WORLD WATER DAY
MARCH 2020

on the theme of
Water and Climate Change

Celebrated by
PAKISTAN ENGINEERING CONGRESS

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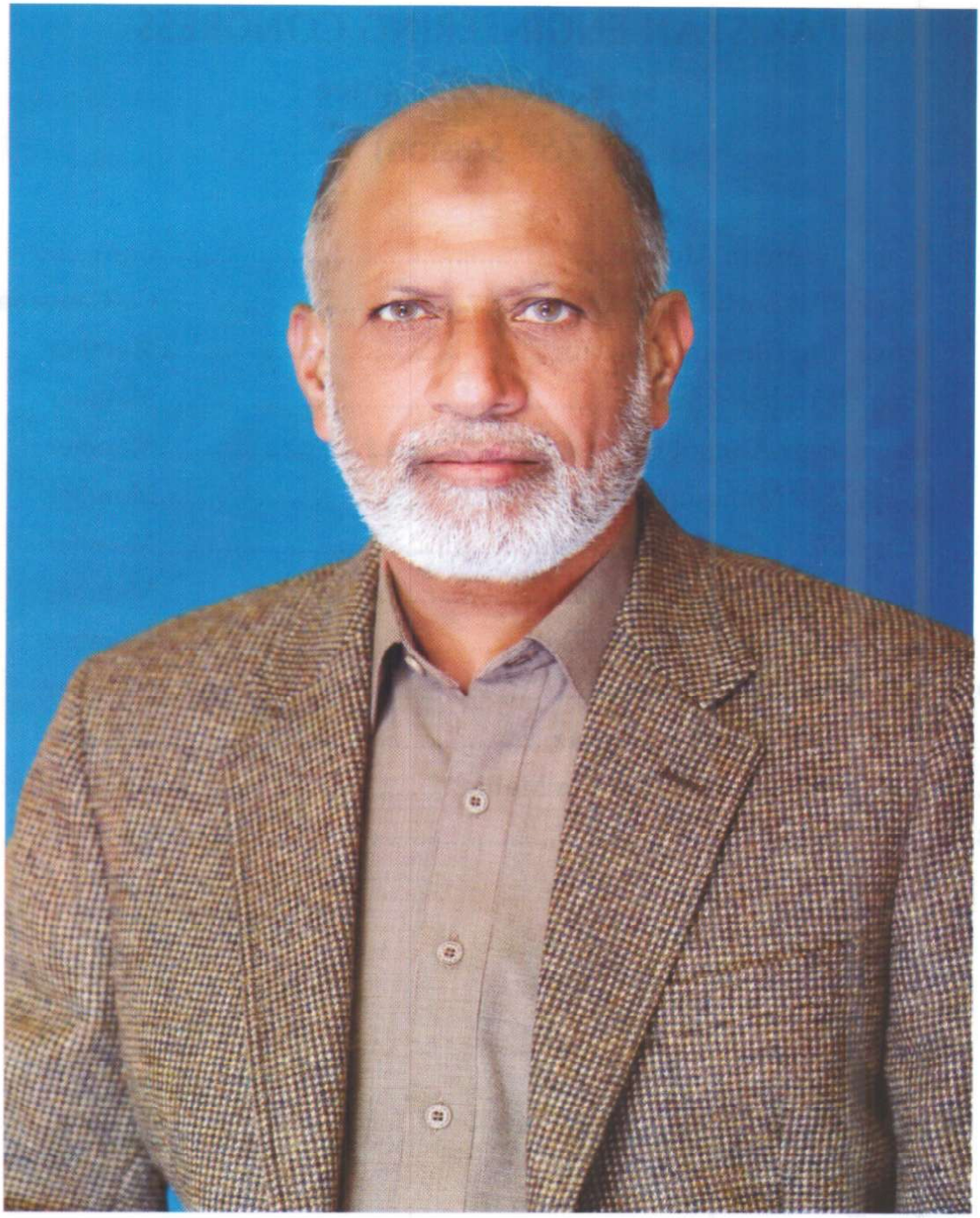
Engr. Amjad Saeed is presently the Chief Engineer, Head/Project Director of Project Management Office (PMO) Punjab Barrages of Irrigation Department. Govt. of Punjab. He completed BSc Civil Engineering from University of Engineering & Technology Lahore, in 1985 and MSc Hydraulics and Irrigation Engineering in 2001 from the same institution.

Mr. Amjad Saeed joined WAPDA in 1985 and then shifted to Punjab Irrigation Department in 1987 and continues his association with this Prestigious Department responsible for management of Water Resources potential, Food Control, Agricultural Irrigation that ensures Food Security for the growing population etc.

Mr. Amjad Saeed was a Member of the team entrusted with the work of restoring design capacity of Marala-Ravi and Balloki-Sulemanki link canal during years 1997-2002. While serving at various high echelons in Irrigation Department, he closely worked with WB, ADB, JICA & the other financial agencies involving project appraisals, loan negotiations and other major issues of the projects.

Mr. Amjad Saeed in his vital capacity of the Head of PMO-Punjab Barrages was instrumental in the Execution / Completion of mega World Bank & ADB Financed Projects of Rehabilitation and Modernization of Jinnah Barrage Construction of new Khanki Barrage, Rehabilitation and upgrading of Sulemanki and Trimmu Barrages a formidable achievement. He is also managing the rehabilitation and upgrading of Panjnad and Islam Barrages.

In view of his excellence in Engineering Profession. He has been recently elected unanimously as the President Pakistan Engineering Congress that was established in 1912 and was the first of its kind in the sub-continent.



Engr. Amjad Saeed
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(76th Session)

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INTRODUCTORY REMARKS

By

ENGR. AMJAD SAEED
PRESIDENT PAKISTAN ENGINEERING CONGRESS

AT

WORLD WATER DAY 2020

ON THE THEME OF

"WATER AND CLIMATE CHANGE"

World Water Day is commemorated every year during the month of March based a universally adopted theme. Pakistan Engineering Congress is actively involved in s process and is celebrating the World Water Day regularly since 2005 The papers: resented in this moot from the Congress forum are formally documented and distributed complementarily to Members of the Congress, Concerned Federal / Provincial Government Departments, Technical Institutions, Libraries and Educationists in pursuit of its cardinal objectives of disseminating information and knowledge. So, far 163 Technical Papers by the Water Resources specialists have been printed in book form. This year the theme of World Water Day 2020 is

"Water & Climate Change"

The theme is well chosen as the climate change is causing catastrophic damages in the shape of Floods, Hurricanes, Forest Fires, and above all loss of Lives, Property Destructions, migration of affectees and rise in Sea Levels etc.

Ladies & Gentlemen!

Pakistan once a water-surplus country, is now a water deficit country The rainfall is either sufficient nor regular, to meet the growing needs of water. About 70 per cent of the annual rainfall occurs in the months of July to September. The -surface water resources of Pakistan mainly consist of flows of the Indus River and its tributaries which briny m about 138 million acre feet (MAF) of water annually. The Indus River alone provides 65% of the total river flows, while the share of Jhelum and Chenab is 17% and 19% respectively. The months of peak-flow are June to August during the monsoon season. The flow during the Kharif (Summer) is 84% and during Rabi (Winter) season is just 16%. There is danger that the country would be facing absolute water scarcity by the year 2025.

This precarious position which is going to become from worse to worst is due to the negligence of the planners/rulers who miserably failed to construct Mega Water Reservoirs despite the World Bank's advice after completion of Mangla/Tarbela Dam that Pakistan is destined to construct at least one major water reservoir every decade India has constructed 5264 Dams with 437 Dams under construction Our tally is 467

Dams with 69 in process of construction which speaks volumes about our apathy towards construction of Multipurpose Dams that would have ensured Water & Power Security.

The present Govt. has taken serious view of problems of looming water scarcity (being Water Short Country). Actions on war footing are being taken for the construction of mega Diamer Hydro-Power Project, Mohmand Dam as well scores of small dams at various sites

- Nature has endowed Pakistan with 720 Glaciers contributing 75% to 79% of Water Resources
- The glaciers in the Northern Mountain Range of Karakorum are surging and even growing as against the World where these are melting.
- A third of the glaciers will be melting by year 2100 in Pakistan resulting in Glacial Lake Outburst floods (GLOFs) that has resulted in creation of 3000 glacial lakes out of which 33 pose serious flash floods that means loss of life, property and displacement of population. Absolutely water scarcity by 2025.
- No storage for flood; flash floods etc. Incident precipitation and river flows are the two major sources of surface water used to meet the requirements of agriculture and other sectors

Total Water Resources percentages (Glaciers contributing 75% to 79%, Rainfall contribution about 10% and Groundwater abstraction about 11% of total irrigation water.

Ladies & Gentlemen!

Groundwater in Pakistan is under increasing threat from over-exploitation, pollution and lack of proper management conforming the demand and supply patterns of this natural resources Importance of groundwater can be realized from the fact that out of the total fresh water resources available on the earth, 96% are located underground. Furthermore groundwater resources provide a great cushion against drought and Low River flows Over the past few years, there has been tremendous increase in private tubewells and ground water use. Now the tubewells has crossed the figure of one million and are being used for abstracting ground water. Out of 65 MAF groundwater potential about 50 MAF groundwater is being pumped annually and it meets the 45 % crop water requirements only and remaining 55% crop water requirements are being fulfilled through surface water supplies

Continued abstraction and extensive exploitation of groundwater has resulted in depletion of groundwater table, dwindling yield, drying up of wells and water quality deterioration in many areas of Pakistan The problem has become more acute in recent years due to the continued and extended drought faced by the country. To meet this challenge in an effective manner, programs of artificial recharge to groundwater are immediately required to be undertaken

Ladies & Gentlemen!

The global temperature has registered 1-degree Celsius of the pre-Industrial era & is causing Global Warming mainly due to use of Fossil Fuels (Diesel, Furnace Oil, Natural

Gases especially coal and dirty coal). Resultantly, a number of countries are raced with floods, droughts, untimely abnormal rains, flash floods, hurricanes causing callosal losses, valuable lives, destruction of crops and infrastructure etc. Recent Bush Fire in Australia which raged for over Six (6) months causing un-paralled devastation of human & animal lives (over 2-million species vast area denuded of trees, destruction of Residential Buildings/displacement of population.

Scientific projections point-out that the temperature of the oceans has also increased reducing its capacity of absorbing the Green-House Gas emissions Resultantly the level of oceans is rising and would be rising one to four feet by the end of the century endangering almost 600 Million people living in coastal areas San Francisco Metropolitan Manila etc. Jakarta is sinking and is going to be relocated. Small island states face extinction.

Pakistan's contribution to Green House Gases emission (CO 2) is only 0.43% of the World but is unfortunately at 7th number in the list of "Most vulnerable Countries" coupled with a negligible 5.2% forested area as against 25% benchmark. It is heartening that KPK Govt implemented "Billion Tree Afforestation Project verified in a publication by IUCN (Pakistan). In addition the Prime Minister has launched extensive afforestation program covering all provinces, departments NGo's etc.

Paper No. 164

WATER AND CLIMATE CHANGE & NATIONAL CONTEXT

Engr. Riaz Nazir Tarar

WATER AND CLIMATE CHANGE & NATIONAL CONTEXT

By:

Engr. Riaz Nazir Tarar

1 CLIMATE CHANGE

1.1 DEFINITION

Climate change is an inconvenient truth. This is defined by Intergovernmental Panel on Climate Change (IPCC) as below: -

"Change in the state of climate than can be defined by changes in the mean and / or the variability of its properties, and that persists for an extended period, typically decades or longer, whether due to natural variability or as a result of human actions".

1.2 CAUSES OF CLIMATE CHANGE

Basic factors contributing to climate change are human activities particularly from Industrial Revolution since 1850, which have resulted in constant global temperature increase. Contributing anthropogenic factors are in essence human actions that are responsible for bringing about changes in climate. Major cause of global warming and the resultant climate change is considered to be rising level of greenhouse gases (GHGs) in the atmosphere. These are emitted from fossil fuel combustion, land use change and industrial processes, such as cement manufacture, etc.

1.3 CURRENT SITUATION

Though global climate has been changing since advent of 19th century Industrial Revolution, it got accelerated during 20th century. According to IPCC 4th Assessment Report (2014), average global temperature increased by 0.6°C over 20th century.

Change in climate has already boosted extent of air pollution to the extent of thick smog particularly in a number of south and central Asian countries (Pakistan is also a victim of this phenomena). This, combined with deadly cold and heat waves, is increasing health hazards.

Change in emissions of GHGs is causing serious unbalance in atmospheric gases. It is observed that percentage of CO2 has increased 42% than pre-industrial era. World's scientists report that to prevent dangerous level of global warming concrete actions are needed to limit global warming to less than 2°C by the end of 21st century by reducing GHG emissions.

Changes in many extreme weather and climate events have been observed since 1950. These changes, linked to human influences, include: a decrease in cold temperature extremes; an increase in water sea temperature extremes; an increase in high sea levels; and increase in number of heavy precipitation events or droughts in a number of regions.

1.4 INTERNATIONAL INITIATIVES TO COMBAT CLIMATE CHANGE

To address the issue, 1st World Climate Conference was held in 1979 and an Intergovernmental Panel on Climate Change (IPCC) set up in 1988. In 1994, United Nations Framework Convention on Climate Change (UNFCC) with almost universal membership of countries, entered into as well as ratified Conference of Parties (CoP). In 1997, Kyoto Protocol was formally adopted by member countries. After extended negotiations, COP21 met at Paris from 30 November to 12 December 2015 for getting commitment of member countries to fight the climate change. This concluded as Paris Agreement to limit global warming below 2°C through 21st century. Though USA has opted out of Paris Agreement, other members are pursuing the effort. The last conference was held in Madrid during late 2019, where members, particularly from developed industrial countries, reaffirmed their commitments for combating the issue through reduction in GHGs.

1.5 PROJECTED CLIMATE CHANGES, RISKS AND IMPACTS

According IPCC 5th Assessment Report (2014), it has been concluded that global climate change is largely human induced and accelerating. Continued emission of GHGs will cause further warming and long-lasting changes in all components of climate system, increasing likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in GHG emissions which, together with adaptation, can mitigate climate change risks.

Cumulative emissions of CO2 (major portion of GHG) will largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy.

Other key findings of IPCC are that: -

i. Past and future anthropogenic CO2 emissions will continue to contribute to warming for very long time spanning over centuries.

ii. Probable temperature rise by the end of 21st century will be between 1.8-4.0°C.

iii. Sea levels may rise between 28-43 cm.

iv. Arctic summer ice cover and most of glaciers (including Pakistan) are likely to disappear during second half of 21st century.

v. It is likely that parts of world will see an increase of heat waves and heavy precipitation causing flooding.

vi. Intensity of tropical storms will increase substantially.

vii. Acidification of oceans will increase due to rising levels of CO_2 in the atmosphere.

Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and generally greater for disadvantaged people and communities in countries at all levels of development.

Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of GHG are stopped. Risks of abrupt or irreversible changes will increase as magnitude of the warming increases.

2 CLIMATE CHANGE IMPACTS MANAGEMENT THROUGH MITIGATION AND ADAPTATION

Latent costs of climate change are far-reaching, mainly for people living in the developing world. Due to lengthy time scales attached to climatic processes and feedback, even if greenhouse gas levels were to be stabilized immediately, the increase in temperatures and sea levels is expected to continue for centuries. If GHG levels in the atmosphere are somehow stabilized during 22nd century a further warming of about 0.5°C would still be anticipated. In fact, just the thermal expansion of oceans would result in an additional rise of 30 to 80 cm in global sea levels by 2300.

Hence it is equally important to prepare for the inevitable impacts of climate change including reduced emissions of GHGs. On the other hand, to manage climate change challenges, the answer lies in mitigation and adaptation. Figure-1 describes link between climate change and its impacts on human and natural systems, and how strategies of mitigation and adaptation are employed for addressing the impacts?

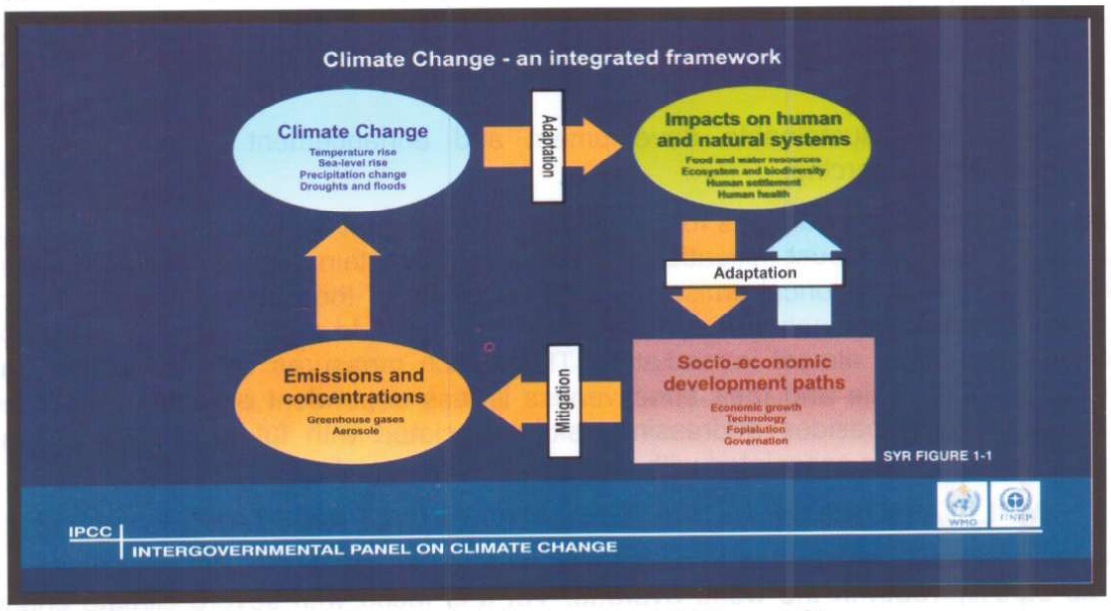


Figure-1: Integrated Framework of Climate Change

Mitigation refers to approach that incorporates efforts to decelerate the process of climate change by decreasing percentage of GHGs in the atmosphere. It is, therefore, imperative to initiate GHG emission reductions immediately in order to control global warming and its consequences in the future. Mitigation is thus an essential point of action for the global community. At international level, Kyoto Protocol to UNFCCC addresses mitigation through a set of market-based mechanisms / instruments involving both developed and developing countries.

Adaptation, on the other hand, refers to modification in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change. Even if mitigation efforts are successful, a certain level of climate change is inevitable during the current century and beyond. Thus, we need to make a realistic assessment of direct implications of changes that we have already brought upon ourselves and adapt to them accordingly. This involves development of strategies to minimize impacts on people and ecosystems by controlling their susceptibility to the effects of climate change. One example of an adaptation strategy is building seawalls and transferring buildings to higher ground levels while protecting communities against increased flooding due to storms and or rising sea levels.

IPCC Working Group-I, that studies aspects of impacts, adaptation and vulnerability in the context of climate change, believes that mitigation and adaptation should be complementing components of the control strategy for addressing climate change. Their contribution to 2014 IPCC Assessment Report makes the following observations:

i. Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts.

ii. Those with least resources have the least capacity to adapt and are the most vulnerable.

iii. Adaptation, sustainable development and enhancement of equity can be mutually reinforcing.

There are convincing arguments for consideration of adaptation as a response measure. First, no matter how robust mitigation measures are, a certain degree of climate change is inevitable due to historical emissions and the inertia of the climate system. Second, while the effects of mitigation may take several decades to manifest, most adaptation activities take effect almost immediately. Third, such measures can be applied on a regional or local scale and their effectiveness is less dependent on actions of others. Fourth, adaptation besides addressing risks associated with future climate changes typically reduces risks associated with current climate variability.

3. IMPLICATIONS OF CLIMATE CHANGE FOR PAKISTAN

Pakistan has least contribution to global warming and its share of GHG emissions is as low as 0.43%, 135th in the world average. Yet it is faced with severe climate change impacts. German Water Report of 2011 ranked Pakistan as "third most vulnerable country to Climate Change".

3.1 NATURAL SETTING

Pakistan is a large geographically diverse country with number of significant ecological features, including extensive mountains, deserts, rivers, wetlands and coastal ecosystems. It is only country in the world where altitude difference is greatest since Pakistan is home to several mountain peaks ranging over 8,000 meters and having its largest port city (Karachi) at almost sea level. It has a vast glacial area which covers about 15,000 km2 comprising 5,000 glaciers which are retreating. Rate of this retreat

has gone up by 23 percent in the previous decade (Geological Survey of Pakistan, 2014). Pakistan has very low forest cover of only 4%. More than half of the population depends on the use of natural resources for its livelihood.

3.2 MAJOR CLIMATE CHANGE RELATED RISKS

Pakistan is facing of major risks related to climate change including rise in sea level, glacial retreats, floods, higher average temperature and higher frequency of droughts. In addition, being a predominantly agricultural economy, climate change is estimated to decrease crop yields in Pakistan not only as a result of flooding, but also as a result of changing temperatures, which in turn will affect livelihoods and food production.

Deterioration of climate may be irreversibly harming Pakistan as glacier melt in Western Himalayas / Karakorams / Hindukush regions is projected to increase flooding along with severe rain events. During 2010 there was record flood on Indus River, which caused colossal damage to infrastructure, agriculture and human lives. Little later August 2014 flood on Chenab River caused 170 deaths and almost one million people were affected. Besides, thousands of acres of agricultural land were destroyed.

Northern part of Pakistan is facing flooding issues due to accelerated snow / glacial melt and monsoon rains while southern part is experiencing drought situation.

Climate change will significantly affect water resources of Pakistan within the next two to three decades. After initial increase in river flows, there could be substantial reduction as glaciers recede. These reduced fresh water flows would have dramatic adverse effects on biodiversity and livelihood with possible long-term implications on farm and non-farm sectors.

Agriculture is the backbone of Pakistan economy as 55% livelihood of the total population is dependent on it. Textile sector is the second largest employer providing livelihood to 42 percent of work force but it is also agriculture centric as it depends on the production of cotton crop in the country. Unfortunately, this sector is often affected by climate change and poor people are most likely to lose their livelihood (due to adverse climate conditions cotton production during 2019 reduced by about 20%). Loss of livelihoods in this and other agriculture sectors (sugarcane and wheat etc.) sectors would put downward pressure on other occupations and increase competition by creating scarcity of jobs.

Temperature increases in Pakistan are expected to be higher than the global average resulting in reduced national agricultural productivity. Yields of wheat, rice, other cereals and some important cash crops including cotton could decline in all regions of the country. Studies have shown that growing season length for major cereals will decrease with increase in temperature in all agro-ecological zones of Pakistan resulting in 6-11 percent decline in yield of wheat and 15-18 percent reduction in yield of basmati rice by the year 2080. Livestock production could also decline by 20-30 percent due to rising temperature creating crises in milk, meat and poultry supplies and pushing prices beyond reach of the common man. On the average, agriculture sector of Pakistan could lose up to US$16 billion dollars per annum due to change in climate by the end of 21st century

3.3 INITIATIVES BY PAKISTAN TO COMBAT CLIMATE CHANGE IMPACTS

Government of Pakistan is making efforts to tackle climate change issues. In 2008 Planning Commission had set up a Climate Change Task Force (CCTF), to provide appropriate guidelines for ensuring security of vital resources of the country such as agriculture, water and energy and contribute to formulation of climate change policy. CCTF issued their final report in February 2010. The report described Pakistan's vulnerability due to climate change impacts on various socio-economic sectors. It recommended various mitigation and adaptation measures based on initial assessment and viewed country's ongoing and planned responses. Findings of this report helped subsequent formulation of Climate Change Policy and Action Plan.

In response to international commitments, Government of Pakistan set up an exclusive Ministry of Climate Change in 2012 which developed National Climate Change Policy (NCCP) in 2012, on the basis of guidelines provided by CCTF. The NCCP comprehensively addresses all possible challenges of climate change adaptation and mitigation in foreseeable future.

As per NCCP, to address the impacts of climate change on water resources and to enhance water security, government of Pakistan should implement the following policy measures:

i. Infrastructure for mega water storages be built not only for meeting initial needs but making up of about one-third loss of storage capacity in on-line reservoirs due to rapid sedimentation.

ii. Hill-torrents be harnessed to control not only flooding but enhance storage capacity.

iii. Existing aging irrigation structure be rehabilitated early.

iv. Water conservation strategies be adopted by reducing irrigation system losses and introduction of high efficiency irrigation systems (HEIS) and rainwater harvesting techniques.

v. Integrated water resources management be adopted through: rationalised water allocations; equitable water distribution; protection of ground water resources; recycling of wastewater; water-shed management in critical catchment areas; and active participation of farmers in water management.

vi. Legislative framework to protect water resources for efficient management and protection of glaciers.

vii. Enhancing institutional capacities by developing efficient technologies, monitoring of irrigation water delivery, preparing inventory of all water resources and application of remote sensing and GIS techniques.

viii. Awareness raising among all stakeholders.

In the field of agriculture, following policy measures be adopted.

i. Research for assessment of climate change impacts on various agro-ecological zones, by developing new variety of crops, better breeds of livestock, quality database, sustainable land management and enhancing capacity of farming community.

ii. Technology for improving crop productivity, energy efficient farm mechanization, modern techniques, financial incentives and improved agronomic and irrigation practices.

iii. General management by establishing climate change units.

iv. Risk management by insurance of crop and by enhancing, agricultural draught farming

To implement NCCP, a Framework for Implementation of National Climate Change Policy was developed in November, 2013. This framework was developed by keeping in view current and future anticipated threats due to climate change to various sectors of Pakistan. Furthermore, appropriate actions relating to disaster preparedness, capacity building, institutional strengthening, and awareness raising in relevant sectors were also prepared.

Good thing is that Pakistan was the first South Asian country to develop Climate Change Policy. This showed its commitment for mitigation and adaptation of climate change. However, still too much work is left to achieve the goal. Still climate change and action plans have to be developed and implemented by Federal Provincial and Local governments along with firm financial commitment. In this respect, Pakistan can benefit from a number of financial incentives for mitigation / adaptation of climate change being offered by international agencies with backing of developed countries.

3.4 IMPACT OF CLIMATE CHANGES ON INDUS RIVER BASIN

Water of Indus River Basin (IRB) is life of predominant agrarian economies of the regional countries. On the other hand, there is a growing recognition that countries of IRB face major and changing threats to their water security and thus to their people's critical food and energy needs. Downstream areas are highly dependent on water resources originating in the upper mountainous catchments. Indus River System of Pakistan has one of highest dependence on snow / glacial melt and its generally semi-arid basin is naturally water stressed. River is also lifeline of Pakistan's huge and growing population. It has the world's largest contagious irrigation system dependent upon transboundary water. Countries in the basin are already facing water shortages in terms of water withdrawal and per capita water availabilities. Climate and socioeconomic changes are further aggravating the situation.

3.4.1 Primary Source of Water

Pakistan's primary source of surface water is the Indus River System (IRS) fed largely by glacier and snow melt from Hindukush-Karakoram-Himalayas (HKH) mountain ranges. Shares of main contributors to IRS are: Indus 44%; Kabul 16%; Jhelum 16%; Chenab 19%; and Others 5%. Details along with seasonal distribution are shown in Table-1.

Table-1: Distribution of Water in Main Rivers of Pakistan

River	Flow Contribution (%)	Seasonal Distribution (%)		Dominant Source of Water	
		Summer (Apr-Sep)	Winter (Oct-Mar)	Summer	Winter
Indus	44	86	14	Snow/Glacier melt	Winter Rainfall + Baseflow
Kabul	16	82	18	Snow/Glacier melt	Winter Rainfall + Baseflow
Jhelum	16	78	22	Mainly Snow melt + Monsoon	Winter Rainfall + Baseflow
Chenab	19	83	17	Mainly Snow melt + Monsoon	Winter Rainfall + Baseflow
Others	5*	100	0	Uncontrolled floods	

* Unmeasured inflows into the river reaches below rim-stations particularly the Eastern Rivers of Ravi and Sutlej

Average annual rim-station in flows of the Western Rivers (Indus / Kabul, Jhelum and Chenab) over the record period of 1977-2003 were about 141 million-acre feet (MAF) or 174 billion cubic meters (BCM). These varied between low of 97 MAF in 2002 to high of 172 MAF in 1992.

Table-1 shows that about 82% of IRS inflows are during Kharif (summer months of April-September) and about 18% in Rabi (winter months of October-March). Summer flows in: Indus / Kabul rivers are dominated by snow and glacier melt; Chenab by snow and glacier melt together with summer monsoon rains; and Jhelum by snowmelt and rains from summer monsoon. Source of winter flows in all the rivers is rainfall combined with the base flow from snow and glacier melt.

It is expected that due to increased variability of summer monsoon and winter rains and loss of natural reservoirs caused by glacier melting as a result of climate change, the inter-seasonal and intra-annual variability of river flows will also increase. It may also be accompanied by incidence of more frequent and intense occurrences of floods and droughts.

3.4.2 Regional Distribution of Glaciers in Upper Indus Basin

Bulk of glacial melt contribution to Upper Indus flows is confined to catchment area of 142,700 km2 at the gauging station of Partab / Bunji Bridges. This results from the regional distribution of glaciers in the Upper Indus Basin as per break-up in Table-2.

Table-2: Regional Distribution of Glaciers in Upper Indus River Catchment

Sr. No.	Region	Approximate Distribution of Glaciers (%)
1.	China Xizang Plateau	22
2.	Great Himalayas	31
3.	Karakoram	19
4.	Pamir	11
5.	Hindukush	17
6.	Total	100

3.4.3 Impact of Climate Change on Pakistan Glaciers

Global warming and consequently the climate change, resulting from increasing concentrations of GHGs in the atmosphere, is now an established phenomenon. Its effects have been observed in most parts of the world including Pakistan. Past temperature trends over Pakistan are seen almost tallying with global trends, whereas future projections show that the rate of increase of average temperature over Pakistan could be higher than globally. As Pakistan is located in sub-tropics, a temperate region with warm climate, its predominantly agrarian economy is highly climate sensitive.

Between 50-80% of average flows in Indus River System (IRS) are derived from snow and glacier melt in western Himalayas-Karakoram-Hindukush part of mountain ranges. Upper Indus Basin (UIB), has more than 5200 glaciers covering a total glaciated area of over 15,000 km2 as shown in Table-3.

Table-3: Glacier Inventory in Upper Indus Basin

Basins	No. of Glaciers	Glaciated Area (km^2)	Ice Reserves (km^3)
Swat	233	223.55	12.22
Chitral	542	1903.67	258.82
Gilgit	585	968.10	83.35
Hunza	1050	4677.34	808.79
Shigar	194	2240.08	581.27
Shyok	372	3547.84	891.8
Indus	1098	688.00	46.38
Shingo	172	36.91	1.01
Astor	588	607.03	47.93
Jhelum	384	148.18	6.94
Total	**5218**	**15040.7**	**2738.51**

Ice reserves of over 2700 km^3 as shown in Table-2 are equivalent to over 15-years of average flows of IRS comprising Indus, Jhelum and Chenab rivers assigned to Pakistan under Indus Waters Treaty, 1960. Therefore, their current and future status with changing climate is of vital concern to Pakistan, particularly in the context of water security. Additionally, energy output from existing / proposed hydropower projects may be affected.

3.4.4 Studies of Glacier Behaviour in Upper Indus Basin

Although glaciers all over the world are found to be receding over the past century, including those in Upper Indus Basin. Notwithstanding this, there is small uncertainty about temporal behavior of Karakorum Glaciers which have not been studied in detail so far. Based on the studies conducted since start of 21st century utilizing scanty data, limited investigation have thrown-up somewhat conflicting information as shown in Table-4.

Table-4: Comparative Results of Studies Conducted Since Start of 21st Century Regarding Glacier Retreat in Upper Indus Basin Due to Climate Change

Sr. No.	Entity	Year of Conducting	Basis of Study	Finding Regarding Mean River Inflow
1.	Wallingford	2004	100-year time horizon starting 1991	Initial increase between 14-90% followed by decrease between 30-90% by the last decade of 21st century
2.	World Bank	2005	Till end of 21st century under scenario of 0.015°C annual temperature rise	Initial increase in flows by about 50% with decrease of over 60% by the end of 21st century
3.	Global Change Impact Studies Center (Islamabad)	2009	Average annual temperature rise of 0.03°C in upper Indus Basin	Flow reduction by about 15% showing considerable change in monthly flow pattern with more water in spring and early summer and less water in late summer
4.	WAPDA Using data collected from automatic high-altitude meteorological network established in 1995 (Refer Fig. 2)	2012	Positive degree day data from 1995-2009 for snowmelt period (May-June) and glacier melt period (July-Sept) covering causing sub-basin of upper Indus Shyok, Shingo, Astore,	Flows from western Himalayan part of Indus from India / China showed a remarkable rising trend in summer mean monthly flows a phenomena attributed to receding glaciers. On the

			Hunza and Gilgit	other hand, Karakorum tributaries from Pakistan part of Upper Indus Basin showed a falling trend in corresponding period attributable to expanding glaciers.
5.	Joint Study by Researchers from Pakistan / Nepal and USA, titled 'Modeling of Future Discharge Estimation from Glacierized Hunza River Basin'	2013	Model calibration from Hunza River discharge data from 1995-2001 and validated for 2002-13	No drastic changes in future discharge except higher discharges in few years that may cause flooding and contribution from a combination of 2°C temperature rise and 20% increase in precipitation may increase the discharge by about 10%.

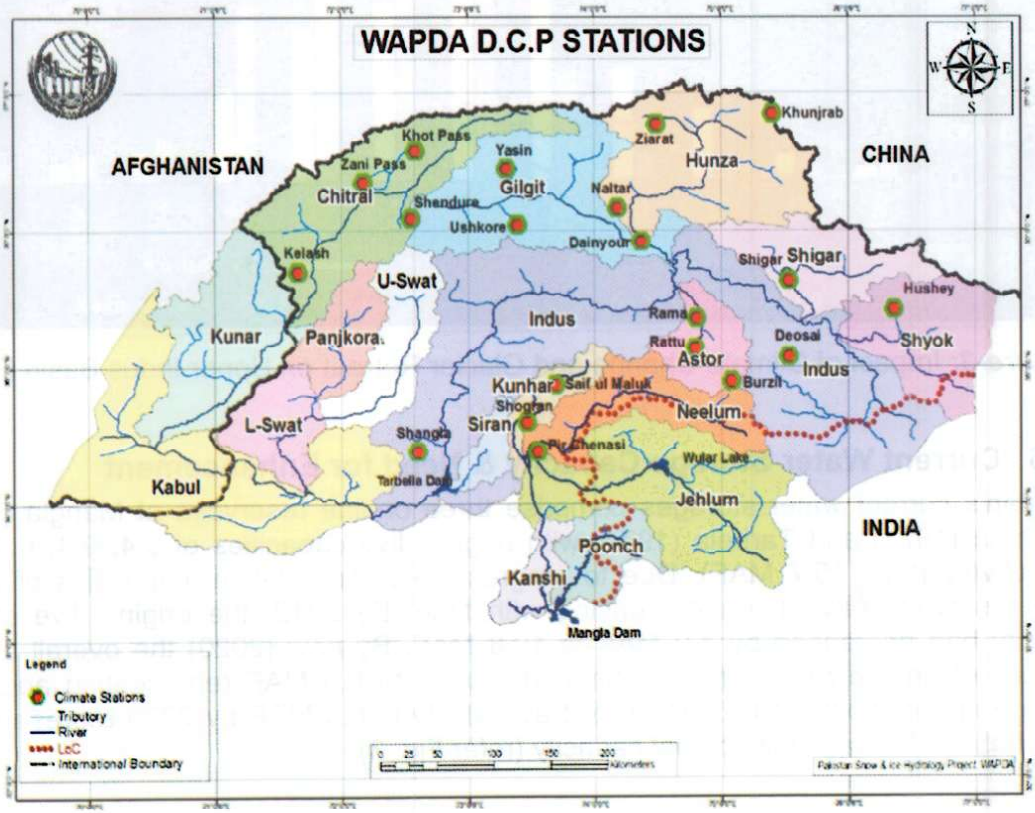


Figure-2: WAPDA's High Altitude Data Collection Platform network in Upper Indus Basin

3.4.5 Impact of Climate Change on Indus River Flows

A simulation modelling study was carried out by Global Change Impact Studies Centre (GCISC) Islamabad in 2009. It showed that, if by the end of 21st century average temperature in Indus watershed was to rise by 3°C (higher than global average of 2°C) and HKH glaciers to shrink to half their present size, the mean annual river flow in Upper Indus could reduce by about 15%. Besides annual flow reduction of 15%, considerable change could occur in monthly flow pattern between snow and glacier melt period. Further, monthly flow pattern would change considerably, with more water coming in spring and early summer and less water in the later part of summer a shown in Figure-4.

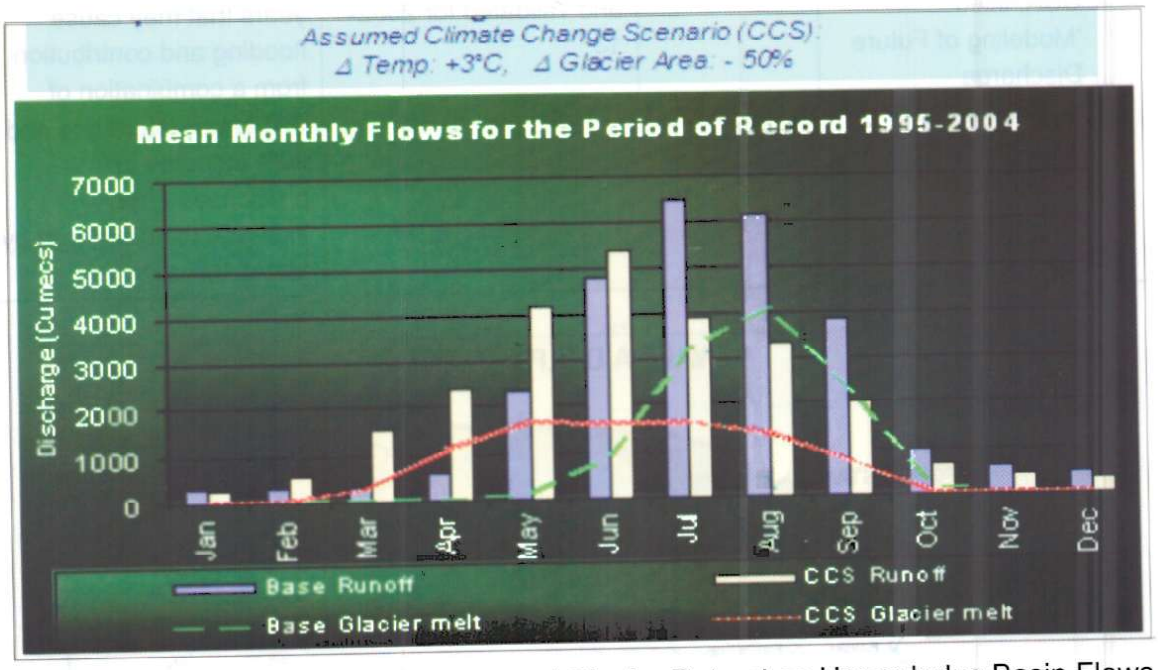


Figure-3: Impact of Climate Change and Glacier Retreat on Upper Indus Basin Flows

3.4.6 Current Water Storage Capacity & Need for Enhancement

Pakistan's current water storages comprise three on-line reservoirs at Mangla (1967), Chashma (1971) and Tarbela (1974) with original live capacities of 5.4, 9.4, 0.9 MAF respectively (total 15.7 MAF). Due to progressive sedimentation, capacities of all the three reservoirs have been decreasing with time. By 2012, the original live storage capacity had decreased by 4.9 MAF to 10.8 MAF. By now (2020) the overall storage capacity of on-line reservoirs is estimated around to 9.9 MAF representing about 7% average annual flows of IRS. Projected availability is 8.5 MAF by 2030 representing a loss of about 46% against original capacity (refer Fig. 3).

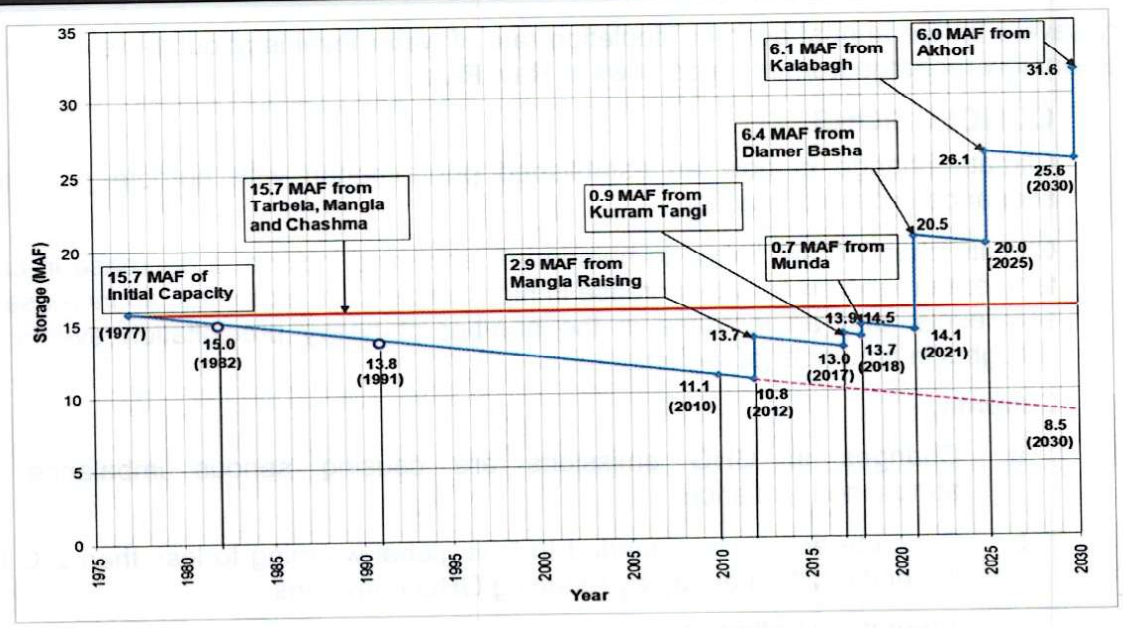


Figure-4: Projected Live Storage Capacity Through 2030

Pakistan's storage capability is very low when compared with the corresponding figures of: world average (40%); India (33%); Nile River Basin in Egypt (347%); and Colorado River Basin in USA (497%). Furthermore, this water storage capacity of 550 m3 per capita in Pakistan is also very low as compared to: 2,200 m3 in China; 5,000 m^3 in Australia; and 6,000 m^3 in US. On the other hand, an average of about over 30 MAF of water escapes to sea annually during flood season, while there is a need to conserve every drop for optimal utilization. With increasing frequency and intensity of floods and droughts as a result of climate change, there will be even greater need to store the surplus water during high river flow periods at all feasible sites.

3.5 IMPACT OF GLOBAL CLIMATIC CHANGES ON NATIONAL GROUNDWATER

Groundwater is an essential part of national hydrology cycle which not only supports the life and eco-system but also plays role of backbone in many commercial, industrial and development activities. Nature has blessed Pakistan with a large groundwater reservoir underlying the Indus Basin primarily due to seepage from large irrigation network over the last 100 years or so. This groundwater resource is being extracted to the tune of about 45 MAF per annum through over 1-million tube wells. This is contributing about more than 40% crop water requirements at farm gate and has thus assumed vital role in irrigated agricultural economy of the country.

Extreme events like floods and droughts have disturbed hydrologic cycle posing severe impacts on water resources. Groundwater quality and levels are changing abnormally due to excessive mining of this resource. Additionally, these events are causing issues like water and land degradation, waterlogging and salinity, spatial and temporal uncertainty in availability, access to users etc. Increase in droughts in some areas has increased frequency of water shortage and led to more restriction on water usages and resulted in more pressure on groundwater. In urban areas, like Lahore City, threat is

very severe where annual average depletion rate of water level is about 1-meter mainly due very low recharge from reduced flows in Ravi River.

4 CONCLUSIONS

i. Climate change is now an established phenomenon with horrible projected scenarios in case of inaction.

ii. Climate changes are linked to human influence and include: a decrease in cold temperature extremes with increase in high temperature extremes; an increase in sea levels; and an increase in the number of heavy precipitation events or droughts in a number of regions.

iii. Currently: -

   a. Changes in GHG emissions are causing serious imbalance in atmospheric balance.

   b. Concrete actions are needed to limit global warming to less than 2°C by the end of 21st century by reducing GHG emissions.

iv. a. International efforts to combat climate change were initiated in 1979 with holding of 1st World Climate Change Conference. An Intergovernmental Panel on Climate Change (IPCC) was established in 1988. In 1994 United Nations Framework Convention on Climate Change (UNFCC) was established. In 1997, Koyota Protocol was formally adopted by almost universal membership.

   b. Subsequently, conferences of parties (COPs) were regularly convened and culminated in Paris Agreement of 2015 to limit global warming below 2°C during 21st century. Though USA has opted out of this agreement, other member countries are pursuing the effort. The last COP was held in Madrid during November 2019 and the next is due in UK in November 2020. Notwithstanding this, the efforts of developed countries to reduce GHG emission seem lukewarm and do not auger well for future.

v. Pakistan is the third most vulnerable country to climate change. It is facing major risks of: glacial retreats; higher average temperature and extreme events of droughts and floods. These are manifested in: continuous drought at the start of 21st century; extreme floods of 2010 and 2014; shortening of winters and prolongation of summers; and unseasonal spring rains during 2019 and early 2020 with dire consequences for agricultural production.

vi. a. Pakistan has already taken significant administrative initiatives to combat climate change impacts through: setting-up of Climate Change Task Force (CCTF) in 2008; establishing Ministry of Climate Change in 2012; and preparing National Climate Change Policy (NCCP) in 2012.

   b. Though Pakistan was first South Asian country to develop NCCP, still action plans have to be developed and implemented by Federal, Provincial and Local Governments. In this respect, Pakistan can benefit from a number of financial incentives for mitigation and adaption to

climate change being offered by international agencies with backing of developed countries.

c. Pakistan is initiating work on multiple projects to be executed under US$200 million grant provided by Green Climate Fund to mitigate environmental degradation and combat climate change.

vii. a. Between 50-80% average flows in Indus River System (IRS) are derived from snow and glacier melt.

b. Global Change Impact Studies Centre (GCISC) Islamabad carried out a study with projected 3°C rise in temperature by end of 21st century against global target of 2°C. This indicated that the flows in upper Indus could reduce by 15% with considerable change between snow and glacial melt period including about 50% reduction in glacial average.

5 PROPOSED WAY FORWARD IN NATIONAL CONTEXT

On the basis of national issues identified in the foregoing, following recommendations emerge for the way forward: -

i. Maximum conservation of river flows be made through construction of mega dams at all feasible sites.

ii. Capacity of relevant national institutions be strengthened to adequately monitor and project the impacts of climate change.

iii. Appropriate adaptation options suitable for climate proofing and risk management for water and energy sectors at different locations in the Indus Bain be identified through an enhanced international collaborative research programme.

iv. Organizing future activities in a coordinated and programmatic manner, bringing in the regional and global knowledge base to improve the scenario analysis and projection of future trends and impacts on water resources.

v. Water and energy programs should be made climate adaptive and proofed through the application of suitable knowledge and tools.

vi. To provide a favourable environment for the implementation for climate change adaptation activities, awareness be created among the public at large and policy decision makers.

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