Paper No.193

CAUSES OF 2022 FLOODS, RECOMMENDATIONS FOR EARLY REHABILITATION & RECOMMENDATIONS TO AVOID MAJOR DEVASTATION IN FUTURE

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By

Engr. Muhammad Mohsin Munir[1]

1. Foreword

Torrential flash floods 2022 caused damages to overall Infrastructure in Pakistan. This paper envisages to identify the root-causes of recent devastating flash floods of 2022 across Pakistan, make recommendations for rapid rehabilitation and take futuristic measures/ Way Forward to avoid such major destruction in future. Accordingly, this position paper has been prepared for consideration by the Committee in its next meeting and accordingly suggest futuristic remedial/rehabilitation measures.

2. PREAMBLE

Pakistan has been facing ferocity of frequent and ever intense devastating floods owing to adverse impacts of very visible climate change. Almost three months have passed since the devastating floods of 2022 began, yet the catastrophe is not over. Millions of people face increased food insecurity as families are returning to their destroyed houses, with ruined crops, and dead livestock. Access to clean water, sanitation and hygiene remain challenging and still standing flood water has significantly led to a rise in water and vector-borne diseases. The 2022 floods have been caused by highly exceptionally heavy rains in the country that followed a severe heat wave, both linked to climate change.

In order to achieve an effective management of floods, role of Engineering Departments/institutions (such as Irrigation, WAPDA, IRSA, PMD etc.) is vital in additional to administration departments which are providing the relief to the effected people (such as Health department, Army, FFC, PDMA, NDMA, NGOs etc.). It is obvious from lessons learnt of 2022 flood and later floods of 2010, 2011, 2012, 2013, 2014, that the traditional approaches of controlling floods through structural measures alone is not sufficient and a more comprehensive, innovative measures need to be adopted to minimize flood damages in the future.

3. Flood Categorization

Pakistan is traversed by the mighty Indus, its four eastern rivers of Jhelum, Chenab, Ravi and Sutlej and also a large number of big and small tributaries including the hill torrents, a major portion of the catchment of the main rivers lies in the high mountains where due to steep grades, heavy and sudden run-off is generated by melting of snow and the rainfall as shown in **Figure 1**. These high

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flows inundate a large area in the plains because of flat topography. The numerous hill torrents bordering the plains also bring flashy floods which too contribute towards the creation of flood situation enroute. The problem is diversified in nature and varies from area to area depending upon the physical, hydrological and socio-economic conditions. The more severe flood problem is however encountered during the monsoon season from July to September.

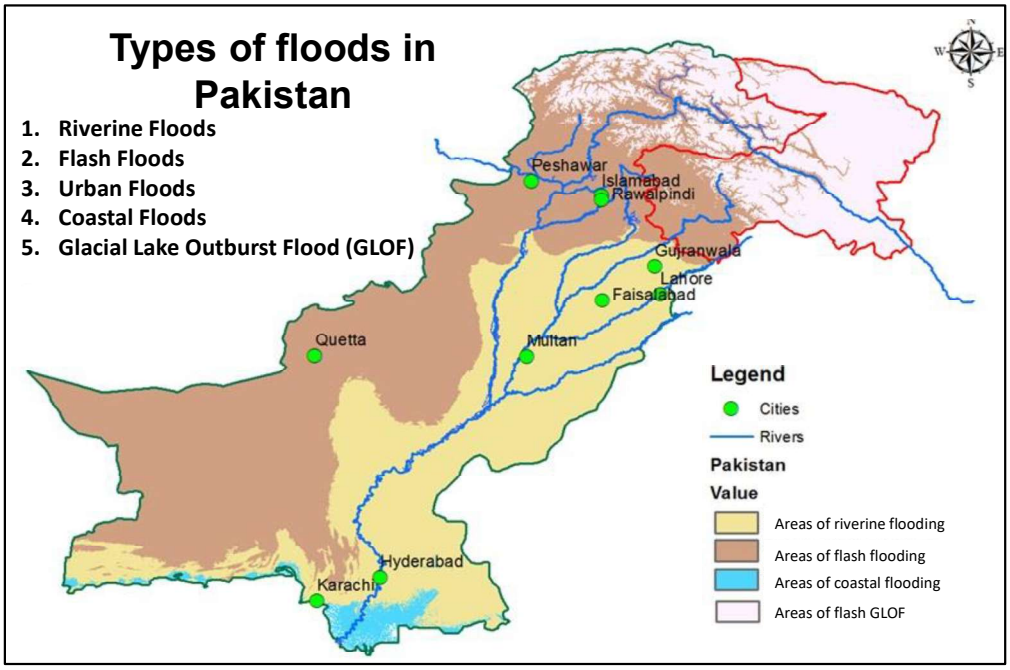


Figure 2: Types of Floods in Pakistan

3.1 Riverine Floods

The floods in rivers are generally caused by heavy concentrated rainfall in the upper catchments, during the monsoon season (July through September), which is sometimes augmented by snow melt flows. Monsoon currents originating in the Bay of Bengal and resultant depressions often result in heavy downpour in the Western Himalayan foothills which occasionally produce destructive floods in one or more of the main rivers of the Indus system.

3.2 Flash Floods in Hill Torrents

Flash floods in the hill torrents occur primarily in mountainous, semi-mountainous regions and in adjoining piedmont. It can also be described as sudden severe increase in the flow of river/stream water within short interval of time (6 hours of causative event). There are thirteen (13) major hill torrent areas of Pakistan which are highly vulnerable towards flood damages. Historic flood events due to high intensity rainfall over Kirther and Koh-e-Suleman hill ranges resulted in huge damages.

3.3 Coastal Floods

Weather and tidal conditions can increase sea levels that result in flooding along coastal areas. The cause of such a surge is generally a severe storm or cyclonic activity in Arabian Sea. The storm wind pushes the water up and creates high waves. Winds generated from tropical storms and hurricanes or intense offshore low pressure systems can drive sea water inland and cause significant flooding. The Makran Coast of Balochistan and south-eastern Sindh experienced such coastal floods from tropical cyclones from Arabian Sea.

3.4 Urban Floods

High intensity rainfall can cause flooding, when the city drainage system does not have the adequate capacity to drain away the runoff generated through concentrated rains. Urban floods are a great disturbance for daily life in the city. Urban floods are being experienced in Pakistan cities, especially in monsoon season-having high population density (Karachi, Lahore, Faisalabad, Multan, Hyderabad, etc.,) with unplanned, clogged, encroached and undersized drainage systems.

3.5 Glacial Lake Outburst Floods

Glacier outburst floods may be broadly defined as the sudden release of water stored either within a glacier or dammed by a glacier. Outburst floods have been reported in all glaciated regions of the world and may be triggered by:

- The sudden drainage of an ice-dammed lake below or through an ice dam;
- Lake water overflow and rapid fluvial incision of ice, bedrock or sediment barriers occur; or
- The growth and collapse of sub-surface reservoirs.

Due to their high and rapid discharge, the outburst floods originating from high mountain glaciers have devastating impacts on downstream communities. The areas of Gilgit-Baltistan region many times experienced glacier outburst floods. The type of flood in the rivers are categorized by the level of flows and its inundation as given in Table 1. Based on the upstream catchment characteristics, western and eastern rivers floods are distinguished as shown in Table 1.

Table 1: Flood Limits

Low Flood	River flowing within deep channel(s) but about to spill over River island / belas.
Medium Flood	River partly inundating River island / belas.
High Flood	River almost fully submerging island / belas and flowing upto high banks / bunds but without encroachment on the freeboard.
Very High Flood	River flowing between high banks / bunds with encroachment on the freeboard.
Exceptional High Flood	There is imminent danger of overtopping / breaching or a breach has actually occurred, or high bank areas become inundated.

Major factors influencing floods disasters include:

1. Uneven population density
2. Unplanned development
3. Poverty
4. Pressure on natural resources
5. Natural hazards
6. Sea intrusion
7. Soil erosion
8. Migration
9. Deforestation
10. Loss of habitat
11. Encroachment in the flood plain

4. PMD's Seasonal Outlook for Monsoon Season 2022

Based on the then prevailing global and regional circulation patterns (i.e., on July 04, 2022), Pakistan Meteorological Department (PMD) predicted overall above normal precipitation for monsoon season (July-August-September; JAS) 2022 over most parts of the country i.e., over the Central Punjab and southern parts of Sindh of the country whereas slightly above normal rainfall over remaining parts of the country as shown in **Figure 2 and Figure 3**. PMD, hence, predicted flash flooding in hill torrents of Punjab, Khyber Pakhtunkhwa and Azad Jammu & Kashmir and also urban flooding in major plain areas of Punjab, Sindh and Khyber Pakhtunkhwa.

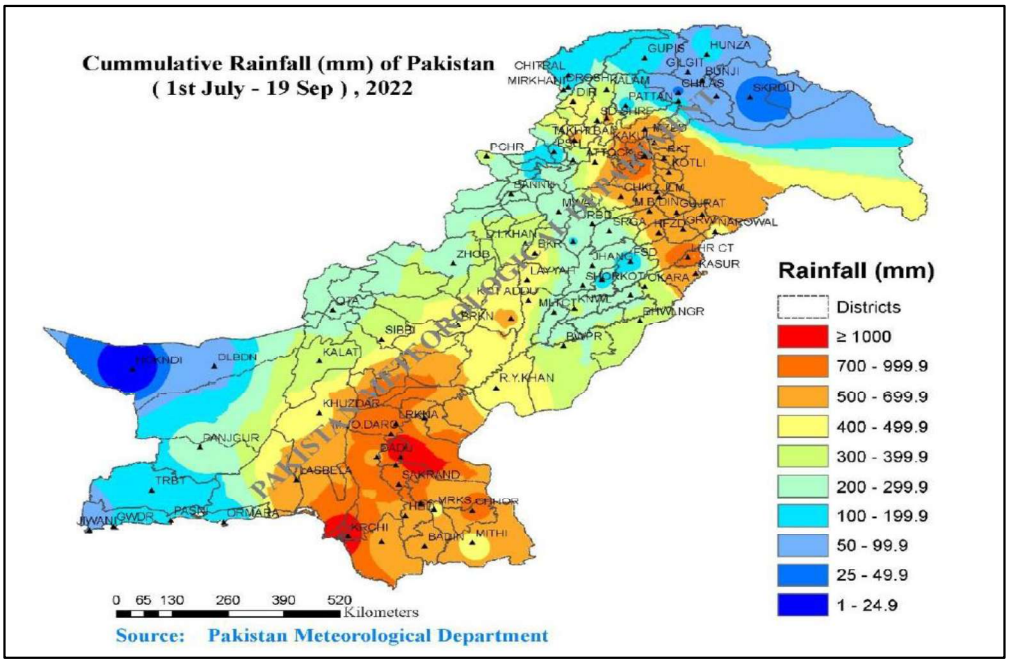


Figure 2: Rainfall (mm) Actually Observed across the Country (Ref: FFC, 2022)

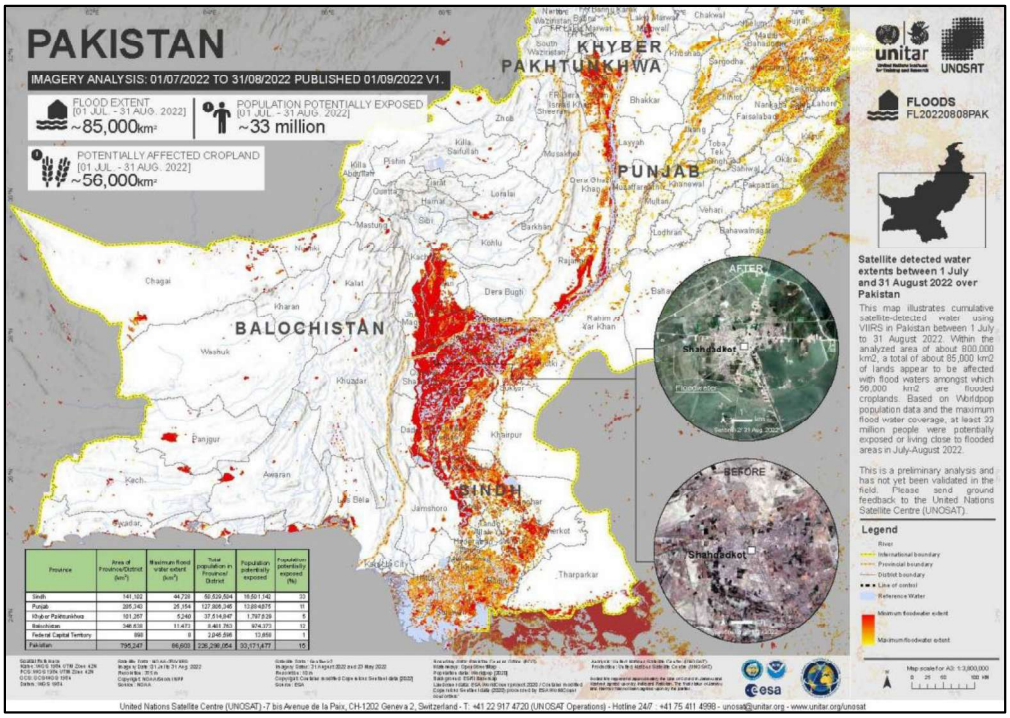


Figure 3: Flood-2022 Inundation Areas in Indus River System

5. Rainfall Recorded during 2022 Monsoon Season

The unprecedented rain induced floods-2022 in Pakistan were caused by the heavier than un-usual monsoon cycle due to rise in sea water temperature, excessive and consecutive Heat Waves in southern parts of the country in May and June 2022 owing to the global warming by climate change. PMD had forecasted (about 40%) above normal) all over the country during 2022 Monsoon Season, however, cumulative rainfall received were around 175% above the normal all across the country. Province wise rainfall including that for Punjab province is shown in **Table 2.**

Table 2: Province wise Rainfall actually observed across the Country (Ref: FFC, 2022)

Sr. #	Province	Rainfall Occurred (mm)	Rainfall Occurred (%age above Normal)
1.	Sindh	703.1 mm	426% above normal
2.	Balochistan	320.7 mm	450% above normal
3.	**Punjab**	**393.5 mm**	**70% above normal**
4.	Khyber Pakhtunkhwa	341.1 mm	33% above normal
5.	Gilgit-Baltistan	81.1 mm	104% above normal
6.	Azad Jammu & Kashmir	382.6 mm	2% less than normal

6. Flood Peaks and Record Torrential Flows observed during 2022

Due to heavy monsoon rains, widespread flooding in Baluchistan, Sindh, Khyber Pakhtunkhwa and Punjab was witnessed during the flood season 2022 and the pattern was erratic and more than usual. There are 13 Nos major Hill torrents in DG Khan and Rajanpur District. A great part of catchment area of these major Hill torrents lies also in Baluchistan. Consequently, flash floods triggered in Koh-e-Suleman range of Punjab especially in DG Khan, Rajanpur and Mianwali besides also in upper catchments of River Chenab and Ravi. & and worst hit areas are Taunsa, DG Khan Fazilpur and Rojhan.

Very high flood at Aik (18,327 Cusecs) & Deg (40,650 Cusecs) whereas Medium flood at Bein (5,722 Cusecs) & Basantar (5,014 Cs) as well as for Palkhu (4,421 Cs) was experienced during 2022 monsoon season. Details related to record floods generated in most of the 13 Major Hill Torrents of D.G. Khan and Rajanpur Districts. Detail may be seen in **Table 3**. The peaks are shown in **Table 4.**

Table 3: Flood Flows in Hill Torrents of D.G. Khan and Rajanpur Districts (Ref: FFC, 2022)

DG Khan Hill Torrent Region		Rajanpur Hill Torrent Region	
Gauge Station	**Flood Peak (Cusecs)**	**Gauge Station**	**Flood Peak (Cusecs)**
Kaura	**105,668 @ 26.8.2022**	Kaha	**108,941 @ 14.8.2022**
Vehova	**154,362 @ 14.8.2022**	Chachar	**75,900 @ 21.8.2022**
Sanghar	**268,149 @ 14.8.2022**	Sori Janubi	**17,000 @ 4.8.2022**
Sori Lund	**135,544 @ 21.8.2022**	Pitok	**5,000@ 25.8.2022**
Vidor	**175,360 @ 21.8.2022**	Sori Shomali	7,150 @ 2.8.2010
Sakhi Sarwar	32,643 @ 4.8.2010	Zandi	**9,000 @ 25.8.2022**
Mithawan	61,905 @ 8.8.2010	-	-

Table 4: Flood Peaks (Cusec) observed in Major Rivers during 2022 Monsoon Season

Sites	Peak Inflows (Cusecs)		Peak Outflows (Cusecs)		Classification
	Flow	Date & Time	Flow	Date & Time	
River Indus					
Tarbela	**404,000**	26-08 @ 2359 hrs	**418,600**	26-08 @ 2359 hrs	**Medium Flood**
Kalabagh	**427,000**	28-08 @ 0600 hrs	**423,000**	28-08 @ 0600 hrs	**Medium Flood**
Chashma	**525,437**	28-08 @1200 hrs	**523,937**	28-08 @1200 hrs	**High Flood**
Taunsa	**622,000**	30-08 @0600 hrs	**622,000**	30-08 @1500 hrs	**High Flood**
Guddu	**576,000**	23-08 @ 1800 hrs	**576,000**	23-08 @ 1800 hrs	**High Flood**
Sukkur	**580,000**	25-08 @ 0600 hrs	**580,000**	25-08 @ 0600 hrs	**High Flood**
Kotri	**626,000**	11-09 @ 0600 hrs	**600,000**	10-09 @ 0600 hrs	**High Flood**
River Kabul					
Nowshera	-	-	**336,461**	27-08 @ 12:30 hrs	**Very High Flood**
Warsak	-	-	**139,086**	27-08 @ 12:30 hrs	**High Flood**
River Jhelum					
Mangla	**95,000**	27-07 @ 0600 hrs	**40,720**	01-07 @ 1200 hrs	**Normal**
Rasul	**25,358**	22-06 @ 1200 hrs	**23,610**	22-06 @ 1200 hrs	**Normal**
River Chenab					
Marala	**225,836**	**28-07 @ 1800 hrs**	**210,936**	**28-07 @ 1800 hrs**	**High Flood**
Khanki	**216,907**	12-08 @ 0500 hrs	**210,945**	12-08 @ 0500 hrs	**High Flood**
Qadirabad	**221,000**	12-08 @ 1000 hrs	**202,000**	12-08 @ 1000 hrs	**High Flood**
Trimmu	**144,147**	31-07 @ 2359 hrs	**112,891**	14-08 @ 1800 hrs	**Normal**
Panjnad	**121,764**	03-08 @ 0600 hrs	**112,564**	03-08 @ 0600 hrs	**Normal**
River Ravi					
Balloki	**52,435**	**03-08 @ 0600 hrs**	**35,235**	**03-08 @ 0600 hrs**	**Normal**
Sidhnai	**22,742**	27-07 @ 1800 hrs	**21,642**	27-07 @ 1800 hrs	Normal
River Sutlej					
Sulemanki	**24,670**	19-07 @ 1800 hrs	**17,462**	19-07 @ 1800 hrs	Normal
Islam	**13,326**	23-07 @ 1800 hrs	**12,501**	23-07 @ 1800 hrs	Normal

7. Flood Damages in Punjab Province

Floods 2022 adversely affected the districts DG Khan and Rajanpur. Worst-hit areas in Punjab Province were Taunsa Sharif, DG Khan, Fazilpur and Rojhan

wherein hill torrent structures of D.G Khan Canal and its system, and drainage network overtopped from numerous spots leaving behind massive destruction to the infrastructure and public and private properties. CRBC main canal system was badly affected due to Vehova and Sanghar Hill Torrents, Kachhi Canal, D.G. Khan Canal and existing drainage system were also breached by Sori Lund, Vidore, Sakhi Sarwar and Mithawan Hill Torrents. The structures on the Hill torrents were also damaged badly.

As per the assessment reports received from Provinces, total Estimates Cost of Structural Flood Damages occurred to Irrigation, Drainage & Flood Protection Infrastructure is around Rs 155.465 Billion**.** Province wise detail is given in **Table 5.**

Table 5: Damages to Irrigation, Drainage & Flood Protection Infrastructure (FFC, 2022)

Sr. #	Province/ Region	No. of Structures Damaged	Estimated Cost (Rs. in Billion)
A.	**WAPDA**		
1.	WAPDA	31	9.393
	Sub-Total (A)	**31**	**9.393**
B.	**PIDs & Federal Line Agencies (FLAs)**		
2.	**Punjab**	**204**	**5.208**
3.	Sindh	1,366	94.78
4.	Khyber Pakhtunkhwa	2,885	22.387
5.	Balochistan (Including Small	974	22.18
6.	Azad Jammu & Kashmir *(Water Channels, Water storage tanks & Flood Protection Structures)*	82	0.115
7.	Gilgit-Baltistan	464	0.4017
	Sub-Total (B)	**5,975**	**145.0717**
	Grand Total (A+B)	**6,006**	**154.4647**

Province-wise detail of damages caused to houses and road infrastructure, including that for Punjab Province, is given in **Table 6**.

Table 6: Province wise 2022 Damages caused to Infrastructure (Source: NDMA)

Province /Region	Roads (km)	Bridges	Houses			Livestock
			PD	FD	Total	
AJ&K	19	33	228	327	**555**	792
Balochistan	2,222	58	125,837*	115,822*	**241,659**	500,000^
GB	33	61	1,126	667	**1,793**	609
ICT	-	-	-	-	**-**	-
KP	1,575	107	53,939	37,525	**91,464**	21,328
Punjab	877	15	42,127	25,854	**67,981**	205,106>
Sindh	8,389	165	1,168,210	716,819	**1,885,029**	436,435
TOTAL	**13,115**	**439**	**1,391,467**	**897,014**	**2,288,481**	**1,164,270**

Data reconciliation:

*PDMA Balochistan has reconciled and updated the figures of house damaged based on reports received from District Management Authorities.

^ Tentative livestock loss of Balochistan (so far confirmed figures are 434,424)

> Reported figures are being verified from PDMA Punjab.

According to PDMA-Punjab's last report on 2022 flood damages dated October 16, 2022, a total area of 1,312,933 acres have been affected by 2022 floods in Punjab province which includes agriculture/ crop lands of 706,777 acres. As per the report, details related to infrastructure damages occurred in Punjab Province, are given below in **Figure 4**.

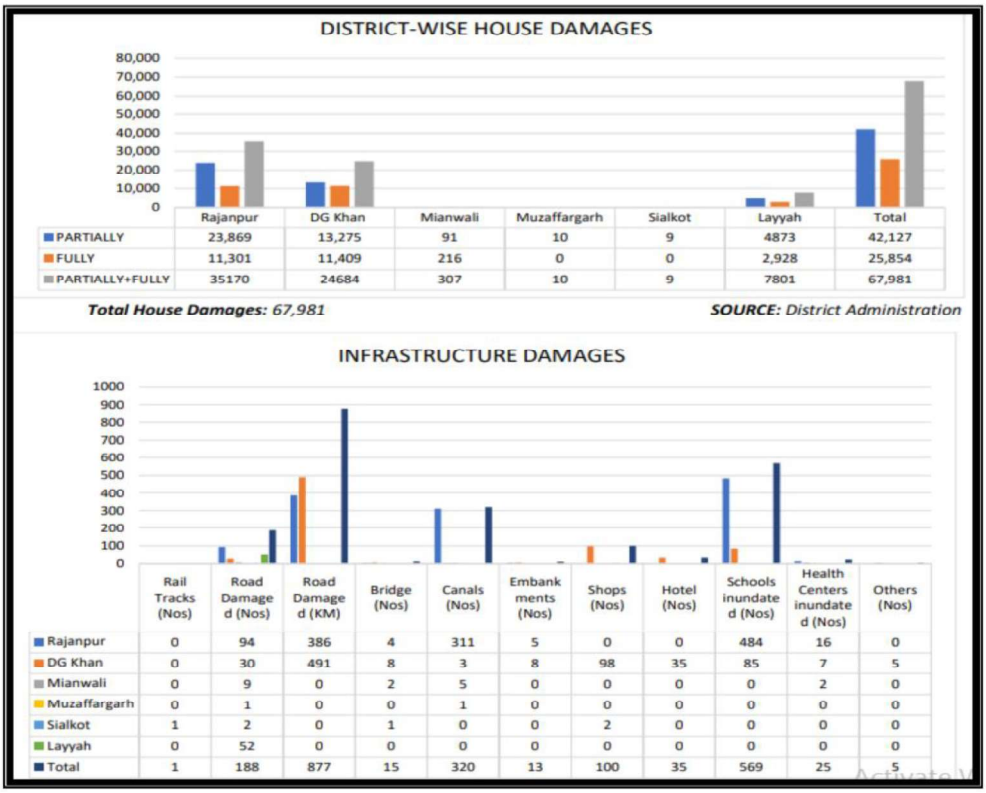


Figure 4: Flood-2022 Damages to Infrastructure in Punjab
(Source: PDMA-Punjab)

8. Damages due to hill torrents

- The flood water of Hill Torrents fans out in pachad area and ponds-up along the right embankment of Kachhi Canal as shown in **Figure 5.**
- Further, flood water after passing through cross-drainage structures of Kachhi, D.G. Khan Canals and induced cuts, frequently creates disaster in the command areas of DG Khan canal up to River Indus.
- During the month of Aug-2022, the devastating flash floods hit the areas of Rajanpur and DG Khan Districts as shown in **Figure 6 and 7**. The immediate damages to the infra-structure were followed up by long ponding up of flood water in the area due to restricted drainage. Comparison of 2022 flood peak with historic peak is shown in **Figure 8.**



Figure 5: Inundation during 2022-Flood

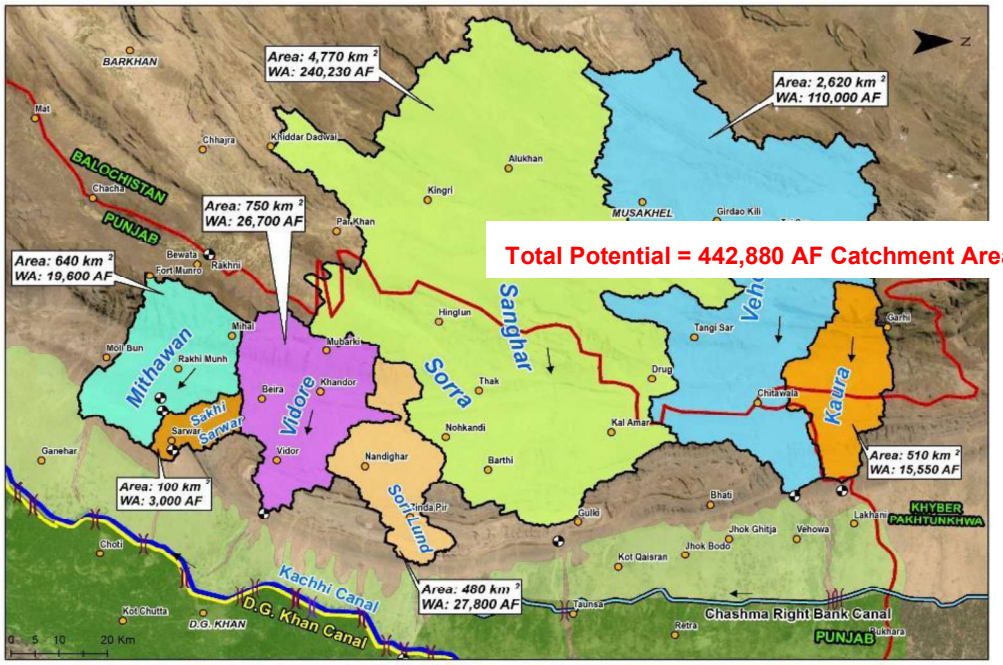


Figure 6: Suleiman Range - Hill Torrents in DG Khan

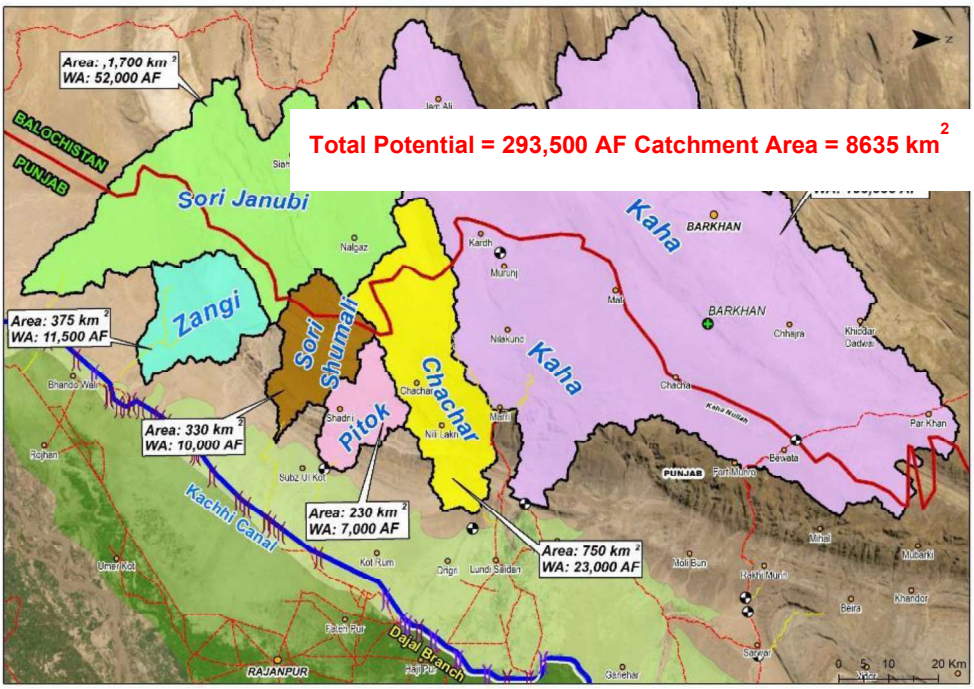


Figure 7: Suleiman Range - Hill Torrents in Rajanpur

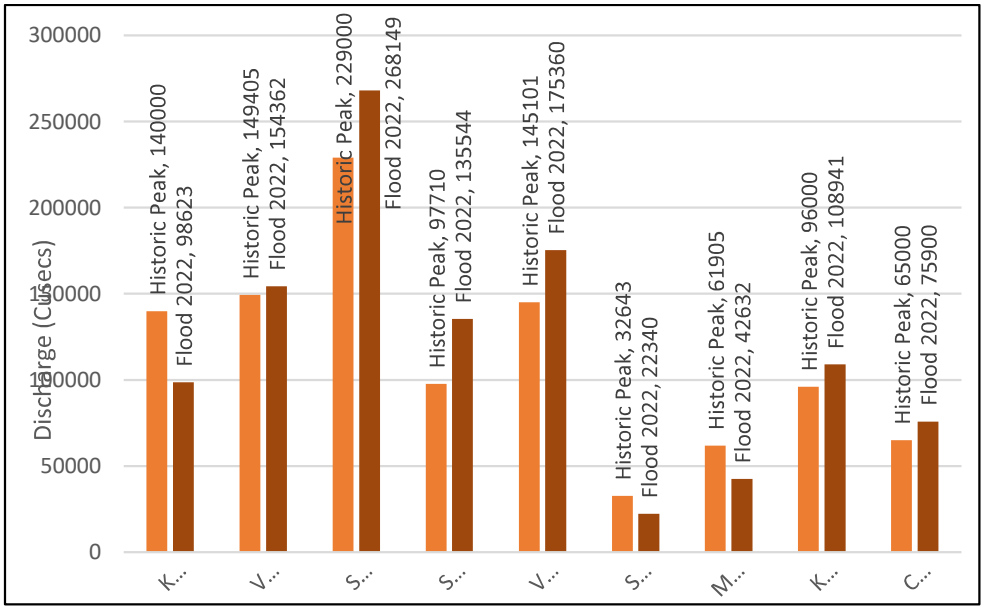


Figure 8: Comparison of Historic Flood Peaks With 2022 Flood

9. SHORTCOMINGS, CONSTRAINTS AND GAPS IN FLOOD MANAGEMENT 2022

1. Shortcomings in Policy and Planning
2. Shortcomings in Design Flood Limits and its Criteria
3. Limitations in Barrage/Bridge Capacities
4. Constraints in Flood Early Warning System
5. Financial Limitations and Constraints

GAPS

- **Institutional Gaps**

i. Lack of coordination between federal and provincial departments during floods

ii. Lack of technical data sharing mechanism among departments

iii. Lack of expertise and specialists in flood handling departments

iv. Lack of definition of roles and responsibility in departments towards floodplain

Encroachments

- **Managerial Gaps**

i. Lack of regular inspection/monitoring of flood protection structures

ii. Lack of technical expertise in operation of water control structures

iii. Lack of information and real-time instructions at water control structures

- **Technical Gaps**

i. Limited real-time data availability

ii. Low density of hydro-meteorological gauges as compared to international standards

iii. Limited information on spatial and temporal forecast of Monsoon events

The flood management mechanism chart is shown in **Figure 9.**

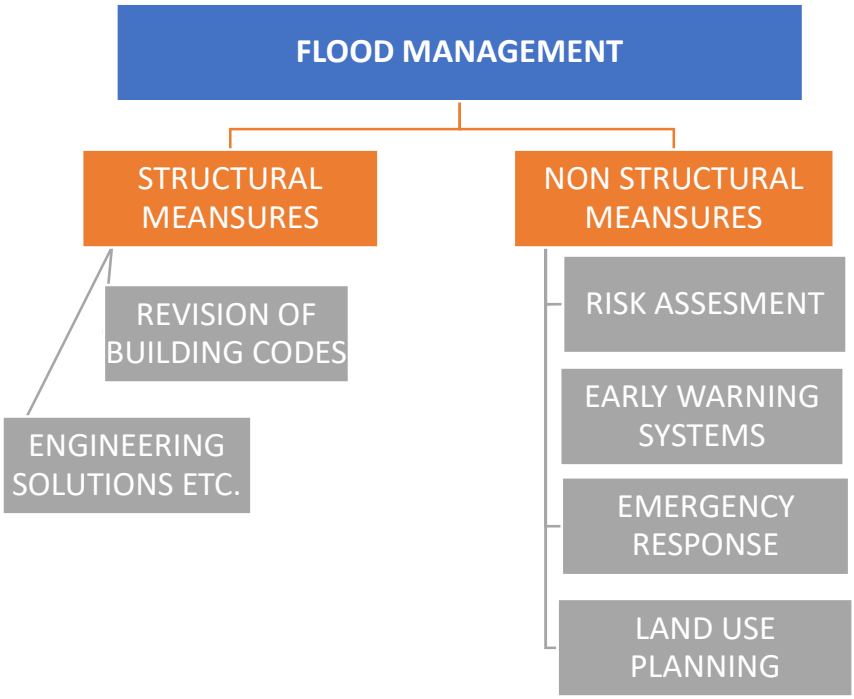


Figure 9: FLOOD MANAGEMENT MECHANISM

The summary of structural and non-structural measures in integrated flood management are shown in **Table 7**.

Table 7: Non-structural and Structural Measures in Integrated Flood Management

Strategy	Options	Category
Reducing Flood	Watershed management	Non-structural Measure
	Dams and reservoirs	Structural & Non-structural Measure
	High flow diversions	Structural & Non-structural Measure
	Channel improvement	Structural & Non-structural Measure
Reducing Susceptibility to Damage	Flood Forecasting and Early Warning	Non-structural Measure
	Strengthening of existing rain and river gauging network	Non-structural Measure
	Floodplain regulation	Non-structural Measure
	Construction of flood protection and river training works i.e. levees, dikes, spurs etc.,	Structural Measure
Mitigating the Flood Impacts	Information and education	Non-structural Measure
	Disaster preparedness	Non-structural Measure
	Post- flood recovery	Non-structural Measure
	Flood insurance	Non-structural Measure

10. FLASH FLOOD MANAGEMENT IN HILL TORRENTS AREAS

The maximum damages have examined in D.G. Khan, Rajanpur and D.I. Khan Districts.

1. Short to Medium Term Measures:
    - Provision of Dispersion Structures
    - Provision of Storage Ponds
    - Channelization of Wahs/ Sub wahs
2. Long Term Measures
    - Construction of Dams
    - Drainage network

11. GENERAL RECOMMENDATIONS

- Pre-flood Inspection of the headworks including training works
- Flood fighting plans need to be updated
- The Breaching sections must be ready to be operated.
- Monsoon Research Centre to be set up under the auspices of PMD to develop more depth and understanding of Monsoons in Pakistan.
- New and latest radars and other equipment to be installed for the catchment areas of Indus as well as the hill torrents.
- Better-qualified, trained, experienced and paid human resource be employed so that proper forecasts are generated at the right time.

- The infrastructure regarding purchase of new Radars and other equipment must be ensured so that MET Office is always in the best state of preparedness at all times.
- Flood Manual (as a subset of an Integrated Flood Management Plan) be developed including instructions from the exiting flood fighting plans, Guidelines, Manual of Irrigation Practice (M.I.P), Sind Bund Manual and other related instructions available on the record.
- Enhanced Flood Resilience of major cities through structural interventions; additional flood bypass channels etc.
- Urban Flood Management SOPs to be prepared by District Administrations.
- Replication of Urban Flood Management System similar/ alike Lai Nullah Flood Forecasting System of Rawalpindi & Islamabad in other major cities.
- River Acts should be enacted in all the provinces and existing land use regulations be implemented strictly in letter and spirit to avoid major loss of life and property in future floods.
- Flood Plain Maps, prepared under National Flood Protection Plan No. IV (NFPP-IV) studies already in place and circulated widely among the provinces, can help determine the extent of inundation and must be used for flood warning in respective districts by the District Disaster Management Authorities (DDMAs). The maps indicate the areas that may submerge at certain flood level/ river discharge.
- Large scale forestation in upper catchments of all the rivers for reducing flood intensity in upper reaches and support combating climate change impacts
- Institutional Capacity Building and Strengthening like; FFC, Modernization of Irrigation Research Institute (IRI), Nandipur, as proposed by the Irrigation Department, Government of the Punjab, Lahore.
- Increased allocation of funds under Provincial ADP for flood protection management works. Also increased O&M yardstick of Maintenance & Rehabilitation (M&R) allocation for existing flood protection infrastructure.

12. SPECIFIC RECOMMENDATIONS PERTINENT TO HILL TORRENTS

1. Government Must Sets Up Hill Torrent Management Policy
2. Implementation Of National Master Plan on Flood Telemetry Network (As A Sub-Project of FPSCP-III With Emphasis on Improved Flood Telemetry Along Hill Torrents (D.G. Khan, Rajanpur & Kirther Range)
3. A Detail Audit Be Conducted Before the Next Flood Season to Assess the Allocation and Utilization of Funds
4. Hill Torrents Contribute to The Flood Peaks and Have Not Been Harnessed or Tamed Over the Years. This Rich Water Resource Can

Be Channelized and Stored for Agriculture in one of The Most Backward Districts of Punjab I.E., DG Khan And Rajanpur.

5. There Is No Reliable Data of The Hill Torrents Discharge That Gets Added to The Peak Discharges in River Indus
6. Rajanpur District Clearly Highlights That Active Flood Plain and The Torrent Flood Plains are the Worst Hit Areas.
7. The Structural Measures that may Be Provided to Reduce the Flood Impact of Hill Torrents by Flood Distribution / Dispersion Structures in Order to Utilize Maximum Flood Flows for Agriculture include; Flood Training Structures Like Guide Banks, Spurs and Auxiliary Weirs for Controlled Channelization of Flood Flows and by Protection of Flood Prone Dwellings by Providing the Appropriate Training and Protection Structures.
8. Construction Of Water Storage Reservoirs Can Only Help Better Manage Flood Waters, In Particular Generating from Hill Torrents; Hill Torrents Generated Almost 9 MAF of Water During Monsoon Season 2022.

Flood Dispersal Structures Along Major Hill Torrents Including Retrofitting of Existing Flood Protection Infrastructure