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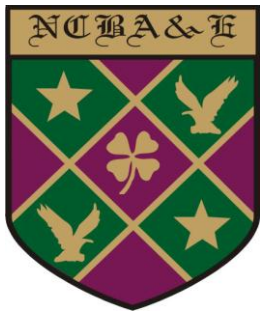

FLOOD DAMAGES ASSESSMENT AND MANAGEMENT AT TAUNSA BARRAGE ON RIVER INDUS

BY

TAHIR ANJUM IQBAL

MASTER OF PHILOSOPHY
IN
ENVIRONMENTAL MANAGEMENT

AUGUST, 2017

NATIONAL COLLEGE OF BUSINESS ADMINISTRATION AND ECONOMICS

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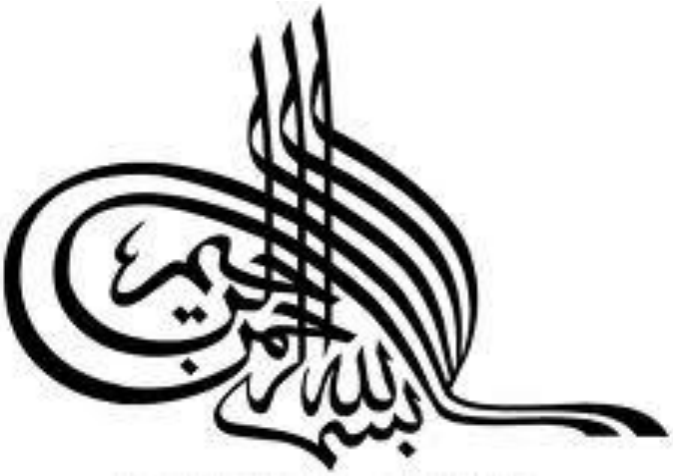

In the name of ALLAH,
The Compassionate,
The Merciful

NATIONAL COLLEGE OF BUSINESS ADMINISTRATION AND ECONOMICS LAHORE

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Dissertation Committee:

_____
Chairman

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Member

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Member

_____
Rector
National College of Business Administration and Economics

DECLARATION

It is to declare that this research work has not been submitted for obtaining similar degree from any other university/college.

TAHIR ANJUM IQBAL
August, 2017

DEDICATION

This effort
is dedicated to
My Parents.

ACKNOWLEDGEMENT

I bow my head to the Almighty Allah, the most beneficent, the most merciful, who enabled me to complete and finalize this thesis successfully. I also take this opportunity to extend my heartfelt thanks to a number of learned people who helped and supported me during the course of this thesis

It is my paramount obligation to pay my deepest regards and gratitude to my supervisor, the exceptionally learned and highly respectable Dr. Rab Nawaz for his valuable guidance and persistent support during the entire course of the thesis, without which I would not have been able to complete this challenging task.

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RESEARCH COMPLETION CERTIFICATE

Certified that the research work contained in this thesis entitled **"Flood Damages Assessment and Management at Taunsa Barrage on River Indus"** has been carried out and completed by **Tahir Anjum Iqbal** under my supervision during his **M.Phil. Environmental Management** Programme.

(Dr. Rab Nawaz)
SUPERVISOR

ABSTRACT

Floods mostly occur due to heavy snow melt down or heavy rain fall in the catchment areas and the runoff water. The water level surpasses the river banks and overflows to cause flood in the terrestrial lands. Global warming has increased the intensity and stretch of rain falls resulting in increased chances of floods. Similarly the rise in the mean temperature of the world is causing glacial melt down at a faster rate with higher risks of floods. The total average availability of river water in Pakistan is about 144 MAF per year out of which about 106 MAF is used for irrigation while the balance flows down the Kotri Headworks into the Arabian Sea. The yearly monsoons are responsible for most of the water availability in the rivers which come during the late summers and cause flash floods. This research work aims to study, analyze and determine the extent of floods at Taunsa Barrage on the great river Indus. It was determined that although the occurrence of floods cannot be eliminated being a natural phenomenon, the damages can certainly be reduced to a great extent through an appropriate technical and administrative management. The administrative and technical weaknesses in the system have been studied and evaluated to ensure a sustainable flood fighting and management system and to reduce the flood related damages.

LIST OF ABBREVIATIONS

GIS	Geographic Information System
IWT	Indus Water Treaty
LGB	Left Guide Bank
LMB	Left Marginal Bund
MAF	Million Acre Feet
NDMA	National Disaster Management Authority
PID	Provincial Irrigation Department
RGB	Right Guide Bank
RMB	Right Marginal Bund
SOP	Standard Operating Procedure
WAPDA	Water and Power Development Authority

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CHAPTER 1

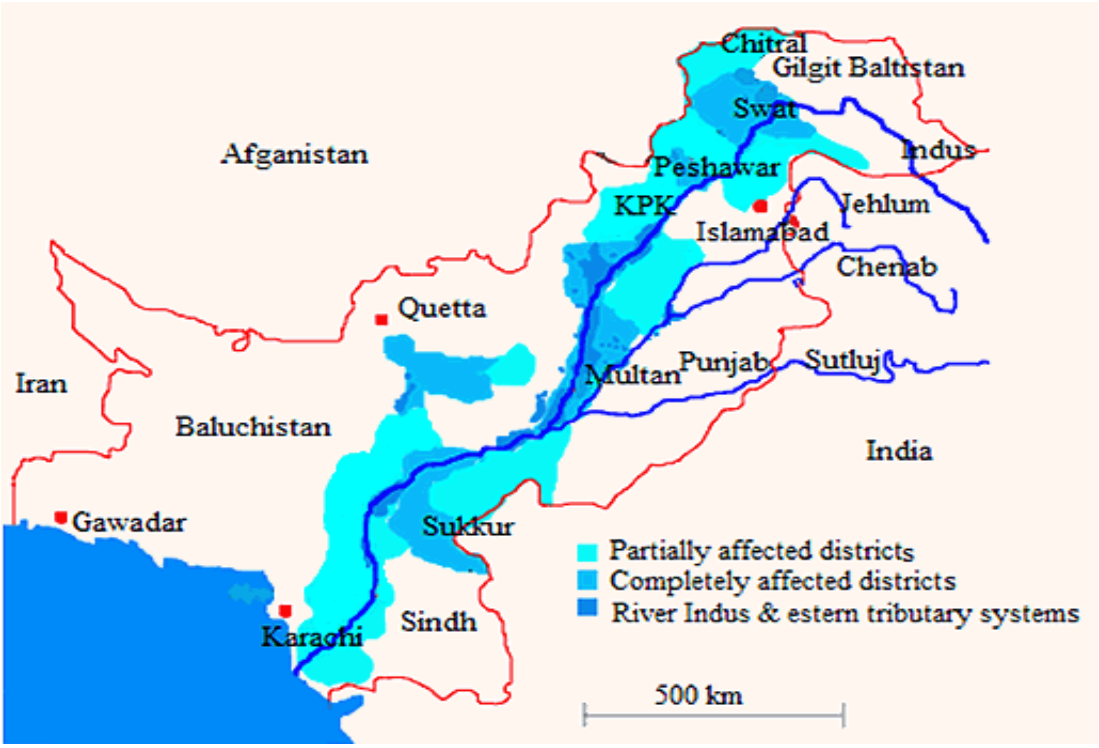
INTRODUCTION

1.1 BACKGROUND

Floods mostly occur due to heavy snow melt down or heavy rain fall in the catchment areas and the runoff water. The water level surpasses the river banks and overflows to cause flood in the terrestrial lands. Global warming has increased the intensity and stretch of rain falls resulting in increased chances of floods (Jamie, 2015; Lotsari, et al., 2015). Similarly the rise in the mean temperature of the world is causing glacial melt down at a faster rate with higher risks of floods.

Floods in Pakistani Rivers, nullahs and water streams are mostly caused by heavily concentrated rainfall in their respective catchment areas (Annual Flood Report-2014). Most of the rainfall in Pakistan occurs during the monsoon season starting from the mid of June. However, early moderate floods are sometimes experienced due to snow melt. The monsoons generally originate in the Bay of Bengal and the adjoining seas during early summers. The moist winds move towards the high temperature low pressure areas of the subcontinent. Starting with downpour in the Himalayan foot-hill, the winds move towards west and north-west causing rain in the northern and central India reaching Pakistan roughly by the mid of June. The Pakistani land strip from Sialkot to Islamabad and the Murree Hills / Galiyat receive most rain in Pakistan.

Heavy rains in the catchment areas generate destructive floods which move southwards and cause inundation in the plain areas. Sometimes the monsoon winds are combined with the westerly winds causing the most destructive floods due to their cumulative effect. Occasionally, due to bursting of weak natural dams formed by landslides and the glacial movements also result in flash-floods. The flood of 2010 swamped 20% of Pakistan’s land, killed 2000 and affected over 20 million people, see Figure flood in 2010 (GFDRR, 2011).



(Source: Ghani, 2010)

Figure 1: Land Inundated by Flood Water during 2010

The most destructive floods in Pakistan occur due to flooding in the major rivers, i.e. the Indus and its tributaries. It results in the destruction of standing summer crops In certain cases of large inundations, the standing water does not dry up by the winter season causing delay in sowing of the winter crops.

In Bangladesh every six to seven years a major flood is reported (Guitars et al., 2015) and in Thailand the flood is becoming a perennial problem as the flood of 2011 lasted for about six months and devastated 65 out of 77 of its provinces (Yuhong, et al., 2015). In June 2013 the province of Uttarkhand, India, had its share of misfortunes levied by the flood. The catchment area of the rivers Saraswati and Mandakini received a rain fall of 325 mm within 24 hours and completely submerged the towns of Gaurikand, Rambara and Kedarnath destroying the infrastructure and taking many lives (Dobhal, et al., 2013). Pakistan is seeing floods every other year since 2010 resulting in heavy losses.

A study conducted on frequency of returning period of peak floods in Europe reports that the extreme floods events are projected to be doubled by the next 30 years (Alfieri et al., 2015). Another paper out of England reports back to back incidences of storms that reached Southern England during

winters of 2013 and 2014. These extreme winds brought heavy flooding and caused an estimated damage of £451 million (Schaller et al., 2014). A study conducted on the variation in the frequency of the maximum annual floods for Danube and Vienna for the period of 1828-2013 shows that there is an escalating frequency past 1950 right until 2013 (Blochl et al., 2015).

Floods are impediment for the growth in the cities by disrupting infrastructure, supply chains, domestic and international communication channels, and paralyzing urban life (Haddada et al., 2015). In several African areas the agricultural outputs are decreasing due to recently increased floods (Borokini, et al., 2014). Another study reveals that central and southern areas of Mozambique were hit by severe floods in January 2013. It displaced around 0.2 million residents and leaving a hundred dead (Manhique et al., 2015). Pakistan also has its share of worries in the lieu of floods. The recent incidents of flood have put the Pakistan's economy under tremendous pressure. Since 2010, Pakistan is facing floods every year. In the year 2010 the floods swamped 20% of Pakistan's land and killed 2000 and affected over 20 million people (GFDRR, 2011). The flood of 2014 caused evermore devastation by submerging 17 districts of the province of Punjab and drowning 308, destroying 100,000 houses and resulting in a death toll of 367 (NDMA, 2014).

The geomorphic system of river beds is genetically dynamic and serves many ecological functions. The rivers change their courses with time. The amounts of rain and topography of the area determine the sediment load and the flow discharges. The recent escalated flood incidents have influenced the geomorphology of the riverine systems affecting the riparian ecologies resulting in loss of habitat and migration of species (Lotsari, et al., 2015; Jamie, 2015). Recent scientific studies suggest that as the Climate Change is going to be more severe, the flooding problem shall be aggravated more in the future (Pao-Shan, et al., 2014).

A study in China that was conducted to see short term impacts of flood on three infectious diseases, namely (a) Bacillary Dysentery, (b) Hand-foot-mouth Disease and (c) Diarrhea. Bacillary Dysentery was confirmed to be associated with floods (Zhang et al., 2016). The intense floods are also reported to undermine the propagation of marine life forms. Their food and reproductive systems are closely linked with the duration and timing of the flood (Oliveira et al., (2015). The impacts of spring floods on riparian taxonomic groups in two controlled rivers of South Australia were sought and reported a hefty reduction in the variety of terrestrial exotic taxa, especially in the case of riparian grasses (Greet et al., (2015). The riparian vegetation usually is found to be resilient in nature and tends to grow back fast after a

flood has passed. For the same token, where the returning rate of flood has increased, the threshold to bounce back decreases (Surian et al., 2014). Some studies also suggested that high flooding is beneficial for deltaic biota as it brings a lot of food, sediments and reduces water pollution (Death et al., 2015).

1.2 FLOODS AND PAKISTAN

Pakistan is a country with amazingly diversified landforms. It stretches from the Arabian Sea in the south to the highest mountain ranges of Central Asia. Pakistan falls into three main geographical regions, the mountainous north where the Hindukush, Karakoram and Himalayan ranges meet; the vast plateau of Baluchistan; and the Punjab and Sindh plains of the Indus River and its five eastern tributaries.

It covers an area of 8,03,944 square Kilometers (3,10,322 square miles). The distance from South-west to North-east is 1800 kilometers (1,120 miles), and the southern coastline along the Arabian Sea is nearly 1000 kilometers long (Pakistan Handbook by Isobel Shaw, 1990).

The Indus River is Pakistan's life-line and, with its tributaries, provides water for the largest contiguous irrigation system in the world. While a number of canal irrigation systems were constructed during the last one hundred years or so, various new dams and canals have been built since independence not only to irrigate vast flat arid areas but also to harness the flood water. Floods are a regular feature in Pakistan and are mostly caused by the annual monsoons during the summer months of June to September. Flash floods are usually caused by torrential rains in the mountains which cause river spills in the flat plains.

The River Indus is 3200 kilometers long and is the third longest river in Asia after the Yangtze and Yellow Rivers of China (Isobel Shaw, 1990). It originates from the Mansarowar lake on the northern side of Himalayas near Kaillos Parbat at an altitude of 18000 feet. It passes through Ladakh in Northern Kashmir and enters Gilgit-Baltistan flowing north-westwards.

It separates the Himalaya and Karakoram ranges and flowing through some of the world's deepest gorges; it emerges into the plains of Punjab and Sindh and discharges into the Arabian Sea through a giant delta. Four major tributaries, i.e., Sutluj, Ravi, Chenab and Jhelum join the Indus from the eastern side while River Kabul and River Swat fall into it from the western side (map). There are also a number of secondary rivers, nullahs and hill

torrents which join the Indus from the western side. Floods in the Pakistan Rivers are generally cause by heavy concentrated rainfall in the catchments during the monsoon season which is sometimes augmented by snow-melt flows.

(Source: Maps of World, 2017)

Figure 2: Geographical Map of Pakistan Showing the Main River Layout

Floods are one of the worlds' most serious environmental hazards. Four thousand years of recorded history tells of man's repeated failure to evade the destructiveness of floods. In spite of centuries of experience and evolution of highly developed scientific techniques, floods still continue to play havoc almost in every part of the world.

In Pakistan, the highest natural hazard is flooding. It destroys vast areas of agricultural crop-lands and affects thousands of people annually. The monitory losses run into billions of rupees every year. Besides the agricultural losses, the floods damage urban and rural settlements as well as private and public properties and infrastructure on large scale.

It is generally recognized that complete prevention of floods in humanly impossible but protection from floods is not only feasible but also a vital necessity. Proper planning can devise means to harness and control the fury of floods to safeguard human life and property. The harnessed flood-water can then be used for the benefit and welfare of society.

1.3 STATEMENT OF PROBLEM

Most of the flood damages in Pakistan are caused due to weak flood forecasting system, improper maintenance of flood embankments & other hydraulic structures, and lack of coordination between the various Government agencies. The flood damages include direct damages to public and private properties, communication, commercial and industrial infrastructure, as well as urban and agricultural areas, etc.

1.4 OBJECTIVES OF THE STUDY

This study was conducted to:

- highlight the flood damages at Taunsa Barrage of River Indus,
- identify the managerial flaws on the Rive Indus

CHAPTER 2

REVIEW OF LITERATURE

In Pakistan most of the literature on floods is available from various flood studies conducted by the relevant federal and provincial departments. Pakistan is the land of Indus, hence many studies / research works are focused on the floods in River Indus and its various tributaries. A look /glimpse into the following literature sources would be essential to carry out research work into the behavior of River Indus.

2.1 INDUS WATER TREATY 1960

Pakistan got independence on August 14, 1947 resulting in the partitioning of the Punjab thus the head-waters of Ravi, Sutlej and Beas fell into India. On April 1, 1948, India unilaterally stopped water supplies of the Pakistani canals. Although the canals were reopened after protest by Pakistan but it was not until Sept. 1960 when the Indus Water Treaty was signed between the two countries through the good offices of the World Bank. Under the treaty India was entitled to the exclusive use of the total water supplies of the three eastern rivers, i.e. Ravi, Sutlej and Beas, while the supplies of the western rivers, i.e., Indus, Jhelum and Chenab were to be passed down to Pakistan.

Table 1:
Mean Annual Flow of the Indus and its Tributaries

River	Rim Station	Catchment Area (Sq. Miles)	Average Annual Flow-1922-61 (MAF)
Indus	Attock	65,180	93.0
Jhelum	Mangla	12,900	23.0
Chenab	Marala	11,400	26.0
Sum Total of these three rivers called Western Rivers			142.0

Source: Ahmed, 1993

Table 2:
Mean Annual Flow of the Six Rivers

River	Rim Station	Catchment Area (Sq. Miles)	Average Annual Flow- 1922-61 (MAF)
Ravi	Madhopur	3,100	7.0
Beas	Mandi Plain	6,500	13.0
Sutlej	Rupar	10,500	14.0
Sum Total of these three rivers called Eastern Rivers			34.0
Total of Six Rivers			**176.0**

Source: Ahmed, 1993

The average annual flow of the Indus at Tarbela is 67 MAF. The Kabul contributes 26MAF, which makes up the total flow above Attock equal to 93 MAF (Ahmed, 1993).

2.2 INDUS RIVER APPORTIONMENT ACCORD-1991

Indus river apportionment accord was signed between the four provinces of Pakistan in 1991 vide which the provinces agreed to distribute the annually available water in the Indus river system as given below:

Table 3:
Proportion of Water of Indus System

Province	Water Distribution (MAF)		
	Kharif	Rabi	Total
Punjab	37.07	18.87	55.94
Sindh	33.94	14.82	48.76
N.W.F.P	3.48	2.30	5.73
Balochistan	2.85	1.02	3.87
Total	77.34	37.01	114.35

Source: Ahmed, 1993

This did not include the water NWFP / KPK and Baluchistan were already withdrawing which was exempted. The balance river supplies including flood supplies and future storages were distributed according to the different proportions, as given in the table (Nazir, 1993).

2.3 ANNUAL FLOOD REPORTS

The Federal Flood Commission, Government of Pakistan, issues Annual Flood Reports at the end of each flood season every year. These reports contain the essential facts regarding the flood of that particular year and highlight the working of the various agencies responsible for flood management and the procedures adopted to fight the menace of floods. These flood reports are comprehensive documents regarding the impacts of floods in Pakistan.

2.4 PROVINCIAL IRRIGATION DEPARTMENTS

The Provincial Irrigation Departments are the first line of defense against the floods. They are the actual 'owners' of the rivers, diversion headwork and irrigation canals with actual deployment of staff on flood / irrigation infrastructure in real time throughout the year. These departments are responsible for the maintenance and operations of all such facilities and also to carry out flood-monitoring, river training and flood-fighting on the rivers. (Similarly engineering organizations like Pakistan Engineering Congress and the Institution of Engineers, Pakistan, also conduct studies and publish technical papers from experts in the subjects of flood management, water resources and river engineering which are presented in conferences, symposia and workshops for the benefit of planners and field formations).

2.5 NON-GOVERNMENT ORGANIZATIONS

A number of non-government organizations such as WWF-Pakistan monitor the occurrence and effects of floods in various regions of the country and carry out research works basically for the study of environment and climate change and its effects on human and other forms of life. It carries out scientific studies on the various aspects which are available for further research purposes.

2.6 DEDICATED GOVERNMENT ORGANIZATIONS

Dedicated government organizations like Federal & Provincial Disaster Managements Authorities, WAPDA, Meteorology Departments, Geological Survey of Pakistan, etc. are also continuously engaged in the study of various aspects of hydrological phenomena including the occurrence of floods in Pakistan.

2.7 INTERNATIONAL SCIENTIFIC ORGANIZATIONS / SOCIETIES

A large number of international scientific organizations and societies engaged in the global hydrological and geographical monitoring also publish their studies in routine which are available for further research work.

This barrage serves 2.351 million acres (951,400 hectares) besides diverting flows from Indus River to the Chenab River through Taunsa-Panjnad Link Canal (TP Link Canal). The barrage also serves as an arterial road bridge, a railway bridge, and crossing for gas and oil pipelines, telephone line and extra high voltage (EHV) transmission lines (Zaidi et al., 2011)

Taunsa Barrage was completed in 1958. The canal system fed by the barrage initially consisted of Muzaffargarh and Dera Ghazi Khan Khan canals. The former was completed in 1960 and is in operation since then, while the latter although opened in 1958 continued to remain under construction in some later years. TP Link canal was added in 1970, as a component work of the Indus Basin Project (Zaidi et al., 2011)

Taunsa Barrage has been identified as the barrage with the highest priority for rehabilitation. It requires urgent measures to avoid severe economic and social impacts on the lives of millions of poor farmers through interruption of irrigation on two million acres (8,000 km^2) and drinking water in the rural areas of southern Punjab, benefiting several million farmers.

In 2003, the World Bank approved a $123 million loan to Pakistan to rehabilitate the Taunsa Barrage on the River Indus whose structure had been damaged owing to soil erosion and old-age. The project was designed to ensure irrigation of the cultivated lands in the area of the Muzaffargarh and D.G Khan canals, and through the TP Link Canal that supplements the water supply to Panjnad headworks canals.

In 2011, the rehabilitation of the Taunsa Barrage was blamed for devastation of the Muzaffargarh district during the 2010 Pakistan floods. Critics blamed the rehabilitation of the barrage, alleging that it failed to raise its height and strengthen protective embankments, used dysfunctional computer control system of the hoist gates and ignored hill-torrent management.

The inundation of useful low-lying agricultural areas around the rivers damage standing crops, communication and irrigation infrastructure and precious urban / settled areas. It also erodes away the river banks and flood embankments.

The river banks in the upper reaches of Indus catchment are mostly higher grounds causing steeper valleys so the water recedes and returns hack to the river after the flood but in the lower parts of the country where vast areas on both sides of the river are at a lower elevation than the river itself, the water does not return to the main river channel. This standing water takes weeks and months to dry up causing further misery to the affected people for an extended period of time. To avoid such a situation the government has built earthen embankments on both the sides of the river throughout the province of Sindh and in most parts of the Punjab and KPK. However, sometimes these embankments / dykes fail to hold the flood water resulting in violent breaches allowing the ferocity of the dammed up water to destroy whatever comes in its way. Such floods are the most destructive as these are sudden in nature and catch up unprepared population.

2.8 FLOOD MANAGEMENT MECHANISM

- The nature and magnitude of flood problems heavily depend upon the topography of the areas adjoining the rivers. In Pakistan, the physical features of the land around the major rivers vary from the upper catchment to the lower reaches therefore appropriate facilities to mitigate the floods have to be provided for the varying topography.

- In Punjab the flood waters are generally contained by the earthen embankments on both the sides of the rivers. As the general slope of the area is from north-east to south west, breaching sections in the Right Margined bunds i.e. the western embankments have been provided to ensure the safety of the headworks, barrages and bridges. The water thus escaped returns back to the main river channel due to the natural topography (illustrate with Figures 2-5).

- In the Sindh province the river Indus generally flows on a mild ridge. It means that the areas around the river are generally at lower levels from the river so the escaped flood water cannot return to the river channel causing sustained long-term damage to the adjoining low-lying areas. Therefore, a double line of flood bunds have been provided to eliminate the spreading of flood water to these areas.

- The rivers in KPK have steep slopes so the destruction is generally due to flash floods and only the adjacent areas are generally affected by flood water. The floods tend to destroy the adjoining banks, therefore, a large number of spurs have been provided on the banks for their protection. Similarly, due to the typical nature of topography of Baluchistan, spurs and diversion channels have been provided in certain areas depending upon the usefulness and settlements in the area.

- As the flood water does not spread out vastly in Giligit-Baltistan, FATA and AJK due to the steep valleys only side protection measures using protection walls, spurs and studs are generally used.

2.9 AGRICULTURAL ECONOMY AND FLOOD MANAGEMENT

The flood plains of Pakistan provide the most feasible livelihood opportunities to a large section of population. Food security is the most essential factor in the developing economies. Hence the control and management of floods in most areas of the country is not only significant but also essentially important to ensure safe and ensured livelihood for the rural population.

2.10 INTEGRATED APPROACH

Integrated Flood Management encourages the participation of all the stake-holders in the system including the planners, the investors, the implementers of the projects as well as the general public. The process has to be totally transparent so that maximum benefit from the resources could be obtained.

The damaging effects of flood and droughts have far-reaching effects on the affected population which may include mass-migrations, socioeconomic implications and environmental impacts, etc.

2.11 CLIMATE CHANGE AND FLOOD MANAGEMENT

Global warming and climate change are serious threat to the world in general and many developing / tropical countries in particular. Pakistan is among such developing countries. There is evidence that the rate of melting of glaciers has increased during the last couple of decades. Climate change has caused floods and droughts and has affected agricultural produce by soil degradation, desertification and deforestation. There is a dire need of strategic planning to address such impacts at the national level.

2.12 ORGANIZATIONS RESPONSIBLE FOR FLOOD MANAGEMENT IN PAKISTAN

Flood management in Pakistan involves a member of national and provincial organizations as discussed below. Their areas of responsibilities are also briefly given in the following section:

i) WAPDA

Water and Power Development Authority (WAPDA) is actively involved in flood forecasting process through its state of the art telemetric / meteor-burst telecommunication systems. WAPDA is also responsible in regulation of water levels in its water reservoirs / dams to manage the inflows and outflows, depending upon irrigation requirements and flood management.

ii) Provincial Irrigation Departments (PIDs)

The PIDs play a vital and front –line role in flood management and control by operation of barrages / head –works, maintaining effective river training works, implementation of Flood Fighting plans in the field, coordination with federal agencies in flood management, etc.

iii) Provincial Relief / Disaster Management Organizations

These organizations plan and work to reduce the loss of life and damages to public and private assets by preparing for natural disasters, conducting rescue and relief operations and arranging rehabilitation of the affected people.

iv) Pak Army

The Pakistan Army coordinates with civil authorities throughout the flood management process starting from flood planning, pre-flood inspections of the flood protection infrastructure, relief

duties during floods, using explosives during execution of breaching sections and during re-habilitation.

v) Pakistan Commissioner for Indus Water

The major flood generating areas of River Sutlej, Ravi, Chenab and Jhelum lie in the Indian occupied Kashmir. India has constructed a number of dams / water reservoirs on these rivers. In order to ascertain the magnitude and duration of rainfall in the Indian territories, Pakistan has installed long-range weather radars at Lahore, Sialkot and Mangla. However, these radars cannot give totally correct data of river flow coming in from across the border. Consequently, an agreement with India was signal during 1989 to promptly get the river-flow data of the rivers in India at the first-hand in order to make appropriate emergent preparations in case of floods.

vi) The Federal Flood Commission

The Federal Flood Commission was established during 1997. To date it has prepared three National Flood Protection Plans which have helped in construction of flood fighting facilities like embankments, spurs and river training works and also in providing flood forecasting and warning systems including the installation of modern radars and remote sensing stations to ensure reliable weather and flood informations to the relevant organizations.

vii) Flood Forecasting Division, Lahore

This organization is actually a flood-coordination center. It provide prompt rainfall / flood data to all the concerned agencies including media and the general public during the flood season.

viii) National Disaster Management Authority (NDMA)

The NDMA was establishment during 2006. It serves as the focal agency in all types of disasters, whether natural or man-made. It coordinates in implementing, coordinating and monitoring of all types of disasters at the national level.

2.13 HISTORY OF FLOOD EVENTS IN RIVER INDUS SYSTEM

The Indus River System has regularly witnessed heavy floods in its rivers since 1947. There have been 22 major flood-years during the last 68 years i.e. during 1950, 1955, 1956, 1957, 1959, 1973, 1975, 1976, 1977, 1978, 1981, 1983, 1984, 1988, 1992, 1994, 1995, 2010, 2011, 2012, 2013 and 2014.

The floods of 2010 were the worst ever floods in the history of the country. Salient data of these floods including direct losses, lives lost, affected villages and flooded area during these years is depicted in the table given below (Federal Flood Commission, 2014):

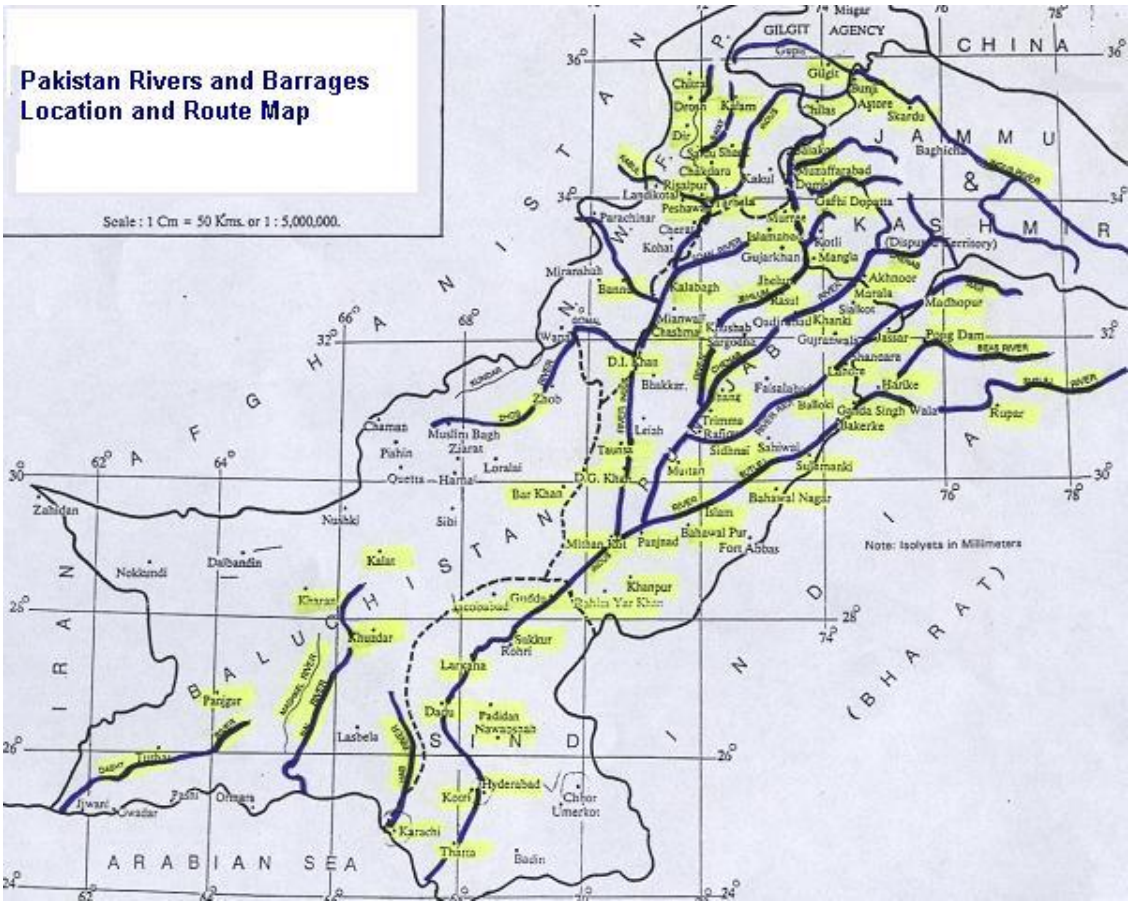
Table 4:
Historical Flood Events Experienced in Pakistan

Sr. No.	Year	Direct Losses (US$ million)	Lost Lives (No)	Affected Villages (No)	Flooded Area (Sq-km)
1	1950	488	2,190	10,000	17,920
2	1955	378	679	6,945	20,480
3	1956	318	160	11,609	74,406
4	1957	301	83	4,498	16,003
5	1959	234	88	3,902	10,424
6	1973	5134	474	9,719	41,472
7	1975	684	126	8,628	34,931
8	1976	3485	425	18,390	81,920
9	1977	338	848	2,185	4,657
10	1978	2227	393	9,199	30,597
11	1981	299	82	2,071	4,191
12	1983	135	39	643	1,882
13	1984	75	42	251	1,093
14	1988	858	508	100	6,144
15	1992	3010	1,008	13,208	38,758
16	1994	843	431	1,622	5,568
17	1995	376	591	6,852	16,686
18	2010	10,000	1,985	17,553	160,000
19	2011	3730	516	38,700	27,581
20	2012	2640	571	14,159	4,746
21	2013	2,000	333	8,297	4,483
22	2014	500	367	4,065	9,779
Total		38,055	11,939	192,596	613,721

Government of Pakistan, (2014).

2.14 BARRAGES IN PAKISTAN

Pakistan maintains the world's largest contiguous irrigation system. There are 18 No. major barrages / headworks on the various rivers from which irrigation canals are taken out to feed a very vast plain areas. The following map shows the land in Pakistan depicting canal irrigated area etc.



(Source: Paki Mag, 2014)

Figure 3: Location of Barrages / Headwork on Main Rivers

2.15 HYDROLOGY OF PAKISTAN

Hydrologically Pakistan is divided into two regions, one is the Indus basin and the other is the dry area of Baluchistan. The Indus River has several tributary Rivers. Important ones joining on its left side are Jhelum, Chenab, Ravi and Sutlej. Each river has its own tributaries. The total catchment area of Indus River system is 3,64,700 square miles 44%, of which lies in the adjoining countries and 56% lies in Pakistan (Ahmed, 1993).

2.16 BARRAGES / HEADWORKS ON RIVER INDUS

River Indus originates from the Mausarowar Lake in Tibet, China. After passing through the Ladakh Region, it enters into Gilgit-Baltistan near Skardu where it is joined by the Shyok River. It flows in a westerly direction up till Jaglot near Gilgit and them turns down towards south eventual reaching Tarbela rim area in KPK province. A few kilometers downstream Tarbela a new Headworks has been constructed at Ghazi from which the power channel of Ghazi-Barotha Hydal Power Station off-takes. At Attock River Kabul joins the Indus. The river then enters a gorge and emerges at Kalabagh/Jinnah Headworks from where the Thal Canal off-takes which irrigate large barren lands of the Thal desert. Moving further south it reaches the Chashma barrage / reservoir from which the Chashma-Jhelum Canal emerges and delivers more than 21000 cusecs of Indus water to Jhelum river. The Chashma Right Bank Canal off-take on the right side of the barrage, which irrigates the barren areas to the west of the Indus River. Further south, in the district of Dera Ghazi Khan, the Taunsa Barrage is located near the town of Kot Addu. Four canals off-takes from the river at this head-works, the Taunsa–Punjnad Link Canal and Muzaffargarh Canal on the left side and the Kachhi Canal and D.G. Khan Canal on right side. Further down the river the river Chenab merges with it from the left side down / stream of Panjnad headworks. The river then enters the province of Sindh where Guddu, Sukkur and Kotri barrages are constructed on it after which it falls into the Arabian Sea after forming a large delta.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 STUDY AREA

Taunsa is located 30°42’20”N-70°39’28”E on the Globe and also the location one of the notable structures on the Indus River called Taunsa Barrage, located several kilometers south of Taunsa city. It was designated a Ramsar site on March 22, 1996. The Taunsa Barrage was completed in 1958, and it has been identified as the barrage with the highest priority for rehabilitation. It requires urgent measures to avoid severe economic and social impacts on the lives of millions of poor farmers through interruption of irrigation on two million acres (8,000 km²) and drinking water in the rural areas of southern Punjab, benefiting several million farmers.

In 2003, the World Bank approved a $123 million loan to Pakistan to rehabilitate the Taunsa Barrage on the River Indus whose structure had been damaged owing to soil erosions and old-age (Tehsil & Union councils in the District of D.G. Khan - Government of Pakistan). The project was designed to ensure irrigation of the cultivated lands in the area of the Muzaffargarh and Dera Ghazi Khan Tehsil canals, and through the Taunsa-Panjnad Link Canal that supplements the water supply to Panjnad head-works canals and its also known by the name of younan-e-sager because of its education.

3.2 STUDY PARAMETERS

The present study was based on secondary data. Different parameters were selected for the study and the relevant data were collected from different departments. Study parameters are given as under:

- Historical Flood Events in Pakistan
- Flood Limits of Rivers
- Flood Protection Facilities
- Peak Discharges at study area
- Affected Areas in 2010 Flood

3.3 DATA COLLECTION

The data regarding the occurrence, reach and effects of floods in Pakistan is available from a number of sources. Important research data regarding the occurrence of floods at Taunsa Barrage, the life line for a large chunk of southern Punjab, is available with various national as well as provincial resources.

This essential data has been rationally gathered, appropriately summed-up, and scientifically tabulated in various computer based forms. It has been statistically and objectively analyzed. The objectives achieved regarding flood damages assessment and management at Taunsa Barrage / River Indus have been complied is a presentable form for policy makers / planners and for further research work.

Various aspects of flood management have been studied and further various avenues for such studies have been exposed for the future scientists, engineers and managers to look into. The floods of 2010, which were the most destructive ever is its depth and reach, have been taken as a bench mark.

3.4 SOURCES OF SECONDARY DATA

This research work is based on collection of secondary data from various sources including different departments and organizations.

These organizations and departments are listed as under:

- Federal Flood Commission,
- Water and Power Development Authority,
- Punjab Irrigation Department, Pakistan
- Commission for Indus Water,
- Punjab Disaster Management Authority,

The services of qualified statistician were acquired to analyze the data

- **GIS / Remote Sensing Studies**

  The satellite images of the study area were obtained before, during and after the 2010, floods. Services of GIS specialists were obtained to analyze and tabulate the data.

3.5 VISITS FOR DATA COLLECTION

Visits were made to different departments and organization for collection of required data and information.

3.6 DATA ANALYSIS

Microsoft office (excel) was used to analyze different study parameters. Different graphs and charts were prepared using MS-excel.

CHAPTER 4

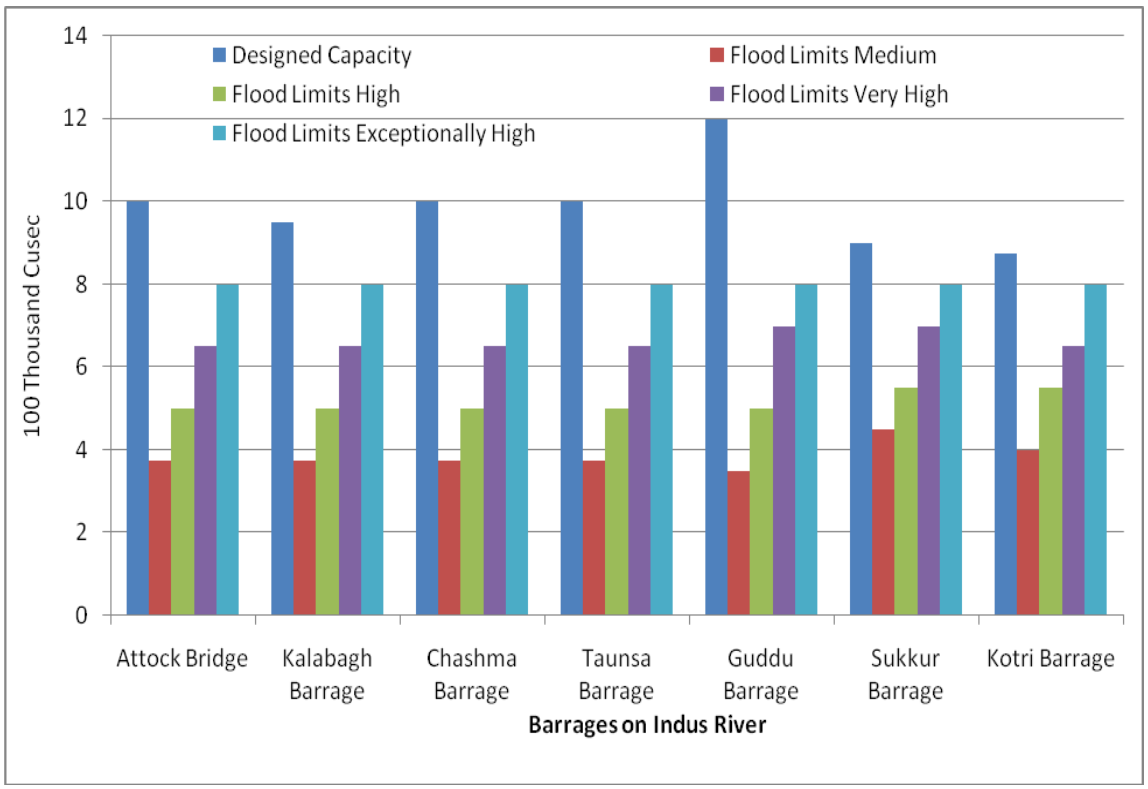
RESULTS AND DISCUSSIONS

4.1 DESIGNED CAPACITY AND FLOOD LIMITS OF MAJOR RIVERS

Table 5:
Flood Limits of Major Pakistan Rivers

Name of River	Site of Barrage of Bridge	Designed Capacity	Flood Limits			
			Medium	High	Very High	Exceptionally High
Indus	Attock Bridge	10.00	3.75	5.00	6.50	8.00
	Kalabagh Barrage	9.50	3.75	5.00	6.50	8.00
	Chashma Barrage	10.00	3.75	5.00	6.50	8.00
	Taunsa Barrage	10.00	3.75	5.00	6.50	8.00
	Guddu Barrage	12.00	3.50	5.00	7.00	8.00
	Sukkur Barrage	9.00	4.50	5.50	7.00	8.00
	Kotri Barrage	8.75	4.00	5.50	6.50	8.00
Jhelum	Kohala Bridge	6.00	1.50	2.00	3.00	4.00
	Mangla Dam	11.12	1.10	1.50	2.25	3.00
	Rasual Barrage	8.50	1.10	1.50	2.25	3.00
Chenab	Marala Barrage	11.00	1.50	2.00	4.00	6.00
	Khanki Headworks	8.50	1.50	2.00	4.00	6.00
	Qadirabad Barrage	9.00	1.50	2.00	4.00	6.00
	Trimmu Barrage	6.50	2.00	3.00	4.50	6.00
	Punjnad Barrage	7.00	2.00	3.00	4.50	6.00
	Jassar Bridge	2.75	0.75	1.00	1.50	2.00
Ravi	Shahdara Bridge	2.50	0.65	0.90	1.35	1.80
	Balloki Headworks	2.25	0.65	0.90	1.35	1.80
	Sidhnai Headworks	1.75	0.45	0.60	0.90	1.20
Sutlej	Suleimanki Barrage	3.25	0.80	1.20	1.75	2.25
	Islam Headworks	3.00	0.80	1.20	1.75	2.25
	Mailsi Syphon	4.00	1.10	1.50	2.25	0

Source: Qadir, 2011



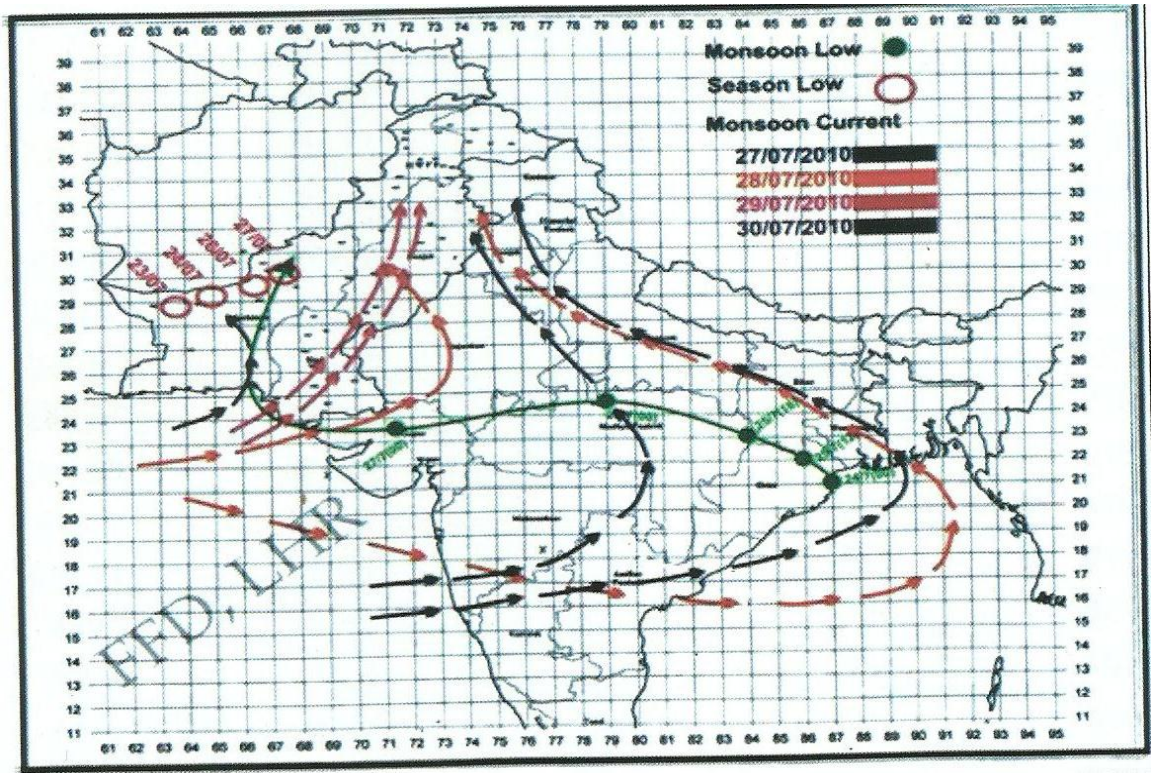
Source: Modified from Qadir, 2011

Figure 4: Designed Capacity and Flood Limits of Barrages on Indus River

4.2 THE 2010 FLOOD IN RIVER INDUS

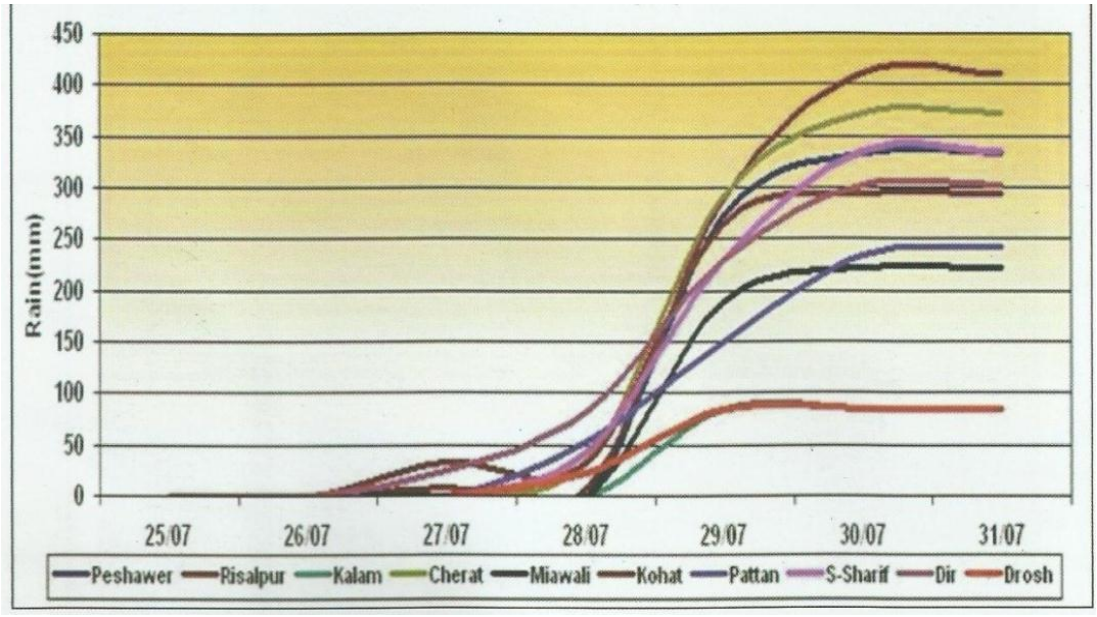
The 2010 flood in River Indus, which is also the main topic of this study, was by far the heaviest and most destructive flood ever witnessed in Pakistan. It started with heavy torrential rains in uppermost catchment areas of the river and its northern most tributaries like Kabul and Swat Rivers during the last days of July 2010. The rains generated heavy flooding in the Indus. Such a flood was never known in history of the region and flood peaks of un-presented magnitude were recorded over the next few days. Figure 8 & 9 show the peak discharges of River Indus at Jinnah Barrage from 1958 to 2010. The high peaks were also much longer in time scale owing to the continued rainfall over a wide area.

Generally, the flood peaks of very high floods last for about 12 to 24 hours but in the case of 2010 flood high peaks for a much longer time period were recorded. For example, at the Jinnah Barrage the high peak persisted for 115 hours while at Taunsa barrage it was recorded for 124 hours. This was highly un-precedented and far higher than the high peaks ever recorded in history. The high peak at Taunsa barrage resulted in the breach of the left marginal bund resulting in the inundation of almost all the Muzaffargarh district.



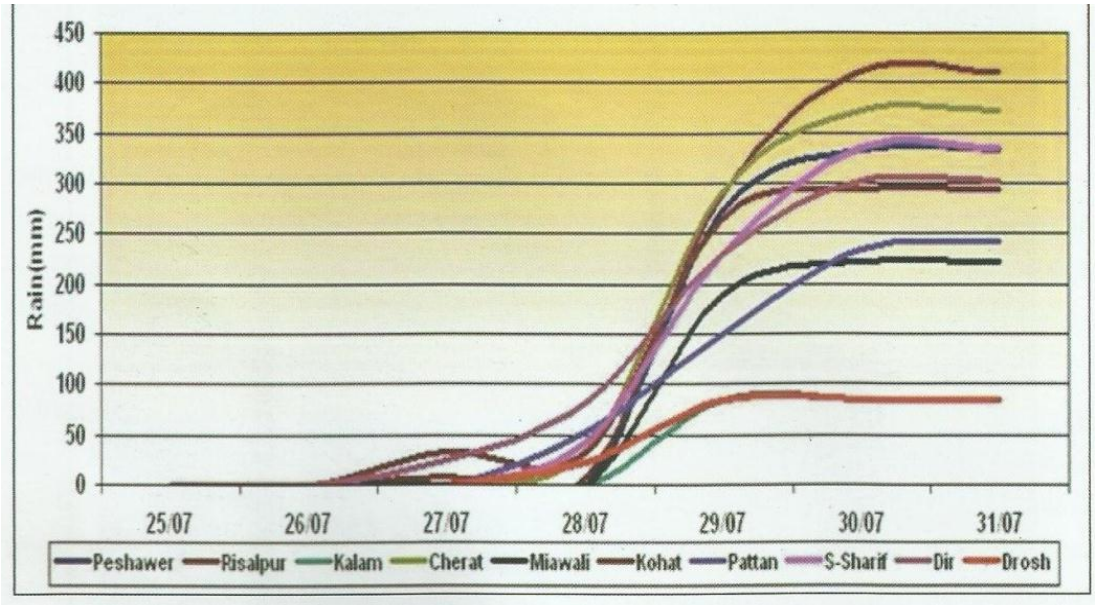
(Source: Qadir, 2010)

Figure 5: Movement of Monsoon Depressions Super Flood 2010



(Source: Qadir, 2010)

Figure 6: Graphical Representation of the Rain Fall Intensity Over Various Locations in North of the Country



(Source: Qadir, 2010)

Figure 7: Graphical Presentation of Rainfall Distribution during Super Flood 2010

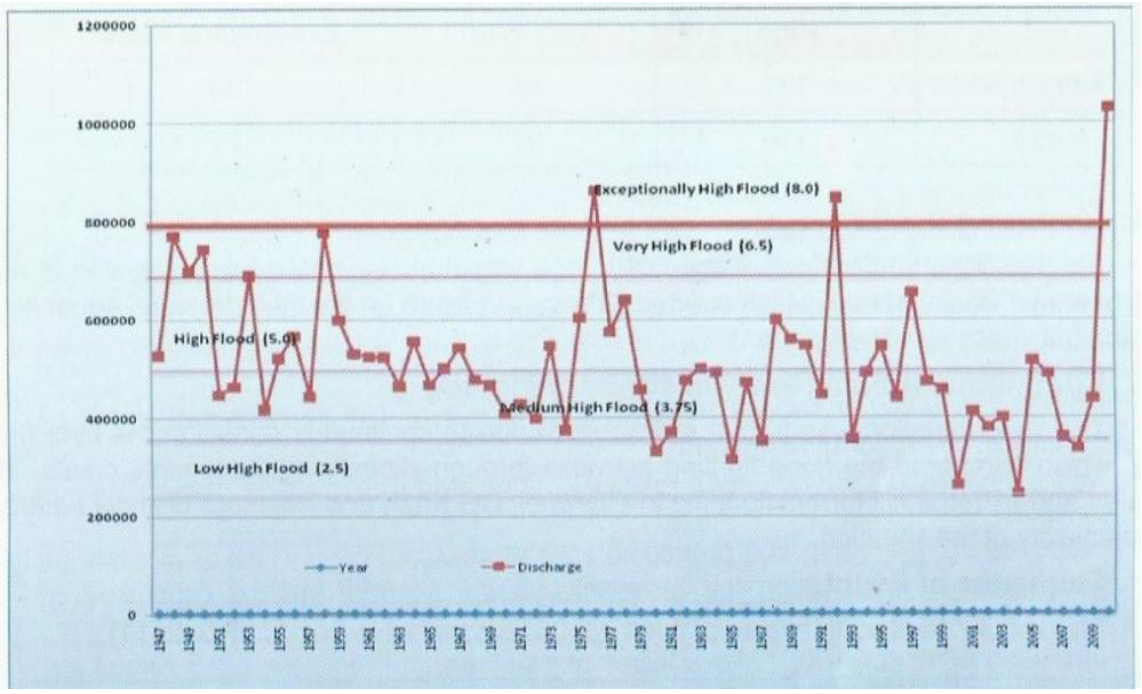


Figure 8: Graphical Representations of Flood Events from 1947 to 2010 in Case of Jinnah Barrage

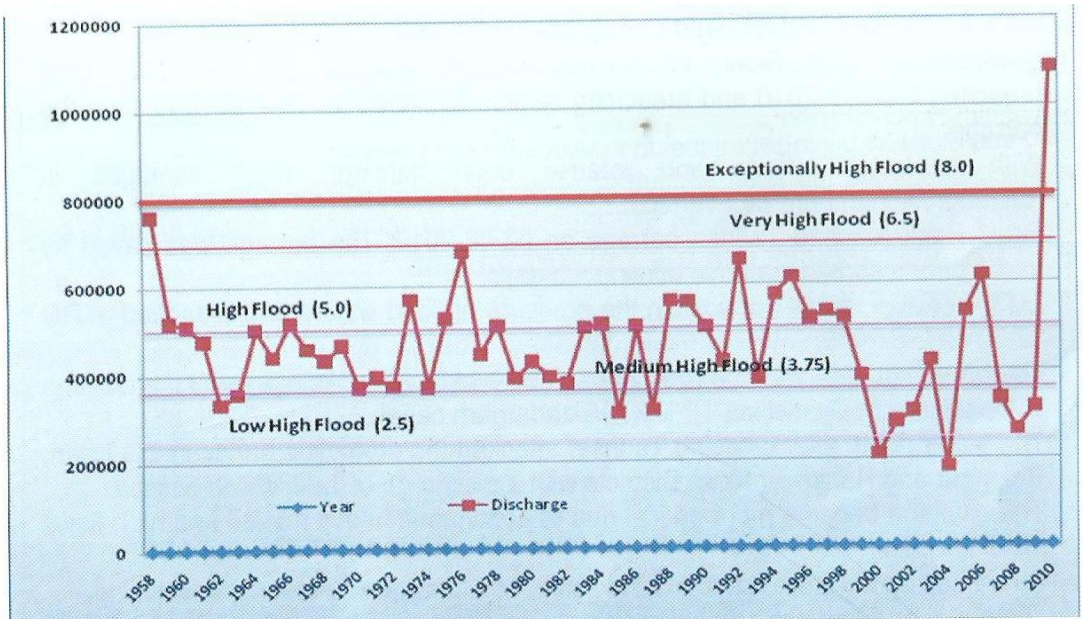


Figure 9: Graphical Representations of Flood Events from 1958 to 2010 for Taunsa Barrage

The flood of 2010 resulted in the violent breach of the Left Marginal Bund of Taunsa Barrage causing the inundation of whole of Muzaffargarh District. An aerial view of breach is shown in Figure 13. The gushing water entered the Muzaffargarh Canal and Taunsab Panjnad Link Canal and breached their banks at several places as shown in Figure 9.

Figure 10: Aerial View of Breach at LMB of Taunsa Barrage

4.3 FLOOD FIGHTING PREPARATIONS

The flood fighting and mitigation system in Pakistan has evolved over the last one hundred years or so and is based on experience and scientific research. The design and development of the existing flood works have been subject to constant revision in line with the ever increasing pattern in the magnitude of floods in intensity as well as in reach. The various flood fighting and mitigation agencies and government department have devised Standard Operation Procedures (SOPs) for all sorts and magnitudes of flood situations which is disseminated to all the concerned persons and organizations.

There are also standing instructions for all such agencies and departments. Likewise there are several monitoring mechanisms at the federal as well as the provincial and district levels which work round the year and especially before the start of the flood season starting from 15th of June every year.

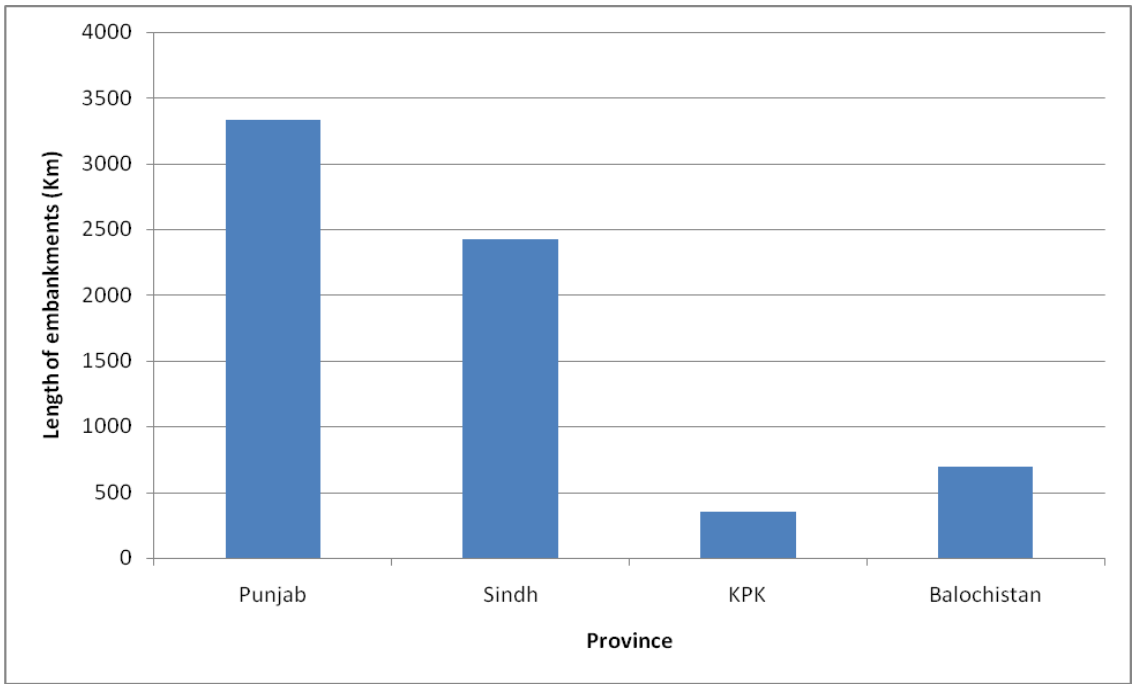
Meetings of the various flood fighting and monitoring agencies start months ahead of the flood season. Teams of Irrigation Departments, Civil Administration as well as the Pakistan Army and even Intelligence agencies are formed to inspect the flood-fighting infrastructure independent of each other. The consequent reports are perused by the authorities and decisions to address the weaknesses are taken. The government sanctions special funding for the repair and maintenance of flood works and all efforts are made to ensure that the weaknesses are covered.

Field offices prepare Flood Fighting Plans which include matters like repair and maintenance of flood embankments and bunds to the employment of additional temporary staff and the provision of necessary material for use in flood fighting. Heavy earth-moving machinery is also kept on stand bye. In short, all the provisions of men and material are made or kept ready for any eventuality. In addition to the agencies and departments directly involved in flood fighting, sister organizations like Health, Food & Agriculture, Live Stock and other departments also have their own work plans in their own spheres of responsibilities to facilitate the affected population as much as possible.

4.4 FLOOD PROTECTION MECHANISM

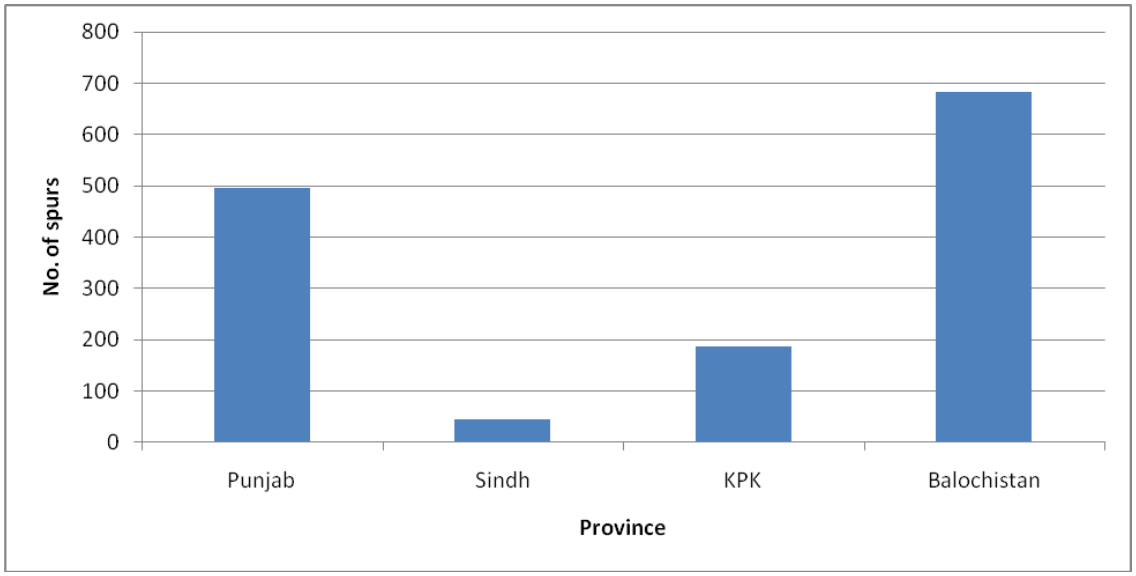
The management of flood water in Pakistan is mainly regulated at the three major reservoirs / dams, i.e., Tarbela and Chashma on the River Indus and Mangla on River Jhelum. There are also about 6807 kilometer long flood

protection embankments and some 1410 No. spurs and groyens along the rivers to fight the floods (Annual Flood Report 2014). The break-up of existing flood protection infrastructure in Pakistan is given as under:



(Source: Modified from Govt. of Pakistan, 2014)

Figure 11: Existing Flood Protection Facilities: Length of Embankments



(Source: Modified from Govt. of Pakistan, 2014)

Figure 12: Existing Flood Protection Facilities: Number of Spurs

4.5 MAJOR WEAKNESSES

If followed in true letter and spirit, the flood fighting SOPs ensure a high level of preparedness against the impending flood events. However, these procedures are not always strictly followed due to one reason or the other, the result is the devastation we have seen over the last so many years.

At Taunsa Barrage, the 2010 floods were the worst ever in the history of floods in Pakistan which need to be studied in depth and analysed on scientific basis. The devastation at Taunsa Barrage was a direct result of a number of deficiencies in the preparation procedures during the flood season. These deficiencies are enumerated below:

- The 2010 flood was the highest flood ever in the history of Taunsa Barrage with a peak discharge of 10, 85,000 cusecs against design discharge of 10,00,000 cusecs. This was a flood of a magnitude of 1 in 600 years return period by some estimation.
- The long gap between high floods had resulted in lowering of the guard in general and a casual attitude at institutional as well as professional levels.
- Flood Fighting / Management Plans were not only out-dated but were obsolete.
- There was no 'Plan-B' in case of any eventuality.
- Exceptionally high flood was experienced after many years as the last high flood with a peak discharge of 6,55,000 cusecs was recorded in 1992. So the overall state of vigilance / preparedness had declined enormously.
- The embankments had developed cracks and rat-holes were in abundance.
- The peak persisted for a long period (124 Hrs.) exerting continuous pressure on the embankments and other infrastructure as well as the supervisory staff.
- Resistance of local people in the execution of timely relief cuts was observed.
- Lack of leadership and poor coordination between the Irrigation Department and the Civil Administration.
- Deferred maintenance routines and non-following of yardstick. The yardstick was also found obsolete.

4.6 PROCEDURAL SHORTCOMINGS

- Flood Fighting Plans are just routine documents which are not updated as per field requirement and have no plan-B provision.
- Many Flood works were not maintained as per design parameters.
- Wetting Channels are inadequate in length and are not being maintained properly and no adequate pump age available to fill them up in time of need.
- Aprons of spurs not constructed at winter low level.
- Most of flood related funds are utilized on stone work and eastern embankments are given low priority.
- Poorly designed and constructed zimindara bunds with no control of authorities.
- Causal attitudes towards the implementation of various inspection reports.
- Slackness of field staff in inspection of earthen embankments for rat holes, rain cuts, and general health of the embankments.
- Inadequate provision of security, logistics, vehicles, shelter and provisions to the field staff at remote and vulnerable sites.
- Growth of uncontrolled vegetation on banks.
- Ramps and tress passing on banks.
- Lack of mobility of field staff on earthen embankments in rains.
- Encroachments.

4.7 EVENTS OF FLOOD 2010 AT TAUNSA BARRAGE

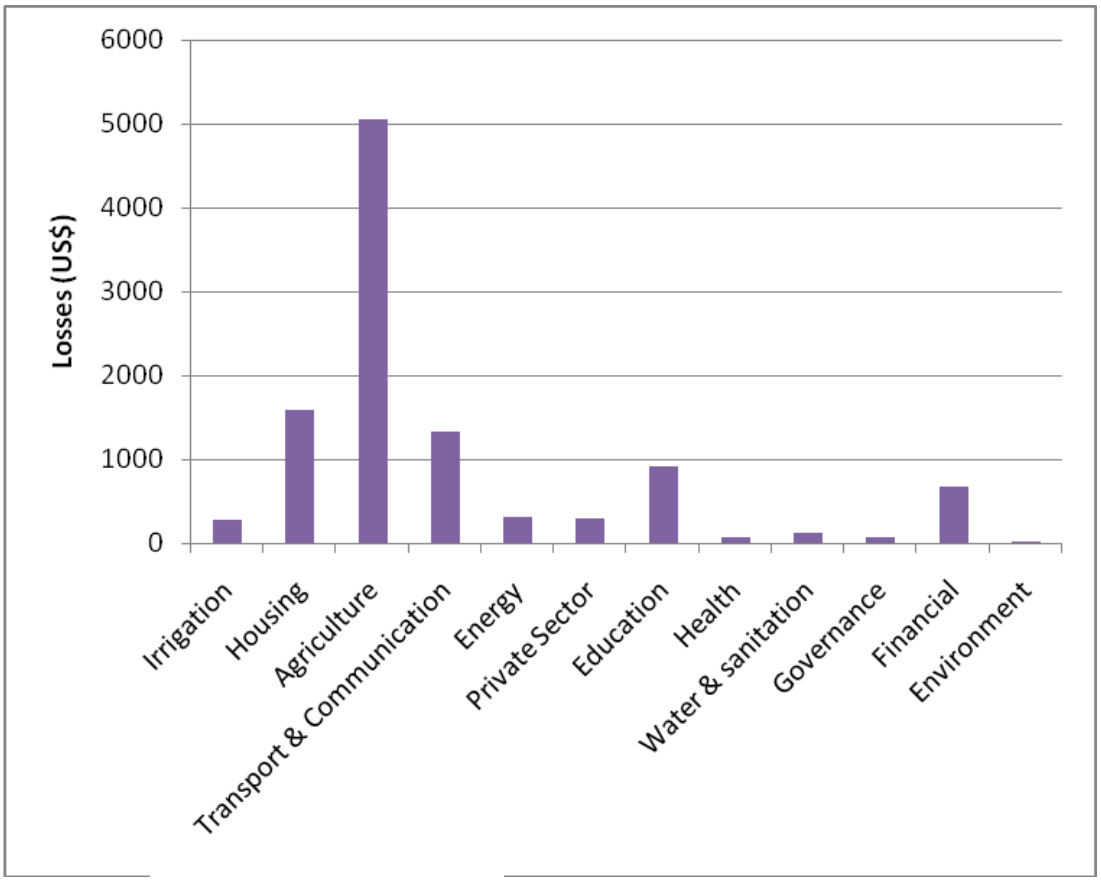
The meteorological system during July and August 2010 stretching from Europe to Central Asia and onwards to South-east Asia was peculiar in the sense that a high pressure ridge had developed in the Central Asian region. This high pressure ridge stayed stationery for a couple of months owing to the adjacent stagnant atmospherically setup. This resulted in jet stream pattern of the waterless which, resulted in heavy rain falls in western and northern Pakistan and in Afghanistan. The torrential rains in the catchment areas of River Indus, Swat and Kabul resulted in unprecedented floods in the Indus River. The flood water peak reached Jinnah Barrage on 30-07-2010 and Taunsa headwork’s on 02-08-2010.

4.8 DAMAGES AT TAUNSA BARRAGE

The barrage structure, which has a design discharge of 10,00,000 cusecs sustained the high peak of 10,85,000 cusecs fairly well but the Left Marginal Bund of the barrage breached on 02-08-2010 which developed to 5300 ft. eventually. The gushing water breached the Taunsa-Panjnad link canal and the Muzaffargarh Canal and after inundating the whole Doaba, reached the Chenab River. The major city of Muzaffargarh and other towns and agricultural areas were all submerged in flood water.

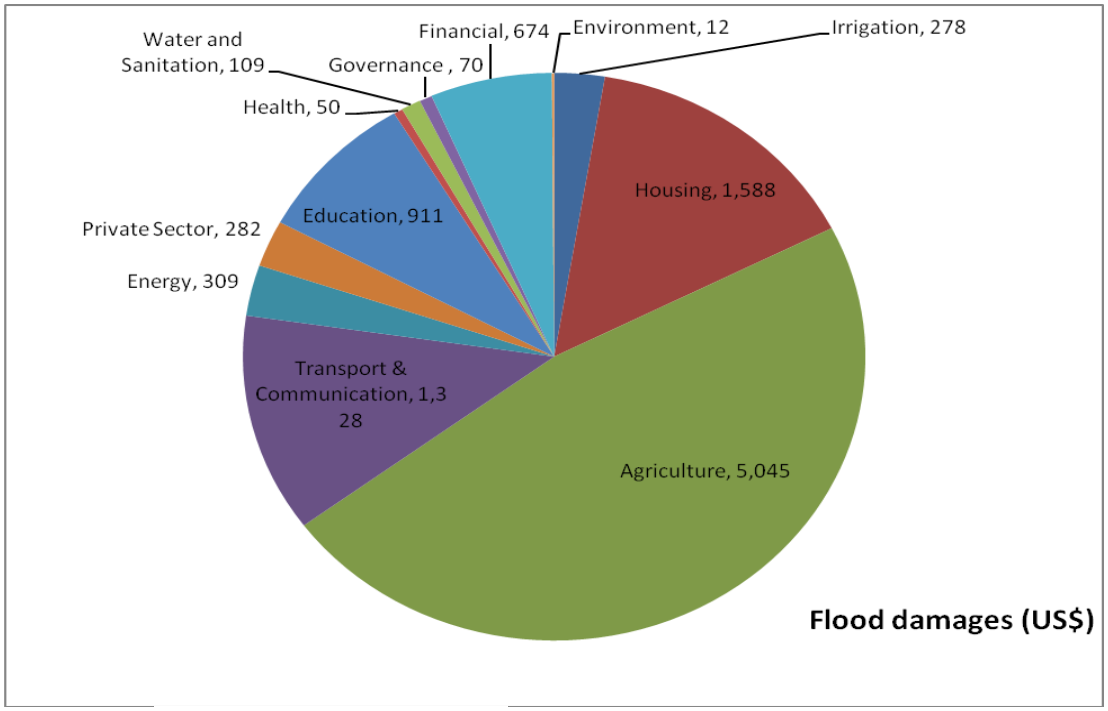
4.9 DAMAGE ASSESSMENT

The total 2010 flood damages assessed were to the tune of US$ 10.00 Billion whereas the Irrigation Department sustained damages of US$ 278 Million. It included damages to the infrastructure, agriculture, housing, etc. Following table shows the sector –wise damages in the country.



Source: Modified from Asrar-ul-Haq and Zaidi, 2011

Figure 13: Flood Damages during 2010 Flood



Source: Modified from Asrar-ul-Haq and Zaidi, 2011

Figure 14: Sector wise Damages during Flood 2010

4.10 FLOOD DAMAGES RESTORATION STRATEGY

The following strategy is generally adopted for the flood restoration works:

- **Immediate Restoration Works**
  The restoration of canal and embankment breaches is the first and foremost task to be completed. This ensures the supply of irrigation water to the already water starved area and also to contain river water within its embankments in case of another freshet. It also ensures the maintenance of pond level in case of a barrage.

- **Medium Term Restoration Works**
  The strengthening of the embankments of rivers and canals, and the restoration of other vital components of the river / irrigation infrastructure.

- **Long Term Restoration Works**
  It includes the strengthening as well as improvement of the flood protection works and other infrastructure to new levels and standards and bench-marks. Provision of second defense lines also fall under this strategy.

4.11 HISTORY OF FLOOD DAMAGES IN PAKISTAN

All the major Pakistani rivers are perennial in nature. However, the discharges in most of the cases fall to just a few thousands of cusecs in winters to hundreds of thousands of cusecs during the flow period usually starting from April each year. At the start of the flow season the discharges are mostly composed of snow-melt whereas the monsoons join during the mid-summers. Peak discharges at Taunsa Barrage, for example, during the last fifty two years are observed only during July to September.

4.12 RECOMMENDATIONS FOR MANAGEMENT OF HIGH FLOODS

Pakistan is one of the countries which is effected by the global climate change phenomenon It faced draught conditions during the year 1996 to 2002, which was the worst during the last 50 year. However, the 2010 floods were unprecedented in history and created new records for discharges, inundations and damages. The flood affected about twenty million people in Pakistan. Total loss in these floods is estimated to the range of US$ 43 billion.

Floods are natural hazards which cannot be avoided completely. However, the flood damages can be minimized to a great extent by adopting appropriate measures. Good management of floods include measures like flood prediction, evacuation, strengthening of flood-fighting techniques and infrastructure and relief measures to the effected people.

4.13 CONSTRUCTION OF DAMS

- During the flood of 2010 about 55 MAF of flood water went to the sea after passing the Kotri Barrage which is the last structure on river Indus. An estimated 17-87 MAF of flood water, however, inundated flat areas and submerged them for several months before drying up. On the river Indus the Tarbeladam adequately absorbed a flood peak of 02 lac cusecs reducing the severity of flood to a great extent. If Kalabaghdamwas there, it would have totally absorbed the flood in Indus by storing 02 MAF of water in its reservoir. Such is the impact of dams / reservoirs in the mitigation of floods. In fact, dams and reservoirs play the most vital part in the mitigation of floods. There is an urgent need to built new reservoirs and dams on river Indus to control the threat of floods. The Tarbela dam has already lost about 30% of its original storage of 9.7 MAF to 6.77 MAF.

- On the river Jhelum Pakistan maintains Mangla dam up stream of Jhelum city. It original storage capacity was 5.34 MAF which has dropped by 15% to 4.5 MAF. However the Mangla dam storage level has been raised by 30 ft. recently increasing its capacity by 2.9 MAF to 7.40 MAF with this raised reservoir capacity Mangla dam can play its decisive role in flood mitigation provided other management techniques are efficiently employed.

- Construction of Munda Dam on river Swat is essential at the earliest to mitigate flood in Swat river as it will be capable to absorb a flood of 1.29 MAF in that river.

- Construction of Diamer –Basha Dam will create a huge reservoir of 6.4 MAF and will absorb flood of this volume.

- Construction of KurramTangi Dam will absorb a flood of 1.20 MAF on Thrrans River.

- Smaller dams in all provinces of Pakistan as well as in Gilgit – Baltistan and Azad Kashmir can play their own role to mitigate flood at local levels.

4.14 FURTHER MANAGEMENT TECHNIQUES

- Construction of Chiniot dam should be considered to reduce the intensity of floods in river Chenab.

- Studies should be carried out to re-route the floods into desert areas especially for river Indus, Jhelum and Sutlej.

- Discharge capacities of barrages should be revised according to new bench marks and parameters.

- Maintenance and rehabilitation of flood protection embankments and dykes in accordance with new flood parameters.

- Construction of fuse-plugs and well defined bye-pass channels up-steam of barrages and bridges to allow the flow to return back to the main river channel.

- Improvement of drainage in the low-typing or inundated areas.

- Improvement of flood fore-casting System to allow more time period for the preparation to mitigate the on-coming flood event.

- Construction of off-channel storages to provide reduction in flood peak discharges.

- Zoning and flood plain mapping along the rivers to identify flood risk areas for human activity and settlements.

- Legislation and enforcement of law to restrict settlements in flood risk areas.

- Computerized simulation analysis to analyse and predict the real-time movement of flood peaks in different points in time. It also includes the simulated scenario analysis of the movement of flood peaks in different rivers in order to mitigate their over lapping at the confluence point.

4.15 SIMULATION OF RESERVOIR OPERATION

- Simulation of Reservoir operation is essential in order to maintain the appropriate pond level of reservoirs against the incoming / outgoing flood discharges for the most appropriate discharge controls while keeping the safety of the dam as the paramount priority.

- Regular River surveys to study the river behavior and to prepare for different magnitudes of flood.

- Creation of wet hands and lakes in depressions and swamps wherever possible.

- The main Nara Valley drain is the remains of HakraRiver or the Sarisvati River. It is a depression leading to the Arabian sea. A study should be carried out to divert the Indus flood water to the drain to minimize the pressure on the Indus river channel.

- Another study to enhance the capacity of Manchar, Hamal and otherox-bow lakes of river Indus may be carried out to divert the Indus water.

4.16 COORDINATION BETWEEN VARIOUS GOVERNMENT AGENCIES

- Lack of coordination between various government agencies has been observed during high floods. Either the preparations for the floods are two much in isolation with each other or the duties of the agencies are not well-defined. Lack of training and professionalism is another factor. The main coordination role has to be performed by the District Coordination Officer among the various relevant departments such as Irrigation, Agriculture, Police, Health, C&W, Pakistan Railway, NDMA/PDMA, Army, etc.

- Mock exercise and drills should be arranged before the floods. Meetings and training sessions should also be arranged at various levels. Every functionary should know his duty in the time of emergency. Right man for the right job is the slogan.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Major conclusions of the study are summarized as under:

- Floods are a natural phenomenon which cannot be avoided but can be safely managed to minimize damages to public and private property by utilizing latest technical and management techniques.
- The 2010 floods inflicted maximum damage to the agricultural sector.
- The areas adjoining the river courses were affected the most.
- Maximum river flood related damages occurred during the year 2010.
- A peak discharge of 1085000 cusecs was observed at Taunsa barrage during 2010 against design discharge of 1000000 cusecs.
- The peak discharge continued for 124 hours against a usual peak discharge of 24 to 48 hours.
- The Left Marginal Bund / Dyke breached due to the high discharge resulting in the inundation of district Muzaffargarh.

5.2 RECOMMENDATIONS

The following important interventions need to be implemented for improving management and mitigation of floods in the country:

- Build water storages to mitigate the impact of super floods.
- Build back better and safer structures keeping in view the new standards and benchmarks.
- Proactive planning in disaster preparedness; and management for relief and early recovery when it occurs.

- Better regulation of riverine areas.
- Better coordination between the state and the media.
- Flood protection works should be given due importance in resource allocation irrespective of the infrequency of floods.
- Regular updating of SOPs (Standard Operating Procedures), drills for disaster management, capacity building / training of managers for flood protection, barrage management and public handling during crisis.
- Promotion of spirit of self reliance in emergency relief and post disaster rehabilitation.

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APPENDIX

Plagiarism Report