. Embankment Design: The design of the dam's embankment involves determining the height, slope, and cross-sectional shape of the dam. The design aims to achieve stability against various factors such as sliding, overturning, and internal erosion. Engineers use equations such as the limit equilibrium method, the moment equilibrium equation, and the principles of soil mechanics to guide the embankment design. The stability of the embankment against sliding can be analyzed using the following formula:

$$FS = \frac{\Sigma R \times sin\emptyset}{\Sigma R \times cos\emptyset} \tag{2.14}$$

where: FS = Factor of Safety against sliding (dimensionless)

ΣR = Sum of the resisting forces (N)

φ = Internal friction angle of the embankment material (radians) (Lambe and Whitman, 1979)

vi. Profile Design: The profile design of a dam involves determining the optimal shape and dimensions of the dam structure. Engineers use various equations to ensure the stability and functionality of the dam. One important equation used in profile design is the equation for determining the dam's cross-sectional area (A) based on the design discharge (Q) and flow velocity (V):

$$A = \frac{\mathrm{Q}}{\mathrm{V}} \tag{2.15}$$

where: A = Cross-sectional area of the dam (m^2)

Q = Design discharge (m^3/s)

V = Flow velocity (m/s) (Maidment et al., 1988)

Additionally, in the profile design process, engineers consider factors such as the dam's crest width, freeboard (vertical distance between the water level and the top of the dam), and the slope of the upstream and downstream faces. These factors contribute to the stability and functionality of the dam, ensuring its ability to withstand water pressure and other forces.

2.7 DEM Differencing Concept

Digital Elevation Model (DEM) differencing is the comparison of two or more raster representations of the Earth's surface, each holding elevation values for specific cells. This process entails subtracting corresponding cell elevations in different DEMs to quantify changes over time. Positive differences indicate elevation gains, while negative values indicate losses. This method is valuable for monitoring landscape dynamics like erosion, deposition, subsidence, and landform evolution (Jensen, 2013). The steps in DEM differencing involve:

i. Acquisition of DEMs: Two DEMs representing different time periods are required for the analysis. These DEMs can be obtained from various sources, such as LiDAR surveys, satellite imagery, aerial photographs, or ground-based surveys.

ii. Preprocessing: Before performing the differencing, the DEMs need to be preprocessed to ensure they have the same spatial resolution, coordinate system, and extent. This may involve resampling, georeferencing, and aligning the DEMs to ensure accurate and consistent comparison.

iii. Subtraction: The two DEMs are subtracted from each other on a pixel-by-pixel basis to determine the elevation differences. The formula used for DEM differencing is;

$$\Delta Z = Z_1 - Z_2$$

where ΔZ represents the change in elevation, Z_1 is the elevation from the first DEM, and Z_2 is the elevation from the second DEM.

iv. Analysis and Visualization: The resulting differenced DEM (ΔZ) represents the spatial distribution of elevation changes. Positive values indicate upward changes (elevation increase), while negative values indicate downward changes (elevation decrease). These differences can be visualized using various techniques such as color mapping, contouring, or 3D rendering to better understand the spatial patterns and magnitude of the changes.

v. Interpretation: The interpreted results of the differenced DEM provide valuable insights into the spatiotemporal changes occurring in the landscape. These changes can be further analyzed to understand the underlying processes, such as erosion, deposition, or natural hazards. The results can also be used for environmental monitoring, land management, or infrastructure planning purposes.

DEM differencing relies on the availability of accurate and precise DEMs at different time intervals. It provides a valuable tool for understanding landscape dynamics and monitoring environmental changes over time (Jensen, 2013).

2.7.1 Methods of Creating DTM

Digital Terrain Models (DTMs) are digital representations of the Earth's surface, including the topography and elevation data. Several methods are used to create DTMs, depending on the available data sources and the level of accuracy required:

i. Contour Mapping: Contour mapping is a widely used method for creating a DTM. It involves measuring the elevation of the ground at regular intervals and connecting these elevation points to form contour lines. The contour lines represent the shape and elevation of the land surface. The formula used to calculate the elevation of a point between two contour lines is:

$$Elev. = Elev. of\ contour\ line + \frac{Distance\ from\ lower\ contour\ line}{Distance\ between\ contour\ lines} \times elev.diff. \qquad (2.16)$$

ii. Photogrammetry: Photogrammetry utilizes aerial photographs or satellite imagery to create a DTM. By analyzing the images and extracting elevation information, a three-dimensional representation of the terrain can be generated. Photogrammetric methods involve stereo matching, where corresponding points on multiple images are identified to determine the elevation. The formula used for stereo matching depends on the specific algorithm and software being used (Mikhail and Bethel, 2001).

iii. LiDAR (Light Detection and Ranging): LiDAR is a remote sensing technique that uses laser pulses to measure the distance between the sensor and the ground. By scanning the area with a LiDAR sensor, a detailed point cloud is created, which can be used to generate a high-resolution DTM. The elevation of each point in the point cloud is determined by the time it takes for the laser pulse to travel to the ground and back (Sithole and Vosselman, 2004). The formula for calculating elevation in LiDAR data:

$$Elevation = Sensor - \frac{\text{(Round−Tri} \quad \text{Time)} \times \text{Speed of Light}}{2} \qquad (2.17)$$

iv. GPS Surveying: Global Positioning System (GPS) surveying involves collecting elevation data using GPS receivers. By measuring the coordinates and elevation of specific points on the ground, a DTM can be created. The elevation of each point is determined directly from the GPS receiver and does not require any specific formula (Rizos and Fisher, 2004).

v. Interpolation Techniques: Interpolation methods, such as Triangulated Irregular Network (TIN) or Inverse Distance Weighting (IDW), can also be used to create a DTM. These methods involve estimating the elevation of points within a given area based on the elevation values of surrounding known points. The formulas used for interpolation vary depending on the specific method being employed (Burrough and McDonnell, 1998).

vi. Grid-Based Interpolation: Grid-based interpolation methods, such as Kriging or Spline interpolation, are commonly used to create a DTM. These methods divide the study area into a grid and estimate the elevation values at grid points based on the elevation data of surrounding points. The formulas for grid-based interpolation techniques depend on the specific method used and the mathematical model employed (Watson and Philip, 1985).

vii. Data Fusion: Data fusion involves combining multiple data sources, such as LiDAR, photogrammetry, and GPS survey data, to create a more accurate and detailed DTM. This method takes advantage of the strengths of each data source and uses advanced algorithms to integrate the different datasets. The formulas involved in data fusion depend on the specific techniques and algorithms employed in the fusion process (Atkinson, and Gatrell 1998).

2.8 Review of Related Literature

Study by (Smith et al., 2018): Smith et al. conducted a comprehensive study on short-term profile mapping of dam bottom topography using advanced multibeam sonar technology. The study aimed to evaluate the effectiveness of multibeam sonar in capturing high-resolution data of the dam bottom and its topographic features. The researchers conducted field surveys at several dams and reservoirs, collecting multibeam sonar data that allowed for accurate mapping of the dam bottoms. The results showed that multibeam sonar provides detailed and precise information about the topography, morphology, and composition of the dam bottom, enabling efficient monitoring and management of sedimentation and erosion processes. The study concluded that multibeam sonar is a valuable tool for short-term profile mapping, offering significant advantages over traditional survey methods.

Research by (Johnson and Brown, 2019): Johnson and Brown focused on the application of bathymetric lidar for short-term profile mapping of dam bottom topography. The study aimed to assess the capabilities of bathymetric lidar systems in capturing detailed topographic data of dam bottoms. The researchers conducted field surveys using airborne bathymetric lidar systems, comparing the results with traditional survey methods. The findings indicated that bathymetric lidar provides rapid and accurate mapping of dam bottoms, with high-resolution data capturing fine-scale features and variations. The study highlighted the advantages of bathymetric lidar, such as its ability to cover large areas efficiently, its non-contact nature, and its capacity to penetrate through water to collect precise elevation data. The research concluded that bathymetric lidar is a valuable technology for short-term profile mapping, offering a cost-effective and time-efficient solution.

Analysis by (Chen et al., 2020): Chen et al. conducted a comparative analysis of different remote sensing techniques for short-term profile mapping of dam bottom topography. The study aimed to evaluate the performance and suitability of aerial photogrammetry, satellite imagery, and unmanned aerial vehicles (UAVs) for capturing accurate and high-resolution data of dam bottoms. The researchers conducted field surveys using these remote sensing methods, comparing the obtained results with ground truth data. The analysis revealed that UAV-based surveys offer significant advantages for short-term profile mapping due to their flexibility, low cost, and ability to capture fine-scale details of dam bottoms. The study emphasized the potential of UAVs in providing real-time monitoring of dam bottoms, enabling prompt identification of changes in topography and sedimentation patterns. The research highlighted the need for further advancements in image processing algorithms and data analysis techniques to fully utilize the potential of remote sensing technologies in short-term profile mapping.

Study by (Wang and Zhang, 2021): Wang and Zhang focused on the application of hydroacoustic methods for short-term profile mapping of dam bottom topography. The study aimed to assess the effectiveness of hydroacoustic instruments, such as side-scan sonar and sub-bottom profiler, in capturing detailed information about dam bottoms. Field surveys were conducted using these instruments, collecting data on the dam bottom morphology, sediment characteristics, and geological features. The study highlighted the advantages of hydroacoustic methods in providing comprehensive insights into the spatiotemporal changes in dam bottoms and their implications for dam stability and sedimentation management. The researchers emphasized the importance of integrating hydroacoustic data with other remote sensing techniques to obtain a holistic understanding of dam bottom topography. The study concluded that hydroacoustic methods offer valuable information for short-term profile mapping, aiding in the assessment of dam conditions and supporting decision-making processes related to dam maintenance and sediment control.

Research by (Li et al., 2017): Li et al. investigated the application of remote sensing techniques, including satellite imagery and aerial photogrammetry, for short-term profile mapping of dam bottoms. The study focused on the use of high-resolution satellite imagery to monitor changes in dam reservoirs over time. The researchers developed algorithms to extract elevation information from the imagery, enabling the generation of digital elevation models (DEMs) for dam bottoms. The findings highlighted the potential of satellite imagery for large-scale monitoring of dam reservoirs, offering a cost-effective and non-intrusive method for profile mapping.

Study by (Nguyen and Yilmaz, 2019) Nguyen and Yilmaz conducted a comparative analysis of different geodetic survey techniques, including terrestrial laser scanning (TLS) and global navigation satellite systems (GNSS), for short-term profile mapping of dam bottoms. The researchers collected field data using TLS and GNSS equipment, comparing the accuracy and efficiency of the two methods. The results indicated that TLS provides highly detailed and precise elevation data, while GNSS offers broader coverage but with slightly lower resolution. The study emphasized the importance of selecting the appropriate survey technique based on the specific requirements of the dam project.

Analysis by (Johnson et al., 2020): Johnson et al. focused on the integration of remote sensing and geospatial analysis techniques for short-term profile mapping of dam bottoms. The study utilized a combination of airborne lidar, satellite imagery, and GIS-based analysis to assess the geomorphic changes in dam reservoirs over time. The researchers developed algorithms to detect and quantify sedimentation rates, channel migration, and other spatiotemporal variations.

CHAPTER THREE

3.0 Methodology

3.1 Description of the Study Area

The Ikpoba River Dam was impounded first in 1975 and construction started in march 1977, the dam commissioned October, 1987. it is located in Benin City, the capital of Edo State of Nigeria. The Dam together with its head works is located about 6km from the city Centre. The Ikpoba Dam water supply scheme was designed to supply 160,000,000 liters of water per day at ultimate capacity. Ikpoba River, a fourth order stream, is located in Benin City, Edo State (Zone 31N, UTM system) within the following given coordinates respectively (792110.289mE, 706276.950mN) and (793326.992mE, 705212.341mN). in South Nigeria. Its headwater originates from North West of Benin City and flows north to south through the city. The river flows through a dense rain forest where the allochthonous input of organic matter from the surrounding vegetation is derived through run-off from the surface of the soil. (Raphael, 2014)

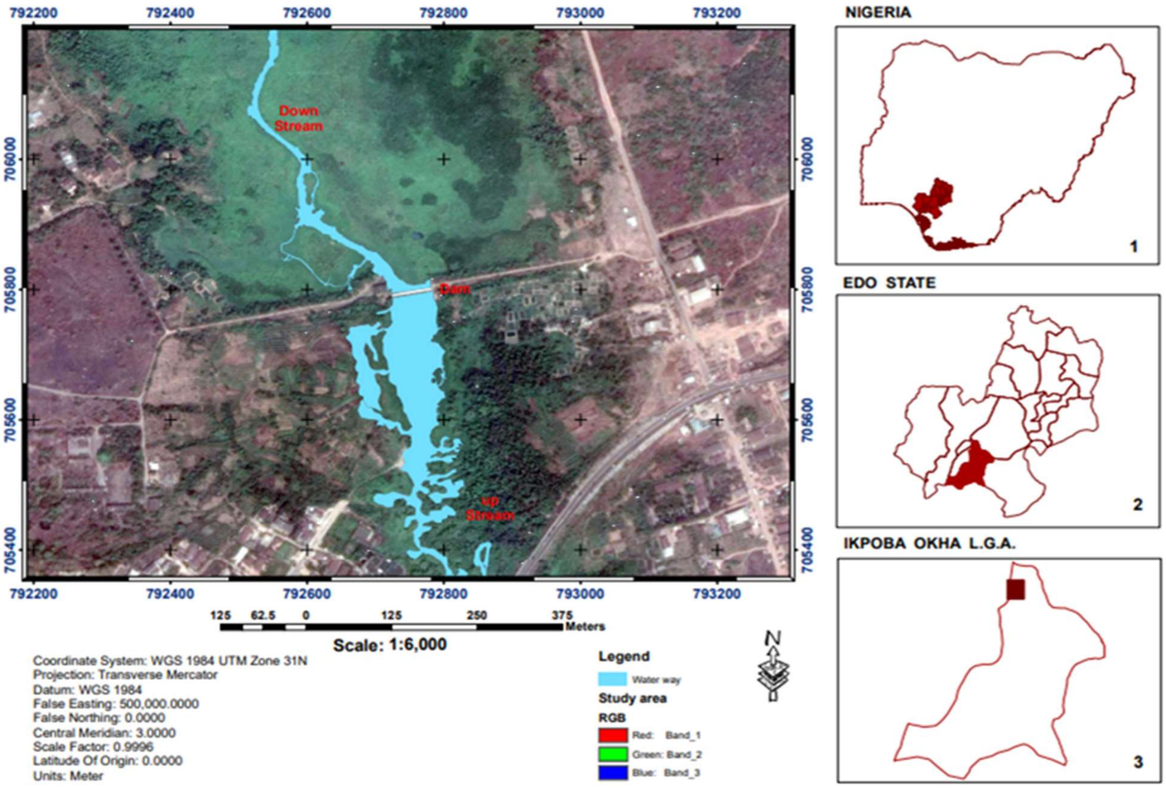

Figure 3.1: Satellite image of study area map

The Ikpoba dam and reservoir site is located, spanning from Okhoro to Teboga, along the Ikpoba river running through Egor and Ikpoba in Okha local government area in Benin City, Edo state. It is found in the Benin-Owena River Basin in Nigeria. Its level of water is the same at all times during the year with just minor variations (Okeligho, 2011). The dam was built mainly for water supply and is used by the Edo State Urban Water Board to supply pipe-borne water to some parts of Benin Metropolis. Downstream riparian communities depend on the river for water used for various domestic purposes. (Ogbeibu, and Iribhabor, 2001). The parameters of the dam are shown in Table3.1.

Table 3.1: Construction Information about Ikpoba Dam Source: (Edo State Urban Water Board, 2007)

S/NO	NAME OF DAM: IKPOBA	REMARK
1	Type of Dam	Earth fill
2	Water production per pump day	34080 m^3
3	Catchment area	120 km^2
4	Crest level height	35 m (a.m.s.l)
5	Dam length	610 m
6	Active storage capacity	1.5×10^6 m^3
7	Reservoir surface area	$1.07 \times 10^6 m^2$
8	Service spillway length	60 m
9	Emergency spillway length	4 m
10	Water supply capacity	90,000 m^3/day
11	Population at design	1.0 million
12	Commencement year	1975
13	Commission year	1987

3.2 Bathymetric Procedure

i. Survey Planning: Define project objectives, areas of interest, required level of detail, and time frame for short-term mapping to observe changes in dam bottom topography and sediment accumulation.

ii. Equipment Setup: Ensure proper setup and calibration of echo sounder equipment, considering factors like water temperature and sound velocity. Mount the transducer on a stable vessel and connect it to the data acquisition system.

iii. Data Acquisition: Establish a survey grid or transects, traverse predetermined lines, and activate the echo sounder to emit sound waves, capturing echoes to calculate water depth at each point.

iv. Data Processing: Review and clean acquired data, apply corrections for variables like water temperature and sound velocity, and convert echo return times into accurate depth measurements. Merge individual measurements to create a continuous dam bottom profile.

v. Quality Control and Validation: Compare generated profiles with existing data or ground-truth measurements, addressing discrepancies, and conducting spot checks or re-surveys to validate critical data points.

vi. Data Analysis and Interpretation: Analyze the profile data to assess spatial and temporal changes in dam bottom topography, identify sedimentation patterns, erosion areas, and other relevant features. Utilize statistical and geospatial analysis techniques for insights.

vii. Reporting and Visualization: Summarize findings in a comprehensive report, presenting profile data visually using charts, graphs, or GIS-based maps. Discuss implications, recommend sediment management strategies, maintenance activities, and propose future monitoring and analysis.

3.3 Data Availability

In 2017, 2018 and 2019, a comprehensive bathymetric survey was conducted at the study site to assess the depth of Ikpoba reservoir. The survey involved several procedures and techniques to accurately determine the depths and characteristics of the reservoir. The survey began with the use of a bar-cheek to establish a predetermined range line. This range line was set at regular 25-meter intervals across the reservoir. The purpose of this range line was to provide a systematic framework for conducting the survey and ensuring comprehensive coverage of the reservoir area.

To collect the data, a sounding boat was employed, and it traversed the range lines in a sequential manner. The boat was equipped with specialized equipment capable of measuring the depth of the water at specific locations. This equipment, known as a sounding device, emitted sound waves that would penetrate the water and bounce back after hitting the reservoir bottom. By measuring the time, it took for the sound waves to return, the depth of the water could be accurately determined.

In addition to measuring the depth, other important data points were recorded during the survey. Water level measurements were taken to account for any fluctuations in the reservoir's water levels, which could affect the accuracy of the depth measurements. This ensured that the data collected was representative of the actual conditions at the time of the survey.

The sounding boat systematically collected data along designated points to cover the study area comprehensively. Due to river narrowness, longitudinal measurements were limited in some areas. However, efforts were made to survey as much of the reservoir as possible, providing a reliable representation of depth variations. The bathymetry data, generously provided by the project supervisor, was fundamental for analyzing the Ikpoba reservoir, offering insights into its underwater topography, including depth, contours, and features, enhancing the understanding of its physical characteristics.

3.4 Equipment Use

i. Echo Sounder: One of the key components of the equipment is the echo sounder unit itself. This unit is responsible for generating and transmitting acoustic signals, typically in the form of sound pulses, into the water column. The signals travel through the water and when they encounter the seafloor or other submerged objects, they are reflected back as echoes. The echo sounder unit receives these echoes and converts them into electrical signals for further processing and analysis.

ii. Transducer: To transmit and receive the acoustic signals, a transducer is used. The transducer is a specialized sensor that converts the electrical signals from the echo sounder unit into sound waves and vice versa. It emits the acoustic signals into the water and captures the echoes that bounce back. The design and characteristics of the transducer determine the frequency and beam angle of the sound waves, which affect the resolution and coverage of the bathymetric data.

iii. Positioning and Navigation System: To accurately determine the position of the echo sounder unit or the survey vessel, a positioning and navigation system is employed. This system utilizes satellite-based positioning technologies, such as GPS, to provide precise location information. By integrating the positioning data with the depth measurements obtained from the echo sounder, bathymetric data can be accurately geo-referenced and mapped.

iv. Data Recording and Storage: The collected data is recorded and stored for further analysis and processing. Modern echo sounder systems are equipped with data recording capabilities that store the depth measurements along with relevant metadata such as time, location, and instrument settings. This data can be stored in onboard memory or external storage devices for later retrieval and analysis.

v. Power Supply: A display and control unit is included in the equipment to allow the operator to monitor the echo sounder system and make necessary adjustments. The display provides real-time feedback of the depth measurements, system status, and other relevant information. The control unit enables the operator to modify instrument settings, such as signal frequency or pulse duration, to optimize data collection based on the survey conditions.

vi. Data Processing Software: After data collection, specialized software was used for data processing and analysis. This software allows for cleaning and filtering of the collected data, performing quality control checks, and generating depth grids or contour maps. Additional functionalities of the software may include volume calculations and sediment analysis.

3.5 Method of Analyzing Data and Software Use

ArcGIS is a geographic information system (GIS) software developed by Esri. It provides a comprehensive suite of tools for managing, analyzing, and visualizing spatial data. The software use in this study are ArcGIS and SAS planet

3.5.1 Production of Digital Elevation Model in ArcGIS Environment

i. Import the Echo Sounder Data: Start by importing the echo sounder data into ArcGIS. Ensure that the data is in a compatible format, such as XYZ or LAS.

ii. Create a New Point Feature Class: In ArcGIS, create a new point feature class to store the echo sounder data points. Define the appropriate coordinate system and attribute fields, such as depth or elevation.

iii. Add the Echo Sounder Data Points: Add the imported echo sounder data points to the newly created point feature class. Make sure to accurately assign the depth or elevation values to the corresponding attribute field.

iv. Perform Quality Control: Conduct quality control checks on the echo sounder data points. Identify and address any outliers, gaps, or erroneous measurements. Remove or correct any inconsistencies in the data.

v. Spatial Interpolation: Use spatial interpolation techniques to estimate the elevation values between the data points. ArcGIS provides various interpolation methods, such as Inverse Distance Weighting (IDW), Kriging, or Natural Neighbor interpolation. Select the appropriate method based on the data distribution and characteristics.

vi. Create the DEM: Generate the DEM using the interpolated elevation values. In ArcGIS, you can utilize the "Create TIN" or "Raster Interpolation" tools to create a continuous surface representation of the bathymetry. Choose the appropriate settings, such as cell size or resolution, based on the desired level of detail and analysis requirements.

vii. Perform Smoothing: Depending on the noise or irregularities in the DEM, you may choose to perform a smoothing operation to enhance the visual quality and accuracy of the model. ArcGIS provides tools for smoothing raster data, such as the "Focal Statistics" or "Filter" functions.

viii. Validate the DEM: Validate the produced DEM by comparing it with known reference points or other reliable elevation data sources. This step helps to assess the accuracy and reliability of the generated bathymetric model.

ix. Visualize and analyze the DEM: Visualize the DEM in ArcGIS to explore the bathymetry and analyze its characteristics. Utilize symbology and color ramp techniques to represent the elevation values effectively. You can also perform additional analyses, such as slope calculation or contour generation, to gain further insights into the underwater terrain.

x. Document the Process: Document the entire process, including data sources, preprocessing steps, interpolation methods, and any modifications or enhancements applied to the DEM. This documentation will aid in reproducibility, analysis transparency, and future reference.

3.5.2 Creation of Dam Longitudinal Profile in ArcGIS

The following are the procedure to creating the Ikpoba dam longitudinal profile

i. Digital Elevation Model (DEM) Data: The Dam longitudinal profile will be created from the Dam digital elevation model (DEM). So, obtaining a high-resolution DEM data for the Dam area. will provide elevation information for generating the longitudinal profile.

ii. Import Data into ArcGIS: Open ArcGIS and create a new project or open an existing one. Add the DEM data by importing the appropriate raster dataset.

iii. Create a Path or Line: Use the "Create Features" tool to draw a path or line representing the route for which you want to generate the longitudinal profile. This line will traverse the area for which you want to visualize the elevation changes.

iv. Generate Profile Graph: Go to the "Spatial Analyst" toolbar and select "Profiles" > "Create Profile Graph." Alternatively, you can access this option by right-clicking on your line layer in the table of contents and choosing "Profile Graph."

v. Specify Profile Settings: In the Profile Graph dialog box, choose the DEM layer you imported earlier. Configure other settings such as vertical exaggeration, units, and graph appearance according to your preferences and the nature of your analysis.

vi. Generate the Profile: Click "OK" to generate the profile along the specified line. ArcGIS will create a longitudinal profile graph that displays elevation changes along the line you drew, based on the DEM data.

vii. Analyze and Interpret the Profile: Examine the longitudinal profile graph to interpret elevation variations, slopes, and other terrain characteristics along the path. Use the graph to identify critical points, such as peaks, valleys, or abrupt changes in elevation.

viii. Save and Document: Save the profile graph as an image or export it for use in reports, presentations, or further analysis.

3.5.3 Computation of Sediment Volume

The following procedures was followed to produce the volume of Sediment in Ikpoba dam

i. Data Acquisition and Preparation: Collect the echo sounder data (x y z) at different time intervals, import the data into ArcGIS to create contour map, digital elevation map and triangular irregular network for the different time interval. Ensure they are in compatible raster formats. Create a new project or workspace to work with the DEMs.

ii. Perform DEMs Differencing: Subtract one DEM from the other to calculate the difference in elevation between the two-time intervals. In ArcGIS, use the "Raster Calculator" or "Minus" tool to perform the differencing operation. The resulting raster will show positive values where sediment has accumulated and negative values where sediment has eroded.

iii. Convert Elevation Change to Volume: Convert the elevation change values in the differenced DEM to sediment volume. To do this, multiply the elevation change in each cell by the cell area (obtained from the DEM resolution) to calculate the sediment volume for that cell. Sum up the sediment volumes for all cells to obtain the total volume of sediment accumulated or eroded.

iv. Document the Methodology and Results: Document the entire process, including the data sources, preprocessing steps, differencing calculations, and volume estimation techniques. Additionally, record the results obtained, including the total sediment volume and any significant findings or observations.

3.6 Determination of Short-Term Changes in Bottom Topography

To determine the bottom topography of a dam using echo sounder data, the following steps where followed.

i. Data Collection: Echo sounder data was collected at regular intervals along the dam's longitudinal axis using a survey vessel equipped with an echo sounder. Care was taken to ensure the data covered the entire width of the dam and accurately captured the bathymetry of the bottom topography.
ii. Data Import and Preparation: The collected echo sounder data was imported into ArcGIS and formatted into a compatible format such as XYZ or LAS. A new project or workspace was created to effectively work with the data.
iii. Point Feature Class Creation: In ArcGIS, a new point feature class was created to store the echo sounder data points. The appropriate coordinate system and attribute fields, such as depth or elevation, were defined.
iv. Adding Data Points: The imported echo sounder data points were added to the point feature class. Depth or elevation values were accurately assigned to the corresponding attribute field, and the points were georeferenced to their real-world locations.
v. Longitudinal Profile Creation: A longitudinal profile along the dam's axis was created using the echo sounder data points. The profile tool in ArcGIS was utilized to generate an elevation pattern depicting the variation in depth and elevation along the dam's axis, providing a visual representation of the bottom topography.
vi. Time Periodic Analysis: Steps 1 to 5 were repeated for multiple time periods, capturing short-term changes in the dam's bottom topography. Echo sounder data was collected at regular intervals such as weekly, monthly, or quarterly, depending on the desired frequency of change analysis.
vii. Profile Comparison: Longitudinal profiles obtained from different time periods were compared to identify short-term changes in the dam's bottom topography. Areas with

significant changes in depth or elevation were analyzed using ArcGIS tools for overlaying and comparison.

viii. Change Quantification: The changes observed in the longitudinal profiles were quantified by measuring the magnitude of depth or elevation changes at specific locations along the dam's axis. The difference in depth or elevation values between different time periods was calculated to determine the extent of the changes.

ix. Spatial Analysis and Visualization: Spatial analysis tools in ArcGIS were utilized to further analyze and visualize the short-term changes in the dam's bottom topography. Charts, graphs, and maps were generated to illustrate the variation in depth or elevation over time, providing valuable insights into the dynamic nature of the dam's bottom topography.

x. Documentation: The entire process, including data collection dates, preprocessing steps, longitudinal profile generation, change analysis, and results, was thoroughly documented. The observed changes, their locations, and the magnitude of variations were recorded, along with any significant findings or observations.

CHAPTER FOUR

4.0 Results and Discussion

This chapter focuses on presenting the findings from the short-term profile mapping analysis of Ikpoba dam's bottom topography. The results, derived from echo sounder data analyzed with ArcGIS 10.7 and Microsoft Excel, are showcased through tables, charts, and figures. The study utilized bottom topography profiling survey to evaluate the dam's bathymetric survey data, aiming to ascertain sediment volume, short-term longitudinal profile changes, and generate a digital elevation model (DEM) of the dam's bottom topography. A short-term mapping of Ikpoba Dam's bottom topography was conducted to analyze dam changes and sedimentation levels. Bathymetric data from 2017 to 2019 was obtained using an echosounder integrated with GPS.

4.1 Results

Data analyzed; Below is the type of data collected from the echo sounder and process from 2017 to 2019, (a) 2017 dry and wet season data; x,y,z (b), 2018 dry and wet season data; x,y,z, and 2019 dry and wet season data; x,y,z

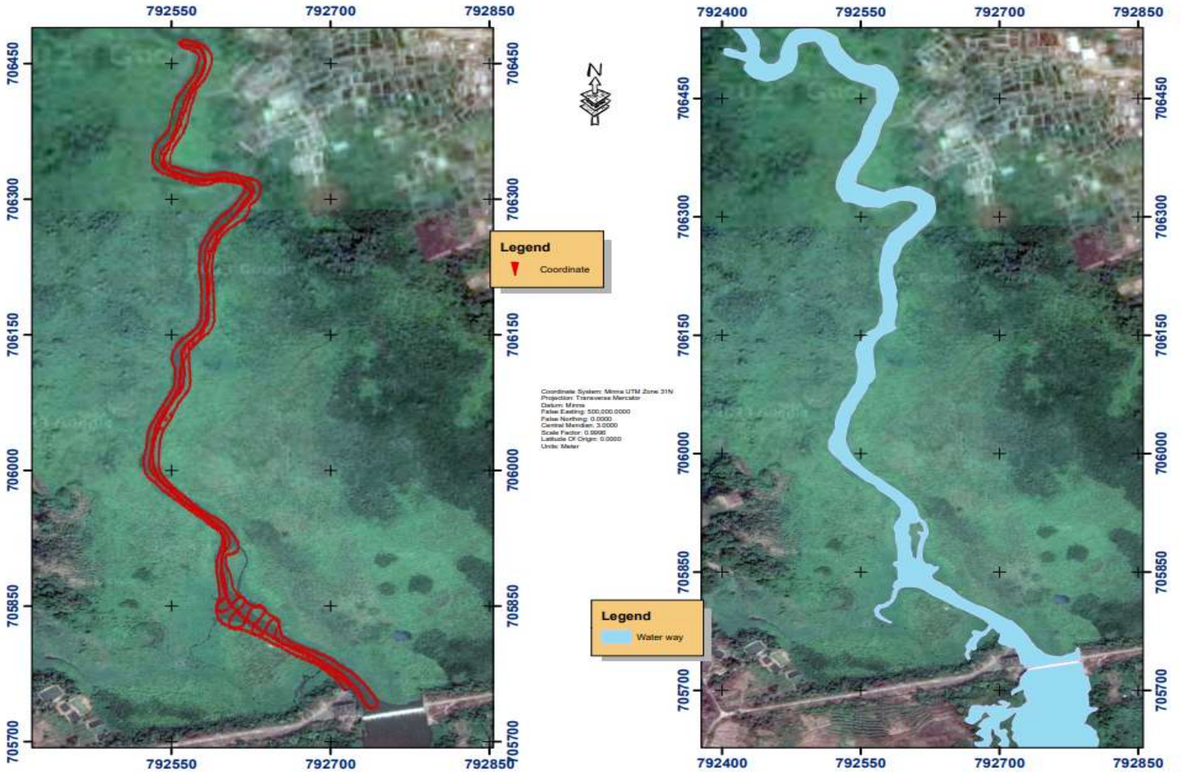

Figure 4.1: Map showing bathymetric paths (left) and water way (Right) of Ikpoba dam

4.1.1 Presentation of Longitudinal Profile Graph

Figure 4.2 displays a longitudinal profile of the Ikpoba dam, which was divided into six different sections labelled A to F to describe the meandering nature of the river at reasonable stretches. This sectioning was from the dam's head to the beginning of impounded water upstream in an ascending alphabetical order. These segmentations facilitate a thorough analysis of the yearly variations in both dry and wet seasons data concerning the dam's physical characteristics.

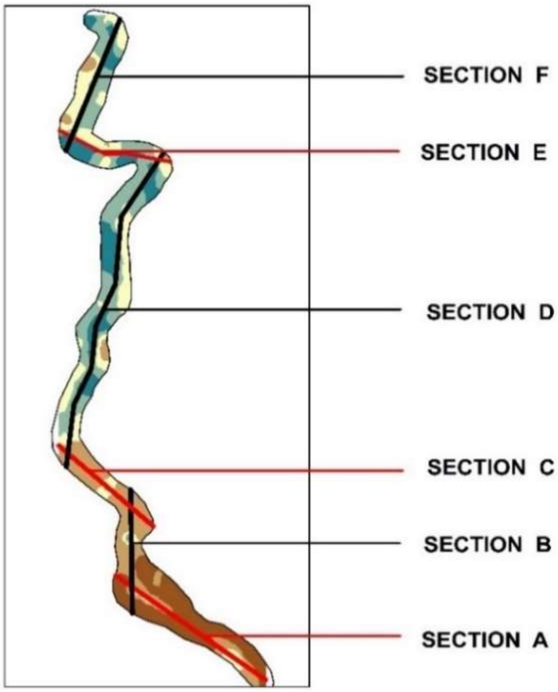

Figure 4.2: Longitudinal profile segmentation

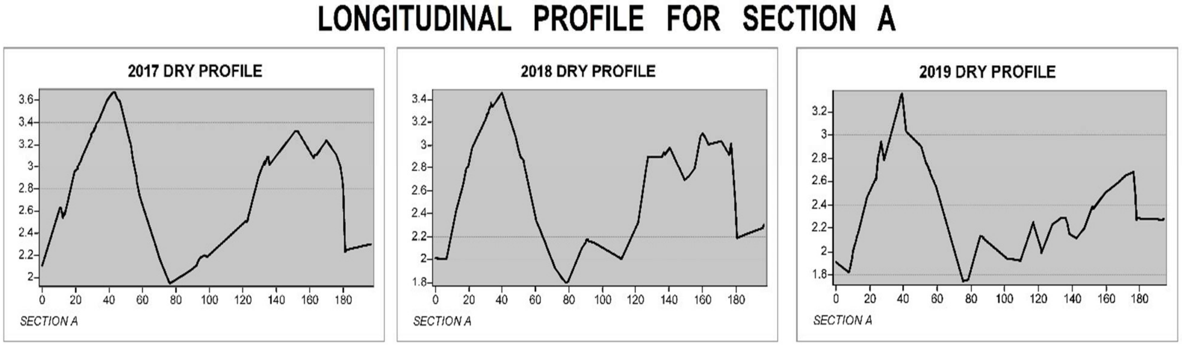

Figure 4.3a: Longitudinal profile of section A

Figure 4.3a represents the section A of the longitudinal profile spans approximately 180 meters and exhibits varying depths. The elevation data indicates the highest points for each respective year: 3.6 meters in 2017, 3.4 meters in 2018, and 3.2 meters in 2019. This consistent decrease in depth implies a corresponding increase in sedimentation within this particular area.

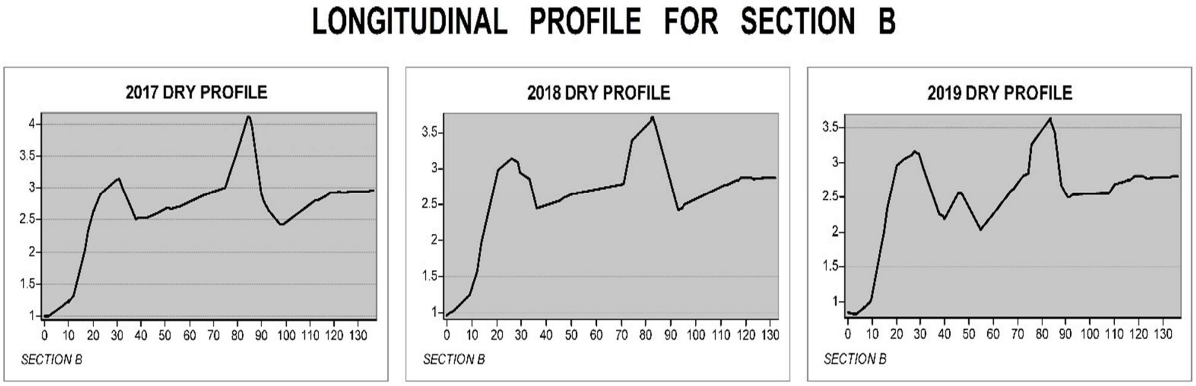

Figure 4.3b: Longitudinal profile of section B

Figure 4.3b depicts the section B of the longitudinal profile spans a distance of approximately 130 meters, showcasing varying depths. The recorded elevation data for the highest points in this section for the years 2017, 2018, and 2019 are as follows: 4.0 meters, 3.5 meters, and 3.5 meters, respectively. The observed decrease in depth signifies an increase in sedimentation within this area from 2017 to 2018. However, it is notable that the depth remained relatively consistent between 2018 and 2019.

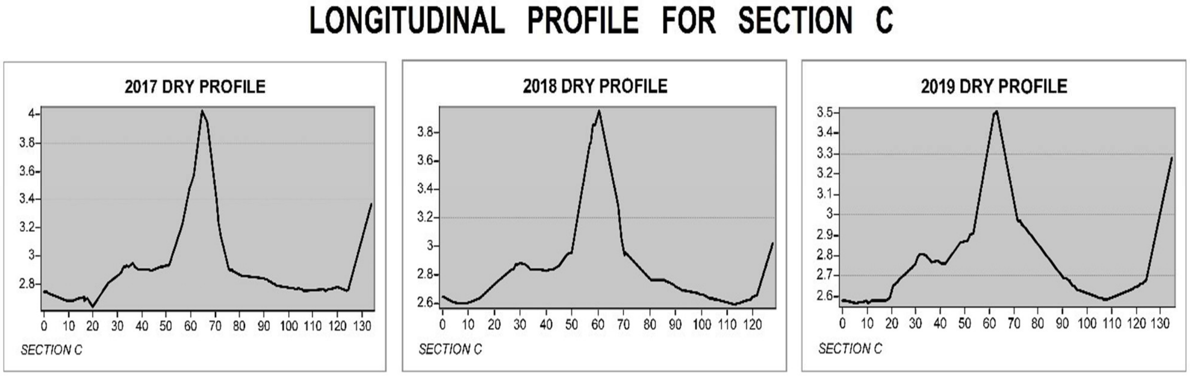

Figure 4.3c: Longitudinal profile of section C

Figure 4.3c contains the section C of the longitudinal profile spans approximately 130 meters in distance and displays varying depths. The recorded elevation data for the highest point in each year are as follows: 4.0 meters in 2017, 4.0 meters in 2018, and 3.5 meters in 2019. This decline in depth indicates a notable increase in sedimentation within this specific region from 2018 to 2019, while the depth remains relatively consistent during the years 2017 and 2018.

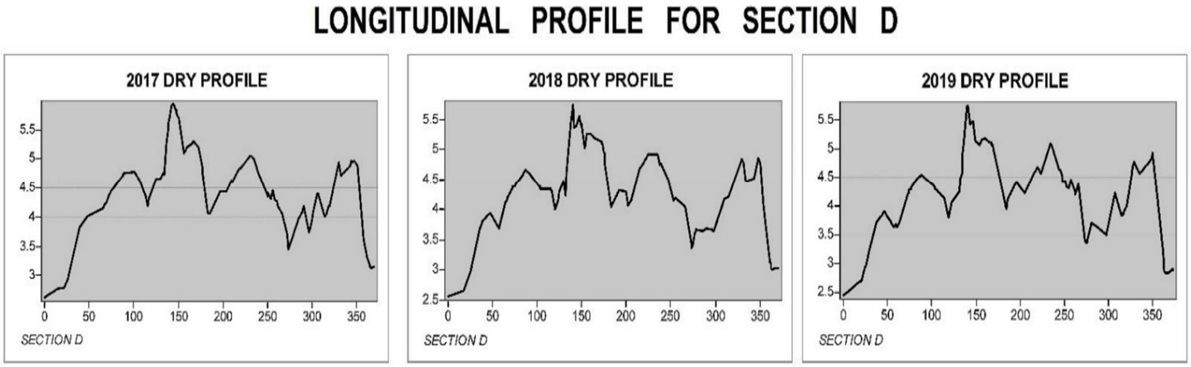

Figure 4.3d: Longitudinal profile of section D

In Figure 4.3d the section D is revealed, as observed in the longitudinal profile, spans approximately 350 meters and exhibits minimal variation in depth. The elevation data indicates a consistent high point over the years: 5.5 meters for 2017, 2018, and 2019. This sustained depth strongly suggests the absence of significant sedimentation accumulation in this specific area during the mentioned period.

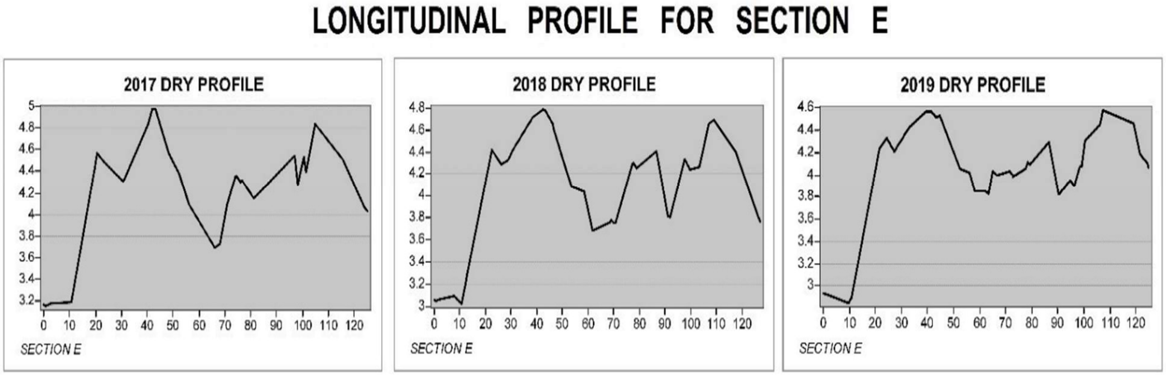

Figure 4.3e: Longitudinal profile of section E

Figure 4.3e shows the longitudinal profile of section E spans a distance of approximately 120 meters and exhibits varying depths. The elevation data indicates the highest points for each year: 5.0 meters in 2017, 4.6 meters in 2018, and 4.6 meters in 2019. This observed reduction in depth signifies an increase in sedimentation within this area from 2017 to 2018, with relatively consistent levels from 2018 to 2019.

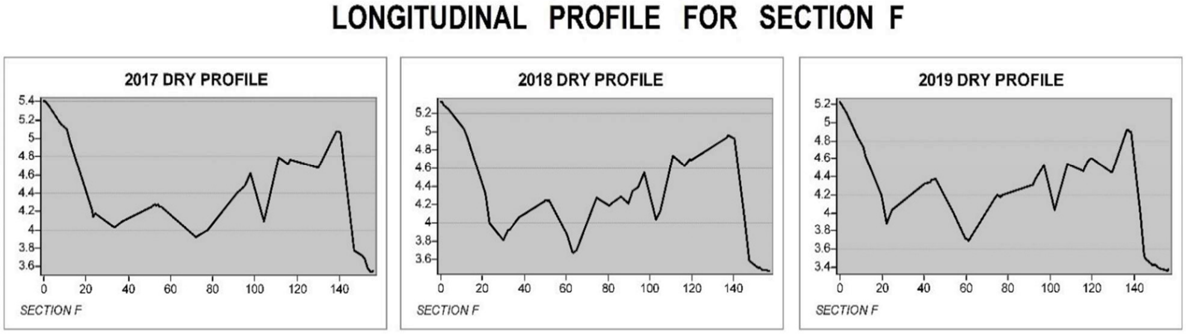

Figure 4.3f: Longitudinal profile of section F

Figure 4.3f shows section F, spanning a distance of approximately 140 meters along the longitudinal profile, exhibits variable depths. The recorded elevation data indicates the highest points for each respective year: 5.4 meters in 2017, 5.2 meters in 2018, and again 5.2 meters in 2019. This observed reduction in depth from 2017 to 2018 suggests an increase in sedimentation within this region. However, it is notable that the depth remains relatively consistent between 2018 and 2019.

4.1.2 Presentation of Triangulated Irregular Network Maps

The production of TIN maps was done and presented both for the dry and the wet seasons. The high and low relative depth range were observed and tabulated in all cases and represented as A, B, and C for the years indicated respectively.

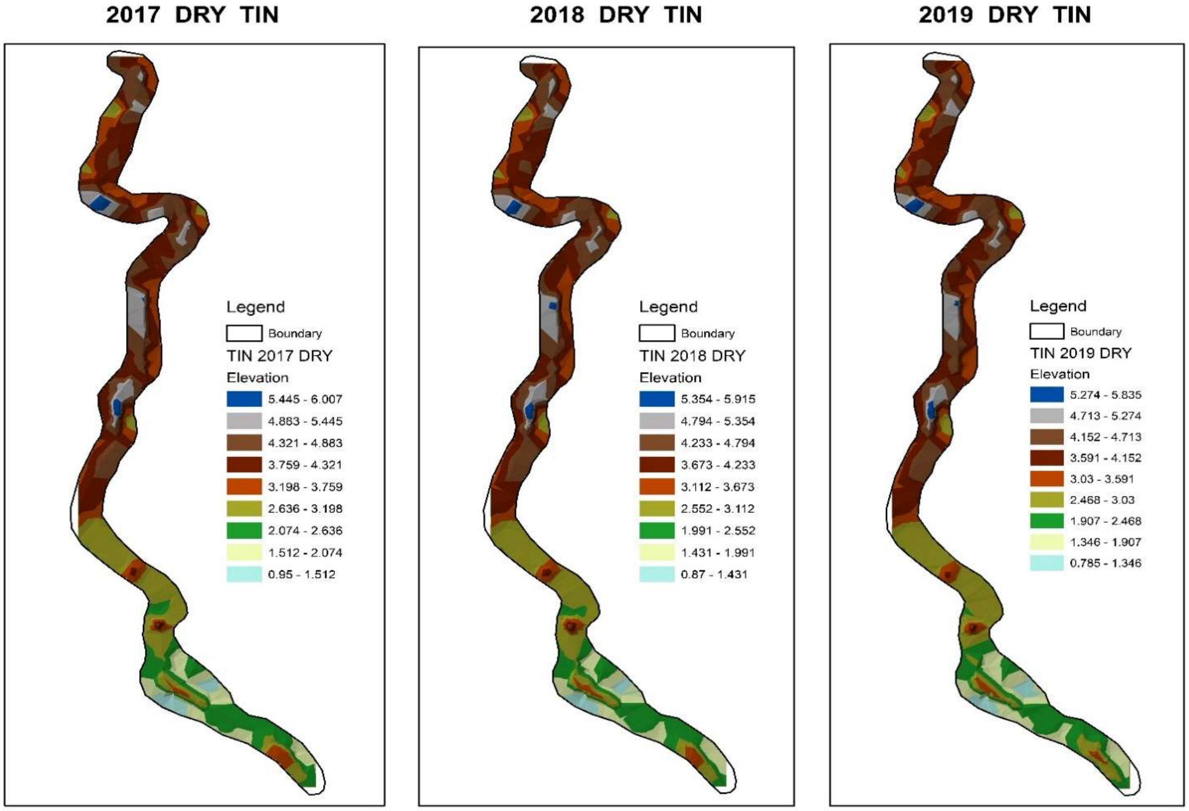

Figure 4.4a: TIN maps of Ikpoba dam for 2017, 2018 and 2019 Dry

Figure 4.4a is the TIN map of the dry season for the three years under investigation. The variation in depth range relating to the years are better summarized and presented in Table 2 at glance. In the 2017 map, the dam's depth reached its peak at 6.007 m, while in 2018 and 2019, it measured 5.916 m and 5.835 m, respectively. This indicates a gradual decrease in the dam's depth over this time period. Conversely, the lowest points in the dam floor were observed at -0.949 m in 2017, -0.870 m in 2018, and 0.785 m in 2019. This trend suggests a gradual rise in the dam's floor, which is attributed to an increase in sedimentation.

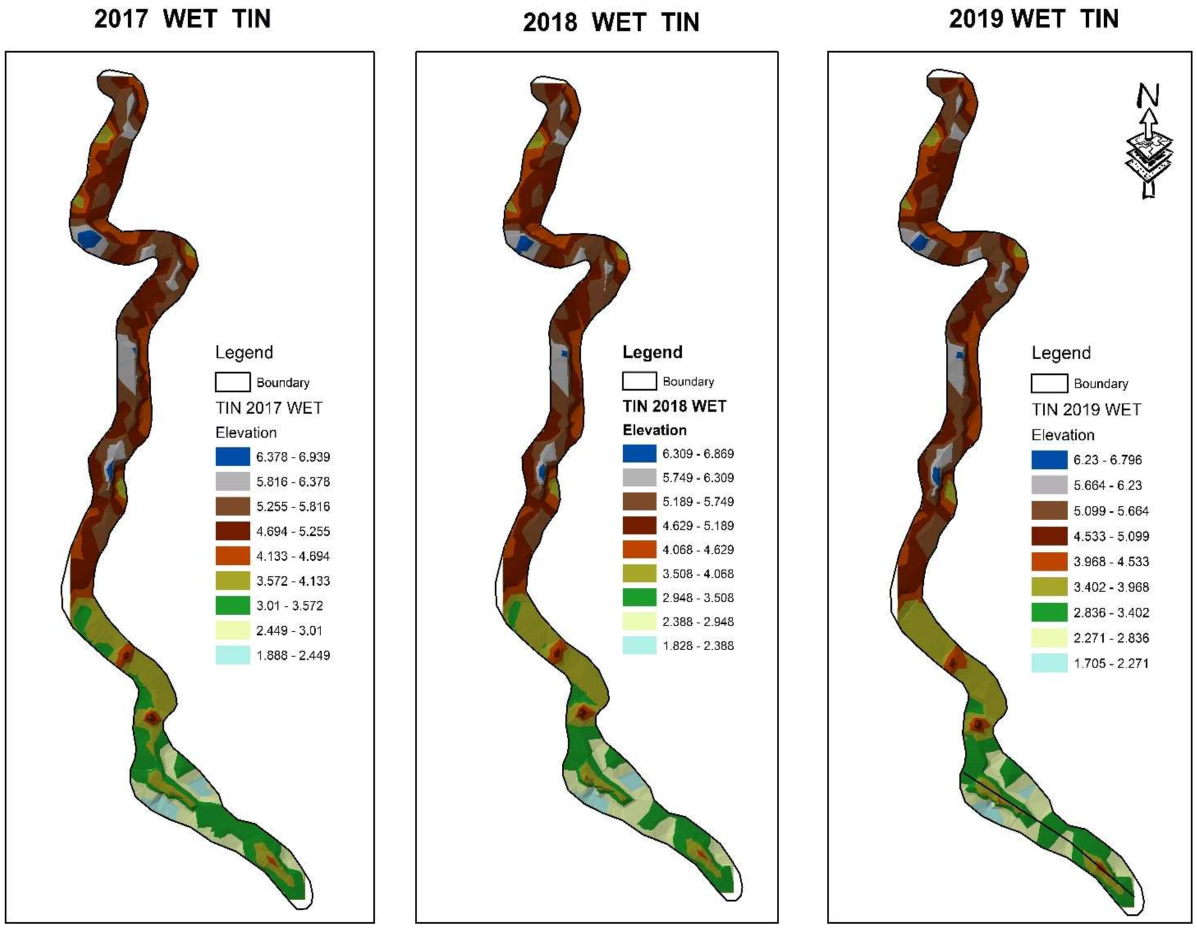

Figure 4.4b: TIN maps of Ikpoba dam for 2017, 2018 and 2019 Wet

Figure 4.4b represents the TIN map of the wet season for the three years investigated. The variation in depth range as relating to the years are better summarized and presented in Table 2 at glance. In the map data from 2017, 2018, and 2019, the highest points were recorded at 6.939 m, 6.89 m, and 6.800 m, respectively. This indicates a gradual decrease in the dam's water depth over this period. Conversely, the lowest points were measured at -1.88 m, -1.828 m, and 1.710 m, respectively, signifying a gradual elevation of the dam floor. This phenomenon can be attributed to an increase in sedimentation.

4.1.3 Presentation of DEM Maps

DEM maps are useful for various purposes. One of the key uses is for sediment volume determination which is part of the focus of this work. The following maps are produced and explanation provided accordingly for the dry and wet seasons.

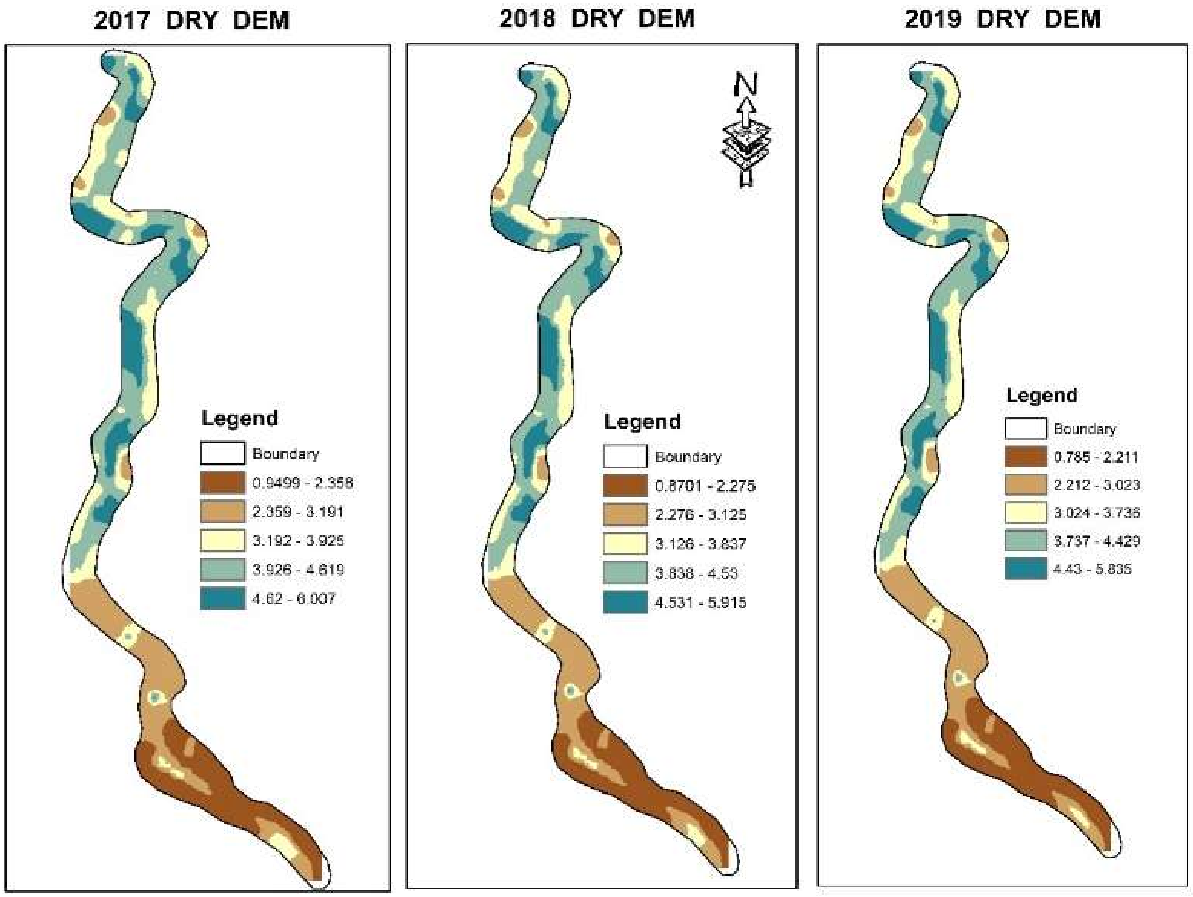

Figure 4.5a: DEM maps of Ikpoba dam for 2017, 2018 and 2019 Dry

Figure 4.5a shows the peak points experienced a decline, shifting from +6.007 m in the 2017 dry season to +5.835 m in the 2019 dry season. The analysis of the digital elevation model (DEM) maps as illustrated in Figure 7a, unveils substantial fluctuations in the depth of the dam throughout the study period. Specifically, the dry seasons exhibited a decrease in the lowest points within the dam, recorded at -0.9499 m in 2017 and slightly ameliorated to -0.785 m by 2019.

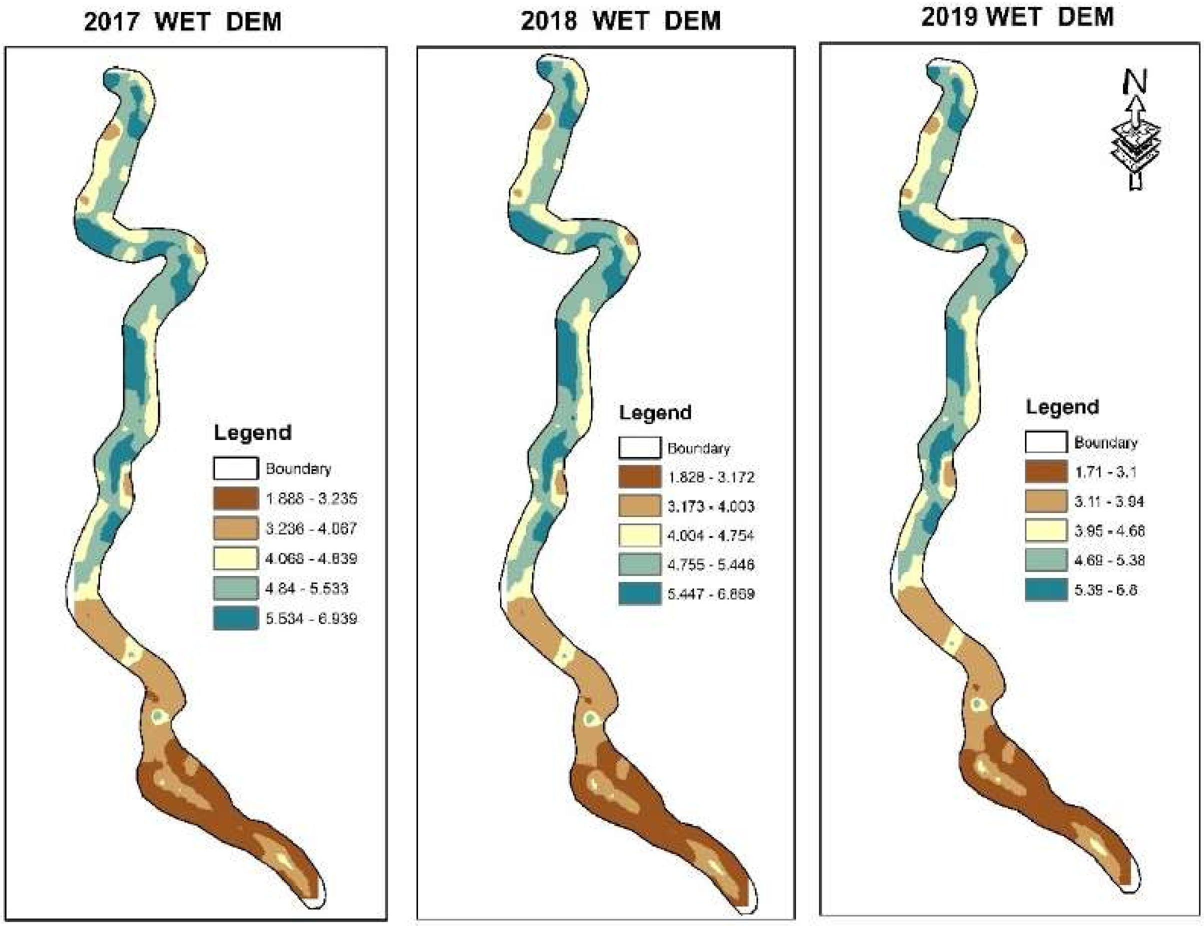

Figure 4.5b: DEM maps of Ikpoba dam for 2017, 2018 and 2019 Wet

Figure 4.5b show on the 2017 map, the peak elevation is recorded at 6.939, followed by 6.89 in 2018, and 6.800 in 2019. This trend signifies a gradual decrease in the dam's water level. Conversely, the lowest recorded elevation is -1.88 in 2017, -1.828 in 2018, and 1.710 in 2019. This indicates a gradual rise in the dam's floor.

4.1.4 Determination of Accretion and Erosion Areas

The region of accretion and erosion can provide substantial insight to know at what point the dam is being is experiencing these morphological changes in order to determine the appropriate means of addressing them. Figures 8a and 8b provided more evidence in this regard.

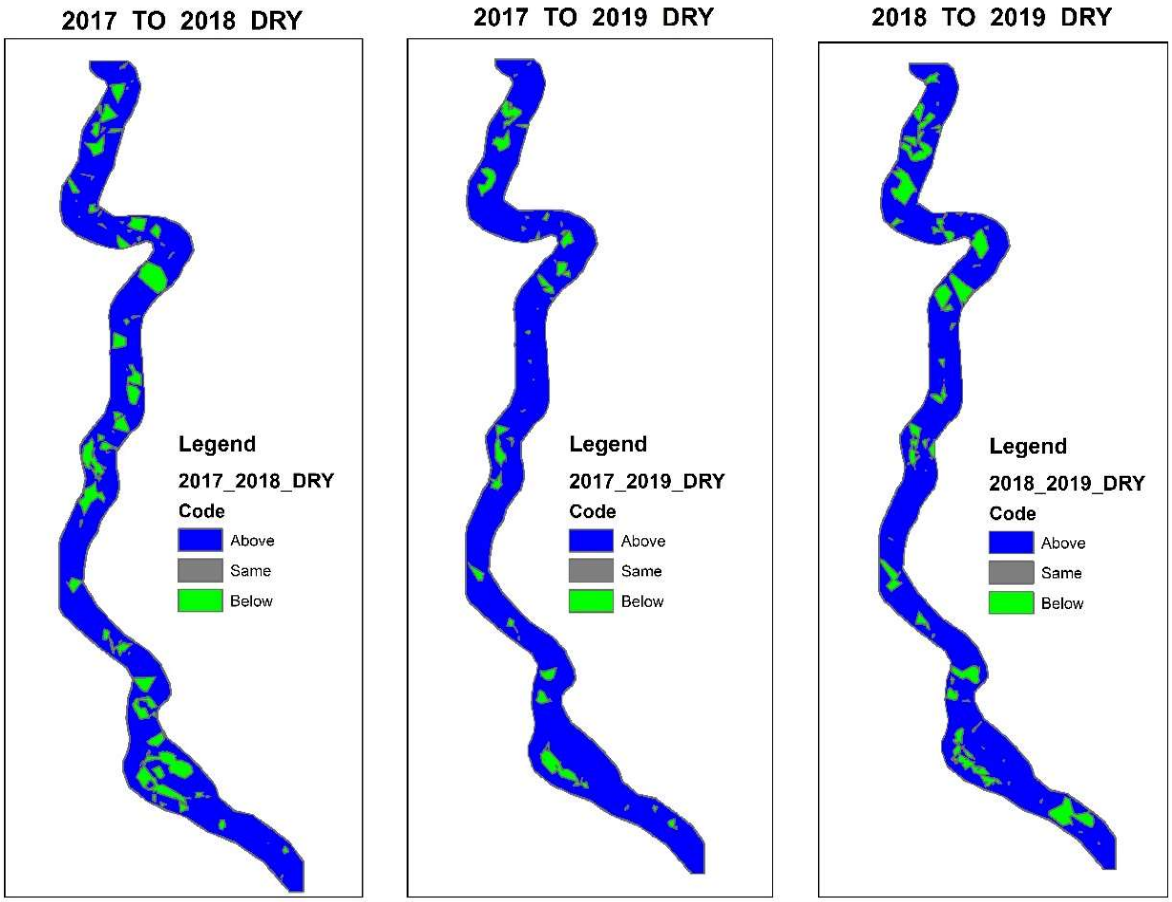

Figure 4.6a: Sediment pattern analysis from 2017 to 2019 for dry season along Ikpoba Dam

Figure 4.6a is a sediment analysis map, the blue region in each case represents the area where sediment accumulation occurred during the study period. The gray areas represent the part where conditions remained relatively invariant with no significant alterations. Lastly, the green areas signified the region where sediment are removed due to erosion throughout the study duration.

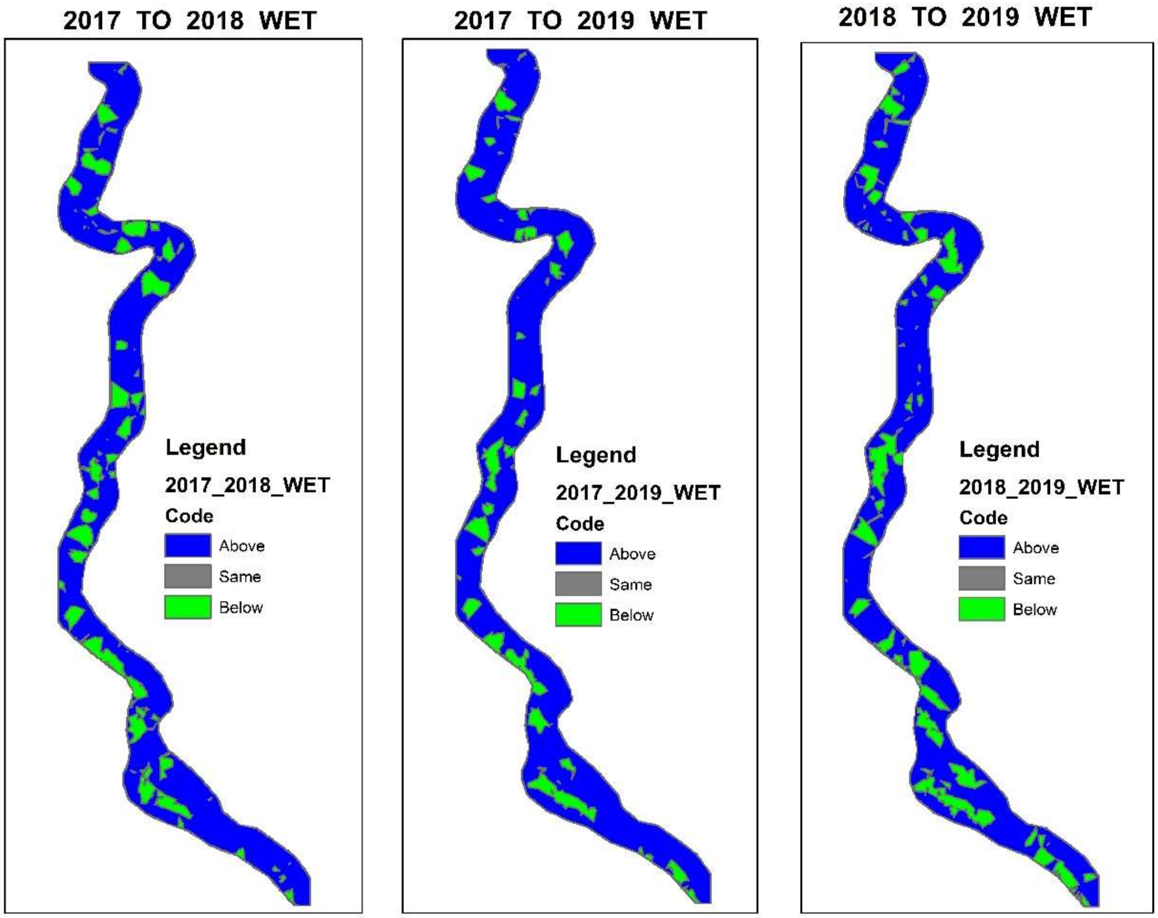

Figure 4.6b: Sediment pattern analysis from 2017 to 2019 for wet season along Ikpoba dam

Figure 4.6b contain the maps of in-between the year sedimentation investigation for both wet and dry season of the Ikpoba dam. The estimated sediment volumes for the periods considered are presented in Table 2 in a summarized form.

Table 4.1: Sediment volume estimated from different sections in 2017 to 2019 at Ikpoba Dam

Section ID	Yearly Duration	Season	Acc. Volume (cubic meter)
A	2017 - 2018	Dry	1,158.124
B	2017 - 2018	Wet	1,091.395
C	2017 - 2019	Dry	4,245.832
D	2017 - 2019	Wet	3,296.810
E	2018 - 2019	Dry	1,599.991
F	2018 - 2019	Wet	735.59015
Total			**11,392.153**

The sediment accumulation map delineates areas experiencing deposition, leading to an increase in elevation, as well as those undergoing erosion, resulting in a decrease in elevation. According to Table 4.2, the highest estimated volume of sedimentation amounts to approximately 4245.832 cubic meters during the period of 2017 to 2019, based on dry data, indicating a moderate level of sediment buildup over the specified study duration. Moreover, an observation from the table indicates that the volume of sediment during the dry season exceeds that during the wet season. This suggests that erosion processes transport sediment out during the wet season.

4.2 Discussion

The objective of this study was to conduct a short-term profile mapping of the bottom topography of Ikpoba dam, focusing on determining sediment volume, creating a longitudinal profile, and developing a Digital Elevation Model (DEM) to assess current sedimentation levels. The short-term profile mapping provided valuable insights into sediment distribution and accumulation within the reservoir. Analysis of survey data revealed non-uniform sediment deposition throughout the dam, with certain regions experiencing higher sedimentation rates. These patterns were attributed to varying factors, including water flow dynamics, sediment load, and topographic features.

Furthermore, the longitudinal profile analysis for the dry season offered a comprehensive overview of elevation changes along the dam's length. The profile exhibited a gradual decline in elevation from the dam's inlet to its outlet, a characteristic often seen in reservoirs designed for water storage. Notably, the longitudinal sectional analysis demonstrated significant changes in the dam's profile between 2017 and 2019, indicating alterations in the underwater terrain surrounding the dam along its length.

The longitudinal profile assessment also identified localized irregularities in elevation, raising concerns regarding the dam's long-term sediment management. Excessive sediment accumulation, reducing storage capacity and impacting downstream water quality, emerged as a potential challenge. Moreover, these irregularities highlighted areas prone to erosion, posing a risk of sediment resuspension and subsequent downstream deposition.

CHAPTER FIVE

5.0 Conclusion

This study effectively achieved its core objectives with precision and thoroughness by examining the short-term profile mapping of the Ikpoba Dam bottom topography using longitudinal profiling techniques.

A thorough examination of the extended profiles of the bottom topography of Ikpoba Dam has yielded valuable insights for discerning short-term alterations in its longitudinal profile and the evolving dynamics of the dam. The methodical gathering and analysis of echo sounder data enabled the detection of noticeable fluctuations in-depth and elevation across sections A to F of the dam's longitudinal axis. These results pinpoint the specific areas undergoing significant changes, holding strategic importance in understanding modifications within the underwater terrain of Ikpoba Dam. This comprehension is pivotal for well-informed decisions regarding structural upkeep, particularly in scenarios necessitating dredging and operational actions.

The strategic creation of Digital Terrain Models (DTMs) for the bottom topography of Ikpoba Dam, employing advanced echo sounder data processing methods and ArcGIS tools, enhanced the study by offering a visual depiction of variations in depth and elevation within the dam. These generated DTMs illustrate the alterations in terrain within this brief timeframe and now serve as fundamental data crucial for ongoing monitoring and management initiatives. Moreover, they establish a foundational reference for forthcoming evaluations and actions, delivering valuable insights for optimizing the operational efficiency and overall structural sustainability of the dam.

Using ArcGIS techniques to analyze the differencing of Digital Elevation Models (DEMs) of Ikpoba Dam from 2017 to 2019, we successfully quantified sediment accumulation in the Ikpoba Dam. This analysis included measuring changes in sediment volume over this timeframe. Our assessment revealed a notable increase in sediment deposition, primarily occurring during the dry season, suggesting an ongoing trend. This phenomenon is primarily attributed to reduced erosion due to lower water levels during this period. Consequently, this study has offered a comprehensive understanding of sedimentation dynamics, providing valuable insights for effective sediment management. These findings are of significant importance for strategic planning of sediment removal efforts and reservoir maintenance, ensuring the continued operational efficiency of the dam and optimal utilization of water resources.

5.1 Recommendations

In our steadfast commitment to ensuring the long-term functionality and optimal performance of the dam, it is imperative to address the challenges posed by sediment accumulation and erosion. Strategic sediment management stands as a fundamental pillar of this initiative, demanding a multifaceted and proactive approach. This project outlines a comprehensive set of strategies to manage sediment effectively and protect the dam's operational efficiency, encompassing:

i. Sediment Management Strategies

The project advocates for the implementation of strategic sediment management practices, targeting critical areas within the dam where sediment buildup poses a significant risk. Emphasizing regular dredging or sediment removal in these identified areas is paramount to sustain the dam's storage capacity and extend its operational life effectively.

ii. Long-term Monitoring

To facilitate informed decision-making and adaptive management practices, the project proposes the establishment of a comprehensive long-term monitoring program. This program will continuously evaluate sediment dynamics, water flow patterns, and sediment transport rates within the dam, providing crucial insights into the evolving state of sedimentation over time.

iii. Public Awareness and Community Engagement

Recognizing the significance of community involvement and awareness, the project underscores the importance of public awareness campaigns. These campaigns will educate the populace on the critical role of sediment management in ensuring the dam's longevity and in preserving downstream ecosystems. Engaging local communities in sediment management initiatives will foster a sense of ownership and shared responsibility towards our precious water resources.

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