REVIEW OF THE ENVIRONMENTAL AND SOCIAL ISSUES ASSOCIATED WITH DAM AND RESERVOIR PROJECTS

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DEDICATION

This work is dedicated to God almighty for the gift of life and resources to carry out this project.

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ABSTRACT

Dam and reservoir construction projects exert substantial influence on the environment and local communities, necessitating an exhaustive investigation. This study aims to scrutinize the impacts of such projects on ecosystems, communities, and cultures, primarily through a rigorous analysis of pertinent online publications. As environmental implications are becoming more widely recognised, several countries now require Environmental Impact Assessments (EIAs) as essential parts of civil engineering projects.

The study will meticulously examine both short-term and long-term environmental effects, delving into surface and ecosystem dynamics within the region, as well as ramifications on both the upstream and downstream aspects of the dam. Concurrently, the project will untangle the intricate network of social and economic consequences ranging from community displacement and cultural heritage erosion to potential conflicts over altered water resource dynamics. To comprehensively grasp these issues, the study will navigate through academic journals, government reports, and news articles, utilizing the Aswan High Dam, Tarbela Dam, and Koyna Dam as targeted case studies.

The anticipated outcome of this research is poised to serve as a cornerstone in formulating sustainable and equitable dam and reservior management policies and practices within the scope of Civil Engineering. By dissecting the environmental and social issues of dam and reservoir construction, this study seeks to pinpoint strategic avenues for mitigating adverse effects while fostering positive outcomes. Its paramount significance lies in guiding the establishment of water management policies and practices that are not only sustainable but also intrinsically aligned with the principles of Civil Engineering.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Water has been a very efficient resource in supporting all forms of life on the earth and maintaining the balance of nature. Nearly 5,000 years ago, people began creating water-holding structures to provide a steady water supply for domestic and agricultural purposes throughout the year. These structures are still in use today. Since the dawn of time, people have been drawn to the rich plains along major rivers, such as the Nile plain in Africa, the Euphrates and Tigris plain in Mesopotamia, and the Indo-Gangetic River plain in the Indian subcontinent. In these places, it was vital to take preventative measures against flooding and drought to minimize the number of human and livestock lives lost and the extent of economic damage. During the past two centuries, hundreds of millions of people have lived along rivers, necessitating river control to provide a stable water supply for residential, agricultural, and industrial use and to reduce flood and drought damage. (A.K. Biswas, 2012). To date, water has remained effective for the survival of man and the development of cities, industries, agriculture, and many others worldwide. Dams play a critical role in the efficient use of water resources. They were built many years before current knowledge of hydrology and hydromechanics was evident. These aren't your typical engineering structures.

The International Commission of Large Dams (ICOLD) defines large dams as dams with a height of 15 m or more from foundation to crest. Dams between 10 and 15 m also fall into this category if the crest length is over 500 meters, spillway discharge is over 2000 cubic meters per second, or the reservoir capacity is more than one million cubic meters.

More than 45 000 large and an estimated 800 000 small dams regulate the world's rivers: some have been built to supply water, including irrigation, control floods, provide for navigation, fishing, and recreation, and, more importantly, to generate electricity. The water held by such a massive structure is referred to as a reservoir. The reservoir is the volume of water stored on the dam's upstream side. Reservoirs play an instrumental role in economic development; however, there has been growing controversy about the failure of these projects to address environmental and social concerns. Unfortunately, besides their benefits, dams can potentially considerably harm living beings. They present a great risk to public safety. Opponents of large dam projects claim that the benefits are outweighed by their environmental and social costs and the related direct and indirect economic concerns.

Dam projects have played a significant role in the evolution of civilization, as they help meet the demand for water at specific times and regulate stream regimes.

Dams create reservoirs that not only regulate floods but also offer water for a variety of human purposes. Some of the purposes include irrigation, flood prevention, human consumption, industrial usage, aquaculture, recreation, power generation, and navigability. Dams and hydropower are frequently used to generate electricity. A dam can also be useful for collecting and storing water that can then be dispersed equitably between different sites via canals or pipelines. Dams are used to retain water, while floodgates and levees (also known as dikes) restrict or prohibit water flow into certain land areas.

Dam projects, or dam construction, have been around for generations. Beginning in Egypt and Iraq, respectively, on the Nile and Tigris rivers. The Egyptians and the Assyrians were believed to be the first architect of this water structure. For instance, the Assyrians built many water structures around 1500 BC across rivers Euphrates and Tigris. Sadd-el-kafara dam, constructed in ancient Egypt, was believed to be almost 300 years old, holding the Nile River waters, which drive the economy of the North African nation. Babylonia and Persians were also recorded to have built earth dams around 1000 BC. Most of our dams in Nigeria are multipurpose dams, such as the Kainji dam in Kano, Tiga dam in Kano, Bakalori dam in Zamfara, Goronyo dam in Sokoto, and Zobe Dam in Katsina state (Norman, 1976). Man has used dams for thousands of years, well before the Christian era. For many years, the concept of ancient river valley civilization has been widely acknowledged, and five important valley cultures are well known: Egypt in the Nile Valley, India in the Indus Valley, and China in the Yellow River Valley. Dam construction costs are high. Aside from the cost, large dams have other disadvantages.

Up until the 1950s, over 700 dams were erected every ten years. After the 1950s, this figure skyrocketed. While the dams were being built and completed, it was noticed that something was missing that was harmful. Although the effects of water on human life and civilization development are well-known throughout the world, it is claimed that the economic benefits expected from projects designed to use water resources were not realized and that necessary precautions to reduce environmental, economic, and social losses were not taken.

1.2 Statement of the Problem

Although the benefits of these large-scale construction projects may seem to outweigh their negative implications in some cases, these negative implications have to be minimized as much as possible. It is important to minimize the negative effects of the dam on the environment regarding sustainable development.

There is a rising fear that dam developments may result in irreversible environmental changes, which are frequently complicated, multiple, and largely unfavorable. Large dams have far-reaching implications for people's lives and livelihoods, including contentious topics like displacement and relocation.

Dams have been criticized for disturbing natural water flows, affecting deposits of nutrients and lifecycles of species that depend on the freshwater habitat. Reductions in water quantities downstream caused by these structures can increase salinity and make the water unusable for drinking and irrigation. The decomposition of organic matter and the leaching of mercury from the soil can introduce toxins. The transport of sediments that are crucial for natural cycles is also affected since the restriction in the free flow of water prevents the transportation of sedimentation. This may cause flood risks and lower groundwater tables and, in turn, affect entire ecosystems.

1.3 Aim and Objectives

The aim of this project is to evaluate the impact the construction of dams and reservoirs has on the environment and society and identify methods that can be used to mitigate and control the problems involved.

The objectives of this study are to;

1. perform investigative studies on the environmental issues and social issues associated with the construction of dams and reservoirs.
2. examine causes of these problems and their implications on the ecosystem
3. discuss possible mitigative measures to control these issues observed and minimize their impact while maintaining the ecosystem

1.4 Scope of Study

The scope of this project includes

i. A review of materials and research conducted on the environmental, social, and economic effects of dam projects before, during, and after the project's duration.
ii. Analysis of the advantageous and disadvantageous impacts of dam construction on the environment and society
iii. Based on study, a conclusive assessment of techniques and recommendations to mitigate the harmful effects as much as practicable.

1.5 Justification of Study

This study is useful to inform the public on the problems surrounding the construction of dams and reservoirs and their impacts on people and the environment and exposing ways through which these issues can be tackled and reduced to a minimal level for efficiency and to maintain the ecosystem concerned in the given area of study.

CHAPTER TWO

2.0 LITERATURE REVIEW

Dams have been recognized to have a wide range of beneficial and negative environmental effects and the ability to disrupt the natural balance between the environment and human activities. This is especially true in most developing countries, where proactive preventative measures are either inadequate or nonexistent. The world's great dams are mostly used for food production by irrigating territory that would otherwise be desert. California and Provence are excellent examples of how dams can alter a landscape. Before it, there was a drought and a desert. Then there are the high-yielding areas. The majority of global population expansion occurs in dry regions that require water to produce food or in locations where rainfall is unpredictable (monsoon lands), necessitating storage solutions such as dam reservoirs. With a global output of 2,100 TWh, hydroelectric energy currently accounts for 20% of total electricity production and around 7% of total global energy consumption (IEA, 2022). By holding large amounts of water in their reservoirs, hydroelectric dams enable variable electricity output.

2.1 Terminologies

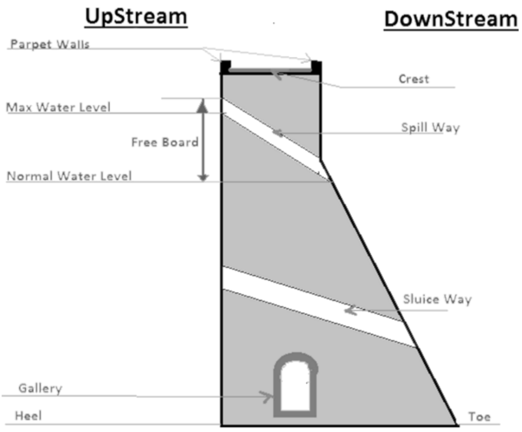

Fig 2.1 Cross-section of a dam structure

A dam structure has several units that perform specific functions. Some of these units vary depending on the kind of dam being built. Below are a few basic parts of a typical dam;

Table 2.1 Basic Terms of Dam Engineering:

Crest	This is on the top of the dam and is usually used as a roadway or a pathway.
Parapet Walls	This is a protective wall on either side of the crest.
Heel	This part of the dam is in contact with the river bed upstream.
Toe	This part of the dam is in contact with the river bed downstream.
Spillway	This is an outlet for the reservoir water when it's level is raised above the maximum water level mark.
Abutment	The valley slopes on either side of the dam wall to which the left & right ends of the dam are fixed.

Gallery	This is a long tunnel-like passage at transverse or longitudinal within the dam. The normal function of a gallery is to provide access for inspection purposes, monitor the dam's behavior, and carry out remedial work if required.
Sluiceway	Opening in the dam near the base provided to clear the silt accumulation in the reservoir.
Freeboard	The space between the highest level of water in the reservoir and the top of the dam.
Dead Storage Level	Level of permanent storage below which the water will not be withdrawn.
Diversion Tunnel	A tunnel constructed to divert or change the direction of water to bypass the dam construction site. The dam is built while the river flows through the diversion tunnel.

2.2 Types of Dams

Based on function

1. **Storage Dam:** As the name implies, this sort of dam is utilized to store water during the rainy season when the river is overflowing. This water can be used in the dry summer months. Storage dams may also serve as a source of water or provide better habitats for fish and wildlife. They could be used to hold water for hydroelectric power generation, irrigation, or flood control.

2. **Diversion Dam:** Dams of this type are used to channel river water into an off-taking canal (or a conduit). Shorter dams are used for irrigation and to divert water from a stream to a storage reservoir further away. A diversion dam usually has a small storage reservoir

upstream and is low in height. This type of storage dam diverts the water to a different location.

3. **Detention Dam:** These types of dams are basically used for flood control. Detention dams restore some of the flood water; thus, the effect of the sudden floods is reduced to some extent. This water is later released gradually.

4. **Coffer Dam:** It is a barrier built around a construction site to keep water out so that the work can be completed dry. As a result, a cofferdam is a temporary dam built to facilitate construction. Typically, these structures are built upstream of the main dam to redirect water into a diversion tunnel (or channel) while the dam is being built. When the river flow is low during hydraulic structure construction, the site is normally contained by a coffer dam and pumped dry. It is sometimes necessary to construct a coffer dam downstream of the dam.

5. **Debris Dam:** A debris dam is constructed to retain debris such as sand, gravel, and driftwood flowing in the river with water. The water, after passing over a debris dam, is relatively clear.

Based on Structure and Design

1. **Gravity Dam:** A gravity dam is a large-scale structure made of concrete or stone masonry. They're made to hold big amounts of water back. The weight of the dam is actually able to resist the horizontal force of the water rushing against it since it is made of concrete. This is why it's referred to as a gravity dam. The dam is simply held down to the ground by gravity, preventing water from overturning it. Gravity dams are ideal for preventing rivers from flowing over large valleys or narrow gorges. Gravity dams must be built on a firm bedrock foundation since they must rely on their weight to hold back water.

2. **Earth Dams:** An earth dam is formed of the earth (or dirt) that has been compacted in layers, with the more impervious components forming the core and more permeable materials on the upstream and downstream edges. A crushed stone facing minimizes wind and rain erosion, while a large spillway, usually made of concrete, prevents catastrophic washout should the water overtop the dam. The shear strength of the soil helps the earth dam resist the forces that are applied to it. Although the structure's weight aids in resistance to stresses, the structural behavior of an earth dam differs significantly from that of a gravity dam. Earth dams are typically constructed in large valleys with flat flanks (abutments). Because the foundation criteria are less severe than those for gravity dams, they can be erected in locations with weaker foundations. They can be constructed on a variety of foundations. However, the foundation material's strength will determine the dam's height. Rongunsky Dam in Russia and New Cornelia Dam in Georgia are two examples of earth-fill dams (USA).

3. **Rockfill Dams:** A rockfill dam is made up of huge stones and rock fragments. An impermeable membrane is put atop the rockfill on the upstream side to reduce seepage

through the dam. Cement concrete or asphaltic concrete is commonly used for the membrane. Steel and timber membranes were also utilized in the early days of rockfill dams, but these are now outdated. Between the rockfill and the membrane, a dry rubble cushion is used to distribute water weight and support the membrane. Instead of an impervious upstream membrane, some rockfill dams contain an impervious earth core in the middle to check seepage. The earth's core is set against a rockfill that has been dropped. Filters must be installed between the earth core and the rockfill on both the upstream and downstream sides of the core to prevent soil particles from being carried by water and pipework. The rockfill side slopes are normally kept equal to the rock's angle of repose, which is usually 1.4:1. (or 1.3:1). The foundations for rockfill dams must be stronger than those for earth dams. Mica Dam (Canada) and Chicoasen Dam are examples of rockfill dams (Mexico).

2.3 Water and Sustainable Development

The sustainable development of dams (according to the World Bank's criteria and the CIGB rules) is indispensable in order for developing countries to have access to energy. It handles drought and river management problems, as well as energy access, without the need for fossil fuels. It is a significantly more consistent and stable renewable energy source than wind. We mostly need to define long-term ground rules that protect the environment through extensive and trustworthy impact studies.

The biological motors of the earth are rivers, watersheds, and aquatic ecosystems. They form the foundation of local communities' lives and livelihoods. To promote equitable human development and the welfare of all species, it is critical to understand, conserve, and restore ecosystems at the river basin level. Living in peace with nature is an idea that dates back to antiquity. Following up on this, the concept of sustainable development emerged in the 1960s and early 1970s, believing that any development that meets their requirements is sustainable (WCED, 1987).

Management and service of water resources are critical for long-term development. The importance of water supply is highlighted in Goal 6 of the United Nations' Sustainable Development Goals (SDGs). In every corner of the world, a reservoir is a vital supply of water. The dam's importance for the SDGs cannot be overstated (ICSU and ISSC, 2015). According to Abdullateef and Ifabiyi (2012), overall sustainability is based on a strong relationship between three elements of sustainability: social, economic, and environmental.

In this debate, there are two schools of thought: the weak and strong sustainability schools (Beckernan, 1995 and Niemeyer, 2003). The strong school of thinking is the radical variety, which thinks that development must not have terrible environmental effects. The weak school, on the other hand, is based on the idea that poverty alleviation, for example, cannot be achieved without environmental changes. As a result, trade-offs limit development to a level that allows social, economic, and environmental cooperation without causing unjustified harm to people and property. Water is a factor in economic development at all levels and for all users (Goal 1), and worldwide demands are not expected to decrease due to population growth. Seasonal variations caused by climate change have resulted in global water scarcity, particularly in developing and disadvantaged countries.

2.4 Environmental Impacts of Dam Projects

Not all dam developments have major, unfavorable environmental repercussions, but it must be established whether they exist. One way to identify possible environmental factors is to evaluate the three broad regions involved with every dam project: the dam and its reservoir, the upstream area, and the downstream area.

Some environmental elements are common to all regions, others to only one or two. Furthermore, not all of the factors listed necessarily apply to all dams, nor will all of them necessarily be found in any one dam. For instance, certain impoundment regions may not contain villages, farmland, or commercially viable timber, but this potential should be taken into account.

It's important to note that the overall impact of dam construction on the environment will depend on a variety of factors, including the size and location of the dam and the potential impacts on the surrounding ecosystem.

2.4.1. Positive Impacts

Below are some positive impacts dam projects have on the environment;

2.4.1.1. Flood Control

The distribution, variability, and intensity of precipitation events are expected to change due to global warming, increasing the risk of flooding. While estimates of the number of people worldwide exposed to river flooding vary greatly among studies, a 4–20-fold rise by the end of the twenty-first century is typically predicted. An estimated 2.8 million dams have been built around the world, with a total water impoundment capacity ranging from 7,000 to 10,000 km^3, which accounts for more than one-sixth of the annual continental discharge to the world's oceans. This has reduced the destructive potential of floods and increased the amount of water available for human consumption. Only 23% of rivers worldwide flow uninterruptedly to the ocean at this time, and about half of the world's major river systems are controlled by dams (Stokstad, 2022). Dams typically change the frequency, length, and timing of yearly flooding events by controlling water flow. Understanding the role of dams in studies of climate impact has become more crucial as there are currently more than 3,700 major dams planned or under construction worldwide. However, due to a lack of data, difficulties parameterizing reservoir outflows, and difficulties implementing features of dams that operate at a scale smaller than those taken into account by global-scale models, previous studies on flood prediction have neglected the role of dams. Previous global-scale analyses of floods have reconstructed historical flood patterns to forecast future floods, taking climate change and/or socioeconomic development factors into account. The Intergovernmental Panel on Climate Change (IPCC) 's Assessment Report (AR5) made the important finding that, when compared to high and low emission scenarios, the number of people annually exposed to the equivalent of a historical 100-year river flood was projected to triple (AR5 2014). Despite the fact that most large rivers are controlled by dams, it is unknown how much their modifications of the river and floodplain dynamics interact with flooding and how exposed populations are to floods as a result of climate change. This is because dams have not been physically incorporated into studies of the effects of global flooding. The few studies that took into account dams and/or flood protection have highlighted how crucial it is to take dam-induced changes in streamflow characteristics into account when modeling flood hazards. Due to the medium to high dam attenuation effects on the 100-year return period discharge of 62% of CONUS hydrological units, it is estimated that dams in the contiguous United States (CONUS) lower total flood exposure by 9%, safeguarding about 590 million people. (Boulange and Hanasaki, 2021).

Dams are a crucial component of any city's flood defense system. They safeguard against the potential loss of life and damage to property that flooding may result in. Dams prevent flooding by gathering and holding water when it reaches a certain level. Once gathered, a dam may be built to either direct the water elsewhere for additional uses or release it back into the river at a controlled rate.

A flow-through dam, also referred to as a perforated dam, is one illustration of this. Flow-through dams are used to prevent flooding in areas downstream and are built specifically for flood control. The opening (spillway) of this type of dam, which is only intended to control flooding, is at the same elevation as the riverbed. This implies that the river will continue to flow naturally when there isn't an excess of water. However, the dam slows the water flow through the opening when water levels rise in order to prevent flooding.

There are likely dams like this one along major rivers if you reside in a flood-prone area. The best part is that these dams also stop flooding from occurring on farmland. Where a flood would otherwise devastate a city's infrastructure and people's means of subsistence, this provides a wide shield of protection.

2.4.1.2. Water Supply

The availability of an adequate amount of water in the correct quantity is one of the key prerequisites for socio-economic development in any region of the world. This is one of the essential requirements. Dams that are effectively planned, designed, constructed, and maintained contribute significantly to providing our required amounts of accessible water. The majority of the world's freshwater supply is derived from precipitation and snowfall. Only one-third of rain reaches our rivers as runoff; the other two-thirds are lost to infiltration and evaporation. Only 36% of this outflow may be utilized productively. Dams and reservoirs are required to store water in order to provide a steady annual supply to accommodate the hydrologic cycle's natural fluctuation (Fisher published, 2018).

Dams can store water for multiple purposes, including irrigation, drinking, and industrial processes. In areas that would otherwise be water-stressed, this can promote food security and stimulate economic growth. During times of strong flow, such as the rainy season or when there is snow on the ground, dams can be used to store water, which can then be released as needed during periods of drought. This can provide a continuous and stable water supply for irrigation, domestic use, and various other uses. Additionally, professionals can utilize them in the treatment and filtration of water before its distribution to consumers. Before the water behind many dams can be used by humans, it must be filtered in water treatment plants to remove pollution and other impurities.

By storing water in a reservoir that is placed behind the dam, dams contribute to the preservation of an adequate water supply. The water can then be released as needed for irrigation, drinking water, and various other purposes. Dams can also be used to regulate the water flow within a river, allowing for more consistent water levels and availability further downstream.

In addition to these direct advantages, dams may also have indirect impacts on the availability of water. Dams, for instance, can prevent erosion, protecting and preserving a region's water supply by preventing the loss of soil and silt that would otherwise be carried by flowing water. When soil and sediment are carried away from an area by moving water, erosion can occur. Dams can also reduce the likelihood of flooding, damaging water infrastructure and limiting water delivery. This is an additional advantage of dams.

In general, dams are capable of playing a vital role in the management and conservation of water resources, as well as being an integral part of a region's water distribution system.

2.4.1.3. Hydropower

Hydroelectric energy accounts for approximately 7% of the world's total energy consumption and 20% of the world's total power generation. The global hydroelectric energy output is 2,100 TWh (IEA, 2022). Hydroelectric dams enable the production of energy in various forms by storing huge quantities of water in their reservoirs. By dams, river water is contained. Using turbines, they create electricity from a renewable source, resulting in extremely minimal carbon dioxide emissions (Eduardo von Sperling 2012). This is referred to as hydroelectric power generation, or hydro for short. In contrast to wind and solar energy, hydro energy may be stored in reservoirs, and all that is required to generate electricity is to open the reservoir gates when the time comes. Using PSPSs (Pumped Storage Power Stations), which are crucial for electricity networks and play a significant role in integrating other current intermittent renewable sources (solar and wind), this natural energy storage is the least expensive kind of power storage. (Tuohy & O'Malley published, 2009).

Fig 2.2: Hydroelectric Power Generator

Many dams are equipped with hydroelectric generators, which can produce electricity in a renewable and relatively low-carbon manner. It is crucial for a nation's social and economic development that energy resources be made available. It is in one's best interest to utilize renewable energy that is also clean, reliable, and efficient. Hydropower is capable of meeting all of these requirements. There are often favorable conditions for the development of renewable energy sources in nations with major development work remaining. Hydropower is the most cost-effective and technologically advanced energy source currently available.

Less than twenty percent of the world's projected feasible hydropower potential has been developed. Asia, South America, and Africa each contain a substantial amount of untapped potential. Hydropower projects generate electricity at a high-efficiency rate without harming the environment or leaving a legacy for future generations (IEA, 2021).

2.4.1.4. Recreation

Dams can create reservoirs that provide opportunities for recreational activities such as boating, fishing, swimming, and water sports. Reservoirs created by dams can also be used for camping, hiking, and picnicking. In addition, the area around a dam may have facilities for other recreational activities, such as picnicking, birdwatching, and sightseeing.

Fig 2.3. McDowell Dam Recreation Area

Reservoirs created by dams can be attractive destinations for recreational activities because they often have calm, clear water that is suitable for swimming and other water-based activities. In addition, the surrounding landscape may be scenic and offer opportunities for outdoor recreation. "It's important to note that dams can also have an impact on the recreational opportunities available in the area downstream of the dam. For example, the construction of a dam may alter the natural flow of a river, which could impact the suitability of the river for activities such as rafting or kayaking.

Providing access to aquatic systems for recreational purposes is one of the most legitimate accommodations that residents who live close to lakes and reservoirs can request. Prior to the building of acceptable infrastructure for recreational activities, however, a comprehensive risk assessment must be conducted. The World Health Organization has released guidelines that provide an in-depth analysis of the key issues connected with this method of water consumption (World Health Organization 2011). In the context of the tropical regions of our planet, where there is a strong demand for leisure activities but a general lack of financial resources to adequately assess the dangers connected with such hobbies, these considerations assume a particularly vital role.

Overall, the impact of a dam on recreational opportunities will depend on a variety of factors, including the size and location of the dam and the potential impacts on the surrounding ecosystem.

2.4.1.5. Inland Navigation

Inland navigation refers to the transportation of goods and passengers by ships along inland waterways (such as canals, rivers, and other bodies of water). Some of the advantages of inland navigation over highway and rail transportation include the ability to handle items with large dimensions, a large load-carrying capacity, and fuel savings.

The use of dams in conjunction with significant basin planning has enabled inland shipping to be improved.

Dams have the potential to be beneficial to inland navigation because they maintain a consistent water level downstream of the dam. This can make it simpler for vessels to cross inland waterways. This is due to the fact that dams have the potential to assist in the regulation of the flow of water in a river or stream, which in turn can help to make the water level more predictable.

In addition, a lot of dams have locks, which are mechanisms that raise or lower boats to the right water level on either side of the dam so that they can pass through the dam. This allows boats to get around the dam. Even though the water level on either side of the dam is different, this may make it possible for boats to go around or through the dam (Boat U.S. Foundation 2018).

Reservoirs that are created as a result of dam construction can offer chances for inland navigation. These reservoirs can also be used for recreational boating and other activities that involve the use of water. The water in reservoirs that dams have produced is typically quite clean and tranquil, making them an ideal location for a wide variety of water-based activities (Rutledge et al., 2022).

2.4.2. Negative Impacts

Below are some negative impacts dam projects have on the environment;

2.4.2.1. Scouring of Rivers

Scouring is the removal of silt and other materials from the bed and banks of a river by water erosion. Scouring is synonymous with "cutting." It can occur naturally due to the flow of water in a river, or it can be caused by human activities such as construction, logging, or mining. Scouring can significantly affect a river's ecosystem because it can alter the living conditions of plants and animals and the stability of the riverbanks. This can have an impact on the river's food web (BGS Research 2006).

Several factors, such as the water's velocity and volume, the sediment particles' size and form, and the riverbed's slope and roughness, can affect the rate and degree of scouring in a river. Extreme scouring can occur during times of high flow or during storms when the river's water moves more quickly and has more energy. Natural scouring can also develop over time.

Fig. 2.4: Scouring of River Banks

Water released from reservoirs, including that existing a turbine, usually contains very little suspended sediments, and this, in turn, can lead to the scouring of river beds and loss of river banks.

2.4.2.2. Human Health Issues

The health concerns linked with dams can be neatly categorized into six major groups. Existing knowledge bases about the construction and operation of dams vary depending on the category. Table 2.2 provides a summary. Each knowledge base has been described in terms of the knowledge volume (big or limited), its dependability, its transferability between projects or areas, and its quantifiability in epidemiological statistics. A small amount of expert opinion was used to characterize the knowledge bases, and additional refining was desired (Dwivedi, Pandey & Gupta 2010).

Table 2.2. The principal categories of health issues and the extent of existing knowledge about their association with dam projects

Health Issues	**Examples**	**Knowledge Base**
Communicable Diseases	vector-borne, water-borne, sexually transmitted, zoonoses, other parasitic	large, reliable, ecosystem specific, some quantification
Non-Communicable Diseases	poisoning by minerals, biological toxins, pesticide residues, industrial effluent	geographically limited, reliable, generalizable, and frequently well quantified
Injury	drowning, construction injuries, communal and domestic violence, catastrophic failures, seismic activity, traffic injury	limited, reliable, transferable, some statistic
Malnutrition	Lack of protein, carbohydrate, or essential elements	limited and controversial, limited transferability, reasonably quantified, limited reliability
Psychosocial Disorder	stress, suicide, substance abuse, social disruption, unrest, violence, decreased tolerance	low volume, of poor reliability with little quantification and cultural variation
Social Well-being	quality of life, social cohesion and support structures, self-determination, human rights, equity	Low volume of variable reliability and quantification and considerable cultural variation

There must be a technique for attributing these hazards to specific dam project components. This is supplied via a health impact assessment (HIA), which is outlined in the following section.

It is difficult to quantify the magnitude of the problem. The annual worldwide death toll from floods is likely rather low (perhaps 100,000; Miller, 1997). These deaths are vivid because they touch huge groups of people simultaneously, have an element of dread, are beyond the control of the individual, and are not part of the average course of events. In contrast, communicable diseases such as malaria and diarrhea kill significantly more people, particularly children (World Bank, 1993). In addition to the high rates of transportation-related injuries, there is widespread malnutrition linked to protein-energy shortages or diet. There is a significant disparity between the perception and statistical quantification of danger. Thus, familiar voluntary risks (such as drowning during routine recreational swimming) are typically given less weight than the novel, frequently dramatic, involuntary dangers (such as drowning during a once-in-a-century flood). Priority selection is a concern for the community.

There is a substantial body of research regarding the global burden of disease, and a measurement unit has been developed to compare the pain, suffering, disability, and loss of productivity resulting from various diseases. This unit is known as the DALY, or disability-adjusted life year. It is intended to facilitate the allocation of scarce health sector resources (World Bank, 1993). Before it can be used to analyze the health risks associated with dam projects and serve as a basis for the selection of health safeguards, additional studies must be conducted to determine the relative burden of numerous diseases and disorders.

2.4.2.3. Greenhouse Gas Emission

An important portion of the increase in emissions can be attributable to methane degassing, which was not accounted for in the initial calculations. This happens when methane flows through a dam and then bubbles up downstream. The annual production of methane, carbon dioxide, and other greenhouse gases by the world's water reservoirs is roughly equivalent to 1.07 gigatonnes of carbon dioxide. Even though this figure is very modest compared to the more than 36 gigatons of greenhouse gas emissions produced year by fossil fuels and other industrial sources, it is nevertheless more greenhouse gas than Germany, the sixth largest emitter in the world, produces annually. It is also nearly similar in weight to 10,000 fully-loaded American aircraft carriers.

When plant matter at the bottom of reservoirs begins to decay, it promotes the production of methane, a greenhouse gas that, over a century, is 34 times more potent than carbon dioxide. In terms of total emissions, methane production is comparable to rice paddies and biomass combustion (Ferguson and Washington State University, 2021).

Gases travel back and forth between the air and natural lakes and wetlands (Ruttner, 1940). Photosynthesis uses up CO_2 and gives off O2, but the breakdown of organic matter does the opposite. The sediment is an important part of this process. On the one hand, since sedimented material is often high in organic carbon, it acts as a sink for carbon. On the other hand, as the sediment breaks down, carbon is released from it. If the sediment surface has much oxygen, CO_2 is the main form of carbon that is released. If the sediment and deeper water layers do not have oxygen, methane (CH_4) is the main form of carbon released.

The water's alkalinity is an important factor. If there are a lot of lime and other earth metals in the water, the pH is high, and the lake or reservoir tends to act as a "carbon sink." This happens because the CO2 binds to the lime and forms stable compounds. If, on the other hand, the water is acidic and there are not enough earth-alkaline metals, the water body tends to send carbon into the air. In acidic water bodies with much humic acid, like the peatland reservoirs of northern Europe and Canada, some humic acid can stick to the sediments and take carbon out of the water.

If the lake or reservoir is eutrophic, which means it has a lot of nutrients and a high level of primary production, it takes in a lot of CO_2 from the air and gives back a lot of it. However, some of this carbon falls to the bottom and gets stored there. So, the lakes and reservoirs act as a sink for this carbon. However, lakes act as a source of carbon for the atmosphere when it comes to allochthonous carbon, which comes with the water and breaks down in the lake (Rantakari & Kortelainen, 2005). Depending on how well these two things work together, the lakes either add carbon to the air or take it out. In eutrophic conditions, the amount of settled, easily broken-down organic matter tends to be large enough to use up all the oxygen in the bottom layers of the water body. The sediments also release methane, phosphorus, sulphides, and other chemicals that speed up the process of eutrophication. Most people think this is a big problem for water quality in lakes and reservoirs.

If a dam is built around a reservoir and water from deeper water layers is let out, the water that comes out could have pressurized gases in it, including greenhouse gases. When the water leaves the reservoir, the pressure drops. This can cause a lot of gases to be released into the air. This process, called "degassing," and its effect on reservoirs' total emissions are the subject of a lot of debate. Even though the process is well understood in theory, there aren't many real-world studies on it.

Even though the basic limnological and ecological mechanisms of gas balances in inland water bodies have been pretty well understood for several decades, there has been a recent rise in interest in greenhouse gas (GHG) emissions from reservoirs because people are becoming more worried about global climate change in general. Except for a few specific cases, these emissions have yet to be studied systematically, and they have not been taken into account in baseline monitoring, performance evaluation programmes, or analyses of reservoirs' effects on the environment.

GHG emissions from making hydropower are what first got people interested in reservoir emissions. However, people have yet to pay much attention to the emissions from reservoirs built for other reasons, like agriculture, flood protection, and others.

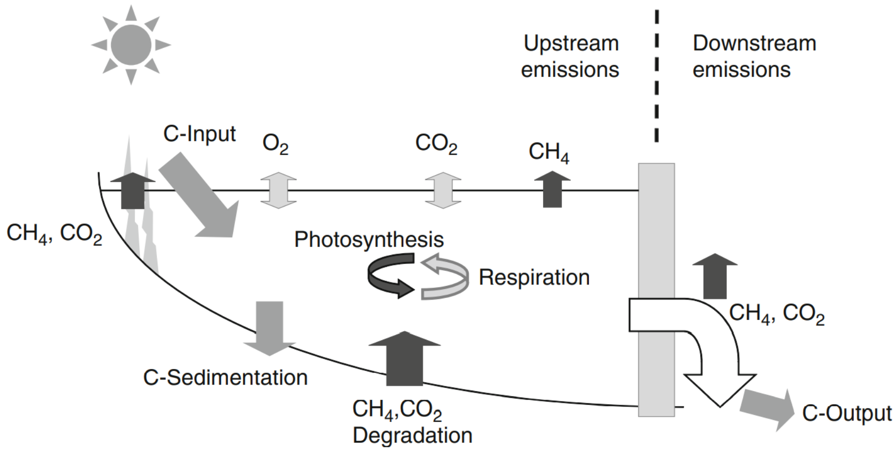

Fig 2.5 Major gas fluxes in a reservoir.

2.4.2.4. The Impact of Induced Earthquake

The construction of a dam and the creation of a large water reservoir will place millions or possibly billions of pounds of fresh strain on the dam and its base when such a load has never been encountered. There are numerous signs of earthquakes caused by dam construction. The results of a study conducted on the 20 largest dams in the world on induced earthquakes indicate that induced earthquakes of varying strengths have occurred during impoundment. According to historical observations, after dam impoundment, certain earthquakes with low or micro intensities occur, and their frequencies and intensities rise with water depth until they reach a predetermined level. The fault movement that creates earthquakes is triggered by the impact of water on the lake bed or the weight of water in the reservoir. When the water level exceeds 100 meters, or the reservoir volume is approximately 1 billion cubic meters, a more violent earthquake with a magnitude of 3 to 5 Richter or, on rare occasions, greater than 5 Richter occurs. Then, until the conclusion, weaker earthquakes occur.

The relationship between earthquakes and dam reservoirs has been demonstrated in over 70 dams. On December 11, 1967, the 103-meter-tall Koyna dam caused a 6.3-magnitude earthquake that destroyed the Maharashtra village of Koynangar. The 261-meter-tall Vaiont dam in Italy was erected in 1960, and earthquakes occurred immediately after impoundment. In 1966, when the height of the dam reached 180 meters, sixty tremors were registered, and on October 9, the city of Longarone was demolished, and all its inhabitants were killed.

2.4.2.5. Habitat destruction

Dams can destroy habitats in a number of ways. One technique is to obstruct the natural flow of water, which can disrupt the environment of plants and animals inhabiting the river's vicinity. This can disturb the migration patterns of fish and other aquatic species, as well as alter the temperature and chemistry of the water, which can have harmful effects on the plants and animals that rely on these conditions.

Swamping formerly dry ground is another way dams can cause habitat damage. This may result in the loss of terrestrial habitats for plants and animals, agricultural land, and other human settlements.

In addition, dams can change the normal sediment flow in a river, which can have detrimental effects on the downstream habitats of plants and animals. Dams, for instance, can hold silt that would ordinarily be moved downstream, resulting in the erosion of riverbanks and the loss of habitat for plants and animals that rely on those places.

2.5 Social Impacts of Dam Projects

The construction of major dams can have significant repercussions on the lives and livelihoods of people, including the sensitive issue of moving entire villages. Opponents of dam construction argue that the social and economic consequences of large dams (as well as the environmental consequences) are more far-reaching than those associated with other infrastructure projects due to the enormous impact that large dams have on the ecosystem as well as on social, economic, and cultural structures. In other words, opponents of dam construction think that the social and economic effects of huge dams are more significant than their environmental effects. Positive and negative repercussions can be highlighted more effectively by relating them to the various phases of the dam construction project. Some of these impacts are discussed below.

2.5.1. Positive Impacts

Below are some positive impacts dam projects have on the society;

2.5.1.1. Increased Access to Electricity

Dams create electricity through the use of hydroelectric power, which can enhance the quantity of electricity accessible in a specific area. The flow of water, often through a dam or hydroelectric power plant, is utilized to power a turbine, which then creates electricity. This is the process through which hydroelectric power is generated. A power grid is capable of transporting this electricity to homes, businesses, and any other users who demand it.

Dams are a significant source of energy in many countries across the world, particularly in places that receive high precipitation and have access to rivers or other bodies of water. They can be found in numerous different locales. Because hydroelectric power is derived from a renewable source of energy, it can contribute to reducing our reliance on fossil fuels and greenhouse gas emissions. Dam-generated hydroelectric power is frequently regarded as superior to other forms of electricity for various reasons.

First, hydroelectric power is a renewable energy source, which means it may be produced forever as long as a water source is present. This makes it a more sustainable choice than nonrenewable energy sources like fossil fuels, which will eventually run out. As the globe faces the difficulties of climate change and the need to shift to a low-carbon economy, hydroelectric power and other renewable energy sources will become increasingly significant.

Second, hydroelectric energy emits a few greenhouse gases. In contrast to fossil fuels, which emit substantial volumes of carbon dioxide and other greenhouse gases when burned, hydroelectric power does not produce any emissions. This makes it a cleaner source of electricity that can help minimize climate change's detrimental effects.

Hydroelectricity is an extremely efficient energy source. Some studies suggest that it can be as efficient as 90 percent in converting the energy of falling water into electricity, making it far more efficient than other renewable energy sources such as wind and solar, whose efficiencies are normally between 20 and 40 percent.

Hydroelectricity may be a dependable source of electricity. Dams can store water in a reservoir and release it as needed to generate electricity, making them less weather-dependent than other intermittent renewable energy sources such as solar and wind. This stability is essential for providing a consistent power supply to suit the needs of residences, companies, and other consumers.

2.5.1.2. Improved Infrastructure

Dam projects can also bring new infrastructure to the area, such as roads, bridges, and power lines. This can improve access to services and opportunities for local communities. Dams can contribute in numerous ways to the improvement of infrastructure, which in turn can support economic growth and enhance the quality of life for the surrounding populations.

Dams can be utilized in a variety of ways to improve infrastructure, notably by providing access to roads. Typically, building dams requires the construction of access roads, which are used to transport materials and equipment to the construction site. These roads can also improve transportation links and provide access to formerly inaccessible communities, so facilitating easier access to services and opportunities.

Another means by which dams can help the enhancement of infrastructure is through the construction of bridges. Once a dam has been constructed, it may be necessary to construct bridges so that people and goods may continue to cross rivers and other bodies of water. These bridges have the ability to provide connectivity and access to a greater variety of services and opportunities, hence facilitating economic and social exchanges.

Energy availability is another way in which dams can help with infrastructure improvement. Hydroelectric power can be used to create electricity at dams, which can then be sent to homes, businesses, and other users via a power grid. The installation of transmission lines has the ability to both enhance access to power and stimulate economic growth, given that energy is a resource required by a wide range of enterprises and activities.

In conclusion, dams can improve infrastructure by increasing access to clean water. Dams are a helpful instrument for cleansing and distributing water, which can be utilized for agriculture, home, and commercial purposes, among others. Establishing water treatment facilities has the ability to increase people's access to potable water and boost agricultural and industrial endeavors.

2.5.1.3. Economic Development

Dam projects can create employment opportunities during the construction phase, as well as long-term jobs in operation and maintenance of the dam. This can contribute to economic development in the region and improve the standard of living for local residents. Dams can increase employment opportunities in various ways, both during the project's construction phase and during the long-term operation and maintenance of the dam itself. Dams can be found in numerous different locales.

During the construction phase of a dam project, it is probable that a large number of workers will be required. These employees will be responsible for the dam's construction, the installation of machinery and equipment, and other tasks. These occupations can range from those requiring specialized training, like engineers and technicians, to those requiring little to no training, such as equipment operators and laborers. During the construction phase of a dam project, employment opportunities may be accessible not just to locals but also to workers from other regions.

In addition to the employment opportunities, they provide during the construction phase, dams can generate long-term employment opportunities in the form of operations and maintenance jobs. For some of these positions, the phrases "operator," "maintenance worker," and "security staff" are all applicable. These jobs have the ability to not only provide a stable source of income but also contribute to the region's general economic development.

2.5.2. Negative Impacts

Below are some negative impacts dam projects have on the society;

2.5.2.1. Involuntary Resettlement

In some cases, the construction of a dam may require the relocation of people who live in the area where the dam is being built. This can lead to social and economic disruption for these communities. According to the World Bank, involuntary population displacement resulting from the construction of dams is the single most severe anti-developmental social impact of water resource development. It is estimated that more than four million people have been relocated as a result of the construction of the 300 big dams that are constructed on average each year, with at least forty million relocated during the past three decades. The social cost of forcible resettlement varies widely between projects; however, a disproportionate number of evictees are tribal or landless people who were often forcibly resettled.

As a result of reduced or demolished social networks and life support mechanisms, the trauma of resettlement can be catastrophic and lead to a loss of autonomy. Cernea (1990) identified eight risks that lead to social impoverishment through an extensive comparative analysis of resettlement issues related to dam construction: landlessness, joblessness, homelessness, marginalization, increased morbidity, food insecurity, the loss of access to common property, and social disarticulation. Scudder (1997) includes the loss of resilience as the ninth risk.

2.5.2.2. Loss of Land and Resources

Frequently, the construction of dams results in the loss of land and resources, such as fertile agricultural areas, forests, and water sources. This can severely affect the lives and well-being of local populations, especially if they depend on these resources for survival.

One way dam construction projects can lead to the destruction of land and depletion of resources is through the purchase of land, particularly for the construction of a dam. The construction of a dam can demand the purchase of a substantial amount of land, which can result in the relocation of entire communities and the depletion of vital resources such as arable land with high agricultural potential and natural forests. This loss of land and resources can have a significant impact on the ability of local inhabitants to engage in economic activities such as agriculture and forestry, which can ultimately result in the elimination of these communities' traditional means of subsistence.

In addition to the immediate loss of land and resources caused by the acquisition of land for the dam's construction, dam projects can lead to the alteration of natural ecosystems, which can result in the loss of resources. The construction of a dam has the potential to alter water flow, which can affect both the quality and quantity of water. This may hinder the ability of local populations to acquire clean water and engage in economic activities such as agriculture and manufacturing.

Also, the construction of dams can have negative consequences on the surrounding ecosystem, including habitat destruction and an increase in pollution, both of which can result in the loss of land and resources. Destruction of ecosystems can result in biodiversity loss and the cessation of traditional subsistence methods, whereas pollution can contaminate land and water resources, rendering them less suitable for use.

2.5.2.3. Widespread Sexually Transmitted Diseases

Reservoir construction projects necessitate a massive amount of labor from both expert and unskilled laborers, which benefits the surrounding towns. Despite the fact that many dam construction projects offer to create employment opportunities for locals, the local population is often only a small percentage of the labor force. At the Saguling Dam construction project in Indonesia, for example, there were no more than twenty-five resettlers employed, while Cree Indians comprised less than five percent of the workforce at the James Bay Project construction site in Quebec. Rarely do the bulk of community members possess the skills necessary by the contractors. Rarely do accelerated training techniques result in abilities that match the predicted levels (e.g., Lesotho Highland Water Project). In addition, contractors bring their own construction-experienced workforces; for example, after the Gezouba Dam in China is completed, a significant percentage of the 40,000 workers are expected to join the Three Gorges Dam Project.

There is evidence that the construction of dams may increase the frequency of sexually transmitted diseases (STDs) in the communities affected by these projects. Potential explanations include the movement of workers into the region, the existence of social and economic disparities, and the lack of access to sexual and reproductive health services.

During dam construction, the influx of workers into the region contributes to an increase in the incidence of sexually transmitted diseases. Typically, the construction of dams necessitates the participation of a large number of individuals, many of whom may originate from various regions of the country or even neighboring nations. These personnel may engage in high-risk behaviors, such as having multiple sexual partners or using drugs, which might raise the risk of sexually transmitted illnesses (STDs). In addition, the nature of the industry may make it difficult for workers to get sexual and reproductive health care, resulting in a lack of both preventative and therapeutic choices.

Social and economic disparities may also contribute to the spread of sexually transmitted diseases (STDs) during dam construction. Frequently, the construction of dams leads to the uprooting of entire towns and the destruction of important land and resources, resulting in social inequities. These disparities can increase the risk of sexually transmitted diseases (STDs) and lead to the exploitation of vulnerable populations, such as women and children.

Lack of access to sexual and reproductive health services during dam construction projects may potentially contribute to the development of sexually transmitted infections (STDs). It is likely that certain dam projects will not provide adequate access to these services or that particular towns will lack the requisite infrastructure or resources to provide these services. This can make it more difficult for people to seek prevention and treatment, leading to an increase in the number of people afflicted with sexually transmitted diseases (STDs).

CHAPTER THREE

3.0 METHODOLOGY

There are thousands of studies on Environmental Impact Assessments (EIAs) of huge dams, some of which are pretty good, while others are only worth the paper they were printed on. It should be noted that all EIAs are forecasts, and that until dams are operational, their effects including their kinds, magnitudes, regional and temporal distributions, and information about who benefits and who pays the expenses, among other things remain speculative. Only around 70–75% of the actual consequences in terms of time, area, size, and beneficiary type can be accurately predicted by even the greatest pre-project impact studies anywhere in the globe (Biswas 2004).

This study was carried out with a few dam projects in view. They are discussed in detail with due consideration to the environmental and social impact on the neighboring communities.

Examples of finished projects include the Aswan High Dam, the Tarbela Dam and the Koyna Dam, the first of which was constructed with World Bank funding. All three are significant undertakings, and the dams and their reservoirs have profound effects on the economies and environments of Egypt, Pakistan and India.

3.1 Aswan High Dam Project

Table 3.1: Overview of the Aswan High Dam

Official name	**Aswan High Dam**
Location	Aswan, Egypt
Type of dam	Embarkment Dam
Height	111m
Length	3,830 m
Reservoir	Lake Nasser

One of the largest embankment dams in the world, the Aswan Dam, or more specifically, the Aswan High Dam, was constructed across the Nile at Aswan, Egypt, between 1960 and 1970. The High Aswan Dam was planned, designed and constructed during an era when the world was significantly less environmentally conscious than it is at present. No nation in the world had an environmental ministry during the late 1950s and early 1960s, and no development project anywhere in the world needed an EIA. In reality, when the High Aswan Dam was formally inaugurated in 1970, EIA procedures were not yet in existence.

Its importance far outweighs that of the earlier Aswan Low Dam, which was initially built downstream in 1902. Following the 1952 Egyptian Revolution, the government made building the High Dam a top priority based on the Low Dam's success, which was then used to its full capacity. The dam was viewed as essential to Egypt's intended industrialization because it could better control flooding, provide more water storage for irrigation, and produce hydroelectricity. The High Dam has had a tremendous impact on Egypt's economy and culture, much like its earlier implementation.

Even with the previous dam in place, the yearly flooding of the Nile during the late summer had continued to flow mostly unhindered down the valley from its East African drainage basin prior to the construction of the High Dam. The lush soil along its floodplain and delta was annually enhanced by the high water with natural nutrients and minerals provided by these floods; this predictability had made the Nile valley excellent for agricultural use since ancient times. This natural flooding varied, though, as high-water years might completely destroy the crop, and low-water years may result in widespread drought and, ultimately, starvation. Both of these incidents continued to occur on occasion. The need and capability to entirely control flooding emerged as Egypt's population, and technological advancements progressed, protecting and supporting farmland and its economically significant cotton crop. The High Aswan Dam significantly expanded reservoir storage, allowing flood control and water storage for several years of release.

The Aswan High Dam measures 4,000 meters (13,000 feet) in length, 980 meters (3,220 meters) in width at its base, 40 meters (130 meters) in height, and 111 meters (364 meters). It has a material volume of 43,000,000 cubic meters (56,000,000 cu yd). The dam's maximum water flow rate is 11,000 cubic meters per second (390,000 cu ft/s). The Toshka Canal connects the reservoir to the Toshka Depression, and there are additional emergency spillways for an additional 5,000 cubic meters per second (180,000 cu ft/s).

The High Dam at Aswan, the second dam constructed close to the first cataract on the Nile, was built with three primary purposes in mind: to produce hydroelectric power, to store water from the annual flood for controlled releases for irrigation and other uses throughout the year, and to control flooding in the Nile.

The dam's construction started in 1960 and was finished in 1967. All significant power facilities were operational by 1970. Due to the dam's enormous size, the extent of its reservoir, and the significant hydrological changes brought on by its construction; there has been significant international attention paid to the dam and its effects on the environment (Biswas and Chu, 1987). Eighteen years after the High Dam's construction, Gilbert White and A. M. Shalaby (1988) evaluated its effects on the environment in recent works. The majority of these examples come from those articles.

The dam has succeeded in achieving its three main project objectives: increased crop irrigation, flood management, and power generation. In actuality, Egypt was able to avert potentially devastating agricultural deficits as a result of the recent drought that began in 1979 because of the water stored in the reservoir. The reservoir's effects and downstream consequences are both considered when examining the project's environmental impacts.

The enormous reservoir, known in Sudan as Lake Nubla and in Egypt as Lake Nasser, has a capacity of 162 cubic kilometers. Due to the reservoir filling, approximately 53,000 people were relocated from Sudan's portland and between 50,000 and 60,000 people to Egypt. Fishing in the reservoir has somewhat predictably grown to be a significant industry, with annual catches ranging from an average of 20–26,000 metric tonnes to as high as 34,000 metric tonnes in 1981. The majority of the displaced Egyptians have been resettled on agricultural lands downstream from the dam, and health has improved through reductions in infectious diseases. Over 7,000 fishermen are working in this sector. When these monuments were being built, there was a lot of international interest in archaeological sites, and there were well-known relocation efforts for Abu Simbel and Philae. Out of the 96 million cubic meters of silt that the Nile typically transports annually, the new reservoir captures around 85 million cubic meters. This is largely compensated by the reservoir's dead storage capacity; at current rates, it will take 350 years to fill the reservoir's dead storage equivalent. Some of the main downstream effects of this dam and reservoir are listed below;

Channel Degradation:

A decrease in bed level of between 25 and 70 cm was caused by channel deterioration brought on by the outflow of comparatively silt-free waters. A pilot project covering the first 22 km of the channel has started, and steps are being taken to enhance some infrastructure further downstream.

Navigation:

The Nile River's flow was controlled, which improved navigation by reducing the maximum water level variation from 9 to 3 meters. In the reservoir located behind the dam, navigation also developed.

Endemic Diseases:

Malaria and schistosomiasis are endemic conditions in Egypt wherever perennial irrigation is used. According to the available data, intestinal schistosomiasis has spread significantly in the delta and has been disseminated to portions of Upper Egypt, although urine schistosomiasis has generally decreased (partly as a result of a significant village water supply program). There has not yet been any proof of malaria around the reservoir.

Hydropower Generation:

The fact that the High Aswan Dam was able to provide power at a time when the nation required it is one of the most significant economic advantages it provided. Because of the renewable energy generated, it was possible to deliver electricity to a significant portion of the country's rural territory. Because of this one development component, the social and environmental conditions of a big portion of Egypt shifted, and the quality of life for a considerable portion of the country's population also greatly improved.

Each year, Aswan's twelve generators have the potential to produce 10 billion kWh of electricity for use. Prior to the dam's completion, Egypt was reliant on the importation of fossil fuel. The country's prospective energy import cost was significantly lowered due to the dam's electrical generation, which was a substantial benefit.

The dam, up until 1979, was responsible for almost half of the nation's electrical production. Its share in some years was significantly higher than 50%. As time went on, especially after 1980, the share of the dam started to decrease due to rising contributions from recently built thermal power plants that satiated the country's expanding electricity demand. This was a result of the country's rising demand for electricity.

Erosion and Sedimentation:

The High Aswan Dam permanently altered many of the Nile River's prevalent features. The alteration of the river from having a riverine to a lacustrine character upstream of the dam was one of the key physical modifications, and the flow was rigorously controlled and managed downstream of the structure. Aswan's Lake Nasser, which is over 500 km long and 10 km broad, was made possible by the dam. Beginning in 1967, the 3,830 m long dam was used to contain the full Nile's flow. Due to the massive amount of water that was stored in the reservoir, the river flow's velocity started to decrease as it got closer to the reservoir. The flow's velocity was zero when it entered the reservoir. The river's capacity to convey suspended sediments decreased as flow velocity did. Consequently, when the water moved closer to the reservoir, suspended sediments started to precipitate. Practically speaking, as the river flowed toward and into the reservoir, it lost almost all of the sediments it had been carrying. This indicated that the water sent downstream will be pure and sediment-free. Nearly all of the sediments were caught upstream of the dam, even during flood seasons when the river's sediment loads were at their highest. In other words, the dam has been nearly 100% effective in capturing silt. In the early years of the dam's operation, it helped to cause erosion of the river bed and banks since the water sent downstream had no silt. Thus, as the river continued downstream, silt was gradually added. All the way to the Nile delta, these alterations were seen. In the past, the flood season accounted for around 90% of the river's annual sediment flow. Before the dam was built, the average amount of suspended silt passing through Aswan was believed to be 134 million tonnes (Abu-Zeid and El-Shibini 1997).

It should be noted that the steady rise in the river's sediment load as it moved downstream during the post-dam period may not have been entirely caused by the building of the structure. The wadis (a valley, ravine, or channel that is dry except during the rainy season in several Arabic-speaking countries), wind-blown sand, and inflows to the river from the drainage system are likely additional natural causes that contributed to the increasing sediment load. It is impossible to identify what proportion of the silt may be attributable to erosion caused by the dam without a thorough investigation of the sediment balance from different sources.

Coastal erosion has become an issue as a result of the post-dam Nile. Prior to the dam's construction, the Nile's flood season carried a heavy amount of sediment that was dumped in the delta. The sediments were washed away by the waves throughout the winter. Over the years, a balance between the volume of sediment deposited during the flood season and its removal by wave action during the winter months was created. This helped to keep the beach line somewhat stable. However, the sediment balance was disturbed as soon as the first hydraulic construction on the Nile was erected over a century ago. The sedimentation-erosion balance in the delta was not significantly disturbed since those built before the High Aswan Dam were not significant. After the dam became operational, there was substantial erosion along the Mediterranean shore as a result of the dam's serious disruption of this balance. The amount of coastal erosion over time and potential preventive measures were the subject of extensive research and monitoring (Smith and Abdel-Kader 1988). The appropriate corrective actions have now been made.

Analyzing some of the positive and negative impacts should make it clear how complex and difficult it is to figure out the effects of a large hydraulic structure. There are several levels of complexity, the most important of which is that it is difficult to precisely allocate the benefits and the costs that may be assigned to any particular impact. This is just one of the many levels of complexity that exist.

The problem is further compounded by the fact that the development of any country is always dynamic. Changes happen all the time, government policies are often flexible, and the range, extent, and size of human activities are always shifting. So, it is hard to separate the benefits and costs of a single activity because they are often affected by many other things. This problem is made difficult because many developing countries do not have the right data or data they can trust, and many of the effects are hard to measure.

This makes it difficult, even in the best of times, to make accurate predictions about the effects of any dam or other large structure.

The major effects of the High Aswan Dam that are looked at in this review show how complicated the issues are and how dangerous it is to jump to simple conclusions because they often need to be corrected. The High Aswan Dam is a great example of how many people worldwide need help understanding and appreciating the problems that come with simple analyses and linear thinking, leading them to come to completely wrong conclusions. Based on the study done by the Third World Centre for Water Management, it is clear that the High Aswan Dam is one of the most successful water structures in the world, not one of the worst, as is often said on an international level.

3.2 Tarbela Dam Project

Table 3.2: Overview of the Tarbela Dam

Official name	**Tarbela Dam**
Location	Haripur, Khyber Pakhtunkhwa, Pakistan
Type of dam	Earth and rock-filled dam
Height	143m
Length	2,743 m
Reservoir	Tarbela Reservoir

The dam, which bears the name of the Pakistani town of Tarbela in the Haripur District of the Hazara Division, is located at a narrow point in the Indus River valley. From the island to the river right, the main dam wall measures 2,743 meters (8,999 feet) and is 148 meters (486 feet) high. It is made of earth and rock fill. The river is divided by a pair of concrete auxiliary dams from the island to the river left. The two spillways of the dam are on the auxiliary dams, not the main dam. Both the main spillway and the auxiliary spillway have discharge capacities of 18,406 cubic meters per second (650,000 cu ft/s) and 24,070 cubic meters per second (850,000 cu ft/s), respectively. Every year, more than 70% of the water discharged at Tarbela crosses the spillways without being used to generate hydropower (Wikipedia contributors 2022).

The outflow activities included the construction of five substantial tunnels. In tunnels 1 through 3, turbines produce hydroelectricity, but tunnels 4 and 5 were intended for irrigation. To boost Tarbela's ability to produce electricity, both tunnels will be transformed into hydropower tunnels. Initially, the Indus River was diverted through these tunnels while the dam was being built.

On the right side of the main dam, the M.A. hydroelectric power plant has 14 turbines that receive water from outlet tunnels 1, 2, and 3. A total of four 175 MW generators are located on Tunnel 1, six 175 MW generators are located on Tunnel 2, and four 432 MW generators are located on Tunnel 3.

Tarbela Reservoir has a surface area of 250 square kilometers and is 80.5 kilometers (50.0 miles) long (97 sq mi). The reservoir initially held 11,600,000 acre-feet (14.3 km3) of water, with live storage of 9,700,000 acre-feet (12.0 km3). However, during the course of the following 35 years of operation, silting caused this amount to drop to 6,800,000 acre-feet (8.4 km3). The reservoir's maximum elevation is 1,550 feet (470 meters) above mean sea level, while its lowest operating elevation is 1,392 feet (424 meters). The 168,000 square kilometers (65,000 square miles) catchment area upstream of the Tarbela Dam is substantially augmented by snow and glacier melt from the southern slopes of the Himalayas. Upstream of the Tarbela Dam, there are two significant Indus River tributaries. These are the Siran River and the Shyok River, which join close to Skardu (Dixon, Talbot & Le Moigne 1989).

In addition to serving the dam's primary function of providing water for irrigation, Tarbela Power Station has produced 341.139 trillion kWh of hydroelectric electricity since it was first put into service. During 1998–1999, a record-breaking annual generation of 16.463 billion kWh was observed. While the station had a peak load of 3702 MW during the year, which was 23.057% of the peak demand for the entire WAPDA system, annual generation in 2007–08 was 14.959 billion kWh.

The Tarbela Dam, the largest earth-fill dam in the world, is the centerpiece of the Indus Basin Project. The dam is a multi-billion-dollar development that was primarily built to replace water that would have been diverted from Pakistan's eastern rivers of Punjab in order to provide controlled water supplies for irrigation, hydroelectric generation, and some flood control purposes. Tarbela construction was underway in 1968, and reservoir filling got underway in 1976. However, as soon as the flolling process started, a number of technical issues emerged that required a ten-year effort that cost hundreds of millions of dollars to resolve. The Tarbela Project's overall cost, including corrective work, increased from over $800 million in 1966 to approximately $1.5 billion when it was finished, expressed in current currency.

Tarbela has a few related environmental effects in addition to providing water and producing electricity through hydropower. Before Tarbela, the hydrological balance of the Basin was significantly impacted by the continual use of Indus water for cultivation for more than a century. The groundwater table gradually climbed due to seepage from canals and continuous irrigation; nevertheless, because of inadequate drainage, widespread salinity and waterlogging issues emerged, which had a negative impact on productivity. To reduce the level of groundwater, a tubewell program was created in both the public and private sectors. A drainage system was built in some places.

If the water deliveries are not properly managed, Tarbela's increased water capture and availability for irrigation could exacerbate these issues. The enhanced water supplies, however, pale in comparison to the overall volume supplied to the irrigation system. When water is scarce and overwatering by farms is less likely, all Tarbela water is utilized.

By sending more surface water to regions with saline groundwater aquifers that are unsuitable as a backup source of supply, better management of the Indus River's water through the Tarbela regulations can be beneficial.

A project like Tarbela functions as a component of a system in a nation with as extensive an irrigation network as Pakistan. In this instance, the conjunctive management of groundwater and surface water can assist in alleviating the dual problems of waterlogging and salinity resulting from the historical development of irrigation.

The naturally large sediment load in the Indus has an impact on the Tarbela Dam as well. Initially, it was estimated that Tarbela would silt up to 90% of its capacity in 50 years. It is currently anticipated that the time will last for at least 150 years based on more recent data. Insofar as Tarbela acts as a sediment trap, it discharges water of higher quality than that which it absorbs, which offers benefits for coming up with new strategies for managing water in the irrigation system.

3.3 Koyna Dam Project

Table 3.3: Overview of the Koyna Dam

Official name	**Koyna Dam D05104**
Location	Koyna Nagar, Maharashtra, India
Type of dam	Rubble-concrete dam
Height	103.2m
Length	807.2 m
Reservoir	Shivasagar Lake

The Koyna Dam is one of Maharashtra, India's largest dams. It is a rubble-concrete dam built on the Koyna River, which springs in Mahabaleshwar, a high station in the Sahyadri mountain ranges. It is located in Koyna Nagar, Satara district, on the state highway between Chiplun and Karad in the Western Ghats. The dam's primary function is hydroelectricity generation, with some irrigation in the surrounding areas. With a total installed capacity of 1,960 MW, the Koyna Hydroelectric Project is currently the largest hydroelectric power project in India that has been completed. The Koyna River is known as the "lifeline of Maharashtra" because of its ability to generate power (Goel and Shrivastava, 2011).

Following India's independence, Maharashtra undertook the construction of the Koyna Dam, which crosses and bears the name of the river Koyna, mostly for producing electricity. The dam has come to represent the growth of water resources during the past five decades. It is located close to the Sahyadri Range, which serves as a continental divide and is over 1000 m high at the head of the significant peninsular Krishna River Basin. It is the upstream most dam in the Krishna River Basin, standing at 103.2 m in height and storing close to 2.8 billion cubic meters (BCM) of water in a reservoir with a spread of over 115 km2. The range goes parallel to and close to India's west coast in a north-south orientation. The country's first significant underground power plant uses water from the reservoir to generate hydropower at an incredibly low cost. The reservoir captures runoff in a high rainfall zone at the highest elevation and drops the reservoir waters over nearly 500 m in a westerly direction across the mountain divide. The Koyna Project has already experienced four groundbreaking stages of development and holds out hope for a fifth stage and beyond shortly (Mahabal, 2000).

The dam's spillway is located at the center. There are six radial gates. In the monsoon season, the dam is essential for controlling floods. The catchment area dammed the Koyna River, creating the 50 km (31 mi) long Shivasagar Lake. It ranks among the biggest civil engineering jobs ordered since India gained its freedom. The Maharashtra State Electricity Board is in charge of the Koyna hydroelectric plant.

In the recent past, the dam has endured numerous earthquakes, including the deadly 1967 Koynanagar earthquake, resulting in cracks. After the catastrophe, the cracks were grouted. Additionally, internal holes were made in the dam's body to release hydrostatic pressure. The scientific community in India has developed a large-scale effort to drill a deep borehole in the area and carefully examine the earthquake activity. This would help with understanding and potential earthquake forecasting. The plan calls for drilling up to 7 km and real-time analysis of the physical, geological, and chemical processes and characteristics of the earthquake zone caused by the reservoir. Indian scientists would oversee a multinational project in this area (The Hindu Business Line and Hyderabad, 2011).

The spillway section of the dam was upgraded in 2006 after the non-overflow segment was strengthened in 1973. The dam is now anticipated to be secure against any upcoming earthquakes, even those of greater severity than in 1967.

Environmental Impacts of The Koyna Dam

The Koyna wildlife sanctuary, which covers 43,500 ha and is located on the western edge of the Koyna Reservoir in the reserved forest area that was not accessible to the general public, was established in the 1970s. As a result, it has developed into a rich forest, home to numerous flora and fauna species. However, other forests in the region have seen some deterioration due to access by the local population. Primarily tropical moist deciduous, and partially semi-evergreen woodland make up the reserved forest. Because of the relative scarcity of shallow waters, the site does not feature migration routes for migratory birds. No harmful aquatic plants have been found. The presence of predators like fish and birds may be the reason why the population of vectors, such as snails and mosquitoes, have not expanded in the reservoir region. This sanctuary will be next to the proposed lake under Stage V, which would have a spread of around 108 ha out of the 285 ha total catchment area. There will not be any endangered species in this area, according to a quick survey conducted by the Science and Technology Park of the University of Pune and submitted to the project in 2004 (Jagdale, 2004). An average of 400 trees per hectare of fresh compensatory tree planting has been done in the 119 ha project area alone. The reservoir has the potential to be a significant fishery, but fishing is not allowed there because it is a "wildlife sanctuary." Fisheries must be planned and permitted in this lake without endangering ecosystems or allowing encroachment on the designated sanctuary. Creating a "Tiger Reserve" within the sanctuary is currently being considered.

Social Impacts of The Koyna Dam

In 98 villages, 11,535 ha of land were submerged by the Shivajisagar Reservoir that was built behind the Koyna Dam (during stages I and II), affecting 9,069 families, or about

30,000 people, and 3,755 households, mostly Thakar and Katkari communities that depend on the harvest of the forest, fishing, and the cultivation of some coarse grain crops.

The Koyna Hydroelectric Project assisted 6,316 people affected by the project with rehabilitation. However, 2,753 families chose to do so on their own. In the catchment region, the project relocated 19,500 people (3,310 project-affected families from 76 villages), who were 8–10 km away from their original places, in forests that had been purchased.

Only 4% of government-owned forestland was submerged; the remainder was terraced or wasteland held by private individuals. In order to find work following the monsoon, people from the submergence area typically engaged in shifting farming on small, isolated land strips. As requested by the owners, such plots were seized by the project and given to the Forest Department for afforestation because they have become even more isolated since the building of the reservoir and continue to be less productive. Residents of 30 villages close to the reservoir's northern boundary preferred to remain and carry on cultivating their land, only a small portion of which was projected to be submerged. Following the annual 30 m drawdown of the reservoir, they could also use the soiled ground for farming.

In total, the 180 homes of their choosing were chosen by 6,316 project-affected households relocated in six districts bordering the project area. One hundred forty-three people were transferred within Satara District. Raigad, Ratnagiri, and Thane are three of these districts that are situated to the west on the coastal strip. At the same time, Sangli, Satara, and Kolhapur are three more that are situated to the east inside the project's command area. In response to their request for alternative land, displaced people received about 6,971 acres of land. 1,670 acres of land in six villages were inundated by the Kolkewadi Reservoir (Stage III), affecting 355 households. A total of 41 acres of agricultural land owned by 181 landowners were impacted. They were relocated to the Thane, Raigad, and Ratnagiri districts.

Approximately 629 ha of agricultural land and 2 ha of forest land were bought for Stage IV. No village was entirely uprooted. 66 landowners were given access to more than 57 acres. No impacted family or individual had filed a lawsuit to stop the project's land acquisition (AIMS Consultancy, 1998). Nawaja, a Stage I resettled village, Kolkewadi, a Stage III partially resettled village; and Kondphansawane, a Stage II and Stage III affected village but not a Stage I resettled village, were the three villages affected in Stage IV. Families impacted by the project were offered land in a neighborhood some distance from the original location, but they chose not to move. In addition, 145 project-affected families were determined to be below the poverty line because they qualified for special support such as skill development, a dairy business, transport vehicles, a lift irrigation facility, trading stores, etc. Families impacted by the project were granted access to 13 different facilities, including a well for drinking water, a school, roads, power, a crematorium, latrines, gutters, a cow stand, a pasture, a threshing floor, and a market, according to a policy from 1986.

Over the past few decades, as relocation and rehabilitation difficulties became more apparent and urgent, several significant initiatives in India came to a standstill due to insufficient funding. Some projects, like the Sardar Sarovar and Tehri ones, had good relocation and rehabilitation plans and could use problem-solving techniques to their benefit. Resettlement and rehabilitation became a major topic in many other socioeconomic areas while the debate over them was raging in the water resources sector. To create a national policy for relocation and rehabilitation, the Indian government started an effort at the national level in the 1990s.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

There is a possibility that the examples provided will be used for a range of additional significant dam construction projects. Different areas Environmental and social concerns are about large-scale population displacement, the destruction of forests and distinctive ecosystems, as well as the health and hydrology problems resulting from water impoundment. All of these difficulties are caused by water impoundment. Almost all significant dams now in existence are viewed negatively by critics. Those who support the projects feel the investment will be beneficial due to the benefits that will result from the development of hydropower, irrigation, and flood control projects. The cases of Tarbela and the Aswan High Dam indicate that both parties have valid reasons for disagreement that merit attention. Huge advantages exist, just as major downsides do. It is crucial to do a thorough study of each benefit and cost, one that takes into account not only the direct outputs of the project but also its environmental and societal implications. At the end, when all costs are accounted for, it is likely that certain dams will not be economically justifiable after all. These projects should not proceed with construction. The majority of the time, however, the analysis will identify the projected costs to the environment and society and make it viable to implement the appropriate mitigation measures, all while creating economic benefits that are greater than the total economic costs.

Dams have been recognized to have a wide range of beneficial and negative environmental effects, as well as the ability to disrupt the natural balance between the environment and human activities. This is especially true in most developing countries, where proactive preventative measures are either inadequate or nonexistent. The world's great dams are mostly used for food production by irrigating territory that would otherwise be desert.

California and Provence are excellent examples of how dams can alter a landscape. Before it, there was a drought and a desert.

The ongoing debate about dams is a dogmatic and emotional argument. This debate should be welcomed to the extent that it brings up new issues that need to be carefully thought through and dealt with. But as long as it's a debate between people with strong opinions, any progress that comes out of it may be limited or even pointless. The discussion needs to be changed. What needs to be done is to think about the overall structure of the water development system that will meet the goals and needs of societies in developing countries, such as reducing poverty, redistributing regional income, and protecting the environment. In this big picture, it is important to figure out how to meet society's water needs in the most cost-effective, fair, timely, and environmentally friendly way. The development world is complicated, and whenever a major policy, program, or project is made, there will be trade-offs. These trade-offs should be considered fairly, accurately, honestly, sensitively, and socially acceptable. Within this kind of overall structure, the best solution for water development must be looked for in each case. This could mean that a large dam needs to be built in a certain place, but it could also mean that a different solution, like locally collecting rainwater, is needed in another place. A "dam" or "no dam" decision shouldn't be made right away, especially by people from outside the region, until the needs, conditions, and requirements of the site have been carefully evaluated and thought about.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

Certain development-focused NGOs are becoming increasingly aware that well-designed and -built dams can be valuable tools for sustainable development. In "democratic" nations, the implementation of large-scale projects (power lines, high-speed rail, dams, and even wind projects) is becoming increasingly challenging. These are met with significant pushback, even spawning defense committees.

There are so many questions for which there is no one answer and no universal model. Regarding the demand for energy in the field, numerous technological, financial, institutional, and psychological issues come into play. Acceptability in society is essential. Numerous micro-decisions must be made; thus, we must maintain realism and pragmatism. Despite the fact that the sheer number of actors can make the formation of partnerships difficult, it is essential that they be established, combining and integrating the expertise and value of the public sector, private sector, and market forces, and establishing local companies to operate and maintain the installations and market their services over the long term.

I believe that in order to be effective in meeting the enormous energy, environment, and sustainable development challenges that lie ahead, the cooperation of all of the actors will be required for a very long time, especially that of the users and communities involved, through a continuous effort of education and learning. The answer resides unquestionably in inventive, durable, and reproducible field deployments near local populations that create a virtuous cycle of progress.

Dams and reservoirs can and ought to be in harmony with the local socioeconomic and environmental conditions. The use of dams and reservoirs for the efficient management of the world's water resources as a part of each nation's objective of social and economic development will be a challenge for the future.

Careful planning and design that incorporates public involvement and feedback in the early stages of this process can limit or eliminate the negative consequences that the dam will have on the environment. Potentially significant sources of greenhouse gas emissions are man-made reservoirs. However, there are few statistics on the subject, so it is subject to much dispute and even controversy. To determine the importance of man-made reservoirs as a source of greenhouse gases, better data, investigations, and more precise definitions are required. Importantly, they are also required to target mitigation measures for constructed or projected reservoirs with a high risk of emitting large quantities of greenhouse gases. The right mitigation measures can be successfully and efficiently included in the project's design, construction, and operation when they are discovered early in the planning and design phase for a dam and reservoir.

5.1 RECOMMENDATIONS

5.1.1 MITIGATIVE FACTORS OR METHODS

In order to minimize or lessen the impacts of scouring, engineers may use tactics such as revetments, which are structures placed along the banks of a river to defend against erosion, or they may employ sediment traps or other steps to reduce the quantity of material that enters the river. These two methods are examples of anti-scouring measures. In addition, land use practices that limit soil erosion, such as conservation tillage or cover crops, can prevent scouring by reducing the quantity of sediment available to be transported by the river. This allows the river to transport less silt, preventing scour (Breusers, 1991).

Several mitigative measures can be taken to address dam and reservoir projects' environmental and social issues.

5.1.1.1 Environmental Mitigation Measures:

Environmental impact assessment (EIA): An EIA is a process that assesses a project's potential impacts on the environment and identifies measures to minimize negative impacts.

Habitat conservation: Dams and reservoirs can negatively impact fish populations and other aquatic life. Habitat conservation measures, such as fish ladders or bypass systems, can help mitigate these impacts.

Water quality monitoring: Water quality monitoring can help identify potential negative impacts of a dam or reservoir on water quality and allow for timely corrective action.

Sediment management: Dams and reservoirs can alter sediment transport patterns, impacting downstream ecosystems. Sediment management measures, such as sediment bypass systems, can help mitigate these impacts.

Green energy: Dams and reservoirs can be used to generate hydropower, which is a renewable energy source.

5.1.1.2 Social mitigation measures:

Relocation and compensation: In some cases, dam and reservoir projects may require the relocation of communities. It is important to ensure that these communities receive adequate compensation and support to rebuild their lives in a new location. Resettlement can have positive impacts if well planned, but this takes time.

Usually, the second generation of the displaced community can realize the benefits of a

successful resettlement with better utilization of the resources available to them.
Provided that such communities are relocated with adequate compensation, new economic opportunities, and social benefits, they can exploit the new circumstances to strengthen their income-earning capacity and, thus their living standards. The new settlement may provide upgraded infrastructure facilities and reduced exposure to natural hazards.

Community engagement: Engaging with local communities and listening to their concerns can help ensure that their needs and rights are taken into account during the planning and construction of a dam or reservoir project.

Economic development: Dam and reservoir projects can bring economic benefits to local communities, such as employment and infrastructure development. It is important to ensure that these benefits are shared equitably.

Cultural heritage: Dam and reservoir projects can impact cultural heritage sites and traditions. It is important to identify and protect these sites and to involve local communities in decision-making processes.
Overall, it is important to carefully consider dam and reservoir projects' potential environmental and social impacts and implement appropriate mitigative measures to minimize negative impacts and maximize benefits.

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