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Sustainable Riverine Flood Risk Management

Potential Techniques and Challenges

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This thesis contains a review on the types of floods and the potential approaches for management of riverine floods. It includes the various engineering methods that can be utilized in order to minimize the hazards occur with floods. Taking references from various sources available on the internet discloses the challenges in riverine flood risk management. Various engineering techniques are available to control floods and minimize their impacts, but they may have various side effects on the society and environment. With references from various sources, those social and environmental impacts are indicated in this thesis.

Floods and other disasters are killing numerous lives and damaging the society and economy as well as the environment. Even though floods are not predictable, it is necessary to implement the possible approaches to defend them. The engineering techniques can play a significant role in minimizing the negative impacts of the catastrophe. Selection of the most efficient techniques is needed so that the side effects can be as minimal as possible.

Basically, two types of engineering techniques are mentioned in the thesis. They are hard and soft engineering techniques. Hard techniques are those techniques which involve large constructions such as dams, levees and dikes. Soft engineering techniques are those techniques which do not include massive constructions. They are the ecologically sensitive methods that promote the originality of natural environment. The impacts of both the techniques and the challenges on commencing them are listed in the thesis.

Findings of environmental researches support soft engineering techniques in instead of hard ones as they seem to pose less or no damage to the natural environment and ecology and tend to support the improvement of environmental quality. Hard engineering techniques are mostly against the nature. They threaten the biological, physical and chemical status of the environment. Hence, hard engineering techniques should be implemented only after enough studies and researches. Ideas generated for protecting the society and environment should not destroy them.

Keywords	flood risk management, hard engineering techniques, soft engineering techniques, environmental impacts

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Abbreviations

UNISDR: United Nations International Strategy for Disaster Reduction
CRED: Centre for Research and Epidemiology of Disasters
WRI: World Resources Institute
FEMA: Federal Emergency Management Agency
EPA: Environmental Protection Agency
MW: Megawatts
FAO: Food and Agriculture Organization
RRC: River Restoration Centre

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1 Introduction

Nature is not always stable and consistent. Due to various reasons, immediate drastic changes can occur in the normal cycle of natural processes. This affects the lives living on the Earth's surface. Sometimes parts of the earth shake to cause earthquakes, hot fire and melted substances emerge from below the land surface causing volcanoes or heavy rains, resulting in a massive flow of water towards normally dry areas which causes floods. Any sudden unwanted variations on stable natural processes, for example earthquakes, volcanoes, floods, landslides, heavy winds and storms which result in a catastrophe are called natural calamities or natural disasters.

Floods are one of the most frequent calamities in the world and are more likely to affect humans and the environment. Most civilizations on earth are settled in flood prone areas such as riverbanks, coastal areas and areas close to other water bodies. The dictionary definition of flood is the overflow of a large amount of water to normally dry areas (Oxford Dictionary). According to UNISDR, a total of 3455 floods were recorded worldwide within the time interval between 1980 and 2011 (Figure 1). Reasons for floods could be anything; Figure 1 shows that the graph illustrating the number of yearly floods is trending upwards.

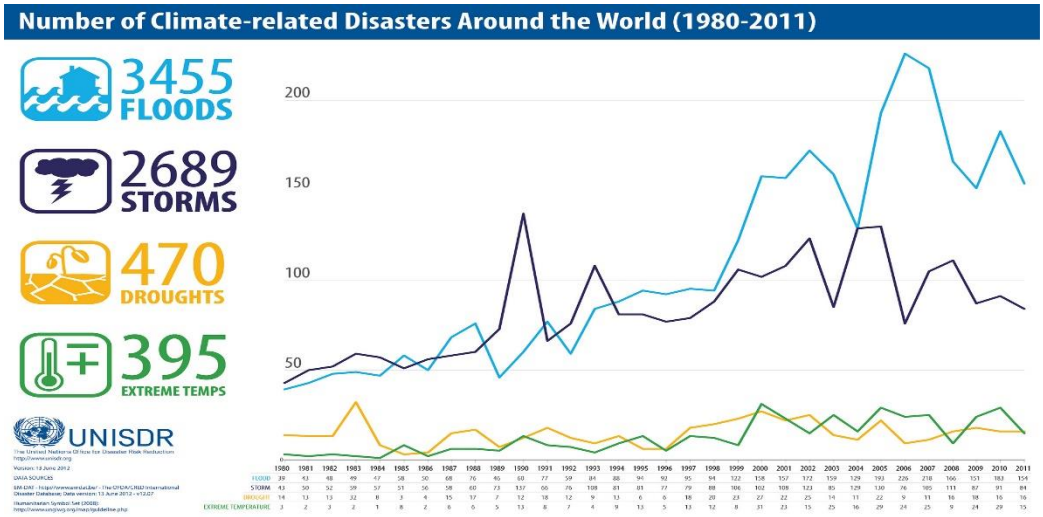

Figure 1. Number of climate-related disasters from 1980-2011 (1)

According to the EM-DAT, Disaster Database by Centre for Research and Epidemiology of Disasters (CRED), riverine floods are more persistent and catastrophic than the other types of floods, coastal and pluvial floods (2).

This thesis contains the statistical data related to floods and their effects and a review of articles and journals published by researchers, professionals, journalists and various organizations about the types of floods, risk management and impacts of the management techniques that should be considered. The main objective of the thesis was to show the challenges in commencing the flood risk management techniques and to indicate the impacts and issues that should be considered.

2 Necessity of Sustainable Flood Risk Management

Undoubtedly, like all the natural disasters, floods have a large impact on the human civilization as well as the environment. As they are mostly unpredictable, it is necessary to be ready to prevent the immediate and long-term effects that result from the floods. Evidences show that floods take away hundreds or thousands of lives as well as properties with high monetary worth. They leave many environmental and health problems afterwards.

According to World Resources Institute (3), if no improvement is made in flood risk management and protection, the flood toll can increase up to three times in the next 15 years due to the increase in population and rapid climate change. A total of 21 million people are at risk, and it already costs about 65 billion pounds a year, which is predicted to reach 54 million people and the possible cost up to 340 billion pounds by 2030. Some countries such as China, India, Vietnam and Bangladesh are at the top of flood risk rankings.

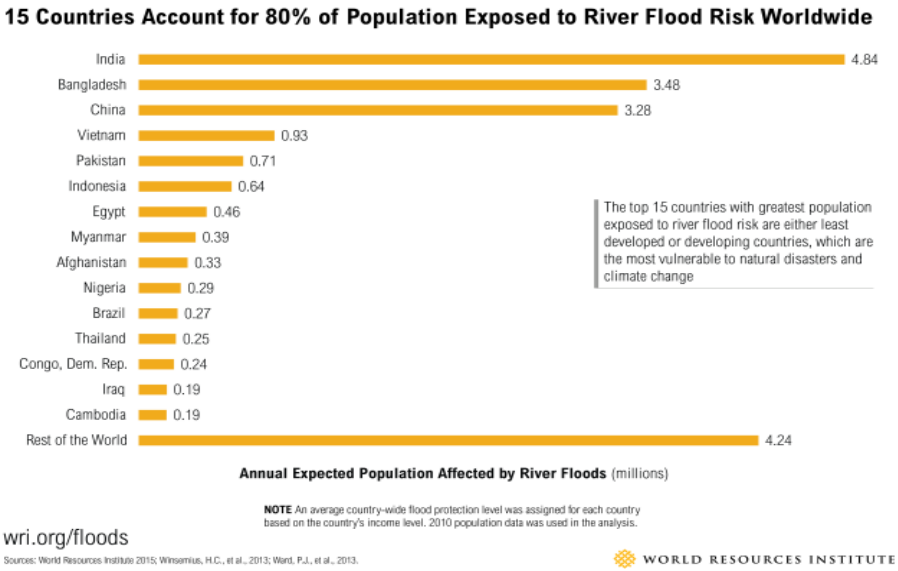

Figure 2. Countries with maximum flood risks (3)

Also, the upward trending graph in Figure 1 shows an increase in the number of yearly flood disasters which means strong necessity of proper flood risk management. As we cannot be far from water resources, we need to protect ourselves from water related disasters. Sustainable implementation of flood risk management ideas can help to decrease the upward trending rate of flood hazards. Pre-planning can save thousands of lives and a lot of valuable properties.

3 Literature Review

3.1 Types of Floods

Depending upon the causes, harm and destruction and the possible methods of forecast, floods can be classified into coastal, pluvial and riverine floods.

3.1.1 Coastal Floods

Coastal or surge floods are those floods that affect the coastal regions of seas and oceans or other large water bodies. Severe storms such as hurricanes or typhoons may create surges and push the water towards the shore of the sea or oceans making higher

tides. Those tides can be high enough to throw the sea or the ocean water in a large amount towards the coastal area to make coastal floods. This type of flood is fatal to the low lands and is likely to cause massive destruction resulting in the loss of huge number of lives and high amount of property. (4)

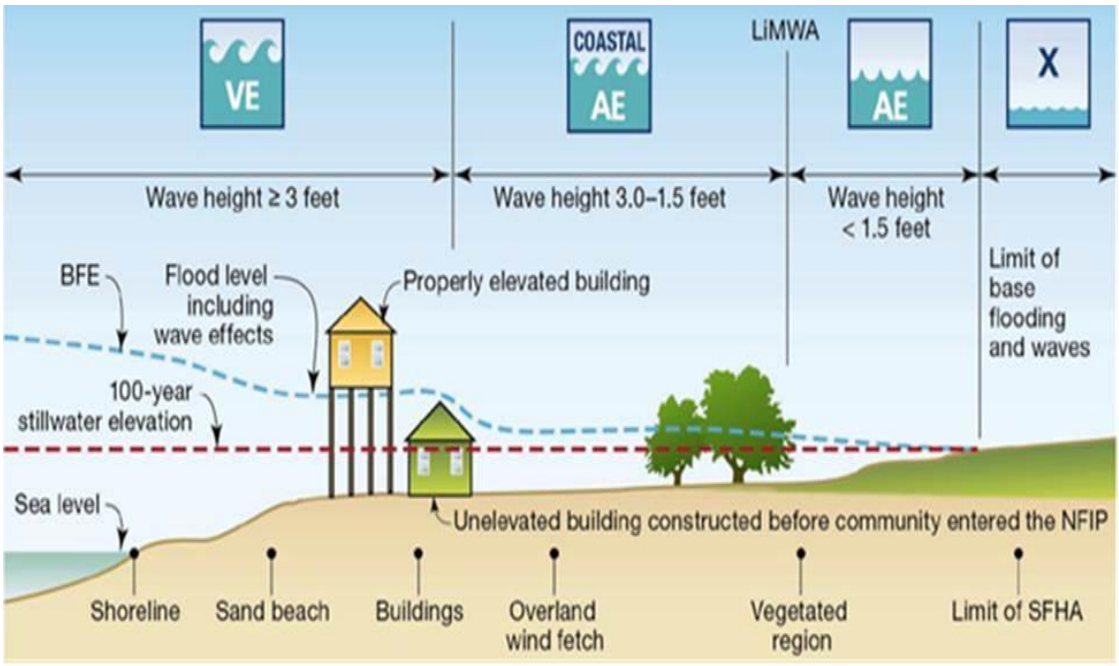

Figure 3. Coastal flood risk zones (5)

FEMA has classified the coastal flood risk zones in different categories, VE, AE and X zones. VE zone is the area where the height of the water wave can reach to more than 3 feet. AE zone is the zone where it reaches 3 feet or less. X zone starts from the limit of base floods. It also has some chances of flooding. In Figure 3, the LiMWA is a limit within the AE Zone up to where the moderate waves can reach. As shown in Figure 3, properly elevated buildings can protect themselves from coastal floods.

3.1.2 Pluvial Floods

It is not necessary for an area to lie near the water bodies to have risk of floods. Pluvial floods occur due to heavy rainfall as the water level exceeds the outflowing capacity or the absorbance of a certain area. Since they are a few centimetres deep, pluvial floods have less chance of fatalities, but they are able to cause notable damage to properties.

Typically, there are two common causes of surface or pluvial floods. During heavy rainfall, the drainage system may not be capable to receive and drain the rainwater. The excess water is dumped to the streets and can even enter dry private and public areas to cause damage (Figure 4). Heavy rain in the hillsides of certain place or city makes the water flow downwards due to low absorbance. This water may dump to the lower areas of those specific places to cause pluvial floods. Pluvial flooding may also arise from coastal or riverine floods. (4)

Figure 4. Pluvial floods after heavy rain in Kathmandu, Nepal June 2016 (6)

Pluvial flood risk may increase with the climate change and population growth. Investing in improvement of drainage system, flood resistant buildings and developing innovative ideas in surface water management can immensely minimize the pluvial flood risk in urban areas. (23)

Pluvial floods may less frequently kill people, but they can significantly damage the properties.

3.1.3 Riverine Floods

Riverine floods or fluvial floods are those floods arising in the flowing water bodies like rivers and streams. Usually, these floods are caused by continuous and extremely heavy rainfall for a long period of time. Specially, this occurs during rainy seasons. Melting of

snow and ice at a high rate due to rapid increase in temperature can also cause riverine floods. Normally, melting takes place during springs to increase the volume of rivers.

Basically, there are two types of riverine floods. When the water overflows outside the banks of rivers or streams exceeding their controlling potential, the situation is called overbank flooding. When a high amount of water flows on a river or stream at a high speed and force, it is called flash flooding. Flash floods arise suddenly without prior notice. They are very calamitous because of their power to sweep anything that comes in the way. They can destroy roads and can be as powerful as sweeping land masses with human settlements. (4)

(A) **(B)**

Figure 5. Types of riverine floods: (A) Gaindakot in Nepal after the Narayani river overbank flooding in 2016 (7) and (B) Buildings and Roads in Nepal Swept by the Bhotekoshi river flash floods in 2016 (8)

Figure 5 illustrates pictures from Nepal from 2016 explaining the types of riverine floods. On the left, the River Narayani overflowed through its bank to enter the Gaidakot village and on the right, Araniko Highway and the Tatopani village was swept by overnight flash floods in the Bhotekoshi River.

3.2 Effects of Floods

Flooding is basically a natural process which cannot be prevented. When floods arise, there is a high chance of destruction. There can be both long and short-term impacts.

Disruption of many necessary infrastructures such as transportation, communication, electricity and drinking water are the examples of short term effects, while massive destructions of properties with high monetary worth and noticeable environmental changes are the examples of long term impacts which may take a very long time to repair or may be irreparable. Effects of floods can be categorised into socioeconomic and environmental effects.

3.2.1 Socioeconomic Effects

Socioeconomic effects refer to the impacts of disaster in the society and economy of the region. There are plenty of examples and evidences of negative effects of floods on the society.

The quick social impact of floods is the loss of life and property, for example fixed assets, crops and livestock. Various services and facilities can be disrupted, and there could be high risk of water related diseases. Damages in the infrastructures such as power supply plants, telephone network, roads and bridges may indirectly affect the nearby non-flooded areas as well. These damages can lead to long-term effect on the local or even on the national economy. The purchasing power of people could decrease due to the loss of properties and the productivity of the region may decrease due to the lack of required infrastructures or sources. The recovery cost of the disaster can be very high which can have a significant effect on the capital market. Figure 6 shoes the exposure of GDP of various nations to floods.

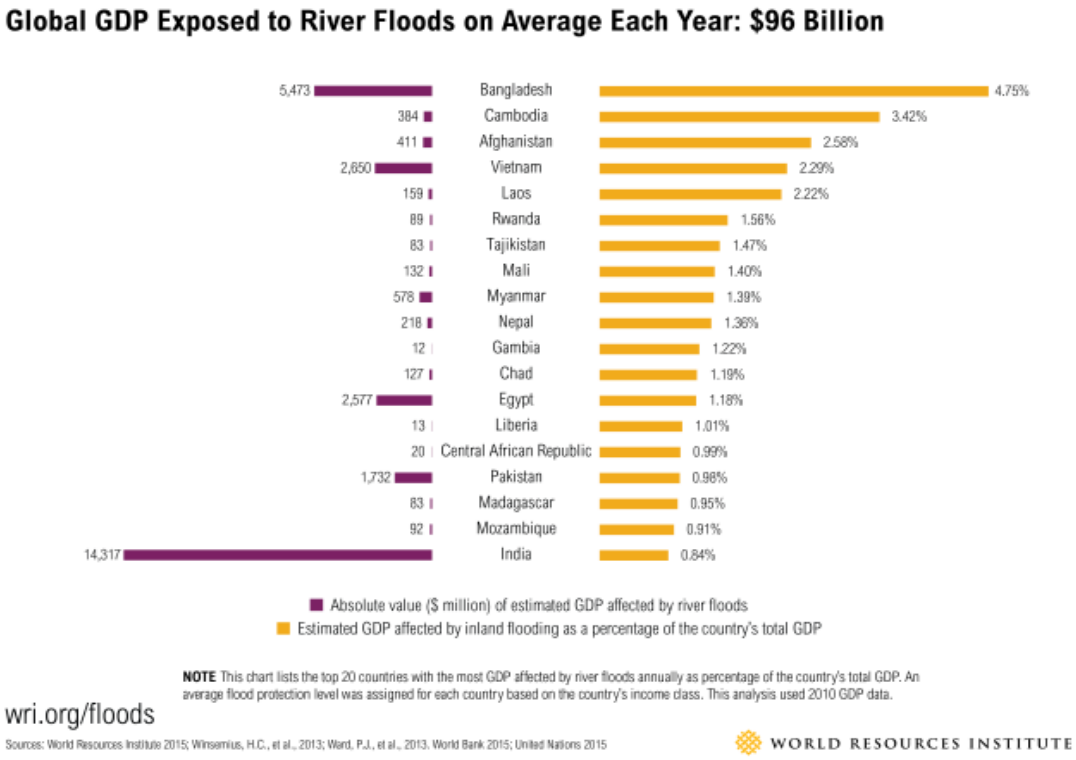

Figure 6. Floods and economy (3)

Other psychological effects have high possibility of occurrence for a long time. Mental pressure can arise due to loss of lives and properties. Poverty and risk of reoccurrence can force people to leave their native place in search of safety and security. Thus, mass migration can create the imbalance in population distribution causing the nearby cities and towns to be overcrowded, which can degrade the social and economic situation of the region. (9)

Floods can also lead to political disputes and inconsistency. If the authority could not provide effective care and support during or after the disaster, the trust of people can be lost. This may create the threat in peace and harmony. (9)

For example, after the Boscastle floods in UK in 2004, more than a thousand people lost their homes, business and cars. Due to the loss of tourism income, degradation occurred in livelihood and economy of people. A large number of insurance claims appear afterwards. Fortunately, due to the urgent response of emergency services, no one was killed. (10)

In the year 2000, flooding in Mozambique after the cyclone Eline caused the cut off of services, and a considerable number of people were left homeless. Numerous died afterwards with diseases and drowning. (10)

3.2.2 Environmental Effects

Besides the effects in human society and economy, floods are capable of making various positive and negative environmental changes. These environmental changes have direct or indirect relation with the society and economy. Hence, environmental effects may later turn into socio-economic effects.

Flooding is considered as a natural ecological process. Biodiversity and productivity of a flood-prone region is directly related to the floods. Regular seasonal floods maintain the ecosystem of the floodplain. Floods can affect health and population of wild or domesticated animals. The death of animals in large numbers causes imbalance in the food chain and ecosystem. Habitat loss could be another serious issue.

Rapid flash floods may cause soil erosion and deposition on the flood plains. Since the topsoil gets washed away, the fertility of the eroded area decreases. Deposition of sand on the usable fertile land can make it uncultivable. Some good side of sedimentation is, the washed topsoil and essential nutrients can come along with the water to deposit on the flood plains and make it fertile productive land over time. Floods may carry anything like debris, polluting agents, microbes and nutrients. This may cause eutrophication and degradation in the water quality. Floods may erode not just the soil but also the essential nutrients and minerals may fade away.

As they are natural processes, flood on dry areas can refill the surface water and restore the ground water of the area. This may lead to better productivity and improve biodiversity.

Floods can change the physical structure of the environment. The changes in highly populated and developed areas can cause massive and expensive losses. However, floods have many beneficial impacts on the environment. They may nourish the landscape, providing nutrients and water to dry areas to make it green and attractive.

The loss of habitat of wild animals after the 2011 Queensland flood in Australia and the change in the scape of Rocky Mountains and foothills after the 2013 Alberta floods could be the good examples of the environmental impacts of floods (11). Due to regular floods, the flat floodplains of Bangladesh are very good for food production while people living there are in high risk and it is difficult to warn and protect them (10).

4 Possible Ideas and Techniques for Riverine Flood Risk Management

Among the different types of floods, riverine floods are most persistent on the earth. They are one of the major causes of flood related deaths and destruction. Abundant evidences and numerous cases of destruction by river floods become the topic of news frequently. Especially in the settlements beside major rivers such as Amazon in South America, Ganges and Brahmaputra in South Asia, flood is a nightmare. With climate change and variation in temperature, these cases are increasing with time. With the population growth, numbers of casualties are trending upwards. The following paragraphs present techniques and ideas to minimize the flood hazards. These techniques have been collected from various online sources, which are being implemented in different parts of the world and have been effective. These techniques are applicable depending on the geographical location of the flood-prone areas and size and volume of rivers.

4.1 Hard Engineering Techniques

Hard Engineering techniques refer to constructions of artificial engineered structures to control the river from entering the dry areas even at its highest strength. The following paragraphs describe various hard engineering techniques, which could be effective in controlling or minimizing the flood risks and hazards.

4.1.1 Dams

Dams are the strong barriers constructed to customize the flow of water downstream. They are built for various purposes. Figure 7 shows a chart from FEMA about the benefits of a dam on the basis of utilization in the USA.

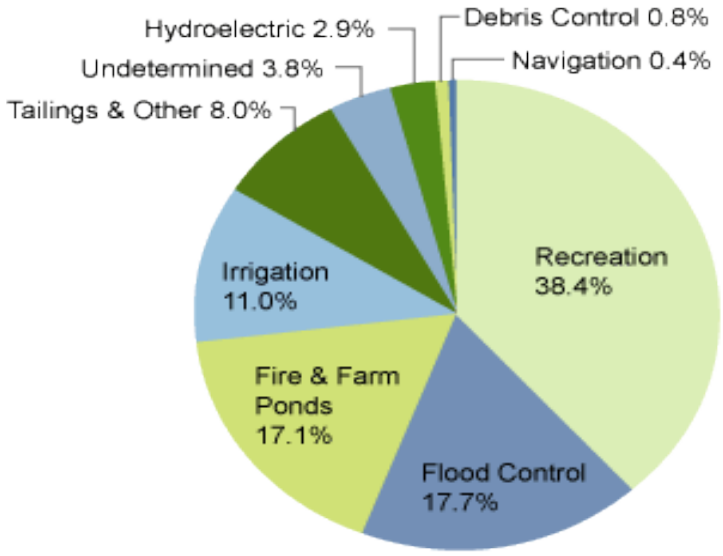

Figure 7. Benefits of dam (26)

They have many benefits and some drawbacks as well. They help in flood control, store water for hydroelectricity and irrigation or other purposes, provide recreational area and also help in controlling the waste flow by sedimenting the hazardous waste and debris. They also provide area for fish farming and control the water to make it stable for water transportation.

A dam is built by making a part of normal flowing channel dry by diverting the water normally through a tunnel (Figure 8). Usually the construction is carried out during the dry season when the water level is low. Cofferdams are built at the two ends of the construction site to protect it during construction.

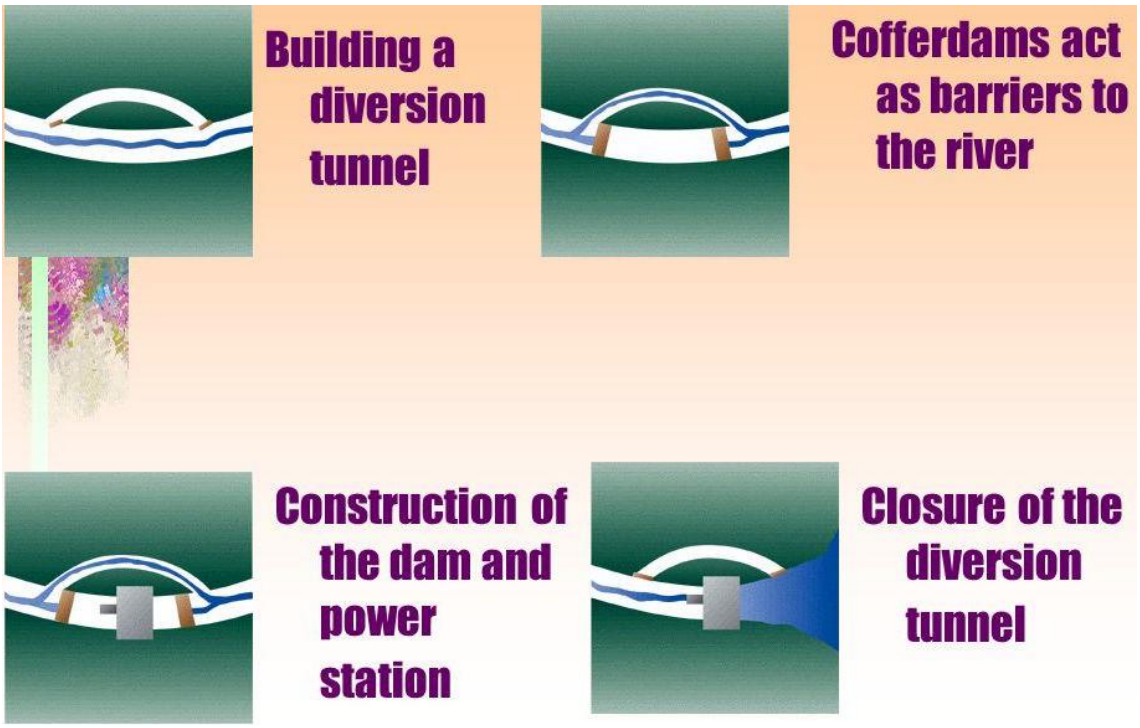

Figure 8. River diversion for dam construction (24)

The upper cofferdam lets the water flow through diversion tunnel, while the lower one stops the backflow chances of the water. The debris and loose rocks are removed from the riverbed, and the dam is constructed. After completion, the diversion tunnel is blocked and cofferdam is removed, thus the dam comes in use. (25)

The basic principle of dams in controlling flood is that they block and store the floodwater and protect the flood plain settlements downwards to the dam. The stored water is either released under control, i.e. below the risk level, or diverted elsewhere for other use or for safety reasons. Floods occur when the river channel is not wide or deep enough to control the water level. Dams control the water and store in the reservoir only releasing the water at safety level that does not erode the banks or overflow through them. (26)

Usually reservoirs have water in them throughout the year as they are built for multiple purposes. When the chances of rainfall increases upstream, the reservoirs release its water slowly which is usually replaced by floodwater later.

Besides the benefits, there are a lot of drawbacks of dams to the environment, which are discussed in a separate chapter below. Also, failure of a dam can be much more devastating than flood itself.

4.1.2 Artificial Levees

Levee is raised wall that prevents the river water to flow out of its track. Levees can be both natural and artificial. Natural behaviour of river to push the sediments towards sideways deepens the channel in the middle while the banks get raised with time. These raised banks act as natural levee and prevent the water to flow out of its channel. Artificial levees are the man made walls or embankments to control the river water enter the unwanted area even at its high strength. Figure 9 below somehow explains the meaning and use of Levee.

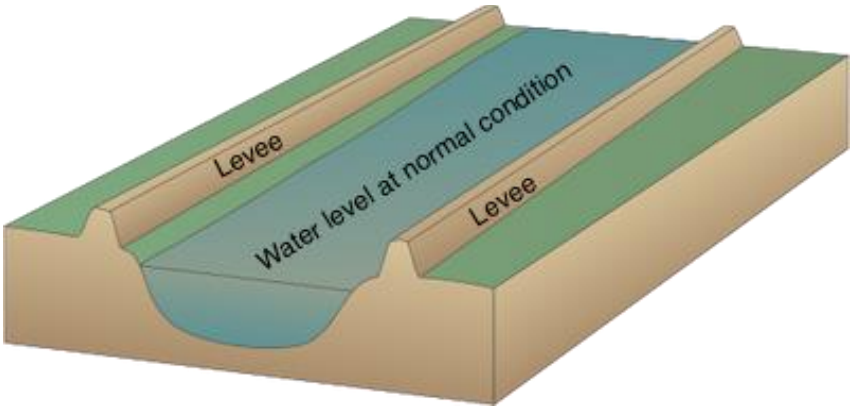

Figure 9. Levee (12)

Levees have been used since historic times. Piling up soil usually makes them. Rocks and sometimes other materials like wood or plastic are also being used for building them. They can be made using temporary sand bags in case of emergency. Sand bags significantly absorb water to control the passage of excess water through them. Concrete levees or embankments are often built beside dense city areas. (13)

Levees should be protected and properly maintained with frequent inspections. Their failure can be much more catastrophic. They act as high raised walls as shown in figure

9 and protect from floods by preventing the overflow through the banks but they also have many side effects too which should be considered. (14)

4.1.3 Wing Dikes (Dykes)

Unlike dams, dikes are the partial barriers generally placed approximately perpendicular to the riverbanks. They are usually placed pairwise to concentrate the flow of water in the middle. The sediments are deposited behind those dikes, which make the force of water flow high from central parts of the river channel. The rapid flow causes the water to escape quickly from the flood prone region and may prevent from floods. It may also control the erosion of riverbanks. Figure 10 below explains the phenomenon of wing dikes. (15)

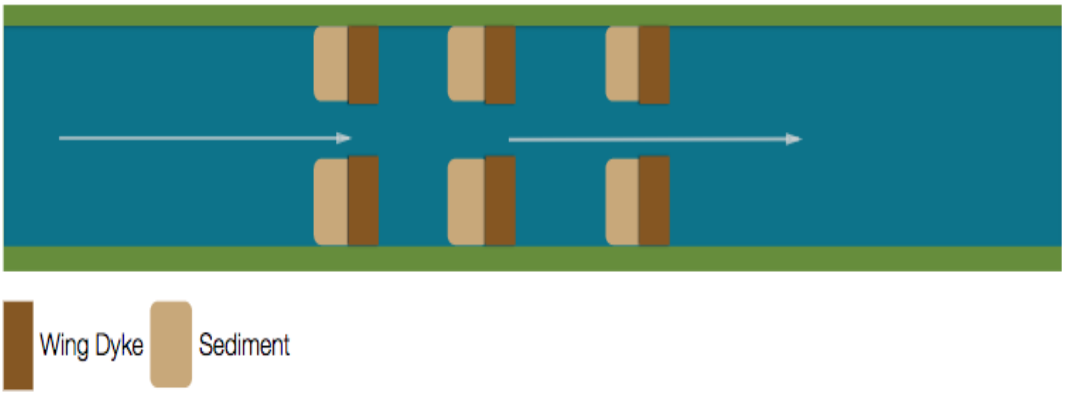

Figure 10. Wing dike mechanism (15)

According to Applied River Engineering Center (AREC) (16), the dikes can be of various kinds built according to the river volume and speed. Usually they are built with rocks and stones. Other substances like wood, geotextile bags with sand and also concrete can be used.

Dikes help in controlling the flooding of an area, but they may also maximize the risk of flooding downwards from them. The fast flow of river can erode the banks downwards and also may break the embankments and levees below the diked region. Hence, they should be built after checking the probability of affecting the settlements downwards.

4.1.4 Channel Straightening

A river may have many natural meanders along its length. These menders create a large floodplain and flood buffer zone. The rate of passage of water from the area may become low due to a long route of water flow and there can be higher chance of pooling. Channel straightening refers to artificial shortening of the routes by removing the meanders and making it straight.

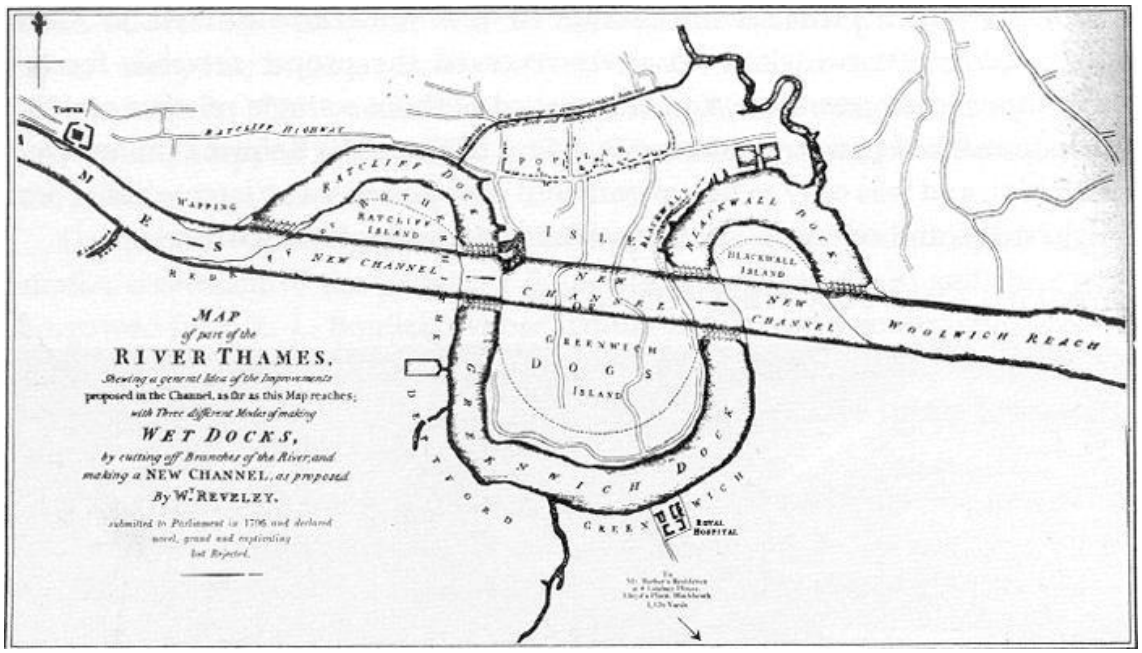

Figure 11. Proposed straightening of The River Thames in 1976 (17)

Figure 11 above is a proposal of W. Reveley in 1796 to straighten a part of the Thames channel in East London. Even though this proposal was not realized in practice, this sketch explains the meaning of channel straightening.
Straightening the river channel makes the flow of water faster and minimizes the flood risk of the region. This also shorten the navigation time and gives more economic benefit. (27)

Like wing dikes, the objective of channel straightening is also to improve the flow and prevent pooling. Therefore, this idea may also increase the floods risk and erosion below the straightened area.

4.1.5 Diversion spillways

River diversion refers to diversion of the river completely or partially from its natural direction of flow. The diverted water is discharged either to other nearby rivers or to the same river downstream. Diversion spillways are those artificial secondary channels that divert the river partially when the flow in the main channel is high. This reduces the amount of floodwater from risk level to safe and protects the flood prone areas residing besides the main river channel. (15)

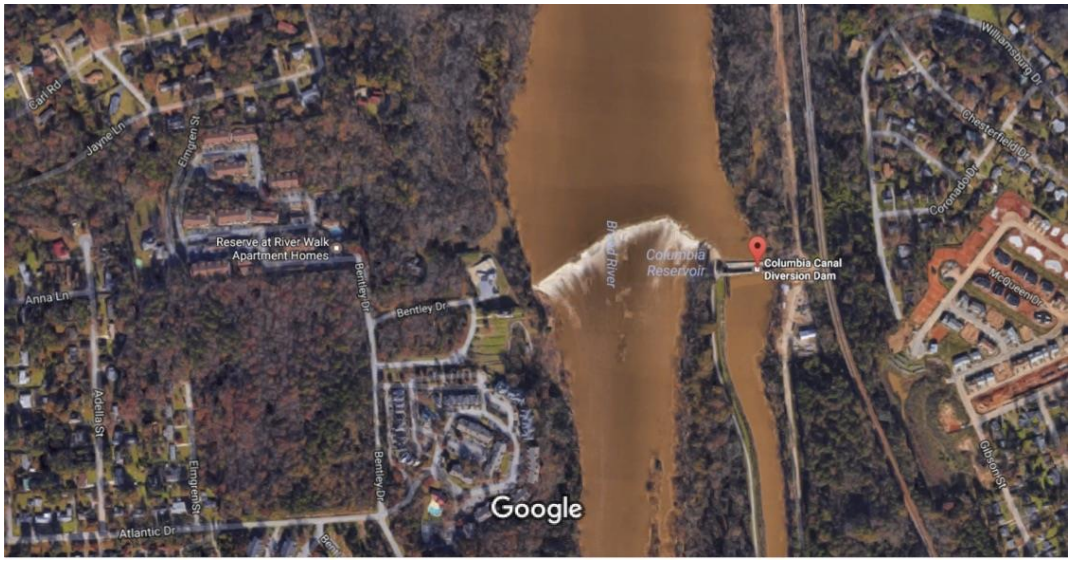

Figure 12. Satellite view of the Columbia Canal diversion dam in the USA (30)

Figure 12 above is a satellite view of Columbia Canal diversion dam, which explains the mechanism of river diversion.

Diversion channels usually have a barrage and gates. If the spillways are just constructed for protection from floods, the gates of those secondary artificial channels remain closed during the normal water flow level. However, the river is usually diverted not just for flood protection but also for multiple purposes such as irrigation, water supply and navigation. Thus these artificial canals mostly come in use throughout the year.

4.2 Soft engineering Techniques

Soft Engineering techniques are those techniques, which do not include artificially constructed structures. These are the ecologically sensitive techniques, which may not show instant benefits. The results probably take long time to be seen but they minimize the flood casualties and losses in environmentally friendly way. The following sections describe the possible soft engineering techniques for flood management and safety.

4.2.1 Floodplain Zoning

Floodplain zoning refers to official mapping of the floodplains and restriction of use of areas that have high flood risk. It prohibits the construction and developmental work in flood-prone areas. It can also be called is a prevention technique. Floodplain generally has two zones; the floodway and the flood fringe zones as shown in Figure 13.

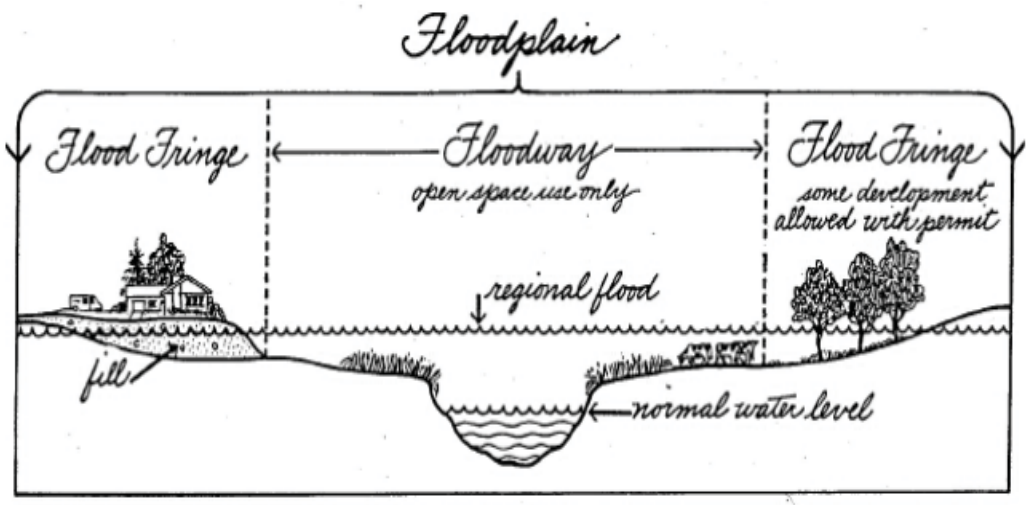

Figure 13. Floodplain zoning. (18)

Floodway is the zone of moving flood water. While Flood fringe is the zone where the flood water may remain stagnant and has less depth. Floodways can be allowed for temporary usage of open spaces during dry season. Construction should be strictly prohibited in order to prevent the losses. Flood fringe zones can be allowed for limited development works giving very special criteria and regulations. (18)

4.2.2 Wetland Restoration

For Urbanization and development, a river may have been modified destroying the wetlands. Embankment, channel straightening, dams and other hard engineering works may have been done to develop a place. These areas may not have the same value with the change in time. Thus, those devalued areas can be restored to their original status as wetlands. (15)

Wetlands are capable of holding large amount of floodwater. This reduces the rate of water escaping the region and minimizes the floods risk downwards. However, restoration of wetland does not reduce the floods of the region where it lies. It can be done only to protect the settlements that are located downstream.

Usually wetlands restoration is not done just to reduce the floods, but to restore the ecological environment. According to US Environmental Protection Agency (19), restoration should include all the ecological components like restoration of plants and animals and their manipulation, the chemical adjustment as it was before, and the historical physical status.

4.2.3 Afforestation

Afforestation means planting the trees on the drainage basins. Trees absorb the water and reduce the runoff from surface. This prevents the high volume of water in the rivers and thus lowers the risk of floods. Interception by the plants may also help in lowering down the flow of water to the river. (10)

Trees also capture the soil tightly to prevent the soil erosion and loss of minerals that could occur with floods. They provide habitat for a lot of animals to improve the biodiversity. Therefore, it is the cheapest technique to get protected from floods and many other natural calamities and is a very ecological way to deal with natural calamities.

4.2.4 River Restoration

The process of changing the modified rivers back to their original historical status is called river restoration. This includes many physical, ecological and spatial methods such as re-meandering and introducing the plants and animals. Usually this is done for flood management, recreation and tourism and supporting the biodiversity.

Restoring the river causes the increase in wetlands; the old meanders come in use, and the floodwater gets enough space to move and pool (Figure 14). Therefore, the water runoff from these regions lowers down and decreases the risk of floods to the areas below. (20)

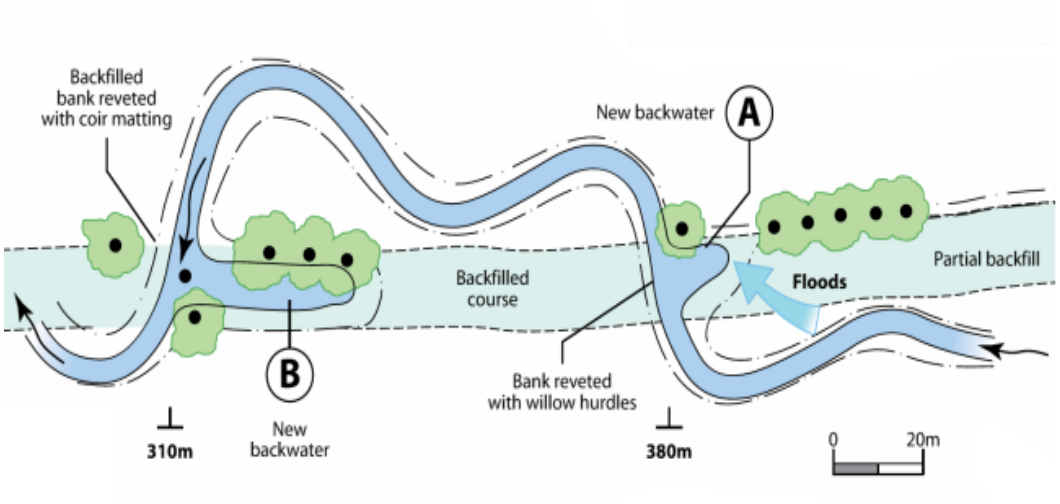

Figure 14. River re-meandering (21)

River restoration makes the flooding more natural. The areas which used to flood before the modification may start to flood again. The historical ecological system, which was dependent to floods, may get re-established. Hence, instead of modifying the rivers to prevent flooding, restrictions should be made in development of settlements in wetlands and flood plains. This could be the best way to minimize flood hazards.

5 Possible Impacts of Flood Risk Management Techniques

Flood risk management techniques save from loss of a lot of lives and properties y annually. As floods are natural processes, disrupting or trying to control these processes has a lot of side effects. Most of the management techniques are against the environmental quality and its natural cycle. Especially the hard engineering techniques may have more side effects. The following sections present the possible impacts of the different flood risk management ideas or techniques.

5.1 Hard Engineering Techniques

As hard engineering techniques are the mechanical ways of protection from floods, they interrupt the natural process directly. Table 1 below contains the types of hard engineering techniques and their socio-economic and environmental impacts.

Table1: Impacts of hard Engineering techniques (22) (10) (14)

Techniques	Socio-economic Impacts	Environmental Impacts
Dams	1. Loss of livelihood of people living downstream. 2. As the production decreases and lifestyle changes, economic imbalance occurs. 3. Water scarcity. 4. Devastating loss in case of dam failure.	1. Blocks migratory fishes. 2. Dryness and loss of wetlands downstream 3. Loss of biodiversity due to habitat loss. 4. Temperature variation.
Levees	1. Higher risk of floods downstream due to narrowed channel causing fast and uncontrolled flow.	3. Loss of wetlands. 4. Loss of biodiversity. 5. Interrupts the natural river - floodplain relation.

	2. Failure of artificial levee can be more hazardous than natural floods.	
Wing dikes	1. Higher risk of floods down-stream due to fast flow.	1. Sediment deposition causes disturbances in normal river system.
Channel Straighten-ing	1. Water scarcity. 2. Abolish natural beauty and effects tourism.	1. Wetland loss. 2. Loss of biodiversity due to habitat loss.
Diversion Spillways	1. Risks of floods from the di-verted spillways or chan-nels.	1. Ecological imbalance.

There can be other much more direct and indirect impacts of these techniques. Basically, Table 1 shows that socio-economic impacts mostly occur indirectly due to the negative impacts on environment.

5.1.1 Case study (The Three Georges dam)

The Georges dam is popular as the world's largest dam and the biggest project of hydroelectricity generation. The construction started in December 1994 and became ready in 2008 (28).

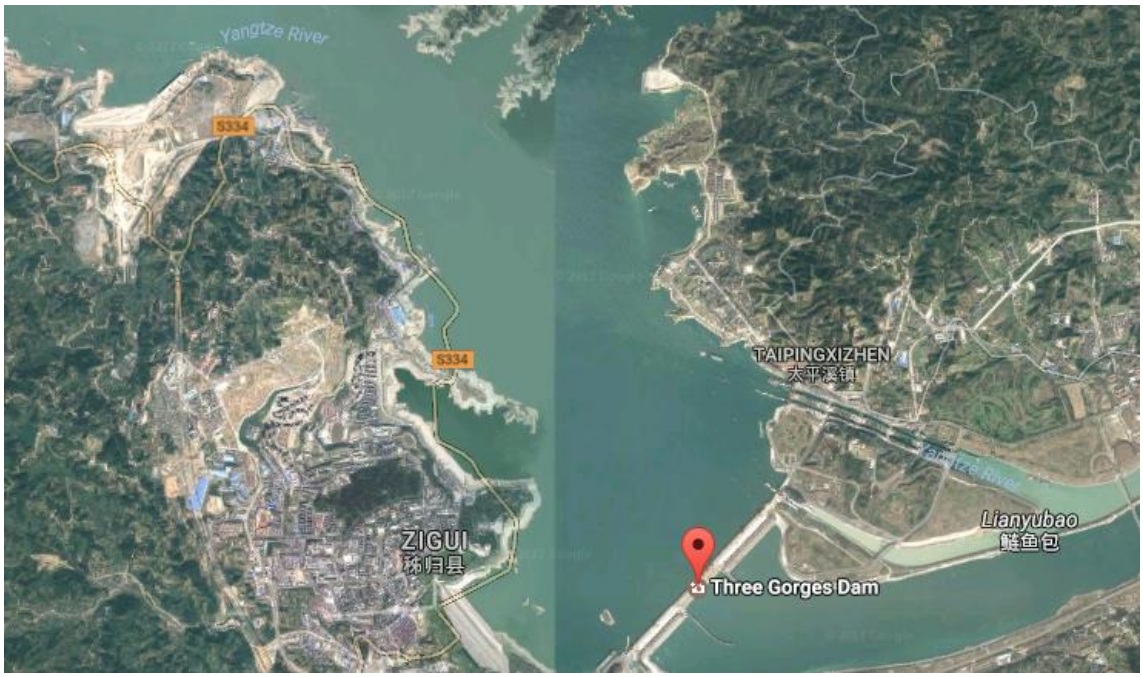

Figure 15. Satellite view of the Three Gorges Dam and Reservoir (30)

The project symbolized Chinese economy and future. Here are some of the positive and negative sides of the project:

Benefits (28)

- It is expected to have the capacity of producing 22500 MW of electricity.
- Coal consumption reduced which has lowered the carbon dioxide emission. 70 % of Chinese energy need was obtained from coal. The project is believed to supply 10% of Chinese energy requirements. This means the reduction of coal usage. It is believed to substitute 50 million tons of raw coal, emission of 100 million tons of CO_2, 2 million tons of SO_2 and 0.37 Million tons of NO_x annually.
- Believed to protect millions of people and millions of acres farmlands from Yangtze River floods. No severe floods have repeated since the great floods of 1998.
- River navigation has not been effected much due to presence of locks lift vessels.

Negative Impacts (28)

- Sediments flow stopped causing the reduction of fertility of farmlands downstream.

- Biodiversity (Threats of extinction of water creatures like Yangtze River Dolphin, various craps, Chinese sturgeon whose numbers seem to be declining since the early 2000s.)
- Variations in water level may have increased the risk of collapsing of slopes and riverbanks. (L. Hongshun, Chongqing University)
- Landslides caused due to lack of land stability.
- In case of the dam's failure, massive number of death and loss of zillions of dollars' worth assets may occur. (P Adams)
- Huge unrecoverable destruction of Chinese culture and heritage.
- About 140 towns and 1300 villages have been drowned by the reservoir chasing about 1.5 million residents away from their origin.
- Some recent earthquakes were claimed by geologists to be the effect of seismic activities created by the reservoir.

The impacts shown by the Three Gorges Project suggests that better options for flood risk management should be considered than the construction of a dam. These points are just the immediate impact seen. Future effects and consequences are yet to be seen.

5.2 Soft Engineering Techniques

Soft Engineering techniques may have some socio-economic impacts, but they rarely have impacts to the environment. These techniques may affect the people and livelihood instantly but sooner or later it will give positive result, which gradually improve the socioeconomic situation too. Table 2 below lists the effects caused by soft Engineering techniques.

Table 2: Impacts of soft engineering techniques. (10) (15) (19)

Techniques	**Socio-Economic Impacts**	**Environmental Impacts**
Floodplain Zoning	1. Local inhabitants displaced	1. Positive impacts only.
Wetland Restoration	1. Could be costly to compensate the displaced inhabitants.	1. May affect the adapted organisms.

	2. Agricultural land may be disappeared.	
Afforestation	1. Decrease in agricultural productivity may occur.	1. Positive impacts.
River restoration	1. Increase in natural flooding.	1. Positive impacts.

There could be various other positive and negative effects of the management techniques. These tables are based on the researches from various free online sources. No paid sources have been used to enlist them.

5.2.1 Case Study (River Cole-Life Project)

The River Cole is a small river in England that flows to the Thames. The river was straightened and used to run a mill since thousands of years ago. It has a long moderation history as recorded in historical books. (29)

Figure 16. Restored River Cole (29)

This restoration project was commenced in June 1995 with the intension of enhancing biodiversity, landscape and quality of water and creating recreational site. Various physical and biological processes such as re-meandering, introduction of plants and animals and the restoration of river bed were carried out. The site was monitored numerous times after the restoration. Surveys have yielded the following results

- Immediate increase in plant species.
- Colonies of small invertebrates reappeared. Breeding birds appeared as well as richness in fish species.
- Increase in river length by 30%.
- Pools and riffles seem to increase and maturing trees form woody debris. These create new habitats for organisms.
- Natural floods promoted.
- Only negative impact was some local residents were upset as they were not engaged initially.

The results show many positive impacts in ecology. Hence, soft engineering techniques should be promoted. The only problem with this was social issue, which can be solved by awareness campaign. Thus, It seems very essential to engage the local residents on undergoing these kinds of projects. (29)

6 Consideration of Challenges and Minimization of Impacts

There could be a large number of challenges to implement the engineering techniques of flood risk management. Ignorance of these challenges can lead to social dissatisfactions, conflicts, accidents and many other long and short-term problems. To meet the national and international legislations related to society and environment is itself a challenge. Local cooperation, awareness and faith is strongly necessary to start the projects of flood risk management. On the basis of the effects of flood risk management techniques, the following factors must be considered

a. Society and Livelihood
b. Economy
c. Local Environment and Biodiversity

d. Infrastructures of development
e. Property Worth
f. Culture and Heritage
g. Tourism and Productivity
h. Others

Studies and research on minimization of impacts of flood risk management techniques on the factors listed above should be efficiently conducted before realizing those techniques. So that the management techniques become smooth and efficient leaving very less side effects.

7 Discussion and Conclusion

The annual evidences of different types of floods show the necessity of measures of flood control and risk management. The trending evidences of massive floods are encouraging the implementation of efficient and sustainable management ideas. On the other hand, there are many challenges in the application of engineering techniques.

In the context of riverine floods, researches show that hard engineering techniques; especially dams and levees have been much popular in controlling floods than other techniques. These techniques have been considerably helping the developing physical world. Hard engineering techniques are offering multipurpose benefits, for example in agriculture, energy and transportation. Nevertheless, modern researches and studies are showing that these ideas are not environmentally sustainable.

Soft engineering techniques are often believed to show much fewer environmental impacts. They support the earth's originality. Their social benefits may not appear immediately but probably come sooner or later. Hence, considering the impacts, soft engineering techniques should be promoted more than hard engineering techniques. Global cooperation is highly necessary for flood safety without destroying natural originality and beauty.

The earth is already highly modernized with a large number of settlements created destroying the environment. Knowing their vulnerability to the natural calamities, human

beings are still expanding their civilization in the risk and buffer zones. Population growth is continuously increasing. With the increase in population, settlements are necessary to be developed in new areas. Those new areas can be chosen in such regions where no flood risk management is necessary and there will not be damages to the environment. Already settled areas may have no options but to undergo the hard engineering techniques.

Destroying the ecology, environment and natural cycle surely does not benefit the mankind for long. The impacts of the destruction of the environment are already being noticed. Climate change, global warming, rising sea levels, loss of species are all believed to be the results of human activities against nature. Environmental ignorance, pollution, overuse of resources, deforestation, etc. probably are the reason for the changing natural state of earth in the past few centuries. These kind of uncontrolled activities may cause the existence of mankind to become a history of earth. Human beings are the sole responsible creatures to destroy or improve the quality of the environment.

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