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# Impact Analyses of Upstream Water Infrastructure Development Schemes on Downstream Flow and Sediment Discharge and Subsequent Effect on Deltaic Region

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**Abstract:** The lavishness of delta and its ecosystem heavily depends on continuous supply of fresh water flow and sediment flux into deltaic region. Since last few decades, the mighty river contributing a portion of fresh water and deposit sediment into the Delta. The extensive use of fresh water for irrigation purposes and construction of vast network of dams, barrages and associated upstream structures have severely reduced downstream discharge of the Indus River to Sea. The reduced down stream flow has resulted in pronounced sea water intrusion into once the fertile and lush green land of Indus Delta. The decline in the inflow of fresh water has uncovered this composite bionetwork to a number of environmental and social stresses in the form of habitation and biodiversity; reduced in productive values of ecology. The Indus Deltaic region, once occupying an area of about 5000 $km^2$ consisting of creeks, mudflats and mangrove forest is now condensed to 1,192 $km^2$. While the mangroves cover, once an approximate area of 250,000 to 283,000 hectares till early 1980s drastically declined to 73, 000 hectares in 2006. The resulting destruction of delta is not a problem of its own but death of fishing culture, ecology and destruction of livelihoods of local fishers and peasants.

**Keywords:** River Indus, water and sediment discharge, Indus delta, environmental impacts

## 1. INTRODUCTION

Indus deltaic region is heavily dependent on water availability in Indus River and its tributaries, which originates from commonly known as greater Hindukush, Karakorum, and Himalaya (HKH) region. The River Indus, after its long journey of about 3000 km from north to south, finally spill out into a deltaic region-covering an approximately area of some 5000 $km^2$ where, more than the centuries, it has developed a 650,000 acre wide mangrove jungle which maintain alien and multicolored plant life, mammals and reptiles. The fan-shaped Delta Indus, the sixth biggest in the planet supports an inhabitants of over 130,000 communities, whose source of revenue are directly or not directly reliant on the water availability in tributary Indus. The integrity and lavishness of delta is directly linked with increased fluvial deposit provide and negligible human intervention (Sanchez-Arcilla, *et al*., 1998 and McManus, 2002). The storage and diversions of freshwater for any consumptive uses have usually resulted to decrease the net sediment load of rivers (Dynesius and Nilsson, 1994; Walling and Fang, 2003; Vörösmarty *et al*., 2003; Nilsson *et al*., 2005 and Syvitski *et al*., 2005). The Indus's silt-laden fresh water sustained the life supporting system of deltaic tract along the coastlines of southern belt of Sindh province. The deltaic population by inborn understanding sensibly operated these capital and preserved sustainability of the structure for centuries. All of this and much more is under threat now. The extensive use of fresh water for irrigation purposes and construction of vast network of dams, barrages and associated upstream structures have severely reduced down stream discharge of the River Indus. The reduced silt-laden down stream flow has resulted in reduction of mangroves cover and consequently sea water intrusion devastated once the fertile and lush green land of Indus Delta (Meynell, and Qureshi, 1993). The decrease in the inflow of fresh water has uncovered this composite ecology to ecological and communal pressure in the form of habitat and biodiversity thrashing and a decline in prolific principles of flora and fauna. The destruction can be manifested in reduction of mangrove coverage, intrusion of sea, degraded groundwater, shrinking of agricultural land and vegetation and significant reduction in livestock grazing areas. In the context of global warming, the vulnerability of HKH region to climate change is of vital importance because of the impact on water resources at lower riparian areas and consequent effect on the Indus deltaic region. The present study will review the effect of past treaty and various water development schemes on water flux and sediment discharge to deltaic region and resulting impact on mangroves cover and shrinking of agricultural land The analyses will provide invaluable information for future water management within the whole Indus River basin and specifically the quantum of possible available fresh water for deltaic region.

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**Description Of Indus Delta Region**

The fan-shaped Indus Delta area scatter with 17 most important and many small stream covers an estimated region of 5000 km$^2$ **(Fig. 1)**. The Deltaic mangroves-forest are exclusive in living being the biggest vicinity of bone-dry climate and 7$^{th}$ major obstruct in the earth, which ropes a inhabitants of above 130,000 people, whose livelihoods are directly or not directly reliant on Indus stream. The mangroves cover occupies around 600,000 ha extending from Korangi Creek in the north to Sir Creek in the south. Over last half of the century, the construction of new water infrastructures-barrages and dams due to development of cultivation, serious yield, power production, boost in residents etc, have resulted in continuous decrease in silt laden fresh water flow into Arabian Sea. The decreased flow have turned whole ecosystem of deltaic region into dying state, where fauna, flora, the livelihood of thousands people are in jeopardy.

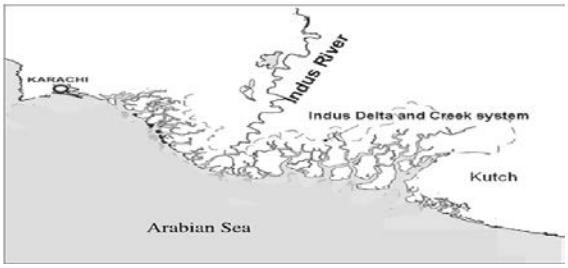


**Fig. 1 The expanding view of Indus Delta and its creek system (Source: Inam *et al*., 2007).**

**Development of Indus Basin Irrigation System (IBIS) And Its Impact on Water / Sediment Flux Below Downstream Kotri Barrage**

After division of Asian subcontinent in 1947, the water distribution of the Indus River and its tributaries become a source of conflict b/w India and Pakistan. However, under arbitration of World Bank an accord was signed among India and Pakistan in September 1960. Under the accord, usually known as Indus basin water agreement, India was exclusively apportioned the use of three eastern rivers (Ravi, Beas and Sutlej), while Pakistan retained the sole rights for the three western rivers, namely Indus, Jehlum and Chenab. As a result, a set of major replacement works were built to redirect water from Pakistan's western rivers to supply the irrigation systems formerly fed by water flowing from the eastern rivers. Since the agreement, around 19 barrages and 43 canal heads with 48 off-takes have been built up on Indus River system-consisting thousands of canals and water courses, irrigating around 42 million acres of land. As shown in (**Fig. 2**). These replacement works include the three major storage dams: Chashma, Mangla and Tarbela-supplying irrigation water to command area of an approximately 14 million hectares.

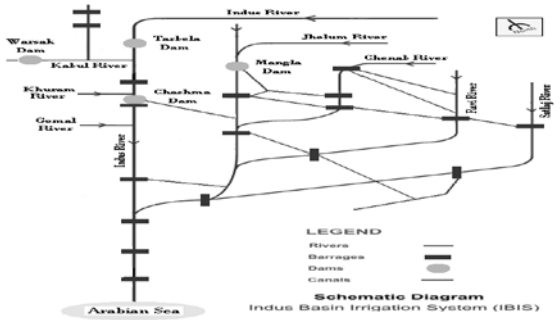


**Fig.2 Indus Basin Irrigation Systems (IBIS) - Water infrastructure developments at Indus River and its tributaries**

The construction of these link canals and storage reservoirs has almost doubled the agricultural activity, once limited to 12 million hectares to 22 million hectares now. However, this agricultural sector development has diverted the River Indus water from once about 80 BCM to 125 BCM for irrigation needs. The said canals and reservoirs have resulted in the siphoning off 74 percent of Indus waters before it reaches Kotri B arrage, the last barrage point on the Indus River in the southern part of country. These anthropogenic changes have also resulted in five times reduction in sediment discharge to Deltaic region. Prior to development of Indus Basin Irrigation System, the sediment and water escapages to the Arabian Sea were about to 108 BCM and 225 BT respectively. After commissioning of barrages and dams, it further reduced to 48 BCM and 50 BT **(Fig. 3)**. The most recent flow was determined by way of the Indus Water Accord in 1994, whereby the allocation of water between the Provinces of Pakistan was decided, based on historical record of available water. As per accord, 141 billion m$^3$ allocated for irrigation purposes, while only 12 BCM were apportioned for Deltaic region. However, in last one and half decade the fresh water flows below downstream Kotri barrage have been inconsistent and mostly below the minimum required quantity as most of the available fresh water in Indus River is being used for upper plain irrigation needs. Therefore, the major decline in fresh water and sediment flux to the delta can be attributed to the development of Indus Basin Irrigation System. Since last 8 years, water and sediment discharges have declined at an alarming pace below Kotri Barrage-it have almost created a worst droughting like situation, where the flow and sediment load is dropped to the single digit **(Fig. 4)**. The figure were also supported by conclusion of (Meynell, and Qureshi, 1993) study, that the delta which once receiving around 250-600 BT sediment in 1930s, just trickled down to less than double digit. The effect of the engineered structures on the Indus River water discharge can further be measured by the number of flowing days downstream Kotri Barrage. Before the construction of Kotri Barrage, the Indus was flowing

through out the year. However after construction of Kotri Barrage, first intermittent breaks in flows were observed and the numbers of flow days were recorded to maximum figure of 250 days. During post Mangla period, the flow days further dropped to 100 days **(Fig. 4).** Since the signing of Water Accord 1994, the river bed is constantly showing deserted look, as most of the available water is used for extensive irrigation needs by upper riparians. The twin menace of almost total absence of silt laden fresh water in the river downstream of Kotri Barrage-the last barrage on Indus River and heavy sea water intrusion into the delta have turned whole ecosystem of deltaic region into dying state, where flora, fauna, the livelihood of thousands people are in jeopardy.

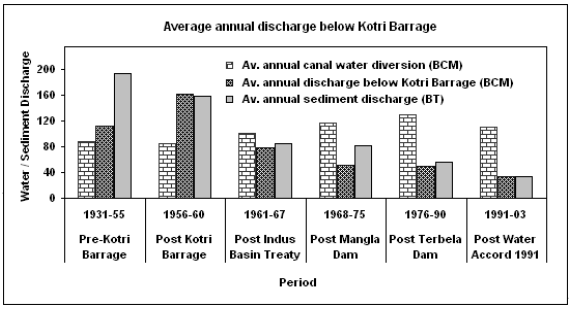


**Fig. 3 The changes in average annual canal water diversions, downstream Kotri barrage flow, and sediment discharge below Kotri barrage after every mega development project (modified from Govt. of Pakistan Report, 2006).**

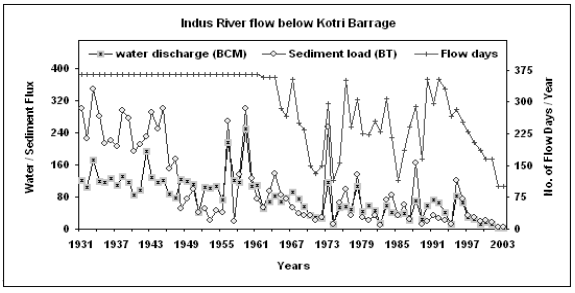


**Fig. 4 Variation in Water / sediment discharge with no. of flow days / year below Kotri Barrage**

## 2. ENVIRONMENTAL EFFECTS

Since last two decades, water released below downstream Kotri barrage only in case of worst flood situations - subsequently the Indus River contributing hardly any water or sediment to deltaic region. As a result, there has been severe intrusion of sea water upstream of the delta - at places extending up to 80 km in the coastal areas. As per Government figures seawater intrusion has resulted in tidal infringement over 1.2 million acres of land in the Indus Delta (Ref, 2004). The twin menace of almost total absence of fresh water in the river downstream of Kotri and heavy sea water intrusion from the delta has destroyed large areas of prime agricultural land, including submersion of some villages in the coastal belt of these districts. The study by Wells and Coleman (1984) concluded that the highest wave energy due to the intense monsoonal winds transforming the Indus delta into a true wave dominated delta, which converting the ever lush green delta into sandy beaches and dunes. The above facts and figures can be verified in satellite view of the Indus Deltaic Region **(Fig. 5).** where large portion of deltaic region have been converted into sandy and saline area. The devastation of delta can further be observed in drastically reduced mangrove forest cover **(Fig. 6)**. The mangrove cover once an approximate area of 250,000 to 283,000 hectares till early 1980s drastically declined to 73, 000 hectares. The sandy area, once just about 30% of the active delta over the years increased around approximately 68% of the total deltaic area till early 90s and it is assumed that the figure should have been jumped to higher percentages in recent years.

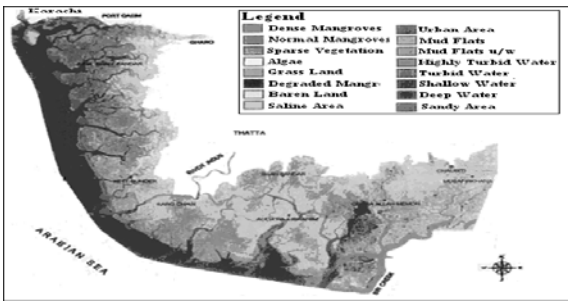


**Fig. 5 Satellite view of the Indus Deltaic Region**

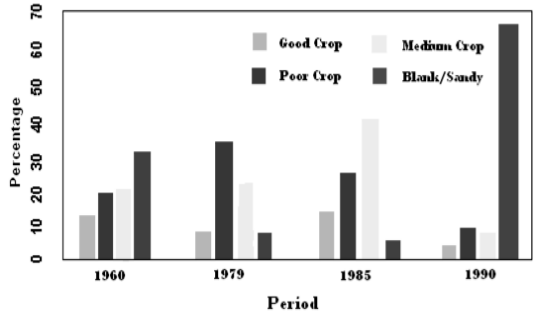


**Fig. 6 Mangrove forest cover at different time intervals (Modified from WWF-Pakistan, 2006).**

The Delta which makes ups around 17 major and many minor creeks now only receives water between Hajamro and Kharak Creeks for few days from the Indus with one main outlet (Khobar Creek) to the sea. The areas of Humbus Wali and Chann Creek were irrigated through regular flow of Indus River up to 1960s. However, the resulting water scarcity after construction of barrages and dams has converted these fertile lands into barren land. The study conducted by WWF-Pakistan (1998), revealed that an area of 8,463 ha of Hajamro and surrounding creeks, which could categorize under mudflat converted into other land cover classes either agriculture land or water. It is due to sea side erosion of mudflats, widening of creeks and conversion of

mudflats into agricultural land **(Fig. 7)**. Out of the 8,463 ha area high land erosion of approximately 2,911 ha was calculated at the sea side. Land erosion map highlights the historic and current deltaic extents in blue and red colors respectively **(Fig. 8)**.

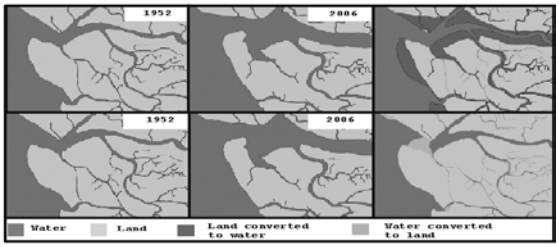


**Fig. 7 Conversion of land to water and vice versa in Chan Creek (Source: WWF-Pakistan).**

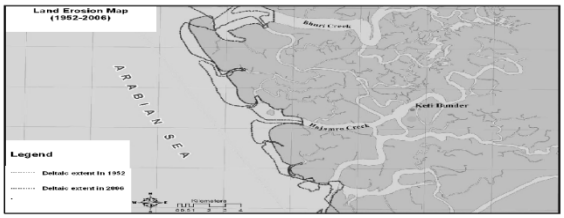


**Fig. 8 Change in Deltaic extent in Hajamro and surrounding creeks (Source: WWF-Pakistan)**

In many ways the Indus Delta study characterize a crisis situation which has already reached critical point, and is likely to deteriorate further in the future. The situation requires immediate revisit and shifting in present policies opted only to allocate scarce water to maximize financial and commercial gains to agriculture even at cost of ecosystem. as a result, require to accept a holistic approach towards the managing of our environmental resources so as to maintain them for our desires and so as to our future generations.

## 3. CONCLUSION

The existence of the delta is dependent on the accessibility of clean water and sediment. The severe decline of mutually as a consequence of barriers, bombardment and connected construction on upstream has outcome in the evident erosion in vicinity of the delta; therefore in the decline of the mangroves. The health of Indus Delta demands a sensible evaluation of the smallest amount of fresh water and sediments necessary to avoid total vanishing of the delta. Present is requiring for a positive quantity of fresh water and sediment to be release in to the delta on year about basis. Above mentioned facts and figures suggest to the least amount of clean water flow to the Delta region set by the Indus stream agreement 1994, (12.3 BCM) is insufficient to uphold effective ecology role of the swampland of the Indus Delta. The result, important decline in the natural property of the Delta has been experiential. It is consequently recommended that the inclusive, free study of collective and ecological impacts of the current irrigation structure on the Delta bionetwork should be carry out and the executive of the delta should be made a part of an integrated Indus Basin management.

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