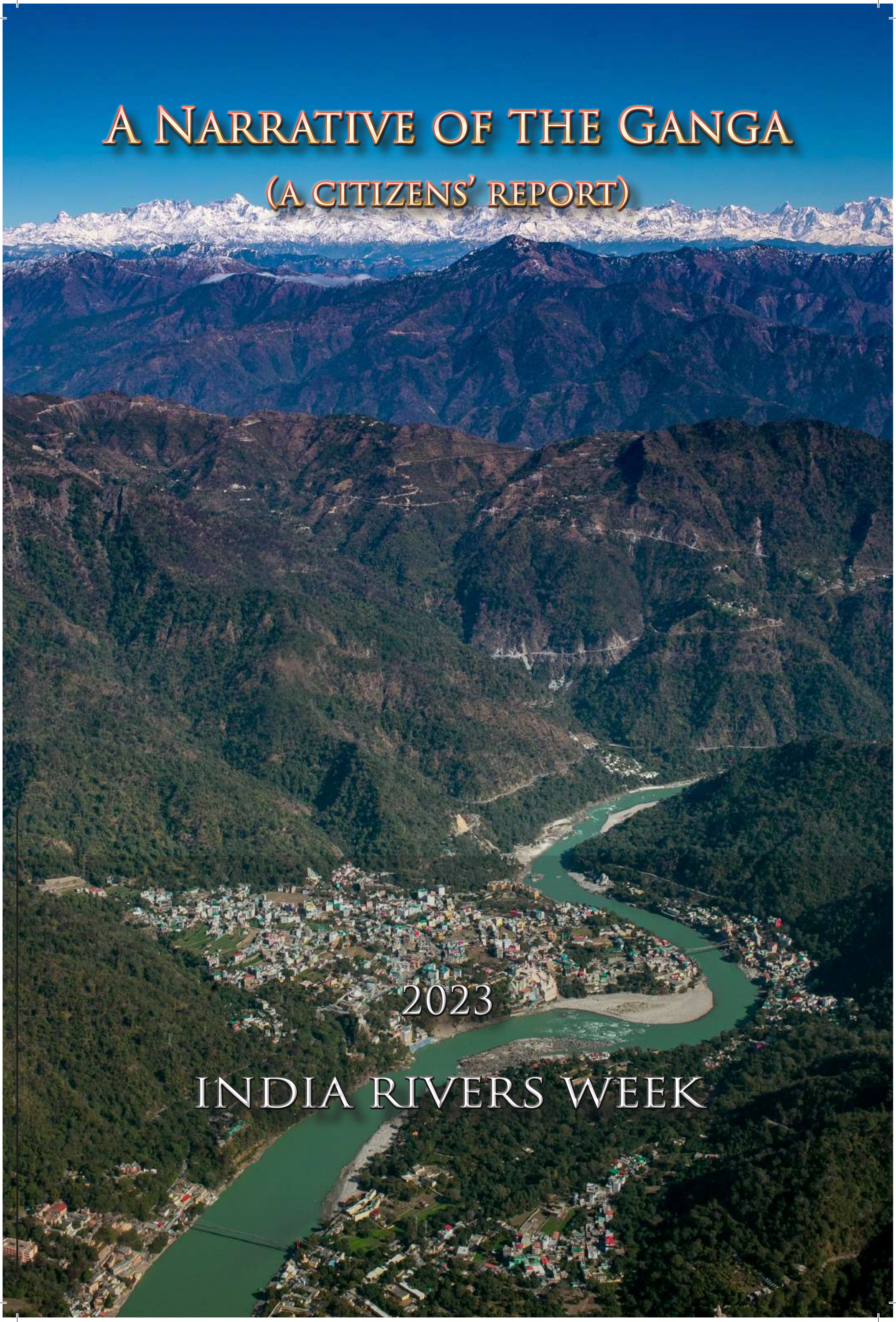
A Narrative of the Ganga

(a citizens' report)



2023

India Rivers Week

The Numerous Glacial Streams Form the Headwaters of the river which is Revered by All – Ganga

A NARRATIVE OF THE GANGA

(A CITIZENS' REPORT)

2023

INDIA RIVERS WEEK

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Cover Photo by - Bhumesh Bharti, Ganga at Rishikesh

PREFACE

Rivers, in India, a crucial part of the hydrological cycle, are in a perilous state. In order to draw attention to the conservation of rivers in a holistic manner a consortium of non-government organizations, namely, INTACH (Indian National Trust for Art, Culture and Heritage), WWF (Worldwide Fund for Nature) India, Toxics Link, SANDRP (South Asia Network on Dams, Rivers and People) and PEACE Institute Charitable Trust, came together in 2014 to organize an annual India Rivers Week (IRW). Later in 2016, the Dehradun-based People's Science Institute (PSI) joined the consortium, which was further expanded in 2021 to include Bengaluru based ATREE (Ashoka Trust for Research in Ecology and Environment), IIHS (Indian Institute of Human Settlements), SOPPECOM (Society for Promoting Participatory Ecosystem Management), Pune and Veditum India Foundation, Kolkata.

River Ganga is much more than a river for the people of India. Over millennia, it has been India's civilizational identity. She is worshipped as an all-forgiving goddess capable of washing away a believer's accumulated sins and as a mother without whose *amrit* (nectar) the life journey of a believer from birth to death is incomplete. Little wonder then that River Ganga is immortalized in prose, poetry, songs, art and timeless rock sculptures. In more recent times, to its devotees its divinity appears to have been reaffirmed by scientific confirmation of its unique self-cleansing ability and curative health properties.

The theme for the event in 2018, was 'Can India Rejuvenate River Ganga?' This book is a result of that event. Much delayed owing to successive years of pandemic the book is a serious effort to promote and strengthen holistic efforts to rejuvenate River Ganga. The book highlights several facets including the geo-morphological and biological diversities of the Ganga basin and their rapidly expanding disruptions with a larger question in mind, which is, its likely future as a physical entity.

The book should be of interest to a wide spectrum of readers and stakeholders including lay persons, researchers, journalists, activists and policy makers. We hope that the readers will find the book informative and useful and that the authorities tasked with rejuvenating River Ganga will find the issues raised and the recommendations made worthy of serious consideration.

MESSAGE FROM CHAIRMAN, INTACH

The emasculation of the holy Ganga began in the mid 19th century with the construction of the Ganga canal system. Since then, the river has gradually been on the decline impacted by human interventions such as dams and barrages, groundwater depletion and sand mining. The more visible aspect of human impact has been the pollution of the great river and this is what has drawn attention to the plight of the river we worship.

Every crisis spurs its own resolution and thus the sorry state of the river has attracted massive efforts to restore its *aviralta* and *nirmalta*. However, the massive efforts being made by government authorities are alone not adequate. Civil Society has ventured into the field and evolved several insights into what ails the river and possible remedies.

This report is the result of a building upon the erudite inputs of several river experts and activists during India Rivers Week, 2018. It is my hope that it will help both researchers and decision makers in shaping their actions in the quest of revival of the Mother River to its pristine glory.

Maj. General [Retd] LK Gupta [AVSM]
Chairman, INTACH

ACKNOWLEDGEMENTS

IRW 2018 attracted a large number of Ganga experts, many of whom led sessions and shared their understanding and research findings in the form of formal presentations and interjections made during different sessions and plenary. This book builds upon those seminal contributions.

On day one they included Ravindra Kumar Sinha (Nalanda Open University, Patna), K J Joy (SOPPECOM, Pune), Manu Bhatnagar (INTACH, Delhi), Mallika Bhanot (Ganga Ahvaan, Uttarkashi), Nachiket Kelkar (ATREE, Bengaluru), Rajiv Sinha (IIT Kanpur), Brij Gopal (NIE, Jaipur), Venkatesh Dutta (Baba Saheb Ambedkar University, Lucknow), Shripad Dharmadhikary (Manthan, Pune), Shashi Shekhar (former secretary, MoWR, Delhi), Ravi Agarwal (Toxics Link, Delhi), Ravi Chopra (PSI, Dehradun), Ravi Singh (WWF India, Delhi), Jagdish Krishnaswamy (ATREE, Bengaluru), Vinod Tare (IIT, Kanpur), Suresh Babu (WWF India, Delhi), Himanshu Thakkar (SANDRP, Delhi), Dinesh K Mishra (Barh Mukti Abhiyan, Patna), Siddharth Agrawal (Veditum, Kolkata), Amita Bhaduri (India Water Portal, Delhi), Seema Ravandale (PSI, Dehradun), Vishwanath S. (Bengaluru) and Swami Shivanand (Matri Sadan, Haridwar).

On days two and three, the speakers included Himanshu Kulkarni (ACWADAM, Pune), Jayanta Bandhopadhyay (formerly IIM, Kolkata), Prakash Nautiyal (HNB Garhwal University, Srinagar), A K Gosain (IIT Delhi), Paritosh Tyagi (former Chairman, CPCB, New Delhi), Sunil Choudhary (Vikramshila University, Bhagalpur), Tarun Nair (ATREE, Bengaluru), Abhilash Khandekar (Journalist, Delhi), Anil Gautam (PSI, Dehradun), Nidhi Jamwal (Journalist, Mumbai), Neha Sinha (Biologist, Delhi), Vijay Paranjpye (Gomukh, Pune), Kishore Kodwani (Indore, MP), K Khairnar (NEERI, Nagpur), Mushtakim Mallah (Ramra village, UP), Bhim Singh Rawat (SANDRP, Delhi), Sitaram Taigor (State Mission for Clean Ganga, UP), Shailendra Singh (Turtle Survival Alliance, UP), Srinivas Chokkakula (CPR, Delhi), Sandeep Behera (NMCG, Delhi), T. Velpandian (AIIMS, Delhi), JR Bhatt (Advisor, MoEFCC), Aprajita Singh (PSI, Dehradun), UP Singh (Secretary, MoWR, Delhi), Ritu Singh (INTACH, Delhi), Chandi Prasad Bhatt (Uttarakhand), E. Theophilus (Munsiari, Uttarakhand), Makarand Purohit (Journalist, film maker, Raipur), Rohit Joshi (Journalist, Uttarakhand), Dhruba Das Gupta (Researcher, Kolkata), Romit (WWF India, Delhi), Sreedhar R. (Environics Trust, Delhi), Joydeep Gupta (Third Pole, Delhi), Seema Mahindra (Ramganga Mitra, Moradabad), BS Sajwan (Yamuna Monitoring Committee, Delhi), SP Singh (IIT, Roorkee), Anand Sharma and Sudeep Sahu (Ghaziabad), Ramesh Mumukshu, Debashish Sen (PSI, Dehradun) and Shailaja Chandra (Yamuna Monitoring Committee, Delhi). UP Singh, Secretary, MoWR,RD & GR graced the valedictory session and gave an insightful speech. This book has tried to capture all that and more.

Normally a book based on conference deliberations is a compilation of papers submitted by the conference participants. This book has not followed the standard pattern. The chapters were written by a select few while taking care to include all that was shared and discussed at the conference. The editors have accessed information from a large number of sources which are referenced at the end of each chapter. Subject matter experts including late Prof. Brij Gopal, Prof. A.K. Gosain, Prof. R.K. Sinha, Prof. Prakash Nautiyal, Himanshu Thakkar and Prof. Rajiv Sinha reviewed select draft chapters.

Ravi Chopra
Manoj Misra
Manu Bhatnagar

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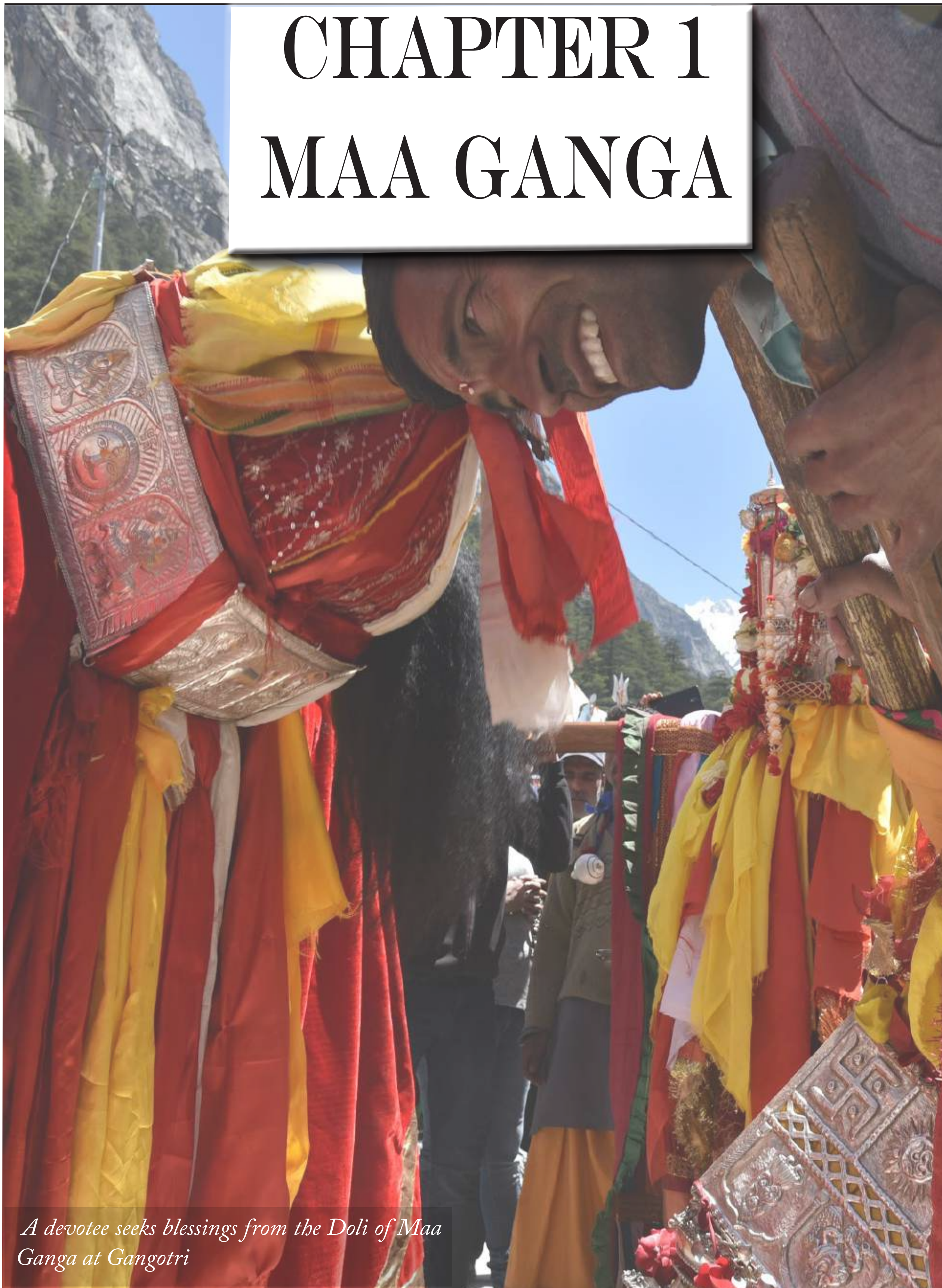
TRIBUTE TO A RIVER WARRIOR

Shri Manoj Kumar Misra
(1954-2023)

CHAPTER 1
MAA GANGA



A devotee seeks blessings from the Doli of Maa Ganga at Gangotri

1.1 INTRODUCTION

Maa, mighty, majestic, mythical – are common descriptors Indians use for their national River Ganga.[1] It is the most revered river in the world. Most Hindus worship river Ganga, the consort of Lord Vishnu, the progenitor in the Hindu trinity along with Brahma the creator and Shiva the destroyer, as a goddess. Its spiritual sanctity has been the essence of Indian culture across millennia. Its devotees respectfully refer to it as 'Ganga ji' and not simply as Ganga.

River Ganga is India's civilizational identity. It binds India emotionally. Jawaharlal Nehru wrote in his will and testament, "The Ganga, especially, is the river of India, beloved of her people, round which are intertwined her racial memories, her hopes and fears, her songs of triumph, her victories and her defeats. She has been a symbol of India's age-old culture and civilization, ever-changing, ever-flowing and ever the same Ganga."[2]

Her devotees, regard the river as a physical manifestation of the goddess and her water as possessing magical healing powers. According to Hindu scriptures a mere drop of *Gangajal* (Ganga water) or the sight or even memory of R. Ganga can cleanse the faithful of all sins. Its spiritual pull draws millions of worshippers every year. This chapter tries to understand what has sustained the faith of millions of Indians in River Ganga across ages.[i]

1.2 GANGA MYTHOLOGIES

Indian scriptures contain hundreds of myths about goddess Ganga and the river. The most popular myth, narrated during childhood over millennia to most Indians, is told in the *Ramayana*, the *Mahabharata* and many *Puranas*. It describes Brahma releasing goddess Ganga from heaven to descend to Earth in response to the prayers and penances of King Bhagirath to liberate the souls of his ancestors by sweeping over their ashes. In this narrative, Shiva tames the tempestuous energy of the descending Ganga by trapping her in his matted locks and gently releasing her on Earth.[ii] Thereafter King Bhagirath's chariot creates a channel through Himalayan gorges, their foothills and the plains to lead Ganga over his ancestor's ashes at Ganga Sagar and her ultimate merger with the sea. Thus, the Ganga is holy from its origin to the sea.

But the oldest myth of River Ganga is the one in the Rig Veda, narrated centuries before the later epics and *Puranas*.[3] In this myth, Indra frees the celestial waters of heaven – containing the immortality-bestowing nectar of the gods, *amrita* -- from the coils of the serpent Vritra for the nourishment of Earth. *Amrita* in Ganga waters may be seen as giving *Gangajal* a divine purity, its unmatched self-purification property and its ability to cure illnesses.

In the Vaishnava tradition, River Ganga's true headwaters are in heaven itself, where she emerged from the foot of Vishnu. She was collected in the water pot of Brahma. As she descended from heaven to Earth, in fulfillment of the boon granted by Brahma to King Bhagirath, Shiva received her on his head to tame her turbulence. Since in this version Ganga is seen springing from Vishnu's foot, she is also known as *Vishnupadi*.[4]

When Ganga realized that she would have to descend to Earth and carry away the sins of her devotees, she became fearful of becoming unclean herself. It is said that Brahma promised her then that, "…. sages and saints would live along her banks, and their bathing would purify her waters just as quickly as sinners could taint them".[5]

River Ganga is known by over 100 names, each recalling a different legend and creating a different image in the mind. Among the commonly known ones are *Jahnvi* (daughter of the sage Jahnu), *Mokshadaayani* (provider of salvation), *Paapharini* or *Paapvinaashini* (sin-cleansing), *Sursari* (river of the gods), *Tripathagamini* (one who traverses the three worlds, heaven, earth and the netherworlds) and *Vishnupadi* (emerging from the foot of Lord Vishnu). (See Box: 108 Names of Goddess Ganga).

108 Names of Goddess Ganga

ॐ गङ्गायै नमः ॐ त्रपिथगादेव्यै नमः ॐ शम्भुमौलविहिारणि्यै नमः ॐ जाह्नव्यै नमः ॐ पापहन्त्र्यै नमः ॐ महापातकनाशनि्यै नमः ॐ पततिोद्धारणि्यै नमः ॐ स्रोतस्वत्यै नमः ॐ परमवेगनि्यै नमः ॐ वषि्णुपादाब्जसम्भूतायै नमः ॐ वषि्णुदेहकृतालयायै नमः ॐ स्वर्गाब्धनिलियायै नमः ॐ साध्व्यै नमः ॐ स्वर्णद्यै नमः ॐ सुरनम्निगायै नमः ॐ मन्दाकनि्यै नमः ॐ महावेगायै नमः ॐ स्वर्णशृङ्गप्रभेदनि्यै नमः ॐ देवपूज्यतमायै नमः ॐ दवि्यायै नमः ॐ दवि्यस्थाननविासनि्यै नमः ॐ सुचारुनीररुचरिायै नमः ॐ महापर्वतभेदनि्यै नमः ॐ भागीरथ्यै नमः ॐ भगवत्यै नमः ॐ महामोक्षप्रदायनि्यै नमः ॐ सनि्धुसङ्गगतायै नमः ॐ शुद्धायै नमः ॐ रसातलनविासनि्यै नमः ॐ महाभोगायै नमः ॐ भोगवत्यै नमः ॐ सुभगानन्ददायनि्यै नमः ॐ महापापहरायै नमः ॐ पुण्यायै नमः ॐ परमाह्लाददायनि्यै नमः ॐ पार्वत्यै नमः ॐ शविपत्न्यै नमः ॐ शविशीर्षगतालयायै नमः ॐ शम्भोर्जटामध्यगतायै नमः ॐ नर्मिलायै नमः ॐ नर्मिलाननायै नमः ॐ महाकलुषहन्त्र्यै नमः ॐ जह्नुपुत्र्यै नमः ॐ जगत्प्रयिायै नमः ॐ त्रैलोक्यपावन्यै नमः ॐ पूर्णायै नमः ॐ पूर्णब्रह्मस्वरूपणि्यै नमः ॐ जगत्पूज्यतमायै नमः ॐ चारुरूपणि्यै नमः ॐ जगदम्बकिायै नमः ॐ लोकानुग्रहकर्त्र्यै नमः ॐ सर्वलोकदयापरायै नमः ॐ याम्यभीतहिरायै नमः ॐ तारायै नमः ॐ पारायै नमः ॐ संसारतारणि्यै नमः ॐ ब्रह्माण्डभेदनि्यै नमः ॐ ब्रह्मकमण्डलुकृतालयायै नमः ॐ सौभाग्यदायनि्यै नमः ॐ पुंसां नर्वाणपददायनि्यै नमः ॐ अचनि्त्यचरतिायै नमः ॐ चारुरुचरितमिनोहरायै नमः ॐ मर्त्यस्थायै नमः ॐ मृत्युभयहायै नमः ॐ स्वर्गमोॐ दुरतिनाशनि्यै नमः| ॐ गरिरािजसुतायै नमः ।क्षप्रदायनि्यै नमः ॐ पापापहारणि्यै नमः ॐ दूरचारणि्यै नमः ॐ वीचधिारणि्यै नमः ॐ कारुण्यपूर्णायै नमः ॐ करुणामय्यै नमः ॐ गौरीभगनि्यै नमः ॐ गरिशिप्रयिायै नमः ॐ मेनकागर्भसम्भूतायै नमः ॐ मैनाकभगनिीप्रयिायै नमः ॐ आद्यायै नमः ॐ त्रलिोकजनन्यै नमः ॐ त्रैलोक्यपरपिालनि्यै नमः ॐ तीर्थश्रेष्ठतमायै नमः ॐ श्रेष्ठायै नमः ॐ सर्वतीर्थमय्यै नमः ॐ शुभायै नमः ॐ चतुर्वेदमय्यै नमः ॐ सर्वायै नमः ॐ पतिृसन्तृप्तदिायनि्यै नमः ॐ शविदायै

नमः।ॐ शविसायुज्यदायन्यिै नमः।ॐ शविवल्लभायै नमः।ॐ तेजस्वन्यिै नमः।ॐ त्रनियनायै नमः।ॐ त्रलोिचनमनोरमायै नमः।ॐ सप्तधारायै नमः।ॐ शतमुख्यै नमः।ॐ सगरान्वयतारण्यिै नमः।ॐ मुनसिेव्यायै नमः।ॐ मुनसिुतायै नमः।ॐ जह्नुजानुप्रभेदन्यिै नमः।ॐ मकरस्थायै नमः।ॐ सर्वगतायै नमः।ॐ सर्वाशुभनविारण्यिै नमः।ॐ सुदृश्यायै नमः।ॐ चाक्षुषीतृप्तदायिन्यै नमः।ॐ मकरालयायै नमः।ॐ सदानन्दमय्यै नमः।ॐ नत्यिानन्ददायै नमः।ॐ नगपूजतिायै नमः।ॐ सर्वदेवाधदिैवैः परपूिज्यपदाम्बुजायै नमः।

1.3 GANGA SABHAYATA (CULTURE): THE RIVER AS GODDESS

1.3.1 Rituals

The story of River Ganga flowing over the ashes of Prince Bhagirath's ancestors and reviving them by cleansing their sin is strongly imprinted in the Hindu mind. Even today most Hindus, including non-believers, desire that their ashes be immersed in River Ganga. Jawaharlal Nehru, a confirmed agnostic, wanted a small portion of his ashes to be immersed in the Ganga. He wrote in his will, "I have been attached to the Ganga and the Jumna rivers in Allahabad ever since my childhood and, as I have grown older, this attachment has also grown………….. the Ganga has been to me a symbol and a memory of the past of India, running into the present, and flowing on to the great ocean of the future. And though I have discarded much of past tradition and custom… ……...I do not wish to cut myself off from that past completely. I am proud of that great inheritance that has been, and is, ours, and I am conscious that I too, like all of us, am a link in that unbroken chain which goes back in the dawn of history in the immemorial past of India. That chain I would not break, for I treasure it and seek inspiration from it."

Ganga's descent or *avtarana* is recalled at river banks all over India during the *shraadha* season when Hindu families ritually commemorate their ancestors every year. The ritual of her descent from heaven to Shiva's head is enacted every day in many Indian homes and temples by pouring *Gangajal*, or just water, on a replica idol of Shiva *linga*.

Every day, in fair weather or foul, all along the Ganga's course lakhs of devotees worship the river goddess at its banks. They offer ritual obeisance to the river, the sun and the Almighty. Devotees face the dawning sun to perform *aachaman*, the purification sip before praying, firm in their faith that *Gangajal* is pure. They take dips or bathe in the river even at Gangotri where the water is icy cold. Most devotees make floral offerings at the banks while some travel in boats to the middle of the river to offer their flowers or garlands. The main worship ritual at many pilgrim towns is the evening *aarti* (prayer) when the faithful gather *en masse* on the river banks and pray. At the end of the prayer, they release colorful floats of flowers and *diyas* mounted on leaves into the river water.

People of other faiths in India also revere the Ganga.[11] Muslim artisans make *kaanwars* for millions of Hindu devotees who gather at Haridwar and other towns on the river banks during the annual *kaanwar yatra* festival. Many of these artisans revere the river. In recent years hundreds of burqa-clad Muslim women in Bhagalpur have begun taking part in the *kaanwar yatra*. Hindu and Muslim boatmen in some parts of Bengal are known to worship Maa Ganga. Guru Amar Das, the third Sikh Guru, visited Haridwar regularly during his lifetime to pray on the banks of the Ganga. Buddhist narratives also make references to the holy Ganga.

Like the Ganga's basin which extends into Nepal, Bangladesh and Tibet, its influence too stretches far beyond India. Most Nepalis being Hindus, also worship the Ganga as a holy river, though for them their own Bagmati river is holier. A statue of river Ganga adorns the royal palace at Mul Chowk in Patan, Nepal.

1.4 A SACRED GEOGRAPHY

Though the entire length of River Ganga is considered holy, a few locations are considered more sacred than others.

Image 1 : Goddess Idol in Gangotri Temple

Photo Cr : Devraj Agarwal

1.4.1 Gangotri

Gangotri is the small temple town near its source -- at an elevation of over 3000 metres. It is visited by around a million people every year. It is one of the four sacred Hindu shrines in Uttarakhand state. After a ritual cleansing dip in the icy Ganga waters, devotees pray inside the Gangotri temple before a golden idol of the goddess on a silver throne embossed with her vehicle, the *makara,* the Gangetic crocodile and bearing a water pot and a lotus in her hands that symbolize her giving nature.

1.4.2 Haridwar

Descending from the Himalayan mountains River Ganga enters the plains at Haridwar, once known as Gangadwar, 'Ganga's Gate'. A Puranic verse says, "The Ganga is easy to reach all along its banks. But three places are precious: Gangadwar, Prayag and Ganga Sagar. Those who bathe in these places go straight to heaven and are never born again".[12] It is also the site for the auspicious 12-yearly *Kumbh Mela* (See later).

The Bhimgoda barrage on the Ganga at Hardwar diverts most of its water into a channel with *ghats* on either side. Railings and iron chains are fixed into the steps for visitors to grip and take a ritual dip in the river. The evening Ganga *aarti* performed in the presence of thousands of visitors is a daily highlight. *Pujaris* from many temples in the town come to the *ghats* with oil wicks burning brightly in five-tiered brass candelabras. With clashing cymbals and ringing of bells the *aarti* is recited, as the *pujaris* wave their candelabras in a circular motion. At the end thousands of people gaze in wonder as devotees release hundreds of broad-leaf rafts holding their offerings of *diyas* and flowers to the goddess flowing rapidly past them.

1.4.3 Allahabad

Sangam is the confluence of two rivers or streams. It is a sacred site, a *teertha*, as one stream is regarded as purifying the other.[iv] The holiest of *sangams* in India, the *teertha* of *teerthas*, is the meeting of the Ganga and the Yamuna at Allahabad, also known as Prayag, or 'the place of sacrifice'. The latter refers to a *yagya* that Lord Brahma is said to have performed here. After the great Mahabharat battle, Rishi Markandeya recommended to King Yudhisthir that he bathe in the waters here to wash away the sins of killing his kin and Brahman guru.

The *Triveni* at Prayag symbolizes the Tripathagamini Ganga as a river flowing in the three realms – the heavens, Earth and the netherworlds. It also seems to express the ecumenical nature of Ganga mythologies, which associate her with the entire Hindu trinity – flowing from Vishnu's foot into Brahma's pot, and then falling on Shiva's head. This triple divinity may be seen manifest in the Prayag *Triveni*. The white Ganga is Shiva's Gauri, the dark Yamuna is Krishna's wife Kalindi and Brahma's wife is the invisible Saraswati.

Based on Eck D.L., p.149

Eck suggests that the Rig Veda is referring to this confluence, when it says, "Those who bathe at the place where the two rivers, white and dark, flow together, rise up to heaven."[13] She cites the poet Kalidasa's description, about a thousand years later that the Sangam of the Ganga's white water with the Yamuna's blue waters is like 'a string of pearls and sapphires combined, or a garland of white and blue lotuses.' The significance of the Ganga-Yamuna *sangam* is enhanced by their supposed merger with the great invisible Vedic River Saraswati, their *triveni* being more auspicious than the *sangam* of two rivers.

The huge flat sandy plain at Allahabad hosts several lakh worshippers during the month-long Magh Mela starting on January 14th every year. The Ardh Kumbh Mela at Allahabad in 2019 was said to be the largest ever human congregation anywhere in the world!

1.4.4 Varanasi

Hindus cremate their dead at river banks, followed by a ritual purifying bath. The most sacred sites are the many *ghats*, or stone-stepped embankments, by the Ganga in Varanasi. The city's origins go back to 11th century BC. Hindus and Jains believe that dying here and getting cremated along the banks of the holy Ganga leads to *moksha* or salvation from the otherwise unending cycle of birth and death, making it a major pilgrimage center. Pilgrims perform ritual ablutions at the *ghats*, particularly at the Dashashwamedh, Panchganga, Manikarnika and Harishchandra *ghats*. The last two are where Hindus cremate their dead and Hindu genealogy registers at Varanasi are maintained.

1.4.5 Ganga Sagar Island

It is a small island at the mouth of the river Hooghly, one of the many distributaries in the great Ganga delta of the Bay of Bengal. Being a deltaic island, its shape is continuously modified by the onrushing sea and the frequent cyclones.

According to mythology, sage Kapila burned to ashes the sons of King Sagara, when they disturbed his meditations in his *ashram* here. Prince Bhagiratha, Sagara's grandson brought the celestial Ganga to revive them. It is also a *teertha* that symbolizes the marriage of the river with the sea. Bathing at the river and sea *sangam* (confluence) and praying at Kapila's temple are two important rituals at Ganga Sagar Island.

1.5 GANGA FESTIVALS

A variety of festivals and fairs throughout the year sustain the legends of river Ganga and people's faith. Over millennia they have made rivers in the Ganga basin cradles for several important pilgrimage locations. These festivals and fairs are ".. a small mirror of the whole society, in which its energy and force, its beauty and its bad qualities, as well, are reflected".[14] They transform riversides into vast assemblies of devotees, preachers, traders and pilgrims.

1.5.1. Kumbh Mela

The most famous festival is the Kumbh Mela. It is held every four years by rotation at Haridwar and Allahabad (both on the Ganga), Nashik on the Godavari and Ujjain on the Kshipra river. Bathing in these rivers during the festival is said to cleanse a person of all sins. Once in six years, an Ardh Kumbh (half Kumbh) Mela is held between the two Kumbhs at Allahabad and Haridwar.

In recent years, increasing religious fervour attracts hundreds of millions of visitors from all over the globe as part of a larger revival mission that makes the Kumbh Melas the largest human gatherings on Earth. As millions collect to create a spectacular gathering the religious fervour reaches a crescendo.

Official records showed that in the 49-day 2019 Ardh Kumbh Mela that began on January 14th, just over 240 million people visited Allahabad, the highest number in the Mela's history, including almost a million foreigners and the ambassadors of 71 nations.[15]

1.5.2 Magh Mela

The first festival during the calendar year is the Magh Mela. It is held annually in Magh month from January 14th, the Makar Sankranti festival day at major pilgrimage sites in India, including the banks of River Ganga and its hundreds of tributaries and feeder streams. Every 12 years the Magh Mela becomes the Kumbh Mela. Mass ritual bathing in the river is the main feature. It is said that Indra the king of gods , cursed by rishi Gautama for lusting after his wife, was freed from the curse by the holy *Magh snan.*

The Magh Mela celebrations on the banks of the Ganga at Prayag , Uttarkashi , Haridwar are more well-known. The Magh Mela at Prayag (Allahabad), now reputed to be one of the largest fairs in the world, is organized on the banks of the auspicious *sangam*. Bathing there during the Magh period, from *Makar Sankranti* to *Maha Shivaratri*, is said to free one from rebirth.

In Uttarkashi district of Uttarakhand, people from various villages bring *dolis* (palanquins) bearing idols of their local deities and immerse them in River Bhagirathi at Manikarnika Ghat in Uttarkashi town. Various groups perform traditional dances and songs while the Bhotia traders sell their handicrafts.

The Uttarayani mela at Bageshwar on the banks of Uttarakhand's Saryu river is another version of the Magh Mela. It is a week-long fair beginning on January 14th every year.

1.5.3 Ganga Dussehra

Every year in the month of *Jyeshtha* (May-June) the Ganga Dussehra, observed all along the river's course, celebrates the descent of Ganga to Earth.

1.5.4 Kaanwar Yatra

Twice every year there is the *kaanwar yatra*, a smaller one around *Shivrartri* (around March) and then the major one during the monsoon month of *Saawan* (July-August). During the *kaanwar* festival Ganga worshippers walk back to their homes carrying *Gangajal*, without allowing the pot to touch the ground, to anoint a local Shiva *lingam*. In recent years the number of *kaanwariyaas* visiting Haridwar during *Saawan* has swelled into millions adding substantially to the local economies as well as civic tumult.

1.6 CELEBRATING GANGA

Across millennia, philosophers, writers, poets and singers have eulogized River Ganga's virtues and powers and kept alive its glory.[16] But some, looking at the river's reality have transcended faith to also question the blind beliefs of the masses.

THE KUMBH LEGEND

Kumbh means a water pot. In the context of the Kumbh mela it refers specifically to the pot of *amrita* the immortality elixir. According to Puranic legends, a sage Durvasa cursed the *devas* (gods), led by the god Indra, to lose their entire strength, energy and fortune for an act of disrespect. In later battles between the *devas* and the *asuras* (demons), the latter gained control of the universe. On the advice of Lord Vishnu, the *devas* made peace with the *asuras* and together they began to churn the sea of milk for obtaining *amrita*. Vishnu also told the *devas* that he would ensure that ultimately only they could possess the *amrita*.

The *devas* and the *asuras* churned the Ocean of Milk using Mount Mandara as a churning rod and Vasuki, the serpent around Shiva's neck, the churning rope. The churning yielded many treasures but also the lethal poison, *Halahala*, that could destroy all creation. The *devas* approached Shiva for protection, who consumed the poison and in the process his throat turned blue, making him *Neelakantha*.

Finally, Dhanvantari, physician of the gods, emerged with a pot containing the *amrita.* The *devas* and the *asuras* fought for it. The *devas* appealed to Vishnu, who took the form of the beautiful and enchanting Mohini to distract the *asuras* and distributed the *amrita* among the *devas*, who drank it. The rejuvenated *devas* then defeated the *asuras*.

When the *devas* were carrying away the *amrita*, some drops fell at Haridwar, Prayaga, Nashik and Ujjain. These places acquired a spiritual value and therefore the Kumbh Mela is celebrated at these four places every twelve years. People believe that after bathing there during the Kumbha mela, one can attain *moksha*. Some scholars, however, believe that the *Samudra Manthana* legend has been applied to the Kumbha Mela much later in order to show scriptural authority for the mela.

(Based on Eck D.L.)

The Rig Veda has only limited references to the Ganga, focusing more on the now lost Saraswati river. But in the myth about Ganga's descent from heaven, the Rig Veda describes its water as life-nourishing. The ancient poet, Valmiki, author of the Ramayana epic, vividly described River Ganga as full of whirlpools, flowing gently sometimes and becoming braided at other times. Its banks were extolled as celestial playgrounds frequented by *devas* (gods), *danavs* (demons) and *gandharvas* (heavenly singers) among others. Its body was home to cranes, swans, other birds and lotuses.

In an octet of praise for River Ganga, the poet Kalidasa wrote that its water was perennially clean. He called Ganga, *Akash Ganga*, a reference to the Milky Way. Tulsidas the 16th century poet-saint who translated Valmiki's Ramayana from Sanskrit into the vernacular *Ramacharitmanas*, lived on the banks of the Ganga in Varanasi. For him the Ganga represented devotion to Rama.

Adulation for the Ganga transcended time and religions. Zafar Khan Ghazi, a 13th century AD proselytizing Islamic warrior, became a Sufi mystic in later life. In an eight stanza Sanskrit ode to River Ganga, he likened her to 'the most compassionate mother of all'.[17] Kabir, the great 15th century weaver-poet who lived in Varanasi, often visited the Ganga *ghats* at dawn and watched the sunrise. In one *doha* (couplet) he compared the purity of *Gangajal* to *nirmala mana* or a pure mind.[18] But he was amused by the unquestioning faith of her devotees. Guru Nanak, the founder of the Sikh religion, also found it difficult to follow the rituals of a devotee when he visited pilgrimage spots by the Ganga river banks. On a visit to Benaras in 1827-28, Mirza Ghalib the celebrated Persian and Urdu poet, expressed his wish to pass away his remaining life on the Ganga *ghats* in Benaras.

Many Bengali thinkers have written about River Ganga. For Swami Vivekananda the Gita and Ganga constituted the essence of Hinduism. Ganga featured prominently in the works of Nobel laureate Rabindranath Tagore. To him River Ganga symbolized India. Amitava Ghosh among modern Indian writers, while celebrating the Ganga, is also critical of the Indians' blind faith in the river. Authors like Manik Bandhopadhyay and Humayun Kabir, poets and musicians with roots in today's Bangladesh have celebrated the Padma, a well-known channel of River Ganga, which merges with River Meghna in Bangladesh.

River Ganga has been held in utmost esteem and reverence throughout India since ancient times. It is the gold standard which people in south India use to praise their own local rivers. People in Telangana refer to Godavari as Dakshin Ganga. In Karnataka and Tamil Nadu, the Kaveri becomes the Ganga of south India. In *Manimekalai*, a famous Tamil epic, the poet Sathanaar describes the Goddess Sambapathy welcoming Cauvery refer to it as 'the Ganges from the blissful sky'.[19]

1.7 GANGA ICONOGRAPHY[20]

Agricultural surpluses in the vast Ganga and Yamuna plains sustained imperial dynasties from the Gupta era through the reigns of King Harsha, the Sultans of Delhi and the Mughals. Many of them demonstrated their gratitude by making the river goddesses emblems of their power. Coins and battle flags bore their images. The extent of reverence for the Ganga and Yamuna can thus be inferred from historical iconography.

During the Gupta era (c. 300-550 CE)[v] goddess Ganga became a symbol of prosperity and imperial power that lasted over two centuries across large parts of India. Kings, queens and prosperous traders issued coins depicting Ganga as a goddess of good fortune and imperial power. Sinuous images of goddesses Ganga and Yamuna astride their mounts, a crocodile and a tortoise respectively, were carved in temples and caves during the Gupta period, though images of Lakshmi were being used on official seals.

The goddesses appear as guardians at the fifth century CE Parvati temple of Nachna Kuthara, near Khajuraho. Such images appear often as far east as Tezpur in Assam. In the west sculptures of the river goddesses can be seen in the Ajanta caves near Aurangabad and the Elephanta caves near Mumbai. As the southern Pallava, Chalukya and Rashtrakuta dynasties began extending their reach beyond the Vindhyas into the Ganga heartland, there was a diffusion of Ganga myths, knowledge and iconography in the south. Ganga and Yamuna sculptures began adorning South Indian temples during their dominance. One of the most well-known sculptures is a massive mural showing Ganga's descent from heaven at the 10th century CE Pallava temple in Mahabalipuram on the southern tip of the Deccan peninsula. Battle flags of the southern dynasties often sported images of the goddesses Ganga and Yamuna.

The Rashtrakuta kings immortalized their worship of Ganga by sculpting her idol in the Kailashanatha rock cut temple in Ellora, adding to similar imagery by the earlier Vakataka kings at the nearby Ajanta caves. The expansion of the Chola Empire took the Ganga image as part of the Nataraja sculptures to various temples in Tamil Nadu. Rajendra, a Chola king, is said to have brought vast amounts of *Gangajal* to be stored in the massive Brihadeshwara temple in Tamil Nadu during the eleventh century CE.

Sprinkling or dousing with sacred Gangajal to enhance the life of the ruler may have been a coronation ritual prescribed in the Atharva Veda. Two copperplate inscriptions of a Vakataka king Pravarasena II, found in Berar (Deccan) and Seoni (Madhya Pradesh) indicate that during the coronation of a king his forehead was sprinkled with the pure *Gangajal* obtained by his own valor. Kalidasa's poem *Raghuvamsa* ends with a description of a queen being doused with *Gangajal* poured from golden jars. A similar ceremony using golden vessels was also performed during the crowning of King Harsha. By the second century CE the sacred waters of river Ganga became an indispensable part of meal-time rituals of kings in northern India.

1.8 GANGA BASIN DOWN THE AGES: THE RIVER AS CAPITAL[21]

A large part of India's history since the ancient period is located in the Ganga basin. The Ramayana and Mahabharata epics, which also contain stories of the origins of River Ganga, are largely centered in this region.

Buddha attained enlightenment in Bodh Gaya, located on river Nairanjana, a tributary of River Ganga and early Buddhism left a significant cultural imprint in the middle Ganga plains. Important Buddhist monastic orders were based in Vaishali, Kaushambi and Sarnath (near Varanasi). Many Buddhist stories (*jatakas*) allude to Varanasi by the Ganga.

The Arthshastra described the Ganga plains region as a landscape with arable land beside forests full of elephants and timber and pastures for cattle. Floods would devastate this idyllic landscape in the monsoon season. Extensive agriculture began producing surpluses that sustained urban centers in the Mauryan Empire. By Ashoka's reign several towns and cities emerged along the Ganga (and Yamuna) banks even as the forests still contained hunting and gathering tribes. Vidisha, at the confluence of the Bes and Betwa rivers, was an important town on the trade route connecting the Ganga valley to central India.

The sanctity of the Ganga continued to grow even later when Jainism and Buddhism spread, since the masses adopting these religions continued to immerse the ashes of the dead in the Ganga. Despite political upheavals for more than two centuries after the collapse of the Mauryan Empire, the anthropogenic utility of river Ganga and its

TRANSFORMING THE RIVERSCAPE

The compositions of Banabhatta, the 7th century CE Sanskrit scholar and King Harsha's court poet, contain elaborate descriptions of lush forests in the Ganga valley and their wildlife.[22] Literature of the early second millennia CE describes a delicately balanced agrarian ecology. The *Matsya Purana* compiled between the 8th and 13th century CE recounts verdant forests, pastures, lakes and marshes in the Ganga plains. Babur (16th century CE), who had a keen eye for the natural landscape, wrote about the abundant diversity of flora and fauna in northern India. He wrote of hearing the roars of lions and rhinos at night from his campsites. Near Allahabad herds of wild elephants were being domesticated. Among smaller fauna he saw local and migratory birds. Babur wrote that in Jaunpur and Benaras the Ganga was full of crocodiles, alligators and dolphins.

As late as in the 18th century CE in the eastern Ganga valley tigers, rhinos, bear, deer and peacocks and roamed the jungles of today's Jharkhand. Reed jungles between the cities of Munger and Pipra were dominated by tigers, rhinoceroses and wild buffaloes.

tributaries grew as they provided transport routes for agricultural surpluses and urban centres flourished on their banks. Some of the well-known towns were Patliputra on the Sone near its confluence with River Ganga, Vaishali on the Gandak and Kosambi and Bhita on the Yamuna. The latter towns had brick houses and grids of broad thoroughfares, not unlike the images of Mohenjo-Daro. During this time Patliputra was perhaps the largest city in the world.

Mahmud of Ghazni was perhaps the first Islamic ruler who crossed the Ganga, in the 11th century CE, and pushed into its heartland by conquering the rich city of Kannauj. His governor, Ahmad Tigin of Lahore, reached as far as Varanasi a few years later. In the early 12th century CE the Gahadavala king Govindachandra endowed the famous Kashi Vishwanath temple and the ghats in Varanasi after he had subdued Turkish invaders.

At the end of the 12th century CE, Muḥammad Ghori defeated Prithviraj Chauhan and Jaichand and firmly established Turkish rule in the Ganga heartland. Later, sculptures and artifacts, including Ganga and Yamuna images were reused in the Qutab complex (Delhi) by Qutubuddin Aibak and Iltutmish.

1.8.1 Expansion Into The Middle Ganga Valley

Mongol armies repeatedly attacked the northwestern territories of the Sultanate. Hence the expansion of the Sultanate Empire took a south-easterly route along the Ganga. The fertile middle Ganga valley held potential for increased agriculture production and revenue generation. Technology, taxation and markets aided the evolution of the middle Ganga valley over a few centuries into one of the world's most densely packed peasant settlements.

New technologies like the *shaduf* for lifting water out of an irrigation canal or a well, the animal-powered and geared water wheel called *saqiya* and the *noria*, a vertical water-powered wheel for harnessing water increased agriculture production. Firoz Shah Tughlak brought water via the Western Yamuna Canal to Hisar town in the semi-arid west.

The eastward push first began in the Ganga-Yamuna Doab and later towards the head of the Bengal delta during the 13th century CE. Loot and plunder of new territories by earlier raiders was gradually replaced by systematic taxation of agricultural produce. It enriched the Sultanate treasuries, enabling new conquests, extension of cultivation and greater revenues that helped extend and strengthen the Sultanate Empires. Later, in the 16th century Sher Shah Suri, the Afghan ruler from Sasaram (Bihar) reformed taxation. Most of the taxation was in the form of a fraction of the farm produce. What was left over was first for subsistence and the surplus was for the markets. *Banjaras* or traders provided access to the markets. They travelled in huge caravans ahead of ten to twenty thousand pack animals carrying household provisions from farmers to distant markets.

The eastward expansion, however, transformed the middle Ganga valley landscape. It led to felling of vast stretches of thick jungles teeming with wildlife. The conversion of the forested alluvial Gangetic plains to agriculture fields had begun in the first millennia CE but it gradually gathered pace in the second millennia. The latter conversion too was often a halting process. The forests would be cut and settled under favourable conditions, but the fields could also be swiftly abandoned during famines, floods or forest fires. With good rains, the forests would quickly regenerate again. Abandonment of cultivated land meant revenue losses for the state. Hence the Sultanate rulers, particularly Alauddin Khilji, introduced reforms and punitive laws to stabilize crops production and prices.

Benaras enjoyed great prosperity during the first 150 to 200 years of the Delhi Sultanate. The grand Vishweshwar temple, a predecessor of the Kashi Vishvanath temple, was built with a large donation by a Gujarati merchant during the reign of Iltutmish. The Padmeshwar temple on Ganga's bank was constructed during the reign of Alauddin Khilji and the Manikarnikeshwar temple during the Tughlak dynasty.

1.8.2 Expansion Into the Lower Ganga Basin

Bengal at the eastern end of the Islamic Empires presented a different picture. Rainfall and, therefore, water was plentiful. But for several hundred years the Ganga had been shifting eastward, reducing the flow in the Hughli-Bhagirathi channels. In the early 13th century CE the Delhi Sultans established their regional capital at Lakhnauti located in the Mahananda and Ganga river valleys, in today's Malda district. By then Saptagram on the Saraswati river had become the busiest port in Bengal. It also became an administrative base for the Islamic rulers.

Zafar Khan Ghazi, the proselytizing Turkish warrior, conquered Saptagram and deposed local rulers in the region to establish the rule of the Delhi Sultanate, before he himself was killed in a battle. His tomb is located at Tribeni, near Kolkata in Hooghly district that is said to have once been the meeting point of three holy rivers Ganga, Jamuna and Saraswati. Zafar Khan is remembered by Hindus and Muslims for his deeds of piety and as a Ganga worshipper. Sen states that late in his life Zafar Khan became a Sufi mystic, wrote evocative Sanskrit poems and became much loved even by the local Hindus he had tried to forcibly convert to Islam. Other Sufi Ghazis are also venerated by local Hindus and Muslims. Pir Badaruddin or Badar Ghazi is regarded as the protector of boatmen and fishers and Bara Khan Ghazi as a protector against tigers in the region.

The military expansion into Bengal was accompanied by the transformation of forests into agricultural lands for rice cultivation by peasants. By the end of the 15th century CE such colonizers had reclaimed many parts of lower Bengal, into Jessore and Khulna districts of the present-day Bangladesh.

AN EVOLVING TRADITION[vi]

Myths about Ganga and other river goddesses and their worshippers have evolved over millennia as part of local folklore. There are interesting tales of Gaji, the son of a local Muslim ruler in Bengal and his foster brother Kalu. In some of these stories Gaji's mother, Ajupa, is said to be Ganga's sister. She appears repeatedly to save the brothers from harm. In one tale a poor woodcutter gives the brothers shelter in a forest but has no food to offer them. Ganga sends her emissaries as serpents bearing food to them.

In one fascinating story Gaji and Kalu reach the sea and scare about 300 meditating *yogis.* When the *yogis* inform them that they are Ganga devotees, Gaji summons Ganga and she arrives before them seated on a lotus leaf to the utter disbelief of the *yogis*. They convert to Islam and Gazi and Kalu build a mosque there with the blessings of river Ganga.

1.8.3 Ganga in the Mughal Period

After ascending the throne of Hindustan in 1526 CE, Babur and later his son Humayun, ruled from Agra on the banks of the Yamuna. Babur quickly took control over the revenue-rich tracts from the Ganga-Yamuna Doab to Saran in Bihar. He noted the abundance of water in the river and its underground flows which the peasants lavished on their crops. But he and Humayun also learnt firsthand that the Ganga and her tributaries in flood could be the bane of kings, armies and warriors.

Akbar consolidated and expanded the Mughal Empire to its zenith in the 16th century CE. Raja Todar Mal, who had regulated the land tenure system under Sher Shah, laid the fiscal foundations of Akbar's Empire. Akbar considered the Ganga-Yamuna *sangam* at Prayag to be a most peaceful place. But the practice of ritual suicide by sorrowful devotees, who flung themselves from a huge banyan tree into the river at Allahabad, disconcerted him. He then built the Allahabad fort around this melancholy spot to end the notorious practice and to serve as a reminder of Mughal authority in the region.

Dr Ram Nath, an Agra-based historian, wrote in his book "Private Life of the Mughals in India" that after the first Battle of Panipat, the wounds of the nobles and prominent generals like Bairam Khan were washed with Ganga water.[23] Babur missed the cool streams of Kabul when he settled in India after 1526. The alternative he found was Ganga water. Babar and Humayun were said to have been convinced of the purity of *Gangajal*

On May 31, 2016 the Union Ministry for Water Resources filed an affidavit in the Supreme Court saying that Emperor Akbar drank either pure Ganga water or water mixed with Ganga water since the Mughals were aware of its healing properties.

https://www.livemint.com/Politics/w25GimZJwY5ebct3d1fVsJ/Even-emperor-Akbar-used-to-drink-Ganga-water-says-ministry.html because it could be stored for long periods without putrefying. They likened it to *Aab-e-Hayat,* the water of paradise. Akbar always drank Ganga water. Jahangir too preferred *Gangajal.*[24] Shah Jahan drank Jamuna water in Agra, though Ganga water was brought on special occasions.

1.8.4 Ganga in the Colonial Age[25]

The Ganga-Brahmaputra delta (See Chapter 5 for details) is one of the largest in the world.[26] It drains rivers and carries the world's highest sediment load from India, Bangladesh, Bhutan, Nepal and Tibet. Each year the rivers expand the land with their sediments while the sea fights back through the estuaries to reclaim a part of the shallow land formations. Thus, the delta is a constantly shifting and changing landscape. Portuguese and Dutch explorers' maps of the 16th century CE show a maze of sea inlets and low-lying islands or mudflats in the delta.

Besides farmers, the delta region of Sunderbans is home to fishers and boatmen. The Sundarbans forests cover an area of about 10,000 km^2. They contain a wide diversity of flora and fauna and also contain the world's largest contiguous stretch of mangrove forests (More details in Chapters 5 & 6).

Rivers have been used as trade routes since ancient times. For example, the *Uttarapatha,* first mentioned by Panini, was the major trade route of northern India. It was a land-cum-river route. The Ganga, Yamuna, Ghaghra and the Saryu were part of this route.[27] It swept down from north-west India, across the Indo-Gangetic plains, down to the port of Tamralipti in the Bay of Bengal. From ancient times, kingdoms devised systems for collecting tolls and taxes from river traders. In return they kept the waterways safe. But when authority collapsed, rivers became waterways to wealth for local powers, rent collectors and raiders.

The Ganga and its many branches in Bengal were major transport routes for taking the produce of Bengali weavers and farmers to various parts of India and abroad to nearby nations. The water traffic generated handsome annual revenues for the Nawabs of Bengal who then paid a tribute to the Mughal Court in Delhi.

In the 16th century CE European traders and maritime powers opened up the Ganga delta region along with other coastal areas in India to international trade. It resulted in massive ecological, economic and demographic changes in the delta.

In the early 16th century CE the Portuguese, who then controlled most of the sea trade routes in the Indian Ocean from the Far East to the Persian Gulf, established themselves along the littoral Ganga delta with two important ports, Hugli in the west and Chittagong in the east. Their presence along the coast kept a growing crowd of seafaring looters out of the large dense forest tract between Hugli and Chittagong hills which was then infested with crocodiles, tigers and other wild animals. In 1579 Akbar issued a *farman* (a decree) to the Portuguese allowing them to trade throughout India without paying any duties. The major items of trade were cotton textiles, jute, rice, sugarcane and minor forest products.

In 1602 CE Dutch merchants set up the Dutch East India Company and soon Dutch factories and ships began to appear in the lower delta. By 1665, the Dutch were the main exporters of all kinds of textiles to Europe and Japan. By the mid-18th century CE, the Dutch owned factories at all major trading centres in Gangetic Bihar and Bengal. They also dominated international trade from China through Japan, Indonesia, India, Sri Lanka and Europe.

The British East India Company began operations in Surat and obtained a *farman* from Emperor Jahangir around 1612 CE to trade freely in India. In 1690, Job Charnock established the British East India Company's headquarters at a place on the Hooghly river that could be more easily defended. He called it Calcutta. Dense tiger-infested forests were cut down to build Fort William in Calcutta.

The British gained complete control of the enormous revenues of Bengal in 1764, after the Battle of Buxar, having defeated the French and the Dutch earlier. Before the end of the 18th century CE, the British East India Company, after edging out its Portuguese, Dutch and French rivals from almost all of India, ventured north of the Ganga delta to Benaras and beyond. In the process forests were felled and swamps cleared to expand the area under cultivation.

During the 1768-1770 famine, millions perished in a few months and Ma Ganga received their skeletal bodies in her bosom. Warren Hastings, the first British Governor-General in India, estimated that one-third of Bengal's population had disappeared by 1772. Much of Europe and England found it hard to believe that such a famine could occur in fertile Bengal, watered by River Bhagirathi (Ganga) and hundreds of small water courses. The fault lay not so much in rainfall failure as in rapacious tax collection and poor or no relief measures.

Thomas Macaulay wrote later, "No part of India possessed such natural advantages, both for agriculture and commerce." Bengal was blessed by the Ganges, which, "rushing through a hundred channels to the sea, has formed a vast plain of rich mould……that rivals the verdure of an English April," enabled rice, spices, sugar and oils to grow easily.

Thereafter the British Parliament passed the Regulating Act of 1773 and took over direct governance of the Indian territories managed by Company officials. Warren Hastings was appointed the first British Governor-General under the direct supervision of the British Parliament. Major reforms in the tax collection system followed. *Rahadari* – the system of waterway tolls -- was abolished. An estimated 30,000 boats ferried merchandise between

Dhaka and Benaras. Duties levied on the pilgrims also enriched the government.

Later Governor-General Charles Cornwallis abolished collection of local tolls by *zamindars* and merchants so that the products of Bengal and imports from Europe could be transported freely from the sea via the Ganga. Cornwallis also legalized a system of land revenue collection in Bengal, Bihar and Orissa by *zamindars*, "who were seen as amenable instruments in the creation of a colonial agrarian order."

With the rapid reduction in the Mughal Emperors' authority during the 18th century CE, safe travel and revenue generation from the roads along the Ganga and on the river itself became hazardous. Powerful religious orders fought to secure rent collection for themselves at pilgrimage centres like Hardwar, leading to bloody conflicts. In the 16th & 17th century CE, Rajput chiefs had overseen the maintenance of the *ghats* and temples in Benaras. Now, powerful Marathas came to rule the destiny of Benaras. In 1765, after the Battle of Buxar, the Mughal Emperor ceded Prayag to the English in the Treaty of Allahabad.

By 1781 CE, Major James Rennell, the first Surveyor-General of British India, had mapped the Ganga to determine the extent of its navigability for commercial and military purposes. Discovery of steam engines and mining of coal brought steam ferries to River Ganga in 1828. They were first used as military transport and then for common people, up and down the river and sometimes across its wide width as from Patna to Hajipur in Bihar. As the East India Company gained more territories in the Ganga basin, the river's physical management was entrusted to engineers who renovated or constructed bunds, barrages, reservoirs, aqueducts and canals to generate more revenues for the Company through irrigation and navigation. Its officials saw canals as better investments rather than spending money on famine relief.

In the early 1850s, Sir Proby Cautley oversaw the construction of the great Ganga Canal from Kankhal, just downstream of Har-ki-Pauri in Hardwar to Kanpur, 325 miles away. With a possible extension of the canal to Allahabad the Company hoped to transport goods from Hooghly to Hardwar.[vii] The Ganga Canal was inaugurated in April, 1854 and the canal authorities took over the lucrative pilgrimage sites in the name of easing the performance of daily rituals. Charles Norton wrote in the North American Review that people had come from different parts of the country to see that their "revered Ganges …… leave her ancient and hallowed channel for one formed for her by the hand of strangers." Eventually the Ganga canal system under the British totaled 898 miles!

Even as the British pillaged the Ganga valley's natural environment, their artists and photographers travelled in the region producing masterpiece representations of a countryside that was gradually disappearing.

1.9 GANGA THROUGH FOREIGN EYES

River Ganga, its worship, size, discharge, water quality, riverside towns, valleys, plains, forests, wildlife and character, have fascinated foreign travelers, conquerors, ambassadors, civil servants, traders, missionaries, authors, artists and photographers over the ages.

Before the start of the Common Era (CE), much of the world had not been explored. The Greeks who came with Alexander's army around 326 BCE (Before Common Era) may have first pronounced Ganga as Ganges.[28] The early statements of Greek historians were based on very sketchy knowledge provided by travelers who went beyond the northwestern part of India conquered by Alexander. Thus, Strabo wrongly asserted that the Ganga was the largest river in all of Europe, Asia and Africa. Arrian also made a similarly incorrect assessment of the Ganga, which he described as the greatest river in India, "with which not even the Egyptian river Nile or the European river of the Danube is to be mentioned in the same breath." Megasthenes, the ambassador of Seleceus Nicator in the Mauryan court determined the Ganga's width (presumably at Pataliputra) to be about 30 stadia or about 3 miles.[29] He too described the Ganga as the greatest river in the world.

In the second century CE, Ptolemy the cartographer in Alexandria, created a map of India showing the Ganga as flowing south to south-east from the Himalayan mountains to the Bay of Bengal.[30] As early as the 5th century CE, Fa Xian, a Chinese Buddhist scholar who visited India, identified Tamralipti as the main port at mouth of the Ganges. He also wrote about Buddha preaching on the banks of the Ganga at Kannauj. Xuanzang, the well-known Chinese traveler of the 7th century CE – better known in India by the earlier spelling of his name as Hiuen Tsang – called Ganga a "river of religious merit" that could wash away sins.

Abu Al-Biruni, an Uzbek traveller in the 11th century CE, and Ibn Battuta, a Moroccan visitor in the 14th century CE, wrote about the importance of the Ganga for Hindu death rituals.[31] In the 13th century CE, Darap Khan Gaji the warrior –turned- mystic considered Ganga water to be the only water pure enough for the ritual ablutions of the Muslims. Ziya-ud-din Barani, an eminent historian of the 14th century CE, found the Ganga and Jamuna nearly impassable during the peak monsoon season.

European traders set up bases in the Ganga delta region in the 16th century CE. Maps prepared by their cartographers showed a shifting delta coastline. Missionaries and other European visitors to the area wrote accounts of the huge, dense wilderness of the delta area, infested with human-eating tigers and crocodiles. Ralph Fitch, an English merchant and emissary from Queen Elizabeth to Emperor Akbar, travelled down to Saptagram in Bengal, "in the companie of one hundred and fourscore boates laden with Salt, Opium, Hinge (asafoetida), Lead, Carpets and divers other commodities down the river Iemena (Yamuna)".[32]

In the early 17th century CE, Thomas Roe, England's ambassador in the court of the Mughal Emperor Jahangir was fascinated by *banjaras* leading thousands of grain-carrying buffaloes in the Ganga plain. A few decades later, Jean Tavernier, a French traveler was also, "astonished … to behold caravans numbering 10,000 or 20,000 oxen together for the transport of rice, corn and salt".[33]

European surveyors in the 18th century CE extensively mapped the Ganga basin. South of the main stem of the river they recorded vast tracts of dense deciduous forests full of wild animals including tigers, rhinoceroses and bears. Forest-dwelling *adivasis* were seen hunting with bows and arrows. Villages by the banks of the Ganga were terrorized by tigers and bears. Up north, in the region of the Gandaki-Ganga confluence, were coniferous jungles. Even a hundred years later these regions were home to nearly impenetrable grasslands and jungles full of wild animals.

Major James Rennell produced his mammoth *Bengal Atlas* in 1781. In it he mapped all the meanders along the Ganga's course, the elevation of its banks, the river's velocities at various locations and seasons, water levels during the driest and wettest months, the spread of its monsoon floods, its discharges in every season, the soil quality of its banks and the area of its surrounding jungles, among other parameters. A few years later G.H. Barlow, an emissary of Governor-General Cornwallis, informed the directors of the Company of the huge potential for transporting goods via the Ganga, "from the sea to its source".[34] To William Hodges, an itinerant artist, who travelled along the Ganga in the 1780s, the fleets of boats, ancient wayside temples with steps leading to the river and the lush forests of its valley were an 'inexpressible grandeur'.[35] Landscape artists, Hodges, Thomas Daniell and his nephew William, who also came to India in the late 18th century, created the first ever visual pictures of the Ganga and the surrounding countryside.[36]

James Fraser was the first Englishman to reach Gangotri in 1815. He described the scenery in the Bhagirathi valley, "Fir trees of immense size, and large fragments of others, are seen half buried in sand and gravel; and huge masses of earth and rock lay in wild confusion at the mountain feet".[37] Fanny Parkes, a 19th century diarist in India, learnt Hindustani and referred to the Ganga and Yamuna with the honorific suffix 'ji'.

Thomas Macaulay's description in the first half of the 19th century CE, of the Bengal plains as being formed by the Ganga, "rushing though a hundred channels to the sea," indicates the tremendous discharge of the river then, in a flat region. [34], Dietrich Brandis, the pioneering forester in the latter half of the same century, was impressed by the vast virgin sal forests in the Himalayan foothills. In the late 19th century, Edward Lockwood, a civil servant and a wildlife buff marveled at the abundance of flora and fauna on the southern banks of the Ganga, around Munger in Bihar, an intensively cultivated area today. Observing swarms of ducks in the marshes and swamps of abandoned channels he remarked that they were, "so close together that they almost hide the water……"[38]

James Prinsep, the 19th century British Orientalist, artist and lithographer was fascinated by the ghats along the Ganga in Varanasi. He wrote, "….. along the ghats passes the busiest and happiest hours of every Hindoo's day: bathing, dressing, praying, preaching, lounging, gossiping or sleeping…… In no city of the world is the population invited to a single street or place of recreation by so many distractions".[39]

Visiting Varanasi almost a century later, Aldous Huxley refused to be taken in by the holiness of the river or its devotees. Watching over a million worshippers descend by the riverside on Makar Sankranti day (January 14th) 1926, he wrote, "The Hindus counted their beads and prayed, made ritual gestures, ducked under the sacred slime, drank (it) and were moved on by the police….". [40]

By the middle of the 19th century CE the East India Company officials had become aware of the tremendous irrigation revenue generation potential of River Ganga. When the Upper Ganga Canal was inaugurated in 1854, the Lieutenant Governor John Colvin bragged that the British had finally left, "A permanent mark on the soil of India to attest to the power, the wealth and the munificence of their nation". [41]

1.10 CONCLUSION

The tremendous hold of river Ganga on the hearts and minds of Indians has been nurtured by myths, legends, mythology passed on from generation to impressionable succeeding young generations, arts and literature -- often embedded in timeless rock iconography. It is sustained by daily rituals, periodic fairs and festivals around the river, nourishing livelihoods across millennia. It is reaffirmed by scientific confirmation of its unique self-cleansing ability and curative health properties. All of these have combined to create an ever-lengthening cultural history of the river and an eternal and living faith in its divinity.

1.11 END QUOTES

i. Several portions of this chapter are based on readings of D.L. Eck (2012) and S. Sen (2019)
ii. In present times Shiva's locks are understood as being the Himalayan forests that tame the Ganga and her myriad headwaters.
iii. The Sanskrit word *teertha* has multiple meanings – a sacred place, a river crossing or a ford, among many others. In Indian scriptures it often refers to pilgrimage sites connected to

sacred waters.

iv. CE refers to Common Era or what used to be A.D.

v. Adapted from S. Sen (2019): *GANGA:The Many Pasts of a River,* Penguin Random House India Pvt. Ltd., Gurgaon, p. 284.

viii. It appears that the Indian government now wishes to pursue this dream.

1.12 REFERENCES

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2. Ibid
3. D.L. Eck (2012). India: A Sacred Geography. Harmony Books. Random House. New York, p.137.
4. Ibid p.138.
5. Ibid p.135.
6. Chopra R. (2016). Op.Cit.
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23. Sen S. (2019). Op. Cit. p.137.

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28. Sen S. (2019). Op. Cit. p.271.
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32. Ibid. p.193.
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34. Ibid. p.41.
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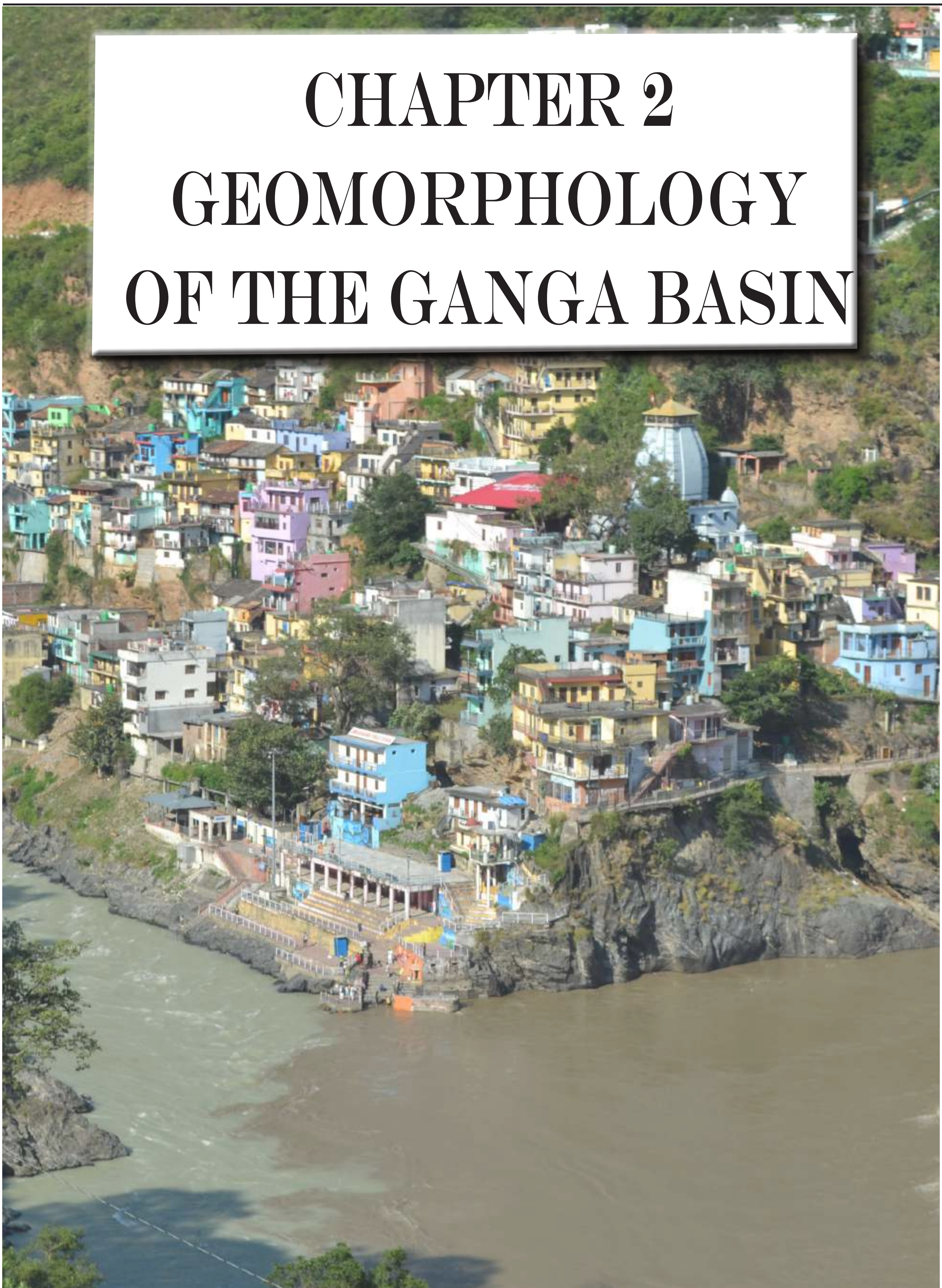
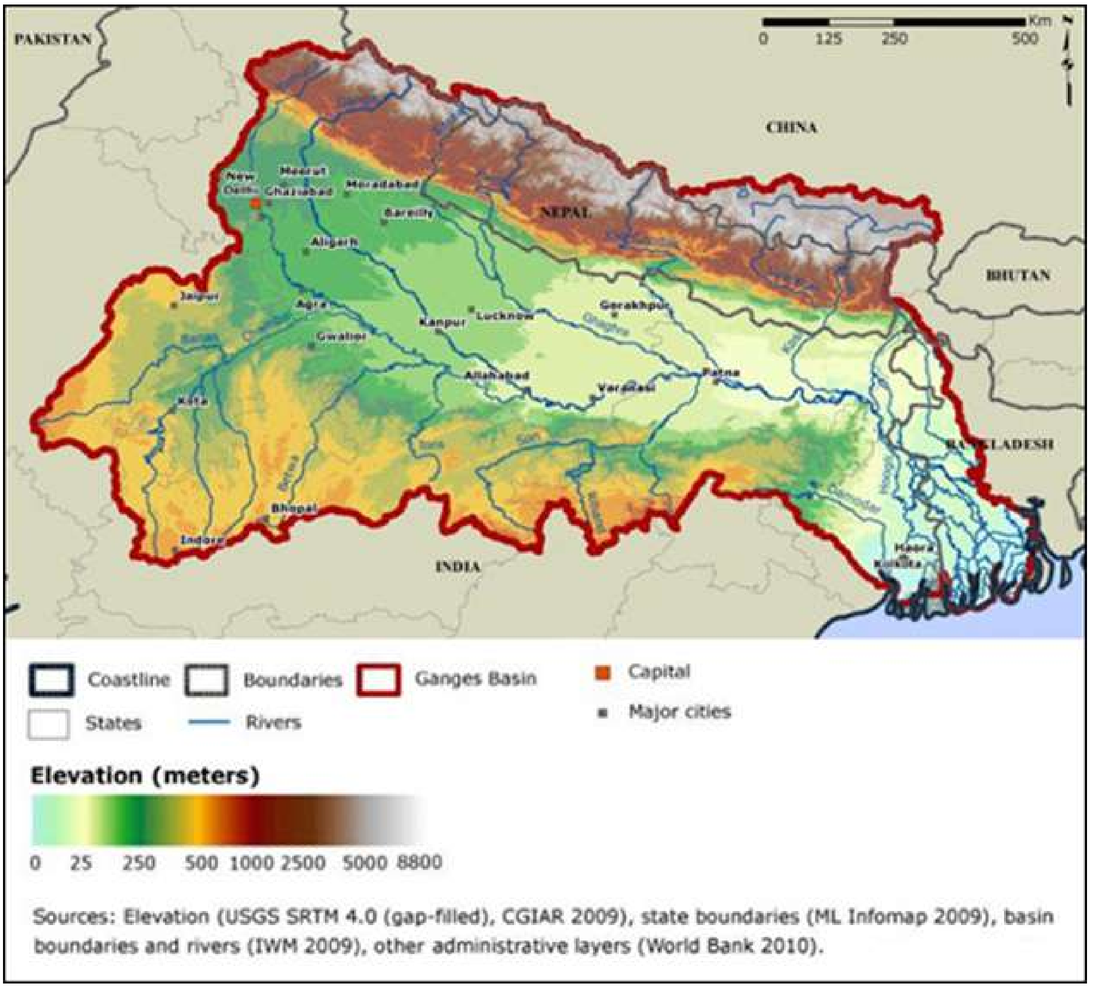
CHAPTER 2
GEOMORPHOLOGY OF THE GANGA BASIN



2.1 RIVER GANGA BASIN

River Ganga is one of the several large rivers that originate in the Himalaya-Tibetan uplift and is joined by a number of major Himalayan tributaries such as the Yamuna, Ramganga, Ghaghra, Gandak, Kosi and Mahananda before meeting the sea in the Bay of Bengal (Sinha R., et al 2005).

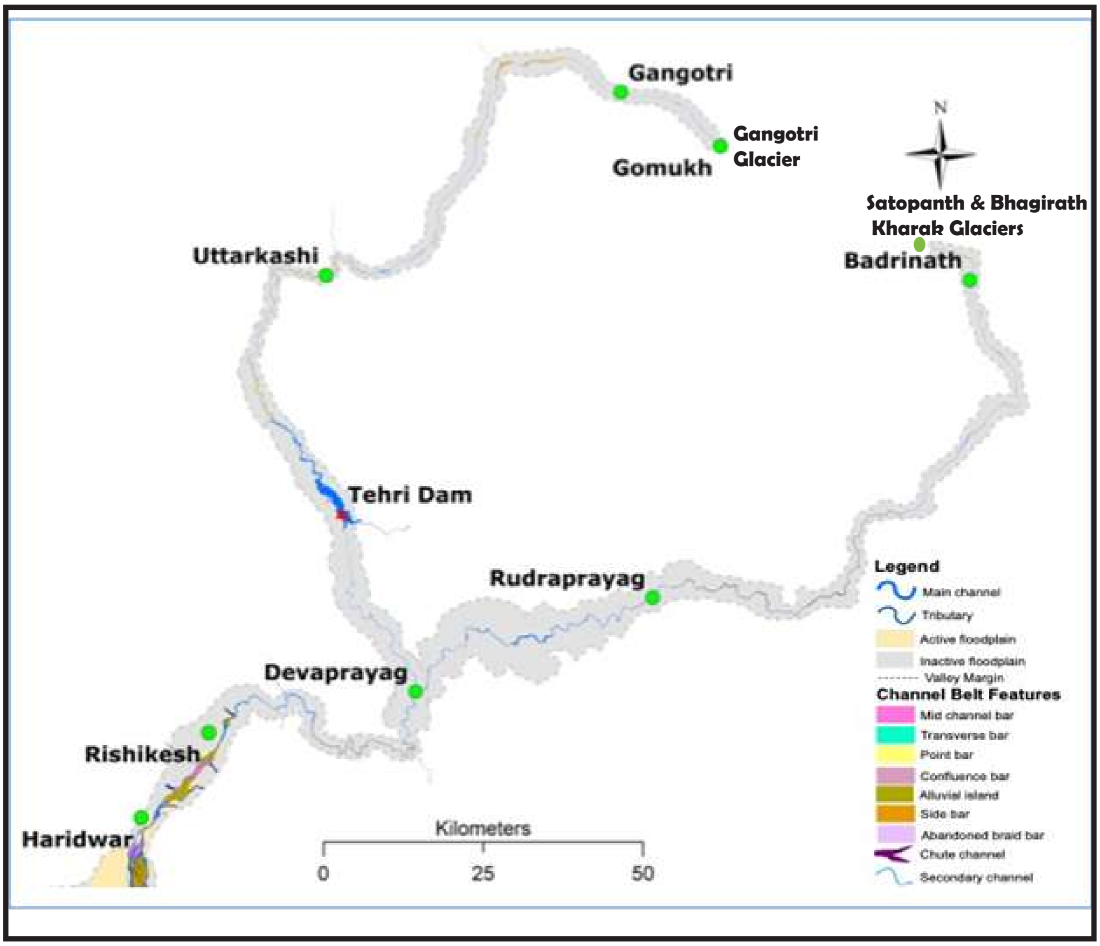


Map 1 : Extent and Topography of the Ganga Basin and its Hinterlands

From the south, several tributaries (primarily of River Yamuna) like the Chambal, Sindh, Betwa & Ken originate from the Vindhyan craton to join the Ganga on the right bank. Rivers Tamas (Tons), Sone and Punpun also join it from the south. River Damodar and its tributaries meet the Ganga (in its lower stretch) from the west after draining the highlands (Hazaribagh plateau) of Jharkhand state (Map 1).

2.2 THE MOUNTAINS

The mountainous catchment of the Ganga river system in India falls in the Garhwal and Kumaon Himalaya which form the western end of the Central Himalaya in northern India. The entire region, lying in the state of Uttarakhand, has been undergoing rapid uplift and intense fluvial[1] and glacial incision[2] manifested in steep gullies and deep valleys and large-scale erosion. It is estimated that over 40 per cent of Uttarakhand state faces severe (8.84%) to very severe (32.72%) erosion (Mahapatra S.K., et al, 2018). The mean erosion rates for the Ramganga, Ganga, Alaknanda, Kali, Bhagirathi and Yamuna river basins were estimated to be 14.64, 22.22, 31.23, 33.24, 36.86 and 38.00 t/ha/yr, respectively (George J., et al 2021).



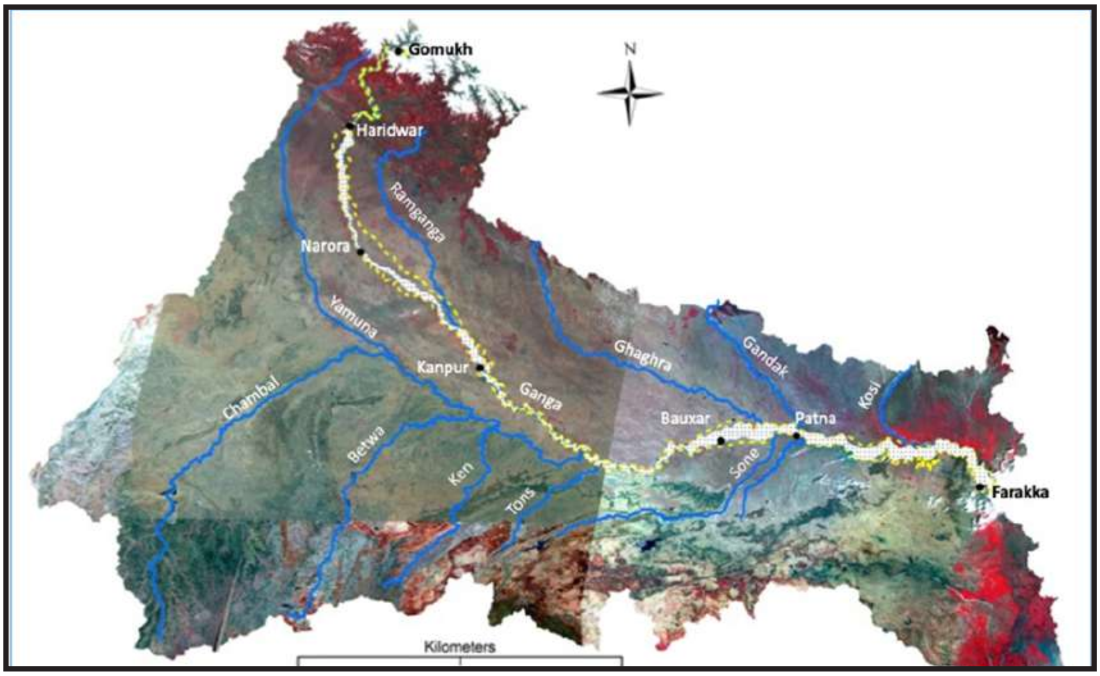
Map 2 : The Alaknanda and Bhagirathi Rivers Join at Devprayag to Become the Ganga

Source: Mohanta H., 2018

The Alakananda river draining the Uttarakhand Himalaya is one of the major tributaries of the Ganga system. Rising at the Mana Pass, it joins the Bhagirathi River - originating from Gaumukh in the Gangotri glacier - at Devprayag to jointly become R. Ganga (Map 2). Several abandoned channels, abrupt swings in channel courses, entrenched meanders, valley floors dropping as much as 1000 m in elevation and the terraces standing several meters above the present river level provide eloquent testimony of rapid uplift (~5 mm/yr) and variable fluvial incision (2-12 mm/yr) (Sinha R., et al 2005).

2.3 ALLUVIAL PLAINS

The Ganga alluvial plain is about 1000 km long in the east-west direction and 300-500 km wide south of the Himalayan Ranges. Rather flat looking, it has a gentle southeasterly slope followed by numerous Himalayan and alluvium-fed rivers. The alluvial Ganga plain is densely populated and highly cultivated. The western part of the Ganga plains is occupied by River Yamuna. River Ganga, which is the trunk river of the basin before entering into the Bay of Bengal, forms the largest delta in the world, the Ganga-Brahmaputra-Meghna delta, after the confluence with the Brahmaputra-Meghna rivers (European Space Assn., 2009).



Map 3 : River Ganga and its Major Tributaries

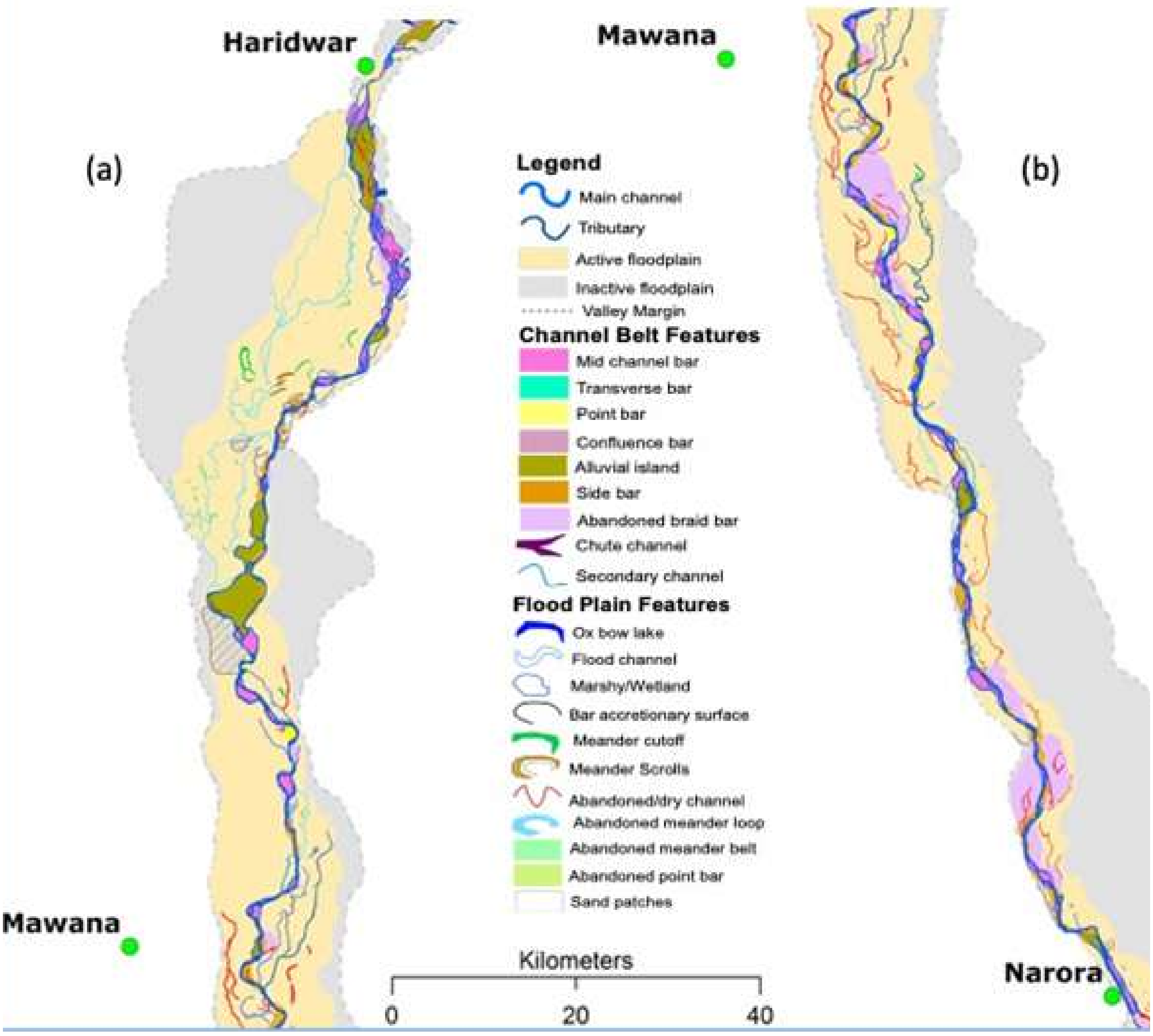
Source: Mohanta H., 2018

2.4 GANGA BASIN AND ITS MAJOR TRIBUTARIES

The alluvial stretch of R. Ganga (Map 3) is characterized by significant diversity in channel form and floodplain characteristics. In the following sections, diagnostic features are discussed in stretches for the sake of clarity. They do not represent any firm zoning (Sinha R., 2017).

2.4.1 Haridwar to Narora

The Haridwar to Narora stretch of R. Ganga has a considerably wide valley on either side of the river. The river channel in this stretch is highly braided. As a result, mid-channel braid bars form a significant geomorphic feature followed by lateral bars, and point bars. In this stretch, wide flood plains are composed of sand, gravel, silt and clay.



Map 4 : Geomorphic Map of the Stretch from (a) Haridwar to Mawana and (b) Mawana to Narora

Map 4 shows a geomorphic map of the stretch from Haridwar to Mawana in which the river first flows along the eastern edge of the upper valley and later swings alternately to the western and eastern parts. An extremely wide valley immediately downstream of Haridwar is due to a sudden decrease in the slope as the river debouches into the plains and forms a large depositional area (piedmont fan). A large number of paleochannels (old inactive channels filled with younger sediment) on the western side of the main channel suggests an eastward migration of the river in recent times. There is a major

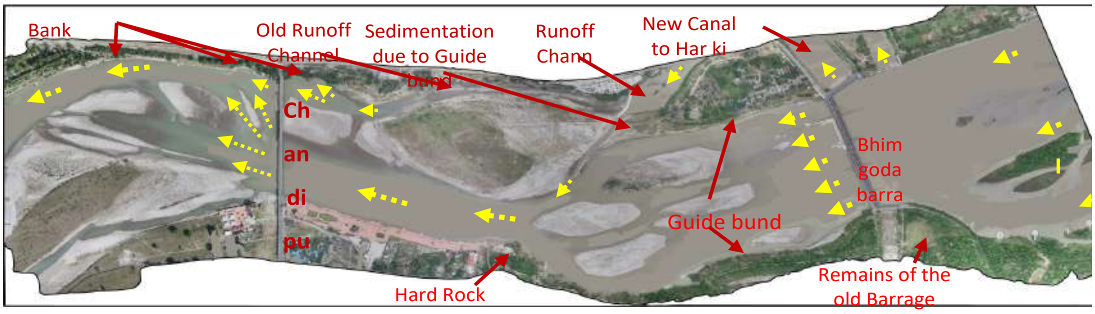


Image 2 : A Drone Image Showing the Stretch of the Ganga River Around Haridwar Between Bhimgoda Barrage and Chandipur Bridge

Source: IIT-Kanpur

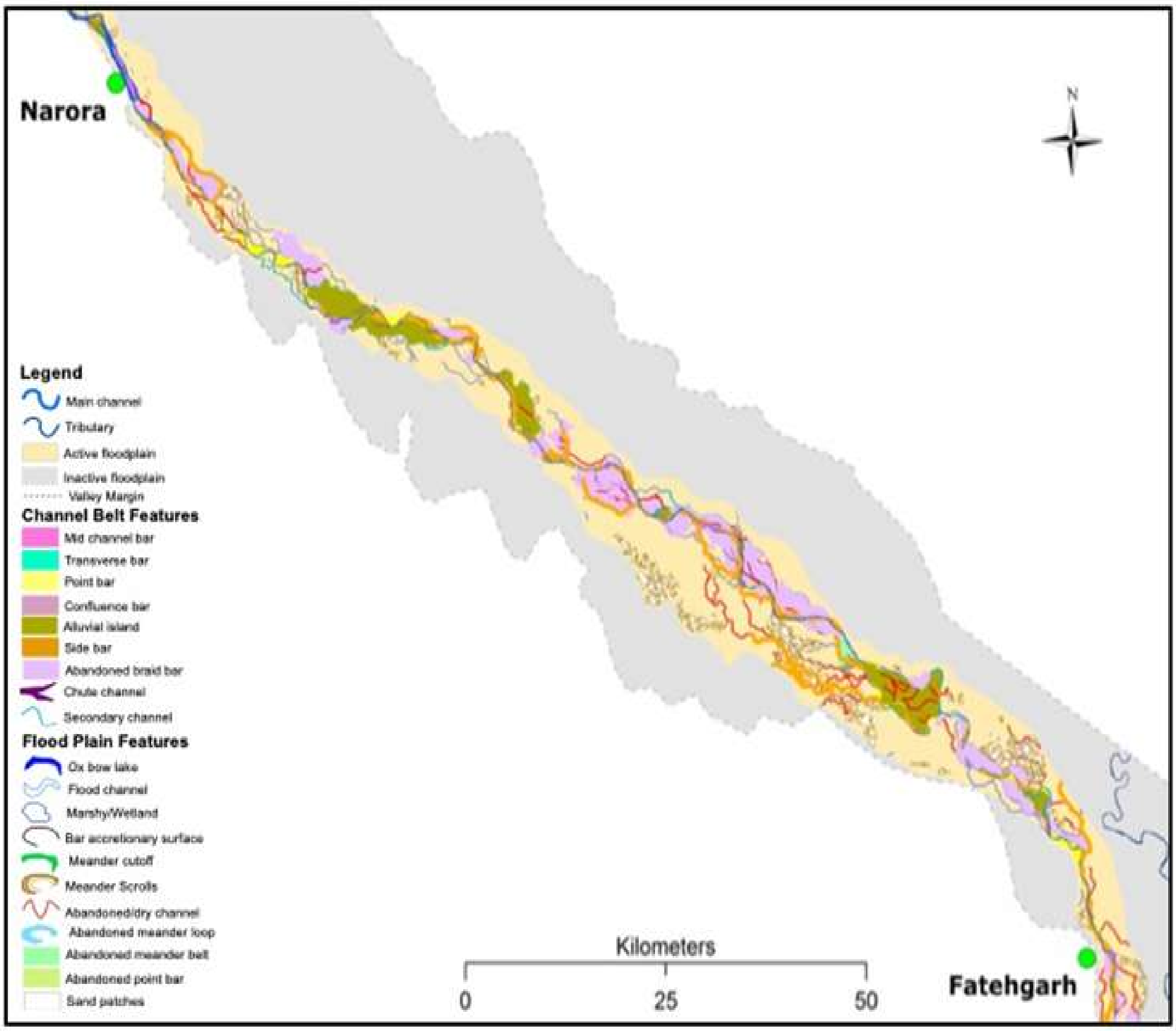
intervention in this stretch. The Bhimgoda barrage at Haridwar has impacted the channel morphology majorly. Image 1 shows that while the reach upstream of the barrage has inundated most of the bars, the downstream reach is heavily silted with large bars and alluvial islands. Further downstream, the Chandipur bridge also obstructs the flows and causes further sedimentation deposition.

The reach upstream of Bijnor has a large alluvial island that splits the channel into two parts. Downstream of Bijnor, the river has a wide floodplain on both sides. However, this situation changes dramatically downstream of Garhmukteshwar. The river now flows close to the western edge of the valley and has developed a wide valley on the eastern side (Map 4). The active floodplain is much narrower compared to the valley all the way to Narora where a barrage is located. Such confined settings are indicative of incisional processes which make the river less mobile and hence restrict the floodplain development. The river channel as well as its active floodplain has simple forms composed of a few mid-channel bars and fewer meander cut-offs.

2.4.2 Narora to Fatehgarh

This stretch of the river has a significantly wide valley on both sides of the river but the river itself is quite narrow with a very thin water line (Map 5) with a clear causal link to the Narora barrage. The latter has transformed the channel morphology in a significant way over the years primarily due to a modified flow regime. The Narora barrage, together with the Bijnor barrage located 135 km upstream, has altered the flow in the Ganga River and has isolated a major Gangetic River Dolphin habitat in this region (Sinha et al., 2010). Sonkar and Gaurav (2020) have documented the morphological changes in the Ganga River between Bijnor and Narora barrage and have shown that the river changed from braided to meandering type in several reaches which provided a favorable habitat for the dolphins. As a result, even though the isolation of a subspecies of dolphins may have limited their extent, their population increased from 22 to 56 during the period 1993–2010 (Sinha and Kannan, 2014).

The river is highly braided but with significant sinuosity in several reaches. As a result, abandoned braid bars form a significant geomorphic feature followed by lateral bars.



Map 5 : Geomorphology of the Ganga River Between Narora and Fatehgarh

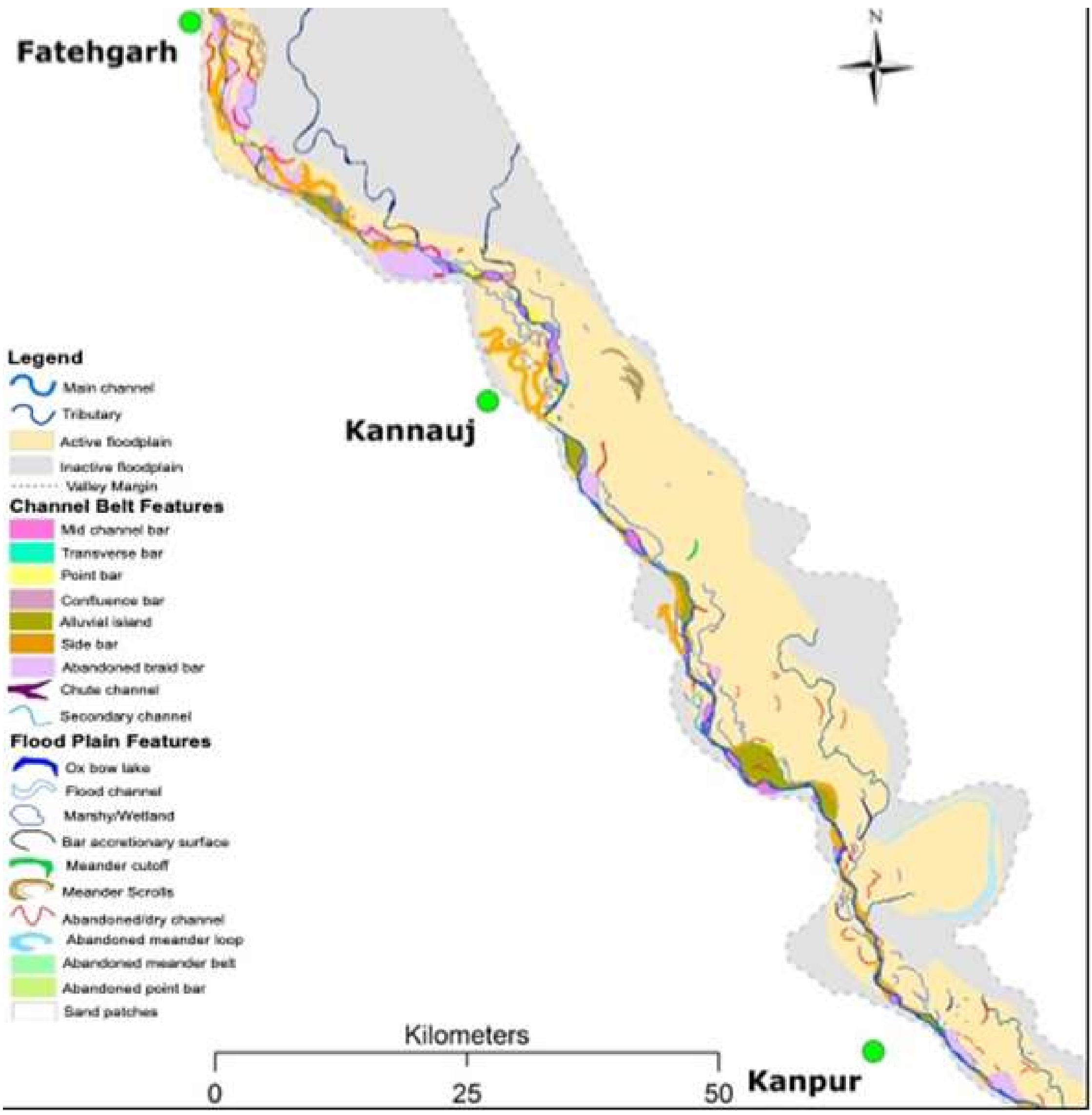
Source: Mohanta H., 2018

A number of abandoned channels are mapped which bound the abandoned braid bars, therefore representing the secondary channels of the Ganga. Some of them probably become active during high flows. Frequent sand patches on the southern side represent flood deposits suggesting a reasonable lateral connectivity in this stretch.

2.4.3 Fatehgarh to Kanpur

Between Fatehgarh and Kanpur two important tributaries, the Ramganga and the Garra, join from the northern side and the river Kali joins from the southern side around Kannauj. R. Ganga flows along the southern margin of the valley (Map 6) and is incised in most reaches with a cliff line varying in height from 10-15 meters. As a result, a wide floodplain runs along the northern bank and a very narrow floodplain along the southern bank. The confluence points of the Ganga-Ramganga as well as Ganga-Garra have been very dynamic on a historical time scale and have moved upstream and downstream (Roy N.G. and Sinha R., 2007).

In terms of channel morphology, the Ganga channel is multi-threaded with frequent and large mid-channel bars and infrequent lateral bars. Abundant meander cutoffs, scrolls and abandoned meander loops in the active floodplain on the northern side suggest that the river has been gradually shifting towards the south. The presence of an abandoned meander loop upstream of Kanpur is conspicuous because of which the



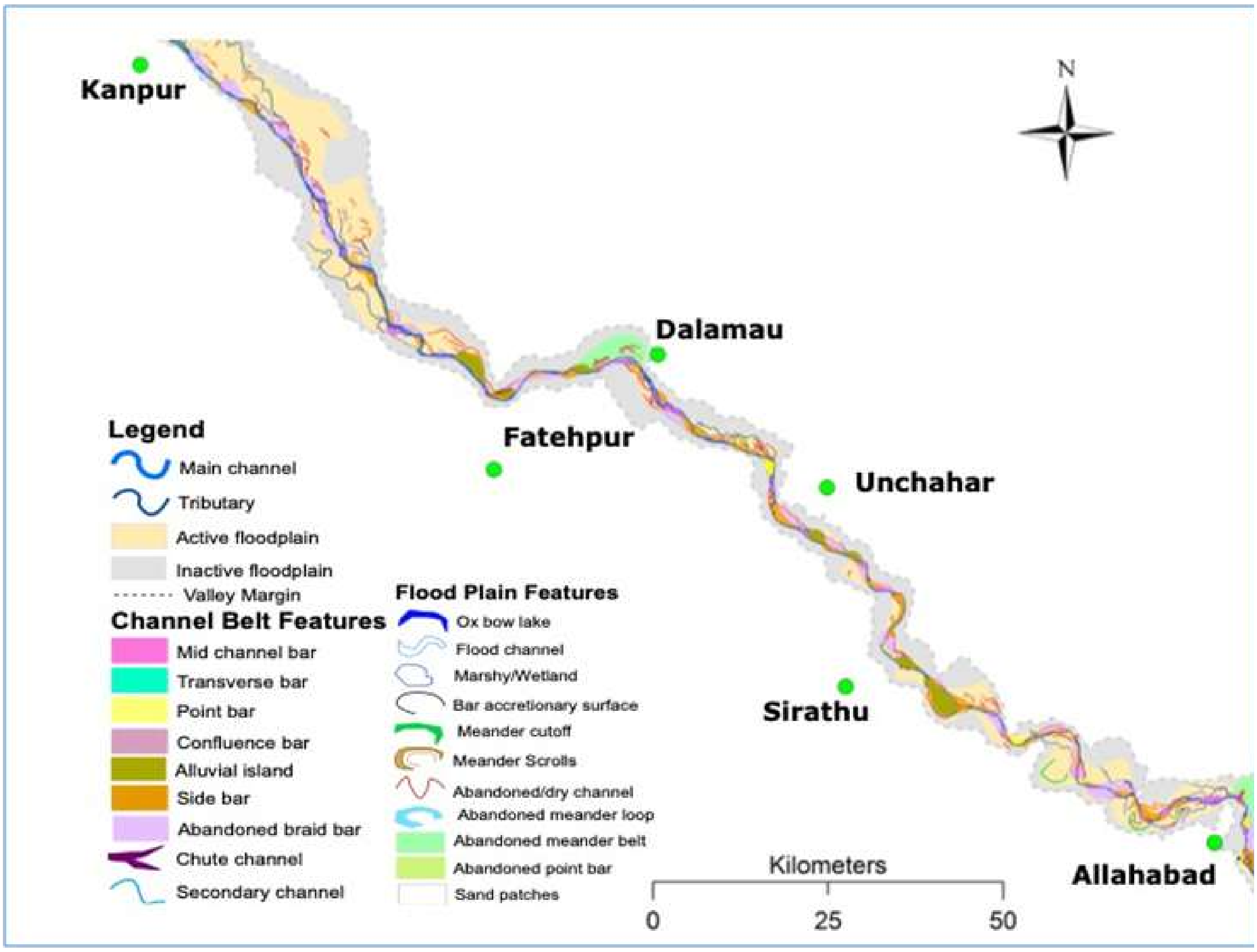
Map 6 : Geomorphology of the Ganga River Between Fatehgarh and Kanpur

Source: Mohanta H., 2018

active floodplain suddenly widens. Limited investigations have suggested that this large meander lies in a low elevation area and has remained connected with the main channel during high flows even though the river has shifted westward. So, this large meander loop is still a part of a wide active floodplain along the left bank while the right bank is incised by 10-15 m with a narrow floodplain. A barrage was constructed at Kanpur in 2000 to augment the water supply of the city. Downstream of this large meander belt and upstream of the Kanpur barrage, the active floodplain is reasonably wide, and intensive urban development is planned here under the Smart City Mission. Given that most of this area falls in low lying active floodplain area and also that the river has been historically dynamic in this stretch, these development plans need to be reexamined carefully.

2.4.4 Kanpur to Prayagraj

Downstream of Kanpur, the river continues to flow along the western edge of the valley for ~ 30 km and 12.8 km further downstream the valley narrows considerably (Map 7). The river starts swinging to the northern and southern edges within the limited space and narrow floodplains have developed alternately on both sides.



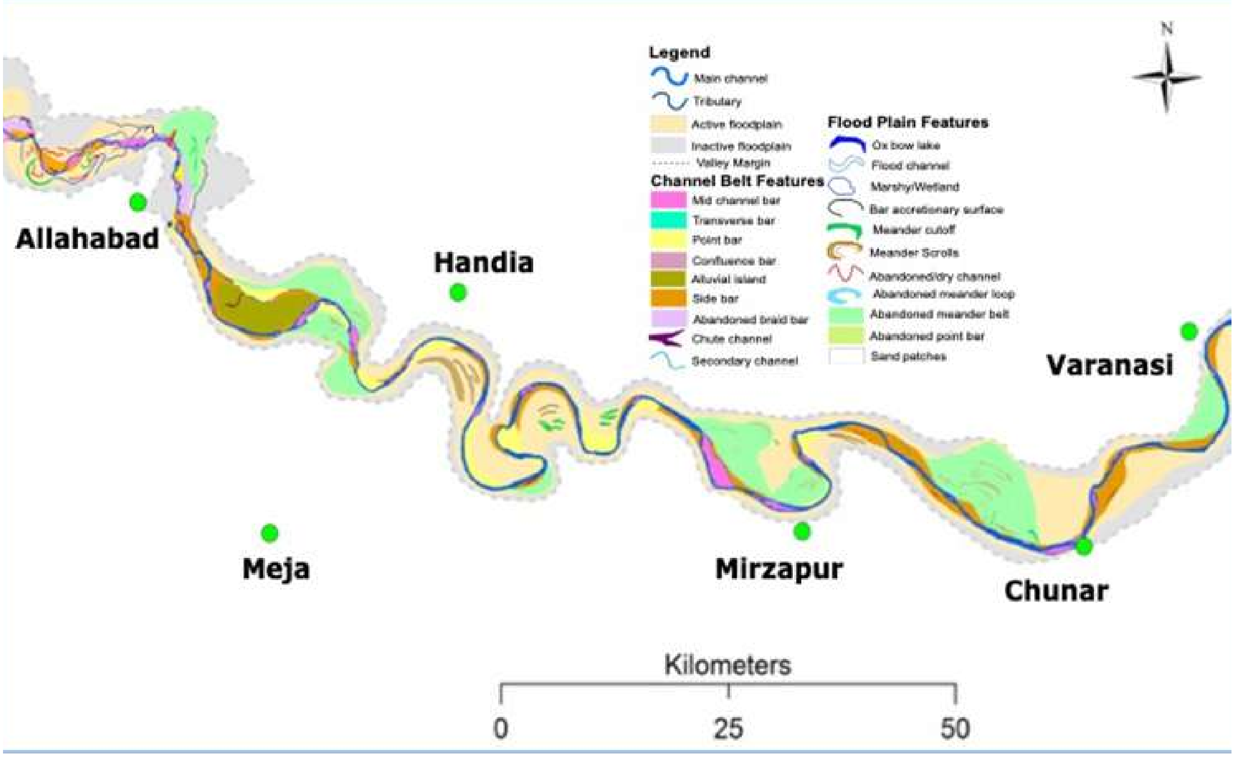
Map 7 : Geomorphology of the Ganga River Between Kanpur and Prayagraj

Source: Mohanta H., 2018

From a point ~ 71 km downstream of Kanpur, the river flows in an east-west trend for ~ 21.2 km and then resumes the NW-SE trend at Dalmau. The river valley is very narrow downstream of Dalmau and attains a minimum width of ~1 km at Unchahar. A wide abandoned meander belt is mapped at Dalmau but apart from this, there is very little evidence of channel migration suggesting this to be a relatively stable stretch. The valley starts widening again downstream of Unchahar and attains a width of ~ 7 km at Prayagraj. Pockets of wide floodplain have developed in the stretches upstream of Prayagraj that are as wide as the valley margin in this region. The frequency of abandoned channels and meander cut-offs also increases and a large abandoned meander belt is very prominent at Prayagraj. Here, River Yamuna meets Ganga on the latter's right bank.

2.4.5 Prayagraj to Varanasi

The 245 km river stretch between Prayagraj and Varanasi (Map 8) is a unique segment of River Ganga as it nearly approaches (~7 km; near Meja) the peninsular shield. The river exhibits a strong basement/tectonic control with a maximum sinistral shift of about 16 km towards SSE (Prayagraj). In addition, these two cities are the most popular religious centers along the mid-river course.



Map 8 : Geomorphology of the Ganga River Between Prayagraj and Varanasi

Source: Mohanta H., 2018

ECO-GEOMORPHIC ASSESSMENT OF THE VARANASI TURTLE SANCTUARY AND ITS IMPLICATION FOR GANGA RIVER CONSERVATION.

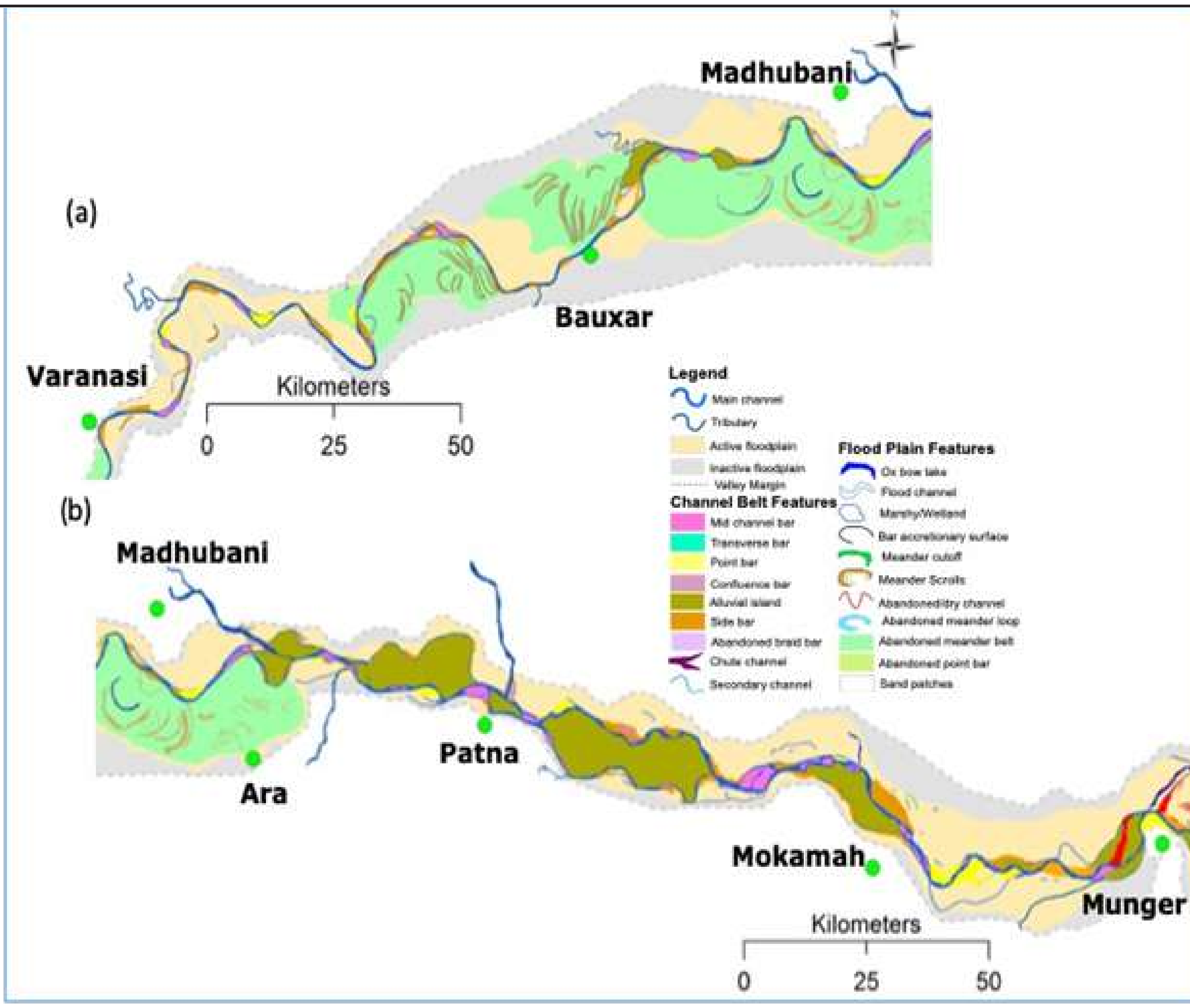
The eco-geomorphology of the Varanasi Turtle Sanctuary (VTS) located on the Ganga River in Uttar Pradesh, India was examined for its stability using hydraulic geometry of the channels, such as width, depth and discharge acquired from an Acoustic Doppler Current Profiler, and the mapping of planform morphology from remote-sensing images. Planform maps were generated using Corona and Landsat satellite images for the period 1965–2018. The assessment suggests a well-defined, stable cross-section profile along this stretch of the river. It provides conclusive evidence that the geomorphology of the Ganga River within the VTS has remained stable for the past 50 years, except for some minor changes in the form of bar growth and erosion both upstream and downstream of the sanctuary. Construction activities along the bank, movement of large vessels, sand mining in the sanctuary or dredging of the main channel may destabilize the river geomorphology that will negatively affect the integrity of the VTS as well as the ghats at Varanasi.

The mapping of the river course based on remote sensing data with limited field checks has shown the various geomorphic units with their respective numbers and areal coverage which includes mid-channel bars, point bars, alluvial islands, lateral bars, meander scrolls, flood channels, and vegetation patches. The width of the flood plain varies between 1.4 km (SE of Handia) and 8.4 km (near Mirzapur). The maximum (14.2 km) and minimum (1.8 km) valley margin width have been noted ~ 63 km downstream of Prayagraj and Varanasi, respectively. The Ganga has a very distinctive morphology between Prayagraj and Varanasi. It is characterized by several meanders in sharp contrast to the braided morphology in the upstream reaches. The valley width is also much narrower compared to other reaches. One possible explanation for this is that a large part of the river in this stretch falls in a partly confined valley setting, bounded by cratonic rocks along its southern valley margin which restricts large scale lateral migration except for local meander migration as manifest in several meander scars.

2.4.6 Varanasi to Munger

For the sake of clarity, the geomorphic map in this stretch has been presented in two parts, one from Varanasi to Madhubani and then from Madhubani to Munger (Map 9). The minimum width of the floodplain in this stretch is 1.8 km downstream of Varanasi, while the maximum width is as high as 28 km near Ara. The minimum valley margin width is 7 km downstream of Varanasi, while the maximum valley margin width increases to 36.1 km at the location 23 km d/s of Buxar. Alluvial islands are the most significant geomorphic characteristic in this reach of the Ganga river .

While the first island, 30 km downstream of Buxar, is only 3.0 km in width, 2 major islands of over 12 km maximum width are present upstream and downstream of Patna. There are 2 more islands further downstream between Mokama (5.5 km max. width)



Map 9 : Geomorphology of the Ganga River Between Varanasi and Munger

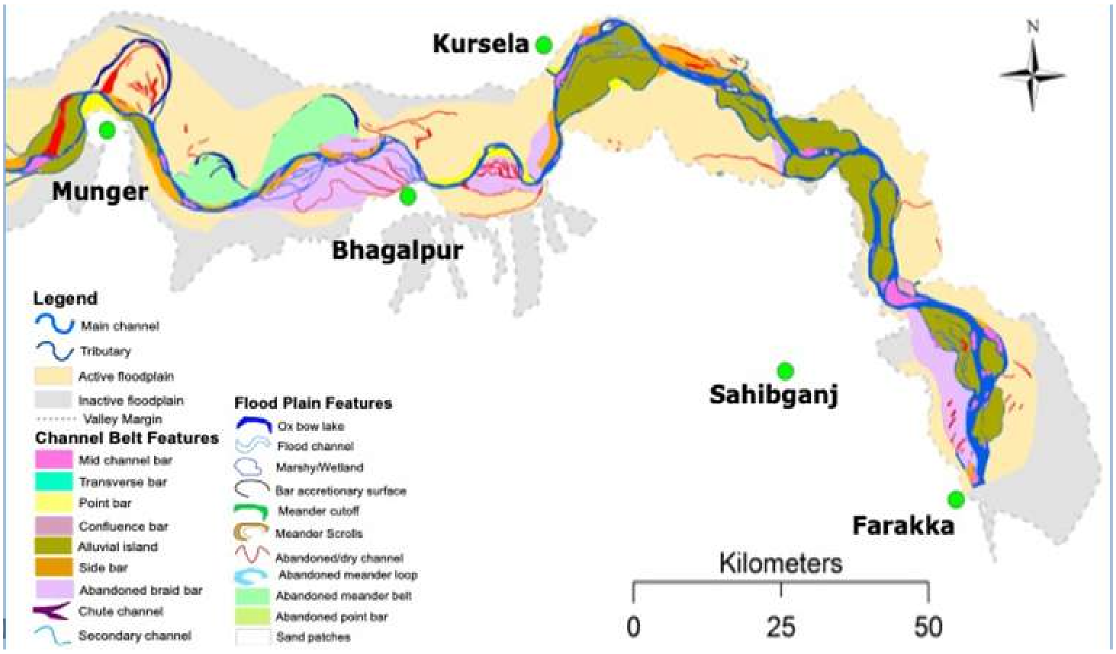
Source: Mohanta H., 2018

and upstream of Munger (2.0 km wide). Alluvial islands seem to gain prominence in width/area downstream of the confluence of Ghaghra and Gandak rivers from the North and Sone river from the South, probably due to the contribution of a large sediment load from the Himalayan terrain as well as the cratonic highlands. Two major areas of meandering belts, one each on the northern and southern banks of river Ganga, downstream of Varanasi have been identified. Another stretch between Buxar and Ara (downstream) and confined only to the southern bank of river Ganga, is a zone of meander scrolls, meander scars and ox-bow lakes. In recent years, the Ganga River around Patna has shifted away from the ghats. This has caused serious concern amongst river scientists and has caused hardships to the local communities dependent on the river.

2.4.7 Munger to Farakka

The total channel length of this reach is about 330 km. The southern valley margin is confined by basement rocks of the craton whereas the northern valley margin is unconfined and merges with the alluvium of the Kosi and Mahananda rivers. The maximum floodplain width in this reach is about 23.3 km and minimum width is 7.2 km. The sinuosity of the stretch has increased a little bit as compared to the immediately upstream stretch, but the river is braided all through in this stretch with many mid-channel bars or large islands and lateral bars, etc. The increase in sinuosity is possibly related to irregular configuration of the basement block on the southern margin of the valley (e.g., Munger-Bhagalpur-Sahibganj stretch).

The major geomorphic characteristic of the river in this stretch is the braided-sinuous pattern, with numerous fine-grained sandy bars in the channel. These channels are extremely mobile and the active channel has migrated more than a km within a year.



Map 10 : Geomorphology of the Ganga River Between Munger and Farakka

Source: Mohanta H., 2018

The active floodplain is marked by abandoned meander and braided bars. Abandoned channels and bar accretion surfaces at places are marked by fine-grained sediment. Levees, active channel bars and many abandoned slough channels (flood channels) over braid bars are marked by dry sandy patches. Most of these abandoned bars (now a part of the floodplain) and in-channel large islands are now agricultural fields (Shukla U.K., 2016). The Farakka Barrage is a major intervention in this stretch which has triggered increased channel siltation that has caused significant morphodynamics and frequent migration of the river in the reaches upstream and downstream of the barrage (Rudra, 2010; Sinha and Ghosh, 2012; Sonkar and Gaurav, 2020). In particular, large-scale siltation upstream of the barrage in the post-1965 period has modified the channel

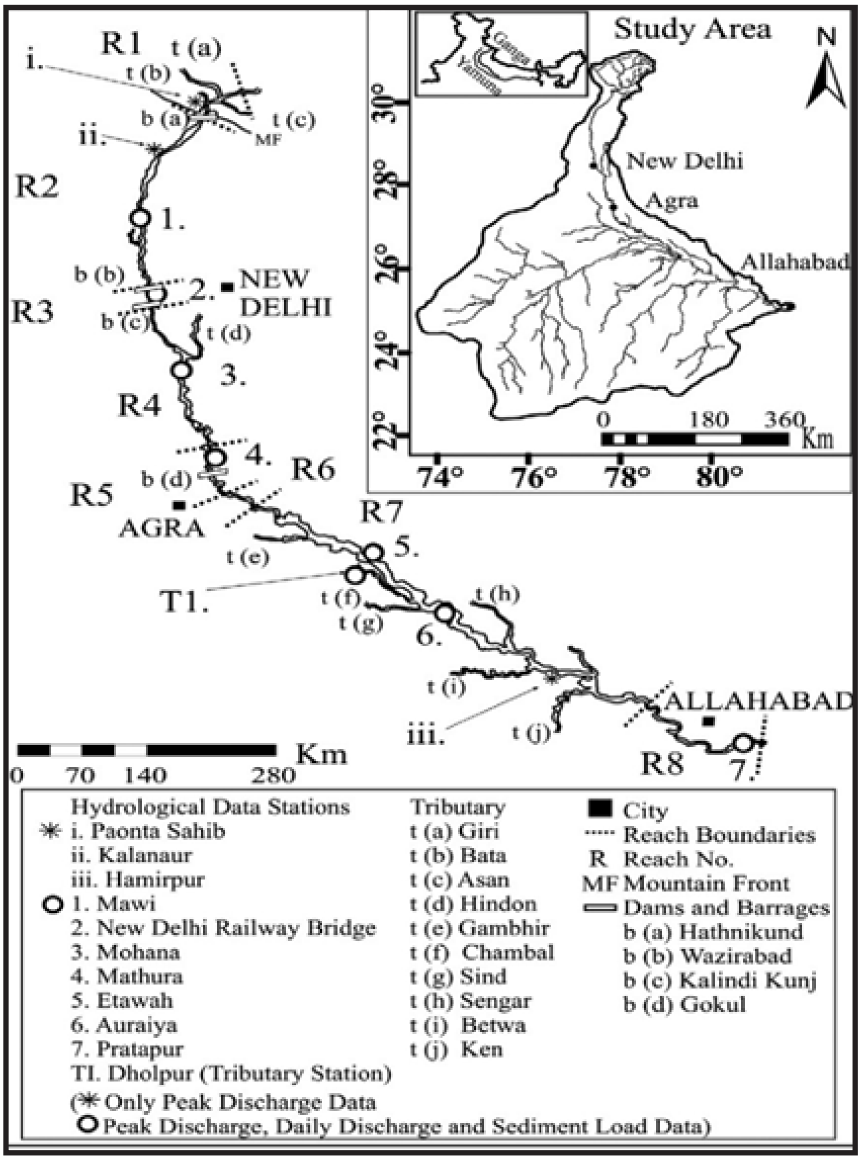


Image 3 : The Yamuna River Basin and Channel Morphology

Source: Bawa et al. (2014)

morphology dramatically. The problem is so acute that there are apprehensions of the river flanking the barrage, forcing more and more interventions in recent years. Also, excessive siltation and loss of connectivity have encouraged macrophyte growth and degradation of the dolphin habitat in the river around Farakka (Sinha, 2000, 2013; Sonkar and Gaurav, 2020).

2.5 RIVER YAMUNA

River Yamuna and its morphological changes over time in its upper basin were studied by a joint team led by Prof. Brij Gopal of Jawaharlal Nehru University (Delhi) and Prof. Patrick Martin of University of Guelph, Ontario (Canada). The land use and land cover (LULC) changes in Yamuna floodplain were studied over a period of 32 years from 1970 to 2002 (Martin P., et al 2007).

2.5.1 The Drainage Basin

The total drainage basin of R. Yamuna extends over 366, 233 sq km (42.5% of the Ganga basin) distributed over the states of Himachal Pradesh, Uttarakhand, Haryana, UP, Rajasthan, Madhya Pradesh and Delhi. The Yamuna is characterised by two hinterlands namely, the Himalayan orogen in the north and the cratonic highlands in the south. Its Himalayan headwaters' area (above 600 m) comprises 3.38% of the total Ganga basin. The Upper Yamuna basin (upto Okhla in Delhi) accounts for less than 20% of its total basin (Martin P., et al 2007). The average annual discharge of the Yamuna River is 96.1 x 10^9 m^3 and the total sediment load at Prayagraj is 107 x 10^6 tons (Jha P.K., et al 1988). The Yamuna is mainly a rainfed river receiving most of its water from rainfall and groundwater and very little (9%) from glacial/snow melt (Bookhagen and Burbank, 2010).

Along its 1,170 km stretch through the Gangetic plain, the average slope of the river bed decreases from about 0.56 m/km between Tajewala and Delhi to less than 0.20 m/km between Delhi and Agra and becomes less than 0.05 m/km thereafter (Martin P., et al 2007). The Yamuna is relatively shallow with an average depth of about 3 m during the monsoon season. Its channel width ranges from about 30 m in the Himalayan stretch to more than 200 m in the plains. But at several places within the Himalayan stretch, the river passes through very wide valleys (Martin P., et al 2007). Alluvial reaches of the Yamuna river in the plain are fairly incised and bounded by interfluve[3] areas (Tandon S.K. et al 2008). This valley–interfluve landscape setting is characterised by a wide river valley bounded by fine-grained thick sediments forming the interfluves (Gibling M.R., et al 2005). The downstream reaches are characterised by badland topography formed by extensive gully erosion.

Table 1 : Sinuosity Index

1970				2002			
Reach	Channel Length (km)	Valley Length (km)	Sinuosity Index	Reach	Channel Length (km)	Valley Length (km)	Sinuosity Index
I	12.4	9.3	1.33	I	10.5	9.3	1.13
II	16.4	9.3	1.76	II	12	9.3	1.29
III	14.2	9.3	1.52	III	13.6	9.3	1.46
IV	11.2	9.3	1.2	IV	11.4	9.3	1.22
V	11.6	9.3	1.25	V	14.4	9.3	1.54
VI	13.5	9.3	1.45	VI	13.5	9.3	1.45
VII	12.5	9.3	1.34	VII	10.7	9.3	1.15
VIII	16.2	9.3	1.74	VIII	11.1	9.3	1.19
IX	15.2	9.3	1.63	IX	13.6	9.3	1.46

Source: (Martin P., et al 2007)

2.5.2 Floodplain Channel Morphology

A detailed geomorphic analysis of the Yamuna River carried out by Bawa et al (2014) shows significant reach-scale variability (Image 3). Reach 1 (R1) that lies in the intermontane[4] setting is characterised by a braided river with occasional floodplain pockets in a confined, bedrock valley setting. Reaches downstream of the mountain front are characterised by depositional landforms and hence formation of floodplain. Different types of planform morphologies play an important role in defining the geomorphic characteristics. The downstream Reach (R2) records a sudden increase in channel and floodplain width, appearance of continuous floodplains and significant increase in bar area. Reaches 3 to 5 are again quite distinct in terms of their combination of valley setting, channel confinement, floodplain bounding and by significant decrease in bar area and channel width in downstream reaches. A relatively short stretch of braided river with unconfined channel and confined floodplain marks Reach R6. Yamuna river then enters a zone of badland topography (Reach R7) where the river is characterised by a confined sinuous channel without a floodplain in the badland area but with significant increase in bar area. Lower downstream in Reach R8, a floodplain starts reappearing in an alluvial setting with channel widening in a partly confined channel setting. The channel becomes less sinuous with a higher bar area and with a variety of bar types.

The sinuosity index for analyzing the changing pattern of Yamuna River was calculated for about 80 km stretch in different reaches (Table 1) for two different years, 1970 and 2002 (Martin et al, 2007). The whole stretch was divided into nine parts to analyze at the micro level. In the intervening 32 years period between 1970 and 2002, the course of Yamuna was shortened from 123.2 km to 110.8 km. A value of 1.5 for the sinuosity was used as the criteria for differentiating the meandering channels from the straight channels.

The overall analysis of sinuosity parameters of the river revealed a significant change in its pattern over the period of study. The river had straightened over the period studied and it had lost a number of complex features like meanders, lakes, water bodies and side channels, etc. Such loss in geomorphic complexity has profound negative impacts on river ecology and it tends to reduce the biodiversity.

2.5.3 Human Impacts

Changes in the flow regime and pattern have altered the morphological feature of Yamuna and its floodplains. Although the flow of Yamuna has been diverted into two canals at Tajewala (and subsequently Hathnikund) for over a century, increasingly more water is being abstracted for irrigation in Haryana and UP upstream of Delhi. Most of the embankments in the river stretch between Hathnikund and Agra have been constructed after Independence, restricting the lateral spread of the river to a narrow corridor.

River Yamuna has been confined between embankments at different locations since 1974 but there is a tendency of eastwards migration of the river. Reduced flow, enormous sediment deposition and encroachment by human activities mainly for farming and construction of bridges and barrages are the major factors that have influenced and changed the morphology of Yamuna and the land use land cover of the floodplain (Martin P., et al 2007).

In a more recent work, Bawa et al. (2014) made an effort to assess the impact of anthropogenic disturbance in the alluvial reaches of the Yamuna using a stream power-based approach. They classified the Yamuna River into three distinct parts based on stream power data: (a) high energy 'natural' reaches in the mountainous region, (b) low energy 'anthropogenically altered' reaches in the midstream part and (c) 'rejuvenated' high energy reaches because of contributions from tributaries downstream. This research clearly demonstrated that the there is a significant loss of flow in the low energy 'anthropogenically disturbed' reaches primarily attributed to the barrages and excessive groundwater abstraction. Consequently, the channel slope has been reduced and discharges have been significantly modified resulting in exceptionally low values of stream power. The authors opined that it is crucial to augment discharge and maintain the environmental flows in such stretches for the river's proper geomorphological and ecological functioning.

2.6 CHANNEL MOVEMENT

Channel movements through avulsion[5] and cut-offs, like those reported above for the Ganga and Yamuna main-stem, have also been recognized in most rivers of the Ganga river system albeit with a difference in scale and frequency. The Kosi river draining through the plains of north Bihar has displayed the most dramatic channel movement in historical time period. The river has moved about 150 kilometers in the last 200 years as documented through maps and satellite images (Gole and Chitale, 1966; Chakraborty et al, 2010). A west to east migration of River Gandak across its megafan over a distance of about 105 km in a period of 5000 years has been reported (Mohindra, 1994). Similarly migration of several smaller rivers such as Burhi Gandak, Bagmati, and Kamla-Balan in the Gandak-Kosi interfluves has been found (Phillip G., et al 1989; Phillip G. and Gupta R.P., 1993; Sinha R., 1996). One of the most comprehensive data on the hyperavulsive[6] Bagmati river over a period of ~250 years has attributed this to neotectonic perturbances and sedimentological readjustments (Jain V. and Sinha R., 2003; Jain V. and Sinha R., 2004). Such rapid movements are known to cause havoc in several regions due to large scale inundation. In recent years, many rivers have been embanked resulting in large scale siltation within the embankments leading to breaching and flooding. One of the most recent breaches that occurred in the Kosi river in August, 2008 at Kusaha impacted more than 3 million people in north Bihar and Nepal (Sinha R., 2009).

The rivers of the Ganga system draining the UP plains are not as dynamic as the north Bihar rivers but they do show some channel movement over a long time period. In the stretch between Bithur and the Kanpur railway bridge, the Ganga river's main channel has recorded major movements in the historical period (1857-present) between its left and right bank (Hegde M., et al 1989) attributed to the highly irregular shape of the valley in the area. The Ghaghra river in the UP plains has also shifted by ~5 km at certain places, on either side of the active channel over a 7-year period of (1975-1982) which has been related with the neotectonics in the area (Tangri A.K., 1986). An avulsion of Rapti river near Baharaich due to aggradation[7] process in the old channel has been noted (Chandra S., 1993) which caused the SW diversion of the Rapti river. The Sarda river is characterized by several westward lateral shifts in different reaches (Tangri A.K., 1992). An upstream migration of the confluence of the major rivers such as Ghaghra, Gandak, Ganga, Sone and Punpun rivers perhaps in response to the change in water budget of source area catchment (Himalaya) has been suggested (Tangri A.K., 1992).

2.7 FLOOD PROTECTION

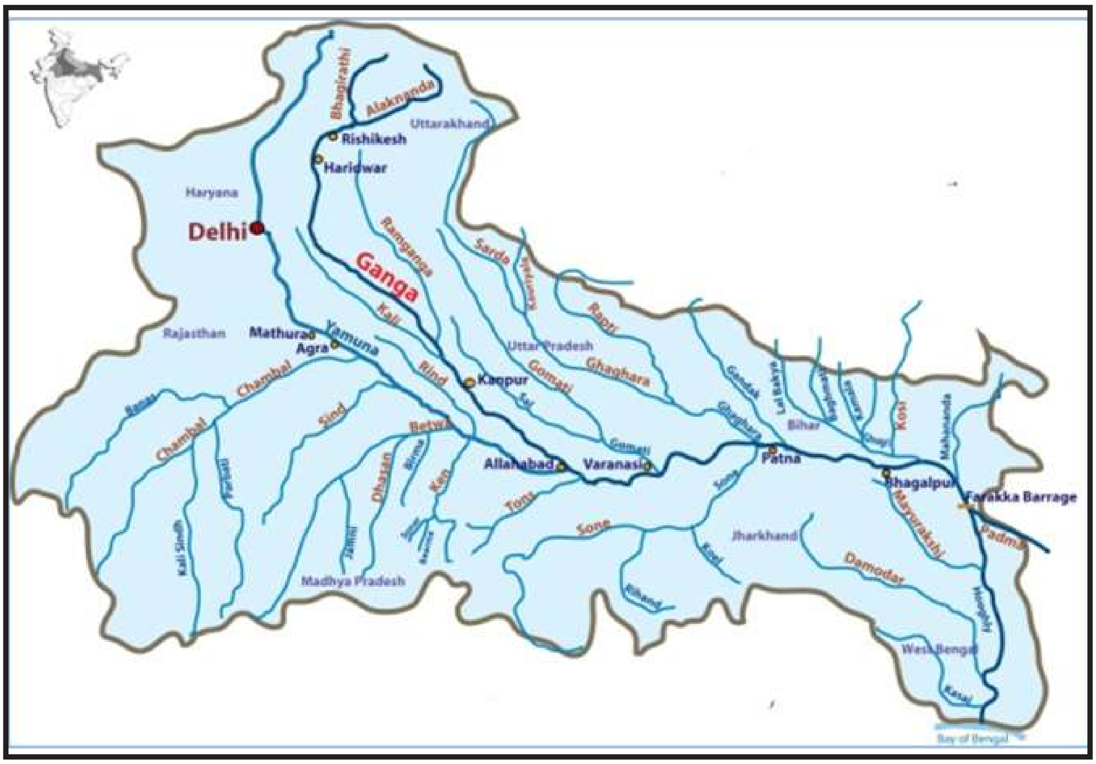
The plains of north Bihar have the dubious distinction of recording the highest number of floods in India in the last 30 years (Kale V.S., 1997). The flood protection measures have largely failed. One of the important reasons for this has been that floods have long been considered as purely hydrological phenomena. A geomorphic understanding of floods is lacking. The overall hydrological response of the basin depends upon its geomorphometric characteristics, neotectonics and fluvial processes, apart from the rainfall intensity and duration. The dynamic behaviour of river channels and frequent avulsions caused by sedimentological readjustments often divert the flow into a newly formed channels with low bankfull capacity causing extensive flooding. Often, people are not prepared for flooding along such newly formed channels and the flood damage later is quite severe (Sinha R., et al 2005).

One of the most important geomorphic considerations in understanding the flooding behaviour of the rivers is the channel-floodplain relationship. In areas of modern sedimentation with continuous subsidence, such as in the north Bihar plains, most of the rivers carry a very high suspended load and the frequency and extent of overbank flooding is considerable. A simultaneous rising of the channel bed and the floodplain surface increases the probability of flooding (Sinha R., et al 2005).

The most favored flood protection strategy in the Gangetic plains is to embank the rivers. In most cases, this measure has proved to be a very short-term solution and has merely transferred the problem from one region to another. Apart from interfering with the natural fluvial processes in the region, these embanked areas have developed severe water-logging problems. Large fertile areas have been destroyed due to drainage congestion and increased soil salinity (Sinha R., et al 2005). Some examples of this are given later in Chapter 8.

2.8 GANGA DELTA

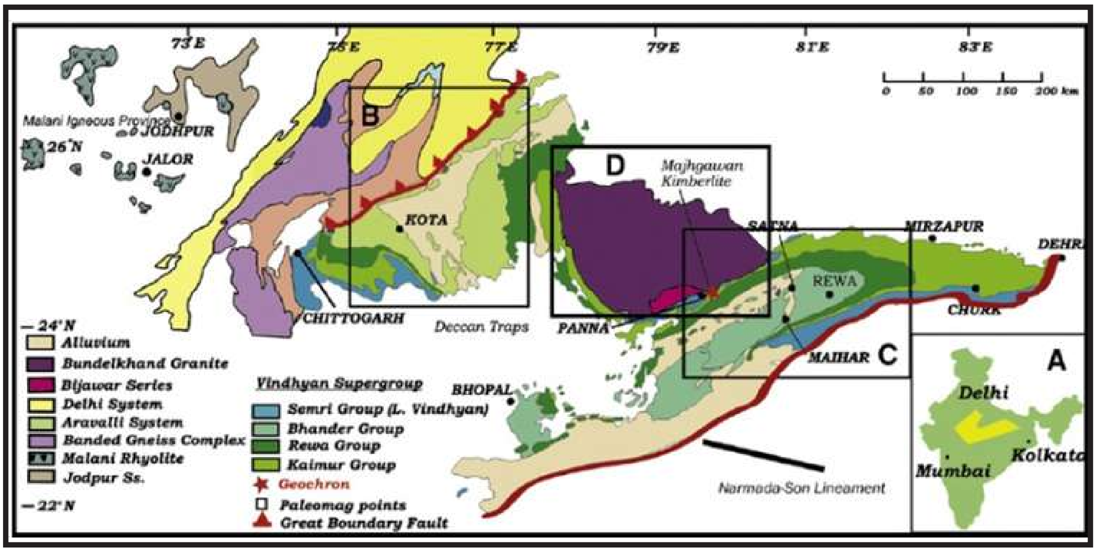
After draining the alluvial plains of UP and Bihar, the Ganga enters the lower basin's plains area and delta region and finally meets the sea in the Bay of Bengal. The Brahmaputra River draining from the northeast joins the Ganga and together they constitute the largest delta in the world (European Space Agency, 2009). The Ganga-Brahmaputra together transport a billion tons of sediments per year and this puts them among the world's largest sediment load carrying systems. The Bengal Basin acts as a large sink for these huge sediments deposit, about 80 per cent of which is delivered during the monsoon (Goodbred and Kuehl, 2000).



Map 11 : The Drainage Network of the Ganga Basin

Source: Neostencil

Increased influx of sediments brought by the Himalaya-born rivers made the sedimentary lobes[8] grow seawards in the form of deltas. During the time of the Last Glacial Maximum, when the sea level was low, there was a strong dissection of the upland surfaces. Sediments were deposited between 12,000- and 10,000-years BP in the Bengal Basin, which was then a part of the sea. By the late Holocene[9] (ca 4200 years before present), broad peat land and marshland had formed even as rivers deposited their load vigorously in the channels. In consequence, mangrove-vegetated islands and peninsula grew in front of the prograding, i.e., advancing deltas (Umitsu M., 1993 and Allison M., et al 2003).



Map 12 : Geology of the Vindhyan Basin

MALWA PLATEAU

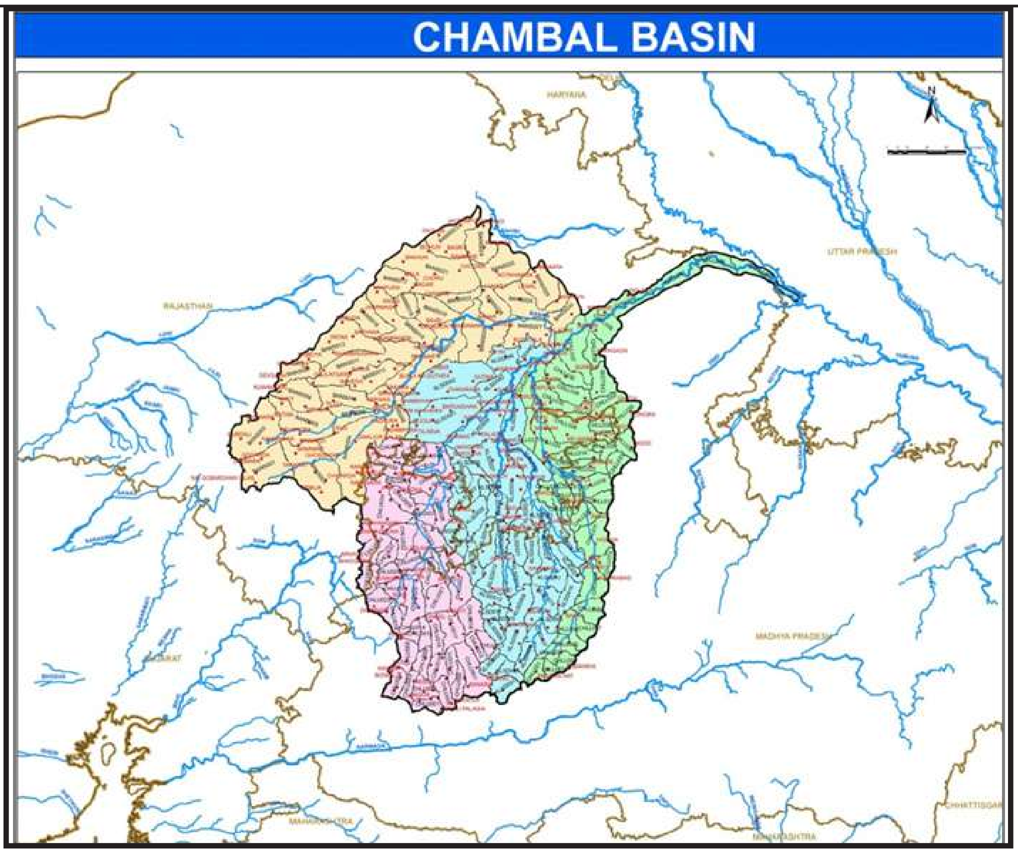
Drained by the northeast-flowing Banas and Chambal rivers, the Malwa Plateau is a 500 – 600 m high terrain of flat-topped hills and rolling plains of late Cretaceous (100-66 Ma) lavas. It embraces the 250-300 m undulating terrain of the Aravalli Range in eastern Rajasthan. To the north east is the Bundelkhand Upland, made up of Late Archean (2500 Ma) gneisses and granites and 300-600 m above the mean sea level. Through the undulating terrain of the Bundelkhand, the Chambal, Betwa and Dhasan rivers have carved their valleys, cutting deep gorges and developing spectacular ravine land – the Chambal Badland – before joining the Yamuna river.

Source: (Goodbred, S.L., et al, 2002)

Apart from the sediment supply, the stratigraphic development[10] in the delta has been controlled by active subsidence. The interplay between the two has resulted in unique and differing stratigraphies, spatially as well as temporally (Goodbred S.L., et al 2002). Areas of active subsidence have preferentially stored fine-grained sediments whereas high energy conditions such as turbidites have favoured the preservation of coarse-grained sediments. Additional controls are applied by riverine processes such as avulsions and episodic earthquakes. A long history of delta switching in the Bengal basin has been related to channel avulsion of the Ganges and Brahmaputra rivers (Sinha R., et al 2005).

2.9 GEOMORPHOLOGY OF SOUTHERN TRIBUTARIES ORIGINATING FROM THE VINDHYAN CRATON

The key southern tributaries of R. Ganga include the Chambal, Sindh, Betwa, Ken, Baghain and Paisuni rivers (all first meeting R. Yamuna) and direct Ganga tributaries like the Tons, Sone and Punpun rivers.



Map 13 : Drainage Network of the Chambal Basin and its Surrounding
Source: Watershed Atlas of India, CGWB

All these rivers with the exception of River Punpun in Bihar and River Sone (also meeting Ganga in Bihar) originate from the Vindhyan basin in central India. The Vindhyan basin is geologically associated with two mega tectonic elements: the Great Boundary Fault (GBF) to the northwest and the Sone-Narmada Lineament (SNL) to the south (Map 12). The Bundelkhand Massif, located in the north-central part of the basin, divides it into two sectors: Chambal Valley to the west and Sone Valley to the east (Mahanti S., et al 2015).

2.9.1 River Chambal

The Chambal river system drains the Malwa plateau region in central India. It has Banas, Kali Sindh and Parbati rivers as its key tributaries. The Sip and Kuno rivers, which arise from the Guna plateau are two direct tributaries from the south of River Chambal. Kuno forms a wide valley within the Kuno Wildlife Sanctuary before meeting River Chambal. The course of R. Chambal comprises of the following three sections:

1. The upper valley or the course in the Vindhyan Hills and the Malwa plateau
2. The middle valley through the concentric triple scarps and the 32 km long gorge (upstream of Kota) in which potholes, rapids and waterfalls are frequently found.
3. The lower valley in the plain country before Chambal joins Yamuna

River Banas

The Banas river basin is located in the eastern part of Rajasthan and occupies a significant area east of the Aravalli mountain range. It stretches between 24° 17' 14.22" to 27° 18' 15.24" North latitudes and 73° 20' 54.84'' to 77° 00' 36.49'' East longitudes. It is bounded in the east by the Chambal river basin, in the north by the Gambhir and Banganga river basins, in the west by the Shekhawati and Luni river basins and in the south by the Sabarmati and Mahi river basins (Anon, 2013).

Originating in the Khamnor Hills of the Aravalli Range, about 5 km from Kumbhalgarh in Rajsamand district, River Banas flows entirely through Rajasthan. It flows northeastwards through Rajasthan's Mewar region, and meets River Chambal near Rameshwar village in Khandar block of Sawai Madhopur district. Its major right bank tributaries include Berach and Menali rivers whereas the left bank tributaries are the Kothari, Khari, Dai, Dheel, Sohadra, Morel and Kalisel. The river is about 512 km long (Anon, 2013).

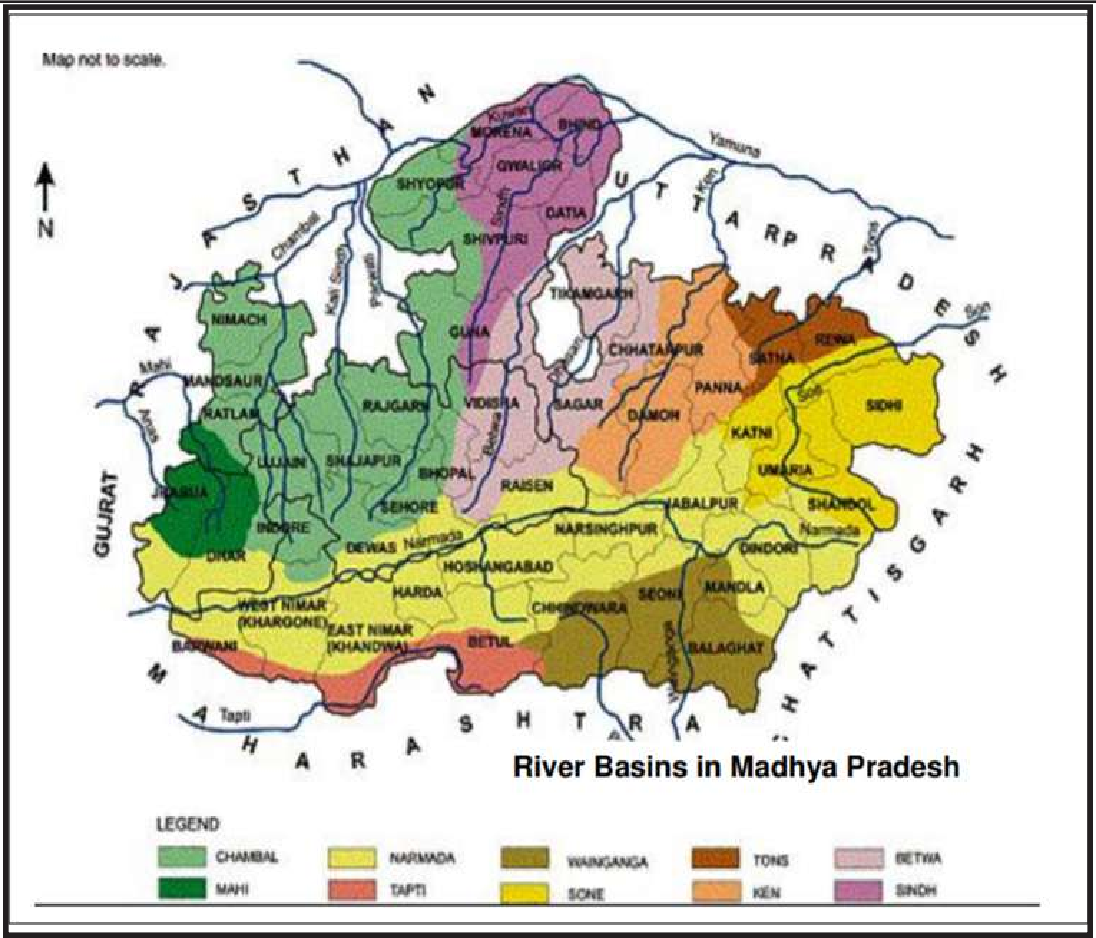
The western part of the basin is marked by hilly terrain belonging to the Aravalli chain. East of the hills lies an alluvial plain with a gentle eastward slope. Ground elevations in the western hilly part range from about 850 m above mean sea level (m amsl) to about 1,291 m amsl, while the alluvial plain elevations range approximately from 176 m amsl to 450 m amsl where the Banas meets River Chambal. Formations ranging in age from Archaean to recent periods are present in the basin represented by the Bhilwara, Aravalli, Delhi and Vindhyan Super Groups of rocks along with Deccan volcanics and alluvium (Anon, 2013).

The total Banas catchment area of about 51,779 km^2 falls in 13 districts of Rajasthan namely Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli. Morphometric analysis has found 5856 streams from which 2819 are first order streams, 1839 are second order, 753 are third order and 445 are fourth order streams (Dubey S.K., et al 2015).

River Kalisindh

River Kalisindh rises at an elevation of about 610 m from the Barjiri hill near Bagli village in Dewas district (M.P.) and traverses a northerly course for its entire length of 351 km till it joins River Chambal. It flows about 180 km in Madhya Pradesh through Dewas and Shajapur districts and the remaining 171 km through Jhalawar and Kota districts of Rajasthan. A number of tributaries, the more important of which are the Lakhundar, Ahu and Parwan (NWDA-A, undated) join the Kalisindh.

The catchment is mainly plain and cascades northwards, interspersed by two hill ranges viz. Mukandwara and Ratibar. The altitude in the catchment falls from 600 m amsl in the upper reaches (Malkidesh physiographic section) to 300 m in the lower reaches (Mukandwara and Ratibar ranges). The lower part of the catchment covers



Map 14 : River Basins in Madhya Pradesh, Central India

Source: ENVIS, M.P.

the northern parts of Shajapur, Rajgarh, Guna and southern parts of Jhalawar districts which forms parts of the Jhalawar plateau having an average elevation of 300 m amsl to 450 m. The catchment area is bounded by the Narmada sub-basin in the east and the upper Chambal basin in the west. The land slopes gently from south to north and has the characteristics of the Malwa Plateau (NWDA-A, undated).

River Parbati

River Parbati rises from the Vindhyan ranges at an elevation of about 609 m amsl. Its sub-basin lies in the Malwa Plateau physiographic region. The river originates in the Bhopal Plateau, a sub-section of the Malwa Plateau. The Parbati sub-basin comprises of upland, eastern ranges, western ranges and a valley portion. The upland areas are either plain rolling land or gently rolling series of mounds and valleys. They cover parts of Sehore, Bhopal, Shajapur and Vidisha districts in Madhya Pradesh. The three eastern ranges are well defined and continuous. They separate the high table land of Sindh sub-basin and the western ranges of the Kalisindh sub-basin. At many places in the sub-basin, there are isolated hills rising up to 600 mamsl (NWDA-A, undated). Banganga and Aheli are the key tributaries of the Parbati.

DHOLA CRATER

There is an interesting geological formation that lies within the Sindh basin. The tiger-paw shaped Dhala (actually Dhola) crater in Shivpuri is an extremely rare meteorite impact structure. Instead of a crater, the meteor penetrated the crust and magma oozed out to form a plateau, The maroon-brown plateau stands out dramatically on the otherwise flat terrain.

Researchers have estimated that the Dhola crater was created between 2.5 and 1.6 billion years ago and that when the collision occurred, life had just begun on Earth.

Source: (Lal P., 2016)

2.9.2 River Sindh

The Sindh river basin (dark purple in Map 14) in MP is squeezed between that of River Chambal (green) in the west and River Betwa (light purple) in the east. River Sindh originates in Vidisha district of Madhya Pradesh. Its total catchment area of 26,699 km^2 and nearly all of it lies in Madhya Pradesh. A length of 461 km of the river falls in Madhya Pradesh and the remaining 9 km are in Uttar Pradesh. The major tributaries of the Sindh are Mahuar, Parbati, Pahuj and Kunwari (Gajbhiye S., et al 2015). It drains areas in the Malwa region and Shivpuri plateau in the districts of Vidisha, Guna, Shivpuri, Sheopur, Morena, Gwalior, Bhind and Datia in central and north-west Madhya Pradesh.

River Kunwari

River Kunwari originating near Sabalgarh in Morena district (M.P.) runs almost parallel to river Chambal (on its right bank) till its confluence with the Sindh and thereby captures all the drainage from Gwalior region which would have otherwise fed River Chambal and transfers its captured runoff to R. Sindh. Consequently, River Chambal for almost 120 km of its later stage flows without any tributary of note, jacketed within its famous badlands (the Chambal ravines).

2.9.3 River Betwa

The River Betwa originates in Raisen district of Madhya Pradesh near Barkhera village, south-west of Bhopal at an elevation of about 576 metres amsl. It is an interstate river between Madhya Pradesh and Uttar Pradesh. It flows in a northeasterly direction through Madhya Pradesh and enters Uttar Pradesh near village Bangawan of Jhansi district. The total length of the river from its origin to its confluence with the Yamuna is 590 km, out of which 232 km lie in Madhya Pradesh and the remaining 358 km in Uttar Pradesh. It joins River Yamuna near Hamirpur in Uttar Pradesh at an elevation of about 106 m (NWDA-B, undated).

The river basin lies between 22^{o} 54' N and 26^{o} 00' N latitudes and the longitudes of 77^{o} 10' E and 80^{o} 20' E. Out of its catchment of 43895 km^2, 30217 km^2 lie in Madhya Pradesh and the remaining 13678 km^2 lie in Uttar Pradesh. (NWDA-B, Undated).

The Betwa basin is saucer-shaped with sand stone hills around its periphery and clays underlain by Deccan trap basalts. Its elevation ranges from 63 m to 724 m above msl. The river drains the areas of Bundelkhand uplands, eastern Malwa plateau and the Vindhyan scarp lands in the districts of Tikamgarh, Sagar, Vidisha, Raisen, Bhopal, Guna, Shivpuri and Chhatarpur of Madhya Pradesh and Hamirpur, Jalaun, Jhansi and Banda districts of Uttar Pradesh. In its course, from the source up to the confluence with the Yamuna, the Betwa is joined by a number of tributaries, the important among them being Bina, Jamini, Dhasan and Birma on the right bank and Kaliasote, Halali, Bah, Saga, Narain and Kaithan on the left bank (NWDA-B, Undated).

Stream Order

The flow in River Betwa becomes significant at Bhojpur where its uppermost tributary (Kaliasote) from the Vindhyachal range joins it, along with other streams from the Bhopal plateau. Thereafter near Vidisha, after the 5th order Halali *Nadi* merges with it, the Betwa broadens and comes out of the plateau (Ahlawat R., 2011).

In its undulating terrain, Bina and Narain are two important 5th order tributaries from the Bhander range, which girdles the region as a semi-circular central plateau. In the middle reaches, Orr Nadi on the left bank and Jamni Nadi on the right bank bring significant runoff. In the Betwa mid-reach, the Jamni's drainage area is second largest after Dhasan and it is dammed at various places in Bundelkhand, near Jhansi (UP). The Dhasan, after leaving the Sagar plateau where two 5th order streams join, becomes the lifeline of Bundelkhand.

Birma is another large 5th order stream in the lower reaches of Betwa after its confluence with the Dhasan. There are more than 4000 ephemeral first order streams and four out of forty five 4th order streams are ephemeral till their mouths (Ahlawat R., 2011). River Betwa at the point of its confluence with Yamuna is a 7th order stream (Ahlawat R., 2011). This is the result of the confluence of Betwa and Dhasan, both being sixth order rivers at their point of confluence.

Map 15 : Map Showing the Location of the Ken Basin

2.9.4 River Ken

River Ken originates from a site close to Rithi village in Katni district. It makes a wide N-E-W arc and creates a gorge as it descends into Panna district from the Katni plateau, meeting river Patne near the town of Pawai after which it turns north. Two of its major tributaries namely, Sonar and Bearma, drain the districts of Sagar and Damoh in a northeasterly direction before meeting Ken at Kamtana village upstream of the mytho-historical site of Pandavan. The Ken river basin is spread across Katni, Satna, Chhatarpur, Panna, Damoh and Sagar districts in Madhya Pradesh and Banda, Mahoba and Hamirpur districts in Uttar Pradesh (Map 15).

GEO-HERITAGE SITE AT PANDAVAN

The River Ken, meets its larger tributary – the Sonar, near Kamtana village in Panna district, where the two rivers fall into a 12–15 m deep and about 2 km long gorge forming a deep lake. Downstream of the lake, for about 1 km the river has a wide bedrock channel which is crossed by the Amanganj–Kishengarh road bridge. About 200 m downstream from the road bridge, the Ken is joined on its right bank by River Mirhasan. Here, River Ken has a 350 m–400 m wide, relatively shallow channel with a typical low gradient, scabland morphology which is also seen along most of its course. Fine sediment deposits are common along the banks.

Image 4 : a) River Ken Rift With A Large Number Of Potholes (B) Ken Close Up In Rift Valley With Large Pot-Holes In Boulders

Here the Ken suddenly plunges into a narrow (less than 3 m), 12–15 m deep rift as a rocky inner channel that widens gradually further downstream but cannot be seen readily from the surface. This place is known as Pandavan, because according to a legend, the Pandavas visited here during their exile.

Geologically, a deep fault runs along the left bank and is visible from a distance. The left side forms a nearly vertical scarp and has a 1–2 m higher elevation than the right side.

Most interesting, however, are the numerous ripples, flutes and thousands of potholes over a distance of more than 2 km. These potholes, on almost every boulder, vary greatly in shape and size. They are oriented in both horizontal and vertical directions and occur from the surface of the river bed down to the level of the water in the channel, and on the left bank scarp. In general, the potholes at this site are larger (up to 3 m in diameter), close to the knick point at the surface and near the water channel in the gorge.

Most of the potholes are visibly carved out by the grinding action of small and large-sized gravel in swirling water moving over the rocks. Many potholes contain pebbles and even large stones. In numerous cases, the potholes have coalesced. Smaller potholes, ripples and flutes on the surface of the bedrock channel may have been formed by turbulent flows, whereas vortex formation during huge discharges seems to be largely responsible for the massive potholes closer to the main, inner channel. Turbulent flows have also left a signature of gouging of large boulders.

Although potholes are considered to be the most effective way of erosion and incision in bedrock channels, tectonic processes have also played a major role because several other gorges occur further downstream up to the Ken Gharial Sanctuary. Another interesting site is only about 6 km downstream at Gehrighat within the Panna Tiger Reserve, where the river has formed a wide fall and a deep, long gorge. Gehrighat is an important habitat of vultures in the National Park. Here tectonic faulting appears to have contributed actively to knickpoint initiation and possibly recession.
Mention should be made here of another tectonic fault that caused the formation of another knick point – the Raneh Falls – about 50 km downstream of Gehrighat, along with a narrow, 5 km long and 30 m deep gorge which also has multi-coloured crystalline granite rocks. Interestingly, pothole formation is weak and negligible at this site.

Among the many rivers flowing through narrow gorges and across north facing escarpments in the Rewa and Bundelkhand Plateaus, R. Ken offers a unique example of forming fluvially sculpted channel morphology in two different rock types (Vindhyan sandstone and Bundelkhand granite) and two different geomorphic settings within about 60 km distance. The hitherto unknown site at Pandavan deserves detailed studies regarding its geological origin, past hydrology and the development of potholes which are unique in the country.

Source: (Gopal B., 2016)

River Ken and its tributaries drain almost the entire Panna district. Physiographically Panna district forms a part of the Vindhyachal ranges in the south followed by Bundelkhand upland in the north. The Vindhyachal ranges contain two linear steps-like tablelands trending ENE-WSW separated by an uneven narrow valley having an average elevation of 440 m amsl. The Bundelkhand upland, having an average elevation of 170 m amsl, is a peneplained[11] surface dotted with mesa[12] and linear ridges (Anon, 2013).

The basin and sub-basins comprise a dendritic drainage pattern with the highest stream order varying from third order to sixth order. A mean bifurcation ratio (2.09) showed that the drainage pattern was not affected by structural disturbances. Coarse texture, low relief, elongated shape of the basin and gentle terrain condition were found to be the dominant morphometric parameters (Panda B., 2019).

2.9.5 River Baghain

River Baghain has its source in Panna district. It then enters UP in Banda district and flows in a northeast direction, separating Banda from Chitrakoot district, before it meets the Yamuna. Geomorphologically the basin exhibits smaller patches of mesa and butte[13] with gentle slopes in the remaining part (Sharma A.K. and Shukla J.P., 2015).

RANEH FALLS

River Ken cuts through an amazing variety of formations, like the one near Raneh in Chattarpur district of Madhya Pradesh, where several types of rocks can be seen in one place.

Image 5 : Granite, Dolomite, Quartzite, Basalt and Sandstone interlaid

There is dolomite which is about 120 Ma old. It lies over a layer of slaty shale which is about 550 Ma and bears impressions of sea creatures. The pink rock is quartzite, which overlies maroon sandstone that is about 90-65 Ma. The grey rock at the bottom is 600-400 Ma granite and below it is the deep grey volcanic basalt which is about two billion years old.

Source: (Lal P., 2016)

GEO-MORPHOLOGY OF SONAR-BEARMA BASIN

Sonar and Bearma together form the largest sub-basin of the Ken basin. Sonar and Bearma drain parts of Raisen, Sagar, Narsinghpur, Damoh and Panna districts in central MP. The total area of the sub basin is 12,380 Sqkm.

Geologically the Sonar-Bearma basin forms the north central part of the Indian tableland. It falls in the southeastern part of the Vindhyan Basin and nearly two thirds of the basin is composed of the Vindhyans. However, the western part of the Sonar-Bearma basin comes within the north eastern margin of the Deccan Trap volcanic rocks. The middle part is mainly covered by Recent deposits.

The key tributaries of Sonar are Bewas, Kopra, Gadheri, Debhar and Kaith, many of which originate from the Deccan trap hills in the western portion of the basin. Bamner, Guraiya and Bhadar all originating from the rocky surface of the Vindhyans are the key tributaries of the Bearma.

An outstanding geomorphic feature in the southeastern part of the sub basin is the 'Jabera basin'. It is a fine example of an inversion of topography. There is a striking difference in the topography on both sides of the Sagar-Jabalpur road along the Katangi valley, which has been carved out in the Bhander formations and the Upper Rewa Sandstone.

2.9.6 River Paisuni (aka Mandakini)

River Paisuni (See also section 6.5 in Chapter 6) is a perennial river, most famous for Chitrakoot, the religious town on its banks. It originates from the central part of Satna district and flows from south west to north east direction and finally joins River Yamuna near Rajpur in Chitrakoot district of UP.

Topographically the basin is hilly in its southern part. The northern part is undulating to plain. Ravines have formed around both sides of the river channel (Rajpoot P.S. et al 2015). Sandstone, limestone and conglomerates are the main rocks exposed in the area. The Paisuni's drainage pattern is dendritic and the runoff is moderate to high. The drainage density and frequency are more and the fine drainage texture shows that the basin is impermeable and has a low ground water recharging character with sparse vegetation. The basin shape is elongated. The basin's longitudinal profile shows high relief in the first order drainages and as the drainage order increases, the relief decreases and finally converts into flat basin at the outlet (Rajpoot P.S., et al 2015).

2.9.7 River Tons (aka Tamas)

The Tons river basin is a sub-basin of the Ganga basin. It spreads across the two states of Madhya Pradesh and Uttar Pradesh and lies between 23°57′N to 25°20′N latitudes and 80°20′E to 83°25′E longitudes. The total catchment area is 17,617 km^2, out of which 11,974 km^2 are in MP and the remaining 5643 km^2 lie in UP (Singh S.K., et al 2018).

River Tons (See also section 6.5 in Chapter 6) originates from a tank "Tamakund" in the Kaimur hills in Satna district (MP) at an elevation of 610 m. The basin lies in the districts of Satna and Rewa in MP and Chitrakoot, Prayagraj and Mirzapur districts in UP. It is surrounded by Kaimur range in its south – east and east and Panna plateau and Vindhyachal range on its west and north-west. Plains of river Ganga make up its north. Satna, Bihar and Belan are the key tributaries of R. Tons. The basin is marked by a number of falls (Chachai, Keuti kund, Purwa and Odda), which are the result of river Tons and its tributaries negotiating the Purwa plateau in its lower basin before the river descends into the Gangetic plains.

The geology of the basin is predominantly Precambrian (Archean and Proterozoic)[14], with patches of Quaternary base rock. These are further subdivided into three series namely the Bhander, Rewa and Kaimur (Singh S.K., et al 2018).

2.9.8 River Sone

The 784 km long Sone (See also Chapter 6) is one of the longer rivers of India and the longest of the southern tributaries feeding into the River Ganga (Khan A.A. and Aziz M., 2016). Out of 784 km about 500 km lie in MP, 82 km in Uttar Pradesh and the remaining 202 km in Bihar (Joshi K. D., et al 2014). The total catchment area of the river is spread over 71,259 km^2 (Joshi K. D., et al 2014).

"It flows, as does the Narmada River, along the line of a major E-W tectonic lineament........" (Williams M.A. J. and Royce K., 1982). Geologically, the lower valley of the Sone is an extension of the Narmada Valley, and the Kaimur Range an extension of the Vindhya Range (Khan A.A. and Aziz M., 2016).

Originating in Madhya Pradesh, just east of the Narmada River, the Sone flows north northwest and cuts through Middle Proterozoic limestone and shale of the Vindhyan Super Group and Middle-Pleistocene and Holocene alluvial plains, before turning eastwards to encounter Middle Proterozoic sandstones of the Kaimur Range (Morad et al., 1991). The modern channel has incised the metamorphic bedrock to a depth of about 30– 35 m, forming deposits of fluvial sand (Williams M.A. J. and Royce K., 1982). Throughout its history, the passage of River Sone has been strongly influenced by climatic factors (reflected in changes in its floodplain deposition and channel down-cutting), since the river is constrained laterally as a consequence of its geological setting (William & Clarke M.F., 1995).

The Sone has a steep gradient (35–55 cm per km) with quick run-off and ephemeral regimes. It becomes a roaring river with the rainwaters in the catchment area but quickly turns into a fordable stream. The wide and shallow lower Sone exhibits disconnected pools of water in the remaining part of the year. The Sone's channel is very wide (about 5 km at Dehri-on- Sone) but its floodplain is narrow, only 3 to 5 km wide (Khan A.A. and Aziz M., 2016).

The major tributaries of River Sone emerge from the highlands and flow in a northward direction to join the main river. The major tributaries are Rihand, North Koel, Gopad, Banas, Mahanadi, Johilla and Kanhar (Joshi K. D., et al 2014).

The Sone's alluvial basin includes terraced surfaces flanked by floodplains, point bars and alluvial fan deposits. The main river channel is bounded by a series of Middle and Late Pleistocene and Early-Holocene sedimentary terraces that are often 30 m high and deeply incised seasonal channels (Khan A.A. and Aziz M., 2016). The terrace, incised by the modern R. Sone, has been intensively studied due to the presence of the YTT[15] marker and the coincidence of archaeological sites, where Middle Palaeolithic and Neolithic artefacts have been found (Williams M.A. J. and Royce K., 1982; Williams M.A. J. and Royce K., 1983).

Four formations have been historically ascribed to the alluvial deposits of the Sone Valley. In chronological order they are: Sihawal Formation, Patpara Formation, Baghor Formation and Khetaunhi Formation (Williams M.A. J. and Royce K., 1982; Williams M.A. J. and Royce K., 1983). The geological context of the incised terrace is unclear, mainly due to the absence of absolute dates and robust stratigraphic correlation (Jones S.C. and Pal J.N., 2009).

Several models have been proposed for the geomorphological evolution of the alluvial plain of the Middle Sone Valley through the Early Pleistocene to Late Holocene period (Williams M.A. J. and Royce K., 1982; Williams M.A. J. and Royce K., 1983). These authors analysed the large-scale evolution of the river based on differences between the four formations and distinct climatic regimes. A stratigraphical model (at 1 km scale) of the emplacement of all the four formations within the river basin was also proposed (William & Clarke M.F., 1995) and modified (Williams M.A.J., et al 2006).

2.9.9 River Punpun

River Punpun is a direct tributary of the Ganga. It originates from the Chota Nagpur Plateau in Palamu district of Jharkhand at an elevation of 300 metres and flows mostly in a north-easterly direction through the districts of Chatra (Jharkhand), Aurangabad, Gaya and Patna of Bihar. It has a total catchment area of 8,530 km^2 and has three main tributaries namely Butane, Madar and Mohar. This 200 km long river is mostly rain fed and carries little water in the dry season. However, during rains, it often causes heavy floods in east Patna district.

2.10 CONCLUSIONS AND RECOMMENDATIONS

2.10.1 Conclusions

Rivers write their own histories. Geomorphological features like palaeochannels, the forms, sizes and colours of sediments, the variety of sediment bars, meanders, oxbow lakes, active and inactive flood plains are markers that make up a script. It is left to us humans to decipher what stories the rivers tell us.

The Ganga basin spans the greatest altitudinal, and hence climatic, range of all river basins in the world – from the peak of Mount Everest to the Bay of Bengal. Its ancient river system has carved a large diversity of natural landforms. As human population has grown and spread in the basin, human interventions over millennia have altered the natural processes and imprinted new morphologies. Morphological changes lead to ecosystem alterations in the rivers and their adjoining valleys. Human-induced morphologies have often had deleterious impacts on the river ecosystems (See Chapters 6 and 8).

Tremendous regulation of rivers in the last two centuries or so, encroachment of their floodplains and unprecedented scale of sediment mining have, perhaps, wrought more rapid and severe morphological changes than at any time in the past. The northern sub-basins and the main stems of the Ganga and the Yamuna have been heavily transformed. In their southern sub-basins, the western tributaries like the Chambal, Banas and Betwa have witnessed more serious human-induced changes, than the Ken, Paisuni and the Tons in the east. But the Sone sub-basin has been significantly interfered with. The Farakka barrage on the Ganga has greatly reduced the huge sediment loads brought down by the Himalayan tributaries of Bihar from reaching the Ganga delta in the Bay of Bengal.

2.10.2 Recommendations

The geomorphic diversity of the Indian rivers is striking. It is a manifestation of variable geologic and climatic settings. The rivers have attained distinctive morphologies in response to the 'imposed' boundary conditions such as geology, valley setting, and topography and 'flux' boundary conditions such as flow, sediment load and vegetation cover. Flux boundary conditions are essentially embedded within the imposed boundary conditions; determined by the energy conditions under which the rivers behave. They also fashion the flow, sediment and vegetation interactions along a river and determine its character and behaviour. Human interventions in several rivers have altered the flux boundary conditions significantly resulting in large-scale modification in channel morphology and hydrological regime. The following recommendations emerge from this review:

1. The management and restoration of such degraded rivers should focus on (a) identification of baseline (pre-disturbance) conditions, (b) mapping of 'hotspots' of degradation and (c) development of site-specific and nature-based mitigation measures.
2. There is a paucity of geomorphic studies and data for rivers in the southern Ganga basin. This deficiency must be made up first to ensure a process of rational river management.
3. High sediment yield has emerged as the most crucial issue in several Himalayan rivers. Modelled soil erosion rates and sediment load values are essential inputs for quantifying sediment balance and understanding the overall sediment dynamics of these river basins which in turn influence river related hazards such as landslides and floods. Given the spatial inhomogeneities, this should be done periodically at a higher resolution.
4. Sediment management should become an essential part of river management strategies and this has to be based on a strong understanding of sediment dynamics. In particular, the framework should be based on estimates of silt accumulated, identification of hotspots of aggradation, mechanisms and techniques for desilting and finally a plan for utilizing the excavated silt. In this context a wider network of sediment load measurements should be established, and periodic surveys of critical sections must be a part of the standard operating protocol (SOP) for river management.
5. Strategic desilting of river channels in several Himalayan rivers may be necessary to increase their water holding capacities and lower the flood risks. However, desiltation in the river channel should be done carefully to avoid any disturbance in the hydro-geomorphic regime and loss of riverine biodiversity.
6. All efforts should be made to involve the local community in river management.

Regular programmes for capacity building should be organized by experts at regular intervals. Knowledge dissemination should become an essential part of the standard operating procedure for river management and success stories should be advertised to instill confidence in the local community.

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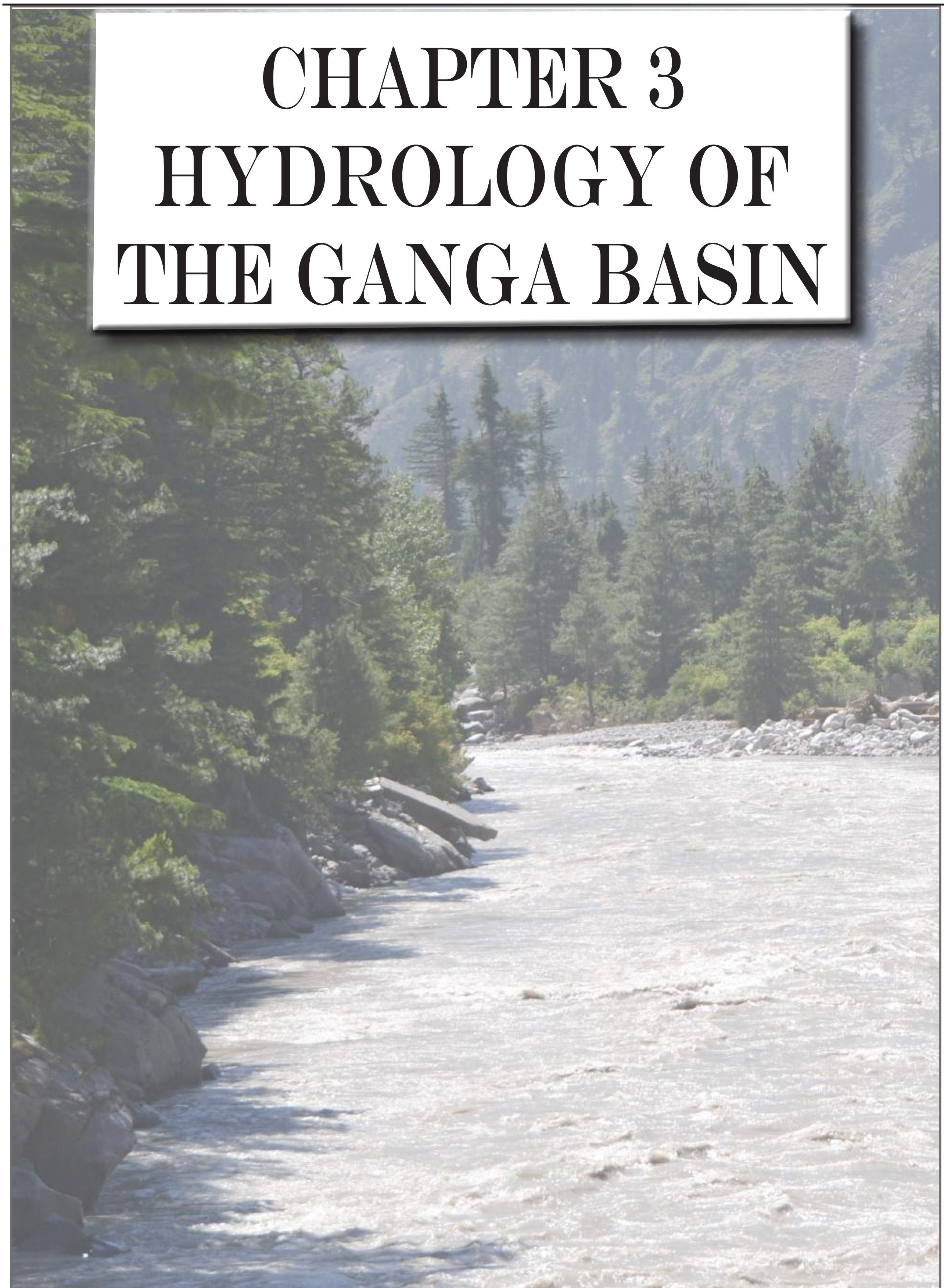
2.12 END NOTES

1. Fluvial: refers to process or action produced by a flowing river or stream.
2. Incision is the process of cutting into a surface or something. In the context of rivers incision is the narrow erosion caused by a river or stream that is far from its base level. It may be caused by a tectonic uplift of the landscape.
3. Interfluve is an area of higher ground between two rivers in the same drainage system.
4. Intermontane: location between mountains or mountain ranges.
5. Avulsion is the natural process by which the flow diverts out of an established river channel into a new course on the adjacent floodplain. Avulsions are primarily features of aggrading floodplains. Their recurrence interval can range from as low as 28 years for the Kosi River to up to 1400 years for the Mississippi.
6. Hyperavulsive river is one that has frequent avulsions like the Kosi or Bagmati.
7. Aggradation is the process of raising the level of a surface like a river bed by the deposition of material like sediments.
8. Lobe: a roundish and flattish hanging part of something, or one of two or more such parts divided by a fissure.
9. Holocene is the most recent part of Earth's geologic history covering the last approximately 12,000 years.
10. Stratigraphic development refers to the successive formation of geological strata or layers.
11. Peneplain: a gently undulating, almost flat plain, in principle, produced by fluvial erosion in the course of geologic time, so that more erosion is unlikely to occur.
12. Mesa is a relatively isolated flat-topped elevated landform with steep sides, found in landscapes with horizontal strata. It is smaller than a plateau but bigger than an isolated small hill or a butte.
13. Butte: an isolated, flat-topped hill or mountain with steep sides that is smaller in area than a plateau or a mesa.
14. Precambrian refers to the earliest part of Earth's history from the time of its formation about 4.6 billion years ago till the Cambrian period (about 541 million years ago). It includes the Archean eon (about 2.5 billion years ago) and the Proterozoic eon (about 2.5 billion years ago to 541 million years ago).
15. YTT refers to Youngest Toba Tuff the youngest eruption from the Toba crater on northern Sumatra island that occurred about 75,000 years ago



CHAPTER 3
HYDROLOGY OF THE GANGA BASIN

River Ganga drains a basin of extraordinary variation in altitude, climate, land forms, land uses and cropping patterns. Topographic extremes in the basin are the largest compared to any other basin on Earth. Within barely 200 km, the elevation plunges from the highest mountain in the world at 8,848 m (Mt Everest peak in Nepal) to about 100 m, the elevation of the flat Ganga Plains in India (Bharti L., et al 2016).

The South Asian monsoon largely determines the hydrology of the Ganga river basin. Each year from June to September, monsoon rain clouds sweep over large parts of the basin and deliver 70-80 percent of its annual rainfall (World Bank, 2013). Water availability in the Ganga basin is high, as on an average around 1,200 BCM (Billion Cubic Meter) precipitation falls in the basin. An estimated 600 BCM (~50%) or so, become stream flow, with the rest directly recharging groundwater or returned to the atmosphere through evapotranspiration (World Bank, 2013).

3.1 LONG TERM AVERAGE ANNUAL FLOWS IN THE RIVER GANGA SYSTEM

Rivers Ganga and Yamuna are the two axial rivers in the Upper Ganga Basin till their confluence at Prayagraj. Post Prayagraj, Ganga receives major contributions from the Tons, Sone and Punpun (all right bank tributaries) and Gomti, Ghaghara, Gandak, Burhi Gandak, Kosi (all left bank tributaries) before it reaches Farakka on the Indo-Bangladesh border. Many of the left bank tributaries have parts of their upper catchment in Nepal, or in some cases even Tibet.

Table 2 : Average Annual Flow

River	Average Annual Flow (MCM)	Comment
Ganga (Haridwar)	23,900	Drainage Of Founder Basin in Uttarakhand
Ganga (Narora)	31,400	Accrual From Minor Tributaries & Groundwater
Ramganga	15,620	Left Bank Tributary
Yamuna (Hathnikund)	10,750	Drainage Of Founder Basin in Uttarakhand & HP
Yamuna (Delhi)	13,700	Accrual From Minor Tributaries & Groundwater
Chambal	30,050	Right Bank Tributary of Yamuna
Sindh	NA	Right Bank Tributary of Yamuna

Betwa	10,000	Right Bank Tributary of Yamuna
Ken	11,300	Right Bank Tributary of Yamuna
Ganga (Allahabad)	58,980	At Confluence
Yamuna (Allahabad)	93,020	At Confluence
Ganga (d/s Allahabad)	152,000	Post Confluence
Tons (Tamas)	5,910	Right Bank Tributary of Ganga
Gomti	7,390	Left Bank Tributary of Ganga
Ghaghara	94,400	Left Bank Tributary of Ganga (Part Sub Basin In Nepal)
Gandak	52,200	Left Bank Tributary of Ganga (Part Sub Basin In China And Nepal)
Burhi Gandak	7,100	Left Bank Tributary of Ganga (Part Sub Basin In Nepal)
Kosi	68,340	Left Bank Tributary of Ganga (Part Sub Basin In China And Nepal)
Ganga (Farakka)	525,040	Total Indian Basin

Source: Modified from Jain S.K., et al (2007)

MELTING OF SNOW AND GLACIERS

The timing and amount of melt water produced from mountain glaciers is different from that derived from snowpacks on land. The major contribution from the seasonal snow reaches the streams between March and June (before monsoon). The glaciers start melting when all the snow accumulated in the last season is melted. The melt water from the snow and glaciers is delayed before joining a stream or ground water reservoir. This delay is more prominent in the glaciers. Although insolation reaches a peak in June in the northern hemisphere, the average albedo* of snow covered glacier surface at this time is relatively higher causing only low or moderate melt rate. In July and August, insolation drops slightly but the mean albedo of the glacier surface drops markedly as old dirty ice gets exposed and the melt rate is higher than in June. A year of heavy snow accumulation increases the high albedo snow layer which persists longer and curtails melting. Thus, production of melt water from glaciers tends to compensate for unusually wet or dry or hot or cold years thereby naturally regulating the streamflow.

*Albedo is the percentage of solar energy striking a surface that is reflected away. It is a measure of energy.

Source: "Water Yield from Snow and Glacier", NIH, 1994.

3.2 SOURCES OF WATER

3.2.1 Snow and Glaciers

Unlike other nearby river systems like the Indus, glaciers contribute a relatively small share of the total river flow in the Ganga basin. Recent studies show that the glaciers' contribution to the MAF (Mean Annual Flow) for the entire Ganga basin, is only about 4-6% (Savoskul O. and Smakhtin V., 2013). Even at Devprayag, less than 200 km from Gaumukh, the glacial source of the Bhagirathi, the contribution from snow and glaciers to the MAF in R. Ganga is estimated to be only about 28% (Anon, 1994). Much of the glacier melt occurs during the early monsoon when the rainfall can be quite heavy (Alford D. and Armstrong R., 2010).

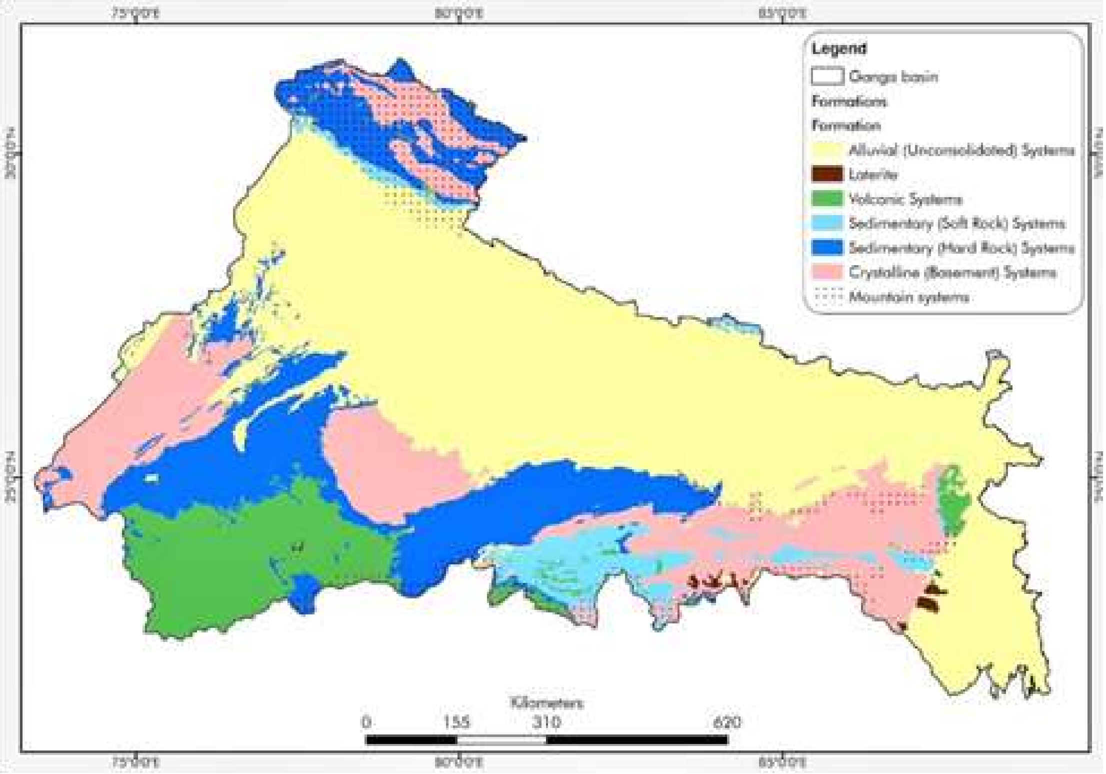
There is greater uncertainty about the timing and overall contribution of snowmelt. Snow and ice together are estimated to contribute about 9 percent (almost 2/3 from snow) of the MAF in the Ganga, though they contribute much more in some tributaries (e.g., 30% of the MAF in the Burhi Gandak) and in small upstream catchments (Immerzeel W.W., et al 2010).

Importantly, glaciers and snow provide valuable natural water storages that help ensure the perennial flow of the Himalayan tributaries, and enhance dry season flows in the Ganga. Estimates of their contribution to the low flows at Farakka in March-May vary greatly, ranging between 12 and 18 percent (Siderius C., 2013).

3.2.2 Ground Water

Base flows form a crucial but often invisible part of India's water resources. Base flows in rivers like the Ganga are influenced by a complex set of factors such as groundwater abstraction through wells and the natural discharge through springs. Base flow character is a consequence of the nature of interactions between groundwater and surface water. The Ganga basin is India's largest river system and modern data shows that groundwater contribution in the form of base flows to the Ganga river basin is three to four times the contribution by snow melt, clearly underscoring the importance of understanding base flows in the basin. Understanding groundwater therefore becomes an important aspect for reviving and rejuvenating R. Ganga (Kulkarni H. and Patil S., 2018).

One of the first lessons in a study of the Ganga river basin [GRB] is its hydrogeological diversity. Much of the discourse on groundwater in the GRB has been around the deep and extensive alluvial aquifer systems that have more recently caught global attention for being one of the biggest hot-spots of groundwater exploitation in the world (Rodell M., et al 2009). Incidentally, more than half of the GRB is underlain by non-alluvial geological formations including hard-rock aquifers that are far smaller than alluvial aquifers in both lateral and vertical scales. These formations have seen a somewhat



Map 16 : Hydrogeological Settings In The Ganga River Basin

Source: Adapted from Kulkarni H. (2005) and Kulkarni H., et al (2009)

Map 17 : Major Sub-Basins of the GRB

Source: Data sources acknowledged in the diagram different trajectory of groundwater development when compared to that in the alluvial aquifer systems. Moreover, a part of the non-alluvial aquifer systems is represented by the Himalayan morpho-geological system, which is not only the source region for snow and glaciers but is also a host to millions of springs that feed water into the Himalayan tributaries of Ganga. Contrary to popular belief, nearly 20 % of the flow in the Ganga basin is base flow (Mukherjee et al, 2018) - contributed by springs and seeps - while only about 5 % is snow melt (Savoskul O. and Smakhtin V. 2013; Siderius C., et al 2013). The GRB presents us with a unique pattern of diverse geological formations, providing a window for gauging how variable the aquifer systems and resultant groundwater conditions are (Map 16).

Some 10 of the 18 major sub-basins in the GRB are underlain by a mixed geology while eight sub-basins occupy major areas of alluvial deposits (Map 17).

3.2.3 Hydrogeology

All the six typical aquifer systems found in India occur in the GRB. Not only are these aquifer systems diverse, but their functional scale and the resultant socio-economic dimensions are also quite varied. Historically, nearly all of these diverse aquifer systems were tapped by shallow sources. Hence, for many centuries, groundwater from the shallow, phreatic (unconfined) aquifers through dug wells (also called 'open wells') was tapped in many parts of the GRB. Evidence for this historical narrative can still be found in continuity of usage through these shallow sources or in the form of relics left behind in pursuit of more modern, often deeper sources – the step-wells, for instance. Whether it is the case of *'naulas'* - spring-wells in the Himalayan region, or the '*rahat*' driven dug well (a version of the Persian wheel driven wells) in many areas of the Southern Ganga River Basin, or even the modern dug wells with energized pumps, the tradition of accessing shallow phreatic aquifers still persists. This long-standing tradition, however, has been overtaken by rapid transitions in the form of deep bore wells and tube wells through the call and clamour for development and modernity (Kulkarni H. and Patil S., 2018).

The crowding of shallow and deep sources of groundwater is not uncommon, particularly in the western parts of the GRB. It is not uncommon to find 10 wells within a stretch of 50 to 100 m along the stretch of a small stream channel in many such areas.

Depleting base flows in the GRB are not as simple to understand as in many other river basins of India. Therefore, the question of *'aviralta'* or perennial flow in the GRB must be understood in the context of the interaction between surface water and groundwater. Aquifers are the missing elements in understanding the significance of base flows in the concept of *'aviralta'* in the GRB. Estimates on the basis of a range of specific yields (based on various studies by ACWADAM) for different aquifers were used to understand

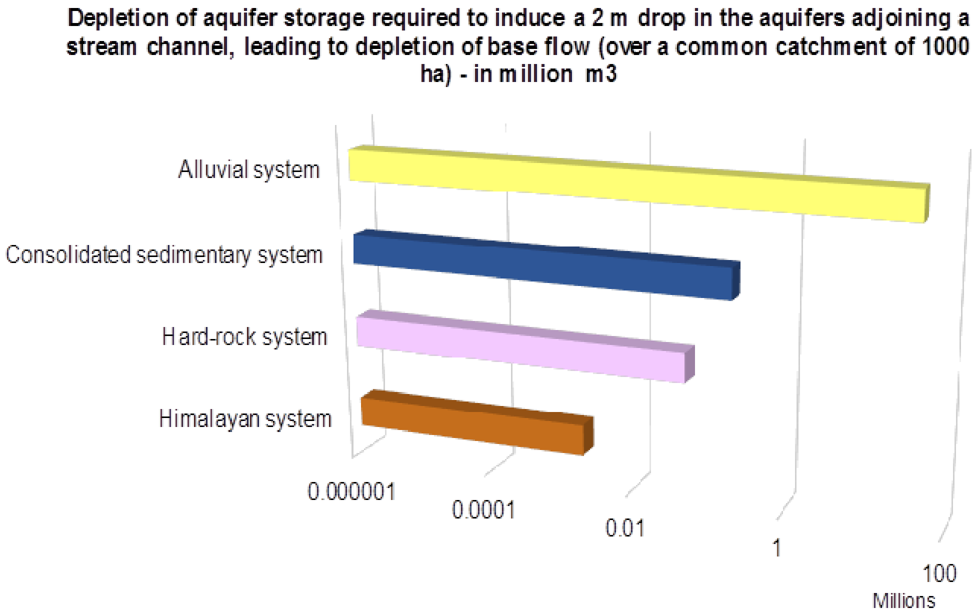


Image 6 : Base Flows In 'Aviralta': The Missing Element Of Aquifers

Source: Kulkarni H. and Patil S., (2018)

the volumes of pumping required to deplete these aquifers for inducing a 2 m drop in groundwater levels in close proximity to stream channels. It is assumed here that this 2 m drop will lead to a significant drop in groundwater discharges to these streams, thereby resulting in a depletion of the base flow of the stream. The 2 m drop in groundwater levels in a shallow unconfined aquifer adjacent to a stream or river channel implies various degrees of depletion in aquifers from different hydrogeological settings. This variability in aquifer storage depletion is estimated to be over 5 orders of magnitude (Image 6). Such a complex relationship between groundwater and surface water in the GRB calls for a robust system of groundwater management and governance, beginning with an understanding of local groundwater-river water dynamics.

Shallow unconfined aquifers are now grossly over-exploited, and in a state of great decline almost throughout in large parts of the GRB, particularly in the western part of the basin. Reviving and protecting them is an essential priority for maintaining and reviving base flows, which in turn will help rejuvenate the GRB in general and River Ganga in particular (Kulkarni H. and Patil S., 2018).

Surface and groundwater resources within a river basin are highly inter-connected. Floods recharge the aquifers. Ground water provides the base flow which is critical for sustaining river flows in the dry season. The contribution of aquifers to maintain river flows is not adequately quantified. It is, however, well-known that ground water extraction – referred to as ground water 'development' by officials and politicians -- reduces base flow and therefore there is a possibility that the environmental (ecosystem) requirements may be compromised.

REDUCED WATER LEVELS IN RIVER GANGA LINKED TO GROUNDWATER EXPLOITATION

Falling water levels in several lower Indian reaches of River Ganga have been observed in the summer (pre-monsoon) months in recent years. A study led by researchers at IIT-Kharagpur has estimated rates of water level declines from −0.5 to −38.1 cm/year between the summers of 1999 and 2013 in the studied reaches. The study shows that this Ganga river depletion is related to groundwater baseflow reductions caused by continuing groundwater storage depletion in the adjoining Gangetic aquifers. Its estimates show that the 2016-baseflow amount ($\sim 1.0 \times 10^6$ m^3/d) has reduced by ~59%, from the beginning of the irrigation pumping age in the 1970s (2.4×10^6 m^3/d) in some of the lower reaches.

The researchers conclude that the net Ganga river water reduction could jeopardize domestic water supply, irrigation water requirements, river transport, ecology, etc. of densely populated northern Indian plains. They foresee a direct impact on food production and vulnerability of more than 100 million people residing in the region.

Source: Based on the abstract in Mukherjee A., et al (2018)

While public investments since Independence have largely focused on surface water, over the last three decades, groundwater has emerged as the main source of both drinking water and irrigation, based almost entirely on private investments by millions of atomistic decision-makers. The relative ease and convenience of its decentralised access has meant that groundwater is the backbone of India's agriculture and drinking water security. Groundwater is used by millions of farmers across the country. Over the last four decades, around 84 per cent of the total addition to the net irrigated area has come from groundwater (Shah M., 2016). India is by far the largest and fastest growing consumer of groundwater in the world. But groundwater is being exploited beyond sustainable levels and with an estimated 30 million groundwater structures in play, India may be hurtling towards a serious crisis of groundwater over-extraction and quality deterioration (Shah M., 2016).

A study carried out by IIT Bombay and published in 'Nature Scientific Reports', based on groundwater data between 1996 and 2017 sourced from CGWB shows a decline of an average 2.6 centimeters per year in the water table. The decline was the highest in western UP.

Another report released by the World Meterological Organisation (WMO) in November, 2022, highlights that the volume of water available in the Ganga and the groundwater in the river-basin have both seen a significant fall between 2002 and 2021.

"The impact of glacial melt and retreat is likely to be more in the Indus basin than the Ganga basin. But the northern parts of Ganga particularly in Uttarakhand can be influenced quite a bit by glacial retreat. That needs to be studied carefully. Downstream, there is massive extraction of groundwater for irrigation particularly Punjab, Western parts of Uttar Pradesh etc."

3.2.4 Water Balance

A study led by IIT Delhi utilized the SWAT (Soil and Water Assessment Tool) hydrological model developed by USDA (US Department of Agriculture) to simulate the hydrology of the Ganga River Basin (Anand J., et al 2018). It quantified the Annual, Monsoon Season (June, July, August and September) and Non-Monsoon Season (October, November and December) hydrologic components for the GRB (Table 3).

Table 3 : Hydrology of Ganga River Basin

Season	Rainfall (mm)	Water yield (mm)	Snow Melt (mm)	Evapo-transpiration (mm)	Baseflow (mm)	Ground water recharge (mm)
Monsoon	975	459.3	3.7	253.7	111.3	271.4
Non-Monsoon	65.9	87.2	1.2	102.1	60.8	-
Annual	1167.5	601.6	12.2	496.5	202.4	274.8

Hydrological Model SWAT

SWAT was developed by the United States Department of Agriculture (USDA) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large un-gauged basins .

The SWAT model is a continuous time model that operates on a daily time step with option of monthly or annual output. The model operates by dividing a catchment into sub-catchments and each sub-catchment is further divided into Hydrological Response Units (HRUs). The HRU is a unique combination of soil and vegetation types within the sub-catchment and serves as the basic computational unit for flow accumulation. The simulation of the hydrological cycle by SWAT is based on the water balance equation as in (Eq. (1)):

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_i - Q_i - ET_i - G_i - B_i) \quad (1)$$

where, SW_t (mm) is the final soil water content, SW_0 (mm) is the initial soil water content on day i, t (days) is time, R_i (mm) is the precipitation amount on day i, Q_i(mm) is the amount of surface runoff on day i, ET_i (mm) is the evapotranspiration(ET) amount on day i, G_i (mm) is the amount of water entering the vadose zone from the soil profile on day i, and B_i (mm) is the amount of return flow on day i.

SWAT has an inbuilt snow module to capture and simulate snowmelt hydrology, permitting the delimitation of up to ten elevation bands with associated precipitation and temperature lapse rates . To determine the water budget, SWAT characterizes liquid and solid rainfall based on temperature of air near-surface. Furthermore, in SWAT, snowpack, snowfall and snowmelt events are always estimated by the model as soon as the temperature drops below the threshold of stipulated snowfall temperature. SWAT also enables these processes to be spatially distinguished as a function of elevation that allows users to add lapse rate for both precipitation (PLAPS in mm H_2O/km/yr) and temperature (TLAPS in °C/km), which is very essential in the study region considered.

Source: Extracted from Anand J., et al (2018)

The water yield (87.2 mm) obtained during the non-monsoon season is higher than the rainfall (65.9 mm) during the corresponding period, due to the high amount of return flow (60.8 mm) inside the catchment because of large areas under irrigation.

Analyses of results for the entire Ganga river basin show that water yield has the maximum share of water balance with approximately 51% (601.6 mm) annually of the total precipitation (1167.5 mm) with evapotranspiration having the next highest share (496.5 mm) which is 42.4% followed by groundwater recharge (274.8 mm).

The assessment of water yield contribution for different sub-basins during the monsoon and non-monsoon seasons reveals that on an average 70% of the water yield is contributed during the monsoon season. The contribution of sub-catchments to water yield varies widely. The, maximum contribution of 4505 mm is from a sub-basin dominated by glacier and snow, with almost 65 percent of this contribution (2900 mm) being made during the monsoon season. The minimum contribution of a sub-basin to the water yield, however, is less than 50 mm showing the huge variation within the GRB. A total of 653 billion cubic meters (BCM) (average annual) of water was estimated by the SWAT model as the potential water yield of the Ganga River basin between the simulation periods of 1990–2013. Analysis for the different sub-basins reveals that the unregulated Ghaghra and Gandak River systems make the largest contribution to the water yield in the basin while the heavily regulated Chambal and Sindh River Systems make the smallest contribution in the total water yield.

In addition, precipitation, water yield and evapotranspiration were found to be higher in the forested and mountainous and comparably unexploited upper areas. However, moving downstream or towards non-perennial systems dominated by agriculture and highly irrigated areas, the value of evapotranspiration increases (Anand J., 2018).

The SWAT model provides an opportunity to generate scenarios that can help in understanding the water resources availability under the virgin or pre-development condition. To develop the virgin scenario, the IIT Delhi study assumed that all the cultivation is rain fed, i.e., there is no irrigation withdrawal within the catchment. Hence all structures, such as reservoirs and canal diversions, were removed from the calibrated SWAT model.

The comparison of water balance between the virgin scenario and present scenario (business as usual) for upper Ganga basin, Yamuna basin, Chambal basin and Sindh basin showed that on an average the present annual water yield is 25%, 30%, 35% and 35%, respectively lower than in the virgin condition for the Ganga basin (upstream of Prayagraj), Yamuna basin (up to Agra), Chambal basin and Sindh basin respectively.

3.3 CONCLUSION

The Indian part of Ganga river basin (GRB) is the most populated, large river basin in the world. But R. Ganga is very highly regulated in its journey to the sea. Four important tributaries, the Yamuna, Ghagara, Gandak and Kosi provide about 60 per cent of the annual flow at Farakka, where the main R. Ganga branches and a part flows into Bangladesh. The Yamuna is also highly regulated in its upper stretch and is rejuvenated by its Vindhyan tributaries. Hence the maintenance of the integrity of R. Ganga's tributaries is a sine qua non for a healthy R. Ganga.

The Ganga is a perennial river. The Indian GRB is estimated to receive over 80 per cent of its annual rainfall in the monsoon season (Anand J. et al 2018). Base flows and glacial and snow melt, though comparatively small in volume, remain crucial for sustaining river flows in the non-monsoon months.

Recent studies, however, show that massive over-extraction of ground water for irrigation in the alluvial plains of the GRB is rapidly depleting the adjoining aquifers, leading to a sharp decrease in the base flows – about 59 per cent between the 1970s and 2016 -- in parts of the lower basin. The resulting decline in the river water availability threatens the survival of the basin's ecosystems and water security for hundreds of million people. Climate change impacts pose additional undetermined threats.

Though enough knowledge exists in India to undertake effective corrective actions, the political mobilization required to begin implementing them is weak.

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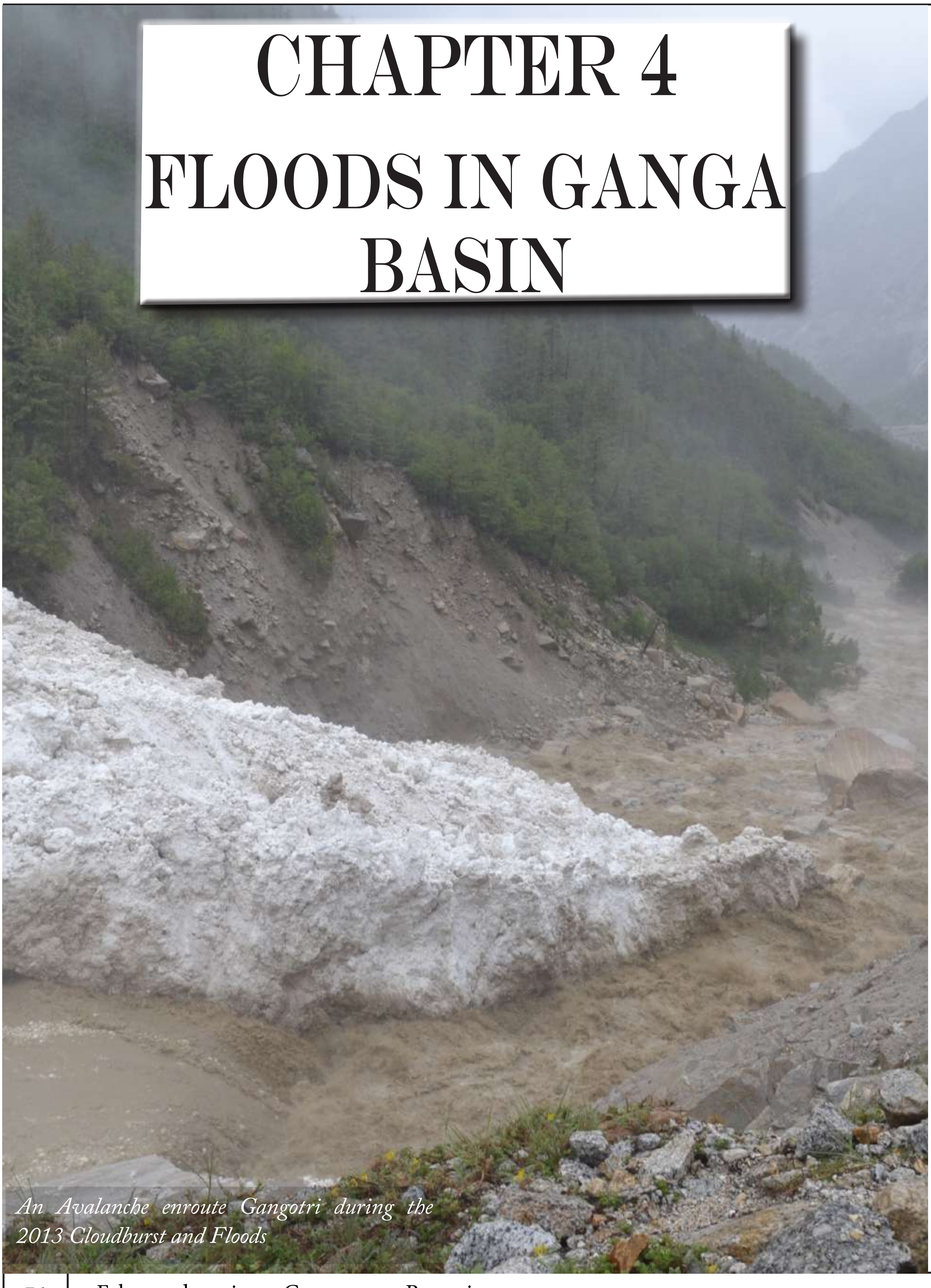
CHAPTER 4

FLOODS IN GANGA BASIN



An Avalanche enroute Gangotri during the 2013 Cloudburst and Floods

4.1 INTRODUCTION

Floods in rivers are a natural phenomenon. It is natural for a river to overflow its banks in the event of heavy rainfall in its upper catchments and spill into its flood plains, which are basically its domain (Anon, 2008). Floods display a cyclic behavior due to the recurrence of similar climatic conditions, at one or another time in one or another part of the river basin. Hence, we often speak of floods with recurrence intervals of 10 years, 50 years, 100 years and even 500 years. In recent times flood intensities and frequencies have been significantly modified by the changing climate.

Floods are often described as natural disasters though they have several positive aspects, including their role in building up the floodplains. Different parts of the floodplain are subjected to differential flooding and vary in character between lentic (standing water) and lotic (flowing water) with time. As most plant species are adapted to specific hydrological pulses and because different parts of the floodplain experience hydrological pulses of a different nature (geomorphic variation and topographic gradient), a rich biodiversity is obtained in floodplains (Gopal B., 2013).

Flooding forces the exchange of materials and energy between the river and its floodplain (Gopal B., 2013). The importance of these exchanges between the river and floodplains has been investigated in the context of fisheries (Low-McConnell R.H., 1987 and Welcomme R.L., 1979). Riverine fishes migrate to the floodplains for spawning, and young larvae and fry grow there feeding on plankton, invertebrates and detritus. Many other animals breed and pass some stages of their life cycle in different parts of the floodplains.

As a flood abates, the receding waters carry with them organic matter, propagules and nutrients from the floodplains to the river stream. Nutrients' cycling within the floodplains is dominated by flooding from the river, runoff from upland forests or both, depending upon the stream order and the season (Gopal B., 2013).

According to a 2017 paper by Zhang, floods are important sources of groundwater recharge in most of the world's arid lands (Zhang et al, 2017 and Sinha R., 2019). With appropriate management practices, floods can benefit the ecology of arid and semi-arid areas (Forman R.T. and Godron M., 1986). Flood spreading (due to river overflows) is one of the methods used for flood management and water harvesting that increases the groundwater recharge (Ryan R.L., 1998). In arid regions, stream beds of ephemeral rivers are largely composed of permeable, coarse, alluvial sediments that promote relatively rapid infiltration of flood water, which then recharges the local alluvial aquifers (Malavoi J. et al, 1998).

Floods reshape and modify the river channel through erosion of banks and deposition of sediments. They also ensure that fresh water and silt reach the river's delta for the latter's ecological functioning and physical security.

Rohan D'Souza, in a recent paper, suggests that floods should be re-conceptualized as a geomorphological process – the net transfer of sediments from higher elevations and hinterlands to the yawning mouth at the delta, a process that cultivators in pre-colonial times tapped for silt to fertilize their crops and create an agrarian world that was flood dependent (D'Souza R., 2020).

CONCEPT OF RIVER SPACE*

Floods are often seen as purely hydrological phenomena, without understanding their geomorphology.

The domain of a river primarily consists of its channel – where its water flows -- and its floodplain -- the area covered by its floodwaters. The term 'river space' refers to the space a river requires to perform its myriad functions such as channel migration, sediment/ nutrient transport, and support to riparian vegetation and ecosystem. This space has been differently defined by various researchers depending upon their perspectives. For example, geomorphologists, ecologists and biologists define a 'river corridor' as the entire space where the river flows, along with the landscape related to the river. Riparian vegetation, at the boundary of the water channel and the adjacent land, provides habitats and nutrients for aquatic and semi-aquatic animals. It also reduces erosion. A floodplain acts as a communication link between the channel and the woodland ecosystem. A hill slope regulates sedimentation and the vegetated upland areas protect the soil cover. Hence, the main channel, riparian vegetation, floodplain, valley, hill slope and the upland areas adjacent to the river are generally included in the definition of the river corridor (Forman R. T. and Godron M.,1986). Ryan suggested that the water's edge vegetation and lowland forest are the essential parts of a river corridor (Ryan R. L., 1998). The river, forests, farms, and even built-up areas need to be included in the river corridor. An 'erodible corridor' is one in which the main channel moves naturally inside the floodplain and therefore can be considered as a functional mobility zone based on the lateral channel movement during the last 5-10 decades (Malavoi J. et al, 1998). Some use the corridor concept in floodplain zoning in order to prevent the hazardous situations created by bank erosion. The river corridor has been considered as a dynamic valley-bottom area that accommodates the dimension, pattern, and profile of a stream channel in its most stable equilibrium condition; its delineation is based on the existing and estimated meander belt width.

From an ecological perspective, the river corridor is a structure which channelizes organisms, matter, and energy between patches (Fraser D. F. et al, 1999). A biological point of view envisages that a corridor should act like a habitat for both feeding and reproduction along with growth of individuals (Forman R. T. and Godron M.,1986). Following the river corridor concept, ecologists define a 'habitat corridor' as a linear habitat that connects two or more patches or core habitats. Further, a 'riparian corridor' has also been defined as the mosaic of landforms, communities and environments within the larger landscapes (Naiman R. J. et al, 1993).

From a geomorphic perspective, river space can be represented by the channel belt plus the active floodplain of a river. The active floodplain is defined as an area on either side of a stream or a river which is regularly flooded. A river with a complete floodplain is not just considered as the one in equilibrium but also in good health. Floodplains support a wide variety of rich life forms ranging from riparian vegetation to different species of organisms which have a direct influence on soil fertility. Thus, these areas are good for agriculture due to their high nutrient content. That is why they are frequently occupied by human population at the cost of other ecosystems. Preserving a river's active floodplain also reduces the risk to life and property due to annual flooding. It is therefore critical that the active floodplain of a river is accurately mapped as it has an important bearing for restoring the natural features of the river. A typical hydrological criterion to designate an active floodplain in a given reach is the area inundated by the mean annual flood (defined as a flood with a return period of 2.33 years).

In addition to the active floodplain, a wider and more extensive area is termed as a river valley. As discussed earlier, the valley margin was delineated on the basis of the topographic breaks across the river and the area between the active floodplain and valley margin has been mapped as 'inactive floodplain'. The course of the river may not be necessarily symmetric to its valley. The valley margin primarily defines:

a) The 'water divide', i.e., the line dividing neighbouring drainage basins (catchment) on a land surface. It can be visualized as a line on the ground on either side of which water droplet will start a journey to different rivers and even to different sides of the region. It is analogous to the 'hydrological boundary' between two watersheds.
b) The limit of 'lateral connectivity' between the river channel and floodplain or in other words, the hydrological and functional connection between the river and the riparian zone.
c) The 'recharge area' of the river in question, i.e., the area in which the surface water infiltrates and is added to the groundwater because of the topographic low.

It is important therefore to use a scientific basis for defining the river space rather than random criteria such as a fixed distance from the river channel.

**Note prepared by Sinha R., (2019) for this publication*

4.1.1 Floods & Culture

Rivers and floods are metaphors for constant change, for the unification of constructive and destructive forces that have driven philosophers since Heraclitus' *"panta rhei"*, meaning 'everything flows'. Aesthetic values of sinuous meanders, rounded pebbles, or mirroring water surfaces inspired painters and sculptors. The rhythm of running water is at the same time monotonous and highly diverse, and has inspired musicians to compose pieces such as Smetana's Vltava (The Moldau), or much of J.S. Bach's diverse work. All these technological and spiritual linkages of human beings to rivers have contributed to diverse forms of culture (Wantzen, K.M. et al, 2016).

4.1.2 Floods – A Disaster?

Unfortunately, floods generally occupy a negative image in the minds of people at large on account of their ability to spread water beyond a river's bank which can then have destructive impacts. But is the river to blame for such state of affairs? Is it not the people who have brought such misery upon themselves by infringing upon the river's space? Unless this fact is accepted and proper policies made to make the river space inviolate, the social and economic hardships associated with rivers in flood shall persist.

4.2 FLOOD MANAGEMENT

Following the unprecedented floods of 1954, Shri Gulzarilal Nanda, the then Union Minister for Planning, Irrigation and Power placed before Parliament on September 3, 1954 a statement on floods which set an objective of reducing the menace of floods. Later on, in a subsequent statement in Parliament on July 27, 1956, the emphasis was laid on doing all that was possible to contain floods in the country. Since then, the Government has taken various initiatives and set up a number of committees to study the problem and recommend several remedial measures. The most important ones are the High-Level Committee on Floods (1957), the Ministers Committee on Flood Control (1964), the Rashtriya Barh Ayog (1980) and the Task Force on Flood Management/ Erosion Control (2004).

The Ganga Flood Control Commission (GFCC) was set up by GoI in 1972 for the preparation of a comprehensive plan for flood control in the Ganga basin and to draw up a phased coordinated programme for the implementation of works. It has also been assigned the tasks of monitoring and appraising the flood management schemes of the Ganga basin states. The Task Force on Flood Management/Erosion Control (2004) recommended strengthening of GFCC to enable it to play a more effective role in flood management in the Ganga basin.

4.2.1 Embankments And Flood Control

During the monsoon of 1956, the plains of Punjab saw widespread flooding. Shri Jawaharlal Nehru, the then Prime Minister toured the area and said the following, as a part of his radio broadcast to the nation on October 9, 1956 :

In regards to the future, many people think of large-scale embankments and the like. There is no doubt that such protective works are helpful and, where necessary, should be erected.

But I think there is too much of the Maginot Line mentality in this matter. No protective work can give much help where widespread cloud-bursts take place bringing a deluge in their train. The best course would be to improve the drainage of the areas concerned so that water can flow away through this drainage system. It is also necessary to build our towns and villages on raised ground so that they might not be affected by the floods. I hope that all these matters will be carefully considered. Meanwhile we must give all the help we can to those who are afflicted not only in the Punjab but in the numerous other areas in north, north-east and east India."

DILEMMA OF EMBANKMENTS*

Embankments prevent a river from overflowing its banks during floods but they also prevent the entry of floodwater. This leads to a major problem as the embanked river is no longer able to fulfill its primary function – draining out excess water. With the tributaries prevented from discharging into the river and the accumulated rainwater finding no way out, the surrounding areas are quickly flooded. The situation is aggravated by seepage from under the embankments. The areas outside the levees remain waterlogged for months after the rainy season because this water has no way of flowing out to the sea. Theoretically, sluice gates located at these junctions should solve the problem but, in practice, such gates quickly become useless; as the bed level of the main river rises above the surrounding land, operating the gates lets river water in instead of allowing inside water out. When the sluice gates have failed, the only option left is to also embank the tributary. This results, then, in river water being locked up between the embankments. Moreover, no embankment has yet been built or can be built in future that will not breach. When a breach occurs, there is a deluge. A status paper on floods in Bihar published by the Government of Bihar calls anyone subscribing to these views as one with a colonial bent of mind because the British held similar views when they ruled India.

Proponents of embankments have tried to rationalize the jacketing of rivers as forcing the same quantity of water through a narrow area. This will increase the water velocity and thereby its eroding capacity. The increased velocity of water dredges the river bottom and transports the sediment out preventing the rise of riverbed levels, increasing the carrying capacity of the river and reducing the extent of flooding. These were the arguments put forward by engineers in independent India when they resorted to massive embanking of rivers in the Ganga and the Brahmaputra basins. Unfortunately, there is little evidence to date that this theory is actually substantiated anywhere in India. The technical debate, however, continues. Politicians and engineers take advantage of this inconclusive debate. There is a nexus between politicians and engineers as the latter bring scientific arguments to defend or reject embankments to suit the convenience of politicians. The contractors are not concerned because, irrespective of the technical debate and the type of structures built, they stand to make money.

**Note prepared by Mishra D.K., (2019) for this publication*

Historically, Singh (2018) notes that during the British times:

"It was to supplement the notion of protecting revenue yielding land from the shifting rivers that the idea of embankments came up. The development of embankments deliberately, though indirectly, encouraged production of wheat and rice, as they would give more revenue. The 'consumption of wheat and rice' was extolled as being 'an index of progress', whereas the traditional crops such as bajra and jowar were described as 'poor subsistence' and 'undesirable'.

"In the process of landmass building, the rivers frequently shift their courses by several kilometers. In this whole geomorphological process, embankments act as an obstacle, as by confining the floods within the narrow river channel, the broad flow of the river is stemmed, and thus silt is not allowed to be deposited uniformly over the floodplains. What follows is that the huge amount of silt gets deposited on the riverbed itself and therefore raises the main riverbed. The immediate fallout of this enhanced river bed is that the low-lying areas remain waterlogged, and this is mostly the diara land. The drainage network of the region gets ruined, and then it takes much longer to drain the lowlands."

In 1952 Bihar had only 160 km of embankments along the north Bihar rivers and the flood prone area of the state was 25 lakh hectares. It has nearly 3800 km of embankments now and the flood prone area of the state is 68.8 lakh hectares. It shows that investment in flood control sector by simply building embankments is doing more harm than good.

4.2.2 Living With Floods

People residing in the plains of Bihar have perhaps the longest experience of dealing with floods on a regular basis. They have evolved a flood 'language' and effective strategies to live with floods.

People's Response to Floods

In his book on floods in Bihar's Bagmati basin, Mishra (2012) describes people's reactions to floods of different intensities as, "From Majarana to Boah it was an occasion to celebrate in a community. Humma used to bother them but there was no casualty linked to it and it did not stay for long (not more than two to three days). Elderly people of the Bagmati basin believe that the floods in the basin rarely exceeded two and half days and the river was scared of the pegs to which the cattle were tied and never went near them. People however were scared of Saah, but it was never more than couple of times in a century. A bumper Rabi crop after the floods was a certainty and that used to keep the morale of the farmers high.

All this happened because the free flow of water was ensured and obstructions to it were few. If the speed with which the flood waters rose during humma and saah was rapid, then so was the subsidence. Besides, fresh silt used to spread all over the fields and the fertility of the soil was rejuvenated year after year."

4.3.1 Flood Prone Areas

According to Map 18 the flood plains of the main stems of Rivers Yamuna, Ganga, Chambal, Ghaghra, areas in north and south Bihar and West Bengal in the Ganga basin are flood prone.

Table 4 : Floods Of Different Intensities From the Mithila Region Of Bihar

NAME	INDICATOR	COMMENT
Majarana	Indicates the presence of fresh sediment in the river. This is when snow melt in the Himalayas in peak summer months sends turbid water down the snow fed rivers	Learned persons in the past were capable of predicting the degree of flooding in the coming season from the color of the water post snow melt.
Baarh	It is the process of river water inundating the fields after the first few rains. This helps in sowing paddy.	This is a common occurrence.
Boah	When the river water travels upto the door steps of dwellings in the villages that are located higher than the normal flood level.	Villagers do not worry about this level of floods.
Humma	When the river water enters the houses and the cattle are submerged to half their height and a buffalo appeared like an elephant due to prolonged submergence under water.	This is at an interval of 25-30 years.
Saah	When the water level rises still further with waves in the flowing water and the cattle has to be let loose as they cannot be saved anymore.	It is very rare for a person to face or remember this twice in one's life time.
Pralay	Anything above Saah.	Floods of extreme nature

Source: Mishra D.K., 2012.

4.3 GANGA SUB-BASINS

The Ganga basin is composed of a number of sub basins. Floods being manifestations of the amount, intensity and duration of rainfall in a particular river's catchment/ basin/sub-basin, on an average annual basis it's propensity to flood can be gauged. The following table which details different sub-basins within the Ganga basin shows that the average annual rainfall in the basin increases from west (650 mm in Chambal) to east (1140 mm in Sone) and from south (910 mm in Betwa) to north (1790 mm in Gandak).

Table 5 : Rainfall in Ganga Sub Basins

SUB BASINS	RIVERS	AREA (sq km)	AVERAGE ANNUAL RAINFALL (mm)	COMMENTS
NORTHERN RIVERS				
Bhagirathi	Bhagirathi, Bhilangana	7648	1090	Glacial origins
Alaknanda	Alaknanda, Mandakini, Dhauliganga (West), Nandakini, Pinder	11076	1370	Glacial origins
Sharda	Sharda, Dhauliganga (East), Goriganga, Mahakali,	20,461	1650	Glacial origins. Part catchment is in Nepal
Ghaghra	Seti, Karnali, Bheri, Babai, Ghaghra	85,120	1380	Glacial origins. Part catchment is in Nepal & Tibet (China)
Gandak	Gandak	41,554	1790	Glacial origins. Part catchment is in Nepal & Tibet (China)
Kosi	Arun, Doodhkosi, Tamor, Kosi	60,178	1060	Glacial origins. Part catchment is in Nepal & Tibet
Western Ramganga	Khoh, Ban, Kosi, Dhela, Kicha, Aril	22,730	1310	Non glacial origins. Aquifer fed.
Garra	Garra	6814	NA	Aquifer fed.
Gomti	Kathna, Sai	30,974	950	Aquifer fed
Rapti	Rapti	17048	NA	Aquifer fed

Bagmati	Balan, Kamla	29466	NA	Aquifer fed
Ganga - mainstem	Malan, Sol, East Kali, Pandu, Kalyani, Loni, Tons, Karmnasa, Banas, Mahananda,	145890	Variable	Mainstem Ganga downstream of Deoprayag till Farakka Barrage
SOUTHERN RIVERS				
Gambhir	Gambhir, Parbati	25685	750	Aquifer fed
Chambal	Banas, Chamla, Choti Kali Sindh, Shipra, Parbati, Sip, Kuno	141948	650	Aquifer fed
Sindh	Mahuar, Sindh, Kunwari, Pahuj	27930	714	Aquifer fed
Betwa	Bina, Keotan, Kethan,Dhasan, Betwa, Jamni, Birma	43770	910	Aquifer fed
Ken	Sonar, Bearma, Patne, Mirhasan, Ken	28,706	1070	Aquifer fed
Tons	Satna, Bihar, Belan, Tons	17523	NA	Aquifer fed
Sone	Johilla, Mahanadi, Banas, Gopad, Rihand, Kanhar, North Koel	67330	1140	Aquifer fed
South Bihar rivers	Punpun, Phalgu, Badua, Chandan, Sundar	26,836	1070	Aquifer fed
Yamuna - mainstem	Tons, Giri, Bata, Asan, Hindon, Sahibi, Baghain, Paisuni, Rind, Non, Sasur Khaderi,	79,664	955	Mainstem R Yamuna till its confluence with R Ganga at Allahabad. Only R Tons has glacial origins.

Source: Mathur N.K., et al. 2018.

In the flood prone areas shown in Map 18 that lie within the alluvial belt of the Ganga basin, the rivers tend to overflow their banks and spread onto their vast flood plains. Here, the rivers in question (Ganga, Yamuna, Chambal, Betwa, Ken, Sone, etc.) flood all along their course. But in areas where rivers flow within well-defined valleys (HP, Uttarakhand and central highlands of MP, Chhattisgarh, Jharkhand) the impact remains confined more or less within the banks. In comparison, the areas where the river beds are shallow (Haryana, UP, NCT of Delhi, Rajasthan, Bihar and West Bengal) the water spread during floods beyond the river channel is substantial.

4.3.2 Floods in the Ganga Basin

The sub-basins in the Ganga basin have seen floods from time to time. The Central Water Commission (CWC) maintains 23 G/D (Gauge/Discharge) sites on the main Ganga stem, 33 G/D sites on the northern tributaries and 31 G/D sites on the southern tributaries which

Map 18 : India Flood Zone Map

Source: commons.wikimedia.org

record floods during the monsoon season (Nandargi S.S. and Shelar A., 2018).

Table 6 : Total Number and Major Floods at Sites in Ganga Main Stem (1986-2016)

G/D sites in the main Ganga river	**State**	**1986-1996**		**1996-2006**		**2006-2016**	
		T	M	T	M	T	M
Hardwar	Uttarakhand	08	02	12	03	17	05
Narora (Downstream)	UP	02		02		02	
Ankinghat	UP	01		02		11	
Dalmau	UP	02		04		12	
Allahabad (Ghatnag)	UP	02		03		15	04
Phaphamau	UP	04	01	05	02	30	09
Mirzapur	UP	03		04		19	04
Varanasi	UP	06		08		36	10
Ghazipur	UP	12	05	21	07	66	41
Ballia	UP	46	22	80	34	155	85
Buxar	Bihar	07		12		52	04
Dighaghat (Patna)	Bihar	10	02	16	02	51	09
Gandhighat (Patna)	Bihar	36	04	65	08	212	40
Hatidah	Bihar	25		44		159	18
Monghyr	Bihar	04		05		32	
Bhagalpur	Bihar	04		10		68	03
Kalalgaon	Bihar	40	08	80	18	270	51
Sahibganj	Bihar					58	17
Farakka	W Bengal	68	33	137	70	430	160

Source: Nandargi S.S. and Shelar A., 2018

Note: T – Total Floods; M – Major Floods (flood level >1m of the Danger Level)

Data in Table 6 suggests that the total number of flood events and major floods in the main stem of River Ganga over the last 30 years (1986-2016) have seen a progressive increase. The massive increase between 2006 and 2016 over the previous decadal periods is indicative of the possible impact of a changing climate pattern. Five locations in the Ganga main stem namely Ghazipur, Ballia, Gandhighat (Patna), Colgong (Kahalgaon) and Farakka stand out in terms of the number of reported flood events and major floods.

Table 7 : Highest Recorded Flood Levels in Major Rivers of Ganga Basin

S. No.	River	G/D site	State	DL (m)	HFD (m) from DL	Date & Year	Remarks
Main Ganga River							
1	Ganga	Rishikesh	Uttarakhand	340.50	1.22	05.09.1995	
		Hardwar	Uttarakhand	294.00	2.30	19.09.2010	
		Allahabad (Ghatnag)	UP	84.73	1.33	26.08.2013	
		Phaphamau	UP	84.73	2.09	26.08.2013	
		Mirzapur	UP	77.72	1.33	27-28.08.2013	
		Varanasi	UP	71.26	1.37	27-29.08.2013	
		Ghazipur	UP	53.11	2.03	01.09.1982	
		Ballia	UP	57.62	6.64	05 - 11.09.1996	
		Buxar	Bihar	60.32	1.12	29-30.08.2013	
		Dighaghat (Patna)	Bihar	50.45	1.67	21.08.2016	
		Gandhighat (Patna)	Bihar	48.60	1.88	21.08.2016	
		Hatidah	Bihar	41.76	1.41	22.08.2016	
		Bhagalpur	Bihar	33.68	1.04	26.08.2016	
		Colgong	Bihar	31.09	1.74	06.09.1998	
		Sahibganj	Jharkhand	27.25	4.21	1998 (?)	Data incomplete
		Farakka	W Bengal	22.25	2.89	7.09.1998	
Northern Tributaries							
2	Ramganga	Moradabad	UP	190.60	2.28	21.09.2010	
3	Sai	Rai Bareilly	UP	101.00	3.81	17.09.1982	
4	Ghaghra	Elgin Bridge	UP	106.07	1.81	1950 (?)	Data incomplete
		Ayodhya	UP	92.73	1.28	11.10.2009	
		Turtipur	UP	64.01	1.99	28.08.1998	
		Gangpur Siswan	UP	57.04	2.17	17.08.1980	
		Chapra	Bihar	53.68	1.07	11.08.1988	
5	Rapti	Birdghat (Gorakhpur)	UP	74.98	2.56	23.08.1998	
6	Gandak	Khadda	UP	96.00	1.50	23.07.2002	
		Rewatghat	UP	54.41	2.97	01.08.1977	

7	Burhi Gandak	Lalbegiaghat	Bihar	63.20	3.81	01.08.1975	
		Muzaffarpur (Sikandarpur)	Bihar	52.53	1.76	15.08.1987	
		Samastipur	Bihar	45.02	3.36	15.08.1987	
		Rossera	Bihar	42.63	3.72	16.08.1987	
		Khagaria	Bihar	36.58	3.08	19.08.1978	
8	Bagmati	Benibad	Bihar	48.68	1.33	12.07.2004	
		Hayaghat	Bihar	45.72	3.24	14.08.1987	
9.	Adhwara Group	Kamtul	Bihar	50.00	2.99	12.08.1987	
		Ekmighat	Bihar	46.94	2.58	12.07.2004	
10	Kamla Balan	Jhanjharpur	Bihar	50.00	3.01	10.07.2004	
11	Kosi	Basua	Bihar	47.75	1.42	25.08.2010	
		Baltara	Bihar	33.85	2.81	20.07.1998	
		Kursella	Bihar	30.00	2.55	10.07.1980	
12	Mahananda	Dhengraghat	Bihar	35.65	2.44	15.08.1968	
		Jawa	Bihar	31.40	4.45	15-21.08.1996	
Southern Tributaries							
13	Yamuna	Tajewala Weir	Haryana	323.70	4.57	03.09.1978	Estimated 130 yr flood event
		Mawi	UP	230.85	1.95	18.6. 2013	
		Delhi Rly Bridge	Delhi	204.83	2.67	06.09.1978	Estimated 130 yr flood event
		Mathura	UP	165.20	4.53	08.09.1978	
		Agra	UP	152.40	2.36	09.09.1978	
		Etawah	UP	121.92	4.21	11.09.1978	
		Auraiya	UP	113.00	5.19	25.08.1996	
		Kalpi	UP	108.00	4.98	25.08.1996	
		Hamirpur	UP	103.63	4.96	12.09.1983	
		Chillaghat	UP	100.00	5.16	06.09.1978	
		Naini	UP	84.74	3.25	08.09.1978	Confluence with Ganga
14	Sahibi	Dhansa Regulator	Delhi	212.44	1.14	06.08.1977	

15	Chambal	Gandhi Sagar	MP	NA	NA	02.06.2005	New HFL on 15.09. 2019
16	Betwa	Mohana	UP	122.66	11.03	11.09.1983	
		Sahjina	UP	104.54	4.13	12.09.1983	
17	Ken	Banda	UP	104.00	9.29	07.07.2005	
18	Punpun	Sripalpur	Bihar	50.60	8.27	07.09.2001	
19	Sone	Koelwar	Bihar	55.52	3.36	20.07.1971	
		Maner	Bihar	52.00	1.79	10.09.1976	
20	Ajoy	Gheropara	W. Bengal	39.42	4.52	27.09.1978	
21	Mayurkoshi	Massanjore dam	W. Bengal	121.31	1.56	25.09.1999	
		Tilpara Barrage	W. Bengal	62.79	4.26	27.09.1978	
		Narayanpur	W Bengal	27.99	1.70	27.09.1995	
22	Mundeshwari	Harinkhola	W Bengal	12.80	1.78	29.09.1978	
23	Kangsabati	Mohanpur	W Bengal	25.73	4.14	02.09.1978	

Source: Nandargi S.S. and Shelar A., 2018

Note: DL – Danger Level; HFD – Highest Flood Deviation from DL; HFL – Highest Flood Level

The greatest number of high floods in the Ganga basin rivers occur in September and August. This is because while the monsoon season in the basin is from June 15th till October 15th, during June and July the rivers are still recovering from the searing summer period (April to June) heat and the lean season low flows marked by parched soil and depleted aquifers, while the other extreme is the month of October marked by the withdrawing monsoon and almost saturated soil conditions.

4.4 DESCRIPTIONS OF A FEW NOTABLE FLOODS

The economic impact and the vulnerability of life to floods have increased worldwide in the last three decades or so. There are reasons to believe that the increasing frequency of medium to large scale floods may be the result of climate change. The 2023 IPCC report on weather and climate extremes concludes that globally there is a statistically significant trend in the number of heavy to extreme rainfall events.

4.4.1 Floods in Uttarakhand

Wasson et al have analyzed profiles of sediments on river and stream banks and related information to construct a fascinating history of large floods in the Alaknanda-Bhagirathi-Ganga basin over the last 1000 years (Chopra R., 2020). They have reported 25 large flood events that have occurred at varying frequencies in different periods of the 1000 years. In the Upper Ganga catchment extremely heavy and sustained monsoon rainfall can trigger large landslides that dam rivers. These 'natural' dams discharge huge quantities of water when they burst, thereby amplifying the effects of rainfall, as in June, 2013. Most of the high flood events have apparently originated in the High Himalaya region, rather than the Lesser Himalayas, and moved downward.

Wasson et al conclude their paper with an ominous warning, "Nonetheless it is likely that large floods generated by LLOFs (landslide lake outburst floods), and heavy rainfall as seen in 2013, will continue, and may increase in frequency."

May, 1894: On September 6, 1893, Birahi Ganga, a tributary of the Alaknanda, was blocked by nearly five billion tons of rocks and sediments that swept down a 900 m high valley slope (Rana N.S. et al, 2013). The debris blocked the river forming a large lake, Gohna Tal. Pulford, a British superintending irrigation engineer, concluded that bursting of this natural dam could cause a huge deluge that would demolish settlements and roads down to Haridwar. With the able assistance of the district surveyor of Garhwal, Pandit Hari Krishen Pant, Pulford and his team estimated the magnitude of downstream inundation and installed a telegraph system between Birahi Ganga and Haridwar to monitor and warn people in the event of a flood. In May, 1894, pilgrim traffic to Kedarnath and Badrinath was diverted to a safer pedestrian route, constructed much above the anticipated flood level, and eight suspension bridges between Chamoli and Haridwar were dismantled to prevent them from being washed away in the event of a dam burst flood. On 25 August, 189,4 the anticipated dam collapse occurred, causing unprecedented damage to the area around Srinagar town. No loss of life, however, was reported!

July, 1970: On July 20, 1970 a mountain face slid in the Alaknanda valley, in the Birahi Ganga catchment between Joshimath and Chamoli, during a cloudburst (Rana N.S. et al, 2013). The resultant flood transported an estimated 16 million tons of sediments within a day. The huge catastrophe wiped out the Gohna lake, left-over after the 1894 landslide. It washed away the small Belakuchi settlement in Chamoli district on the Rishikesh-Badrinath pilgrim route, along with a convoy of 30 buses and 13 bridges. It silted up a 10 km stretch of the Upper Ganga canal in Haridwar, over 200 km away. The flood destroyed the lower part of Srinagar town. Local relief workers from Dasholi Gram Swarajya Mandal attributed the flood to large-scale commercial forest felling in the High Himalayan region. Later scientific studies supported their observations (Rana N.S. et al, 2013). The 1970 Alaknanda flood led to the birth of the Chipko movement (see Chapter 8).

August, 1978: In August, 1978, a major natural dam outburst at the confluence of the Kandolia Gad, a small mountain stream, and River Bhagirathi at Dabrani led to a cataclysmic flood in the Bhagirathi valley. A massive collapse at the Gararidhar ridge at an elevation of 4,268 m amsl, following continuous heavy rains, brought down a huge mass of debris and boulders which blocked the Kandolia Gad and the main R. Bhagirathi (Juyal N. et al, 1998). The 3.75 km long and 1 km wide landslide formed a 52 m high wall on the Bhagirathi. It created temporary dams in each valley with large lakes behind them. Bursting of the dams a few days later led to flash floods which devastated a large number of villages and agricultural fields downstream along the Bhagirathi. It swept away two motor bridges, eight pedestrian bridges and a 5 km stretch of a metalled road. It restricted the Gangotri pilgrimage for the next two years.

August, 2012 : Unusually heavy rains in the first week of August, 2012 led to flash floods in Uttarkashi and Chamoli districts. Over 30 persons died and hundreds were left homeless. A dozen bridges were swept away and debris from landslips blocked most roads including national highways leading to the shrines at Gangotri, Yamunotri, Badrinath, Kedarnath and Hemkund Sahib. A several kilometers long stretch of the Gangotri National Highway was washed away. The Uttarakhand Government had to suspend the Char Dham Yatra and had to initiate steps for the safe return of over 1,500 pilgrims stranded at various locations. Power generation halted as huge amounts of silt choked turbines in the powerhouses.

The Assi Ganga valley in Uttarkashi district was the worst affected due to a cloud burst at the Pandrasu ridge dividing the Yamuna and Bhagirathi watersheds. It led to widespread loss of life and property and destruction of natural resources and physical infrastructure. An unofficial preliminary damage assessment report listed Uttarkashi town and 19 villages as worst-hit with 31 human deaths, 436 livestock deaths and destruction of 145 houses, 136 shops, 7 hotels, 43 cattle sheds, 7 motor bridges and 6-foot bridges. The 19 affected villages were without drinking water and power supply for several days. The property damage was estimated at over Rs. 600 crores.

The Gangori bridge on the Gangotri National Highway, near the confluence of the Assi Ganga and the Bhagirathi, collapsed. In this area, Bhagirathi breached the danger level. Several houses, the Gangori fire station, a fire tender and some private vehicles were washed away. The power houses of Assi Ganga HEPs I and II were also damaged. Large tracts of agricultural land were washed away. About 200 families were evacuated to higher ground. Three firefighters died while rescuing people.

Flash floods were also reported from the Alaknanda valley during the same period leading to the deaths of three children in Chamoli district. The Ganga rose to just short of the danger mark at Haridwar. An alert was sounded in areas along the Ganga and its tributaries. People living in low-lying areas were asked to shift to safer locations.

June, 2013: In a rare meteorological occurrence, a dynamic monsoon trough in the northwestern Himalayan region pulled the normal southwest monsoon system from eastern India and moisture-laden monsoon clouds from the Arabian Sea in the southwest. When the warm moist southern clouds collided with cold air above the mountain ranges in Uttarakhand and eastern Himachal Pradesh, they quickly dumped all their moisture over eastern Himachal, Uttarakhand and western Nepal between June 15-18, 2013 (Chopra R., 2014).

India's Meteorological Department (IMD) reported 590 mm rainfall in Dehradun city in the west on June 15-16, breaking an 88-year-old record. Nainital in the east recorded 176 and 170 mm on June 16 and 17. Intense rain --an estimated 350 to 400 mm in a period of about 48-72 hours -- fell in the Inner Himalayan region, particularly around Badrinath–Hemkund Sahib–Kedarnath–Gangotri shrines (barely 60 km apart as the crow flies) and the Gori Ganga and Darma valleys in the eastern Pithoragarh district. It caused devastating floods in many river valleys of Uttarakhand and caused landslides at thousands of locations. The result was a tragedy with colossal loss of human and animal lives along with infrastructure. The main impact was felt near the more fragile high ranges. Preliminary assessments data in Table 8 below reveal the scale of the catastrophe in Uttarakhand.

The Catastrophe at Kedarnath*

A massive tragedy took place in the uppermost reach of Mandakini river and caused immense destruction downstream up to its confluence with the Alaknanda at Rudraprayag. Kedarnath town (3,546 m asl) lies less than a kilometer from the origin of the Mandakini river at the snout of the Chorabari glacier (3,895 m asl). It is built on a terrace, on either side of which are steep mountain slopes covered with snow and moraines (mud and rocks) left behind by receding glaciers in the past.

A meteorological station established by Wadia Institute of Himalayan Geology (WIHG) at Chorabari glacier camp recorded 325 mm rain in 24 hours from 5 p.m. onwards on June, 15th. Intense rainfall and the melting snows opened up a number of landslides on the eastern slopes on June 16th. Rambara village (2740 m asl), downstream, was inundated by the afternoon of June 16th (Petley, 2013). Up in Kedarnath the edges of the terrace on which the town stood began to erode causing buildings to collapse.

Around 6 p.m on June 16th, a huge landslide, laden with boulders, rocks and mud from the companion glacier to the northeast of Kedarnath, slammed into the town with the flood waters. It devastated the town's upper part. The flood water with its bed load then sped down the steep slope and demolished small settlements including Rambara village a few minutes later. Many people lost their lives at Rambara that evening. All night long the valley resounded with the thunderous claps of big boulders and rocks crashing down.

Meanwhile the Chorabari lake filled up with rain and snow melted from the glacier. On the morning of June 17th, swollen waters in Chorabari lake overtopped its old moraines-filled natural dam. The barrier breached catastrophically and a wall of water rushed down the slope collecting more debris and water en route. Soon it hit Kedarnath town, carrying away people, buildings and shops. The rest got buried in several feet of sand. Everywhere there were dead bodies, Lifeless hands and legs stuck out of sand-packed windows and doors. Further down-slope at Rambara nothing remained.

** Extracted from Chopra R., (2014). Uttarakhand: Development And Ecological Sustainability. Oxfam India. New Delhi. page 41.*

Table 8 : Preliminary Assessment of the Uttarakhand Disaster 2013

S. No	Nature of Damage	Numbers
1.	Affected Persons	5 lakhs (approx)
2.	Affected Villages	4,200
3.	Severely Affected Villages	Over 300
4.	Persons Injured	4,463
5.	Number of Dead Persons	Over 900*
6.	Number of Missing Persons	5,748*
7.	Number of *Pukka* Houses Damaged	2,679
8.	Number of *Kuccha* Houses Damaged	681
9.	Number of Animlas Lost	8,716
10.	Number of Roads Destroyed	2,302
11.	Number of Bridges Washed Away	145
12.	Number of Drinking Water Schemes Damaged	1,418
13.	Number of Villages Without Power	3,758

Source: DMMC, IAG, UNDMT, Internet

*Note: *These are government figures. Most unofficial estimates of the dead and missing are much higher*

Record-setting floods in many large rivers and small mountain streams affect rural and urban areas. The flood levels in the Alaknanda river at Srinagar (Garhwal) town and its immediate downstream areas may have been the highest in the last 600 years (Sundriyal Y.P. et al, 2015). They drowned the lower parts of Srinagar under 30 feet of water, mud and silt. The Mandakini level rose 30 to 50 feet in its lower reach, near Rudraprayag. River Bhagirathi flooded parts of Uttarkashi while the Yamuna inundated Vikasnagar. The swollen Bindal and Rispana rivers rendered scores of families homeless in Dehradun, the state capital. The usually tranquil Kosi overran the market town of Someshwar in Almora district and many villages in the Pinder valley were simply washed away.

Fatalities: The official human death toll was over 900 and 5748 persons were recorded as missing. The unofficial death and lost estimates were much higher, at above 10,000 persons.

Survivors described horrific scenes of Kedarnath littered with dead bodies, of arms and limbs sticking out of thick layers of sediments. Rescuers at Rambara saw dead bodies hanging from trees. Kul Bahadur, a Nepali palanquin bearer on the Gaurikund-Kedarnath stretch, told a news reporter, "I witnessed many of my villagers and other Nepali friends drown in the floodwaters." Thousands of mules, ponies, buffaloes and cows perished on the trek routes to Kedarnath and Hemkund Sahib shrines. Deaths due to house collapses or drowning were reported from Uttarkashi, Rudraprayag, Tehri Garhwal, Dehradun, Haridwar, Chamoli, Pithoragarh and Almora districts.

Loss of infrastructure: Torrential small mountain streams eroded their banks, causing landslides. The Indian Space Research Organization (ISRO) identified 2,395 landslides just in the Mandakini, Alaknanda and Bhagirathi watersheds. Landslides blocked various sections of national highways to Gangotri, Kedarnath, Badrinath and Hemkund Sahib.

Infrastructure was badly hit. Roads, bridges, power lines, irrigation canals, drinking water supply systems, telecommunication towers and hotels and houses were destroyed or damaged, abruptly ending the main annual tourist season. Officials valued the lost structures at tens of billion rupees. The consequent business losses were similar.

Government data showed that 145 bridges had been swept away and that roads were damaged at over 2300 locations (See Table 8). Toe-cutting of mountain slopes washed away many riverside sections of these highways. The loss of road connectivity posed problems in providing relief immediately after the disaster. Villages in the upper reaches of the affected river valleys ran out of rations. Injured people in many locations could not get medical attention. Air-Force and private helicopters air-dropped supplies at Kedarnath, Badrinath, Ghangaria and northeast Pithoragarh.

HYDROPOWER PROJECTS AS PLAUSIBLE CAUSES OF DAMAGE IN 2013*

Detailed field mapping immediately after the 17th June, 2013 flood around Srinagar and downstream at Bhainswara by Rana et al. (2013) led to the following observations:

1. June 17, 2013 flood deposits invariably overlay the 1970 flood sediment and occur at an elevation of 536 m at ITI (the lower terrace at Srinagar) to 516 m at Bhainswara.

2. During 1970, the highest flood mark was at 533 m at Srinagar and 511 m at Bhainswara. This implies that the June, 2013 flood was the highest flood recorded below the Srinagar hydropower power project barrage in the Alaknanda valley during the last 600 years (Rana et al., 2013). Contrary to this, the 2013 flood remained below the 1970 flood level upstream of Rudraprayag which was inferred from the absence of June, 2013 flood sediment on top of the 1970 flood deposits that are preserved at Kaleshwar (Karanprayag), Chamoli, Chinka and at the confluence of Birahi Ganga and Alaknanda river

The past floods (at least those of 1894 and 1970) were associated with landslide-induced dam breaching. The recent flood in the Alaknanda valleys does not seem to fit into that category. Commercial deforestation in the region was banned since 1980 so it is unlikely that deforestation can be implicated in the June, 2013 flood. If the rivers were not blocked by landslide dams what led to the generation of such a large quantum of sediment in the Mandakini and Alaknanda valleys? A definite answer to this important question may require a more detailed multidisciplinary study in the Himalayan region. However, based on the present study we are able to provide some answers to the questions posed above :

a. In the upper catchment of the Mandakini Valley (around Kedarnath) moraines left behind by receding glaciers and debris flow fans provided voluminous sediments. These sediments were transported by a combination of high intensity rainfall and steep gradient streams including the water released from Chorabari Lake. A significant quantum of sediments was arrested at Sonprayag and Sitapur villages. Further downstream, the sediment bulking was caused largely by landslides and to some extent by the contribution from the hydropower muck dumped around Kund and Vijaynagar. In the lower reaches, where the valley gradient is gentler, sediment laden flood water was temporarily obstructed by the man-made structures particularly the partially constructed barrages and the human settlements that encroached upon the river bed. The sediment bulking amplified the flood magnitude and lateral migration of the Mandakini river that caused lateral bank erosion and collapsing of unconsolidated slopes below Kund and Tilwara in the Mandakini valley.

b. The destruction between Lambagarh and Govindghat was increased by the obstruction to the high intensity debris flow caused by the (Vishnuprayag HEP) barrage. It seems that the project proponents failed to appreciate that floods generated in the paraglacial domain are highly peaked and carry large volumes of debris that can pose a serious threat to the safety and longevity of the power projects as demonstrated during the recent flood. The present study, therefore, suggests that the paraglacial zone (Higher Himalaya), should not be subject to any major human intervention, particularly for harnessing hydropower. However, in areas where such projects are essential, these should be tuned to the terrain boundary conditions, particularly taking into consideration the various environmental, ecological and social constraints within the entire catchment above the project locations.

c. Around Srinagar valley, the study demonstrates that the anthropogenic debris was one of the major factors in aggravating the flood magnitude. Geochemical analysis indicates that the contribution from those debris to the June, 2013 flood varied from 47% (proximal to the barrage) to 23% (distal location below Kirtinagar).

Therefore, it cannot be a mere coincidence that maximum destruction of land and property was narrowly focused in areas proximal to hydropower projects. In our opinion, the June, 2013 tragedy should be an eye-opener to policy planners, particularly the proponents of hydropower projects. They must re-evaluate their methods because the high mountains are particularly sensitive to extreme rainfalls during which floods can incorporate huge amounts of sediments.

**Excerpted from Sundriyal Y.P., et al (2015)*

GANGANI HYDROPROJECT ON YAMUNA IN UTTARAKHAND:
Small Project, Huge Flood Damages*

Kharadi is a small road side market place on river Yamuna, some 40 km short of the holy shrine of Yamunotri. It is also a popular night halt site on the Char Dham Yatra route. Resultantly, over the period of time a number of hotels and residential properties have come up along the road and the river side.

Sometime in 2008-09, work was started by a private firm called Regency Gangani Energy Private Limited, immediately upstream of the Kharadi village for the construction of an 8 MW run of the river HEP. The works involved a diversion head, laying of pipes to convey the diverted river water and a power house around 5 km downstream of Kharadi at a place called Gangani. It is notable that the planned HEP is on the main river Yamuna.

By the year 2012, construction works had progressed to a considerable extent, when on the night of 3 August, 2012, a cloud burst at Hanuman Chatti area resulted in a flash flood in the river Yamuna. The flow of Yamuna was obstructed by the diversion head of the HEP and was diverted towards its more populated left bank. This diversion swept away around 9 hotels and residential properties of the local people at Kharadi. It also resulted in damages to the pipes laid in and near the river bed by the HEP.

Image 7 : Partially Constructed HEP Head

If the above was not enough then on 17 June, 2013, another cloud burst and heavy rains over most of the higher reaches of Uttarakhand led to yet another diversion of the river and sweeping away of around 28 properties in the market village of Kharadi.

The Project also applied for Clean Development Mechanism (CDM) status under the United Nations Framework Convention on Climate Change to get Carbon Emission Reduction Credits. Yamuna Jiye Abhiyaan and others objected to this application at the validation stage earlier and at the registration stage in August, 2013 as the project was not only unsustainable, but its application was full of contradictions and misleading claims.

Image 8 : Widespread loss of property at Kharadi market

NOTE: About 25 additional households after June, 2013 floods came within the slip zone, which could slip or get washed away any time in the event of high rainfall or another flood. Entire Kharadi village was declared as disaster affected by the District Administration.

** Extracted from Misra M.K., (2014)*

Nineteen small HEPs were destroyed, mostly in the Gori Ganga catchment in Pithoragarh district and the Kaliganga catchment of the Mandakini river in Rudraprayag district. Half-a-dozen large projects, existing or under-construction, were severely damaged. Electricity supply was hampered to an estimated 3,758 villages (See Table 8).

Among the severely affected hydropower stations were the Vishnuprayag HEP (400 MW) and the Srinagar HEP (330 MW) on the Alaknanda, the Maneri Bhali-I (90 MW) and Maneri Bhali-II (304 MW) projects on the Bhagirathi river in Uttarkashi district. The boulder-laden Mandakini buried the 76 MW Phata-Byung dam and severely damaged the 99 MW Singoli-Bhatwari HEP. Floods submerged the 280 MW Dhauliganga project powerhouse in Pithoragarh on June 16th.

Buildings and Tourist Hotels: The swirling flood waters swept away thousands of private homes and tourism infrastructure like hotels, lodges and restaurants in Uttarakashi, Rudraprayag and Chamoli districts. Revenue losses in the tourism sector alone for 2013–14 were estimated at over Rs. 12,000 crores (Chopra R., 2014).

Life and Livelihoods: The human tragedy resulting from the disaster was grimmer. Restoring livelihoods without homes, lands and livestock, became a major challenge. The abrupt end of the annual Char Dham yatra season impoverished thousands of families who serviced pilgrims and tourists on the *yatra* routes. When many male service providers at Kedarnath simply disappeared, Manmendra Singh of Mandakini-ki-Awaz, a community radio station in the Mandakini valley, described the plight of the all-women families left behind saying, "They are numbed by the thoughts of coping with the future."

Almost all through the 2013 monsoon season there were several spells of heavy rainfall. Areas where the soil was saturated with water became vulnerable to repeated landslides. The human and animal death toll continued to rise steadily. The state economy took a few years to recover. Many families simply migrated to safer locations in the plains.

The Supreme Court Orders an Investigation : In August, 2013, the Supreme Court of India ordered MoEF to appoint an Expert Body (EB) to investigate, among other issues, whether the commissioned and under-construction hydroelectric dams in the state had aggravated the impacts of the floods or not. On the basis of its investigations, the Expert Body concluded that HEPs had indeed aggravated the impacts of the floods.

Massive destruction had been observed downstream of all the HEP sites visited by the EB. The EB noted that the severity of flood damage in Srinagar town, downstream of the Srinagar HEP, was partly due to the under-construction barrage on the Alaknanda river bed and partly due to construction of buildings along its banks. Geo-chemical analyses of the flood sediments indicated that the Srinagar hydropower project significantly enhanced the flood magnitude in Srinagar town (EB-I, 2014). The EB's report was formally accepted by MoEF in 2016. Later the NGT accepted the evidence provided by the EB and ordered the Srinagar HEP to pay compensations amounting to over Rs 9 cr to the families whose residences had been damaged in Srinagar town.

The EB also warned about the hazard of dams/barrages construction in the paraglacial zone – above 2500 m in Uttarakhand. In this region, floods due to a combination of very heavy rain and melting snows in small mountain streams can easily mobilize sediments left behind by receding glaciers in the past. Dams and barrages hinder the passage of such sediments-laden flood waters which subsequently cause heavy destruction downstream. The EB attributed the destruction of the Vishnuprayag HEP in the upper reach of the Alaknanda, and downstream of the barrage, to such a phenomenon. It noted that here no major sediment flux was contributed by the main Alaknanda river. The sole contributor was the Khiron Ganga, a small tributary of the Alaknanda.

2015 : Uttarakhand and the neighbouring Himachal Pradesh states were the worst hit after extreme monsoon rains struck northern India. According to media reports nearly 60 persons died in Uttarakhand and an estimated 60,000 pilgrims were stranded. Knowledgeable experts blamed the unabated expansion of hydropower projects and road construction to accommodate ever-increasing religious tourism, for the unusual scale of devastation. "... the huge expansion of roads and transport is bringing down the mountains in Uttarakhand," says Maharaj Pandit, Professor of Environmental Sciences at Delhi University (Basu S. and Singh J., 2013).
Local observers are increasingly beginning to wonder whether the frequency of

cloudbursts
in Uttarakhand is increasing now, probably a result of a changing climate. Such events cause landslides and flash floods, leading to human casualties and destruction of property, natural resources and infrastructure on a large scale. A cloudburst 'is a localized weather phenomena representing highly concentrated rainfall over a small area (not exceeding 20–30 km^2) lasting for a few hours' (Kumar V.V.G. et al, 2013). Therefore, sustainable development paths need to be favoured over conventional development interventions -- such as urbanization, road construction, hydropower projects -- in the steep sloping Himalayan parts of the Ganga basin.

4.4.2 Floods in Yamuna in Delhi

The Master Plan of Delhi, MPD 2021 defines the river Yamuna flood plains as spread over 9700 ha and a length of about 48 km with its width ranging from 1 to 3.5 km. The Marginal Bund (called the Yamuna Pushta) in the east and the Ring Road in the West define the two margins of the flood plains in the city proper.

River Yamuna in Delhi has a history of medium and major floods that occur from time-to-time, primarily in the months of August and September. Major floods in the river have occurred in 1924, 1947, 1955, 1977, 1978, 1988, 1995, 2010 and 2013. The flood danger mark (204.83 m amsl) has been fixed at the Old Railway Bridge in the city.

Major Recent Floods: Profile

August, 1977 : The Najafgarh drain experienced a heavy flood due to the discharge from the Sahibi River. High Flood Level (HFL) of 213.58 m amsl was recorded at Dhansa regulator on 6.8.1977. The drain breached at six places between Dhansa and Karkraula, marooning a number of villages in Najafgarh block. Six human lives were lost due to house collapse. Fourteen persons died in a boat mishap. Crop damage was then estimated at Rs 10 million (delhi.gov.in, undated).

September, 1978 : River Yamuna experienced a devastating flood. Widespread breaches occurred in rural embankments, submerging 43 sq km of agricultural land under 2 meters of water, causing a total loss of the kharif crop. In addition, colonies of north Delhi, namely, Model town, Mukherjee Nagar, Nirankari Colony, etc. suffered heavy flood inundation, causing extensive damage to property. The total damage to crops, houses and public utilities was estimated at Rs 176.1 million (delhi.gov.in, undated).

The flood of September, 1978 in River Yamuna is considered to be the highest flood of recent times. According to a study (Chakrabarti S.P. et al, 1999) the maximum observed floods (1913-1978) and corresponding Return (T) period at Tajewala Barrage (since replaced by a new barrage at Hathnikund) are given in Table 9 below :

Table 9 : Maximum Observed Floods in Yamuna at Delhi

Year	Flood (Cumec)	T Year
1924 Sept	25110	105
1947 Sept	18390	35
1955 Oct	13234	13
1978 Sept	26410*	130

Source: Chakrabarti S.P., et al (1999)

*Note: *Estimated figure*

There is no information in the public domain if the lessons from the 1978 floods were expertly enumerated and appropriate policies formulated to prevent loss of life and property on its recurrence. This is observed on the basis of subsequent actions upstream and within Delhi where the integrity of the available floodplain has been compromised by various government authorities, time and again.

What we do have is some indication of the severity of the flood situation as is found from the minutes of the 37th meeting of the Yamuna Committee (accessed through use of RTI).

A study by Dr P.R. Rao, Dy Director, CFFD, CWC attempted to reconstruct the discharge hydrographs of the River Yamuna at Tajewala, Kalanaur, Mawi and Delhi taking into account the discharge which bye-passed various structures during the September, 1978 floods and water budget studies based on rainfall and run-off estimate on river Yamuna at Wazirabad barrage in the 1978 floods.

Table 10 : Peak Discharge (Estimated) at Various Sites

Site	Date	Peak Discharge through structure(cusec/ cumec)	Estimated bye-pass discharge (cusec/cumec)	Estimated Total (cusec/cumec)
Tajewala	3 Sep, 1978	7,07,000 (20,017)	2,25,000 (6,370)	9,32,000 (26,387)
Kalanaur	3 Sep, 1978	8,65,340 (24,500)	2,61,370 (7,400)	11,26,710 (31,900)
Mawi	4 Sep, 1978	4,02,650 (11,400)	3,00,220 (8,500)	7,02,870 (19,900)
Wazirabad Barrage	6 Sep, 1978	2,75,500 (7,800)	-	2,75,500 (7,800)
Okhla Barrage	6 Sep, 1978	2,13,302 (6,209)	-	2,19,302 (6,209)

Source: P.R. Rao, CWC

The flood level at the Old Railway Bridge in Delhi reached an all-time high of 207.49 m. It has not been surpassed till now despite subsequent very high floods experienced in 1995, 1998, 2010, 2013 and 2018.

September, 1988 : River Yamuna experienced floods of very high magnitude, flooding many villages and localities like Mukherjee Nagar, Geeta Colony, Shastri Park, Yamuna Bazar and Red Fort area, affecting approximately 8,000 families (delhi.gov.in, undated).

September, 1995 : The Yamuna experienced high magnitude floods following heavy rains in the upper catchment area and the resultant release of water from Tajewala water works. Slow release of water from Okhla Barrage due to lack of coordination between interstate agencies further accentuated the problem. Fortunately, the flood did not coincide with heavy rains in Delhi, and could be contained within the embankments. Nonetheless, it badly affected the villages and unplanned settlements situated within the embankments, rendering approximately 15,000 families homeless. These persons had to be evacuated and temporarily housed on roadsides for about two months, before they went back to living in the floodplain (delhi.gov.in, undated).

August-September, 2010 : The River Yamuna went in spate thrice during the months of August and September, 2010. The first occasion was on 22 August, 2010 when 3,40,000 cusec of water was discharged into the river at the Hathnikund Barrage in Haryana. This resulted in the flood level at the Old Railway Bridge in Delhi touching 205.95 m on August 26, 2010. Later, on September 8, 2010 at 4 and 5 pm 6,07,000 cusecs were discharged into the river following incessant rains in the catchment areas in Uttarakhand and Himachal Pradesh.

The flood water reached Delhi only by September 11, 2010 when the water level at the Old Railway Bridge in the city measured 206.78 m at 6 pm almost 2 m above the danger mark of 204.83 m. The entire available flood plain in the city went under deep water necessitating shifting of a large number of people from the low-lying areas to safe areas.

Later there was another high flood in the river in Delhi on September 22-23, 2010 when 7,44,000 cusecs water were discharged in the river at Hathnikund with the level in Delhi consequently rising to 207.11 m, slightly below the highest flood level of 207.49m in Delhi in 1978.

The pictures of the active floodplain in Image 9 show that the embankments provide a false sense of security to structures standing there and a breach in them as a result of severe flooding could be catastrophic (Misra M.K., 2019).

June, 2013 : The Yamuna river valley in Uttarakhand and HP was similarly affected as the rest of Uttarakhand due to unusually heavy rains on June 15-17, 2013. It caused high floods all along the river Yamuna in Uttarakhand. A release of 8,06,443 cusec on June 17th at Hathnikund led to the flood level at the Old Railway Bridge in Delhi rising to 207.32 m on June 19, 2013, the highest ever recorded flood level in Delhi since 1978.

As in 2010, the entire available floodplain in Delhi went under the flood waters, necessitating large scale eviction and temporary resettlement of people from the floodplains (Misra M.K., 2019).

Image 9 and 10: On September 11, 2010 Yamuna flood waters threatened the Commonwealth Games Village (Right) and the Akshardham temple complex (Left)

(Photos: M.K. Misra)

4.4.3 Floods in the Ganga in Bihar

The Ganga enters Bihar from Uttar Pradesh near Chausa in Saran district. It is joined by the Karmanasa, Dharmavati, Gangi, Sone, Punpun, Kiul, Harohar, Belharanaa, Chandan, Chir, Bhena and the Koa on its right bank in Bihar. On the left bank it is joined by the Ghaghra, Mahi, Gandak, Baya, Burhi Gandak, Kosi and the Mahananda's Phulahar branch before it exits Bihar beyond Manihari Ghat in Katihar district. It flows along UP - Bihar border in a stretch of 110 km. The river's length in Bihar is 445 km. Some of the important places situated on the banks of the Ganga are Buxar, Ara, Sonepur, Hajipur, Mokama, Barauni, Begusarai, Khagaria, Munger, Bhagalpur, Kahalgaon and Katihar. The total drainage area of the Ganga basin in India is 862,769 km^2 of which 143,803 km^2 is in Bihar and Jharkhand.

The Ganga is the master drain of almost the entire water that falls on the soil of Bihar and its slope is very gentle almost through its entire run within the State. It is as flat as 1:15,705 (0.06 m/Km) starting in Bihar and further flattening to 1:24,000 (0.04 m/Km) as the river moves into West Bengal.

Thus, as a rule, when the Ganga water is high (in flood), the tributaries find it hard to discharge their water into the Ganga and their flow is locked at the confluence with the Ganga. The situation gets worse when the high flow in the Ganga coincides with that of the tributaries and its water starts back-flowing into the tributary. For all practical purposes, the flood level of the Ganga dictates the drainage of the flood water in the state. Flooding in the confluence areas of the river and its tributaries becomes a common phenomenon and is observed in different degrees almost every year. Severe erosion of the flood plains, flooding of the villages surrounding the river banks, displacement of the people, loss of agriculture and farms, health services and market facilities, washing away and death of people and livestock, total loss of accessibility to roads to escape from the wrath of the river and reciprocal inaccessibility to get any external help and relief materials like food, fodder, medicines, boats, are the obvious outcomes of such a situation. Deposition of sand in the river bed results in formation of shoals and meandering of the river that further leads to encroaching of banks and flooding of the adjoining areas (Mishra D.K., 2019).

4.4.4 The Kosi Flood of 2008[iv]

On August 18, 2008 the Kosi River burst through its eastern embankment at Kusaha about 13 km upstream of the Kosi Barrage in Nepal, 8 km north of the Indian border. At its peak, the flood discharge went up to 166,000 cusecs compared with the regular 25,744 cusecs, running straight down south through a new course 15-20 km wide and 150 km long, north to south. This created major flooding in Nepal and India - Bihar in particular. According to official sources 3.3 million people were affected in Bihar alone. The districts of Supaul, Saharsa, Madhepura, Araria and Purnia in Bihar were severely affected by the flood. A total area of close to 3700 sq. km was inundated, 30 percent of the affected districts, flooding 412 Panchayats and 993 villages. An estimated 493 lives were lost and 3,500 were reported missing after the disaster (Anon, 2010).

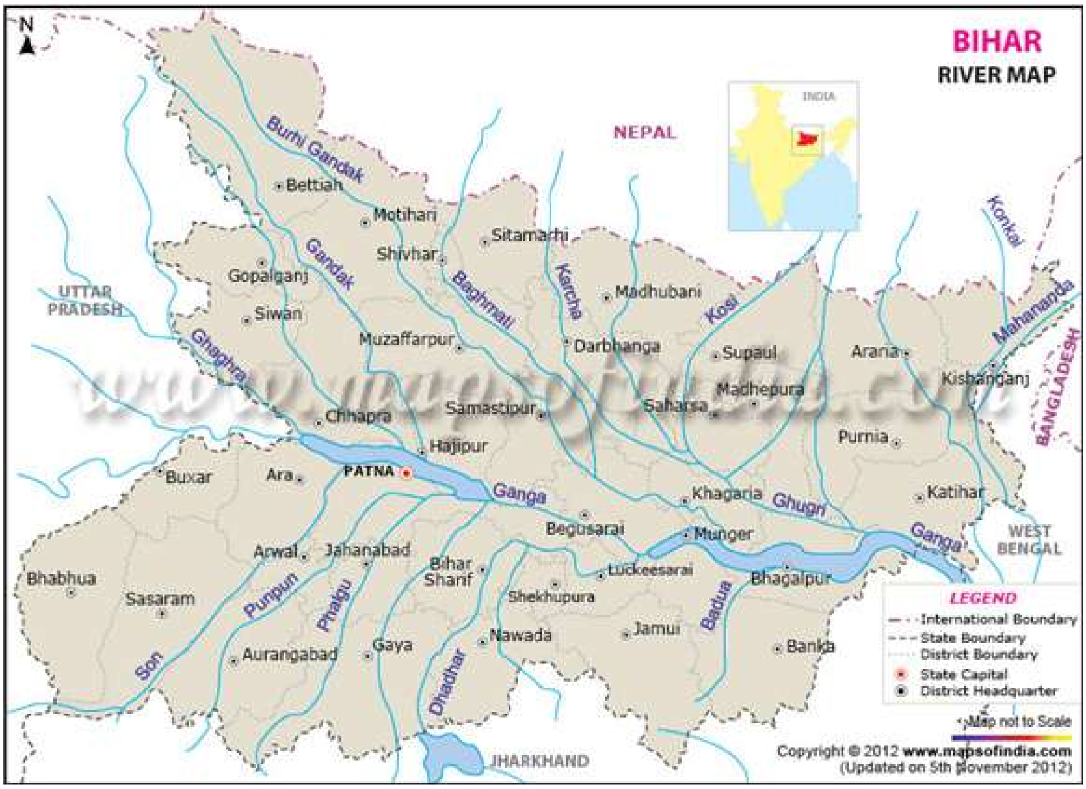
The Government of Bihar's institutional capacity to manage the disaster was particularly challenged with the preceding large-scale flood of 2007 followed by the Kosi floods of 2008. Furthermore, except Saharsa in 1984, the affected districts were not exposed to inundation from the Kosi River since it's embankment in 1963.

Damage Overview

Housing : According to GoB figures, 236,632 houses were fully or partially destroyed across the districts of Supaul, Madhepura, Saharsa, Araria, and Purnea. The estimated damage was Rs. 5,935 million (US$ 134.9 million). Of these, the first three districts were the worst hit with over 95 percent of the reported damage.

Roads and Bridges : About 1800 km of paved and unpaved roads and about 1100 bridges and culverts were destroyed in the floods. Maximum damages were reported in Supaul, Madhepura and Saharsa.

Water Resources (Irrigation and Flood Protection) : Extensive structural damage was caused to irrigation and flood protection infrastructure, including the Kosi Barrage. More than 6 km of the main Eastern Kosi Canal were destroyed, and other portions were partially damaged. Over 150 km of the distributaries and sub-distributaries were fully damaged, as well as 730 km of the water courses, 151 canal bridges and 138 regulators.



Map 19 : Major Rivers of Bihar

Source: mapsofindia.com

Agriculture and Livestock : Over 350,000 acres of paddy, 18,000 acres of maize and 240,000 of other crops were adversely affected, impacting close to 500,000 farmers. Approximately 10,000 milk animals, 3000 draught animals and 2500 small ruminants perished in the disaster.

Livelihoods were severely affected and major damages were reported in the health, education, social and environment sectors. Over 90 percent of the flood-affected population dependent on agricultural livelihoods were severely affected. Educational infrastructure and scholastic calendars were disrupted in all the five districts and regular curative and preventative health services were hampered.

In addition, 273,000 acres of arable land has been rendered fallow due to sand-casting with long-term implications for the environment, agriculture and livelihoods (Anon, 2010).

4.4.5 The Floods of 2016

In July and August, 2016, Bihar state witnessed a series of floods. While first it was the rivers in the north that flooded, it was primarily river Sone which flooded in August, 2016.

According to CWC (Undated):

- There was an unprecedented flood in river Ganga basin during August 19-28, 2016.
- According to IMD, two low pressure systems were active from August 1 to 10, 2016.
- The resulting rainfall in the Ganga basin was: Chittorgarh 445 mm (Aug 9th); Rihand dam 183 mm, Daltonganj 142.8 mm, Chopan 135 mm, Chittorgarh 73.8 mm (Aug 12th)
- Another deep depression in west Bengal on August 19th, brought more rain at Rihand dam 344 mm, Bansagar dam 177.8 mm, Banda 144.2 mm, Satna 120 mm, Kaimaha 113 mm, Mirzapur 70.4 mm.
- Bansagar dam on river Sone released a peak discharge of 15,600 cumecs (546,000 cusecs) for about 21 hours from 2100 hrs on August 18th, till 1800 hrs on August 19th, 2016. Rihand dam also released around 2 lakh cusecs adding to the flow in river Sone.
- The flood level at Gandhighat in Patna reached a peak of 50.52 m by 1800 hr on August 20, 2016 as compared to the previous HFL of 50.27 m.

Clearly the immediate reason for the high floods in Patna was the sudden release of waters from the dam on river Sone at Bansagar and from the Rihand dam.

4.4.6 Chambal floods (2019)

According to IMD west Madhya Pradesh witnessed 'large excess' to 'excess' rainfall (against average) from August 14th till September 30th, 2019. Only the fourth week of September saw deficient rainfall. The result was an exceptional flood situation in the entire River Chambal basin and downstream in the Yamuna and Ganga. The Central Water Commission issued daily flood situation report-cum-advisories as under (CWC, undated):

09.08.2019

"The Gandhisagar dam in Mandsaur District is realizing heavy inflows in view of the rain in Ujjain, Indore, Mandsaur Districts. Due to rainfall forecast, this is likely to increase. However, the dam is having sufficient storage to account for incoming floods."

13.9.2019 (RED ALERT):

"River Chambal in Kota district of Rajasthan continues to flow in EXTREME FLOOD SITUATION at 17:00 hrs today. At 17:00 hrs, it was flowing at a level of 218.18 m with Rising trend which is 0.50 m above its previous HFL of 217.68 m."

15.9.2019 (RED ALERT):

"River Chambal at Mandawara (Flood Monitoring Station) in Kota district of Rajasthan is flowing in EXTREME FLOOD SITUATION at 18:00 hrs today. At 18:00 hrs, it was flowing at a level of 224.87m with rising trend which is 7.19 m above its previous HFL of 217.68 m."

20.9.2019

"Ganga Basin: In association with heavy releases from various dams in Chambal and

CABINET SENDS PANEL TO STUDY GANDHI SAGAR DAM AMID FLOOD FURY, ALLEGATIONS OF MISMANAGEMENT *

New Delhi: The National Crisis Management Committee in an emergency meeting convened by the Cabinet Secretary on Sunday decided to send an expert panel to the Gandhi Sagar dam after the Central Water Commission (CWC) declared its overtopping a "great crisis," sources told News18.

"The Madhya Pradesh and Rajasthan governments had already sought the Centre's intervention due to the heavy rains and flooding. The committee has also dispatched an expert panel to Mandsaur on Monday to prepare a report on the crisis that has raised alarms of overtopping along the Chambal and Yamuna rivers," said an official privy to the developments. "The expert panel will conduct a post-flood analysis of the dam's behaviour and review its performance on the release of excess water since Saturday," he added.

Located in Mandsaur district of Madhya Pradesh, the Gandhi Sagar dam is one of the four major dams built on the Chambal river. It was completed in 1960 as part of the Chambal River Valley Development projects in the First Five Year Plan of 1951. The dam has a storage capacity of 7.32 BCM from a catchment area of 22,584 km^2 and can generate power to the tune of 564 Gigawatt hours (GWh).

The CWC declared a crisis at India's third largest reservoir on Saturday when heavy rains in Madhya Pradesh caused an inflow of 16 lakh cubic foot per second (cusec) and outflow of 5 lakh cusec of water. This led to overtopping in other smaller dams in Rajasthan and Madhya Pradesh, the effects of which were being felt in Uttar Pradesh and Bihar as well. "The effect of around 45,000 cumec overflow from Gandhi Sagar dam may be seen all along the Ganga, from Allahabad to Patna," the CWC said.

Himanshu Thakkar of the South Asia Network on Dams, Rivers and People (SANDRP) blamed faulty dam management behind the crisis. "The Gandhi Sagar dam was filled to full capacity few weeks ago. Why was the dam filled up with almost a month of monsoon to go? This violated many of the dam management rules. Sudden heavy rains only made things worse," he told News18.

Sixty years since it was built, climate change has pushed the dam to go beyond its designed spillway capacity of 21,238 cumec. Heavy rains caused the dam to cross both its Full Reservoir Level (FRL) of 399.9m and Maximum Allowed Water Level (MAWL) of 401m.

In 1990, the CWC had declared the dam as unsafe after it was found the spillway capacity of the dam is much lower than the floodwaters it could receive. The World Bank too had declared it unsafe. However, Thakkar said it is difficult to know the actual condition of dam today.

According to Pramod Narayan, programme director at the CWC's Dam Rehabilitation and Improvement Project, dams across the country are reviewed according to rules of compliance safety analysis. "A pre- and post-safety inspection of all dams on their strength happens every year. However, in terms of a comprehensive evaluation, not many dams have been reviewed. Until the Dam Safety Bill was passed in 2019, there was no Central protocol and policy on dams," he said.

The city of Kota faced an unprecedented situation when a record 6.93 lakh cusecs of water was discharged from the Kota barrage – 104 km downstream of the dam after heavy downpour. Kota District Collector Muktanand Agarwal told reporters that more water is likely to be discharged as the Gandhi Sagar dam is still overflowing.

Large areas in several districts of Rajasthan flooded after incessant rains and the release from Kota barrage forced thousands to evacuate. Rescue operations were carried out by the National Disaster Response Force (NDRF) over the weekend in parts of Kota and Chittorgarh district. Mandsaur district, where the Gandhi Sagar dam is located, faced a worse situation due to the heavy rains. Close to 46,000 people from Mandsaur and Neemuch districts were evacuated and moved to safer places on Sunday.

**Excerpted from Sharma A., (2019)*

Betwa Basins, River Yamuna is rising all along its course from Jalaun District upto Prayagraj District in Uttar Pradesh. River Yamuna has started falling at Auraiya and Kalpi in Auraiya and Jalaun District. The peak level attained during the last 10 years from 2010 to 2019 at most of the Stations in Yamuna Downstream of Chambal Confluence is the highest this year upto Hamirpur as given in the Table below:

Table 11 : Peak Level attained by Yamuna at Different Stations 2010-2019

SI No.	Station	District	Danger Level	HFL (m)	Peak Level Attained (m)		
					2019	2016	2013
1.	Auraiya	Auraiya	113	118.19	117.36	113.27	113.81
2.	Kalpi	Jalaun	108	112.98	112.26	108.98	109.55
3.	Hamirpur	Hamirpur	103.63	108.59	106.79	104.94	106.33
4.	Chillaghat	Banda	100	105.16	102.55	102.10	103.33

"Downstream of Kalpi, River Yamuna is flowing in Severe Flood Situation. In districts of Hamirpur, Banda, Pratappur and Prayagraj District in UP. This rise in river Yamuna is also being felt on river Ganga which is rising all along its course from Prayagraj to Farakka. River Ganga at Phaphamau and Prayagraj in Prayagraj District, Varanasi in Varanasi District, Ghazipur in Ghazipur District, Ballia in Ballia District of Uttar Pradesh, Buxar in Buxar District, Dighaghat, Gandhighat & Hathidah in Patna District, Kahalgaon in Bhagalpur District of Bihar and Sahebganj in Sahebganj District of Jharkhand and Farakka in Murshidabad District of West Bengal, is flowing in Severe Flood Situation and is likely to rise further. River Ganga at Mirzapur in Mirzapur District of Uttar Pradesh and Munger in Munger District and Bhagalpur in Bhagalpur District of Bihar also flowing in Above Normal Flood Situation with rising trend.

Close watch on situation has to be maintained all along the course of these rivers."

22.9. 2019

"The levels on Ganga at Prayagraj, Mirzapur have started falling. Varanasi and Ballia have

Image 11 : Flood waters in Kota (Rajasthan)

started stabilising and are likely to fall.

“River Ganga is reaching its peak level at Ganga in Patna Gandhighat and will remain steady for another 12-24 hours and then slowly fall. Similarly, river Ganga at Bhagalpur may reach its peak by tomorrow and then remain steady for around 6 to 12 hours before falling.”

23.9.2019

“The levels on Ganga at Prayagraj, Mirzapur and Varanasi have started falling. River Ganga at Ballia, Buxar, Dighaghat, Gandhighat and Hathidah has started stabilising and are likely to fall. Slow rise is being witnessed at Munger, Bhagalpur, Kahalgaon, Sahibganj and Farakka. The peak at these stations may be attained by tonight or early tomorrow morning and then slow fall.”

24.9.2019

“River Ganga at Ballia has started falling. River Ganga at Buxar, Dighaghat, Gandhighat and Hathidah are steady and are likely to fall. Slow rise is being witnessed at Munger, Bhagalpur, Kahalgaon, Sahibganj and Farakka. The peak at these stations may be attained by tomorrow and then slow fall.”

25.9.2019

“River Ganga at Patna Gandhighat has started falling. River Ganga at Munger, Bhagalpur and Kahalgaon are steady and are likely to fall slowly. Slow rise is being witnessed at Sahibganj and Farakka. The peak at these stations may be attained by tomorrow and then slow fall will commence.”

It is seen that the extreme flood situation in River Chambal which began on September 15th continued to impact downstream right till Farakka for over ten days.

Problems with Flood Moderation Role of DVC*

A funnel-shaped basin, with a wide upper catchment and a narrow lower catchment (bottle neck location, elbow shape near Burdwan) will generally have phenomenal increases in peak discharge or stream flow in the lower catchment with a considerable time lag as is evidenced in the Damodar Basin (Sen P.K., 1993). In the pre-dam period, the peak discharges were observed in the month of August (on an average 1238 cumecs). But the construction of the dams and flood regulation shifted the monsoonal peak discharge from August to September (on an average 1247 m^3/sec), having low variation from former. The dams temporarily store runoff, inflow and streamflow till late August but due to continuation of heavy rainfall and critical reservoir storage limit, they are compelled to release water in September when the soils of West Bengal have gained full moisture. The excess water adds to the streamflow. For that reason, now the flood probability or chances are more common between September and October.

As the mean cross-sectional area of the river decreases downstream (12,290 to 7077 m^2), the bankfull volume of reach also declines at downstream section from 346568177m^3 to 133259910 m^3. Now we have estimated that threshold levels of peak discharge are 4011, 2366 and 1542 cumec respectively for the selected reaches of Lower Damodar River (Rhondia to Paikpara). So, now any bankfull discharge above 4011 cumec at Rhondia is considered as threshold level of flood discharge for the lower catchment. It is estimated that a discharge of 2000 cumec or more (having 5 years of return period) has 73 per cent of probability of occurrence (Chandra S., 2003). That's why in post-dam period the riverine tracts of Bardhaman, Hooghly and Howrah Districts had experienced high magnitude of floods in 1958, 1961, 1976, 1978, 1995, 1999, 1987, 2000, 2006, and 2007.

Now the situation is more critical because east and south-easterly flowing distributaries or paleo-channels of Lower Damodar, e.g., Khari, Banka, Behula, Gangur, Kana Damodar, etc. are completely detached from the main Damodar by embankments and agricultural activities. So, huge volume of water does not get a chance to distribute through these channels.

A recent study of August, 2011 has again confirmed the inefficiency of dams and low carrying capacity of Damodar River (ABP, 2011). Due to heavy cyclonic rainfall (145 mm on 7.08.2011 to 8.08.2011) over Jharkhand and Chhattisgarh from 7th August, 2011 Tenughta, Panchet and Maithon reservoirs released 454 cumec, 510 cumec and 481 cumec respectively on 8th August, 2011 that had a cumulative effect on Durgapur Barrage when 1275 cumec water was released through main channel and canals. As a result, on 13th August, 2011 the numbers of total flood affected blocks of West Bengal were fifteen and sixteen million people were directly affected by flood inundation.

It is clearly observed that the existing drainage system and Damodar river basin was forced to enter into a new phase of equilibrium after the establishment of DVC (1948-58). In the present phase, the whole basin and river bed are the products of complex hydro-geomorphic and rigorous anthropogenic processes, though the modification of floodplain was first set forth by British rulers through installing embankments. In many cases DVC controls the flood situation minimally through water storages but the upper catchment dams repeatedly do not control the heavy inflow water. So, it is inevitable that when a huge volume of water would pass through the narrow and shallow Lower Damodar River, flood will occur. If we observe the shape and geographical entities of the Damodar basin we have found that the distributaries of the Damodar river system will flood whenever the water contributed by the upstream does not find easy passage to Hooghly River due to drainage congestion, burdens of roads, railways, canals and finally tidal behavior of lower reach. In other words, the larger the ratio of contributing drainage net and distributing drainage net, the greater is the chance of flooding which is exactly what happened to Damodar River Basin (Sengupta S., 2001). It is noted that in the pre-dam period the flood peaks were high but the duration was small. The installation of dams has moderated the peaks but increased the duration of floods (Rudra K., 2002).

Now the fallacy is completely wiped out – the dams too often generate flood and create many hydrogeomorphic problems to river and its adjoining floodplain (Rudra K., 2002).

** Edited extract, Ghosh S. and Mistri B. (2013)*

4.4.7 Damodar Valley Corporation – Flood Control in River Damodar valley

Damodar river valley has been ravaged frequently by floods of varying intensities. Serious floods occurred in 1730, 1823, 1848, 1856, 1882, 1898, 1901, 1916, 1923, 1935 and 1943 (Wikipedia/Damodar_Valley_Corporation, undated). The river basin spans an area of 25,235 sq. km. covering the then states of Bihar (now Jharkhand) & West Bengal. The catastrophe caused by the 1943 flood led to serious public indignation against the Government. As a result, the Government of Bengal appointed a board of Enquiry called "Damodar Flood Enquiry Committee" with the Maharaja of Burdwan and the noted physicist Dr. Meghnad Saha as members for suggesting remedial measures.

The Damodar Flood Enquiry Committee suggested the creation of an authority similar to the Tennessee Valley Authority in the USA and recommended the construction of dams and storage reservoirs at two sites with a total capacity of 1.850 MM^3 and highlighted the possibilities of multipurpose development in the valley area (Wikipedia/Damodar_Valley_Corporation, undated). The Government of India then commissioned the 'Central Technical Power Board' to study the proposal and appointed Mr. W L Voorduin, a senior engineer of the TVA to study the problem of the Damodar and to make his recommendation for comprehensive development of the valley. Accordingly, in August, 1944, Mr. W L Voorduin submitted his 'Preliminary Memorandum on the unified Development of the Damodar River.'

Mr. Voorduin's "Preliminary Memorandum" suggested a multipurpose development plan designed for achieving flood control, irrigation, power generation and navigation in the Damodar Valley (Wikipedia/Damodar_Valley_Corporation, undated). Four consultants appointed by the Government of India examined it. They also approved the main technical features of Voorduin's scheme and recommended early initiation of

Image 12 : Flood waters in Prayagraj (UP)

construction beginning at Tilaiya to be followed by the Maithon dam. By April, 1947 full agreement was practically reached between the three Governments, the Central, West Bengal and Bihar on the implementation of the scheme. In March, 1948 the Damodar Valley Corporation Act (Act No. XIV of 1948) was passed by the Central Legislature, requiring the three Governments, The Central Government and the State Governments of West Bengal and Bihar to participate jointly for the purpose of establishing the Damodar Valley Corporation. The Corporation came into existence on July 7, 1948 as the first multipurpose river valley project of independent India.

Four multipurpose dams were constructed during the period 1948 to 1959.

a) Maithon Dam
b) Panchet Dam
c) Tilaiya Dam
d) Konar Dam

A flood reserve capacity of 1,292 MCM has been provided in 4 reservoirs, which can moderate a peak flood of 18,395 cumecs to a safe carrying capacity of 7,076 cumecs. About 419 MCM of water are stored in the 4 DVC reservoirs to supply 680 cusecs of water to meet industrial, municipal and domestic requirements in West Bengal and Jharkhand. The Durgapur barrage on river Damodar was constructed in 1955 for the supply of irrigation water to the districts of Burdwan, Bankura & Hooghly (Wikipedia/Damodar_Valley_Corporation, undated).

4.5 FLOODPLAIN REGULATIONS AND LEGISLATION FOR ZONING

Floodplain regulations are needed to minimize public and private harm due to flood conditions in specific areas. They are primarily designed to:

1. Protect human life and health;
2. Minimize expenditure of public and private money for costly flood control projects;
3. Minimize the need for rescue and relief efforts associated with flooding;
4. Minimize prolonged business interruptions;
5. Minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets and bridges located in areas of special flood hazard;
6. Ensure that potential buyers and those who occupy the areas of special flood hazard are aware and assume responsibility for their actions in these areas;
7. Protect the natural functions of rivers and streams.

For regulatory purposes, the floodplain is divided into two areas based on water velocity: (a) floodway and (b) flood fringe (Sinha R. 2020). The floodway includes the channel and adjacent floodplain area that is required to pass the 100-year flood without unduly increasing flood heights. This is the hazardous portion of the floodplain where the fastest flow of water occurs. Due to the high degree of hazard found in the floodway, floodplain regulations require that proposed floodway developments do not block the free flow of flood water as they can dangerously increase the water's depth and velocity. The flood fringe is the portion of the floodplain, outside of the floodway, that contains slow-moving or standing water. Development in the fringe will not normally interfere with the flow of water. Therefore, floodplain regulations for the flood fringe allow some development to occur but require protection from flood waters through the elevation of buildings above the 100-year flood level or flood proofing buildings so that water cannot enter there.

One of the most effective solutions now being pursued in many developing countries is the concept of flood plain zoning. This concept is based on defining three major zones along the river based on long-term analysis of river behavior and flooding history. Zone 1 is the Channel belt itself which is considered as the prohibitive zone and no development is allowed except for essential waterfront facilities. Zone 2 is the Regulatory Floodway which is the restrictive zone, where only essential development and recreational activities are permitted. All buildings should be waterproof. Zone 3 is termed as Floodway Fringe and this is a warning zone where inhabitants receive warnings of impending floods and are reminded regularly of the flood hazard.

An important requirement for the success of flood zoning in any region is to have floodplain regulations which could control or modulate the land use on flood plains by zoning ordinances so that flood prone areas are not encroached. Keeping in view that a large population, generally rural, live very close to the river in many parts of India, such regulations may require relocation of people from the floodway and floodway fringe areas, if occupied. More than the personal adjustments and administrative procedures, this requires educating people and a strong political will.

The legislative context of floodplain zoning includes the following:

1. Designation of areas that are susceptible to periodic flooding, including the river's meander belt or floodway
2. Comprehensive schemes for flood control protection and improvements for the areas that are subject to such periodic flooding.
3. Land use regulations that preclude the location of structures, works, or improvements in critical portions of such areas subject to periodic flooding
4. Restrictions on construction activities in areas subject to periodic flooding
5. Restrictions on land clearing activities and development practices that exacerbate flood problems by increasing the flow or accumulation of flood waters

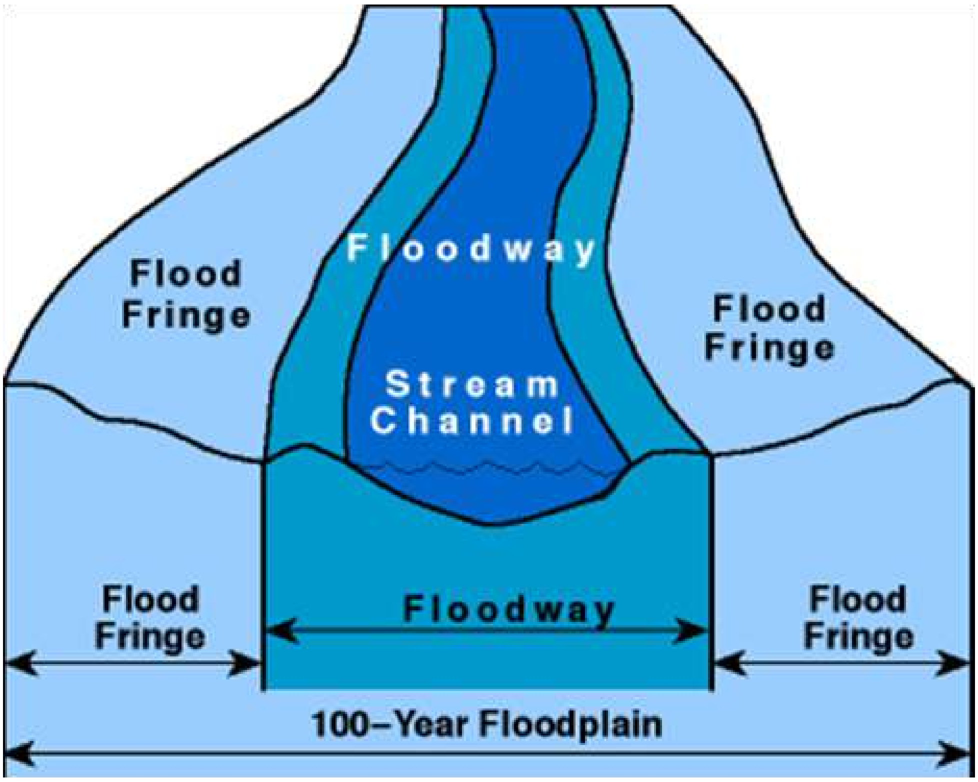


Image 13 : Floodplain Schematic

The Central Water Commission (CWC) has continuously impressed upon the states the need to take follow-up action to implement the flood plain zoning approach. A model draft bill for flood plain zoning legislation was also circulated by the Union Government in 1975 to all the States.

In the Ganga basin, the state of Rajasthan has enacted legislation for flood plain management in the State but its enforcement is yet to be done. The Government of Uttar Pradesh has decided to take suitable measures for regulating the economic/ development activities in the flood plains. The Government of Bihar has initiated action to prepare flood plain zoning maps, which are essential before any executive measures could be undertaken. The Government of West Bengal had intimated that a draft bill on flood plain zoning was under process. The Government of Madhya Pradesh had intimated that they had demarcated 36 towns affected by floods and the necessary administrative measures had been taken towards the demarcation of flood zones.

An exercise to frame a River Regulation Zone (RRZ) on the lines of CRZ (Coastal Regulation Zone) Notification for the entire country for safeguarding the floodplains of rivers has been in the works since 2002. A serious exercise in the matter carried out in 2015-16 resulted in an assurance by the then Union Minister of Environment on the floor of the house in Parliament that a Notification would be finalized by June, 2016 (Anon, 2016). But an RRZ is still to see the light of the day.

The lukewarm response of the states towards the enactment and enforcement of the flood plain regulations has enabled a significant increase in the encroachments into the flood plains, sometimes authorised and duly approved by the town planning authorities. Fortunately, the River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016 notified on October 7, 2016 has stipulated in Section 6 (3) that “No person shall construct any structure, whether permanent or temporary for residential or commercial or industrial or any other purposes in the River Ganga, Bank of River Ganga or its tributaries or active flood plain area of River Ganga or its tributaries (NMCG, undated).”

4.6 CONCLUSIONS

River management in India has always been dominated by water allocation (considers rivers as ‘conduits’ of water) and pollution problems (considers rivers as ‘sinks’). There is a strong need to consider a river as a ‘live natural system’ meant for supporting not just human civilizations but also act as complete eco-systems. This means that we need to understand how a river functions as a system and how it maintains the ‘dynamic equilibrium’. The time is ripe to move from ‘river control’ to ‘river management’ which necessitates the appreciation of the role of geomorphology – the science of form and processes of rivers and the concepts of threshold, lag and complex response in river adjustment.

Further, the impact of engineering structures on river systems must be assessed primarily focusing on natural equilibrium and assessment of degradation due to anthropogenic factors; this may include geomorphic assessment of rivers as well as the impact on the ecosystem. Alternatives to embankments for flood management with an emphasis on 'living with the floods' concept must be emphasized; this may include floodplain zoning and other non-structural approaches.

It is high time that we recognize that the era of climate change is upon us. The most recent report released by the Intergovernmental Panel on Climate Change (IPCC), highlighting the resulting disasters, has been described as a 'Code Red' alert for humanity by the United Nations. Unprecedented heat spells and extreme rainfall events resulting in flash floods are being witnessed all over the world. Recent experiences in the Himalayan part of the Ganga basin have shown that floods in small Himalayan streams are far more destructive than floods in the main trunk rivers, especially in the paraglacial zones of the Upper Himalaya. Such stream valleys and high riverbed slope stretches of the larger rivers, past the confluences with the small streams, need to be kept free of engineering structures like dams to avoid loss of life and property, including public infrastructure.

Hence, it is essential to do long-term cost-benefit analyses of major interventions in the river basins and their utility in the present context. Such analyses should include the benefits accrued as well as the impact on livelihood and ecology. Basin scale flood-risk maps should be prepared based on scientific data and reasoning; such GIS-based, interactive maps may be based on historical data analysis as well as modeling approaches and can be linked to an online data base and flood warning system. Drainage improvement and land reclamation in low-lying areas should be taken up on an urgent basis; several successful case histories are available from different parts of the world but they need to be taken up seriously and systematically.

Finally, there is an urgent need for a wide section of people from academia, governmental organizations, NGOs, social institutions and the society at large to get together to roll back the flawed flood management policies which are plaguing the country.

END NOTES

i Ref 23 cites a report published by the PHD Chamber of Commerce & Industries, New Delhi, 2013.

ii In view of more recent events, scientists are veering around to the view that river beds north of the Main Central Thrust may be considered as lying in a paraglacial zone due to the huge amounts of glacial sediments on the river beds brought down in recent floods. This has been experienced at Sitapur, Kalimath and Monsoona in the Mandakini basin and at Tapovan in the Dhauliganga (West) basin in Uttarakhand.

iii For state-wise areas of the Ganga basin see http://117.252.14.242/rbis/basin%20 maps/ganga_about.htm

iv See also box: 'Dilemma of Embankments', earlier in this chapter.

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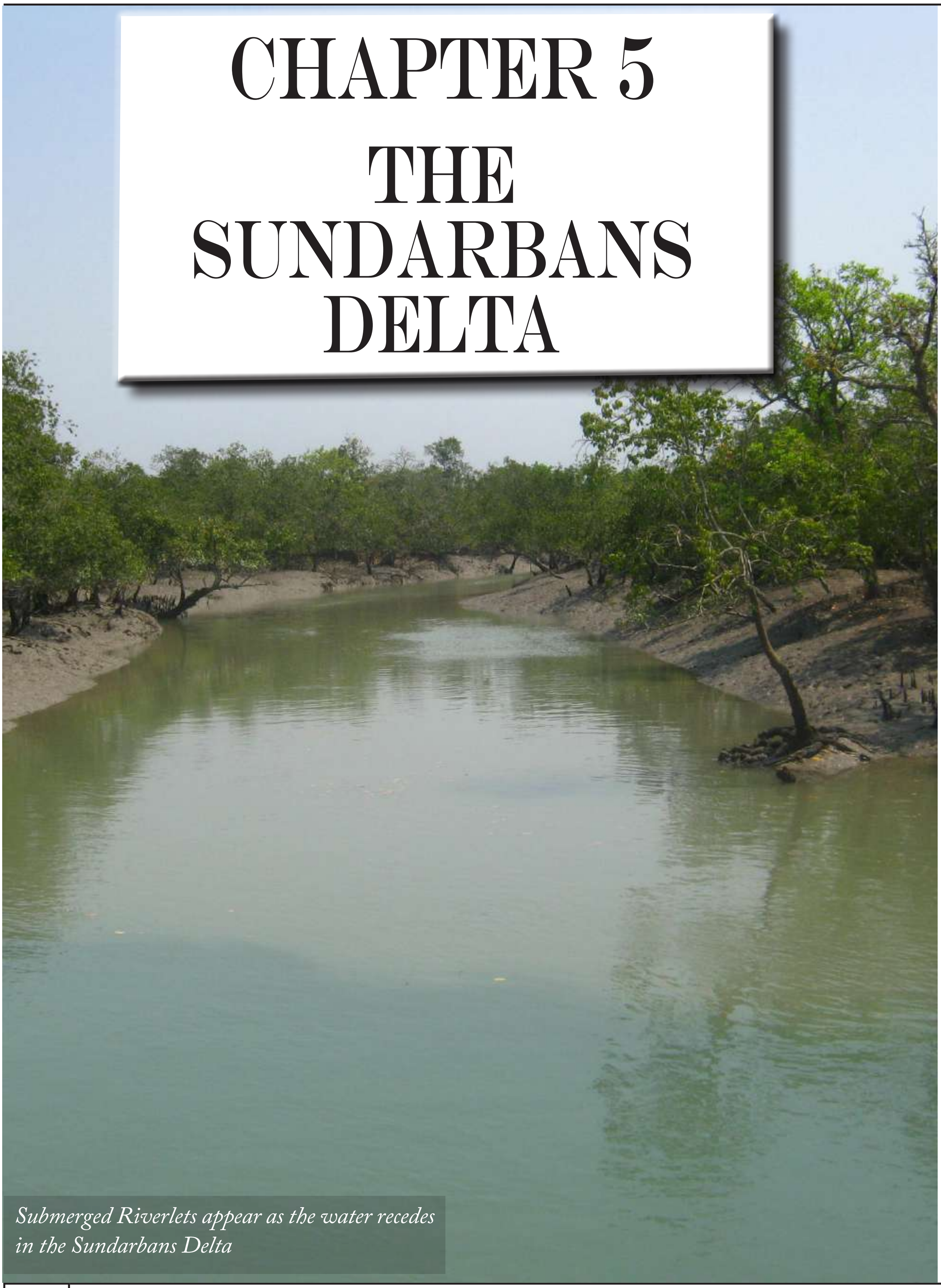
CHAPTER 5

THE SUNDARBANS DELTA



Submerged Riverlets appear as the water recedes in the Sundarbans Delta

5.1 INTRODUCTION

Like most large river systems, Ganga at its mouth meets the sea in the form of numerous distributaries that together form a delta. This vast delta straddles India and Bangladesh.

Sundarbans, as they are popularly known, are the world's largest contiguous block of mangrove forests, comprising of a dense network of islands, formed by the sediments deposited in the delta by the Ganga, Brahmaputra and Meghna rivers (See Map 20). The mangroves are bound by the Hooghly River in India and the Baleshwar River in Bangladesh, covering approximately one million hectares (Mha). About 40 percent of the forests lie in India, spanning the North and South 24-Parganas districts of West Bengal.

The landscape is a vast network of waterways, estuaries, mud banks and beaches. It is highly dynamic, constantly being erased and reshaped by water and sediment. The delta is home to several species of mangroves representing nine families, many of which are endemic to the area. The number of species present here accounts for a third of the global total. The Indian section of the Sundarbans accounts for 85 percent of the total mangroves area of India and hosts 63 of the 69 species in the country (Danda and Sriskanthan, 2011). The Sundarbans islands are covered with thick forests of the eponymous Sundari trees or *Heritiera fomes*, evergreen mangroves with a preference for low saline and freshwater zones. The Indian Sundarbans, spread over 4260 km^2, was declared a World Heritage Site in 1987 by UNESCO and designated as the Sundarbans Biosphere Reserve.

The islands are the trailing threads of India's fabric, the ragged fringe of her sari, the *ãchol* that follows her, half wetted by the sea. They number in the thousands, these islands. Some are immense and some no larger than sandbars; some have lasted through recorded history while others were washed into being just a year or two ago. These islands are the rivers' restitution, the offerings through which they return to the earth what they have taken from it, but in such a form as to assert their permanent dominion over their gift. The rivers' channels are spread across the land like a fine-mesh net, creating a terrain where the boundaries between land and water are always mutating, always unpredictable. Some of these channels are mighty waterways, so wide across that one shore is invisible from the other; others are no more than two or three miles long and only a thousand feet across. Yet each of these channels is a river in its own right, each possessed of its own strangely evocative name. When these channels meet, it is often in clusters of four, five or even six: at these confluences, the water stretches to the far edges of the landscape and the forest dwindles into a distant rumor of land, echoing back from the horizon. In the language of the place, such a confluence is spoken of as a mohona — an oddly seductive word, wrapped in many layers of beguilement.

From The Hungry Tide by Amitav Ghosh pages 3-4.

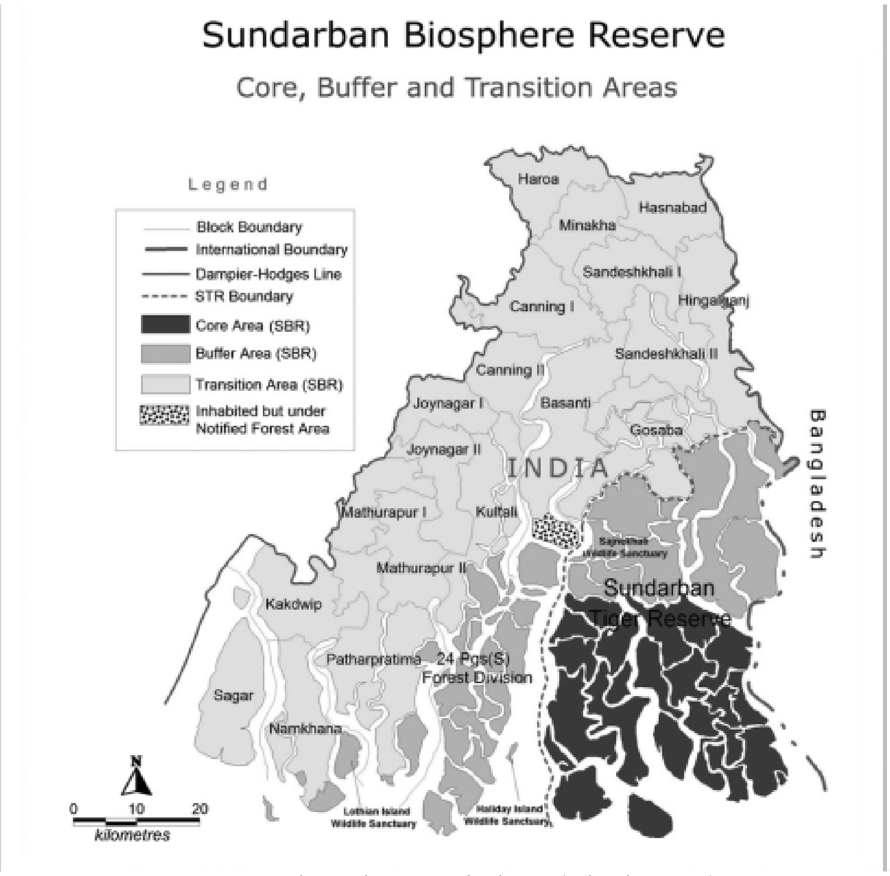
Map 20 : The Ganga-Brahmaputra-Meghna Delta

Source: Wikipedia

The Sundarbans Biosphere Reserve has three sections, the core, the buffer and the transition zones. The first is the same as the core area of the Sundarbans Tiger reserve and covers an area of 1700 km^2. All human activity is prohibited in this zone, apart from regulated research related movements. The buffer zone for the Biosphere Reserve is spread over 2563 km^2, out of which 885 km^2 is also the buffer zone for the Tiger Reserve. There are other, less strictly regulated wildlife sanctuaries in the remaining area (Sajnekhali Wildlife Sanctuary, Lothian Wildlife Sanctuary and Haliday Island Wildlife Sanctuary). Together, the buffer and the core zones form the Sundarbans Reserve Forest. Fishing and honey gathering are permitted activities within the buffer zone, albeit only for permit holders. The transition area is the largest part of the Reserve and comprises of 5367 km^2 of densely populated, mono-cropped agricultural land (Ghosh, 2015).

The mangroves are also home to many rare and endangered animal species, the most famous of which is the Royal Bengal Tiger. The Sundarbans Tiger Reserve extends over 2585 km^2, all within the Sundarbans Biosphere Reserve, as explained above. The Tiger Reserve's core zone (1330 km^2) has been designated as a Critical Tiger Habitat.

The Sundarbans tiger population is said to be one of the largest and best protected in the world (Danda A., et al 2017). The animal is an important part of the Sundarbans narrative not just because of its dwindling population, but also because the landscape belongs as much to the tiger as it does to the people. Nowhere else do the lives of these two species intertwine to the degree that they do in these parts. The presence of the tiger here has also played a part in the conservation measures taken to protect these forests.



Map 21 : The Indian Sundarbans (Ghosh, 2015)

Sundarbans' Tigers

The tigers of the Sundarbans are notorious for actively hunting out human prey unlike anywhere else in the tiger-inhabited parts of the world. The threat of being hunted by the animal is a part of those who venture into the mangroves, so much so that the animal has found its way into local folklore and even in literary accounts of life in the region, such as in some of the works of Amitav Ghosh. Colonial accounts and descriptions by travellers to these parts are also rife with tiger encounters. The occurrence of death-by-tiger is so common that entire villages are known locally as '*vidarbha palli*', or 'tiger widow villages'. The reasons for this aggression are largely unknown. Various hypotheses have been presented over time though. It has been suggested that the lack of availability of freshwater may contribute to health impacts and therefore physical discomfort to the tigers, making them irritable. Another theory is that they became used to partially cremated corpses that used to flow down to these parts before the barrage was built. Or it is possible that the nature of the terrain makes humans the easiest prey around?

Chakrabarti, R. (2009). Local people and the global tiger: An environmental history of the Sundarbans.

Montgomery, S. (1995). Spell of the Tiger: The Man-eaters of Sundarbans (1st ed.).

Besides the tiger, saltwater crocodiles, extremely rare species of river dolphins, river terrapins, turtles, and the Indian Python are also found here. At one time, these jungles were also home to the Javan rhinoceros, wild buffalo and barking deer, but not anymore (Gopal and Chauhan, 2006). The saltwater crocodiles, the largest living species of crocodilians, are important inhabitants, measuring between 6-7 meters long as adults. They are, however, at risk here from poachers who value their skin, as well as anthropogenic and natural threats to their habitat.

The Sajnekhali Wildlife Sanctuary (WLS) is a well-known bird-watching area where rare, threatened and endangered species such as darters, black-necked storks, Greater Adjutant storks, spoon-billed sandpipers and masked finfoots can be spotted. The Sundarbans are also part of the range of the Irrawady dolphin, an endangered species of oceanic dolphin, known for their intelligence and mutual relationship with local fishermen where they drive shoals of fish towards waiting nets in return for some of the catch (Clark, 2017).

The boundary of the Indian Sundarbans eco-region is marked by the Dampier-Hodges Line, drawn up in the early 19th century by the British Commissioner of the Sundarbans to demarcate the *khas mahal*, or government estate, from land owned by the zamindars. The eastern and western boundaries are marked by the Ichamati-Raimangal River and the Hooghly River respectively (Danda and Sriskanthan, 2011, p.8). The line marks the extent of the influx of the tidal flows and also what once used to be the mangrove forests (Gopal and Chauhan, 2006). In the past two centuries, a lot of this area has been cleared to make way for paddy farming and later, shrimp cultivation.

The Sundarbans are highly susceptible to the impacts of climate change. Projections made by IPCC show that as little as a 0.5^0C increase in average temperature and a 10 cm rise in sea levels could inundate 15 percent of the Sundarbans area. But a 2^0C increase and 45 cm rise in sea level would inundate 75 percent of the Sundarbans. Adaptation may be possible for mangroves elsewhere, but species redistribution beyond the inland boundaries of the Sundarbans is already restricted due to the presence of infrastructure, so this inundation is likely to result in a permanent loss of biodiversity, forest and estuary-based livelihoods and human habitation (IPCC 2001).

5.2 HUMAN PRESENCE

The Sundarbans have been intermittently inhabited by humans for millennia, but the populations were sparse due to the difficult terrain. There is evidence of depopulation during the Middle Ages, perhaps due to piracy, sudden environmental changes as in the flow of the rivers, earthquakes or sudden subsidence of land (Ghosh A., et al 2015). Fishing was the key source of food for the largely Hindu population until the thirteenth century, when Islamic settlers arrived here. Following their example, wet-rice was more commonly cultivated and consumed.

After a brief period of Mughal rule, the area formally came under the control of British East India Company in 1773. This also marked the beginning of large-scale land use change within the delta. Beginning in the second half of the eighteenth century, the low-lying lands were leased out by the British to landlords for timber and to bring more land under revenue, resulting in the clearing of large tracts of forest land (Sanchez-Triana E., et al 2014).

The zamindars in turn brought workers from other parts of the state and the neighbouring states, or hired migrant workers employed by the British to build embankments and to cultivate the land for them. The workers were mostly from poor tribal populations. According to an extremely modest estimate made by the British at the time, between 1793 and the 1870s, 2790 km^2 of wetland had been brought under paddy cultivation by settlers, which was a fifth of the total officially surveyed land area at the time (Sevak 2000). In the late 19th century, partly in order to prevent landlords from expanding their agricultural land into the forest area without paying revenue for it, the British demarcated the mangrove area and declared it protected (Ghosh A., et al 2015). Once ryotwari (direct collection of taxes from the ryot or the cultivator) was introduced to the area in the early 20th century, there was further reclamation of previously unsettled forest areas and marshes by individual ryots (farmers). (See maps in diversity paper)

As can be seen above, there was a sharp increase in the population, the total settled area and land under rice cultivation, corresponding to a decline in the total wetland

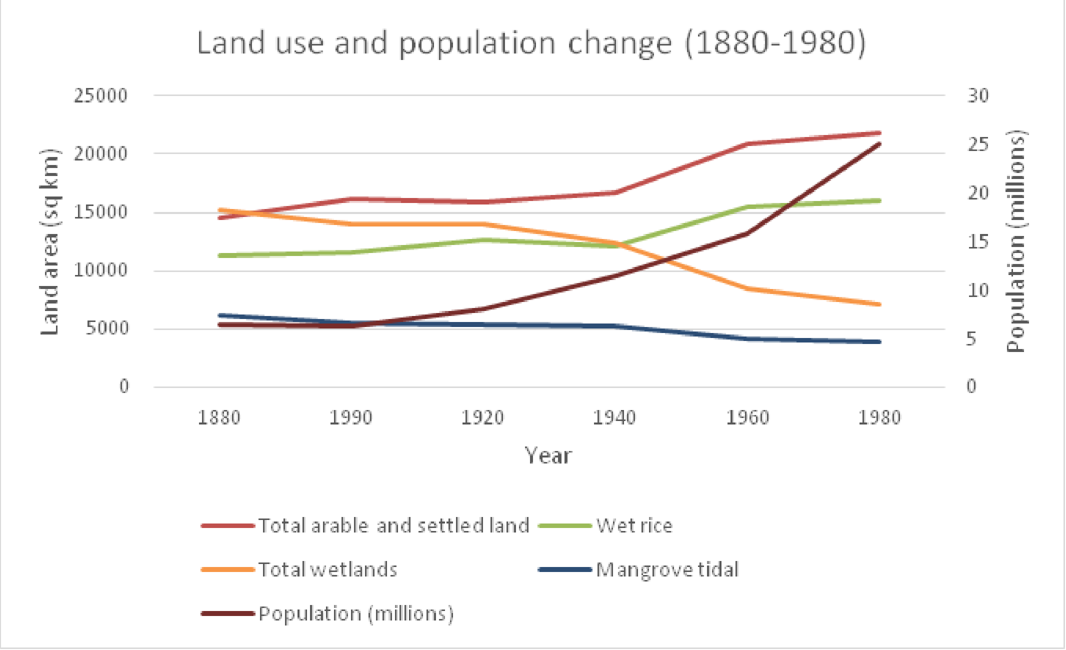


Image 14 : Land use changes in the Sundarbans 1880-1980

(Adapted from (Sevak, 2000))

and tidal mangrove area. The Bengal Famine and Partition triggered mass migration of people across the border. They also left their imprint on the forest area (Sanchez-Triana E., et al 2014). During Partition, the first wave of upper- and middle-class refugees were settled in urban areas and the surrounding arable lands, but the refugees that arrived later and were living in refugee camps, mostly poor Hindu families belonging to marginalized communities, were allotted land in the Sundarbans (Bhalla 2018). Accounts from families that settled in the area at the time reveal the difficulties faced by them. "When we began farming, it was difficult. The area was 60% water and 40% jungle. The drinking water was not clean, and many people died of cholera. The doctor would come once in 15 days. There was a famine and we had to suffer great hunger." (Sarkar 2017)

The current socio-economic profile of the Sundarbans varies across its parts, and depends on factors such as geography, connectivity, access to resources and demographics. For example, blocks closer to Kolkata enjoy better market connectivity and access to services such as electricity, which further enables economic activities that other, more remote blocks cannot access. In the more remote blocks, poor access to electricity and transport results in a lack of cold storage or value addition to perishables such as fish or vegetables, resulting in lower incomes. Rainfed rice cultivation, only possible with the help of embankments that prevent salt water intrusion into the fields, is the main occupation in this area (Majumdar 2015).

Currently about 44 lakh persons live in the 24 South and North Parganas Districts, nearly double the population recorded in the 1971 Census. Most of the inhabited areas are in the North 24 Parganas district, where the population density is 2462 per km^2, more than double the state average of 1029 per km^2. The population density of the South district is slightly lower than the state average since most of the buffer and core zone of the wildlife protected areas falls here. More than half of this population lives below the poverty line, and 10 percent is classified as extremely poor. Most families come from marginalized groups; 56 percent belong to Scheduled Castes and 6 percent to Schedule tribes. Housing, for the most people, comprises of kaccha one room huts (Sanchez-Triana E., et al 2014).
Development indicators of the island blocks perform worse than the non-island blocks. They point to the additional vulnerability of this population to the increasingly frequent natural disasters, predicted by climate change models. Very few of those affected in past disasters such as cyclones received adequate warnings. Recovery is made difficult by their poor resource access and poverty (Sanchez-Triana E., et al 2014).

5.3 LIVELIHOODS

Agriculture is one of the main sources of livelihood, particularly paddy cultivation. Embankments prevent salt water intrusion into the fields. There were a number of salt-tolerant varieties of paddy in the area earlier, but the number has shrunk since the green revolution (WWF-India, undated). Double cropping is rare. Incomes from paddy cultivation are low and most people are engaged in a mix of other livelihoods, mostly forest-based, the rest of the year.

Local inhabitants also depend on the Minor Forest Produce (MFP) they collect from the forests for households use and from sale. The MFP includes Sundari bark for tannins, timber, firewood, fish, prawn, crab, shrimps and lime [see Table 12].

Natural or cultivated honey is a very important forest produce and the Sundarbans account for 90 percent of the total natural honey production in India (Ghosh A., et al 2015). Honey collectors, often also fishermen, venture into the forest into tiger territory to look for natural honey. After research in the 1980s showed that tigers only attack people from behind, honey collectors in the mangrove forests started wearing face masks on the backs of their heads. The trick appears to have worked (Simons 1989).

Image 15 : A Honey Hunter from the Sundarbans wearing a Mask

Source: Zackary Canepari/Panos

The prices the honey collectors receive for their troubles are very low since they are forced to sell to the forest department since forest rights have not yet been settled in the Sundarbans districts (Sen 2017). The profession is mostly practiced by members of the Lodha or Munda tribes who are early settlers in the region and Muslims. Honey collection mainly takes place from March till the onset of the monsoons (Santhakumar V., et al 2005). Pisciculture is small scale and largely for subsistence. Prawn farming, practiced by few residents earlier, was taken up by many paddy farmers following cyclone Aila (2009) after their embankments were destroyed and their fields flooded by saltwater.

5.4 ECOSYSTEM SERVICES

The Sundarbans provide a variety of ecosystem services. In its state-of-the-art report on Biodiversity of the Sundarbans, WWF-India has listed numerous services by type.

Table 12 : Ecosystem services from the Sundarbans (adapted from WWF-India)

Category	Service	Examples and Comments
PROVISIONING	Food	Production of fish, prawn, honey, grains, and fruits
	Freshwater	Storage and retention of flows from the Ganga, Brahmaputra and Megha rivers for domestic and other uses
	Fibre and Fuel	Production of fuelwood, golpatta[i], hantal, and hogla.
	Biochemical	Extraction of medicines and other materials from biota such as beeswax and lime (extracted from shellfish)
	Genetic Material	Genes for resistance to plant pathogens, ornamental species
REGULATING	Climate Regulation	Source and sink of greenhouse gases; influence local and regional temperature, precipitation and other climatic processes
	Water Regulation	Groundwater recharge/ discharge
	Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
	Erosion regulation	Retention of soils and sediments
	Natural hazard regulation	Flood control and storm protection, which is crucial given the high frequency and intensity of storms in the Bay of Bengal
	Pollination	Habitat for pollinators

CULTURAL	Spiritual and Inspirational	Source of inspiration for writers, poets, lyricists and conservationists; religious and cultural values, sense of peace, cultural heritage
	Recreational	Opportunities for ecotourism
	Aesthetic	Beauty or aesthetic value in aspects of wetland ecosystems
	Educational	Opportunities for formal and informal education and research
SUPPORTING	Soil Formation	Sediment retention and accumulation of organic matter
	Nutrient Cycling	Storage, recycling, processing and acquisition of nutrients

5.5 KEY CONCERNS/PROBLEMS

The problems plaguing the Sundarbans can be traced to four main causes which often overlap and act in tandem.

5.5.1 Erosion

Changes in the surface levels of deltas are dominated by the aggradation rate, the rate of change of sea levels, natural and anthropogenic compaction and downward movement of land influenced by global geological phenomena. Aggradation is highly influenced by engineering interventions such as dams and barrages on the main stem of the Ganga-Bhagirathi as well as tributaries of the river. It essentially depends on how much sediment is brought into the delta by the rivers, besides a possible contribution from storm surges.

Image 15 below, shows that the Bangladesh Sundarbans islands are large. Google Earth imagery shows that the sediment deposited in the Bay of Bengal by the Padma-Brahmaputra -Meghna river system has a much greater extent than the sediment visible in the sea on the Indian side. The Indian Sundarbans islands appear to be large ones that have been broken up into smaller ones. This imbalance in the processes of sediment deposition and erosion has severe consequences for the delta and its human population.

People's lives and livelihoods are severely disrupted as their homes disintegrate into the sea due to extreme flooding events and storm surges. It is estimated that 1.5 million persons may have to be relocated outside of the Sundarbans in the future (Sarkar 2018a).

Image 16 : The Sundarbans (Islands In Green)

Source: Wikipedia

Islands in the Sagar administrative block, housing over 200,000 people, have disappeared in living memory. Many have been either internally displaced within the block or even within the same island or have been forced to migrate to other parts of the state altogether, causing great socio-economic upheaval in an already disadvantaged population. Lohachara island has disappeared completely. Ghorachara island has been reduced to 6.7 km^2 from 26 km^2 in the past few decades, causing the population of 40,000 to shrink to a mere 5000 (Bhattacharya 2016). Saline intrusion is exacerbated when landowners migrate off the islands. Since the embankments keeping the salt-water at bay are not repaired, agricultural productivity declines (Hajra and Ghosh, 2018).

A study published in 2009 of changes in aggradation rates due to anthropogenic interference in deltas across the globe classified the Ganga delta among deltas 'in peril', the second highest category of risk after 'greater peril', due to the decrease in aggradation and the increase in compaction and climate change-induced sea-level rise (Syvitski J.P., et al 2009). Sub-surface water, oil and gas mining activities have accelerated compaction. The change in aggradation rates from the last century to the present is from 2 to 3 mm/year, while the annual sea level rise is 8-18 mm per year. The study also notes that distributary channels of the Ganga have been reduced by 37 percent in the 20th century to ensure the navigability of the main channel, and the construction of levees to prevent flooding (Syvitski

J.P., et al 2009). Left alone the distributary channels would constantly change their path and deposit their sediment load across the delta, but their disappearance is resulting in lower rates of aggradation across the delta, and hence aggravating its sinking and the inward penetration of the sea (Syvitski J.P., et al 2009). The subsidence of the Ganga delta due to the reduction in sediment load has also been attributed to retention of sediment by dams and reservoirs on the river (Gupta H., et al 2012). The latter impact, however, may be far less significant than the impact of the Ganga shifting eastwards, particularly in the mid to late Holocene, many millennia ago, and adding its sediments to those of the Brahmaputra in what is Bangladesh today (Goodbred et al, 2014).

5.5.2 Pollution

Pollution is also critically affecting the health of the Sundarbans ecosystem. Domestic sewage carried into the mangroves by the tributaries, disposal of contaminated mud from harbour dredging, and the presence of the nearby Haldia Port complex are the main culprits (Binelli A., et al 2007). The port mainly deals in trade of petroleum products, chemicals, iron and coal. Paper, chemicals, textiles, pharmaceuticals, shellac, leather, plastic and tire manufacturing units along the Hooghly also discharge their wastes into the river which then flows down to the mangroves. Testing has revealed heavy metal accumulation in tiger prawns. This is alarming for the ecology of the area and also trade and human health since these prawns are widely cultivated here and shipped globally. Heavy metals have also been found in the flesh of the Indian white shrimp, which is also important for the livelihoods of the residents of the Sundarbans (Sarkar 2018c).

Pollution and salinity have also resulted in mangrove species redistribution, with economically important species declining. Different species in the Sundarbans have different tolerances to salinity. The reduction in freshwater inflow due to the Farakka barrage and the increasing pollution load have affected the forest quality. Canopy closure has decreased and more trees are affected by top dying disease, a condition specific to the economically important *Heritiera fomes* (Sundari)species. The lethal disease affects the canopy of the trees and makes them vulnerable to attacks by fungi or insects. It has been correlated with the increase in heavy metal contaminants in the sediments deposited in the delta (Sarkar 2018c).

5.5.3 Climate Change

The region is also vulnerable to extreme events such as storms and coastal flooding. The Sundarbans act as a natural buffer during natural disasters such as cyclones, tsunamis and storm surges (Kathiresan and Rajendran, 2005), but at the same time sustain damage to themselves during such events. The relatively low number of casualties in surrounding villages and the Kolkata area during the 2004 tsunami and cyclone Aila in 2009 (outside the Sundarbans districts) are attributed to the mangroves absorbing the worst of the impact (Ghosh A., et al 2015). Even so, the damage to the Indian Sundarbans delta from Aila was estimated by the World Bank to be USD 550 million, with 300 dead and 8000 reported missing (Mohanty B., et al 2017).

Although mangrove forests demonstrate a faster regenerative capacity after such disturbances as compared to other ecosystems, their recovery period has been estimated to be 25 years. Climate change models predict an increase in the frequency of freak cyclones of tremendous disruptive capacity in this region. The intensification rates of severe cyclonic storms in the area in November, which is the peak season for cyclonic activity, have increased by 26 percent over the past century (Singh 2007). This has been corroborated by people's perceptions of increased cyclonic activity in the delta area (Mohanty B., 2017). This change has consequences for the already vulnerable population, the health of the Sundarbans delta and the inland areas it currently acts as a buffer for, including Kolkata and its suburbs. Coupled with the damage wrought by anthropogenic interferences, the problem has already reached formidable proportions.

In the case of the forest itself, there may be a shift in the species distribution of the sundari trees, with salt-tolerant species gaining more ground and those on the land-bound edges receding. The fauna of the forests is also expected to change their annual movement patterns and distribution in response to rising temperatures and other climatic factors (Danda and Sriskanthan 2011).

Rising sea temperatures and ocean acidification will affect shell-forming organisms the most, especially plankton which are an integral part of the marine food chain, and thereby impact the fishery resources.

5.5.4 Other Anthropogenic Activities

Population pressure on the fringes of the Sundarbans is a concern. Kolkata's suburbs are expanding, nearly into the Sundarbans. The rapidly growing population that inhabits the fringe, due to its poor access to resources, is forced to venture into the forests to illegally exploit forest resources, especially in the aftermath of extreme events, as it did after cyclone Aila (Danda and Sriskanthan 2011).

Salt water intrusion due to rising sea levels is driving people towards brackish aquaculture. The collection of wild shrimp seed is unsustainably high. It has impacted the wild populations of shrimps and other species whose hatchlings also get collected and then discarded as waste by-catch. Large corporate houses have opened hatcheries in the area. The abandonment of farming by traditional farmers to pursue prawn seedling fishing instead, is resulting in the erosion of the dykes and embankments that currently keep the sea at bay.

Other problems include the volume of the catch and the techniques used; the fine nets employed by many fishermen can cause silt build up at the mouth of the river, which in turn can block and redirect tidal waves and bores, posing a risk for nearby human settlements (Dutta 2015). Nowadays, the cultivation of soft-shelled crabs has been favoured over prawn cultivation, driven by demand from countries such as Japan. The crabs are popular because of their relative resilience to disease as compared to prawns, and therefore involve less risk (Sarkar 2018b). Such unsustainable aquaculture poses a threat to future fisheries operations and the health of the mangrove ecosystems.

5.6 CONCLUSION

The state of a delta reflects the state of the river itself. The health of the Sundarbans today and the threats that it faces are indicators of the health of the Ganga-Brahmaputra and Meghna rivers. The worst problems like subsidence and pollution, are a direct result of anthropogenic activities upstream such as construction of barrages, establishing industrial units and releasing domestic sewage from towns and cities.

The fragile landscape is under attack on both fronts, saline intrusion from the sea and a burgeoning human population with its subsequent requirements and pollution on the other. In the coming decades, these pressures, acting in tandem, pose a great threat to the survival of the forests, and certainly the lives and livelihoods of those who live in these parts, especially since they are highly dependent on biomass for their survival. At the same time, there are internal pressures created from within by this same vulnerable population by the overuse of the limited biomass resources.

The Sundarbans are unique among river deltas due to their extraordinary biodiversity and ecosystem services. They are also highly sensitive and vulnerable to changes upstream and around their inland and sea-facing peripheries. Current conservation measures may not be enough to protect them from the rapidly changing environment they face. Serious attention to river ecology, flow and geomorphology related policies and adverse impacts of technological interventions is necessary, especially the policies pertaining to barrages and other impediments to flows upstream, and projects like the inland waterways project or interlinking of rivers (See also Chapter 11).

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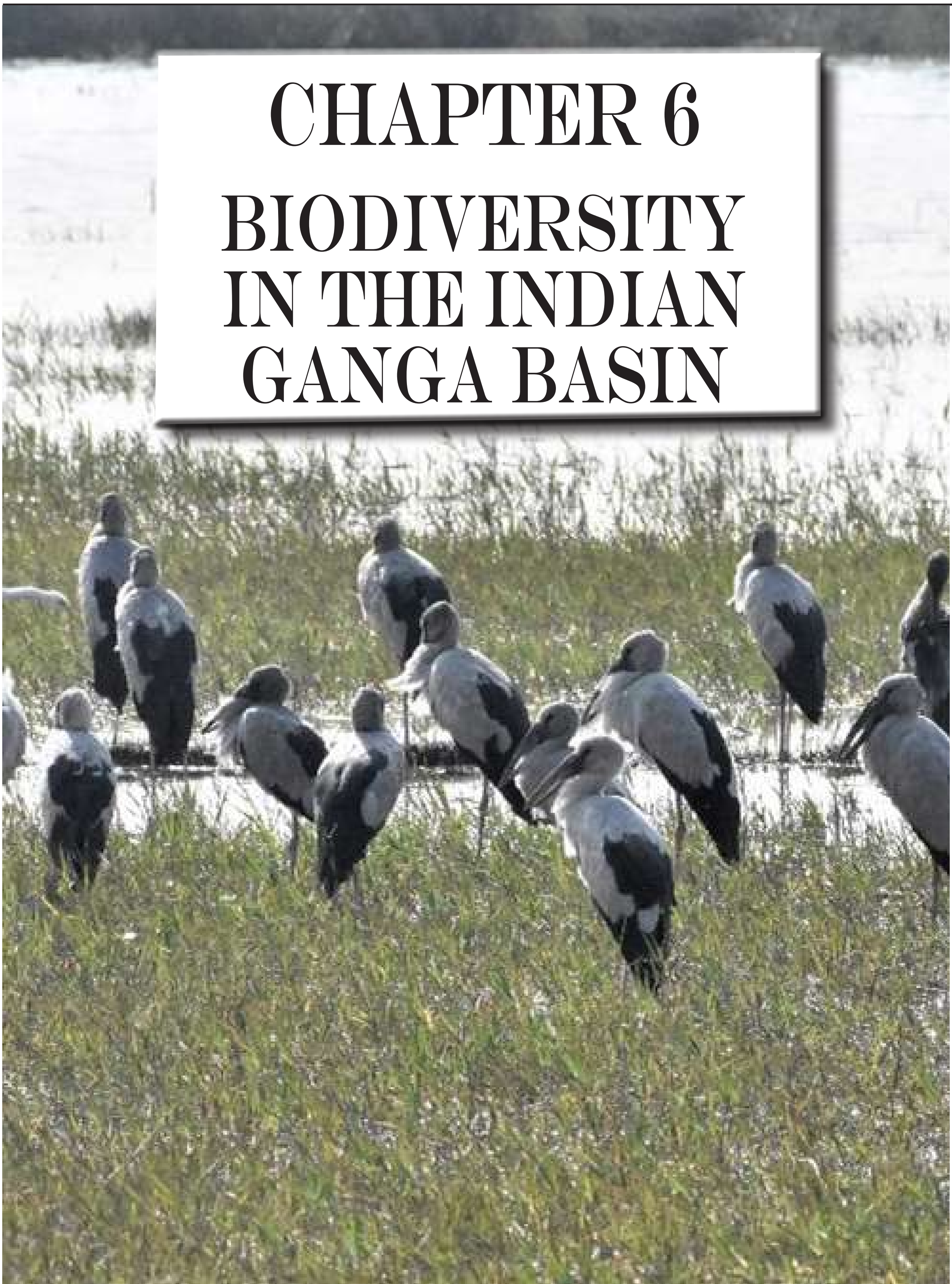
[i]Golpatta leaves (*Nipa fruticans*) are used for thatching and can be woven into bags, baskets, mats and raincoats. Hantal(*Phoenix paludosa*) is a small palm used for shelters, walls and fencing. Hogla (*Typha elephantina*) is woven into mats and grains are made into cakes.

CHAPTER 6

BIODIVERSITY IN THE INDIAN GANGA BASIN



The Indian Ganga Basin (IGB) covers an area of 861,404 sq km. which is more than one-fourth of India's geographical area. Its altitudinal scale ranges from sea level at its delta to the snow-capped Himalayan sources of the main stem and its headwaters. This altitudinal variation produces a vast range of climates from the arctic glacial regions of Uttarakhand to the semi-arid parts of Rajasthan and Haryana to the heavy rainfall states of West Bengal and Jharkhand.

The range of vegetation types in the IGB is vast, from temperate (Uttarakhand) to thorn (Rajasthan) and to littoral and swamp in W. Bengal (See Map 22). The largest natural vegetation in the basin consists of tropical moist and dry deciduous types. The Zoological Survey of India estimates that India has a total of about 78,000 faunal species, out of which River Ganga's ecosystem is estimated to support 25,000 or more species ranging from micro-organisms to mammals (Nawab et al, 2016 and Singh & Singh, 2007).

The primary biodiversity assessment of an ecosystem is a listing or a count of the different types of species that exist in it. Since an ecosystem's biodiversity is the result of the interplay between a number of natural and anthropogenic factors, it is far more important to record changes in the mix of the species composition. These changes can help identify the causal factors or processes. If the changes are due to natural causes, the ecosystem may respond in an adaptive manner, reflected in a change in species composition. Undesirable changes due to anthropogenic causes, such as pollution, require implementing corrective or mitigation measures.

The role of biodiversity in the functioning of river ecosystems is little understood or appreciated. It provides a variety of ecosystem services. Many biodiversity components absorb or breakdown pollutants in rivers and thereby help in improving water quality and productivity (R.K. Sinha, 2014, p.299).

6.1 TERRESTRIAL FLORA

Reliable and recent data is becoming increasingly hard to come by in India.[i] The Forest Survey of India's latest State of Forests Report (2019) shows forest cover data for the IGB determined by it in 1995 and pertaining to satellite imagery over the1981-91 period! In 1995 FSI had estimated a total forest cover of 122,710 sq km out of the basin area of 861,404 sq km, or just over 14.2 per cent. The dense forest cover then was about 51.35% (of the forest area) or 63,011 sq km. These forests house a rich variety of flora and fauna in a number of sensitive environmental habitats.

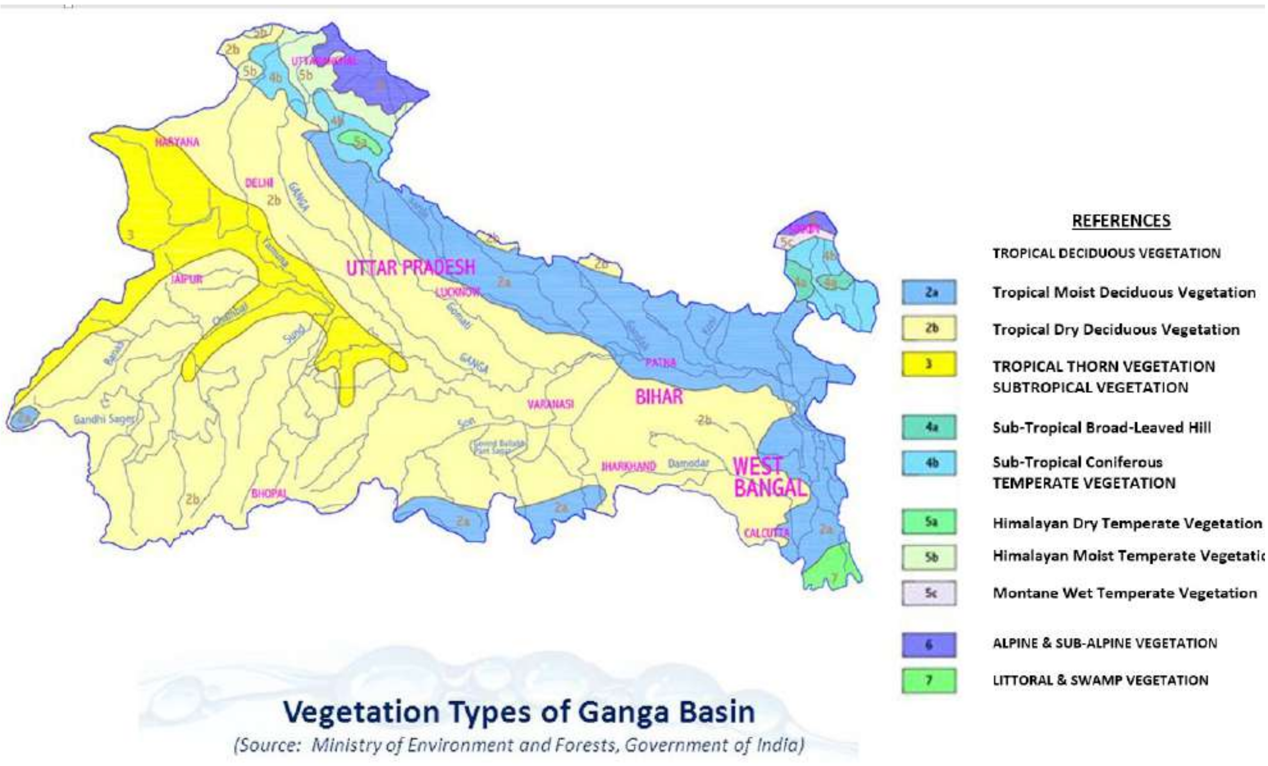
Researchers at the Centre for Oceans, Rivers, Atmosphere and Land Sciences, IIT-Kharagpur, conducted an extensive study of the forest cover and land use transformation in the IGB between 1975 and 2010 using 216 Landsat satellite images for the two terminal years and 1,509 ground sampling points (Matin et al, 2018). Their data showed that forests (27 types), mangroves and forest plantations covered 113,786 sq km in 2010. Scrub forest data was not reported separately but included under a wider scrubland category.

Table 13 : Forest Vegetation Types in R. Ganga Basin

Vegetation Type	**Climate**	**Sub division**	**Champion & Seth Class**	**Distribution**	**Key species**
Tropical Deciduous			2		
	Mean Annual Rainfall 100-200 cm MAT (27^{0}C)	Tropical Moist Deciduous	2a	Parts of Ukd, UP, Bihar, West Bengal, MP, CG & Rajasthan	Sal & Teak with associates
	MAR 100-150 cm	Tropical Dry Deciduous	2b	Parts of HP, Haryana, NCT of Delhi, UP, Bihar, Jharkhand, WB, MP, Rajasthan	Kardhai, Dhawra, Teak with associates
Tropical Thorn	MAR <75cm MAT (25-30^{0}C) Hum <50%		3	Parts of Haryana, UP, MP, Rajasthan	Acacias, Euphorbias with associates
Sub Tropical			4		
	MAR 75-125cm MAT 18-21^{0}C Hum 80%	Sub-tropical broad- leaved hill	4a	Parts of north Bengal	Oaks
	Elev 1000-2000 m	Sub-tropical Coniferous	4b	Parts of HP, Ukd, north Bengal	Chir pine
Temperate			5		
	Pptn <100cm (snow)	Himalayan Dry Temperate	5a	Parts of Ukd	Coniferous trees (Deodar, Oak, Ash) with xerophytic shrubs

	MAR 150-250cm Elev 1500-3300m	Himalayan Moist Temperate	5b	Parts of HP, Ukd	Deodar, Oak with associates
	MAR-150-300cm Elev–1800-3000m MAT 11-14^{0}C	Montane Wet Temperate	5c	Parts of north Bengal	Deodar, Birch, Plum,
Alpine and Sub Alpine	Elev 2900-3300m		6	Parts of north Bengal	Fir, Spruce, Rhododendron
Littoral & Swamp	Almost sea level brackish water		7	South Bengal	Mangroves (*Heritiera spp*)

MAR-Mean Annual Rainfall; MAT- Mean Annual Temperature; Elev-Elevation; Hum-Humidity; Pptn-Precipitation



Map 22 : Forest Vegetation Types in the Indian R. Ganga Basin

6.2 RIPARIAN VEGETATION[ii]

Riparian vegetation is the 'marginal' or 'edge' vegetation that grows on the banks of rivers in or near water where it may be emergent, submergent, or floating. It links the terrestrial and aquatic habitats. It consists of macrophytes or aquatic plants that are visible to the naked eye and water-loving (hydrophilic) native grasses, sedges, climbers, shrubs and trees (Dutta R. et al, 2011).

The macrophyte vegetation changes continuously in response to floods and associated changes in water level. Some macrophytes are ecologically and economically very important as they minimize the adverse effects of floods to a considerable extent.

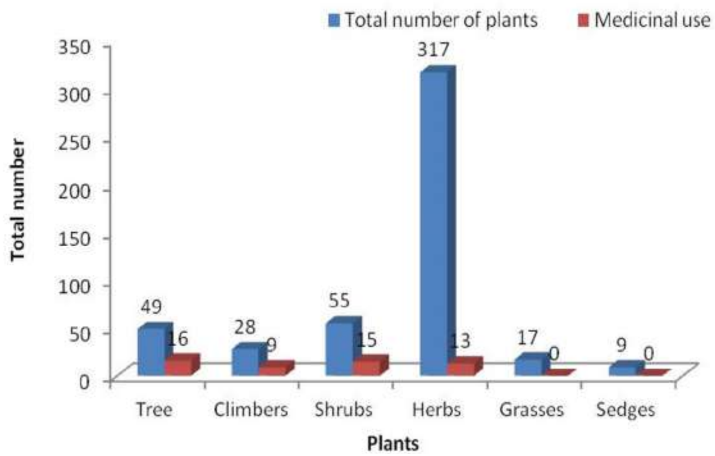


Image 17 : Riparian Flora of Ganga River with Medicinal Properties

(Source: IIT-Consortium, 2012)

Sinha has reported 32 macrophyte species besides 31 species of trees, 17 climbers, 36 shrubs, 139 herbs, 8 grasses and 5 sedges as comprising the riparian vegetation in R. Ganga (Sinha R.K., 2014, p.301).

An earlier compilation of research papers had documented 475 riparian species along the banks of river Ganga, from Rishikesh to Chinsura in Hooghly district (Krishnamurti, 1991). Many of these species have medicinal properties as shown in Image 16.[iii]

Riparian Flora from Gangotri to Haridwar in the Upper Ganga Basin

In the last two decades, several researchers have documented riparian flora along the Bhagirathi-Ganga stretch from Gangotri to Haridwar and along the Alaknanda and its tributaries. More than half (~56 %) of the 276 species identified between Gangotri and Haridwar are said to have medicinal properties. They belong to 82 families and 225 genera. Poaceae with 19 species are the dominant family.

Riparian Flora from Narora to Barh in the Middle Ganga Basin

Different researchers have recorded riparian flora along different stretches of River Ganga and its tributaries. These flora include:

- 40 riparian macrophytes between Narora and Kannauj (Siddiqui 1991)

- 36 macrophytes between Mirzapur and Ballia (Tripathi 1991)
- 7 shrubs, 41 herbs, 6 grasses and 2 sedges besides a number of trees from Buxar to Barh (Kumar 2001)
- 48 species of 23 families in the diara lands of the Ganga (Bilgrami 1991a)

Riparian Flora from Munger to Gangasagar in the Lower Ganga Basin

In this section, the banks are freshwater habitats up to Nabadwip. In the approximately 100 km stretch from Nabadwip to Konnagar, the river water can be described as nearly fresh water. Between Konnagar and Diamond Harbour is an estuarine zone and the marine zone starts thereafter. The riparian flora identified in these stretches include:

- 212 macrophytes from Munger to Farakka (Bilgrami 1991b)
- 32 macrophytes between Bandel and Bally (Datta N.C., 1991)
- Mangrove forests are the dominant species in the marine zone. (Naskar & Guhabakshi (1987) recorded 30 trees, 20 shrubs and 20 herbs as true mangrove species in this zone.
- Naskar (1993) listed 154 angiosperms (flower-bearing) families in the Ganga delta region. He also observed that just over a quarter of all these species were exotics.

Mangrove forests: The biodiversity of mangroves has acquired increasing interest because mangrove ecosystems are among the most threatened by global warming and climate changes, particularly the sea level rise (Macintosh and Ashton, 2002, 2004). The Sundarbans mangrove forests form an important store of carbon (Nawab et al, 2016, p.191).

Mangrove forests consist of salt-tolerant plant species and occur along the inter-tidal zones of rivers and seas. The plants form narrow strips or extensive patches in the estuarine habitats and/or river deltas of tropical and sub-tropical climates. Since mangroves must survive the tidal fluctuations and storms surges associated with the harsh environment between land and sea, they display distinctive morphological and physiological adaptations that make them one of the more resilient and unique ecosystems on the planet. These extensive adaptations enable mangrove forests to become perhaps the most productive and diverse kind of wetland area in the world (Anon, 2011). Mangrove ecosystems also serve as a plentiful source of firewood, timber, fodder, fruits, medicines for neighbouring human settlements while providing a critical buffer zone against cyclones, sea-level rise and other natural threats (Anon, 2011). It is estimated that the value of the ecosystem services provided by the Sundarbans between 2050 and 2100 will be around US $63 trillion (Nawab et al, 2016, p.189).

The floral diversity of mangroves is well documented; they consist of about 65-69 species of vascular plants which have several specific adaptations to the dynamic coastal environment (Kathiresan and Bingham, 2001). The Indian part of the Sundarbans, with higher salinity, hosts different varieties depending on the nature of the soils.

The famous Sundari (*Heritiera fomes*) tree, from which the region takes its name, may be facing extinction in the Indian Sundarbans (See also Chapter 5). Only a few plants of *H. fomes* are now found in the eastern part of the Indian Sundarbans in association with other species. They are being gradually replaced by Excoecaria. Most of the *H. fomes* plants are noted for scanty growth and their sizes are smaller than the normal tree. Gopal and Chauhan (2006) have enumerated 17 riparian floral species (11 families) in the Indian Sundarbans as being rare, endangered or threatened (RET).

6.2.1 Importance of Riparian Vegetation and Threats

Riparian vegetation provides shelter for breeding animals and fishes. It helps in soil conservation, reduces sedimentation, nutrients and pollution load in the river and provides human settlements with a variety of daily needs like timber, fuel, fodder, medicine, fruits and other purposes. Riparian vegetation can effectively reduce pollution only when the vegetation is managed. If it is not periodically harvested, then when it dies the pollutants can re-enter the water.

Many species have medicinal values. Native macrophytes and grasses on the river bank reduce stream flow rates and keep banks drier by intercepting precipitation, transpiration and increased drainage through the soil (Dutta et al., 2011). Dispersal of their seeds by the river water helps maintain their diversity and the health of the riparian zones.

Saccharum species, like sugarcanes, constitute a sucrose-bearing genus that belongs to the grass family. They are very effective in checking bank erosion. *Saccharum munja* (moonj grass) and *Saccharum spontaneum* have been reported near Rishikesh and Shyampur (Gangwar and Gangwar, 2011) but their density is said to be low (Shyam, 2008). *C. dactylon*, commonly known as *doob* or *durva* grass, reported from the right bank of river Ganga near Uttarkashi, used for worship in temples – particularly for Lord Ganesha's worship, also has a high soil conservation value (Gangwar and Gangwar, 2011).

Due to the durability and hardness of its wood, the Sundari tree is a highly valued timber species, which is very useful for boat building, furniture making and several other domestic uses. These trees have for long been indiscriminately exploited for their timber value. Besides the *H. fomes* species, *Nypa fruticans* is also rapidly disappearing because of extensive exploitation.

Threats: The survival and growth of riparian vegetation in the Ganga basin face natural and anthropogenic threats. Natural degradation may be gradual or catastrophic (sudden). An ecosystem can adapt to gradual natural change, but catastrophic changes can result in severe damage or destruction. Among the principal natural factors for degradation of riparian flora are (i) Adverse climatic conditions, particularly extreme rainfall events leading to heavy floods and bank erosion, (ii) forest fires, and (iii) invasion by weeds and pathogens.

The major anthropogenic hazards are due to

(1) Development projects particularly construction of roads, hydropower projects and tourist resorts. Diversion, channelization and regulation of river flows by dams, dykes, barrages (weirs), embankments and canals are the most important threats to riparian biodiversity. Extensive floodplain areas are eliminated by dykes and embankments for protecting settlements and agriculture from floods, and the creation of reservoirs.

(2) Expansion of farming and horticultural activities.

(3) Release of heavy loads of toxic pollutants which can affect the less pollution tolerant species like riparian grasses, which are particularly susceptible to toxic industrial pollutants.

(4) Extensive sand mining activity which damages habitats on floodplains.

(5) Household requirements for timber, fuel-wood and fodder. Anthropogenic hazards require societal or government action to implement corrective measures.

The report 'Riparian Floral Diversity of River Ganga' prepared for the Ganga River Basin Management Plan (See Endnote ii), lists the following steps to restore riparian biodiversities:

- Determine the root cause of vegetation depletion, which may be biological or non-biological.
- Prepare an inventory of riparian flora through primary data collection and preserved through an information retrieval system.
- Ensure environmental flows (E Flows) to sustain riparian vegetation downstream of dams and barrages and to reduce siltation and the salinity levels in the delta regions. In some stretches (Dakshineshwar, Naihati and Bandel) the rise in the river bed may cause the river to cease flowing there and change its course in the coming years.
- Prepare social awareness programmes for conservation of plant resources.
- Preserve indigenous knowledge of the local people regarding plants.
- Governments should take the steps for proper management of the vegetation, reforestation and strong implementation of laws for the purpose of conservation.

6.3 AQUATIC BIODIVERSITY[iv]

The Ganga's long course (~ 2510 km) from Gangotri in the Higher Himalaya to Ganga Sagar in the Bay of Bengal may be divided into (i) Upper Ganga (294 km) from Gangotri to Haridwar, (ii) Middle Ganga (1082 km) from Haridwar to Varanasi and (iii) Lower Ganga (1134 km) from Varanasi to Ganga Sagar (IIT-Consortium, 2010). Its basin in India can also be divided into north and south basins. The major tributaries of the north basin have their origins in the Himalaya. The Vindhyan ranges give rise to the tributaries of the south basin. Though the Yamuna rises in the Himalaya, its major portion flows in the south basin and it joins the Ganga at Prayagraj.

A complete and comprehensive study of the Ganga basin's aquatic biodiversity in India is a difficult task because of the size of the basin, the diversity of its terrain, climate zones (arctic to wet tropical), geology, soil, vegetation (temperate, wet and dry tropical) and the physiographic conditions of the tributaries from their diverse topographies. Comprehensive studies on the aquatic life in the main stem of river Ganga were first undertaken during the Ganga Action Plan (GAP) between 1985-88, by 14 universities mostly located along the river's main stem (Krishnamurti et al, 1991). But there were considerable gaps. In general, there was more data from the river stretches near the universities. Prior to GAP I there was considerable information on fish fauna for a sizeable portion of the Ganga and Yamuna, because of their commercial and livelihood significance (Talwar & Jhingran, 1991). In recent decades much more information and data have been generated, particularly with respect to physical, chemical and some biological communities (phytobenthos or periphyton, plankton, benthic macroinvertebrates) of direct relevance to fisheries.[v]

The river bed is teeming with all kinds of life-forms, ranging from single-celled organisms invisible to the naked eye (e.g., green and blue-green algae, diatoms, protozoans, rotifers) to mammals (dolphins and otters). A consortium of bottom-dwellers (benthos) occurs throughout the course of the river even in shooting water currents and ice-cold waters of the Himalayan stretch. Years of evolution have shaped their bodies and their parts in order to maintain their populations in conditions inhospitable for human life. These organisms have a variety of mechanisms (adaptations) to attach (gelatinous tubes, nests), adhere (flattened body) or cling (claws) to hard substrata of varying dimensions. Even fish, which have powerful locomotor organs have specialized organs (similar to wall lizards) to facilitate movement against torrents. There are other adaptations as well. The river becomes more hospitable in the valleys of the upper stretch and as it approaches the foothills, resulting in an increase in biodiversity.

Life on the river bed continues to thrive in the Gangetic Plains. Here, the organisms are those which can burrow in the soft sediments or move with ease on the shifting unstable bottom. In the plains the river hosts more communities such as plankton, nekton (fish, crocodile, gharial, turtle, serpents, dolphin) and neuston (insects, birds). As the river becomes deep and wide, many niches come into play, enhancing the biodiversity.

Physical conditions such as the discharge, water velocity, the substrate (river bed material), transparency, water temperature, depth, etc. and the water chemistry, i.e., pH, electrical conductivity, dissolved O_2 and nutrients (macro, micro), govern the structure (richness, density, species composition, assemblages) and functions (productivity, trophic state) of a river's ecosystem, especially for the producer community (algae, macrophytes). Anthropogenic activities in the river and land use changes in the floodplains and the watershed also affect its ecosystem. Since these factors are continuously changing, the aquatic biodiversity also varies over time. Periodic characterization of the biodiversity is therefore necessary to assess the ecosystem changes over a period of time. It is more important to analyze periodic changes in the species composition of the aquatic life forms rather than just identifying the various taxa in the river. Changes in the species diversity of life forms are indicative of changes produced in the river's ecosystem by the natural (e.g., climate change) and anthropogenic factors.

Floods play important roles in tropical river ecology (Sinha R.K., 2014, p.295). They import energy, matter and biota from the catchment to the river and create new, high-quality habitats. They enhance the ecological health of the river by maintaining its longitudinal, lateral and vertical connectivity. Annual floods especially high-floods are important for the riparian vegetation, recharge of groundwater and maintenance of wetlands. The water holes for wild life in the floodplains also get replenished.

In this section the aquatic biodiversity is primarily discussed with reference to the mountainous zone (MZ) of upper Ganga and the Ganga stretches in the middle and lower plains. The plains zone (PZ) of the middle Ganga stretch is further divided into Zone I (PZ I) from Haridwar to Prayagraj and Zone II (PZ II) from Prayagraj to Varanasi.

Some physico-chemical characteristics of R. Ganga's main stem are listed in Table 14.

Table 14 : Physico-chemical Characteristics of R. Ganga's Main Stem

Sl. No.	Feature	MZ (Mountainous Zone)	PZ (Plains Zone)	
			PZ I	PZ II
1.	Length	275 km	938 km	144 km
2.	Physiography	Mountainous, gorges & narrow valleys.	Wide river bed with extensive flood plains and meandering channel.	
3.	Habitats	Rapids & riffles near the source, short deep pools between riffles and rapids in the middle zone, long pools between short rapids and riffles in lower zone. Large (hard) bed sediments.	Pools, riffles and runs. Soft sediments (small particles size --silt, clay, sand, pebbles) in varied proportions of the river's stretches.	

4.	Water temperature	Ice-cold to cool (4.3-25°C)	Mod. Cool (~12°C)	Warm (~30°C)
5.	Slope	10 m/km	0.2 m/km	0.07 m/km
6.	Flow velocity	3.3-0.38 m/sec.	25-30 cm/sec.	
7.	DO	Declines from MZ to PZ		
8.	pH	Ranges from neutral to moderately alkaline		
9.	Turbidity	1500 NTU	< 300 NTU	

Source: Extracted from Nautiyal P. et al (2014)

6.3.1 Bottom Dwellers: Phytobenthos Communities

Richness

Richness is the total number of species at any location. It is quite dependent on the sample size; more species are likely in a large sample. Nautiyal P. et al, (2014) reported a comprehensive study of benthic flora in the MZ including (i) the Bhagirathi, Alaknanda and Ganga (Devprayag to Haridwar) sub-basins and (ii) the Ganga main stem's plains stretch (PZ).

The compositions of the phytobenthos (benthic algae) and phytoplankton are shown in Table 15.

Table 15 : Richness of Benthic Flora (PB) and Periphyton (PP) in MZ and PZ

Flora	MZ		PZ I		PZ II	
	PB	**PP**	**PB**	**PP**	**PB**	**PP**
Bacillariophyceae	443	47	101	90	51	135
Chlorophyceae	29	26	52	5	0	7.3
Cyanophyceae	12	10	21	7	0	45
Euglenophyceae	0	1	4	0	0	4
Dinophyceae	0	0	0	0	0	8
Chrysophyceae	0	0	2	0	0	1
Xanthophyceae	0	0	1	1	0	0
Total	**484**	**84**	**181**	**103**	**51**	**266**

Source: Nautiyal P. et al (2014)

Table 15 shows that in the studied stretch (MZ to PZ II) most of the phytobenthos species belong to Diatoms (D) Class Bacillariophyceae (overall 501 species); green algae (GA) Chlorophyceae (132 species) and blue-green algae (BGA) Cyanophyceae (67 species). Diatoms predominate the phytobenthos community, particularly in the MZ.

A 2014 inventory shows that primary producers are largely phytobenthic in the MZ with 328 taxa reported up to Haridwar (Nautiyal P., et al, 2014). Lack of hard substrate material and increasing presence of softer sediments in the PZ leads to a drop in the richness of phytobenthic community after Haridwar, giving way to plankton community.

Regulation of river flow also has a strong effect, as seen in the Rishikesh-Haridwar stretch. Even though about 256 taxa have been recorded from the Doon Valley, the species richness in the Ganga declines (181 taxa) owing to shrinking of the habitat, caused by extraction of a large proportion of the river water downstream of the Pashulok and Bhimgoda barrages in Rishikesh and Haridwar, respectively.

Compared to MZ and PZ I, species richness in PZ II is much lower. The benthic GA and BGA are replaced by planktonic forms. Secondly, the number of phytoplankton diatom species (135) exceeds the number of phytobenthos diatom species (51). These changes reflect differences in the regimes of the physical factors like the lowered flow velocity, deeper water column, higher water temperature and/or softer substrates (silt, sand). Because of their quick response to environmental changes, epilithic (attached to stones or rocks) diatoms are good biological indicators of water quality in a water body.

The periphyton[vi] status was studied by CIFRI along the entire main stem of R. Ganga (CIFRI, 2019, p.79). The seasonal values were the highest during the post-monsoon period between Tehri and Prayagraj. From Buxar to Diamond Harbour, the highest values were observed during the monsoon season. Earlier, Verma and Prakash (2010) identified 293 species of epilithic diatoms in the south-basin tributaries joining the Yamuna before Prayagraj (Please see Section 6.5 also) and R. Ganga after Prayagraj.

Density

Density is a measure of the abundance of a particular group of organisms in an ecosystem. It declines gradually from Devprayag to the foothills (Rishikesh). Again, in the regulated river stretch between Rishikesh and Haridwar, community density was quite low compared to its unregulated stretch. The benthic density further declines from MZ to PZ I, though a slightly higher density was reported at Kanpur than in the mountain foothills (Nautiyal R., 2005).

Community Composition

There is a steady decline in species richness and the quantitative share of diatoms going down the Ganga. The composition at Devprayag showed a dominance of GA and BGA over diatoms (D). By contrast, in the lower MZ from Devprayag to Rishikesh, diatoms dominated (D 51–84%, GA 5–31%, BGA 11–20% during summer and D 96% in winter). Though the share of diatoms fluctuates in PZ I (Narora – D 58–85%, GA 11–36%, BGA 4–6%; Kachla Ghat – D 90–97%, GA 3–10%; Bithoor – D 54–70% and GA 27–46%) it is still dominant, as in the MZ.

6.3.2 Plankton

Richness

In the longitudinal study from Gangotri (MZ) to Varanasi (PZ II), a total of 464 plankton taxa were recorded (Nautiyal P., et al, 2014, p.82). Plankton richness increased from MZ to PZ I. The maximum abundance of plankton in terms of quality and quantity was recorded between Kanpur (lower PZ I) and Varanasi (PZ II).

Phytoplankton: Phytoplankton are autotrophic organisms, individually too small to be seen by the naked eye, except as algal blooms (present in large numbers) when the water may appear green due to the presence of chlorophyll. They form the foundation of the food web for most aquatic life and contribute around 20% of global primary productivity and 40% of marine primary productivity (Field, et al, 1998), making them important to both local and global ecosystems.

In the Ganga's reach till Varanasi the phytoplankton community was represented by six taxonomic groups; Bacillariophyceae: (48-195 taxa), Chlorophyceae: (54-126) Cyanophycean: (18-60), Euglenophyceae (4-10), Xanthophyceae (1) and Chrysophyceae (3) from the MZ to the PZ II (Nautiyal P. et al 2014, p. 82). Planktonic diatoms dominated in the plankton community also, as in the benthic communities, followed by planktonic GA and BGA. Comparison of the phytobenthos and phytoplankton shows that many benthic diatoms lead a planktonic existence in the plains.

Richness of the phytoplankton community increased going down the middle Ganga stretch, a reverse trend than that of benthic communities. The increasing presence of soft sediments, a wide bed span, open surface area for incoming radiations, lower current velocity and rich nutrient load probably contributes to this.

An early study (Singh H.R., et al 1994) reported that 27 of 42 genera of phytoplankton in the MZ (Gangnani to Rishikesh) were diatoms genera. Krishnamurti et al (1991, p.335), reported an increase in phytoplankton taxa from the foothills (83 taxa) to 100 taxa (43 BGA, 35 D, 22 GA) between Rishikesh and Garhmukteshwar and 237 taxa at Varanasi.

CIFRI identified six phytoplankton categories from 20 stations along the entire length of the main stem of R. Ganga from Harsil to Fraserganj in its study between 2016 and 2018 (CIFRI, 2019, p.75). The major Classes were Bacillariophyceae, Chlorophyceae, Cyanophyceae, Charophyceae, Orchophyceae and Euglenophyceae. Out of 87 phytoplankton genera, 39 were Bacillariophyceae (D) and 35 were Chlorophyceae (GA). The Ganga stem up to Varanasi showed higher abundance than the lower Ganga stretch between Buxar and Fraserganj.

High concentrations (>2000 u/l) were found in the pre-monsoon sampling between

Narora and Prayagraj with a peak at Kanpur (7634 u/l), a likely result of pollution. Kanpur also recorded the post-monsoon maximum at 165 u/l. Both maxima reflect anthropogenic stress and high nutrient load (CIFRI, 2019).

Zooplankton: Zooplankton are a part of the aquatic food chain. They generally feed upon other plankton, including phytoplankton, along with bacteria and various types of particulate plant matter. They are in turn consumed by larger predators – vertebrates and/or invertebrates.

The Gangotri to Varanasi longitudinal study (Nautiyal P. et al, 2014, p.82) noted that zooplankton (61 taxa) up to Varanasi included rotifers, crustaceans (Cladocera and copepods), protozoa and miscellaneous taxa (4), primarily in PZ I. Zooplankton richness also increased from MZ to PZ I.

The above-mentioned CIFRI study identified four zooplankton phyla: Rotifera, Arthopoda, Ciliophora and Protozoa. The major groups were copepods, cladocerans, rotiferas and protozoans. In the pre-monsoon sampling, high abundance was found from Haridwar to Kanpur, above 200 u/l at Haridwar, Narora and Kanpur. In the lower Ganga stem, the maximum density (u/l) was at Bhagalpur during the monsoon and post-monsoon periods.

Density

In R. Ganga, the phytoplankton density varies spatially and temporally along the different stretches of the river. The densities increase with the water temperature during the first half of the year (January to May). During the monsoons due to the increase in the turbidity, less solar penetration leads to fewer phytoplankton (Krishnamurti, 1991). Phytoplankton density is generally very high in the middle stretches of R. Ganga (Mirzapur to Farakka), relative to upper (Gangotri to Garhmukteshwar) and lower stretches (Berhampur to Bally).

Planktonic Doom

Referring to River Yamuna's 22 km stretch in Delhi - between the Wazirabad and Okhla barrages, the noted ecologist and former Delhi University Professor C.R. Babu says, "Downstream from Wazirabad, the river is ecologically dead as it has no aquatic life. Low levels of dissolved oxygen (DO) and a very high degree of pollution are the reasons that killed the river." He adds, "In the urban stretch of Yamuna there are no phytoplanktons or zooplanktons left; these play an important role in maintaining the aquatic life of any water body. They have vanished."

https://www.thehindu.com/news/cities/Delhi/Delhi%E2%80%99s-waste-chokes-Yamuna-of-all-aquatic-life/article14587041.ece, accessed on October 2, 2020.

The 1994 report by Singh et al registered a general increase in plankton density in the MZ from Gangnani to Rishikesh (Singh H.R. et al, 1994). Nautiyal P. et al (2014, p.90), found an increase in the plankton density from Devprayag (510 u/l) to Rishikesh (777 u/l). They attributed a general decline of density in PZ I, compared to the MZ, to river regulation and influx of municipal and industrial effluents.

A lower density of plankton in middle and lower freshwater stretches of the river was reported in the late 1990s compared to the levels reported in early 1960s, but the composition showed little change (Sinha M. et al, 1998).

Community Composition

Nautiyal P. et al (2014, p.91), reported a relatively higher quantitative share (number of individuals irrespective of species) of diatoms than GA and BGA. The plankton composition varied mildly from Devprayag to Rishikesh. Compared to the MZ, the diatom and zooplankton shares increased marginally while BGA declined in PZ I.

Earlier, Singh H.R. et al (1994), had observed that in the MZ phytoplankton accounted for 81.3% of the total plankton density, of which diatoms constituted 92.0%. Vaas et al (2010), found that in the PZ, the phytoplankton accounted for a very large share while zooplankton formed only 16.6%. In Sultanpur and Farakka zone, phytoplankton was 70.9–89.2% and rest were zooplankton. The community composition data also confirmed that in the PZ, diatoms were present mainly in the planktonic form.

Threats

Drying of river beds due to minimum flow releases downstream of dams and barrages, pollution and riverbed mining are the most serious threats to plankton populations in the Ganga river system. Mining river beds for sand, gravels and boulders increases turbidity and destroys plankton habitats (R. Prabhakar et al, 2019). High turbidity levels can affect primary production. It can lower the foraging efficiency of zooplankton as well as the nutritional value of algal food due to the increased presence of inorganic particles on phytoplankton matter. These factors can affect their weight, body size and feeding behaviour.

The Ganga course in the plains and its southern tributaries are major sources of coarse sand. River Sone originating from the Amarkantak Hills in Madhya Pradesh and discharging into the Ganga about 35 km upstream Patna deposits coarse sand around Patna. A study of the impact of riverbed sand mining in the Ganga at Patna concluded that it led to marked changes in the abundance and diversity of zooplankton in the Ganga. Increase in turbidity and decrease in transparency of the physico-chemical attributes were responsible for the observed changes (R. Prabhakar et al, 2019).

6.3.3 Bottom Dwellers: Benthic Macroinvertebrate Communities

Richness

Diversity studies of macro-invertebrates can help in understanding their roles and value in the existing ecosystem and their suitability as bio-indicators (Nawab et al, 2016, p.194).
The benthic macroinvertebrate fauna in the mountain and plains zones belong to 65 taxa from the Annelida, Arthropoda and Mollusca phyla (Nautiyal P. et al, 2014, p. 84). This study found Molluscs only in the PZ, while an earlier study (Singh H.R. et al, 1994) reported Molluscs only being a small fraction of the organisms present. The Annelida were represented by one taxon each of Oligochaeta, Polychaeta and Hirudinea. The Arthropoda consisted of 10 orders, 52 families of Insecta and one taxon each of Crustacea and Arachnida. Among the Arthropods, Ostracoda (Crustacea) and Hymenoptera (Insecta) were present only in PZ. The Arachnida were present only in the MZ. The Mollusca consisted of Class Gastropoda (5 families) and Pelecypoda (2 families).

Earlier studies in the Bhagirathi (MZ) had reported 29 taxa belonging to 7 insect orders, of which 20 genera belonged to Ephemeroptera-7, Diptera-8 and Trichoptera-5 (Singh et al, 1994). Downstream, 20 and 17 families were present at Devprayag and at Rishikesh respectively (Singh et al, 1994 and Joshi 2005).

Nesemann et al documented benthic invertebrate species including polychaetes (6), oligochaetes (31), hirudinea (15), molluscs (bivalves 36, gastropods 40), and arthropods (crustaceans 10, odonates 52) from different rivers and streams of the Ganga Basin in Bihar and West Bengal (Nawab et al, 2016, p.193).

The CIFRI study (2019, p. 88) found 59 species of phyla mollusca and arthropoda, categorized in three Classes: Gastropods, Pelecypoda (Bivalvia) and Insecta. Mollusks accounted for 79 per cent of the composition. Balagarh station in the LGB had the highest abundance (16%). Farakka and Patna had the highest number of taxa (15), while Tehri and Godakhali had the lowest (2). Among invertebrates, crabs, bivalves and freshwater shrimps are the main groups exploited for various purposes including food. Mollusc shells were used on a large scale for making lime as a substitute for cement in the basin area. The thick shells of the bivalves are being commercially exploited to sustain buttons and garments small scale industries at Mehsi in Bihar (Gopal Sharma citation in Sinha R.K., 2014, p.307).

Density

In the MZ the benthic macroinvertebrate density ranged from 327 to 1,053 units/m^2 in the Bhagirathi, 125–1357 u/m^2 in the Alaknanda and 169–612 u/m^2 in the Ganga (Nautiyal P. et al, 2014, p.91). Later investigations from Devprayag to Rishikesh during summer revealed very low densities,15 and 22 u/m^2. In PZ I the density at Narora varied from 143 to 178 u/m^2, 59–62 u/m^{2}at Kachla Ghat and only 11 to 27 u/m^2 at Bithoor. It was slightly higher (ca. 100–150 u/ m^2) in shallow areas along the banks (15 cm depth). Other studies have reported an annual density ranging from 44 to 286 u/m^2 in the lower MZ (CIFRI Annual Reports).

Community Composition

In the MZ, Ephemeroptera, Diptera and Trichoptera accounted for 40.8, 35.5, and 13.1% respectively of the total benthic density (Singh et al, 1994). Other orders present included Plecoptera, Hemiptera, Coleoptera, Odonata, Phyla Mollusca and Nematoda and other miscellaneous forms. Trichoptera was the only order from Devprayag to Rishikesh in the lower MZ during the summer, whereas Diptera 90%, Trichoptera 2% and Ephemeroptera 8% were present in winter. Flows (its manifestation as water current velocity), breeding-growth cycles of larvae/nymph with changes in temperature from winter to summer, are the most probable factors for seasonal variations in the compositions.

In the PZ, there were diverse communities at Narora (Diptera 11%, Odonata 11%, Coleoptera 2%, Gastropoda 72% and Pelecypoda 5% all on the right bank; Ephemeroptera 1%, Diptera 57%, Odonata 1%, Hemiptera 7%, Gastropoda 30% and Pelecypoda 4% on the left bank) and Kachla Ghat (Ephemeroptera 4%, Diptera 50%, Odonata 21%, Gastropoda 11% and Pelecypoda 14% right bank; Diptera 100% left bank). At Bithoor the composition was restricted (Diptera (92%), Odonata (8%) – right bank; Pelecypoda (100%) – left bank).

Thus, the prominent insecta components of MZ (Ephemeroptera, Trichoptera, Colepotera) are either few or absent (Plecoptera) in the PZ. Most of the aquatic nymphal or larval stages of these Orders live in ice-cold or cool waters. They are typical to stony river beds, torrents and gushing DO rich waters. Besides, they are highly sensitive to the slightest change in the physical and chemical properties of the river water.

6.4 VERTEBRATE BIOTA OF RIVER GANGA[vii]

The vertebrates found in R. Ganga besides fish include amphibian, reptilian, avian and mammalian species.

Amphibia: Rana is widely distributed in River Ganga. *R. limnocharis, R. tigrina* and *R. cyanophlyctes* are typically found in the middle and lower stretch of the Ganga. Tadpole larvae are quite common during the breeding season.

Reptilia: Some of the important reptiles found in the Ganga river include *Trionyx gangeticus, Kachuga Kachuga, Lissemys punctata, Gavialis gangeticus* (Gharial), *Crocodylus palutris* (Magar), *Crocodylus porosus* (Brackish water crocodile) and *Natrix piscator* (Grass snake). Freshwater turtles in the Ganga basin are broadly divided into hard-shell turtles (Emydid turtles) and soft-shell turtles (Trionychid turtles).

Birds: The Ganga basin is a sanctuary for a large number of birds including migratory ones. A large number of migratory birds visit the Gangetic belts during winter.

Mammals: Aquatic mammalian fauna are represented by the Ganges River Dolphin (*Platanista gangetica*) and three species of Otters : Smooth coated Otter (*Lutra perspicilata*), Eurasian Otter (*Lutra lutra*), and Small clawed Otter (*Aonyx cinereus*) (Joshi, K.D. et al, 2016).[vii]

6.4.1. Fish[ix]

Richness

Hamilton's record of 268 fish species in River Ganga is said to be the first ever scientific documentation of the fauna of the river (Nawab et al, 2016 p.192). Fisheries in the upper stretch of the river comprise only fresh water species whereas the lower stretch comprises both fresh- water and estuarine species (Krishnamurti, 1991). Talwar and Jhingran (1991) listed 266 species from the entire Ganga basin out of which 158 were freshwater and 108 marine species. In 2001, fish variety in the Haridwar to Sundarban stretch was described as rich and diverse with cyprinids (176 spp.) and silurids forming the mainstay (Sinha M. & Khan M.A., 2001).

Quarterly field surveys conducted at 18 sampling stations all along the length of the Ganga by CIFRI between January, 2016 and December, 2018 recorded 190 fish species belonging to 133 genera, 60 families and 17 orders (CIFRI, 2019, p.17). The species richness at the different stations is shown in Image 17. The commercially most important freshwater family Cyprinidae (including carps and minnows) were recorded at each sampling point up to Tribeni, upstream of Kolkata while the freshwater catfish families were found at all the sampled spots.

Mountain and Upper Ganga Plains (UGP) Zones:

A study of fish fauna in the ~1300 km stretch of river Ganga, from Gangotri to Varanasi, identified the presence of 149 fish species from 25 families (Nautiyal P. et al, 2014, p.84). Fifty-eight species were present in the MZ and 122 species in the PZ.

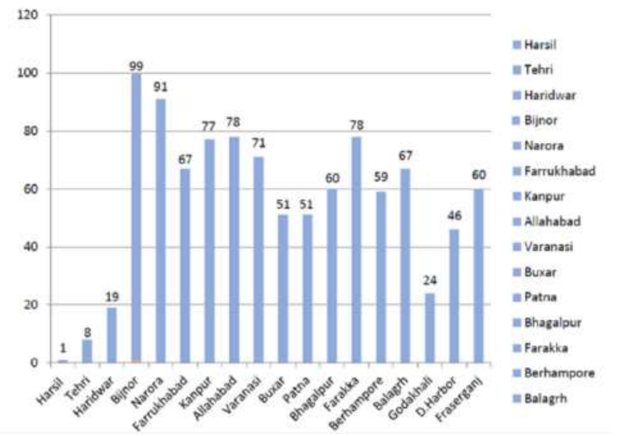


Image 18 : Number of Fish Species at Different Locations

Source: CIFRI, 2019

The dominant species reported in various studies belong to the Cyprinidae (carp) family, followed by Sisoridae (Asian catfish) and Balitoridae (loaches) families. These families account for two-thirds of all the species. Less common species include eels and hilsa, while mullet, tilapia are relatively much fewer. Generally, carps are predominant in the colder waters. In the warmer water stretches though carp species are still usually the largest in number, the proportions of catfish and other species increase (Table 16). A general increase in fish richness is also evident from MZ through the PZ.

Table 16 : Fish Diversity and Common Communities' Composition in the Upper Ganga Basin

Stretch	**Carp: Catfish: Others (Total number of Common Species)**	**References**
Devprayag to Rishikesh	18:2:1 **(21)**	Nautiyal P. et al, 2014
Rishikesh to Haridwar	20:3:7 **(30)**	Khanna et al, 1994
Bijnor district	14:4:9 **(27)**	Sharma & Rajput, 1986
Brijghat to Narora	45:17:20 **(82)**	Rao, 2001 & WWF-India, 2004
At Narora	26:18:14 **(58)**	March 2010 web citation
At Narora	13:6:3 **(22)**	Nautiyal P. et al, 2014
At Kachla Ghat	8:7:14 **(29)**	Nautiyal P. et al, 2014
At Bithoor	12:7:12 **(31)**	Nautiyal P. et al, 2014
Around Kanpur	7:10:7 **(24)**	Shukla & Asthana, 1995
Below Prayagraj	36:23:29 **(88)**	Nautiyal P. et al, 2014

Source: Compiled from Nautiyal P. et al (2014)

In the last few decades, the ratio of Carp: Catfish: Other has changed at Prayagraj; 46:30:24 in the1960s; 36:36:28 in 1970s, 14:45:40 in 1990s. Thus, the fish community composition has shifted from carp to catfish dominated to others dominated. Earlier, however, hilsa was prominent among others, whereas now miscellaneous fish dominate the 'others' category. Breeding for most of the Ganga fish begins at the onset of monsoon. Although there is no marked variation in different seasons in general, the varietal diversity is greatest during winter and the post monsoon period.

From the viewpoint of fish distribution, the river stretch from Haridwar to Bijnor (77 km.) is of special interest since it is the junction of the west Himalaya and the Upper Gangetic Plains biogeographic regions (Nautiyal P. et al, 2014, p.86) The junction zone has a larger share of mountain element and just one-third from the plains. Some cool-water species like the large Labeo, like *L. dyocheilus*, and a mixture of loaches and barils (carp) are found beyond the junction zone in PZ I.

The most typical fish in MZ are Cyprinidae (snowtrouts: *Schizothorax sp.*, *Schizothoraichthys*

GANGA FAUNAL BIODIVERSITY IN THE HIMALAYAN ZONE

Mahseer: A case in point

Prakash Nautiyal*

The Himalayan Mahseer resides in the mountain tract of the Ganga river system, using selected spring fed tributaries for spawning. These tributaries are the nurseries for the juveniles. This is an elaborate migration because it needs the period February to June to produce viable sperm and ova, especially the latter. Since the last century the Gangetic mahseer stock has declined, adversely impacting its fishing. What was stated for Doon in 1871 "….breeding fishes are destroyed in great numbers and the small fries also captured…" is true even today.

Natural and anthropogenic constraints responsible for the decline of the mahseer include: (1) Slow growth rate, hence delay in sexual maturity, low fecundity, demersal eggs, long hatching periods; (2) Habitat destruction due to barrages and dams along with overexploitation act synergistically to impact the recruitment process of mahseer stocks. Consequently, the age group 0+ to 4+ constitutes 90% of the present population. A population composed wholly of pre-reproductive adolescents and oldsters too feeble to breed will not increase at all in the near future.

The mountain tract has very specialized biota adapted to living in torrents. Even single celled algae have a mechanism (mucilaginous stalks) to maintain themselves in the fast flowing rivers. The invertebrates too have diverse adaptations. The fish fauna of torrential glacier fed rivers have adhesive pads of varying shape and size and are specific only to cold waters. Some of these are important to capture fishery (snow trout and mahseer species) which form a source of livelihood for many living close to the river. *Tor putitora* also has recreational and religious value. *Barilius bendelisis, Glpytothorax sp.*, and loaches are suitable for aquaria trade. The producer community in these rivers are dominated by diatoms and contribute to the grazing chain. The macro invertebrate community largely contributes to the grazing and detritus chains as primary consumers. Diatoms and macro-invertebrates are both of great value in bio-assessment as they are good indicators of the water pollution.

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sp., *Naziritor chelynoides*), Balitoridae (loaches: *Schistura sp.*) and Sisoridae (catfish: *Pseudecheneis sp., Glyptothorax sp.*). Besides Schistura and *Glyptothorax sp.*, a wide variety of other genera of these families are exclusive to PZ I. The presence of four diverse silurid (catfish) families is a unique feature of this zone. In PZ II cyprinid elements become fewer and among catfish besides a few Bagridae, Siluridae, Schilbidae, there is more representation of Sisoridae, as in the MZ, but the genera are different. Some unique elements appear in PZ II, especially clupid, mugil and perch.

Declining Fish Yields: Fish are the most exploited fauna of the Ganga. Past records indicate that fish production declined by 22% and 75% at Prayagraj and Buxar respectively between 1958 and 1984 (Natarajan, 1989). Further downstream the annual fish production at Patna decreased by over 58% (72 kg/ha) from 1961-69 to 1980-86 (30 kg/ha).

The major carp yield at Prayagraj decreased from 44.5% in 1958-66 to 8.3% in 1996-97 and *Tenualosa ilisha* (hilsa) from 9.7% to 4.2, while large catfishes yield increased slightly from 22.7% to 24.1% (Sinha R.K., 2014, p.303). The miscellaneous fishes yield increased from 23.1% to 63.4% at the same centre and duration. The yield of the major carps in the longer middle stretch of the Ganga (roughly, past Prayagraj to Bhagalpur) fell even more rapidly to 2.55 kg/ha by 1995 from 26.62 kg/ha in 1958-61 (Sinha M., 2001).

The stock of most of the economically important fishes, e.g., the Indian major carps (*Labeo rohita, Catla catla* and *Cirrhinus mrigala*) in the Lower Ganga Plains was severely affected by the end of the 1990s (Hassan, 1999). The proportion of the Indian major carps collectively accounted for about 40% of the catch in 1958-61. By 1995 it had fallen to about 22 percent. The decline at Patna was even worse, from 31.4% of the total catch in 1958-61 it decreased to only 6.5% in 1993-95 (Sinha M. & Khan M.A., 2001). Hassan (1999) reported a yield of only 1.37 kg/ha/yr of the Indian major carps from a stretch of 30 km of the Ganga in an around Patna. Juvenile fishing during the breeding season at the onset of monsoon, which resulted in the destruction of millions of fingerlings of major carps (Anon, 2011), could be one factor.

A steady decline was seen in the populations of prized carp and *Tenualosa ilisha* (hilsa) fishes, as well as minnows after the commissioning of the Farakka Barrage in 1975 (Ray P., 1998). Farakka Barrage's construction significantly impacted fisheries as far up as Prayagraj. Hilsa catches reportedly declined from an average of 19.2 ton hilsa/year to 0.9 ton hilsa/year.

The average annual yield of prawn and fish in the estuary zone, however, increased from 9481.5 tons in the pre-Farakka barrage period (1966-67 to1974-75) to as high as 61032 tons, during 1997-2000 in the post-barrage period, due to the increased influx of freshwater in the Hooghly after commissioning the barrage. Hilsa fishery in the Hooghly also increased from 1457.1 tons in 1975 to 9576.9 tons in 1997-2000 (Sinha R.K., 2014, p. 303).

In the last few decades fishers and fishery researchers have reported the appearance of exotic fish species in river Ganga and related it to the declining yields of local varieties, including the commercially important carps and the hilsa. The latter, which constituted a major fishery in Ganga until the 1960s, began disappearing after exotic fishes like tilapia and common carp started appearing in the 2000s (Anon, 2011). Thai Mangur (*Clarias gariepinus*), Chinese Grass Carp (*Ctenopharyngodon idella*), common carp, (*Cyprinus carpio*), Southern sailfin catfish (*Pterygoplichthys anisitsi*), *Oreochromis niloticus niloticus, Aristichthys nobilis, Hypophthalmichthys molitrix* are some of the introduced species in the Ganga River system (Sinha R.K. et al, 2010). The maximum catches of exotic species have been recorded between Varanasi and Buxar, while fewer numbers have also been reported from Bijnor, Berhampore (WB) and Balagarh (WB) (CIFRI, 2019, p.44). (See also Section 6.5)

Community Composition

Table 17 summarizes the commonly observed species identified by CIFRI during 2016-2018 in the main Ganga stem. The CIFRI report states that the stretch around Tehri was practically non-fishing zone and as such no regular fishing activity takes place in the area (CIFRI, 2019, pp 50-53).

Table 17 : Species Most Available in Different Stretches of the Main Stem of River Ganga

Stretch	**Common Species**
Tehri-Haridwar	*Tor putitora, Labeo dyocheilus, L. angra, Schizothorax richardsonii* are most common[x]
Narora-Farukhabad	*L. calbasu, Cirrhinus reba, L. bata, L. dero, Salmophasia bacaila, Cabdio morar, Botia spp., Rita rita, Clupisoma garua*, dominate among others
Kanpur-Prayagraj	*Puntius sophore, Cabdio morar, Barilius barila* are abundant
Kanpur to Varanasi	*Gibelion catla, Cirrhinus mrigala, L. calbasu* and *L. rohita*
Kanpur to Patna	*S. bacaila* available throughout the stretch; Among catfishes *Sperata aor, S. seenghala, R. rita, A. coila, Clupisoma garua, Eutropiicthys vacha*, and *Mystus spp.* were the important species available throughout the stretch
At Patna	**Pre-monsoon:** *C. morar, Crossocheilus latius, C. reba*; **Monsoons:** Cyprinids (69%) *C. morar, L. calbasu, Systomus sarana*; **Post-monsoon:** mainly catfishes (55%) like *Clupisoma garua, E .vacha* and *A. coila*
At Buxar	**Pre-monsoon**: Cyprinids (*Osteobrama cotio, Puntius sophore*), Clupeids (*Gudusia chapra* and *Gonialosa manmina*) & Exotics (*Cyprinus carpio* and *Oreochromis niloticus*); **Monsoon:** Small catfishes Schilbidae (60%) plus Cyprinids like *L. rohita, L.calbasu, C. reba, C. morar, S. bacaila, Puntius sophore, Cyprinus carpio*, among others; **Post-monsoon:** Clupeids like *Gudusia chapra* (37%) Cyprinids (22%), Sciaenids (13%) Schilbids (15%) Aillids (8%) Engraulids (5%)
At Bhagalpur	**Pre-monsoon:** Cyprinds (35%) and Clupeids (31%) namely *L.calbasu, L. rohita, S. bacaila, Osteobrama cotio, Gudusia chapra* etc.; D**ominant catches in the monsoon:** Cyprinids (40%) *L. rohita, L. calbasu, Gibelion catla, L. bata*, etc., Schilbid catfishes (32%) like *A.coila, E. vacha* etc.

At Farakka	**Pre-monsoon:** The upper barrage is dominated by Schilbidae family (30%) like *A. coila, E.vacha* and *P. atherinoides*; Cyprinids (25%) like *C. morar, L.bata, L.calbasu* among others. **Monsoon:** dominated by cyprinids (48%) like *L. calbasu, L. gonius, L.rohita, C. reba, L. bata, C.morar*, etc. Scianeids (16%) namely *Johnius coitor* and Schilbid catfishes (15%).
Around Behrampore	**Pre-monsoon:** Small cyprinid carps and minnows (58%) like *C.morar, Puntius spp. L. calbasu*, etc. **Monsoon:** Clupeids (53%) mainly hilsa (*Tenualosa ilisha*) and Cyprinids (21%) like *Amblypharyngodon mola, C. reba, L. calbasu*

Source: CIFRI (2019, pp 50-53)

Downstream of the Farakka barrage, hilsa is the major commercial fish starting from the monsoon to post-monsoon months. Migrant fishermen from nearby areas fish intensively during this period. The average fish length ranges between 25 cm to 70 cm, while the average catch is up to 20 kg per boat after 3 – 4 trips per day in the peak season.

The commissioning of the Farakka barrage has led to an improvement of the general habitat for a few saltwater tolerant as well as freshwater fish species (CIFRI 2019, p.53). The salinity and temperature of an estuary restrict the distribution limit of its biodiversity. The additional freshwater discharge through the barrage drastically changed the estuary zone by reducing its turbidity and salinity and pushing the salinity zone further downstream. Freshwater fish species like *E. vacha, C. garua, Rita rita, Wallago attu, Sperata seenghala, S. aor, C. catla* and *L. calbasu*, not reported from the freshwater zone prior to the barrage's commissioning in 1975, have appeared at Tribeni and Balagarh in the upper freshwater zone of the Hooghly estuary.

Threats

Fish diversity is largely affected by changes in flow patterns, water quality changes, over-fishing, introduction of exotic species and riverbed sand mining.

Flow Changes: The construction of a large number of hydroelectric projects in Uttarakhand has severely restricted the distribution range of fish species in the MZ. Most of them are diversion projects which release minimal water downstream of the barrages, leading to nearly dry river beds between the barrage and the powerhouse, several kilometres downstream. Migratory species become fragmented populations. The Wildlife Institute of India (WII) has estimated that 87% of the 76 fish species found in the Alaknanda and Bhagirathi basins could be potentially affected if all the planned HEPs in these basins are constructed (WII, 2012).

Fish ladders are often proposed as a mitigation measure. But even for relatively low height

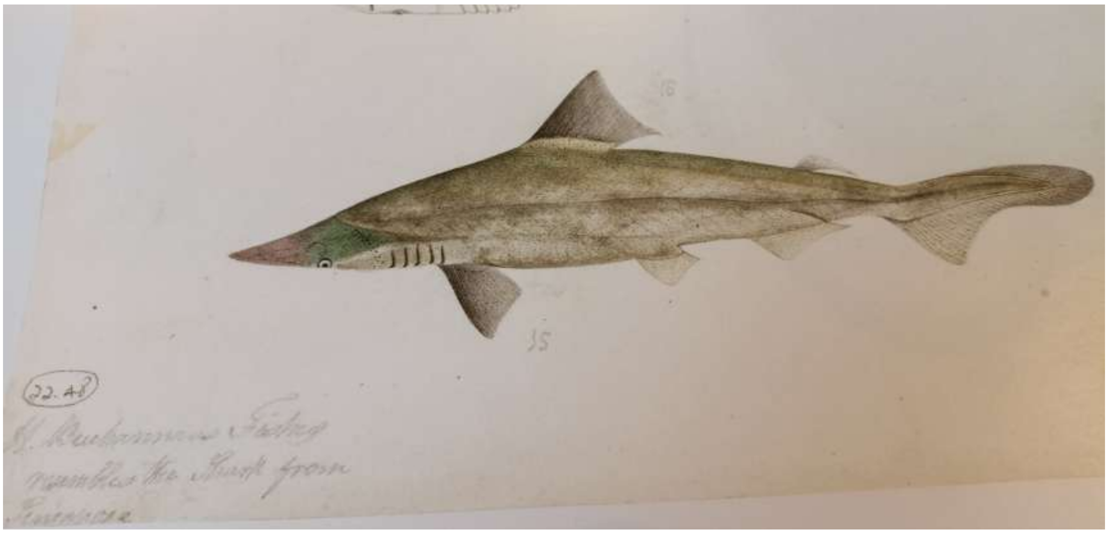


Image 19 : Gangetic Shark (Glyphis gangeticus)

Source: Francis Hamilton's Gangetic Fishes

The Gangetic Shark

The Ganges shark (*Glyphis gangeticus*) is a rare fresh water shark species that inhabits the waters of Ganges. It shouldn't be confused with the Bull shark, which also inhabits the same river. It is stocky, with a broadly rounded snout and has small eyes. It is a freshwater species and is known from only two surviving specimens collected in the Ganges River. Its small eyes indicate its habitat to exclusively include murky waters. It is restricted to Hooghly River of West Bengal and is widely feared as a ferocious man-eater.

Source - www.speakingtree.in/allslides/10-little-known-facts-about-ganga/111592

dams, they are not very efficient. The golden mahseer migrates upstream in the Western Ramganga river. But a multipurpose dam at Kalagarh is a barrier to this migration. The fish passage constructed here has rarely worked (AFC, 2012).

Water Quality: Ganga water is affected by waste discharge from domestic and industrial sectors as well as surface runoff and seepage from agricultural fields. The river water becomes hazardous for the growing carp, affecting the normal food chain in the river ecosystem and creating imbalances.

In a UPCAR-funded (U.P. Council for Agricultural Research) research study, 2014-17, of the Ramganga water quality, Neelima Gupta of M.P. Rohilkhand University found bio-accumulation of heavy metals in fish flesh, beyond safe levels for human consumption (ToI, October 20, 2017).

An unholy mess of tannery effluents, agricultural runoff and domestic sewage enters the Ganga in Kanpur. Black sludge, emitting a nauseating stench, empties untreated carcinogens like chromium, cadmium and lead at Dabka Ghat in Jajmau into a debilitated Ganga downstream of the Kanpur barrage. "Fish often die in this stretch of the Ganga because of the water pollution," a local resident Sarvesh Kumar, told Juhi Chaudhary of the Third Pole (Chaudhary J., 2018). The Central Leather Research Institute estimates that only about a small fraction of tannery effluents out of the 50 MLD generated are treated.

In the late 1990s, a CIFRI-research study concluded that the Damodar river had lost its natural flow pattern after independence due to massive exploitation of its water for industrial development (CIFRI, 1998). Except during the monsoon, it had become a drainage channel, receiving effluents from thermal power plants, coal washeries, steel and fertilizer plants and numerous other small industries, especially in the middle stretch between Tenughat and Panchet reservoirs. Toxins in the effluents included heavy metals, oil and grease, phenol, TSS and nitrogenous compounds. The endemic fishes were under extreme stress. Compared to the fish diversity in 1957, before industrial development had taken off, 33 fish species had become endangered, including 9 commercially important ones. The normal breeding and growth of the prized Indian major carp and prawn was also badly affected.

More recently, CIFRI has determined the concentrations of copper, zinc, manganese, lead, cadmium and chromium in Ganga water and the sediments between Buxar and Fraserganj (CIFRI, 2019, pp 83-86). The concentrations of all the metals in the water were maximum at Fraserganj, the last station, probably the result of the heavy load of metal ions brought down by R. Damodar from mining and industrial areas in its catchment. The Damodar meets the Hooghly at Falta about 50 km downstream from Kolkata. CIFRI analyzed fish samples of 14 species for the six heavy metals. All the concentrations in the fish flesh were below the international safety standards. Zn, however, was found in relatively high levels (c. 22 to 55 ppm) in *M. cavassius, P. conchonius, X. cancila* and *O. rubicundus*.

Laboratory experiments and partially controlled field investigations conducted by Bhagalpur University with various detergents reveal that the most commonly used detergents are highly toxic to fish and fish seed, reducing growth and reproductive ability while increasing mortality.

Impact of Exotic Species: Another threat is the emergence of exotic fishes and invertebrates in the Ganga system (Sinha R.K., 2014, p.306). Exotic species mostly replace native species in natural habitats because of altered environments that provide the foreign species an ecological advantage. They can eliminate native species through the introduction of diseases or by being more pollution tolerant.

Though details of the impact of exotic species on the native fish fauna are not yet fully understood, the Big Head carp *(Hypothalmicthys nobilis)*, the Common carp *(Cyprinis carpio)* and Tilapia *(Oreochromis niloticus)* have replaced the native Catla *(Labeo catla), Cirrhinus mrigala* and other native species in significant numbers (CIFRI, 2019, p.48).

Riverbed Mining: Unscientific mining of river beds for construction materials like coarse sand, gravels and boulders destroys aquatic habitats by channel and bed degradation and lower water levels (Padmalal and Maya 2014). Aggregates mining negatively impacts the local fish populations. Suction dredging poses grave risk to fish during their embryonic stages (Harvey and Lisle, 1998).

Kamboj & Kamboj (2019) observed a decline in the fish diversity in the Haridwar stretch due to unscientific riverbed mining using heavy earth moving machinery. In-stream mining here seriously altered the channel morphology in the last two decades. Whereas they found 20 fish species belonging to 5 families in River Ganga through its Haridwar city stretch, there were fewer varieties downstream in Bhogpur village where the river was impacted by riverbed mining activities. Due to mining, River Ganga had divided into a number of channels. In the summer and winter seasons these stream orders remain largely dry and aquatic biota like phytoplankton, zooplankton, benthos and fish are severely diminished

6.4.2. Amphibians

Amphibians are semi-aquatic vertebrates. They are critical secondary consumers in freshwater and terrestrial food chains. Their characteristic feature is a semi-permeable skin, that can absorb extra oxygen into blood vessels close to the surface or even water in the case of some toads. Their eggs are laid in water or moist habitats and their larvae metamorphose into adults in water bodies. Adult amphibians consume flying insects while larvae that are close to becoming adults feed on mosquito larvae. Hence, they are excellent biological pest controllers.

The amphibians' semi-permeable skin makes them very sensitive to environmental and climate changes. Harmful pollutants can enter their bodies through the skin. Therefore, they are also good indicators of ecosystem stress and pollution.

Amphibians are present over a wide range in the Ganga river basin, from elevations up to around 3000 m amsl to the delta. The WII-GACMC report has listed 25 species in the Ganga river basin. The Chakrata stream frog *(Amolops chakrataensis)* is found only in the Lesser Himalayan streams around Chakrata in Uttarakhand. Other mountain species like the Himalaya paa frog *(Nanorana vicina)* or the Nepal paa frog *(Nanorana micina)* have a greater range in the river basin. Bilgrami (1991c) recorded *Rana limnocharis*, *R. tigrina* and *R. cynophlyctes* from the middle and lower Ganga stretches.

"Surprisingly, amphibians are little studied and time-trend information of their populations in the Ganga River basin is scanty," says Dr Ruchi Badola of WII. Their populations are declining rapidly, however, due to pollution, habitat loss, over use and fungal diseases. The alteration of water flows due to the construction of dams and barrages is a major threat to the survival of many species, especially in the Himalayan region.

In terms of the IUCN Red List classification, the Nepal paa frog species is Vulnerable, Annandale's paa frog, found at altitudes of 1500-2000 m amsl, is Near Threatened, 19 species are of Least Concern, while three species (Dehradun stream frog, Jaunsar stream frog and Dudhwa tree frog) are Data Deficient and the Assam cascade frog is Not Evaluated.

6.4.3. Reptiles

Crocodilians

Gharials: *Gavialis gangeticus* or gharial, also known as gavial, is a fish-eating crocodile. Gharials have a distinctive bulb at the end of the snout resembling a *ghara*. Hence the name "gharial". Excavations of their fossil remains from the Shivalik ranges of Haryana and Himachal Pradesh suggest that the species probably evolved in the north Indian subcontinent in the early Pliocene period. Seals and tablets of the Indus Valley Civilisation show gharials with fish in their mouths. Their long snouts have about 110 teeth. They are among the longest living crocodilians. The males of the species can be almost 20 ft.

Historically, the perennial Himalayan rivers, Ramganga, Ghagara, Gandak, Kosi and Girwa had large wild populations of gharials (WII-GACMC, 2018). The wild gharial population declined drastically since the 1930s. They were hunted for skins, trophies and indigenous medicine. Their eggs were eaten. The major reasons for their decline, however, are the loss of riverine habitats with the construction of dams, barrages, irrigation canals and artificial embankments; change of river course due to siltation and sand-mining, the increased use of gill fish nets in their habitats and land encroachment near rivers for agriculture and livestock grazing. By the mid-1970s their population was estimated at less than 200 individuals. (WII-GACMC, 2018).

Conservation programmes initiated in India since the late 1970s, successfully re-introduced captive-bred gharials in the early 1980s in protected stretches of the Ganga River basin. Captivity-bred populations are now present in the Western Ramganga River in the Corbett National Park, in the Hastinapur Wildlife Sanctuary, along R. Ganga's main stem, the Girwa River in the Katarniaghat Wildlife Sanctuary, in the National Chambal Sanctuary where more than 1250 individuals were counted in 2017, in River Parbati, a tributary of the Chambal River, R. Yamuna near the confluence of the Ken and Yamuna rivers and R. Sone in Bihar. Wild-born gharials are seen in the Gandaki and the Kosi rivers. Gharials are also occasionally sighted in R. Ganga between Bhagalpur and Sultanganj in Bihar (Nawab et al, 2016). GACMC's rapid biodiversity assessment, reported gharials in the Rajaji NP, downstream of the Bhimgoda barrage on R. Ganga.

The gharial is legally protected in India under the Wildlife Protection Act, 1972 as a most endangered Schedule I species (Nawab et al, 2016). Since 2007 it has been on the IUCN Red List as critically endangered. It is also listed in CITES Appendix I (Lang J. et al, 2019).

Mugger Crocodile: The mugger crocodile *(crocodylus palustris)* is a highly-adaptable, swamp-loving, protected species under Schedule I of the Wildlife (Protection) Act1972. It preferentially inhabits slow-moving rivers, deep pools, swamps, lakes and village ponds. In Uttarakhand it is found in the Kalagarh dam reservoir and the Corbett National Park, R. Ganga's stretch near the Rajaji National Park and the Haridwar and Lansdowne Forest Divisions (Nawab et al, 2016). In Uttar Pradesh, its presence is reported from the Hastinapur Wildlife Sanctuary and the Ramsar site between Garhmukteshwar and Narora. Significant populations are present in the Bihar-Jharkhand stretch of the Ganga and in R. Chambal. Habitat alteration and destruction, agricultural and industrial expansion, illegal poaching for skin, meat and eggs, entanglement in fish nets and the use of body parts for medicine are the major threats to this species.

Estuarine Crocodile: The salt water estuarine crocodile *(crocodylus porosus)* was once found all along eastern India's Bay of Bengal coastline, from the southern Kerala tip to the Sundarbans. A much smaller population now exists only in the Sundarbans Ganga delta and the Brahmani-Baitarani delta in Odisha (WII-GACMC, 2018). Nest damage for its eggs, illegal poaching for meat and skin, and habitat loss or alteration due to natural or anthropogenic causes, gravely threaten its survival.

Testudines (Turtles, terrapins and tortoises)

With 24 freshwater turtle species and four species of tortoises, India has a very diverse turtle fauna. River Ganga has nine hardshell species, viz., *Batagur kachuga, B. dhongoka, B. baska, Hardella thurjii, Pangshura tecta, P. smithii, Geoclemys hamiltonii, Melanochelys trijuga* and *P. tentoria*. The soft-shell turtle species in the Ganga are *Nilssonia gangetica, N. hurum, Chitra indica* and *Lissemys punctata.*

R. Ganga is home to 13 turtle and one tortoise species (WII-GACMC, 2018, p.45). Much earlier, however, a WWF-India study had reported that the Ganga river system supported 18 species of turtle fauna (Choudhury & Bhupathy, 1993). In the Ganga river stretch between Haridwar and Kanpur, Rao (2001) identified 12 turtle species. Sinha (1999) observed plenty of hard shell and soft-shell turtles in the Ganga between the Bijnor and Narora barrages.

The WII-GACMC rapid biodiversity assessment sighted 2788 turtles. They were most frequently encountered between Makdumpur (south of the Bijnor barrage) and Kanpur. Of these 2693 (~97%) were hard-shell species, *Pangshura* being the most abundant, followed by *B. dhongoka* and a few *Geoclemys hamiltonii* and *Hardella thurjii*. *Nilssonia gangetica* was the more frequently encountered soft-shell species. Turtles are mostly seen in shallow water or basking on sandy islands and river banks, especially those that are far from human settlements as between Bijnor and Narora. But given the nature of the river, these are often dynamic (shifting) locations. *Pangshura spp.* and *Batagur sp.* were also seen basking on submerged logs and bushes, while *N. gangetica* were mostly seen basking on sandy islands.

Soft shell turtles are collected from Uttar Pradesh and Bihar and sent to markets in West Bengal. In the last decade, every year hundreds of such turtles were often confiscated in Bihar. Local fishermen reported that organized smugglers poached large numbers of soft-shell turtles in River Ganga at Patna during April-May 2013 and smuggled them to Kolkata after sun-drying them (Sinha R.K., 2013). The populations of hard-shell species like the *B. baska* in the lower Ganga stretches were destroyed by habitat destruction and poaching (WII-GACMC, 2018).

Soft-shell turtles are natural scavengers of the river and to augment their population, about forty thousand turtles were released in the 1990s in the Ganga near Varanasi under the Ganga Action Plan. Sightings of turtle hatchlings and juveniles between Bijnor and Narora lend hope of a recovering population.

6.4.4. Birds

Several avifauna habitats, including wetlands, lakes and marshes in the Ganga River basin are Protected Areas (PAs) for local waterbirds and migratory species (See also Chapter 8). The Zoological Survey of India reported 177 bird species from River Ganga (ZSI, 1991). Later surveys identified 162 species in the 500 km stretch from Buxar to Maniharighat, Katihar (Sinha R.K., 2014, p.304). WII-GACMC's rapid biodiversity assessment recorded 140 bird species, including 129 waterbirds and obligate species in River Ganga habitats.

There is a dearth of older avifauna distribution studies along River Ganga. Rahmani (1981) recorded 120 bird species at the Narora barrage (WII-GACMC, 2018, p.24). Much later, Bashir et al (2012) found 55 species between Bijnor and Narora. Bilgrami (1991) reported 23 bird species from Munger to Farakka. Rao (2001) observed 46 species between Rishikesh and Kanpur.

The WII-GACMC rapid survey in 2017 found that ducks and geese (Family Anatidae) were dominant with 26 species, followed by waders (Scolopacidae) and egrets and herons (Ardeidae). Six species are critically endangered, three are endangered species and three are vulnerable. Eleven species are near threatened.
The survey confirmed the rich avifauna abundance of the middle Ganga stretch, from Bijnor to Ghazipur. Several globally threatened species like the Sarus crane *(Antigone antigone)*, Indian skimmer *(Rynchops albicollis)*, river lapwing *(Vanellus duvaucelii)* and black-bellied tern *(Sterna acuticauda)* breed on the Ganga's islands, banks and sandbars.

The river lapwing was the most commonly encountered and distributed species. Its richest stretch was from Bijnor to Ghazipur with maximum abundance at Kanpur. The

Indian skimmer was also most frequently found in the Bijnor-Ghazipur reach, with maximum abundance at Varanasi. Sarus cranes were observed from Brijghat to Mirzapur with maximum abundance near Bhitaura, followed by Kanpur. Black-bellied terns were frequently seen in a shorter stretch from Bijnor to Kannauj. Their maximum abundance was between Narora and Kannauj and Sahibganj to Rajmahal.

The WII-GACMC survey did not estimate population trends of the different species due to lack of adequate time-trends data. The distinctive avifauna of River Ganga and its sandbanks like black-bellied tern and Indian skimmer are increasingly threatened by declining dry season flows and agricultural encroachment, sand mining and flooding of nests. The Pink-headed duck *(Rhodonessa caryophyllacea)* is already probably extinct (Nawab et al, 2016, p.199). Sarus cranes are vulnerable to habitat loss due to degradation of wetlands and chemical pollution (WII-GACMC, 2018, p.28). Since migratory birds prefer wetlands and water bodies, they are also threatened by urban expansion, effluents discharge, xenobiotic compounds and bird flu. Some of these species are also susceptible to global climate fluctuations. Heavy use of pesticides and loss of riparian vegetation are other important threats (R.K. Sinha and K. Kannan, 2014).

The WII-GACMC report concluded that, "More extensive studies on the distribution and ecology of these birds are essential for planning their conservation."

6.4.5. Mammals

India's National Aquatic Animal, the Gangetic River Dolphin *(Platanista gangetica)* and three otter species, the Smooth-Coated Otter *(Lutrogale perspicillata)*, the Eurasian Otter *(Lutra lutra)* and the Asian Small-Clawed Otter *(Aonyx cinereus)* are the known mammalian species in the R. Ganga basin (WII-GACMC, 2018). "These animals are at the top of the food chain. They can move rapidly between habitats. They help stabilize the ecosystem by transporting energy and nutrients between systems," says Dr. Ruchi Badola, a scientist at WII's Ganga Aqualife Conservation Monitoring Centre (GACMC).

Gangetic River Dolphin (Platanista gangetica)

Anderson (1878) estimated an abundance of about 10,000 Gangetic River Dolphin (hereafter Gangetic Dolphin) in R. Ganga and its tributaries. "But today the species is facing a severe threat of extinction throughout its distribution range in the Ganga and its tributaries," says Dr. R.K. Sinha, who has spent a lifetime researching the species and is often referred to as 'Dolphin Sinha'. The Gangetic Dolphin is included in Schedule-I of the Indian Wildlife (Protection) Act, 1972.[xi] IUCN (International Union for Conservation of Nature) moved it from the vulnerable category to the endangered list in 2004 (WII-GACMC, 2018).

Reeves et al. (2000) suggested a population of only 2500 Gangetic Dolphins in the entire Ganga basin (including India, Nepal, Bhutan and Bangladesh) of which the Indian population was put at about 1800 individuals (Nawab et al, 2016 p. 203). Smith et al. (2001) estimated 5000-6000 Dolphins (Nawab et al, 2016 p. 204). More recently Sinha and Kannan (2014) gave an estimate of 3526 for the early 2000s out of which just over 3000 were in the Indian Ganga basin (WII-GACMC, 2018). Nawab et al. (2016, p. 195) have summarized the different numbers of Gangetic Dolphin sightings in different stretches of R Ganga between Haridwar and Farakka in recent years.

The population is now largely concentrated in the middle Ganga stretch where dams and barrages and shallow waters are minimal. The WII-GACMC (2018) study reported maximum encounter rates between Prayagraj and Buxar, followed by the Vikramshila Gangetic Dolphin Sanctuary. Earlier studies had reported the highest encounter rates from this Sanctuary stretch. But the decision to develop the 1620 km long National Waterway 1 (NW 1) from Haldia to Prayagraj could devastate the Sanctuary, an optimal dolphin habitat (See box: Underwater Vessel Noise and River-bottom Dredging Harms Ganges River Dolphin in Chapter 11).

Reduced water flows, lower prey availability and water pollution have restricted the Gangetic Dolphin habitats. Fishing with gill nets and overfishing have reduced their numbers. In the main stem, the optimal habitats up to the Farakka barrage are from Brijghat to Narora and from Prayagraj to Bhagalpur, while downstream of Farakka on the Hooghly they are from Gopal Ghat to Palasi and from Ram Nagar to Nabadwip and further downstream to Howrah-Kolkata.

Otters

Otters are specially adapted for a semi-aquatic existence. They are top predators in aquatic

Image 20 : Gangetic River Dolphin (Platanista gangetica)

Source: Ganesh Choudhary, NMCG

Image 21 : Smooth Coated Otter

Credits: Lip Kee Yap, Singapore | wikicommons.org

ecosystems but are sensitive to degradation of their habitats and food chain. They are mainly nocturnal, live in small groups and therefore hard to spot.

In the late nineteenth century, British administrators and naturalists wrote the earliest authentic accounts of otters in the Ganga river basin. Atkinson's well-known Himalayan Gazetteer (1882, 1974) reported the existence of the smooth-coated otter in the Terai region, from the Yamuna, Salt Lake and the Sundarbans (WII-GACMC, 2018). In the last decade its presence was observed in the Alaknanda, Western Ramganga and Sonanadi rivers in Uttarakhand, the Hastinapur Wildlife Sanctuary, Bijnor-Narora stretch and the Vikramshila Gangetic Dolphin Sanctuary.

Historically, the Eurasian otter was distributed in the Himalaya and the Upper and Lower Ganga plains up to Kolkata (WII-GACMC, 2018). Atkinson found its presence in rivers throughout the Himalayan foothills like the Ramganga and Suswa (Dehra Doon) and the Terai region. More recently signs of its existence have been reported from the Ramganga river.

The Asian small-clawed otter's distribution has been historically discontinuous but wide, ranging from the colder Pindar and Nandakini rivers in Uttarakhand, the Sharda river at Barmdeo, other major tributaries of R. Ganga and in the Sundarbans. They are said to prefer streams free from human disturbances.
During the rapid biodiversity assessment in the R. Ganga basin by WII-GACMC, evidence or direct sighting of the smooth-coated otter was reported from the Ganga downstream of Devprayag, in the Rajaji NP downstream of Bhimgoda barrage, Munger and at Kahalgaon in the Vikramshila Gangetic Dolphin Sanctuary. It was also noted that the distribution of all the three otter species was patchy with decreasing populations in their entire range. The historical and present distribution of otters in the Ganga river basin is summarized in Table 18.

Table 18 : Distribution of Otters in the Ganga Basin

Species	Scientific name	IUCN	Uttara-khand	Uttar Pradesh	Bihar	Jharkhand	West Bengal
Smooth-coated otter	*Lutrogale perspicillata*	Vul	H+P	H+P	H+P	H+P	H+P
Eurasian otter	*Lutra lutra*	NT	H+P	-	-	-	-
Asian small-clawed otter	*Aonyx cinereus*	Vul	H+P	-	-	-	-

Source: WII-GACMC, 2018, p.20

Note: Vul=vulnerable, NT=Near threatened, H=Historical, P=Present.

Otter populations in the Ganga are declining rapidly due to reclamation of wetlands for human habitations and agriculture, construction of large-scale hydroelectric projects, reduction in prey biomass, poaching and contamination of waterways (WII-GACMC, 2018).

6.5 BIODIVERSITY IN SOME RIVERS OF R. GANGA'S SOUTHERN BASIN

6.5.1 Biodiversity in River Chambal

The 960 km long Chambal River originates in the northern slopes of the Vindhyan range and joins the Yamuna near Bareh in Uttar Pradesh. Its rain-fed catchment is characterized by an undulating floodplain, gullies, forests, ravines and varying other land uses (Nair T., 2016). The major tributaries of the Chambal include the Shipra, Kalisindh, Choti Kalisindh, Banas, Parbati, Parwati and Kuno, among many others (Jain et al. 2007; Gopal & Srivastava 2008). The Chambal River suffers severe hydrological modifications from water impoundment, extraction and riverbed mining.

The National Chambal Sanctuary (NCS) extends over a ~600 km long arc of the Chambal River, in two stretches: (i) The upper sector, extends from Jawahar Sagar Dam to Kota Barrage and (ii) The lower sector begins from Keshoraipatan in Rajasthan to the Chambal-Yamuna confluence in Uttar Pradesh. The Chambal averages 400 m in width while depth ranges from 1–26 m (Nair T. & Krishna Y.C. , 2013). The NCS lies within a semi-arid zone with a mean annual precipitation of 590mm, the bulk of which is received during the south-west monsoon. Evergreen riparian vegetation is completely absent, with only sparse ground-cover along the severely eroded river banks and adjacent ravine lands (Nair T. & Krishna Y.C., 2013).

Vertebrate Fauna

Nair and Krishna (2013) recorded 147 fish species of 32 families, 56 reptile species comprising 19 families, 308 bird species from 64 families and 60 mammal species comprising 27 families in the Chambal basin, based on available literature and field observations (Nair T. & Krishna Y.C., 2013). The IUCN Red List of Threatened Species (IUCN 2011) has included six species as Critically Endangered, 12 Endangered and 18 Vulnerable.

The NCS is among the most important and significant habitats where several globally threatened fauna still survive. It contains the most viable breeding populations of the Critically Endangered Gharial *(Gavialis gangeticus)* and the Red-crowned Roofed Turtle *(Batagur kachuga)*.

It is among the most important habitats of the Deccan Mahseer *(Tor khudree)*, Putitor Mahseer *(Tor putitora)*, Narrow-headed soft-shell Turtle *(Chitra indica)*, Three-striped Roofed Turtle *(Batagur dhongoka)*, Indian Skimmer *(Rynchops albicollis)*, Black-bellied Tern *(Sterna acuticauda)*, Sarus Crane *(Grus Antigone)*, and the Gangetic River Dolphin *(Platanista gangetica)*. The Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), lists both the flagship species of the NCS, the Gharial and the Gangetic River Dolphin. The NCS is also a strong candidate for the World Heritage and Ramsar Convention listings.

The NCS functions as a vital source and nursery for fish fry and fingerlings, contributing significantly to downstream fisheries in the Gangetic river system (Nair T. & Krishna Y.C., 2013). It is an Important Bird Area particularly for the Pallas's Fish-Eagle *(Haliaeetus leucoryphus)* and the Greater Spotted Eagle *(Aquila clanga)* among other water birds (Islam & Rahmani 2004). The NCS also serves as among the best over-wintering sites for migratory birds.

6.5.2 Biodiversity in the Ken and Betwa rivers

The Ken and Betwa rivers are the two major tributaries of the Yamuna in Bundelkhand. The Ken originates on the northern slope of the Kaimur Range and flows about 427 km before joining the Yamuna at Chilla Ghat in Fatehpur district, Uttar Pradesh. It is one of India's few remaining pristine major rivers (See also section 6.7.3 for River Ken). The Betwa rises near Raisen in Madhya Pradesh and joins the Yamuna in Hamirpur district, Uttar Pradesh after traversing about 590 km. Much of its flows have been modified by dams and barrages.

The biotic parameters were observed in similar ranges and moderate condition. Sixty-one planktonic forms were recorded from the two rivers out of which 55 were phytoplankton. For the first time, 89 fish species belonging to 10 orders, 26 families, and 62 genera have been recorded in the river Ken, while 81 species classified under 10 orders, 24 families, and 55 genera were found in the Betwa. Exotic fish species were also observed in the downstream stretches of both rivers. Out of the total fish species, 77 were common to both rivers, 12 were found only in the Ken River, and 4 species were restricted to the Betwa (Joshi K.D. et al, 2017).

Analysis of relative abundance showed dominance of *Labeo boggut* (minor carp) in the Ken and *Osteobrama cotio* (also a minor carp, dhela in Bengali) in the Betwa River. The Shannon–Wiener Diversity and Evenness Indices values for fish were slightly higher for the Ken (3.76 and 0.842) than for the Betwa (3.66 and 0.835). Nine near-threatened fish species was recorded in the two rivers (Joshi K.D. et al, 2017).

6.5.3 Comparative Biodiversity of Ken, Paisuni (Mandakini) and Tons Rivers[xii]

Besides R. Ken, two other tributaries in the south basin of R. Ganga originate from the Central Highlands (CH). The Paisuni river, also known as Mandakini, to the east of the Ken, is a small interstate tributary of the Yamuna. Its origin is in the central part of Satna district in Madhya Pradesh. It merges with the Yamuna in Chitrakoot district of Uttar Pradesh. It is considered to be a sacred river. The historic town of Chitrakoot on its banks is a pilgrimage centre. Lord Ram, Sita and Lakshman are said to have spent many of their years in exile in the forests of the Paisuni basin. River Tons (also known as Tamas or Tamsa), further to the east, is another interstate river whose source is in the Kaimur range of Madhya Pradesh. It joins the Ganga at Sirsa, between Prayagraj and Mirzapur. Lord Ram, Sita and Lakshman are said to have spent their first night of exile on its banks. River Ken is the longest of the three rivers and Paisuni is the shortest.

Longitudinal Patterns Of Richness And Density Of Benthic Flora

Verma, Nautiyal and Srivastava (2016) undertook a pioneering study of diatoms diversity in the Ken, Paisuni and Tons (K, P, T) rivers. They observed that diatoms in the three CH tributaries are dominated by biraphids, like the Ganga's Himalayan tributaries. The indices of taxa richness and diversity showed that these CH rivers are more diverse than rivers in other parts of India, probably due to their catchments being less exploited for anthropogenic purposes. More specifically Nautiyal P. et al (2017a) recorded overall 293 taxa of benthic diatoms from 50 genera in the Ken (205), Paisuni (202) and Tons (211) rivers. In the Ken, diatom richness declined downstream of the headwater section, while in the case of the Paisuni and Tons, richness increased from the headwaters to the middle section but decreased from the lower to lowland section.

Benthic Macroinvertebrate Fauna

Nautiyal P. et al (2017a) recorded 28 invertebrate taxa (class/families), including those from seven insect classes at the ecoregion scale, and 21, 24 and 27 taxa at the basin scale in the Ken, Paisuni and Tons, respectively. Species richness was high in the middle and lower sections of the Ken, the middle and lowland sections of the Paisuni, and the headwater and lower sections of the Tons. Longitudinally, the mean density decreased from the headwater to the lowland section in the Ken and Tons, but increased in the Paisuni.

The community consisted of Insecta (20 taxa), Crustacea (1), Gastropoda & Pelecypoda (3), Oligo, Polychaeta, Hirudinea (1 Family each) and Miscellaneous (4).

Table 19 : Longitudinal Distribution of Benthic Macroinvertebrates in the Ken, Paisuni and Tons Rivers

S.No.	Stretch	No. of Species	Remarks
K	**Ken**		
K1	Headwaters	12	Mayflies relative abundance decreases and that of Diptera, Odonata and Heterodonta (mollusc) increases from headwaters to mouth. Caddisflies increase towards lower section, but decline abruptly in at the mouth, whereas Polychaeta increases abruptly. Neoephemeridae, Chironomidae, Thiaridae decline; Caenidae increase.
K2	Middle	15	
K3	Lower	14	
K4	Lowland	NA	
T	**Tons**		
T1	Headwaters	19	Chironomidae increased and Leptophlebiidae decreased from T1 to T4. Assemblages varied from headwater to mouth but dominated by Thiaridae at all stations except Neoephemeridae in lower section.
T2	Middle	NA	
T3	Lower	19	
T4	Lowland	11	
P	**Paisuni**		
P1	Headwaters	10	Longitudinally mayflies are the major component. Baetidae, Chironomidae and Gomphidae increase from P1 to P4, while Leptophlebidae, Heptagaenidae, Neoephemeridae, Rhyacophilidae and Thiaridae decline from P1 to P4.
P2	Middle	NA	
P3	Lower	NA	
P4	Lowland	13	

Source: Compiled from Nautiyal P., Pers. Comm.

Functional composition: The headwaters are heterotrophic and lowlands are autotrophic. In the Ken and Tons rivers the share of collectors decreased from headwater to mouth. The scrapers increase substantially downstream of source in the Ken and Tons, but decrease in the Paisuni.

Fish Catch

The fish fauna constituting catch comprised of 56 species in the Ken, 48 in the Paisuni, 52 in the Tons, with 43 species being common to all three rivers. The invasive exotic *Cyprinus carpio* and miscellaneous fish species dominate the present day catch, as the exploitation rate of the endemic species (*L. rohita, T. tor* and other major carps) is high.

Table 20 : Community Composition of Fish Catch in the Ken, Tons & Paisuni rivers

S. No.	River	Community Composition in %
1.	Ken	*Cyprinus carpio* dominated (17.8%) the catch compared with *Aorichthys spp* (17.1%) and miscellaneous (12.4%). *L. rohita, Catla catla, Cirrhinus mrigala* and *L. calbasu* contributed 6.21%, 2.8%, 6.17% and 11.0%, respectively. *T. tor* and *Wallago attu* accounted for 2.82% and 8.7%.
2.	Tons	Miscellaneous fish dominated the Tons river (15%) compared with *Aorichthys spp* (14.3%) and *L. calbasu* (12.1%). *L. rohita, C. catla* and *C. mrigala* accounted for 8.3%, 4.35% and 7.75%, respectively. *T. tor, C. carpio* and *W. attu* contributed 5.75%, 4.06% and 7.22%, respectively.
3.	Paisuni	*L. calbasu* dominated (14.8%) compared with *H. molitrix* (13.6%) and miscellaneous (12.3%). *L. rohita, C. catla* and *C. mrigala* contributed 4.88%, 4.1% and 6.5%, respectively. T. tor accounted for 1.27% only. *Aorichthys spp.* and *C. carpio* contributed 8.53% and 6.43%, respectively.

Source: Dwivedi A. C. et al, 2017

Image 22 demonstrates the adverse impact of over-fishing in terms of the exploitation rate, exploitation ratio and mortality rates of the fish species. The mortality and therefore the exploitation rates are highest for *T. tor* followed by *L. rohita*. The maximum contribution to mortality is from fishing mortality (F) in all three species. This can be extrapolated to all fish species of any consequence to fishery (Dwivedi A. C. et al, 2017).

6.6 CONCLUSIONS & RECOMMENDATIONS

Broad conclusions and recommendations pertaining to the biodiversity in the Ganga river system and its sustenance are discussed in this section in terms of (i) the high biodiversity stretches that still extend over almost half of the main stem's length, (ii) the major threats to the diversity in the river system and (iii) the broad principles that must guide effective strategies to sustain and enhance the biodiversity.

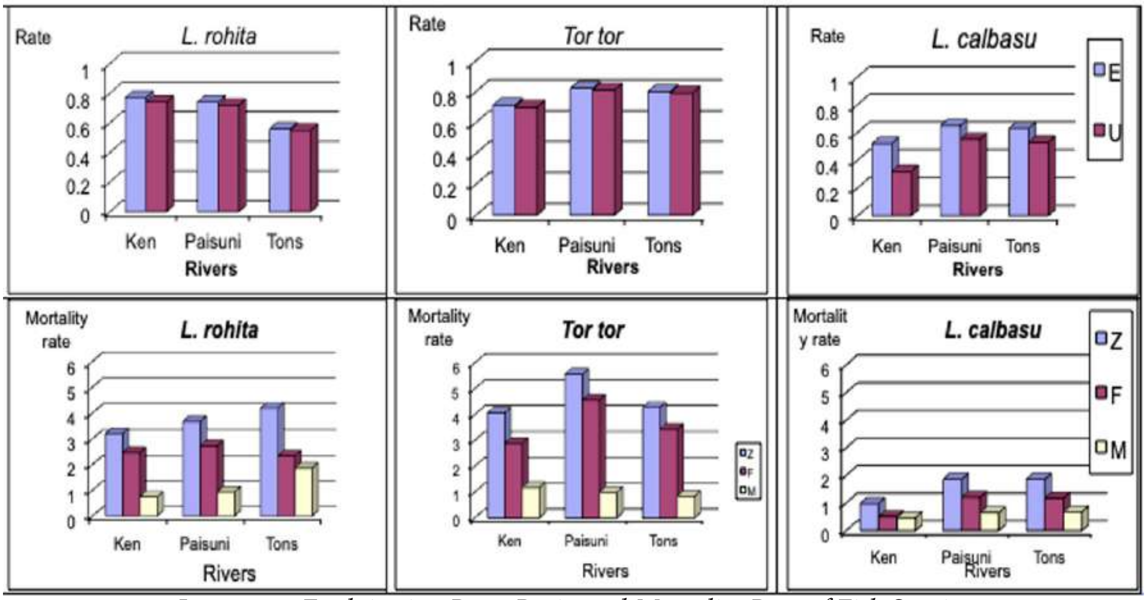


Image 22 : Exploitation Rate, Ratio and Mortality Rate of Fish Species

Note: E-exploitation rate; U-exploitation ratio; Z -Total mortality; F-Fishing mortality; M-Natural mortality

Source: Dwivedi A. C. et al, 2017

6.6.1. Ganga River Stretches with High Biodiversity Values

Natural attributes like a wide altitude range and a variety of climates make the Ganga river basin one of the most biodiverse basins in the world. Nilsson et al (2005) studied the world's 292 large river systems and reported that, "the Ganga-Brahmaputra system encompasses the widest diversity (10 biomes)."

An important output of WII-GACMC's 2016-2018 rapid biodiversity assessment is the identification of Ganga river stretches with high biodiversity value. These are shown in Map 22. Their characteristics are summarized in Table 21. It shows that almost half the entire length of River Ganga has high biodiversity value. It is perhaps an indication of the well-known very high self-purifying capacity of R. Ganga and its tremendous resilience.

The WII-GACMC study has also suggested that channel depth is a major limiting factor for species distribution. It estimates that about 38.7% of the channel depth is optimal for the Gangetic river dolphin (8.4%, > 10m) and the gharial (30.3%, 4-<10m). These depths are available in scattered pools, while shallow depths (<4m) prevail throughout the river.

6.6.2. Biodiversity Threats in the Ganga and its Major Tributaries

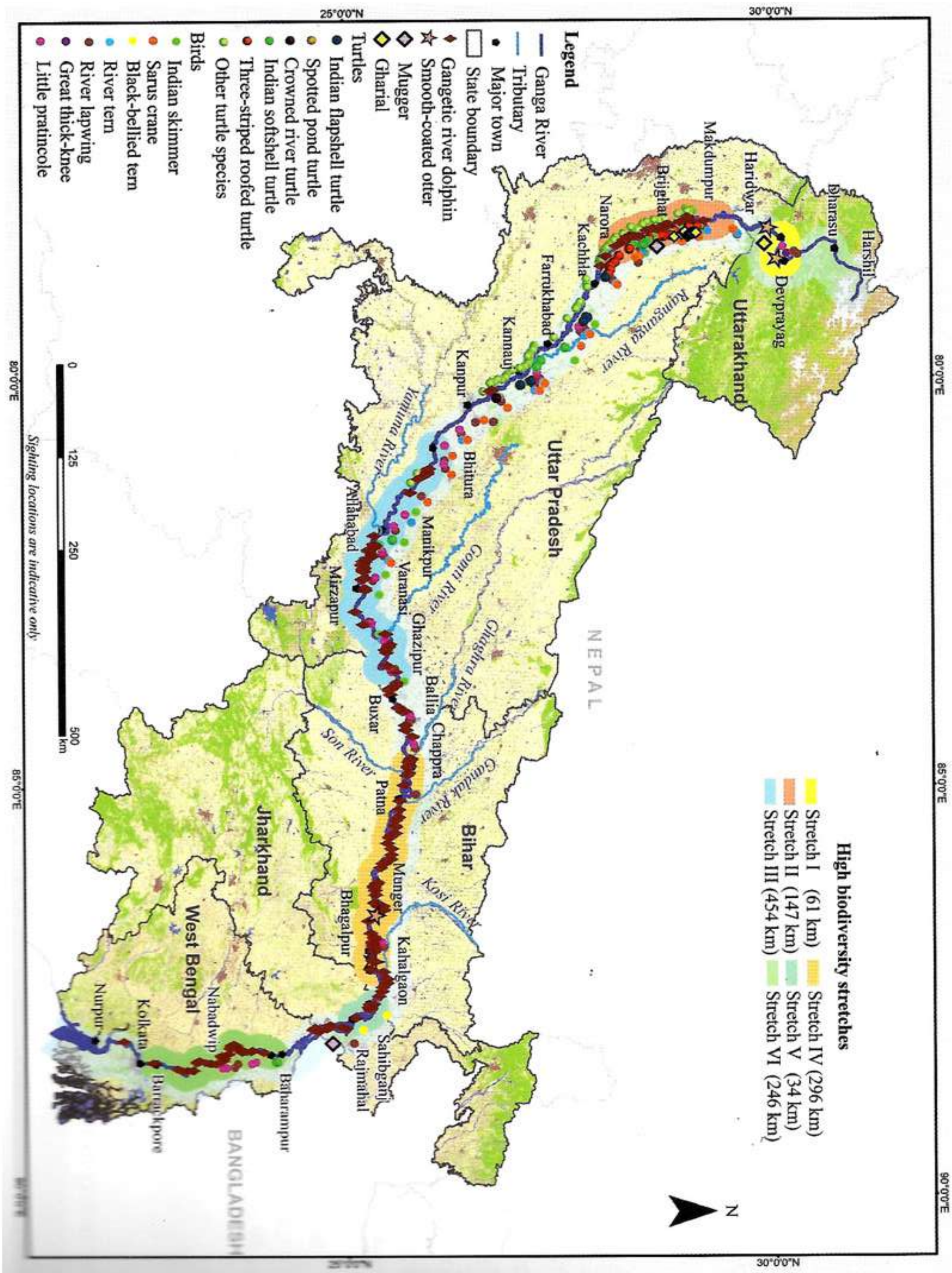
The primary threats to the biodiversity in River Ganga and its major tributaries are due to

(i) flow alterations by dams, barrages and embankments and deforestation in the catchments; (ii) pollution by urban sewage releases, industrial effluents and the indiscriminate use of chemicals in agriculture; and (iii) excessive resource extraction like riverbed materials (RBM), over-fishing and poaching. As mentioned earlier (See section 6.4.1), polluted river water has increased pollution-tolerant invasive fish species over native species in large numbers (CIFRI, 2019, p.48).

New threats have emerged this decade from the development of National Waterway 1 (See Chapter 11) and the push to interlink rivers (See Chapter 11). Land use changes and a high human population density also threaten the biodiversity of the Ganga River system.

Table 21 : High Biodiversity Value Stretches Along River Ganga

Stretch	**Location**	**Length (km)**	**Biogeographic Province**	**River Characteristic**	**River depth (m) (average)**	**Significant Aquatic Flora & Fauna Observed**	**Threats**
I	Devprayag to Rishikesh[xiii]	61	2B	Rapid with rocky or stony bottoms (e.g., Kaudiyala, Rishikesh), deep gorges and gentle slopes	NA	93 phytoplankton, 76 periphyton and 19 zoobenthic species Otter species – 3 Avian water bird species - 41 Fish species – 56 cold water species including the Golden Mahseer	Structural changes in river morphology and loss of connectivity due to hydroelectric projects. Collection of sand and boulders. The cold-water fish species display a variety of hill stream adaptations in different body parts (lips, throat, fins, body shape)



Map 22: High Biodiversity Value Stretches in the Main Stem of R. Ganga

(Source: WII-GACMC)

II	Makdumpur to Narora	147	7A	Meandering channels with extensive alluvium sandbars and mid-river	1.6 to 5.2 (2.3m)	35 phytoplankton and 31 zooplankton 41 Gangetic river dolphin individuals Avian water bird species - 62 Reptilian species – 2 Crocodilians; 3 Turtle species Fish species – 80	Excessive water abstraction leading to reduced flow and water depth. Unsustainable resource extraction, such as excessive fishing and sand mining. Cultivation on river islands and sand bars, leading to altered river bank. Poaching of turtles.
III	Bhitaura to Ghazipur	454	7A	Highly braided and anastomosed, with sandbars, meander belts and ox-bow lakes	1.1 to 20.4 (3.7m)	357 phytoplankton, 19 periphyton, 19 zooplankton and 45 zoobenthic species 269 Gangetic river dolphin individuals Avian species - 140, including 193 Indian skimmer individuals and 6 nesting colonies Reptilian – 2 Turtle species Fish species – 50	Excessive water abstraction leading to reduced flow and water depth. Industrial and domestic discharge into the river. Unsustainable resource extraction, such as excessive fishing and sand mining. Cultivation on river islands and sand bars, leading to altered river bank. Poaching of turtles.

IV	Chhapra to Kahalgaon	296	7B	Very wide, highly braided with large, stable islands, meanders and ox-bow lakes	1.6 to 33.2 (4.7m)	More than 80 phytoplankton, zooplankton species Gangetic river dolphin – 141 individuals Otter species – 1 Fish species – 61 species	Excessive water abstraction leading to reduced flow and water depth. Unsustainable resource extraction, such as fishing. Cultivation on river islands and sand bars, leading to altered river bank. Poaching of turtles and Gangetic river dolphin. Industrial and domestic discharge into the river.
V	Sahibganj to Rajmahal	34	7B	Very wide, highly braided and anastomosing with multichannel formation on an alluvial plain	1.5 to 14 (5.8m)	182 phytoplankton and 40 zooplankton species Gangetic river dolphin – 7 individuals Otter species – 1 Fish species – 89 species	Alteration of the river bank due to agriculture, sand mining. Unsustainable resource extraction such as over-fishing. Poaching of turtles and Gangetic river dolphin. Industrial and domestic discharge into the river.

VI	Baharampur to Barrackpore	246	7B	Highly meandering, with convex sandbars and a few mid-river islands	2.9 to 31 (8.1m)	44 phytoplankton and 21 zooplankton species Gangetic river dolphin – 49 Reptilian species – 2 Turtle species Fish species – 25 species	Altered flow regime due to Farakka barrage leading to river bank erosion. Industrial and domestic discharge into the river. Destructive fishing practices.

Source: Adapted from WII-GACMC (2018) Table 3.8 & pp.77-81

Notes: 2A = West Himalaya, 7A = Upper Gangetic Plain, 7B = Lower Gangetic Plain

Upper Ganga Basin

The headstreams of R. Ganga in the upper mountainous stretch in Uttarakhand mainly flow through gorges and narrow valleys, with very few flood plains to speak of. Generally, the bed slopes are steep and the stream velocities are high in this stretch. Forested slopes provide year-round base flows. The overall population density is relatively low (~190 pers/km^2).

Flow Alterations: The Uttarakhand state government's plans to build about 450 hydroelectric projects (HEPs) on these rivers pose the greatest threat in the Upper Ganga basin. Most of these structures are diversion projects that dry the river between the dam and the powerhouse reduce it to a narrow channel. A Supreme Court-appointed Expert Body report on the environmental impact of hydropower development in Uttarakhand cited several rivers with dams located in a series that have fragmented their lengths, disrupted fish migration and led to loss of biodiversity (EB, 2014, p. 40).

A CPCB study at 11 HEP stations concluded that populations of sensitive benthic macro-invertebrates declined 50 to 90 per cent downstream of dams/barrages, because stream flow alterations changed the bed strata (CPCB, 2007). A report on aquatic biodiversity under Namami Gange prepared by the Wildlife Institute of India categorically said that 28.6 per cent of R. Bhagirathi channels and 35.2 per cent of Alaknanda channels had become 'ecological deserts' due to 16 existing, 14 ongoing and the situation would be worsened by 14 proposed hydroelectric projects on the Bhagirathi and Alaknanda river basins. The report expressed an apprehension that loss of flows due to dams and barrages on R. Ganga could lead to the extinction of the Ganga River dolphin (Kaur, 2018).

The Bhimgoda barrage, the Srinagar dam and the Tehri dam have affected the migration of the prized golden mahseer. Dams in the Upper Ganga reach have also fragmented and shrunk the distribution range of cold water schizothorax (trout) species (Sarkar et al., 2012).

Deforestation in the Upper Ganga catchment is a serious threat to the sustenance of base flows in the headstreams. The contribution of base flows to the annual discharge in rivers is generally under-appreciated, e.g., the average contribution of snow- and glacier-melts to the annual flow of R. Ganga at Devprayag is estimated to be only about 28% (Singh P. et al, 1994). The rest is rain water and a large fraction of that is base flows. Forested slopes ensure sustained base flows during the non-rainy months, especially where the underlying rocks have good water holding capacities. Since the formation of Uttarakhand state in November 2000, by 2013 more than 30,000 ha of forest areas had been diverted for non-forest use. The base flows in several rainfed rivers of Uttarakhand like the Kosi, Nayar, Gaula, Panar, Gagas, etc. have declined precipitously in the last few decades due to deforestation. The Nayar is a critical breeding habitat for the golden mahseer and associated species (EB, 2014, p.119).

Water Quality: Water pollution is not a major problem in mountain rivers, except at a few specific locations downstream of large towns or cities. From time-to-time the BOD levels in R. Ganga downstream of Haridwar city rise above the 3mg/l permissible limit due to the release of untreated or partially treated effluents from the Jagjeetpur STP.

Mining Riverbed Materials (RBMs): Besides sand, RBMs include boulders, cobbles and gravels. Illegal mining of RBMs, using heavy earthmoving equipment, has reached menacing proportions in the Ganga – downstream of Haridwar and the Yamuna, near the border of Uttarakhand and Himachal Pradesh. Truckloads of RBM are removed every day at various locations on major Ganga tributaries like the Alaknanda and Sharda and several small feeder rivers like the Gaula, Nandhaur, Kosi, Song and Jakhan in Uttarakhand. Unscientific mining of river beds destroys aquatic habitats and thereby affects all aquatic biota from tiny periphytons to the local fish populations (See section 6.4.1).

Critical Locations: River Bal Ganga sub-basin of the Bhagirathi is a breeding habitat for many threatened migratory species, including the golden mahseer. The Nayar is perhaps the only other breeding habitat for the golden mahseer in the Upper Ganga stretch. WII has proposed that they be protected as Fish Conservation Reserves (EB, 2014, pgs 114 & 119). The stretch of the Ganga in Haridwar and just downstream of it faces episodic pollution threats during festivals when lakhs of people arrive for mass bathing, unless there are adequate releases from dams upstream. Inadequately treated and accidental releases of untreated effluents from the Jagjeetpur STP are added threats. Massive illegal RBM has also wrecked the aquatic biota just downstream of Haridwar (See section 6.4.1).

Middle Ganga Basin

The initial stretch of the main stem of R. Ganga consists of sand, gravels and boulders which give way to only fine sand lower downstream. The bed slope is almost flat, about 1 in 5000 and the river velocity past Narora becomes sluggish in the non-monsoon months. The biodiversity in many tributaries in the Middle Ganga Basin is also endangered.

Flow Alterations: The Bhimgoda Barrage at Haridwar, the Middle Ganga Barrage at Bijnor and the Lower Ganga Barrage at Narora divert almost 90% of the flow in the lean season. These abstractions severely deplete the Ganga until the Western Ramganga at Kusumkher, the Kali at Kannauj and the Yamuna at Prayagraj replenish it. The river channel becomes lean in some parts and braided in others, grievously harming the bottom dwelling biota.

- Once the Gangetic Dolphin was found in the entire plains stretch from Haridwar to the Sundarbans, but now it is limited to downstream of the Bijnor barrage, with the Garhmukteshwar-Narora stretch being an optimal habitat. The depletion of the Yamuna's flow by all the barrages on it in Uttarakhand, Haryana, Delhi and Uttar Pradesh has led to the dolphin being sighted only below its confluence with River Chambal near Etawah (WII-GACMC, 2018, p.16).
- Dams on R. Chambal have played havoc with the finely-tuned evolutionary processes of its resident species and its natural flow patterns (Moudgil, 2016). Nesting of gharials, turtles and some bird species takes place when water levels are low and hatching precedes the monsoonal highwater levels. But untimely and erratic water releases often inundate the nesting sites. Sometimes sudden discharges wash away gharial hatchlings from the safety of the National Chambal Sanctuary (See Chapter 8) to the hostile waters of the Yamuna, Betwa and Ken rivers where they can get trapped in fishing nets.

Dry river beds are spreading in the southern sub-basin of the Ganga. The Kota Barrage just upstream of Kota city dries R. Chambal for about 50-60 km till the Kalisindh adds fresh water flows. The proposed Parwati-Kali Sindh-Chambal river link is a looming threat. It will divert the waters of the Parwati, Newaj and Kali Sindh rivers to the Gandhisagar/ Rana Pratap Sagar dam on the Chambal. River Banas, once a major perennial tributary of R. Chambal has been reduced to only pools, due to several obstructions and a major dam called Benisagar on it. It flows briefly only during the monsoons. Similarly, R. Kali Sindh, another important tributary of the Chambal is known to have lost most of its virgin flows.

Water Quality: Water quality and biomonitoring studies in the main stem of R. Ganga and its tributaries have recorded the decrease of pollution-sensitive species and increase in the pollution-tolerant ones at locations or stretches with poor water quality.

- Researchers from People's Science Institute (PSI) conducted monthly biomonitoring and water quality testing at 13 locations, between Shivpuri (upstream of Rishikesh) and Varanasi on the main stem of river Ganga, and three locations on the Ramganga from December, 2018 to April, 2019, during the Ardh Kumbh mela (PSI, 2019).

Water quality problems were observed at:

1. Haridwar, d/s of the Jagjeetpur STP, moderately to heavily polluted
2. Jajmau, near the Lucknow-Kanpur bridge, moderately to severely polluted
3. Prayagraj, u/s of Sangam, moderately to heavily polluted
4. Prayagraj, 4 km d/s of Sangam, moderately to heavily polluted
5. Varanasi (only in April, 2019) at Sarai Mohana, severely polluted

It was observed that sensitive benthic macro-invertebrate species decreased as pollution levels rose. Local fishers in Prayagraj and Varanasi reported that the traditionally common fish species like the Rohu, Mahseer, Hilsa and Desi Tengar, had reduced numerically while the foreign species 'China' (probably the Chinese Grass Carp - *(Ctenopharyngodon Idella)*, Mangur *(Clarias gariepinus)* and Tilapia *(Oreochromis niloticus)* among others had increased. The invasive species being more pollution tolerant, this change could largely be due to pollution of the river water.

- WII-GACMC has identified the release of persistent toxins like heavy metals (from industries) and polychlorinated bi-phenyls (PCBs) and polyfluorinated compounds (PFCs) from agriculture and healthcare sectors as endangering the aquatic diversity. PCBs and PFCs disrupt the hormonal and immune systems of aquatic species, including the Gangetic River dolphin, through bioaccumulation and biomagnification along the food chain (WII-GACMC, 2018, p. 89).

Mining Riverbed Materials (RBM): Extensive sandbar agriculture, construction along river banks and sand mining have disrupted lateral connectivity at many locations and deprived turtles and some of the avifauna species of their nesting sites.

National Waterway 1: The development of the 1620 km long National Waterway 1 from Haldia to Prayagraj will severely disrupt aquatic life in the middle Ganga stretch, especially the most optimal dolphin habitats (See box: Underwater Vessel Noise and River-bottom Dredging Harms Ganges River Dolphin in Chapter 11).

Critical Locations: WII-GACMC has identified the Farrukhabad to Kanpur and Prayagraj to Varanasi stretches as having "high concentrations of all the threats to the aquatic diversity" (WII-GACMC, 2018, p. 90). Several shorter critical stretches lie along the tributaries of the Ganga and small feeder streams like (i) R. Kali from Meerut to its confluence with the Ganga in Kannauj district; (ii) Ramganga from Moradabad to about 25 km downstream is a dead river; (iii) River Pandu near Kanpur and River Varuna at Varanasi are also dead feeder streams. These stretches need to be cleansed. The Banas and Sindh rivers in the Chambal sub-basin are largely dry and need to be revived.

Lower Ganga Basin[xiv]

The Farakka Barrage and the embankments on the Bihar tributaries have structurally altered the flow in the main stem and the Bihar tributaries. This is the most densely populated stretch of River Ganga. It also hosts almost all the high-profile animals like the Gangetic River dolphins, otters and estuarine crocodiles and turtles. Gharials are found in the Gandak river which joins the Ganga near Patna.

Flow Alterations: Floods and breaches in embankments along some of the major tributaries of the Ganga in Bihar are notorious hazards (D.K. Mishra, 2008). They have increased sedimentation and raised bed levels between the embankments. They have also disgorged heavier sediment loads in the Ganga itself. The construction of the Farakka barrage further downstream has led to accretion of sediments and nutrients up to about Mokameh, around 250 km upstream. Downstream, the Barrage has caused increased banks erosion in the Hooghly river stretch.

Gangetic River Dolphin sightings in the Bhagirathi-Hooghly river system downstream of the Farakka Barrage dropped from 152 during 1994-1995 to 125 in 2004-2006 and 97 in 2008 (Nawab et al, 2016, p.195). Eighty-five Gangetic dolphins were recorded in the Kosi river in Bihar (Sinha & Sharma, 2003). Almost a decade later 257 dolphins were seen in the Gandak river (Choudhary et al, 2012). But Dr D.K. Mishra, the doyen of river embankments researchers, says that in recent years he has not seen any dolphins during his visits to villages inside the Kosi embankments. It is likely therefore that the number of Gangetic dolphins in the Kosi river has decreased significantly.

It has been stated earlier in this chapter that the construction of the Farakka Barrage led to significant decrease in fisheries as far upstream as Prayagraj. Dr. Mishra adds, "Around 1810, Buchanan reported 134 fish species in the Ganga at Purnea. Now that number is down by about a hundred." The average annual yield of prawn and fish, including the hilsa, however, has increased several times downstream of the Barrage (See section 6.4.1).
Agriculture, buildings construction and riverbed mining activities have altered the river banks. Sand bar cultivation in Bihar and Jharkhand has damaged nesting sites for turtles and island-nesting birds.

Water Quality: Rising pollution levels in the lower Ganga stretch signified by a drop in DO values over time and a high average nitrate concentration could negatively affect biodiversity in the river (WII-GACMC, 2018, p.90). The WII-GACMC study observed 31 active wastewater outfalls releasing raw sewage and industrial effluents in the lower Ganga stretch.

Scientists at Bhagalpur University have shown that the release of the most commonly used detergents into R. Ganga are highly toxic to fish and fish seed, reducing growth, increasing mortality and hampering reproductive ability.[xv]

The Damodar river lost its natural flow pattern after the construction of the dams at Tenughat and Panchet (CIFRI, 1998). By the 1990s, pollution in the middle stretch due to effluents from thermal power plants, coal washeries, steel and fertilizer plants and numerous other small industries established after independence had reduced fish diversity and 33 fish species became endangered, including 9 commercially important ones.

More recently, CIFRI reported that the concentrations of copper, zinc, manganese, lead, cadmium and chromium in Ganga water and sediments measured between Buxar and Fraserganj, were maximum at Fraserganj. It is probably the result of metal ions brought down from mining and industrial areas by R. Damodar, which meets the Hooghly 50 km downstream of Kolkata at Falta (CIFRI, 2019, pp 83-86). Though all the heavy metals concentrations in the flesh of 14 fish species analyzed by CIFRI were below the international safety standards, Zn was found in relatively high levels (c. 22 to 55 ppm) in *M. cavassius, P. conchonius, X. cancila and O. rubicundus*.

Critical Locations: Sediments brought down by the Ganga are a very significant contribution to the annual aggradation of the Ganga-Brahmaputra-Meghna delta, more popularly identified as the Sundarbans region (See also Chapter 5). It has unique biodiversity elements, including the world's largest contiguous mangrove forests block. The Indian portion of the Sundarbans was recognized as a World Heritage Site in 1987 and renamed as Sundarban Biosphere Reserve. Its unique biodiversity, however, is now imperilled due to decrease in annual aggradation because of sediments held back by dams and barrages and climate change induced sea-level rise (Syvitski et al, 2009).

Climate change models predict an increasing frequency of devastating cyclones in this area. Mangrove forests are known to lessen the havoc caused by cyclones in the Bay of Bengal (Ghosh A. et al, 2015). But low flows and heavy metals pollution has made the Sundari (*H. fomes*) species vulnerable to diseases (Sarkar et al, 2018). Scientists at Calcutta University have observed that heavy metal pollution from industrial units located in Kolkata and Haldia on the Hooghly River in the Gangetic delta are polluting the fragile Sundarbans ecosystem. They have found heavy metal accumulation in the muscles of tiger prawns, a commercially exported species. Researchers have also found increased amounts of zinc, copper and lead in the Indian white shrimp which is an important livelihood resource for local fishers.

Dredging inside the Vikramshila Gangetic Dolphin Sanctuary for National Waterway 1 combined with low flows, pollution and poaching is threatening the survival of the National Aquatic Animal (See section 8.3.1).

6.6.3. Conservation: The Tasks Ahead

A general impression created over the past four decades or so is that our rivers are dying and that even the Ganga, India's National River, is in dire straits. Hence, the recent assessment of the Ganga Aqualife Conservation Monitoring Centre at the Wildlife Institute of India (WII-GACMC) that six sections in the Ganga's main stem stretching over 1238 km or just under half the river's entire length, despite their existing problems, still have high biodiversity values is welcome news. It probably reflects a combination of the remarkable self-purifying property of Gangajal, the river's resilience and some impact of various measures undertaken to restore the river. It offers hope, a starting point for more vigorous and sustainable initiatives.

To sustainably rehabilitate biodiversity in River Ganga, a few basic principles and practical imperatives need to be kept in mind. Among others, these include:

- Ideally the perspective of restorative planning should be to restore the biodiversity in the river to its natural or pristine state, keeping in mind that living systems are dynamic and that the natural state itself changes over time. For example, the expected climate changes may redefine a new natural state in the future. This will require a good knowledge base and understanding of the structure of the ecosystems of the river and its catchment under the prevailing natural conditions.
- Once the above perspective is accepted, the goal of rehabilitation is to revive the biodiversity of the entire river length to a pristine state. Since the vast majority of Indians regard River Ganga as the physical manifestation of a goddess and that we have legally recognized Ganga as India's National River, in principle we ought not to accept anything less. In practice it may be impossible goal to achieve in a decade or two, but it may perhaps be possible in a phased manner, over a longer time-frame, say by the end of the present century. Such a goal will always remind us of how much more we have to do.
- Restoration must be based on a comprehensive approach that involves (i) rehabilitating the catchments so that sustained base flows are restored and (ii) reviving the health of the tributaries. The lesson we must learn from our present experience is that healthy lower order tributaries are the building blocks of the higher order rivers. The Chambal is almost dead below the Kota Barrage till a healthy Kali Sindh revives it 50 or 60 km downstream. The Yamuna is almost lifeless till Etawah where the rejuvenated Chambal joins it and later the fresh waters of the Betwa and Ken reinvigorate it. The Ganga is a debilitated stream above Sangam at Prayagraj where a healthy Yamuna infuses life into it. Once revived at Prayagraj, the Ganga is repeatedly renewed by the waters of the Sone, Ghagara, Gandak and the Kosi in Bihar.
- Practically, it is important to adequately tackle the four big threats to biodiversity in the Ganga river system, namely, low flows, river water pollution, mining RBMs and excessive groundwater extraction. Increasing the flow of fresh water in the river

will require policy measures and practices to reduce the freshwater demand for agriculture, industry and domestic use. Related measures are discussed elsewhere in this report.

- Effectively implementing these measures will take time. In the interim, the first steps must be to sustain the high biodiversity value stretches, enrich them and expand them.
- In all these steps people have also very practical roles to play. High school and college students can measure pollution levels and biodiversity in the river. Desired Eflows must be honestly determined. Markers indicating discharge in the river can be put up at intervals all along the river. That will enable common people to monitor whether flow norms are being observed or not. Lapses can be identified and punitive and deterrent action can be sought. This kind of data gathering empowers the common people. With mobile phones in the hands of hundreds of million people in India, such data can be fed into larger data banks for more detailed analysis and understanding.

Ultimately it is important to realize that (i) a river lives when its biodiversity flourishes and (ii) it is more important to analyze periodic changes in the species composition of the aquatic life forms rather than just identify the various taxa in the river. Changes in the species diversity indicate changes occurring in the river's ecosystem due to natural (e.g., climate change) and anthropogenic factors.

6.7 END NOTES

[i] The Forest Survey of India (2019) reports the catchment area of the IGB as 851, 675 km^2 whereas the Central Water Commission (also 2019) shows a drainage area of the IGB as 861,404 km^2.

[ii] This section has benefitted by reference to a report Riparian Floral Diversity of River Ganga (Report Code: 032_GBP_IIT_ENB_DAT_10_Ver 1_Jun 2012) prepared for the Ganga River Basin Management Plan, Tare V. (Coordinator), by the IIT-Consortium (2012).

[iii] The number of herbal species with medicinal properties appears to be low according to knowledgeable sources.

[iv] Parts of this section have been excerpted from a paper by Nautiyal P. et al (2014). Dr. Nautiyal is also a major contributor to this chapter.

[v] **Biological Community or Community** is an interacting group (consortia) of individuals of various plant and animal species (unlike 'population' which are interbreeding individuals of one species) living together in a particular area and at a particular time.

Aquatic communities are classified largely by location – either as neuston, plankton, nekton or benthos from surface to bottom as explained below.

1. **Neuston --** small (macro) aquatic organisms "associated with air-water interface" (surface

layer or moving on the surface film).

2. **Plankton --** derived from Greek planktos 'wandering', microscopic organisms drifting or floating in the sea or fresh water. These organisms "live essentially in water-water interface" (suspended in water column) and either lack or have 'feeble locomotory organs' (cilia, flagella - microscopic hair like structure) and therefore cannot swim or float faster than currents. Net plankton is often used synonymously for plankton.

Plankton size is usually measured in microns and are classified according to size as well (1,000 microns (μm) equal 1 mm).

Plankton are grouped as phytoplankton (plant origin) or zooplankton (animal origin).

3. **Nekton** are free-swimming organisms associated with a "water-water interface" (water column). They have powerful locomotory organs like fins (fish) and modified appendages (squid) and limbs (turtles, otters, dolphin) and can swim freely and faster than currents.
4. **Benthos** are bottom dwelling organisms. They live on or in the bottom sediments and are associated with a "solid-water interface". They can be attached or free moving, but lack swimming organs and are unable to swim, e.g., anemones, clams, sea stars, crabs, and most seaweeds, which attach to rocks by holdfasts.

The diatom [unicellular silica-walled photosynthetic organisms/algae] associations may be either benthic, i.e., bottom-dwelling in a water body or planktonic in which the algae drift passively in the water, or move through the water. The intrinsic movement of plankton algae is usually slight relative to the turbulent water movement induced currents.
The algal component of the benthos is often termed as phytobenthos.

[vi] Periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes and detritus that are attached to submerged surfaces, like rocks or boulders, in most aquatic ecosystems.

[vii] For vertebrates other than fish, this section has immensely benefitted from WII-GACMC (2018)

[viii] The Irrawady Dolphin(*Orcaella brevirostris*) mainly populates the Bangladesh Sundarbans but are said to swim in and out of the Indian Sundarbans also. Milan Das, a local fisher says, "Twenty years ago we used to often see dolphins while fishing in the Sundarbans. But now they are rarely seen. The last time I saw one was about 8 months ago, in December 2019 or January 2020."

[ix] Partly based on Nautiyal P. et al, 2014.
[x] CIFRI's categorization of *T. Putitora* as being common is disputed by Prof. P. Nautiyal of the H.N.B. Garhwal University. The IUCN Red List of threatened species describes its conservation status as endangered. Prof. Nautiyal believes that CIFRI's categorization is based on the local abundance of T. Putitora in the Tehri dam reservoir (where it may have been introduced by the dam authorities -- eds). Prof. Nautiyal adds, "Under present regulation of Ganga for irrigation & HEP between Pashulok and Bhimgoda barrages there is hardly any habitat for snow trouts. I think S*. richardsonii*

should be evaluated only till Pashulok barrage."

[xi] The Wildlife (Protection) Act, 1972 grants protection status to various plants and animals under six schedules. Schedule I covers endangered species that need rigorous protection. The species are granted protection from poaching, killing, trading etc., with harshest penalties for violation of the law under this Schedule.

[xii] Based on Nautiyal P. et al (2017).

[xiii] In a personal communication, Prof. P. Nautiyal of H.N.B. Garhwal University argued, "The entire Bhagirathi and Alaknanda rivers should be considered as HBV (High Biodiversity Value) stretches for the same specialized elements and visitor species as emphasised in this Chapter. However, HBVS has been restricted to D-R stretch (in Table 6.9) because Uttarkashi to Devprayag has been fragmented extensively by a series of impoundments, tunnels and reservoir. The 100 km stretch from Gangotri to Maneri is still intact and it can rejuvenate the fragmented stretch as the cyprinid snow trouts, visitor Mahseer species, catfish and loaches can repopulate the deserted stretch. If we do not claim it as HBVS today then there would be no chance to keep the rest of stretch intact. Similarly, the whole of Alaknanda must be claimed as HBVS, because it had all those elements found in D-R section.

"The high value is not only because of fish, but also because of producers (diatoms) and consumers (macroinvertebrates), as all are adapted to ice-cold and torrent conditions. The plains stretch of the Ganga are just not their habitat."

[xiv] This section has benefitted from the text in WII-GACMC (2018, p. 90)
[xv] P. Nautiyal, written communication.

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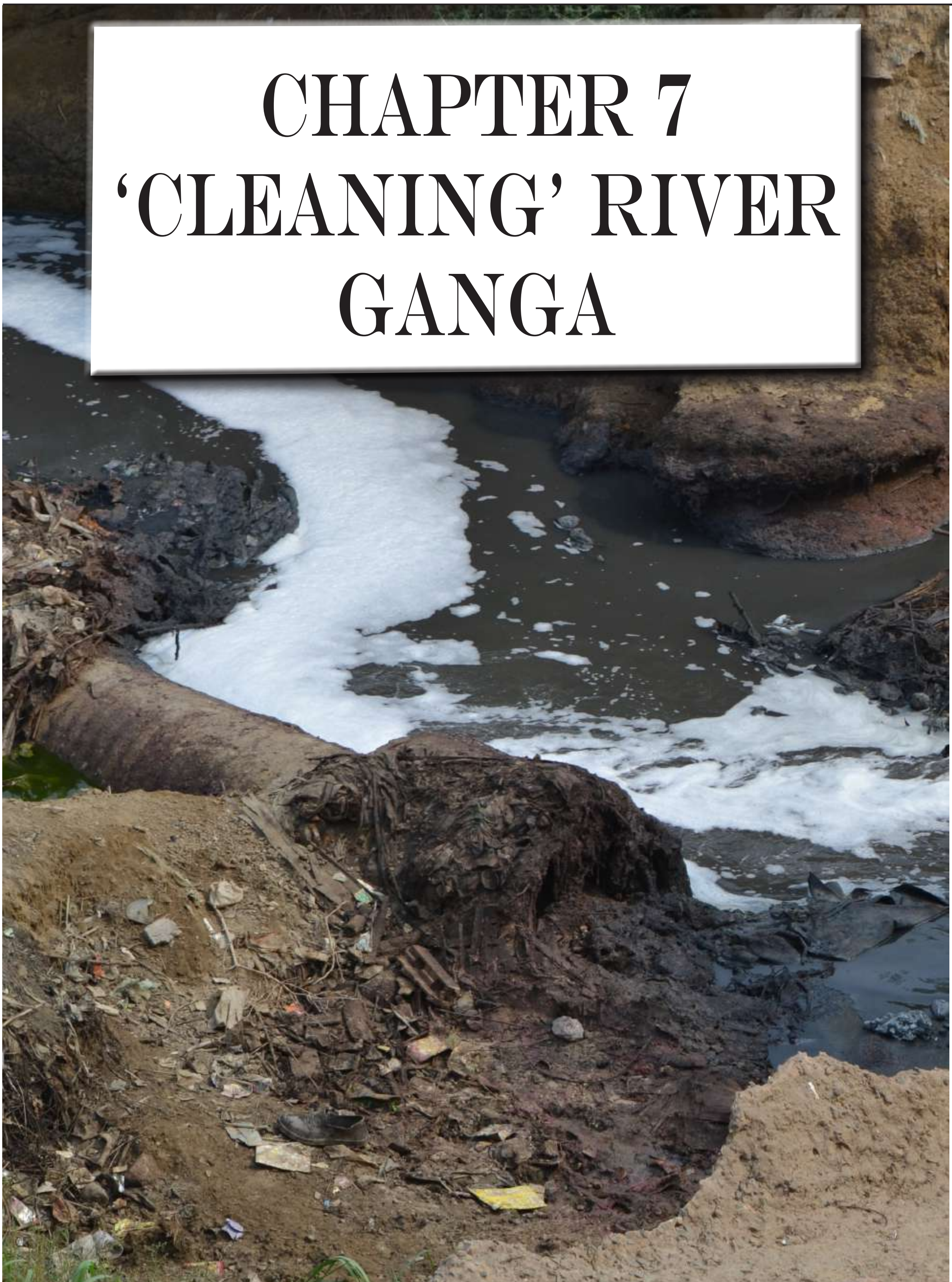
CHAPTER 7
'CLEANING' RIVER GANGA



7.1 INTRODUCTION

An important aspect of the divinity attributed to Gangajal in India is the long-standing belief that it possesses properties not found in rivers elsewhere. Since ancient times it has been known that Gangajal stored for long periods does not putrefy. Imbibing its waters is believed to promote good health and cure diseases (Nautiyal C.S., 2009. See also Chapters 8 and 13).

Gangajal's Self-Purifying Capacity Confirmed

Ernest Hankin, a British bacteriologist who had worked under Louis Pasteur, after he began working in India, studied the frequent outbreaks of cholera. In 1896 he reported in a paper published through the Pasteur Institute (Paris) that unboiled Ganga water killed cholera germs in less than 3 hours, but on boiling the same water it did not have the same effect. He also attributed such a bactericidal property to the Yamuna waters (Nautiyal C.S., 2009).

In the 1970s, Dr. G.D. Agrawal and his research students at IIT-Kanpur conducted experiments that showed that the self-purifying ability of River Ganga was higher than rivers studied elsewhere in the world. Later studies by the National Environmental Engineering Research Institute (NEERI) attributed the self-purifying ability to the presence of bacteriophages in Ganga water. In 2017 the CSIR-Institute of Microbial Technology reported that Ganga water had the ability to kill bacteria responsible for 17 different diseases (See also Chapter 8).

Social customs created rules for the proper use of water in the ancient past. Some were codified in Manusmriti, such as forbidding the pollution of river water by releasing excreta, urine or other body fluids into the water (Chopra R., 2003). But rivers have always been convenient media for releasing wastes. The flowing water carries away and dilutes the pollutants. Similarly, riverbanks and floodplains have always provided extremely fertile areas for agriculture and easy access to water for irrigation. In the past few decades, however, unprecedented population growth, industrialization and urbanization have led to vast amounts of pollutants flowing into rivers. These factors and the modern geopolitics of water, have also led to unprecedented water abstraction from rivers. As a result, even the world's largest and most voluminous rivers, once thought to be vast enough to absorb everything that was thrown into them, are miserably polluted today.

This chapter largely deals with pollution in the main stem of R. Ganga and efforts to improve its water quality. The health of the tributaries in the Ganga basin is dealt with in Chapter 10 and the rejuvenation Namami Gange programme is dealt with at length in Chapter 12.

7.2 RIVER WATER QUALITY (WQ) MONITORING IN THE GANGA BASIN

River WQ in India is officially monitored by agencies of the Ministry of Environment Forest & Climate Change and the Ministry of Jal Shakti.

7.2.1 National Water Quality Monitoring Programme (NWMP)

NWMP is a national programme of MoEFCC to monitor the status of WQ and to facilitate the prevention and control of pollution in water bodies in India (CPCB, 2020). The Central Pollution Control Board (CPCB) in collaboration with State Pollution Control Boards (SPCBs) in the States and Pollution Control Committees (PCCs) in the Union Territories has established the NWQM Network for the purpose.

Water quality monitoring of rivers in the Ganga basin is done at 360 locations by CPCB and the SPCBs of the basin states. Out of the total stations, 96 are along the main stem of River Ganga flowing through Uttarakhand (15), Uttar Pradesh (30), Bihar (33), Jharkhand (4) and West Bengal (14). Similarly, 29 stations are along the main stream of River Yamuna, Uttarakhand (4), Himachal Pradesh (4), Haryana (4), Delhi (4) and U.P. (13). The remaining 235 stations are along the tributaries of the Ganga and Yamuna (CPCB, 2019).

Water samples are analysed for 9 core parameters, 19 general ones, 9 trace metals and a set of pesticides in conformity with MoEFCC's Guidelines on WQ Monitoring (2017) and depending on the use of the water bodies, as shown in Table 22. The analysed WQ parameters data are compared with the relevant standards set by CPCB or the Bureau of Indian Standards. These parameters measure the WQ or pollution levels at the time of sampling. CPCB and some of the SPCBs also undertake biomonitoring of rivers in the Ganga basin to assess the long-term effects of pollution on the ecology of the rivers.

Table 22 : List of Parameters Under NWMP

Field Observation	**Core Parameters**	**General Parameters**	**Bio Monitoring**	**Trace Metals µg/L**	**Pesticides µg/L**
• Weather •Depth of Mainstreamor depth of water table •Colour & intensity •Odour •Visible effluent discharge •Human activities around station •Station detail	•pH •Temperature •Conductivity (µmhos/cm) •DO, mg/L •BOD, mg/L •Nitrate –N, mg/L •Nitrite – N, mg/L •Faecal Coliform, MPN/100 ml •Total Coliform, MPN/100 ml	•Turbidity, NTU •Phenolphthalein Alkalinity, as $CaCO_3$ •Total Alkalinity, as $CaCO_3$ •Chlorides, mg/L •COD, mg/L •Total Kjeldahl - N, as N mg/L •Ammonia - N, as N mg/L •Hardness, as $CaCO_3$ •Calcium, as $CaCO_3$ •Sulphate, mg/L •Sodium, mg/L •TDS, mg/L •Total Fixed Dissolved Solids, mg/L •TSS, mg/L •Phosphate, mg/L •Boron, mg/L •Magnesium, as $CaCO_3$	•Saprobity Index •Diversity Index •P/R Ratio	•Arsenic •Cadmium •Copper •Lead •Chromium (Total) •Nickel •Zinc •Mercury •Iron (Total)	•Alpha HCH •Beta HCH •Gamma HCH (Lindane) •O P DDT •P P DDT • Alpha Endosulphan, •Beta Endosulphan, •Aldrin •Dieldrin •Carboryl (Carbamate) •2-4 D •Malathion •Methyl Parathion, •Anilophos •Chloropyri-phos

Source: Monitoring of Indian National Aquatic Resource Series: MINARS/35/2013-14

CPCB and the SPCBs maintain three types of WQ monitoring stations, namely baseline, trend and flux stations. Baseline stations are located where there is no influence of human activities on WQ. They monitor WQ four times a year for perennial rivers and three to four times annually for seasonal rivers. Flux or Impact stations measure the mass of particular pollutants on the main river stem arising out of human interference or a geological feature. They monitor river WQ twelve to twenty-four times annually depending on the pollution potential or importance of water use. Their data helps to determine the impact of pollution control measures that have been adopted. Trend stations conduct monthly monitoring of WQ parameters to show the variation of pollution levels over time at their locations. The frequency of monitoring and the parameters sampled are summarized in Table 23.

Table 23 : Frequencies And Parameters For Analysing River Water Samples (Minimum Requirements)

Type of Station	Frequency	Parameters Monitored
Baseline	**Perennial rivers:** Four times a year (seasonal) **Seasonal rivers:** 3-4 times (at equal spacing) during flow period	**A) Pre-monsoon:** Once a year Analyse 25 parameters as listed below: **a)General:** Colour, Odour, Temperature, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Turbidity, Total Dissolved Solid (TDS) **b)Nutrients:** Ammoniacal Nitrogen (NH_4N), Nitrite & Nitrate Nitrogen (NO_2 + NO_3) Total Phosphate (Total P) **c)Demand parameters:** Biological Oxygen, Demand (BOD), Chemical Oxygen Demand (COD) **d) Major ions:** Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Carbonate (CO_3) Bicarbonate (HCO_3), Chloride (Cl), Sulphate (SO_4) **e) Other inorganic:** Fluoride (F), Boron (B) and other location specific parameter, if any **f) Microbiological:** Total coliform and Faecal Coliform **(B) Rest of the year (after the pre-monsoon sampling) at every three months interval analyse 10 parameters:** Colour, Odour, Temperature, pH, EC, DO, NO_2 + NO_3, BOD, Total Coliform and Faecal Coliform

Trend or impact or flux	Once every month starting April-May (pre-monsoon) i.e., 12 times a year	**A. Pre-monsoon:** Analyse 25 parameters as listed for baseline monitoring **B. Other months:** Analyse 15 parameters as listed below **(a) General:** Colour, Odour, Temp, pH, EC, DO and Turbidity **(b) Nutrients**: NH_3 - N, $NO_2 + NO_3$, Total P **(c) Organic Matter:** BOD, COD **(d) Major ions**: Cl **(e) Microbiological:** Total and Faecal coliforms **C. Micropollutants:** Once in a year/pre monsoon. **a) Pesticides –** Alpha Benzenehexachloride (BHC), Beta BHC, Gamma BHC (Lindane), OP-Dichlorodiphenyltrichloroethane (OP_4 DDT), PP-DDT, Alpha Endosulphan, Beta Endosulphan, Aldrin, Dieldrin, Carbaryl (Carbamate), Malathian, Methyl Parathian, Anilophos, Chloropyriphos **b) Toxic Metals:** Arsenic (As), Cadmium (Cd), Mercury (Hg), Zinc (Zn), Chromium (Cr), Lead (Pb) Nickel (Ni), Iron (Fe) (The parameters may be selected based on local need)

Source: MoEF. 2005. Notification S.O. 2151. New Delhi. June 17th

Notes:

I. More parameters may be added for analysis depending upon the specific requirements of the analyzing agency and the local conditions.

II. If bio-monitoring is done in the river, additional specific parameters may need to be considered.

In 2017, CPCB installed equipment for continuous Real Time Water Quality Monitoring (RTWQM) of River Ganga at 36 locations (CPCB, 2018). Its Bio-science Division undertakes biomonitoring at all the 36 RTWQM locations along with 8 hydrology locations in the pre-monsoon and post-monsoon seasons. CPCB's IT team has developed a dashboard to show the real-time data from the 36 stations (CPCB, Undated).

7.2.2 River WQ Monitoring at CWC

The Central Water Commission (CWC) monitors river WQ at 552 key locations covering all the major river basins of India. It maintains a three-tier laboratory system for analysing the parameters. Its Level-I laboratories at 295 stations on various rivers monitor mainly physical parameters such as temperature, colour, odour, specific conductivity, total dissolved solids, besides pH and DO. Its 18 Level–II laboratories at selected division offices analyze 25 physico-chemical characteristics and bacteriological parameters of river water. Of its 5 Level-III/II+ laboratories, three are in the Ganga basin at Lucknow, Varanasi and Delhi, where 41 parameters including heavy metals and some pesticides are analysed. Like CPCB, the CWC has baseline (sampling once in two months), trend (monthly sampling) and flux monitoring stations (sampling thrice a month).

A point worth noting is that the CWC discloses WQ data only on request (CWC, undated). In contrast, CPCB is mandated to disseminate information on matters relating to water and air pollution and their prevention and control. It lists among its achievements the regular public dissemination of WQ data, including river WQ, and fulfilling the requirements of NGOs, students and researchers (Bharadwaj R.M., 2005).

7.2.3 River WQ Standards

Designated Best Use River WQ Standards: Different uses of water require different levels of purity. Hence the most commonly used standards for describing river WQ in India are the Designated Best Use Standards devised by CPCB (Table 24). It categorizes river water into five classes from A to E. Each class refers to the use which demands the highest quality and is termed its designated best use. This classification helps WQ managers and planners to set WQ targets and design suitable treatment measures for improving polluted water to meet the desired use quality (RBIS, undated).

Table 24 : CPCB's Designated-Best-Use WQ Standards

Designated Best Use Of River Water	Class of Water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	Total Coliforms Organism in MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20^0C 2mg/l or less

Outdoor bathing (Organised)	B	Faecal Coliform in MPN/100ml: 500 (desirable) and 2500 (Maximum Permissible) Faecal streptococci in MPN/100 ml: 100 (desirable) and 500 (maximum Permissible) pH between 6.5 to 8.5 Dissolved Oxygen: 5mg/l or more Biochemical Oxygen Demand 3 Day BOD, 27^0C: 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliform Organisms MPN/100ml shall be ≤5000 pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20^0C 3mg/l or less
Propagation of Wildlife and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling	E	pH between 6.0 to 8.5 Electrical Conductivity at 25^0C: 2250micro mhos/cm (max) Sodium Absorption Ratio Max. 26, Boron Max. 2mg/l

More recently, in response to an order from NGT, more detailed tolerance limits for Classes A through E have been published by UPPCB (2019). These are given in Appendix I at the end of this Chapter. In 2012, the Bureau of Indian Standards had revised its standards for drinking water. These are added at the end in Appendix II.

7.3 GANGA RIVER WATER QUALITY

7.3.1 Overview of Pollution in the Ganga Basin

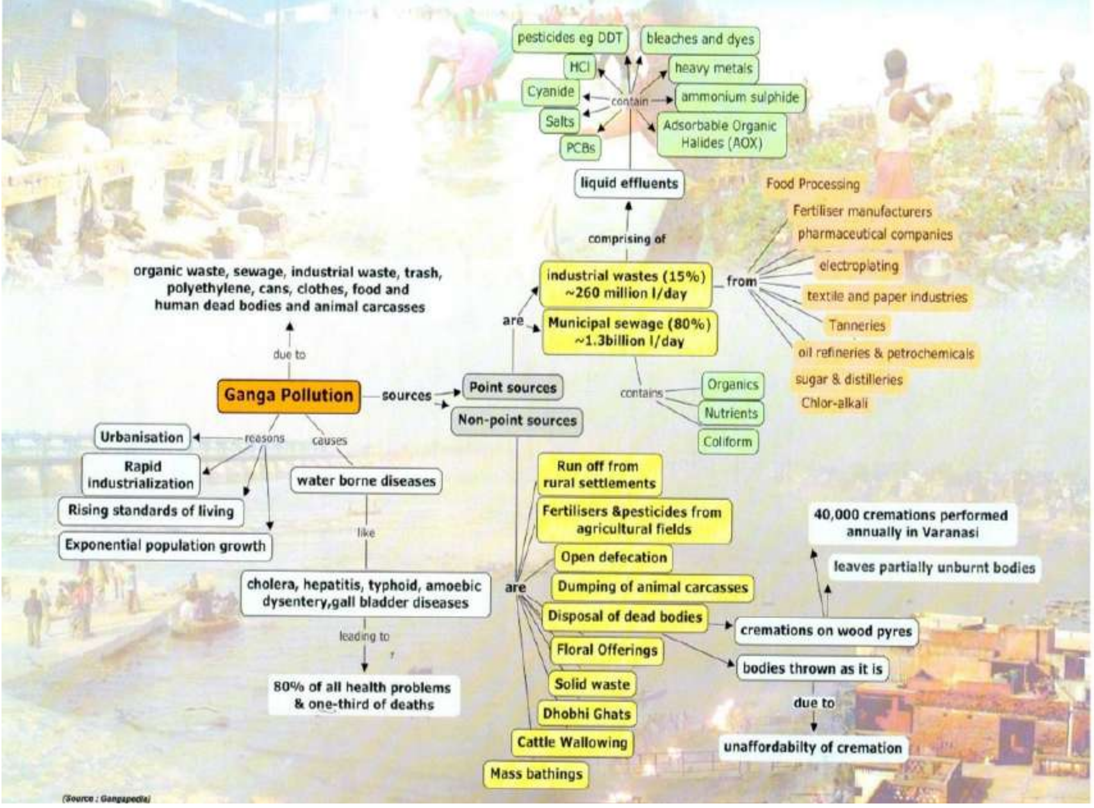
India's most sacred river Ganga, may also be its most polluted major river. Its basin is the most densely populated river plain in the world (Bharati et al, 2016). Over 12 billion litres of sewage are generated every day in the Ganga basin (NMCG, undated). Domestic sewage is said to comprise an overwhelming 80% share by volume of the basin's daily pollution. Decomposition of solid waste, and an excess of nutrients, such as those from fertilizer run off, results in the creation of oxygen-deprived, biologically-barren dead river zones.

Urban Pollution

Waste management systems in cities and towns in the Ganga basin have lagged far behind the rapid growth of their population and size. In November, 2018 the United Nations estimated that about 80 percent of sewage discharged into two major tributaries of the Ganga was untreated (Scarr S., et al, 2019). According to NMCG, 97 towns and cities on the main stem generated about 2953 MLD domestic sewage (25% of basin) in April, 2019 but their treatment capacity was only 1930 MLD (Luthra B. and Yadava H., 2019). By April, 2019, STPs with an installed capacity of 3308 MLD had been sanctioned. More than 70 per cent of the existing properties in these towns have onsite sanitation systems like septic tanks and pit latrines (Luthra B. and Yadava H., 2019). Capacity created up till March, 2023 is 2610.05 MLD (NMCG) Newly created capacity remains under-utilized until the supporting sewerage network is ready and linked.

Besides liquid wastes, 28,000 tons of solid waste are released into the main stem of the Ganga every day (Shekhar S., 2018). The Quality Council of India conducted a solid waste management survey of 97 towns and cities along R. Ganga in late 2018 for the Union Ministry for Housing and Urban Affairs. Its surveyors found that in many towns there were no screens in the drains to intercept the solid wastes and in 66 towns at least one *nullah* was draining directly into the Ganga. In several towns the screens were blocked by accumulated solid wastes and in 33 towns solid waste was floating on at least one ghat. Upon degradation, many wastes release toxins into the water. The waste may also eventually enter the marine food chain, where it can cause mass mortality amongst marine animals and birds.

Image 22 : Mind Map Of Pollution In R. Ganga Basin



Source: Gangapedia, NMCG

Mass religious gatherings on river banks cause episodic pollution. The volume of solid waste entering the river multiplies manifold during mass cultural events such as the Kumbh Mela (See also Section 7.3.4 below), the annual Kanwar Yatra, or the Chhath puja.

Cremation of bodies takes place at several open cremation grounds slong the river banks and it is sometimes noticed that partially burnt bodies are found floating in the waters. This is often due to high expense of the wood required for cremation which is unaffordable by many.

Industrial Pollution

Industrial effluents comprise an estimated 15% of the waste entering the Ganga but pose no less a concern (See Image 19). While the proportional volume is small, the nature of these pollutants is often toxic, non-biodegradable and persistent. Through the process of bioaccumulation, these pollutants may also enter the human food chain.

A large number of industrial hubs exist along the Ganga such as Prayagraj, Kanpur, Varanasi and Patna, which house tanneries, textile mills, chemical plants, distilleries, slaughterhouses and hospitals, often disposing their untreated refuse into the river. Tributaries of the Ganga, especially the Yamuna (at Yamunanagar, Panipat, Sonepat, Delhi, Mathura, and Agra), Hindon (Muzaffarnagar, Meerut, Ghaziabad), Chambal (Nagda, Kota), Kshipra (Indore), Betwa (Mandideep, Bina), Ramganga (Moradabad), Gomti (Lucknow), Tons (Satna), Sone-Rihand (Katni, Singrauli, Renukoot) and Damodar (Bokaro, Asansol, Durgapur, Burdwan and Howrah), also carry heavy industrial pollution loads. There were reports in the early 1980s of radioactive materials leaking into the Chambal river from the Rajasthan Atomic Power Plant (RAPP) near Kota (Gupta S., 1984). One of its units remained shut for more than two years.

Chemicals released from most of the older industries located in the Ganga basin are largely inorganic compounds, heavy metals – many of which are carcinogenic, e.g., tanneries in Kanpur-Jajmau release chromium, thermal power stations in the Singrauli region discharge ash containing mercury, cobalt, chromium, etc. into the Rihand dam reservoir. In the areas surrounding the Rihand reservoir, into which thermal plants and coal mines discharge their wastes, 84 per cent of the blood samples tested positive for the presence of mercury (Sahu R. et al, 2012). According to a study conducted by the Centre for Science and Environment, mercury levels in Moradabad were found to be eight times the permissible limit (Sohail S. and Sambyal S.S., 2015). Copper, zinc, chromium levels above the BIS standards for irrigation were recorded in the Damodar river, near the east Bokaro coalfields (Mahato M.K., et al, 2017).

New chemical industries established in recent decades release organic compounds synthesized, used or released in manufacturing processes. Typical ones include polycyclic aromatic hydrocarbons (PAHs) like naphthalene, polychlorinated biphenyls (PCBs) or organotin compounds (OTCs). PCBs are recognized as Persistent Organic Pollutants (UNEP, 2018). They are notorious for their detrimental health and environmental effects and are now regulated by international and Indian authorities. PAHs and PCBs are periodically monitored in India. The Bureau of Indian Standards (BIS, 2012) has defined acceptable concentration limits for drinking water (See Appendix II). PAHs are well-known mutagens and human carcinogens (Abdel-Shafy H.I., and Mansour M.S.M., 2016). PCBs are carcinogenic and have been reported as endocrine disruptors (Sharma S. and Kapoor S., 2014).

Monitoring studies for the newer organic chemical contaminants have largely focussed on the middle and lower stretches of the main stem of R. Ganga, in the Gomti sub-basin and the Yamuna in the NCT. Foam floating in the Yamuna in Delhi due to phosphates and surfactants released by local industries in Delhi during the time of the Chhath Puja in November 2021, created headlines, though such occurrences have happened earlier too in the last decade. The foam is created by the surfactants reacting with the dirt in the water. The maximum concentration values of some the newer organic chemical pollutants in the Ganga basin river waters and sediments are given in Table 26.

Agricultural Pollution

Pesticides and other chemicals generally enter the river as run-off from cultivated farms. Though ranked 12th in world-wide pesticides consumption levels, India consumed about 58160 tons or about one per cent of the international consumption (Nayak P. and Solanki H. 2017). They include insecticides (~80%), herbicides (~15%) and (~2%) fungicides (Agarwal A., et al., 2015). The application rate was about 0.31 kg/ha (31mg/m2) in 2017 compared to 13.07, 11.76 and 3.57 kg/ha in China, Japan and the USA. Bio-pesticides consumption in India in 2017, however, was only eight per cent.

Pesticides are a significant hazard for non-target organisms ranging from beneficial soil micro-organisms to insects, plants, fish, birds and humans (Mateo-Sagasta J. and Tare V., 2016). Significant levels of DDT and lindane have been found in the fatty tissue of catfish, indicating bio-accumulation in the fatty tissue of fish (Mateo-Sagasta J. and Tare V., 2016). Organo-phosphorus insecticides are responsible for neuro-degenerative disorders in humans (Jokanovic M., 2018).

The use of pesticides in agriculture has led to widespread non-point pollution in the Ganga basin. Many pesticides are Persistent Organic Pollutants (POPs) and hence they are ubiquitous in the environment. WQ monitoring studies have reported the presence of organochlorine pesticides (OCPs) like DDT and lindane (HCH: Hexachlorocyclohexane) and organophosphate insecticides in the Ganga basin rivers (Ghirardelli A., et al, 2021). The use of DDT though banned in many countries, is permitted in India for malaria control.

Pesticide' pollution has been detected in the middle stretch of the Ganga's main stem, around Kanpur, Unnao, Prayagraj, Varanasi, Patna and in the Alaknanda, Bhagirathi and their tributaries (Ghirardelli A., et al, 2021). The Gomti sub-basin, Delhi and the neighbouring districts of Haryana and Uttar Pradesh along the Yamuna and the Hooghly and Sundarbans wetlands show OCPs presence. Kumar et al (2012) identified organophosphorus compounds and herbicides in the Yamuna in Delhi. bank rivers other than the Yamuna do not appear to have been assessed for pesticides. (See also Table 26).

Researchers report declines in pesticide concentrations in the recent decade, especially after the formation of the NGRBA in 2009, though the levels of some organochlorines are beyond the permissible limits for drinking water (Dwivedi S., et al, 2018). Bans and limitations for persistent pesticides appear to have positively affected the environmental status of the Ganga water, but no clear trend is shown for sediment (Ghirardelli A., et al, 2021). There may be various reasons for this, such as the review of fewer studies of sediment pollution and the different pollution dynamics in terms of mass load and flow rate in the two matrices.

7.3.2 Polluted Stretches of Rivers in Ganga Basin

BOD measures the amount of oxygen required by aerobic bacteria (those bacteria that live only in an environment containing free oxygen) to decompose waste organic matter in water. Therefore, it is an index of the degree of organic pollution in water. Table 25 summarizes BOD values from CPCB's river WQ monitoring in the Ganga basin rivers in 2016-2017. (The data of polluted river streches in 2022 is given in the Chapter Annexure)

Table 25 : Polluted River Stretches in Ganga Basin (2016-17)

RIVER	SUB BASIN	STRETCH	BOD (mg/l)
CPCB's standard for outdoor bathing purposes, the 3-days BOD value is ≤ 3mg/l			
MADHYA PRADESH			
Chambal	Chambal	Nagda to Rampura	12 - 80
Khan	Chambal	Kabit Khedi to Khajrana	30.8 - 80
Kshipra	Chambal	Siddhawat to Trivenisangam	4 - 38
Betwa	Betwa	Mandideep to Vidisha	3.3 - 20.2
Sone	Sone	Along Amlai	12.4
Chamla	Chambal	Along Badnagar	4.0
Choupan		Along Vijaipur	3.4
Kaliasot	Betwa	Mandideep to Samardha	4.1
Mandakini	Paodhoi	Along Chitrakut	5.8
Gohad	Kunwari/Sindh	Gohad dam to Gormi	6.3
Malei	Chambal	Jaora to Barauda	3.5

Newaj	Chambal	Along Shujalpur	4.0
Parvati	Chambal	Batawada to Pilukhedi	3.2
Simrar	Katni	Along Katni	3.9
Tons	Tons	Chakghat to Chapper	3.5
RAJASTHAN			
Banas	Chambal	Along Bisalpur Dam till Newta Dam	13.2
Chambal	Chambal	Kota to Sawaimadhopur	3.2 – 4.8
HARYANA			
Yamuna	Yamuna	Panipat to Sonepat	4 - 55
DELHI			
Yamuna	Yamuna	Wazirabad to Asgarpur	9 - 80
UTTAR PRADESH			
Hindon	Yamuna	Saharanpur to Ghaziabad	48 - 120
Kali nadi	Hindon/Yamuna	Muzzafarnagar to Gulaothi town	8 - 78
Varuna	Ganga	Rameshwar till confluence with Ganga	4.5 – 45.2
Yamuna	Yamuna	Asgarpur to Etawah Shahpur to Prayagraj	12 - 55
Gomti	Ganga	Sitapur to Varanasi	3.1 – 18.0
Ganga	Ganga	Kannauj to Varanasi	3.5 – 8.8
Ramganga	Ganga	Moradabad to Kannauj	6.6
Betwa	Yamuna	Hamirpur to Wagpura	3.5 – 4.2
Ghaghara	Ganga	Barhalganj to Deoria	4.0 – 4.5
Rapti	Ganga	Dmnigarh to Rajghat	4.7 – 5.9
Sai	Ganga	Unnao to Jaunpur	4.0 – 4.5
Saryu	Ganga	Ayodhya to Elafatganj	4.3
BIHAR			
Sirsia	Ganga	Ruxol to Koirea Tola (Raxaul)	20
Farmar	Ganga	Along Jogbani	3.6
Ganga	Ganga	Buxar to Bhagalpur	3.2

Punpun	Ganga	Gaurichak to Fatuha	3.3
Ram rekha	Ganga	Harinagar to Ramnagar	5
Sikrahna	Ganga	Along Narkatiaganj	4.5
JHARKHAND			
Garga	Damodar	Along Talmuchu	6.2
Damodar	Damodar	Phusro rd to Turio	3.9
Konar	Damodar	Tilaya and Konar	3.4 – 3.6
Nalkari	Damodar	Along Patratu	3.8
WEST BENGAL			
Vindadhari	Ganga	Haroa Bridge to Malancha burning ghat	26.7 - 45
Mahananda	Ganga	Siliguri to Binaguri	6.5 - 25
Churni	Ganga distributary	Santipur town to Majhadia	10.3 – 11.3
Dwarka	Ganga	Tarapith to Sadhak Bamddebghat	5.6 - 17
Ganga	Ganga	Tribeni to Diamond Harbour	5.0 – 12.2
Damodar	Damodar	Durgachakm to Dishergarh	4.4 – 8.2
Jalangi	Ganga	Laal Dighi to Krishna nagar	8.3
Kansi	Ganga	Midnapore to Ramnagar	9.9
Matha-bhanga	Ganga	Madhupur to Gobindapur	8.5
Barakar	Damodar	Kulti to Asansol	5.7
Dwarakeshwar	Damodar	Along Bankura	1 – 5.6
Mayurakshi	Ganga	Suri toDurgapur	5.2
Rupnarayan	Damodar	Kolaghat to Benapur	5.2
Silabati	Damodar	Ghatal to Nischindipur	3.8
HIMACHAL PRADESH			
Giri	Yamuna	Along Sainj	4.4 - 6
Pabbar	Yamuna	Along Rohru	3.6 - 4
UTTARAKHAND			
Bhela	Ram Ganga	Kashipur to Rajpura	6 - 76
Dhela	RamGanga	Kashipur to Garhuwala	12 - 80
Suswa	Ganga	Mothrowala to Raiwala	37
Kichha	Ram Ganga	Along Kiccha	28

Kalyani	Ram Ganga	Downstream Pantnagar	16
Ganga	Ganga	Haridwar to Sultanpur	6.6
Kosi	Ganga	Sultanpur to Pattikalan	6.4
Nandour	Ganga	Along Sitarganj	5.6 - 8
Pilkhar	Ramganga	Along Rudrapur	10

Source: CPCB

Table 25 clearly shows that in 2016-17 no river monitored in the Ganga basin had an average annual BOD value within the acceptable limit for outdoor bathing or drinking water supply after conventional treatment and disinfection. This is a poor reflection on all the national programs to significantly rid Indian rivers of pollution. However, the situation may have improved with various interventions since then.

7.3.3 Pollution Trends in R. Ganga (main stem)

The main stem of R. Ganga and almost all its major tributaries are facing pollution problems. The trends in FC and BOD levels at 16 stations monitored by CPCB along the main Ganga stem between 2003 and 2020, are shown in Figs 23 and 24.

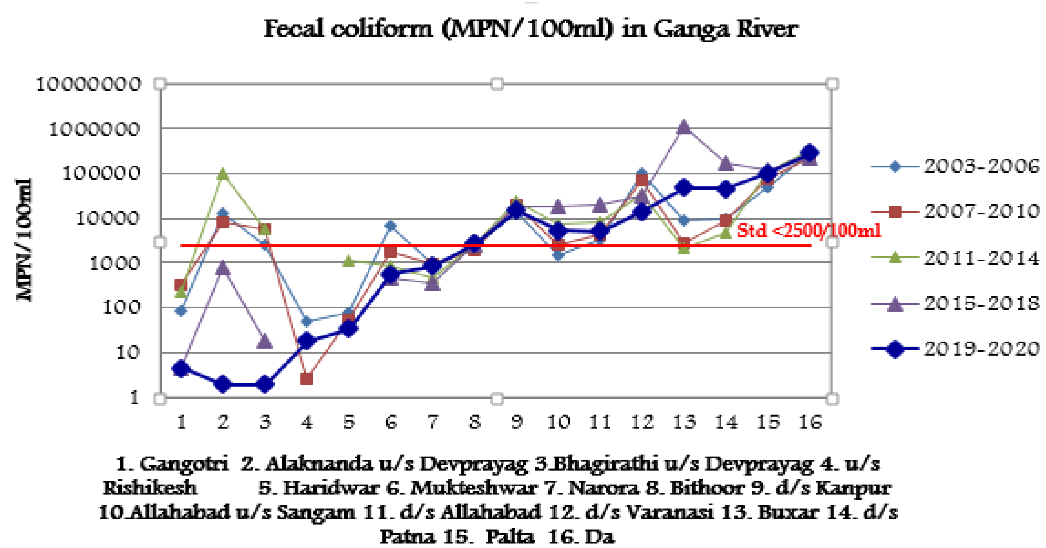


Image 23 :(a) Change In FC Levels (2003-2020) Along The Main Stem Of River Ganga

Source: CPCB data compiled by PSI

In Fig 23 (a) average FC values for four-year periods from 2003 to 2018 plus the latest available data (2019-20) are plotted for 16 monitoring stations, from Gangotri to Dakshineshwar on the right bank of Hooghly river in West Bengal. Most of the stations are at urban locations. From the plots it is apparent that the FC averages are unacceptable(i) in Alaknanda (2003-14) and Bhagirathi (2003-10) rivers just upstream of Devprayag; (ii)

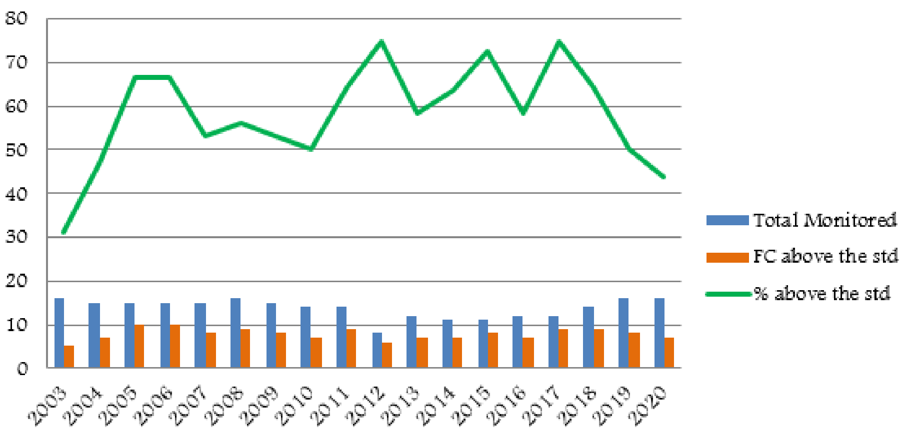


Image 23(b) Trends In Percentage Of Stations With Unacceptable FC Levels

Source: CPCB data compiled by PSI

at Mukteshwar (2003-06); (iii) after Narora, from Bithoor downstream of Kanpur city to Dakshineshwar, the FC averages are consistently in the unacceptable range and the graph displays a generally rising trend in all the periods; (iv) at Haridwar (2003-14) and Narora (2007-18) the average FC values are within the standard limit. All the large urban sites after Bithoor show unacceptably high average FC values. This is indicative of inadequate treatment of municipal sewage loads generated in those cities. The very high averages for the two West Bengal stations may be due to sewage loads from high population density areas, less treated volumes and the effect of reduced flows d/s of the Farakka barrage.

Image 23 (b) reveals a broadly increasing proportion of reporting stations with FC values above the standard, as indicated by the trendline, between 2003 and 2018. It is also noted that there is a gradually increasing number of reporting stations from 2003

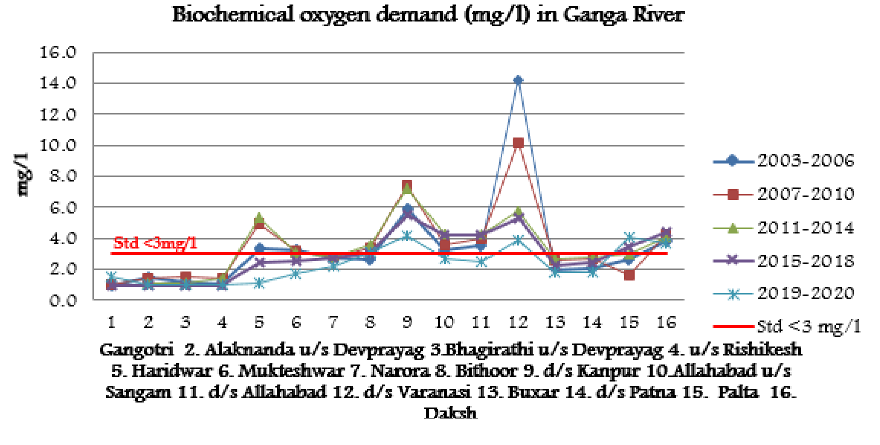


Image 24 a) : Change In Average BOD Values (2003-2020) Along Main Stem Of Ganga

Source: CPCB data compiled by PSI

and 2017 thereafter there is a steady decline in the number of stations with unacceptable FC values. But even in 2020 about 45 per cent stations reported unacceptable values.

This observation is partly corroborated by the data in Image 23 (a) which shows that FC averages for the five stations upstream of Narora were not recorded.

In Image 24 (a) , average BOD values for four-year periods from 2003 to 2018, plus the latest available annual data (2019-20) are plotted for the 16 monitoring stations, from Gangotri to Dakshineshwar (West Bengal). It shows that from Haridwar to Dakshineshwar the BOD four-year averages are above the 3 mg/L standard set for outdoor bathing and drinking water supply after conventional treatment and disinfection by CPCB. The Buxar and Patna stations in Bihar, have reported average BOD values within the standard limit, while Palta in West Bengal has reported an acceptable average for 2007-2010

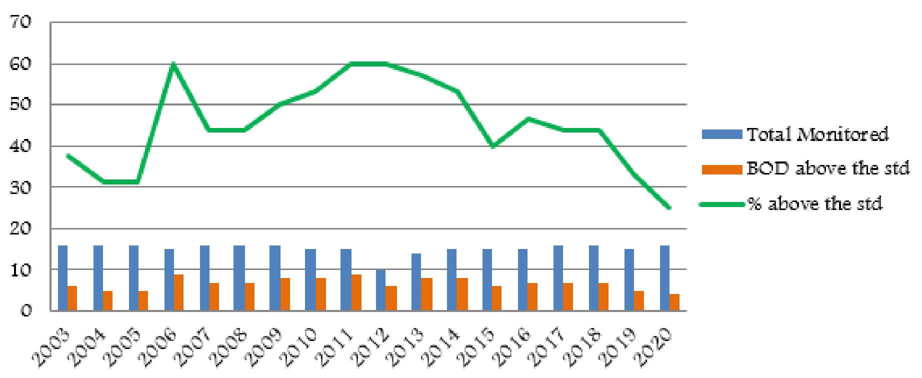


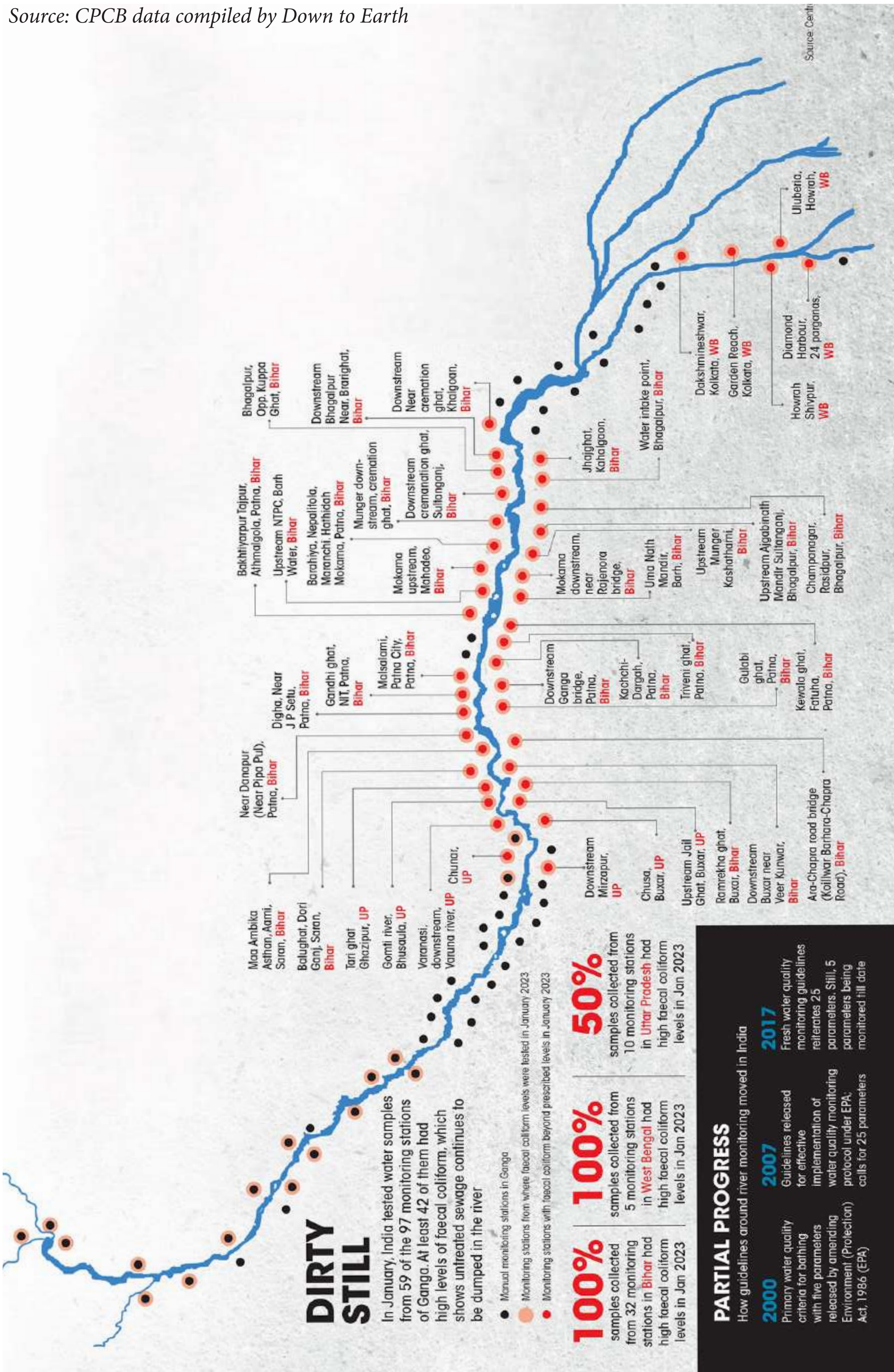
Image 24 (b) : Trends In Percentage Of Stations With Unacceptable FC Levels

Source: CPCB data compiled by PSI

In Haridwar, Kanpur and Varanasi, the averages are consistently very high and the variation between the maximum and minimum values is large. This is similar to the average FC trends in. Image 23 (a). Four-year average BOD values are reported by almost all the stations between 2003 and 2018. Image 24 (b) below also reveals a broadly increasing proportion of reporting stations with average BOD values above the standard, as indicated by the trendline, between 2003 and 2020. It is also noted that there is a gradually increasing number of reporting stations from 2003 to 2009 and a generally declining number thereafter.

"While Uttarakhand had permissible levels of faecal coliform at all 12 tested stations, numbers in three other states — Uttar Pradesh, Bihar and West Bengal — are alarming. No samples were collected from Jharkhand. Bihar and West Bengal had unhealthy levels of faecal coliform at all 37 monitoring stations. In Uttar Pradesh, five of the 10 monitored

Source: CPCB data compiled by Down to Earth



stations had high levels of pollution, showed data accessed by Down To Earth (DTE) under the Right to Information (RTI) Act." (Down to Earth, 16-04-2023)

"Of the 42 polluted stations, 34 had faecal coliform over 11,000 most probable number (MPN) per 100 ml, which is four times the permissible limit (less than 2,500 MPN per 100 ml). Seven stations, all in Bihar, had 92,000 MPN per 100 ml, nearly 37 times the permissible limit." (Down to Earth, 16-04-2023)

7.3.4 Biomonitoring

Testing the physico-chemical parameters of concern in water samples gives a snapshot picture of WQ at a specific time and place. Biomonitoring involves physically determining the diversity and composition of benthic macro-invertebrate communities dwelling in fresh water bodies. The latter are generally bottom-dwelling species that can be affected by pollution over a period of time (See details about benthic macro-invertebrates in Chapter 6). Hence, biomonitoring helps to assess the impact of river pollution on the health of the river ecosystem over a period of time. In recent decades biomonitoring has emerged as an important tool to ascertain the cumulative impact of the pollutants in water bodies.

Many benthic species are consumed by fish. Changes in the diversity and abundance of benthic species therefore affects the breeding and migration of fish species. Therefore, the assessment of river benthos also helps in understanding the impact of pollution on fisheries.

CPCB has established and validated biomonitoring as a cost-effective system for WQ assessment and initiated nation-wide WQ assessment exercises based on this technique. Other organisations and researchers also routinely use this technique.

CPCB's biomonitoring studies in R. Ganga

2017-18: CPCB scientists conducted pre-monsoon and post-monsoon biomonitoring studies at 41 locations in Uttarakhand (3), Uttar Pradesh (25), Bihar (4) and West Bengal (9) in 2017-18 (CPCB, 2018). The main results are summarized below.

1. In Uttarakhand, there was a gradual deterioration of the Ganga's biological WQ in the pre-monsoon phase from clean water (biological WQ class A) upstream of the Bhimgoda Barrage at Haridwar to moderately polluted (biological WQ class C) downstream from the Jagjeetpur STP outfall at the southern end of the city. In the post monsoon period, the WQ had deteriorated further, from slight (biological WQ class B) to moderate pollution upstream of the Jagjeetpur STP and from moderate to heavy pollution (biological WQ class D) downstream of Jagjeetpur.

2. There was no clean or unpolluted station in Uttar Pradesh. In the pre-monsoon period

R. Ganga was severely polluted (biological WQ class E) at Varanasi (old bridge) and moderately polluted at 16 other locations out of the 18 locations monitored. The least pollution level, slight pollution (Class B), was at Ghatia ghat in Farukhabad. Among the six tributaries studied in Uttar Pradesh, Pandu river at Kanpur was severely polluted (Class E), while the remaining five tributaries showed moderate pollution. In the post-monsoon phase, out of 25 locations studied, at two locations, i.e., the bridge on state highway (SH 21) downstream of Kannauj and in R. Pandu, the biological WQ showed heavy pollution (Class D) while at the remaining 23 locations the water was moderately polluted.

3. The Ganga's main stem in Bihar receives heavy flows from several Himalayan tributaries like the Ghaghra, Gandak, Kosi and Burhi Gandak. Hence, its water indicated only moderate biological pollution levels at the four stations monitored during the pre- and post-monsoon rounds.

Map 23 : Sampling Locations R. Ganga WQ Monitoring, Dec 2019-April 2019

Source: PSI

4. In the pre-monsoon period, R.Ganga was moderately polluted at eight out of the nine monitoring stations in West Bengal. Only downstream of Serampore was the river slightly polluted. In the post-monsoon period, all the 9 locations were moderately polluted.

2014-2018: The biomonitoring results of 2017-18 were compared with the results of similar studies done in 2014-15 and 2015-16 (CPCB, 2018). It was observed that the average biological WQ in Uttarakhand, through the Haridwar stretch, had deteriorated from slightly to moderately polluted. But across the middle and lower Ganga sub-basins (Uttar Pradesh, Bihar and West Bengal), the river's biological WQ on an average was judged to be moderately polluted during the three study years.

In Uttar Pradesh three tributaries – Ramganga, Pandu and Varuna – were heavily polluted before their confluences with the mainstream of R. Ganga at Kannauj, Kanpur and Varanasi, respectively. In general, their pollution levels dropped after the monsoons. The Pandu and Varuna streams recorded severe pollution levels, Class E, at different times.

In Bihar, R. Ganga was moderately polluted at all locations in all rounds of bio-monitoring, except at Gandhi ghat in Patna city where it was in the heavy pollution range during 2015-16. The results in West Bengal were similar, with all stations except one (downstream of Serampore) reporting moderate pollution levels in all the monitoring rounds.

7.3.5 Ardh Kumbh Mela, Prayagraj, 2019

More than 240 million people took part in the 49-day Ardh Kumbh Mela held at the Triveni Sangam in Prayagraj between January 15, 2019 to March 4, 2019 (John K., 2019). The Uttar Pradesh government allocated an expense of about Rs 4236 cr, including a contribution of Rs 2200 cr from the Central government, for the event spread over 32 km^2 (Business Today, 2019).

The organizing committee claimed that all the necessary steps had been preemptively taken to ensure that this would be a 'green' Kumbh with minimal impact on the river. But some 18,000 tons of raw sewage from the mela alone lay untreated at defunct sewage treatment plants (PSI, 2019). Other plants had insufficient capacity to treat the sheer volume of waste that was being diverted to them. Several temporary unlined soak pits collected wastewater along the banks of the river. The much-hyped geo-tube technology, supposed to treat wastewater from drains before it entered the river also failed, allowing untreated wastewater to flow directly into the river (PSI, 2019).

A host of measures were implemented at Prayagraj and elsewhere before the Ardh Kumbh to ensure that visitors and tourists at the Mela could experience a clean river with a healthy flow. These measures included increasing the water released from the Tehri dam and the Kalagarh dam (Western Ramganga), closure of major polluting industries, diversion of effluents discharge usually released directly into the Ganga and treatment of wastewater through bioremediation measures, etc. About 120,000 temporary toilets and 160,000 dustbins were also installed at the site as a part of solid waste and sanitation management. Trash skimmers were deployed on the river to keep it clear of floating solid waste.

These measures had a visible effect. Many bathers at the Mela, local residents and visitors from elsewhere, who were interviewed, said that the Ganga had never appeared as clean as it did during this Mela. This perception of 'cleanliness' primarily arose from the absence of visible solid wastes and suspended solids floating on the river's surface.

But scientific testing of River Ganga's WQ across the Ardh Kumbh period belied these visual impressions. A team of scientists from Dehradun-based People's Science Institute monitored the CPCB-defined physico-chemical and bacteriological river WQ parameters (pH, TDS, DO, BOD and FC) following standard procedures. PSI's team did the tests over several days a month from December, 2018 to April, 2019, at about eight stations between u/s of Rishikesh and d/s of Sangam (See Map 23). One additional station at Varanasi was monitored in April, 2019. Biomonitoring was also done.

The data clearly revealed that despite all the efforts of the Mela authorities, the Ganga water was unfit for outdoor bathing in the Mela stretch between December, 2018 and April, 2019. Overall, the data showed that while the Ganga was clean at Rishikesh in all the months, its WQ deteriorated steadily thereafter. The BOD (Biological Oxygen Demand) and FC (Faecal Coliform) values in the Ganga, u/s and d/s of Sangam, and the Yamuna u/s of Sangam were well above the standards for outdoor bathing, namely BOD ≤ 3mg/l and FC ≤ 2500 MPN/100 in all the months. According to the biomonitoring data, the WQ of R. Ganga u/s and d/s of Sangam fluctuated between moderate and heavy pollution between December, 2018 and April, 2019. Taking all the parameters together the worst WQ was d/s of Sangam. One possible reason could be that the toilets constructed along the Ganga leached pollutants through the alluvium into the river water.

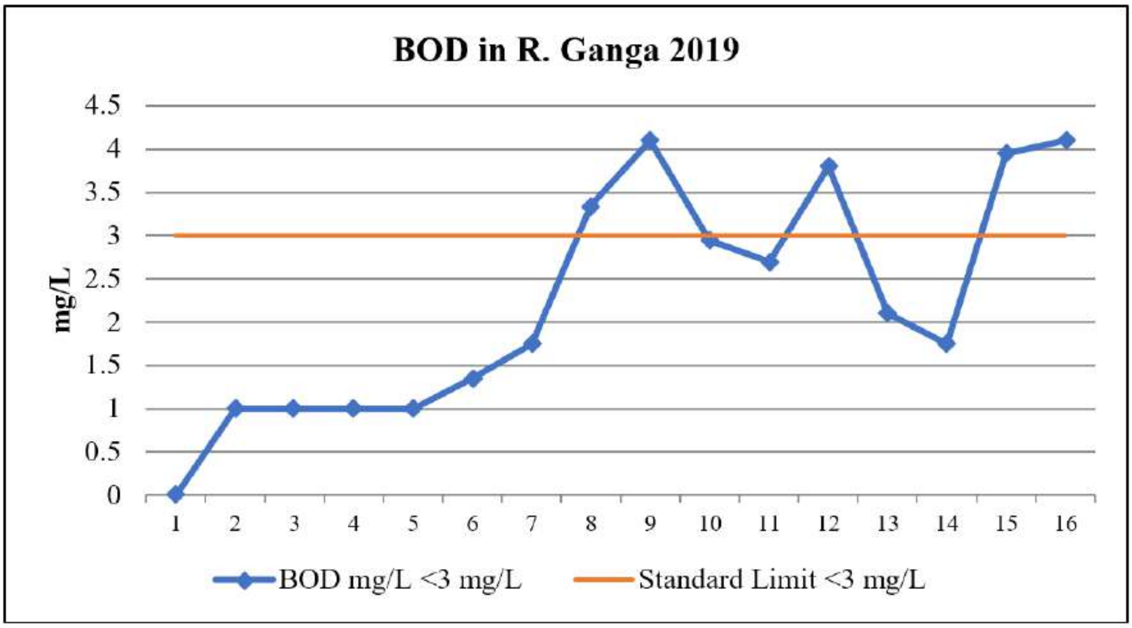


Image 25 a: DO Concentrations In The Main Stem Of R. Ganga, 2019

Source: CPCB

Note: 1. Gangotri 2. Alaknanda u/s Devprayag 3. Bhagirathi u/s Devprayag 4. Rishikesh 5. Haridwar 6. Mukteshwar 7. Narora 8. Bithoor 9. d/s Kanpur 10. Kadaghat 11. d/s Sangam 12. d/s Varanasi 13. Buxar 14. d/s Patna 15. Palta (WB) 16. Dakshineshwar (WB)

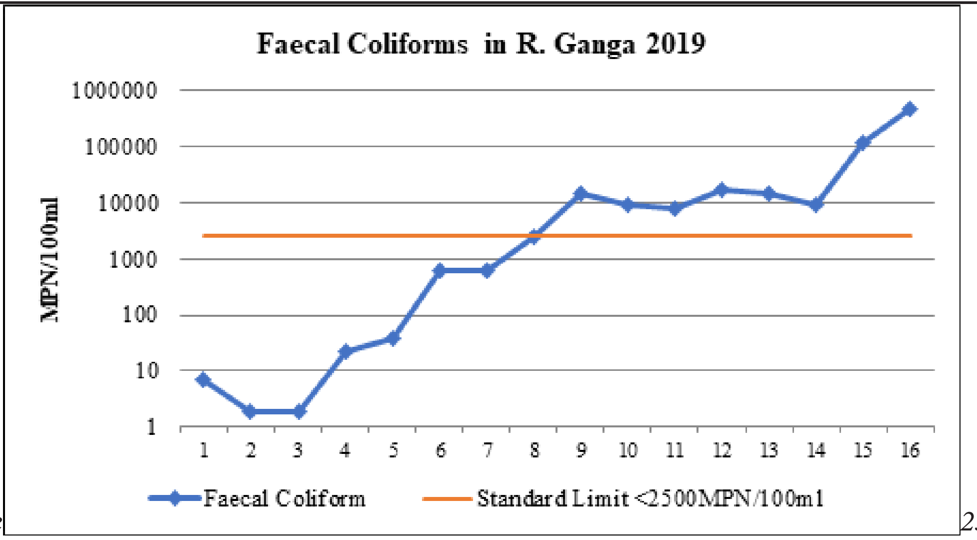


Image 25 b : FC Concentrations In The Main Stem Of R. Ganga, 2019

Source: CPCB

Note: 1. Gangotri 2. Alaknanda u/s Devprayag 3. Bhagirathi u/s Devprayag 4. Rishikesh 5. Haridwar 6. Mukteshwar 7. Narora 8. Bithoor 9. d/s Kanpur 10. Kadaghat 11. d/s Sangam 12. d/s Varanasi 13. Buxar 14. d/s Patna 15. Palta (WB) 16. Dakshineshwar (WB)

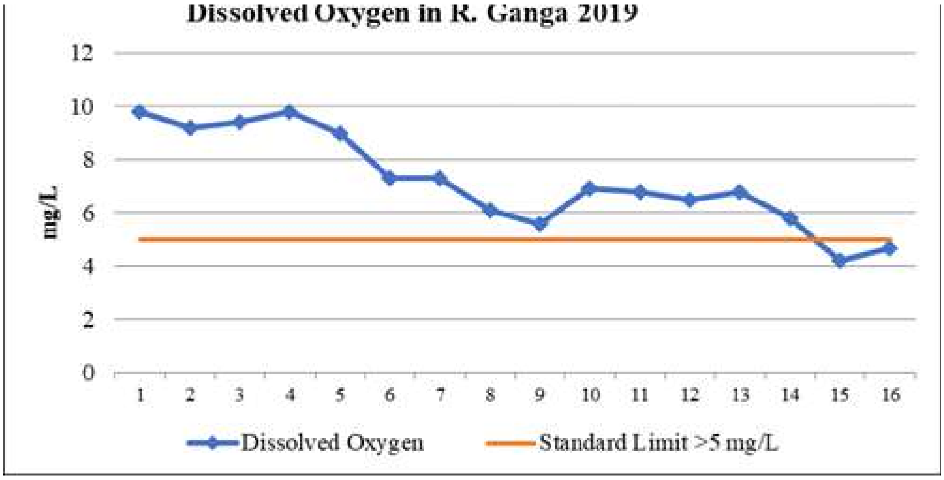


Image 25 c : BOD Concentrations In The Main Stem Of R. Ganga, 2019

Source: CPCB

Note: 1. Gangotri 2. Alaknanda u/s Devprayag 3. Bhagirathi u/s Devprayag 4. Rishikesh 5. Haridwar 6. Mukteshwar 7. Narora 8. Bithoor 9. d/s Kanpur 10. Kadaghat 11. d/s Sangam 12. d/s Varanasi 13. Buxar 14. d/s Patna 15. Palta (WB) 16. Dakshineshwar (WB)

A committee set up by the NGT and headed by retired Justice Tandon to supervise the Mela steps concluded that, "An attempt has been made to hoodwink the cleaning of waste from the soak pits and septic tanks, ponds, etc." On April, 22nd, the NGT, said that Prayagraj was facing a potential epidemic that had to be dealt with "on an emergency basis" (NGT 2019).

Average WQ parameters for 2019 released by CPCB show that the clean-up done for the Ardh Kumbh Mela did not have a lasting effect during 2019 (CPCB, 2019). The average annual FC levels were well above the acceptable standard beyond Bithoor (u/s of Kanpur), while the average annual BOD levels were also similarly unacceptable at most stations from Bithoor till Dakshineshwar (See Images 25 a, 25 b, and 25 c).

7.3.6 Impact of COVID-19 Lockdown on River Ganga's Water Quality

The imposition of a strict nationwide lockdown due to the COVID-19 pandemic in March, 2020 led to a significant improvement in R. Ganga's WQ (Dutta V., et al 2020). The GoI imposed a strict nationwide lockdown on March 24, 2020 in an attempt to control the spread of COVID-19 in the country. Inspite of some relaxations from mid-April, 2020 onwards to encourage resumption of economic activity, industrial activity did not significantly pick up till mid-June, 2020.

As industrial and commercial activity came to a halt, the discharge of industrial wastewater became negligible. The lockdown period coincided with the harvesting and post-harvest seasons so that agricultural run-off was also much less. The end of the strict lockdown was followed by heavy rains in the riparian districts. Greater rainfall over the normal, less irrigation and industrial power demand and increased releases from storage reservoirs, led to increased discharge in the river and dilution of the pollutants.

Dutta V., et al (2020) analysed real-time WQ monitoring data of CPCB and various SPCBs and compared it with similar data from the previous (non-COVID) year. The comparison showed significant improvement in the river WQ due to nearly nil discharge of industrial effluents and solid wastes to the river. Though the discharge of domestic sewage did not reduce in the lockdown period, values of bacteriological contamination did decrease, mainly due to the increased flows in the river.

The Uttarakhand Pollution Control Board rated the Ganga's WQ at Haridwar as Class A, fit for drinking without conventional treatment but after disinfection, for the first time after the formation of Uttarakhand state in 2000 (Dutta V., et al, 2020). Water quality between Haridwar and Kanpur was fit for out-door bathing (Class B).

Since domestic wastewater discharges did not diminish much during the lockdown, there was little reduction in the Ganga's organic load. The weekly BOD levels did not improve much in the first four weeks and remained above the level acceptable for outdoor bathing (≤ 3mg/l) at Kannauj, Kanpur and all the monitoring stations in West Bengal. Compared with the same March to May period in the previous year, however, BOD values had decreased in the lockdown period, except at Varanasi and Murshidabad (Khagra).

There was a significant decline in the average faecal coliform concentrations at all the stations from Bijnor to Howrah bridge during the lockdown period, compared to the same period in the previous year. Total coliforms also decreased similarly, except for the Bithoor-Kanpur Bridge 1 stretch.

The above data analysis suggests that adequate treatment of municipal sewage and industrial effluents along with adequate flows in our rivers can keep contamination levels within the standards for direct human use.

It is surprising, however, that in a report submitted to the National Green Tribunal (NGT) in September, 2020, the CPCB stated that the WQ of river Ganga had deteriorated during the lockdown. The apparent discrepancy with the study of Dutta V., et al detailed above, is due to the different periods of comparison. Dutta V., et al compared the March to May period of 2020 with the same period of the previous year, whereas CPCB compared the values of April 2020 (lockdown month) with March 2020. The March to May period reported by Dutta V., et al had witnessed heavy rainfall, leading to greater releases from storage reservoirs and hence dilution.

7.3.7 Organic Chemical Contaminants

Until recent decades, organic chemicals have generally not been considered as major contaminants in Indian rivers. Their concentrations often appear low in comparison to the primary pollutants. Their growing importance as compounds of concern derives from their rapidly growing production and consumption. The Indian chemical industry is the 6th largest in the world. A large fraction of the organic chemicals produced include pesticides, industrial compounds and emerging contaminants (ECs) like pharmaceuticals and personal care products (PPCPs), artificial sweeteners, surfactants, detergents and plasticizers among many others.

India's chemicals industry is estimated to account for seven per cent of its GDP and employs over 2 million people (Ramanjulu J., 2020). As chemical consumption in India increases, their presence in Indian rivers also increases. They enter the rivers through sewage, industrial and hospital wastewaters and agricultural run-off. The issue came into public prominence after 'Nature' highlighted the presence of common drugs like ciproflaxin (31 mg/l) and cetirizine (1.4 mg/l) in R. Yamuna near Delhi in 2009 (IITC 2011a). Several reviews of organic chemical contaminants in Indian rivers have emerged in recent years (IITC 2011, Philip J.M. et al, 2018 and Ghirardelli A. et al, 2021).

Ghirardelli A., et al (2021) systematically reviewed 61 research publications spanning 33 years to identify the sources, levels and spatio-temporal distribution of organic pollutants in the water and sediments of the Ganga basin rivers. Fifty of the 61 papers were published after 2000. In all, they identified 271 organic compounds, including pesticides, industrial compounds and emerging contaminants (ECs), such as pharmaceuticals and personal care products (PPCPs) and caffeine among others less known. Most of the studies reported on the main stems of the Ganga, Yamuna, Gomti and the Hooghly rivers. Other northern tributaries of the Ganga and its southern basin rivers were not investigated.

The review showed that the main sources of organic compounds in the Ganga and the tributaries were sewage, industrial effluents, agricultural runoff and religious activities. Delhi, Kolkata, Kanpur, Varanasi, and Patna are the contamination hotspots. Pesticides levels had decreased at most of the sites in the recent decade, but potentially harmful concentrations of poly-chlorinated biphenyls (PCBs), organotin compounds (OTCs), and some pharmaceuticals and personal care products (PPCPs) were detected in the last decade.

Emerging Contaminants: ECs are synthetic or naturally occurring chemicals or micro-organisms that are not commonly monitored in the environment but can potentially have adverse ecological and/or human health effects (Churchill C.J., et al., 2020). They include many substances of daily use like pharmaceuticals, artificial sweeteners (ASWs), personal care products (PCPs), surfactants, detergents, insect repellents and sunscreen agents. Sewage and industrial effluents are the main sources of ECs in rivers.

The studies have mainly focussed on the large cities like Kanpur, Prayagraj, Varanasi and Patna along the main stem in the middle Ganga basin and along the Hooghly in the delta region of the lower Ganga basin. Other papers have reported from the NCT stretch of R. Yamuna and cities along the Gomti.

The maximum concentration values of some ECs in the Ganga basin river waters and sediments are given in Table 26.

Table 26 : Max. Observed Concentrations Of Organic Chemicals In The Rivers Of The Ganga Basin

Compound	**Study Area**	**Maximum concentration**	**Value**	**References**
I. Emerging Contaminants in river waters (µg/L)				
Antibiotics, and other pharmaceuticals	Bhagirathi, Alaknanda and Ganga	Ketoprofen	0.107	Sharma et al. 2019
Antibiotics	Yamuna (Delhi area)	Ampicillin	27.1	Mutiyar and Mittal 2014a

NSAIDs, other pharmaceuticals	Yamuna (Delhi area)	Ibuprofen	2.302	Mutiyar et al. 2018
Other compounds (caffeine)	Yamuna (Delhi area)	Caffeine	2.640	Mutiyar et al. 2018
Biocides (triclosan)	Gomti	Triclosan	9.650	Nag et al. 2018
Anionic surfactants	Hooghly and small tributaries (Kolkata)	Total anionic surfactants	0.425	Ghose et al. 2009
II. Emerging Contaminants in river sediments (in mg/kg dry weight)				
Phtalates	Gomti	DEHP	324.72	Srivastava et al. 2010
NSAIDs, other pharmaceuticals	Hooghly	Carbamazepine	519	Chakraborty et al. 2019
III. Pesticides in river waters (µg/L)				
OCPs; herbicides	Gomti	Butachlor	135	Trivedi et al. 2016)
OCPs	Sharda river, Reetha river, drains surrounding lindane factory (Lucknow)	alpha-HCH	290	Jit et al. 2011
OCPs	Ganga and Yamuna (Prayagraj)	Lindane gamma-HCH	24.5	Raghuvanshi et al. 2014
IV. Pesticides in river sediments (in mg/kg dry weight)				
OCPs	Gomti	o,p'-DDT	345.66	Malik et al. 2009
OCPs	Drains discharging into Yamuna (Delhi area)	Chlorpyriphos	286.56	Malik et al. 2009
OCPs; OPhs	Ganga and Jamania River (Bhagalpur)	p,p'-DDT	3329.3	Singh et al. 2012
V. Industrial Chemicals in river waters (µg/L)				
PAHs (16 compounds)	Bhagirathi, Alaknanda and Ganga	Pyrene	0.021	Sharma et al. 2018
PCBs (27 congeners)	Yamuna (Delhi area)	PCB-18	0.280	B. Kumar et al. 2012b
PAHs (16 compounds)	Gomti	Acenaphthylene	82.67	Malik et al. 2011

VI. Industrial Chemicals in river sediments (in mg/kg dry weight)				
PAHs (16 compounds)	Gomti	Acenaphthylene	2726.4	Malik et al. 2011
PAHs (16 compounds)	Hugli, Sundarban wetland	Fluoranthene	1839.5	Zuloaga et al. 2013

7.4 CLEANING RIVER GANGA: THE FACTS

7.4.1 GAP and YAP

India's Water (Prevention and Control of Pollution) Act, 1974 was enacted not long after the return of the then Prime Minister Mrs. Indira Gandhi from the United Nations Conference on the Human Environment, held in Stockholm in 1972. With the emergence of the Chipko movement environmental consciousness took firm roots by the end of the 1970s.

In 1979, the Central Board for the Control and Prevention of Water Pollution, now called Central Pollution Control Board (CPCB), was entrusted the task of investigating the degraded states of the Yamuna and Ganga rivers. It produced two reports by October, 1984. These reports formed the basis of the river cleaning programme named Ganga Action Plan.

In April, 1985, the Union Cabinet approved the Ganga Action Plan (GAP) at an initial cost of Rs 350 crores as a 100 per cent centrally sponsored scheme. At its formal launch in Varanasi on January 14, 1986, the then Prime Minister Sri Rajiv Gandhi said, "*The purity of the Ganga has never been in doubt. Yet we have allowed the pollution of this river which is the symbol of our spirituality. The felling of trees has caused severe floods, and silt and mud now flow into the Ganga making the river shallow so that boats cannot ply in it as they did before. Sewage and pollution from cities, industries and factories and dead animals are also being thrown into the Ganga. From now on, we shall put a stop to this. We shall see that the waters of the Ganga become clean once again.* "

"The Ganga Action Plan is not just a government plan. It has not been prepared for the PWD or government officials alone. It is a plan for all the people of India; one in which they can come forward and participate. It is up to us to clean the whole of Ganga and refrain from polluting it. This programme, starting at Varanasi here today will reach out to every corner of our land and to all our rivers. In the years to come, not only the Ganga, but all our rivers will be clean and pure as they were thousands of years ago."

Objectives of GAP

The objectives of GAP were broad:

i. to abate pollution and improve water quality,
ii. to conserve biodiversity and develop an integrated river basin management approach,
iii. to conduct comprehensive research to further these objectives, and

iv. to gain experience for implementing similar river clean-up programs in other polluted rivers in India.

The Basic Plan: An action plan was developed to achieve these objectives. The actions that addressed the major, direct causes of pollution in the Ganga were identified as "Core Sector" schemes, and those that addressed indirect sources or direct sources but with a lower impact were called "Non-core Sector".

The Core Sector schemes involved the interception and diversion of domestic wastewater and the construction/rehabilitation of sewers and pump houses. The Non-core Sector schemes consisted of a) installation of crematoria; b) river front development and aesthetic improvement; c) implementation of low-cost sanitation systems; and d) miscellaneous activities such as WQ monitoring, research programmes, and identification and management of waste from grossly polluting industries.

At the time of its launch, the main objective of GAP was to improve the WQ of Ganga to acceptable standards by preventing the pollution load from reaching the river. But in June, 1987, the programme Monitoring Committee under the Chairmanship of Prof M.G.K. Menon, then Member, Planning Commission, recast the objective of GAP as restoring the river WQ to the 'Bathing Class' standards which is as follows:

S.No.	Parameter	Standard
1	Biochemical Oxygen Demand (BOD)	Max 3 mg/litre
2	Dissolved Oxygen (DO)	Min 5 mg/litre
3	Total Coliform MPN	10,000/100 ml
4	Faecal Coliform MPN	2,500/100 ml

Source: (MoEF, 1999)

Institutional Structure of GAP

To oversee the implementation of GAP and to lay down its policies and programmes, the Union Government constituted the Central Ganga Authority (CGA) in February, 1985, under the chairmanship of the Prime Minister. It was renamed in September, 1995, as the National River Conservation Authority (NRCA).

In June, 1985, the Union Government also established the Ganga Project Directorate (GPD) as a unit of the Department of Environment, to execute the projects under the guidance and supervision of the CGA. It was renamed as the National River Conservation Directorate (NRCD) in June, 1994.

State River Conservation Authorities (SRCAs) were created in Uttar Pradesh, Bihar and West Bengal. SRCAs were also formed in the states of Uttarakhand and Jharkhand after they were separated from Uttar Pradesh and Bihar respectively, in 2000. These Authorities primarily had coordination and monitoring roles.

Various agencies of the respective states carried out the actual work on the ground. These included UP Jal Nigam (UP), Bihar Rajya Jal Parishad (Bihar) and the Public Health Engineering Department in W Bengal. In Delhi it was the Delhi Jal Board. Other than SRCA, state level agencies like the State Pollution Control Boards, respective Commissioners and Dy Commissioners also had monitoring roles. A few autonomous institutions like IIT-Kanpur and Patna University were given responsibilities for monitoring WQ and the functioning of the sewage treatment facilities.

At the local level, according to a report filed by the IIT-Consortium (IITC 2011a) municipal bodies were given the role of overseeing project implementation and operation. Citizen's Monitoring Committees (CMC) were also formed to monitor the functioning of the STPs.

GAP-II

GAP-I was designed to intercept, divert and treat 882 MLD (Million Litres Daily) out of 1340 MLD of wastewater generated in 25 class-I towns in Uttar Pradesh, Bihar and West Bengal. The CGA had scheduled its completion by March, 1990, but extended it progressively up to March 2000. While GAP-I Gomti.was still in progress, the CGA decided in February, 1991 to initiate GAP-II, covering the following pollution abatement works :

(a) On the tributaries of river Ganga, viz. Yamuna, Damodar and
(b) In 25 class-I towns left out in Phase-I.
(c) In other polluting towns along the river.

Table 27 : Number Of Towns Selected For River Pollution Abatement

River	**Number of towns**					**Total**
	UP	Bihar	WB	Haryana	Delhi	
GAP-I						
Ganga	6	4	15			25
GAP-II						
Ganga	16	10	23			*49
Yamuna	8			12	1	**21
Gomti	3					3
Damodar		8	4			12
Total	**33**	**22**	**42**	**12**	**1**	**110**

**12 towns in Uttar Pradesh, 3 in Bihar and 15 in West Bengal taken up on directives from the Supreme Court.*

***6 towns in Haryana taken up on direction of the Supreme Court*

Yamuna Action Plan (YAP)

Yamuna Action Plan Phase - I (YAP-I) began in April, 1993 as an externally-aided project with a loan from the Japan Bank for International Cooperation (JBIC), since renamed Japan International Cooperation Agency (JICA). Implemented like GAP, primarily as a pollution abatement effort, in 21 cities of Haryana and UP and the National Capital territory of Delhi, it claims to have created a total sewage treatment capacity of 753 MLD at a total cost of Rs 682 crores.

YAP II began, again with JICA assistance in 2003, at a total cost of Rs 624 crore for abatement of pollution in river Yamuna in Delhi, Uttar Pradesh (98 towns) and Haryana (6 towns). It claims to have created additional sewage treatment capacity of 189 MLD.

Yamuna Action Plan III aimed at pollution abatement in the city of Delhi, again with JICA assistance and with a projected life span of seven years, has been underway since 2012. The cost estimate of YAP III is Rs 1656 crores. Its components include rehabilitation of damaged trunk sewers in the Kondli and Rithala catchments; rehabilitation and modernization of STPs at Okhla, Rithala and Kondli in tune with the sewerage master plan for the city that is under-preparation.

March, 2000: CAG finds GAP to be a failed effort

According to the Comptroller and Auditor General of India (CAG), by the year 2000 the GAP launched in 1985 was able to achieve only 39 per cent of its target to bring the WQ of R. Ganga and its tributaries to bathing quality level, despite an expenditure of 91 per cent of its budget (Das and Tamminga, 2012). It said, "There were shortfalls in allocation of resources. Of the total domestic sewage of 5044 MLD, in 110 towns selected for pollution abatement along the banks of river Ganga and its tributaries, the GAP addressed itself to process only 2794 MLD. The reported achievement of the participating States was 1095.69 MLD, i.e. only 39 per cent of truncated target. The assets created in the Scheme suffered impairment and closure because of technical design flaws, internal mismatch of the schemes and their components, problems in land acquisition, contract mismanagement, lack of adequate maintenance, and in general because of lackadaisical attitude of the States and their implementing agencies. Technologies adopted by the NRCD for construction of STPs were often questionable inasmuch as they could not adequately address the problem of reducing bacterial load in the river to the desired level. The NRCD has abandoned the crucial activity of monitoring the WQ monitoring on river Ganga since September, 1999, reportedly for want of funds, and deprived itself of a key instrument of overall performance monitoring of the GAP." (CAG 2000)

7.4.2 NGRBA

By the end of the Tenth Five Year Plan (2002-2007), River Ganga was not getting cleaner and there were growing demands from various quarters, often voiced by the media, that it was time for the government to take more effective steps. Public support for the fast-unto-death by Dr. G.D. Agrawal in June, 2008, demanding an aviral (uninterrupted) and nirmal (pristine) flowing R. Bhagirathi, pushed Prime Minister Manmohan Singh to declare River Ganga as the National River of India on November 4, 2008.

In February, 2009 the Government of India established the National Ganga River Basin Authority (NGRBA) with the Prime Minister of India as its Chairperson. It was a financing, planning, implementing, monitoring and coordinating authority for R. Ganga, initially under MoEF, GoI. Its objectives were:

i. Development of a River Basin Management Plan
ii. Regulation of activities aimed at prevention, control and abatement of pollution in river Ganga to maintain its water quality and to take measures relevant to river ecology and management in the river Ganga basin states
iii. Maintenance of minimum ecological flow in river Ganga
iv. Measures necessary for planning, financing and execution of programs for abatement of pollution in river Ganga including augmentation of sewerage infrastructure, catchment area treatment, protection of floodplains, creating public awareness
v. Collection, analysis and dissemination of information relating to environmental pollution in river Ganga
vi. Investigation and research regarding problems of environmental pollution and conservation and of river Ganga
vii. Promotion of water conservation practices including recycle and reuse, rainwater harvesting and decentralized sewage treatment systems
viii. Monitoring and review of the implementation of various programs or activities taken up for the prevention, control and abatement of pollution in river Ganga
ix. Issue directions under section 5 of the Environment (Protection) Act, 1986 for the purpose of exercising and performing these functions and for achievement of its objectives

In July, 2014 NGRBA was transferred to the Ministry of Water Resources, River Development & Ganga Rejuvenation, later renamed as the Ministry of Jal Shakti.

NGRBA's Ganga Pollution Abatement Project: GAP in a New Avatar

In April, 2011 the Central Government approved a Rs 7000 cr project under NGRBA with World Bank assistance for abatement of pollution in river Ganga. The World Bank would provide technical assistance and financing of US $ 1 billion, then approximately Rs 4600 cr (ENVIS, 2013). The assistance would be in the form of a loan of $801 million from International Bank for Reconstruction and Development (IBRD) and a credit of $199 million from International Development Association (IDA).

The principal objective of the project was to fund creation of pollution abatement infrastructure for conservation and restoration of WQ of the river. Its focus was on:

i. Building and strengthening the institutional framework at the Central and State level;

ii. Establishing a Ganga Knowledge Centre;
iii. Enhancing river basin management; and
iv. Financing priority investments for pollution abatement in a sustainable manner

The project implementation was to be in accordance with a Program Framework, developed by the Centre and States for NGRBA. It included implementation arrangements, criteria for selection of investments, Procurement Manual, Financial Manual, an Environment and Social Management Framework, etc.

7.4.3 How much money has been actually spent for cleaning River Ganga?

Victor Mallet, in his book, "River of Life, River of Death" (Mallet 2017) laments, while discussing the river Ganga clean-up efforts, "What should give optimists pause for thought is the record of previous clean-up projects. It is not just that the river evidently remains filthy after they were supposedly implemented. No one is even sure how much money was spent or where it went."

One of the reasons for this confusion is the periodic change in the nature of the funds allotment for works to the states by the Central Government. What began as a 100% Centrally sponsored project subsequently in various Plan years underwent a change, whereby the Central Government provided only part of the funds, with the rest supposedly coming from the respective State Governments as the State's share. With the States either not fulfilling their commitments or contributing in a delayed manner, the account keeping went haywire. Finally GoI's share of the expenditure would be Rs 5100 cr and that of the State Governments of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand would be Rs 1900 cr.

7.4.4 Funding Pattern

Table 28 : Funding Pattern

Period	Pattern	Comments
1985 - 1993	100% Central sector	This is only GAP scheme
1993- 1997	50% Centre, 50% State	GAP and YAP schemes
1997 - 2001	100% Central sector (except land cost)	GAP, YAP & other rivers
2001 - 2014	70% Centre, 30% State	GAP, YAP & other rivers
2014 - onwards	100% Central sector*	Namami Gange Program

*Presumably the overruns in projects from the pre-Namami Gange programmes continue in the previous funding pattern. Operation & Maintenance (O&M) of assets created is the responsibility of the respective state governments.

7.4.5 Expenditure

According to a 2010 report by the national Auditor's office (CAG) the expenditure figures at the end of the tenth Five Year Plan (2002 – 2007) were as shown in Table29.

Table 29 : Total Expenditure Till The End Of The Tenth Five Year Plan (2002-2007)

Plan	**Expenditure (Rs. Crores)**
Ganga Action Plan I	462
Ganga Action Plan II	1015
Yamuna Action Plan I	680
Yamuna Action Plan II	624
Other Rivers	1164
TOTAL	**3945**

Since 2014, all rivers' related works are being executed by the NMCG (National Mission for Clean Ganga) in the Ministry of Water Resources, River Development and Ganga Rejuvenation. The CAG's report No 39 of 2017 stated that, "As on 1 April, 2014, there were 55 projects costing Rs 4588.35 Crore, which were ongoing."

Thus, it can safely be said that at the start of FY 2014-2015, a total sum of Rs 8533.35 cr (3945 + 4588.35) had been spent (released) for river cleaning in India.

7.5 EMERGING LESSONS

7.5.1 IITC: A SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis

A seven Indian Institutes of Technology (IIT) consortium was given the task of preparing a Ganga River Basin Environment Management Plan (GRBEMP) by the Ministry of Environment & Forests (MOEF), Government of India. The MOU for this purpose was signed on 6 July, 2010. One of its reports, titled SWOT Analysis of Ganga Action Plan, reviewed the Ganga Action Plan (IITC, 2011b). The report's main findings are summarized in Table 30 below.

Table 30 : IITC's SWOT Analysis of GAP (See notes at the end of the Table)

Parameter	Strengths	Weaknesses	Opportunities	Threats
Design of Program	• Initial vision • Strategy of Interception & diversion of drains	• Limited scope of issues addressed (e.g., Impact of water diversion on river health and lack of dilution of pollution not addressed; Pollution from industries underrated) • Inadequacy of standards for assessing WQ (Standards in Indian conditions should have been for drinking and not just bathing quality) • Influence of Overseas Aid on Planning in general, prioritization of programs and selection of technologies in particular (Eg Introduction of UASB technology due to aid from the Netherlands) • Inappropriate choice of treatment technology • Inappropriate policy of discharging treated effluent and sewage into the river • Lack of clear policy-legal and institutional framework • Frequent alteration in central sector funding mechanism* (Central, State funding mechanism changed from 100% to 50-50% to 100% to 70-30% and again 100%)	• Adoption of River basin approach • Learn from experiences of technology used under GAP • In country funds to take the program forward • Involvement of civil society • Evolving a robust regulatory framework and institutional model***	• Developmental imperatives dilute the emphasis on and effectiveness of river cleansing projects • Challenges associated with implementation of newer regulatory and institutional mechanisms • Bilateral and multilateral funding agencies influence policy and programs • Inadequate capacity and lack of incentives for ULBs to own the programs • Misappropriation and wastage of funds (Corruption, etc) • Complexity in monitoring technical parameters • Inadequate analytical framework for future plans

Implementation of programs	Creation of Institutional structure	• Political motivations for GAP (So whenever political support waned, the program suffered) • Inordinate delays in creation of assets • Partial coverage in collection, coverage and treatment of sewage across cities in Ganga basin • Overdesigned STPs (resulting in underutilization of STPs from lack of adequate sewage reaching them due to various reasons)		
Operation and Maintenance of Assets created		• Irregular maintenance • Sub optimal functioning of assets • O&M forced upon States & ULBs** (resulting in lack of ownership of the assets) • Unclear, unviable finance model (treated sewage should have become a resource & helped in O&M funding)		

Monitoring, Evaluation and Regulation of Program	• Peer review (CAG, Parliament Committees, etc.) and monitoring by a number of agencies • Appointment of independent agencies for WQ assessment • Provision for Citizen's Monitoring Committees	• Neglect of monitoring of aspects of river, other than WQ • Failure to utilize available monitoring data • Failure in monitoring and regulating the industrial pollution • Weak monitoring by central institutions • Flaw in design of Citizen's Monitoring Committees • Failure in establishing Citizen's Monitoring Committees		
Other Strengths/ achievements	• Creation of knowledge base (on river Ganga) • Awareness building among government agencies • Awareness building among civil society			

Note: Comments have been added in brackets based on mentions made in the text of the report.
**This was not part of the IITC report and is an insertion;*
***This we believe is a weakness and not a strength as shown in IITC report;*
****This is an opportunity and not a threat as listed in the IITC report.*

The overall conclusion of the above-mentioned IITC report, based on the strengths and weaknesses of the Ganga Action, painted an extremely grim picture. It said, "The core weaknesses of the GAP in all aspects of design, implementation, monitoring, evaluation and regulation have defeated the very purpose of GAP ...."

7.5.2 Eco Friends Report

A report dated 28 May, 2007 by Rakesh Jaiswal -- founder of Eco Friends, a Kanpur-based NGO (See also Chapter 8), provides a good reflection of what has gone right (very little) and wrong (almost everything) with the Ganga Action Plan (GAP). He has used the example of Kanpur as a GAP I city to highlight the progress of GAP and its obvious shortcomings/failures. Some of his observations are reproduced below:

- No one is willing to take ownership of the assets created under GAP.
- GAP has done little to improve the condition of Ganga in Kanpur. Instead it has adversely impacted the local environment, health and livelihoods of the people .....
- At Jajmau, Kanpur, so-called treated sewage water supplied to farmlands for irrigation has caused a sharp decline in the productivity of food crops and contaminated food chains, soil, vegetables, livestock and even milk. Contamination of underground water meant for drinking purposes has grave public health implications.
- Can we define success in terms of percentages when the river WQ is visible to the naked eye? Do we need WQ data if the water looks black and brown and if it stinks?
- The actual ground situation and the WQ data findings do not match.
- GAP has focused on curative measures, end of the pipe solutions.
- The co-existence of worship and defilement of Ganga defies logic and leaves most thinking people confused.
- The eternal Ganga today needs new heroes and new voices. A whole new approach is required to restore the river.
- Ironically governments have spent more money on Magh melas, Ardh Kumbhs and Kumbhs than in cleaning the river.

It was thus expected that any new river cleaning program would take into account the findings and recommendations of the above two reports, one by a government agency (IITC) and another by an NGO.

7.5.3 Beyond GAP, YAP and NGRBA

By the middle of the first decade of the 21st century it had become common knowledge that the much-trumpeted Ganga and Yamuna Action Plans (GAP and YAP) had failed to 'clean' the two rivers and that their condition was going from bad to worse. There was growing realization that the pollution abatement centered approach to rejuvenate rivers was going nowhere and that the problem was far more acute than previously understood. It began to become clear that rivers had to be studied at the level of their basins (catchment area). Simultaneously, the idea of ensuring adequate flows (popularly known as E-Flows) in the rivers for their rejuvenation began gaining ground.

The issue of ensuring adequate flows in Indian rivers has its origin in the litigation at the Supreme Court of India (Cdr. Sureshwar D Sinha Vs Union of India; W.P. (C) 537 of 1992) in which the Court's indulgence was sought to 'permit fair levels of water flow in the Ganga and Yamuna rivers that have been severely curtailed depriving millions of people in downstream areas of the benefits of these rivers.' The petitioner also averred that wild life and fish had been deprived of fresh water that once flowed in these rivers and been killed.

A High Powered Committee [HPC] had been created in 1998 by the River Conservation Directorate at the MOEF. It was chaired by Mr. Thimayya, Member Planning Commission and it included the Chief Secretaries of the Yamuna riparian states of Delhi, Haryana, Uttar Pradesh (including the present Uttarakhand), Himachal Pradesh and Rajasthan. It had the following mandate:

a) To assess the requirement of a minimum flow in the river Yamuna to facilitate restoration of the desired river water quality

b) To suggest remedial measures both short term and long term for maintaining the minimum flow in the river

Based on the recommendation of the HPC, the Supreme Court of India on 18th August, 1999, directed that a minimum flow of 10 cumecs had to be ensured throughout the river. It directed the HPC to monitor the implementation of this decision. The HPC had arrived at this figure subject to Delhi's entire waste water being redirected away from the river (Dutta R., 2009).

It is a matter of record that this flow of 10 cumec water in R. Yamuna was not realized till the month of July, 2015 when the NGT vide its judgment in '*Maily Se Nirmal Yamuna*, 2017' (OA No 6 of 2012 & 300 of 2013) insisted upon the state of Haryana to at least start fulfilling the directions of the Supreme Court. In fact, this flow is presently ensured only downstream of the barrage at Hathnikund in Haryana and not 'throughout the river' as the Supreme Court had mandated. There was, however, little move to redirect the entire waste water of Delhi away from the river. Obviously little improvement if any in the health of river Yamuna has been achieved.

Namami Gange

In June, 2014 GoI launched the Namami Gange programme with an indicative cost of Rs 20,000 crore to integrate ongoing pollution abatement projects and new initiatives planned as its part (MoJS, 2021). Shri Gajendra Singh Shekhawat, Union Minister for Jal Shakti, informed the Rajya Sabha on July 26, 2021 that a total of 346 projects had been sanctioned at a cost of Rs.30,235 crore. Out of them, 158 (~46%) had been completed already. Till June 30, 2021 the annual allocations for NMCG, the executive agency, totalled almost Rs 15075 cr and Rs 10,792 cr had been released to it by then.

By October 31, 2021 in all 353 projects had been sanctioned with a budgetary allocation of Rs 30383.52 cr (NMCG, 2021). Of these, 263 were construction-related projects (including sewage infrastructure, sanitation, industrial pollution abatement, ghats, crematoria, riverfront development and solid waste management projects). Green projects related to afforestation, biodiversity conservation (including stocking fish) and bioremediation totalled 54. The budget sanctions for construction related projects amount to Rs 28, 910.37 cr (over 95% of the total sanctions) while the sanctioned budgets for green projects total Rs 870.44 cr (2.9%).

Thus GoI's fixation on infrastructure rather than catchment regeneration and other measures to enhance river flows continues unabated.

7.6 CONCLUSIONS AND RECOMMMENDATIONS

River Ganga is India's most sacred river but it is also its most polluted major river. As CPCB's own data, reported in this chapter shows, despite continuous efforts for pollution abatement in the major rivers of the basin for over 35 years now and an expenditure of over Rs. 20,000 cr, major stretches of rivers Ganga and Yamuna remain unfit for outdoor bathing.

In a recent webinar organized by India Rivers Forum, Paritosh Tyagi, former Chairman of CPCB, observed that, "The demand of water for agriculture, industry, domestic consumption and power generation is recognized but the demand of water and a water habitat for riverine flora and fauna goes unrecognized." He added that while there is a Forest Conservation Act, a Wildlife Protection Act and a Biodiversity Act, there is no river policy or law to protect rivers. The National Water Policy is focussed on provisioning water for various anthropogenic demands.

A river is a live, flowing ecosystem. The first requirement for the well-being of a river is to have a healthy pattern of year-round flows. The study of the COVID-induced lockdown effect on the Ganga's water quality outlined in this chapter, highlights the importance of combining adequate natural flow along with the discharge of return water treated to the highest standards for moving towards a clean Ganga.

It would be juvenile to claim that no progress whatsoever has been made for cleaning Ganga. In an interview to PTI, Rajiv Ranjan Mishra, former Director General, NMCG, reported that in 2014, 32 out of 53 locations (~60%) monitoring biochemical oxygen demand (BOD) were compliant with the primary water quality criteria for bathing whereas in 2021, 68 out of 97(~70 %) monitoring locations were BOD compliant. It cannot be ignored, however, that in the intervening years NMCG has spent over Rs 10,000 cr on cleaning the river. Kanpur, Prayagraj, Varanasi, the lower stretch in West Bengal and to a lesser extent Haridwar continue to remain hot spots. Research studies show that some pesticides levels have decreased at many sites studied in the recent decade, but potentially harmful concentrations of organics continue to be detected in the rivers.

It is encouraging that in recent years CPCB and BIS (Bureau of Indian Standards) have expanded the list of river water quality parameters, including emerging contaminants from non-point sources, for which standards and monitoring schedules have been set. But the regulatory mechanism is weak and is being continuously weakened. While CPCB and the SPCBs occasionally take action against private industries, there is no attempt to hold urban local bodies accountable for the pollution loads discharged by their cities into the rivers.

Reports of the IITs' consortium, research studies by academia and research institutions, and reports by NGOs and the media offer many practical and effective recommendations that can be implemented. For example, IIT-Kanpur has recommended that urban sewage treatment ought to be done in a dispersed manner at a larger number of smaller STPs so that erstwhile urban rivers like Pandu (Kanpur), Varuna (Varanasi) or the Sahibi (Delhi) are no longer polluted drains discharging stinking, contaminated water that kills the biota in the higher order rivers.

Without people's involvement, it is almost impossible to ensure *aviral* and *nirmal* rivers. Conscientized citizens can reduce the disposal of solid wastes and the volume of domestic wastewater released. Citizens' organizations, particularly college students and their teachers, can undertake local monitoring of river flows and the quality of effluents discharged. NMCG has shown some awareness of this issue. Namami Gange has a 'Public Awareness' component. But at present it is simply spending budgets on routine 'awareness generation' activities with no attempt to assess their impact or otherwise. What is needed is strategic people's involvement that leads to real improvement in the river water quality. It can be said in a nutshell that while some cleaning of the Ganga is being done, the pace is slow, the approach is routine and not comprehensive. A lot more needs to be done.

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Annexure I

TABLE-1: TOLERANCE LIMITS FOR INLAND SURFACE WATERS, CLASS – A

S. No.	Characteristic	Tolerance
(1)	(2)	(3)
(i)	pH	6.5 to 8.5
(ii)	Dissolved Oxygen, mg/l,	6.0
(iii)	Bio-chemical Oxygen Demand	2.0
(iv)	Total Coliform Organisms, MPN/100 ml, Max	50
(v)	Colour, Hazen units, Max	10
(vi)	Odour	unobjectionable
(vii)	Taste	Agreeable taste
(viii)	Total Dissolved Solids, mg/l, Max	500
(ix)	Total Hardness (as $CaCO_3$), mg/l ,Max	300
(x)	Calcium Hardness (as $CaCO_3$), mg/l, Max	200
(xi)	Magnesium (as $CaCO_3$), mg/1,Max	100
(xii)	Copper (as Cu), mg/l, Max	1.5
(xiii)	Iron (as Fe), mg/l,Max	0.3
(xiv)	Manganese (as Mn), mg/1,Max	0.5
(xv)	Chlorides (as Cl), mg/l,Max	250
(xvi)	Sulphate (as SO_4), mg/l ,Max	400
(xvii)	Nitrates (as NO_3), mg/1,Max	20
(xviii)	Fluorides (as F,) mg/l,Max	1.5
(xix)	Phenolic compounds(as C_6H_5OH), mg/l,Max	0.002
(xx)	Mercury (as Hg), mg/l ,Max	0.001
(xxi)	Cadmium (as Cd), mg/1,Max	0.01
(xxii)	Selenium (as Se), mg/l ,Max	0.01
(xxiii)	Arsenic (as As), mg/1,Max	0.05
(xxiv)	Cyanides (as CN), mg/l, Max	0.05
(xxv)	Lead (as Pb), mg/l, Max	0.1
(xxvi)	Zinc (as Zn), mg/l, Max	15
(xxvii)	Chromium (asCr^{6+}), mg/l,Max	0.05
(xxviii)	Anionic detergents, (as MBAS), mg/l ,Max .	0.2
(xxix)	Poly-nuclear aromatic hydrocarbons (PAH),	0.2
(xxx)	Mineral oil, mg/l ,Max	0.01
(xxxi)	Barium (as Ba), mg/l ,Max	1.0
(xxxii)	Silver (as Ag), mg/l Max	0.05
(xxxiii)	Pesticides	Absent
(xxxiv)	Alpha emitters, μc/ml, Max	10^{-9}
(xxxv)	Beta emitters, μc/ml, Max	10^{-8}

TABLE- 2: TOLERANCE LIMITS FOR INLAND SURFACE WATERS, CLASS – B

S. N.	Characteristic	Tolerance Limit
(1)	(2)	(3)
(i)	pH Value	6.5 to 8.5
(ii)	Dissolved Oxygen, mg/1,Max	5.0
(iii)	Biochemical Oxygen Demand (5 days at 20 °C),	3.0
(iv)	Total Coliform Organisms, MPN/100 ml, Max	500
(v)	Fluorides (as F)<mg/l, Max	1.5
(vi)	Colour, Hazen units, Max	300
(vii)	Cyanides (as CN), mg/l, Max	0.05
(viii)	Arsenic (as As), mg/l, Max	0.2
(ix)	Phenolic Compounds (as C_6H_5OH) mg/l, Max	0.005
(x)	Chromium (as Cr^{6+}), mg/l, Max	1.0
(xi)	Anionic detergents (as MBAS), mg/l, Max	1.0
(xii)	Alpha emitters, μc/ml, Max	10^{-9}

Source: UPPCB, 2019

TABLE - 3: TOLERANCE LIMITS FOR INLAND SURFACE WATERS, CLASS – C

S.No.	Characteristic	Tolerance Limit
(1)	(2)	(3)
(i)	pH Value	6.5 to 8.5
(ii)	Dissolved Oxygen, mg/l Minimum	4.0
(iii)	Biochemical Oxygen Demand	3.0
(iv)	Total coliform organisms, MPN/100 ml, Max	5000
(v)	Colour, Hazen units, Max	300
(vi)	Fluorides (as F), mg/l ,Max	1.5
(vii)	Cadmium (as Cd), mg/l, Max	0.01
(viii)	Chlorides (as Cl), mg/l, Max	600
(ix)	Chromium (as Cr^{6+}), mg/l, Max	0.05
(x)	Cyanides (as CN), mg/l, Max	0.05
(xi)	Total Dissolved Solids, mg/l, Max	1500
(xii)	Selenium (as Se), mg/l, Max	0.05
(xiii)	Sulphates (as SO_4), mg/l, Max	400
(xiv)	Lead (as Pb), mg/l, Max	0.1
(xv)	Copper (as Cu),mg/l,Max	1.5
(xvi)	Arsenic (as As), mg/l, Max	0.2
(xvii)	Iron (as Fe), mg/l, Max	50
(xviii)	Phenolic compounds (as C_6H_5OH), mg/l,	0.005
(xix)	Zinc (as Zn), mg/l, Max	15
(xx)	Insecticides, mg/l, Max	Absent
(xxi)	Anionic detergents (as MBAS), mg/l, Max	1.0
(xxii)	Oils and grease, mg/l, Max	0.1
(xxiii)	Nitrates (as NO_3), mg/1,Max	50
(xxiv)	Alpha emititers, μc/mg, Max	10^{-9}
(xxv)	Beta emitters, μc/ml, Max	10^{-8}

TABLE- 4: TEOLERANCE LIMITS FOR INLAND SURFACE WATERS, CALSS – D

S.No.	Characteristic	Tolerance Limit
(1)	(2)	(3)
(i)	pH value	6.5 to 8.5
(ii)	Dissolved Oxygen, mg/l, Min.	4.0
(iii)	Free Ammonia (as N), mg/l, Max.	1.2
(iv)	Electrical Conductance at 25 °C, μS, Max	1000
(v)	Free Carbon Dioxide (as CO_2),mg/1, Max	6.0
(vi)	Oils and Grease, mg/l, Max	0.1
(vii)	Alpha emitters, μc/ml, Max	10^{-9}
(viii)	Beta emitters, μc/ml, Max	10^{-8}

TABLE- 5: TOLERANCE LIMITS FOR INLAND SURFACE WATERS, CLASS – E

S.No.	Characteristic	Tolerance Limit
(1)	(2)	(3)
(i)	pH value	6.0 to 8.5
(ii)	Electrical Conductance at 25°C, μS, Max	2250
(iii)	Sodium Adsorption Ratio, Max	26
(iv)	Boron (as B), mg/l, Max	2.0
(v)	Total Dissolved Solids, (inorganic), mg/l, Max	2100
(vi)	Sulphates (as SO_4), mg/l, Max	1000
(vii)	Chlorides (as Cl), Mg/l, Max	600
(viii)	Sodium Percentage, Max	60
(ix)	Alpha emitters, μc/ml, Max	10^{-9}
(x)	Beta emitters, μc/ml, Max	10^{-8}

Appendix II

Bureau of Indian Standards Drinking Water Specifications (IS 10500:2012)

Table 1 Organoleptic and Physical Parameters

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Colour, Hazen units, *Max*	5	15	Part 4	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources
ii)	Odour	Agreeable	Agreeable	Part 5	a) Test cold and when heated b) Test at several dilutions
iii)	*p*H value	6.5-8.5	No relaxation	Part 11	—
iv)	Taste	Agreeable	Agreeable	Parts 7 and 8	Test to be conducted only after safety has been established
v)	Turbidity, NTU, *Max*	1	5	Part 10	—
vi)	Total dissolved solids, mg/l, *Max*	500	2 000	Part 16	—

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 2 General Parameters Concerning Substances Undesirable in Excessive Concentrations

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Aluminium (as Al), mg/l, *Max*	0.03	0.2	IS 3025 (Part 55)	—
ii)	Ammonia (as total ammonia-N), mg/l, *Max*	0.5	No relaxation	IS 3025 (Part 34)	—
iii)	Anionic detergents (as MBAS) mg/l, *Max*	0.2	1.0	Annex K of IS 13428	—
iv)	Barium (as Ba), mg/l, *Max*	0.7	No relaxation	Annex F of IS 13428* or IS 15302	—
v)	Boron (as B), mg/l, *Max*	0.5	1.0	IS 3025 (Part 57)	—
vi)	Calcium (as Ca), mg/l, *Max*	75	200	IS 3025 (Part 40)	—
vii)	Chloramines (as Cl_2), mg/l, *Max*	4.0	No relaxation	IS 3025 (Part 26)* or APHA 4500-Cl G	—
viii)	Chloride (as Cl), mg/l, *Max*	250	1 000	IS 3025 (Part 32)	—
ix)	Copper (as Cu), mg/l, *Max*	0.05	1.5	IS 3025 (Part 42)	—
x)	Fluoride (as F) mg/l, *Max*	1.0	1.5	IS 3025 (Part 60)	—
xi)	Free residual chlorine, mg/l, *Min*	0.2	1	IS 3025 (Part 26)	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be minimum 0.5 mg/l
xii)	Iron (as Fe), mg/l, *Max*	0.3	No relaxation	IS 3025 (Part 53)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xiii)	Magnesium (as Mg), mg/l, *Max*	30	100	IS 3025 (Part 46)	—
xiv)	Manganese (as Mn), mg/l, *Max*	0.1	0.3	IS 3025 (Part 59)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xv)	Mineral oil, mg/l, *Max*	0.5	No relaxation	Clause **6** of IS 3025 (Part 39) Infrared partition method	—
xvi)	Nitrate (as NO_3), mg/l, *Max*	45	No relaxation	IS 3025 (Part 34)	—
xvii)	Phenolic compounds (as C_6H_5OH), mg/l, *Max*	0.001	0.002	IS 3025 (Part 43)	—
xviii)	Selenium (as Se), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 56) or IS 15303*	—
xix)	Silver (as Ag), mg/l, *Max*	0.1	No relaxation	Annex J of IS 13428	—
xx)	Sulphate (as SO_4) mg/l, *Max*	200	400	IS 3025 (Part 24)	May be extended to 400 provided that Magnesium does not exceed 30
xxi)	Sulphide (as H_2S), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 29)	—
xxii)	Total alkalinity as calcium carbonate, mg/l, *Max*	200	600	IS 3025 (Part 23)	—
xxiii)	Total hardness (as $CaCO_3$), mg/l, *Max*	200	600	IS 3025 (Part 21)	—
xxiv)	Zinc (as Zn), mg/l, *Max*	5	15	IS 3025 (Part 49)	—

NOTES

1 In case of dispute, the method indicated by '*' shall be the referee method.

2 It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 3 Parameters Concerning Toxic Substances

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Cadmium (as Cd), mg/l, *Max*	0.003	No relaxation	IS 3025 (Part 41)	—
ii)	Cyanide (as CN), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 27)	—
iii)	Lead (as Pb), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 47)	—
iv)	Mercury (as Hg), mg/l, *Max*	0.001	No relaxation	IS 3025 (Part 48)/ Mercury analyser	—
v)	Molybdenum (as Mo), mg/l, *Max*	0.07	No relaxation	IS 3025 (Part 2)	—
vi)	Nickel (as Ni), mg/l, *Max*	0.02	No relaxation	IS 3025 (Part 54)	—
vii)	Pesticides, µg/l, *Max*	See Table 5	No relaxation	See Table 5	—
viii)	Polychlorinated biphenyls, mg/l, *Max*	0.000 5	No relaxation	ASTM 5175*	— or APHA 6630
ix)	Polynuclear aromatic hydro-carbons (as PAH), mg/l, *Max*	0.000 1	No relaxation	APHA 6440	—
x)	Total arsenic (as As), mg/l, *Max*	0.01	0.05	IS 3025 (Part 37)	—
xi)	Total chromium (as Cr), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 52)	—
xii)	Trihalomethanes:				
	a) Bromoform, mg/l, *Max*	0.1	No relaxation	ASTM D 3973-85* or APHA 6232	—
	b) Dibromochloromethane, mg/l, *Max*	0.1	No relaxation	ASTM D 3973-85* or APHA 6232	—
	c) Bromodichloromethane, mg/l, *Max*	0.06	No relaxation	ASTM D 3973-85* or APHA 6232	—
	d) Chloroform, mg/l, *Max*	0.2	No relaxation	ASTM D 3973-85* or APHA 6232	—

NOTES

1 In case of dispute, the method indicated by '*' shall be the referee method.

2 It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 4 Parameters Concerning Radioactive Substances

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 14194	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Radioactive materials:				
	a) Alpha emitters Bq/l, *Max*	0.1	No relaxation	Part 2	—
	b) Beta emitters Bq/l, *Max*	1.0	No relaxation	Part 1	—

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 5 Pesticide Residues Limits and Test Method

Sl No.	Pesticide	Limit µg/l	Method of Test, Ref to	
			USEPA	AOAC/ ISO
(1)	(2)	(3)	(4)	(5)
i)	Alachlor	20	525.2, 507	—
ii)	Atrazine	2	525.2, 8141 A	—
iii)	Aldrin/ Dieldrin	0.03	508	—
iv)	Alpha HCH	0.01	508	—
v)	Beta HCH	0.04	508	—
vi)	Butachlor	125	525.2, 8141 A	—
vii)	Chlorpyriphos	30	525.2, 8141 A	—
viii)	Delta HCH	0.04	508	—
ix)	2,4- Dichlorophenoxyacetic acid	30	515.1	—
x)	DDT (*o, p* and *p, p* – Isomers of DDT, DDE and DDD)	1	508	AOAC 990.06
xi)	Endosulfan (alpha, beta, and sulphate)	0.4	508	AOAC 990.06
xii)	Ethion	3	1657 A	—
xiii)	Gamma — HCH (Lindane)	2	508	AOAC 990.06
xiv)	Isoproturon	9	532	—
xv)	Malathion	190	8141 A	—
xvi)	Methyl parathion	0.3	8141 A	ISO 10695
xvii)	Monocrotophos	1	8141 A	—
xviii)	Phorate	2	8141 A	—

NOTE — Test methods are for guidance and reference for testing laboratory. In case of two methods, USEPA method shall be the reference method.

Table 6 Bacteriological Quality of Drinking Water

Sl No.	Organisms	Requirements
(1)	(2)	(3)
i)	*All water intended for drinking*:	
	a) *E. coli* or thermotolerant coliform bacteria[2), 3)]	Shall not be detectable in any 100 ml sample
ii)	*Treated water entering the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria[2)]	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample
iii)	*Treated water in the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample

[1)]Immediate investigative action shall be taken if either *E.coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause shall be determined by immediate further investigation.

[2)]Although, *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests shall be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

[3)]It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for progressive improvement of water supplies.

[i] The references to newer organic chemical pollutants in this section have benefitted from readings of the review paper by Ghirardelli et al, 2021.

[ii] This section is largely based on a detailed review paper by Ghirardelli et al, 2021.

[iii] In October 2016, the Union Government replaced the NGRBA with a new authority named National Council for River Ganga (Rejuvenation, Protection and Management). NCRG has the overall responsibility for supervising pollution prevention and rejuvenation of the river Ganga Basin.

Table 7 : Polluted River Stretches in Madhya Pradesh

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BETWA	MANDIDEEP TO VIDISHA AND ALONG KANJIYA	7.3	IV
2.	BICHIA	ALONG REWA	4.0	V
3.	CHAMBAL	NAGDA TO GANDHISAGAR	72.0	I
4.	CHAMLA	ALONG BADNAGAR	3.4	V
5.	HIRAN	ALONG JABALPUR	7.8	IV
6.	JOHILA	ALONG NAROJABAD	7.7	IV
7.	KALIASOT	ALONG MANDIDEEP	3.9	V
8.	KANHAN	ALONG CHINDWARA	7.8	IV
9.	KHAN	INDORE TO SANWER	46.0	I
10.	KSHIPRA	ALONG UJJAIN	18.0	III
11.	KUNDA	ALONG KHARGONE	4.2	V
12.	MAHI	ALONG BAJNA	5.0	V
13.	MALEI	ALONG JAORA	4.0	V
14.	MANDAKINI	ALONG CHITRAKUT	3.2	V
15.	NEWAJ	SHUJALPUR TO RAJGARH	3.5	V
16.	PARVATI	ALONG BATAODAPAR	3.7	V
17.	SONE	ALONG DEORA	6.1	IV
18.	TAPI	ALONG BURHANPUR	6.0	V
19.	WARDHA	ALONG BANGON	4.0	V

Source: (CPCB, 2022)

Table 8 : Polluted River Stretches in Rajasthan

S NO.	RIVER NAME	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BANAS	BASSI TO BISALPUR	35.7	I
2.	BANDI	ALONG PALI	94.0	I
3.	BERECH	ALONG NAGARI	3.9	V
4.	BHANWAR SEMILA	ALONG BHANWAR SEMLA	3.8	V
5.	CHAMBAL	ALONG KESHORAIPATTAN AND ALONG PALI (SAWAI MADHOPUR)	5.7	V
6.	GAMBHIRI	ALONG CHITTORGARH	4.9	V
7.	GUWARDI	ALONG GUWARDI	9.5	IV
8.	JAWAI	AT JAWAI DAM	11.7	III
9.	KANOTA	ALONG SUMEL	9.5	IV
10.	KHARI	ALONG KELWARA	7.6	IV
11.	KOTHARI	ALONG BHILWARA	6.2	IV
12.	LUNI	ALONG RANAKPUR	3.8	V
13.	MAHI	ALONG BANSWARA	5.0	V
14.	PIPLAAD	AT PIPLAAD DAM	3.2	V

Source: (CPCB, 2022)

Table 9 : Polluted River Stretches in Haryana

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	GHAGGAR	BHAGWANPUR TO SURAJPUR; ALONG KALA AMB, ALONG CHANDRAPURA, ALONG SIRSA	206.0	I
2.	MARKANDA	ALONG NARAINGARH	29.0	II
3.	YAMUNA	HATHNIKUND TO PALLA AND PALWAL TO HASANPUR	43.0	I

Source: (CPCB, 2022)

Table 10 : Polluted River Stretches in Delhi

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	YAMUNA	PALLA TO OKHLA D/S	83.0	I

Source: (CPCB, 2022)

Table 11 : Polluted River Stretches in Uttar Pradesh

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BAHELA	ALONG TANDA	287.0	I
2.	BANGANGA	ALONG SHUKRATAL	4.1	V
3.	BETWA	GOVIND SAGAR TO HAMIRPUR	6.1	IV
4.	GANGA	FARRUKABAD TO ALLAHABAD, MIRZAPUR TO GHAZIPUR	6.0	V
5.	GHAGHARA	ALONG AYODHYA AND BARHALGANJ TO DEORIA	5.8	V
6.	GOMTI	MOHMEAK TO VARANASI	15.2	III
7.	HINDON	SAHARANPUR TO GHAZIABAD	126.0	I
8.	KALI (W)	ALONG MUZAFFAR NAGAR	81.0	I
9.	KALINADI (E)	MEERUT TO KANNAUJ	144.0	I
10.	PILKHAR	ALONG RAMPUR	3.5	V
11.	RAMGANGA	ALONG SHERKOT AND KANNAUJ	7.2	IV
12.	RAPTI	ALONG GORAKHPUR	6.0	V
13.	RIHAND	ALONG RENUKUT	3.4	V
14.	SAI	ALONG UNNAO AND JALALPUR	4.2	V
15.	SONE	ALONG CHOPAN	4.0	V
16.	VARUNA	RAMESHWAR TO TILL COFL WITH R. GANGA	32.4	I
17.	YAMUNA	ALONG ASGARPUR, NOIDA, VRINDAVAN TO HAMIRPUR	127.0	I

Source: (CPCB, 2022)

Table 12 : Polluted River Stretches in Uttarakhand

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BAHELA	ALONG KASHIPUR	56.0	I
2.	BANGANGA	ALONG IDRISHPUR	4.0	V
3.	DHELLA	THAKURDWARA TO ADAMPUR	60.0	I
4.	KALYANI	ALONG PANTNAGAR	30.0	II
5.	KICHHA (KITCHA)	KICHHA TO PUL BHATTA	12.0	III

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
6.	KOSHI	ALONG KASHIPUR	12.0	III
7.	NANDOUR	ALONG SITARGANJ	15.0	III
8.	PILKHAR	ALONG BILASPUR	14.5	III
9.	SUSWA	ALONG MATHURAWALA	30.0	II

Source: (CPCB, 2022)

Table 13 : Polluted River Stretches in Bihar

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BAGMATI	ALONG SIRNIA	3.6	V
2.	BURHI GANDAK/ SIKRAHNA	NARKATIAGANJ TO PAKRIDAYAL	10.0	IV
3.	DAHA	GOPALGANJ TO SIWAN	10.0	IV
4.	DHOUS	ALONG MADHUVAPUR	5.6	V
5.	GANDAK	ALONG REWAGHAT	3.8	V
6.	GANGA	ALONG BUXAR, PATNA, FATWAH AND BHAGALPUR	7.9	IV
7.	GANGI	AT ARA	8.0	IV
8.	GHAGHARA	ALONG REVELGANJ	3.6	V
9.	HARBORA	ALONG NARKATIAGANJ	8.0	IV
10.	KAMALA	ALONG DARBHANGA	5.0	V
11.	KOHRA	ALONG MANJHAULIA	8.0	IV
12.	LAKHANDEI	ALONG SITAMARHI	11.0	III
13.	MANUSMAR	ALONG SITAMARHI	6.0	V
14.	PARMAR	ALONG JOGBANI	3.4	V
15.	PUNPUN	ALONG PUNPUN	10.0	IV
16.	RAMREKHA	HARINAGAR	12.0	III
17.	SIRSIYA	RAXAUL	30.0	II
18.	SONE	KOELWAR	4.0	V

Source: (CPCB, 2022)

Table 14 : Polluted River Stretches in Himachal Pradesh

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	ASHWINI KHAD	MATHOLI TO BHOG	80.0	I
2.	BALD	ALONG BADDI	40.0	I
3.	GIRI	ALONG YASHWANT NAGAR AND ALONG DADAHU	4.8	V
4.	MARKANDA	SALANI TO RAMPUR JATTAN	4.0	V
5.	PABBAR	ALONG SWARAKUDDU	4.6	V
6.	RATTA	ALONG NALAGARH	8.0	IV
7.	SHIKARI KHAD	ALONG ROHRU	4.6	V
8.	SIRSA	ALONG NALAGARH	40.0	I
9.	SUKHANA	ALONG PARWANOO	72.0	I

Source: (CPCB, 2022)

Table 15 : Polluted River Stretches in Jharkhand

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BOKARO	ALONG JARANGDIH	3.9	V
2.	DAMODAR	ALONG TELMUCHO, ALONG JARANGDIH, ALONG RAMGARH	3.5	V
3.	GARGA	ALONG TELMUCHO	4.9	V
4.	HARMU	ALONG RANCHI	10.1	III
5.	JUMAR	NAGRI TO BHUTI	5.3	V
6.	KATRI	ALONG MOONIDIH	3.6	V
7.	KHARKHAI	ALONG SONARI	8.0	IV
8.	KOINA	ALONG MANOHARPUR	3.1	V
9.	SUBARNAREKHA	ALONG RANCHI, ALONG MURI, ALONG JAMSHEDPUR	10.0	IV

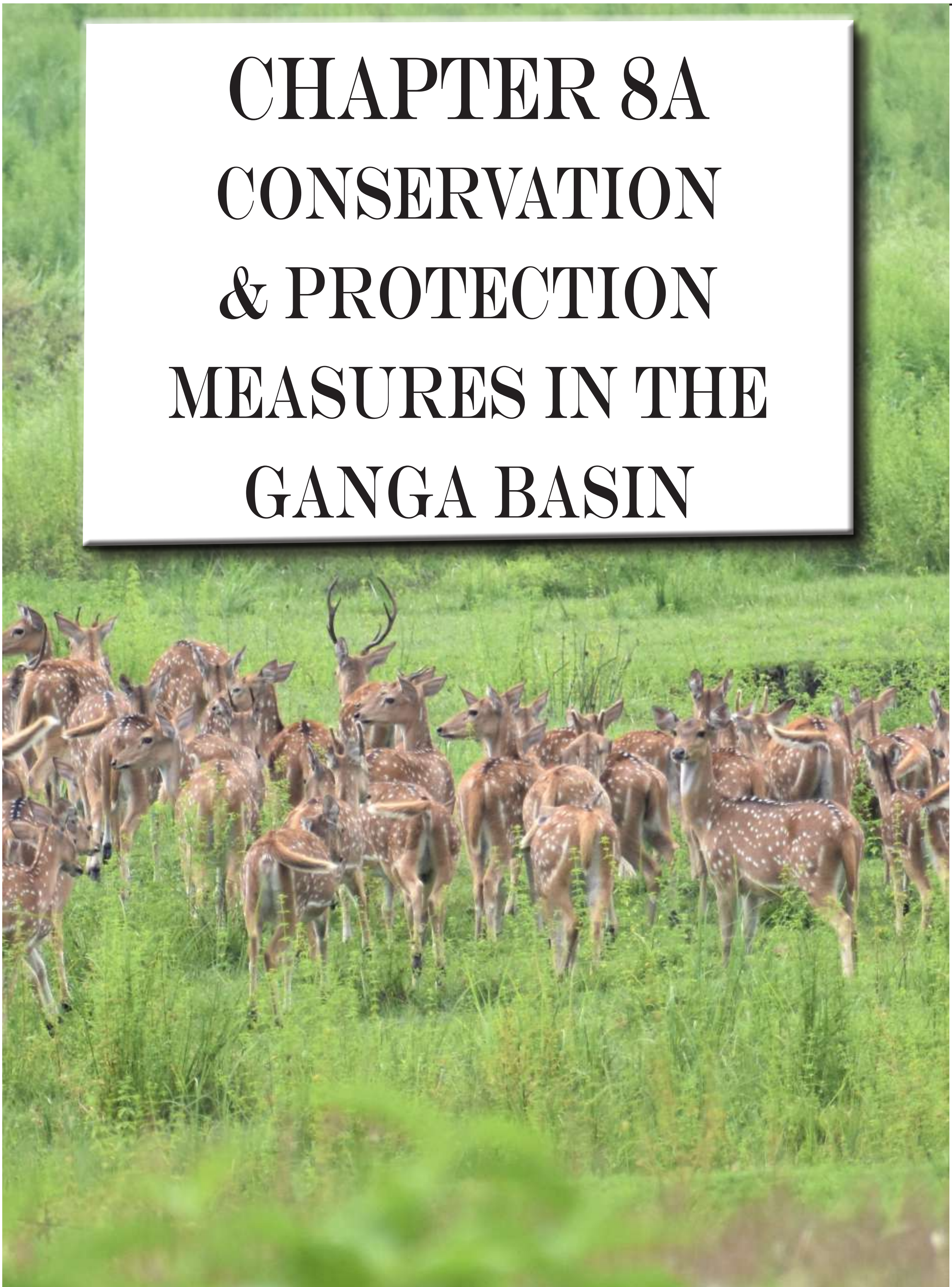
Source: (CPCB, 2022)

Table 16 : Polluted River Stretches in West Bengal

S NO.	RIVER	POLLUTED RIVER STRETCH/ LOCATION	MAX BOD OBSERVED (mg/L)	PRIORITY CLASS
1.	BARAKAR	ALONG ASANSOL	3.1	V
2.	CHURNI	BIJOYPUR TO RANAGHAT	20.8	II
3.	DAMODAR	DISHERGARH TO BURDWAN	5.2	V
4.	DWARAKESHWAR	ALONG BANKURA TOWN	3.8	V
5.	DWARKA	ALONG TARAPITH	5.7	V
6.	GANGA	BEHRAMPUR TO HALDIA	8.0	IV
7.	JALANGI	ALONG KRISHNA NAGAR	6.2	IV
8.	KANSI	ALONG MIDNAPORE	6.3	IV
9.	MAHANANDA	ALONG SILIGURI	31.0	I
10.	MATHA BHANGA	ALONG GOBINDAPUR	15.3	III
11.	RUPNARAYAN	KOLAGHAT TO GEONKHALI	3.7	V
12.	TEESTA	ALONG SEVOKE	3.8	V
13.	VINDYADHARI	HAROA TO MALANCHA	29.6	II

Source: (CPCB, 2022)

CHAPTER 8A CONSERVATION & PROTECTION MEASURES IN THE GANGA BASIN



8.1 INTRODUCTION

Forests in a river's watershed or basin have a significant impact on its discharge. They regulate the volume of discharge and its quality. Leaf litter and animal matter on forest soils decay to form humus -- a dark spongy layer of newly formed organic matter. It increases the ability of soil to absorb and retain water. Consequently, forests enable rainwater or snow melt to be absorbed and released slowly as base flows to a stream or river. They also help moderate floods.

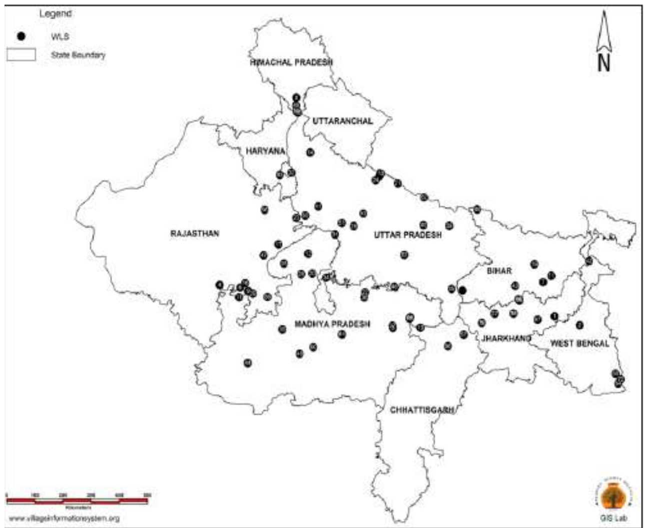
Forests preserve and enhance water quality. In general, they trap contaminants in the surface runoff -- like pesticides or bacteria, or in the ground below, e.g., when deep root systems absorb nitrates in the soil. The forest canopy shades and cools streams running through it. Riparian forests are present only along river banks (See also Chapter 6). They are a transition zone between the aquatic ecosystem and the terrestrial upland. They provide habitats for a variety of wildlife including macro-invertebrates, fish, reptiles, amphibians and birds.

Himalayan forests in the Indian Ganga Basin (IGB) are said to play a very critical role in providing River Ganga with special self-purifying, bactericidal and healing properties. For almost 125 years now scientists have studied and reported many medicinal values of Gangajal (IMT, 2017). Some scientists have attributed these values to the soil particles and vegetative debris brought down from its vast catchment in the remote Himalayan region. Conservation and protection of the immense biological resources in the IGB is therefore an imperative.

Designated forest lands cover about 16 per cent area in the IGB (Gangakosh, undated). The forest cover, however, varies widely in the different IGB states. In states like Haryana, Delhi, Bihar, Uttar Pradesh, Rajasthan and West Bengal the forest cover varies from a mere 0.1 to 13.2% of the geographical area. It is high in Uttarakhand, Madhya Pradesh and Himachal Pradesh but the area under dense tree cover is declining. Several forest tracts within the IGB are under moderate to severe stress.

The vastness of the IGB's biological resources is accompanied with a tremendous diversity which stems from its high degree of climatic, hydrological, geomorphological and environmental heterogeneity. It is one of the most biodiverse basins in Asia. Practitioners of traditional Indian medicine over millennia have studied and used rare biological resources in the IGB to treat a variety of illnesses and medical disorders. But this rich biodiversity, including its rare species, is under increasing threat.

Early concerns for protecting wildlife in India prompted its pre-independence government to initiate conservation measures as far back as in 1936 when Jim Corbett led the effort for the establishment of Asia's first National Park, the Hailey National Park in the



Map 24: Important PAs in the Indian Ganga Basin

Source: PSI

Note: For Uttarakhand's PAs please see Map 26

Kumaon-Garhwal region. After the adoption of the Wildlife (Protection) Act, 1972 a network of National Parks and Wildlife Sanctuaries was created in India to protect, propagate and enhance wildlife and its environment in specified areas.

The early Protected Areas (PAs) were all meant to protect well-known large terrestrial mammals. More recently the concept has been extended to protect river stretches to preserve animals like otters, gharials, mugger crocodiles and dolphins among others. Today there are over ninety PAs in the IGB. Some of the important National Parks (NPs), Wildlife Sanctuaries (WLS) and Conservation Reserves (CRs) in the IGB are shown in Map 23. They are storehouses of biodiversity. They nourish water bodies including rivers, streams, lakes and ponds. Bird sanctuaries are generally wetlands or lakes. Besides birds they sustain a variety of aquatic life and recharge ground water.

An estimated 10-13 million fishers are said to be fully or partly dependent on riverine and floodplain fisheries in India's Gangetic basin (DoF, 2020)[i]. River fishing provides cheap protein subsistence for these impoverished, marginalized and dispersed communities. But inland freshwater fishing remains a badly neglected development sector in India. By recharging and sustaining rivers and other water bodies PAs play a supportive role for inland freshwater fishing. Many fish species, e.g., certain trout varieties, require clean, cool, well oxygenated water and are very sensitive to changes in habitat and water quality (Maine.gov, undated). PAs provide such protected habitats in the form of lakes, ponds, wetlands and other water bodies. Rivers and streams typically provide spawning and nursery habitats. Adults are commonly resident in streams, but migrate throughout and between drainages to meet seasonal life history requirements.

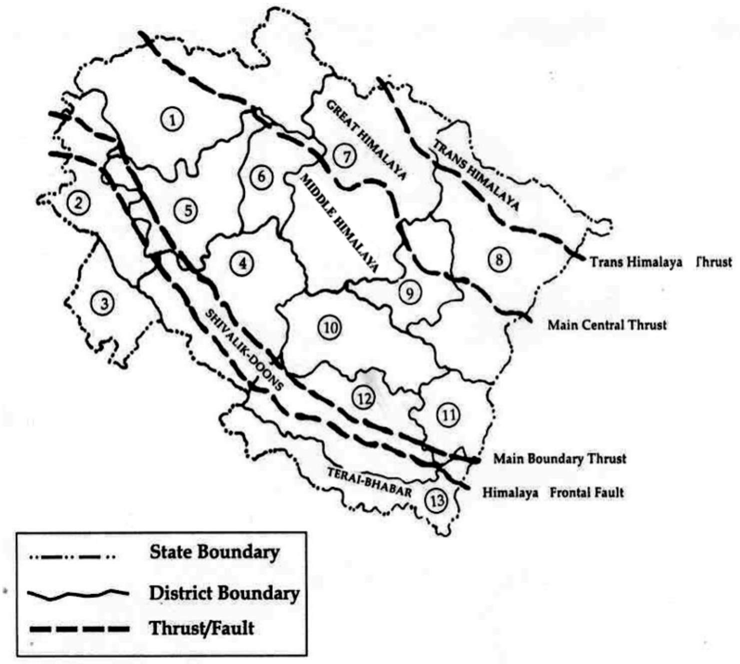
This chapter details governmental and people's efforts to conserve and protect the Ganga basin's natural heritage. Section 8.2 summarizes the present status and conditions of PAs in the Indian Gangetic Basin. Section 8.3 discusses the important initiative of establishing the Bhagirathi Eco-Sensitive Zone (BESZ) from Gaumukh to Uttarkashi, to conserve the until now less-interfered uppermost catchment of the Bhagirathi sub-basin. The focus of Section 8.4 is the variety of citizens or non-governmental efforts to conserve and revive rivers in the Ganga Basin.

8.2 PROTECTED AREAS (PAs) in the INDIAN GANGA BASIN

This section discusses the IGB protected areas in three parts: Upper, Middle and Lower IGB.

8.2.1 Conservation in the Indian Upper Ganga Basin

The Upper Ganga Basin in India lies in the Indian Himalyan Region, in the state of Uttarakhand. Two major Ganga tributaries in Kumaon division of Uttarakhand, Ramganga (West) and Sharda – the boundary between Uttarakhand and Nepal – are par



Map 25: Longitudinal Divisions of Uttarakhand

Source:PSI

But in this section, we have considered the PAs of the entire state of Uttarakhand, since the most prominent PA, the Corbett National Park, straddles Garhwal and Kumaon Divisions and because the PAs in Kumaon are analogous to those in Garhwal.

The altitudes range from about 300 m above sea level (masl) to over 7800m. The climate varies from severe sub-arctic winters along the mountain peaks to warm summers in the lower valleys. The monsoon rainfall is heavy to minimum in the small arid areas like the Nelong valley in the upper Bhagirathi watershed. The wide climatic variation across the altitude range gives rise to a profusion of flora and fauna. Most major west Himalayan forest types are present here.

Physiographically, Uttarkhand can be divided into five longitudinal regions viz. :(1) Trans Himalaya, north of the Trans Himalayan Thrust (THT); (2) Higher or Great Himalaya – between the THT and the Main Central Thrust (MCT); (3) Lesser Himalaya – between the MCT and the Main Boundary Thrust (MBT); (4) the Shivalik, between the MBT and the Himalayan Frontal Fault (HFF); and (5) the Terai region south of the Shivaliks (See Map 24).

Wildlife conservation has been of serious interest in the Himalayan region because its inaccessibility till recently has provided natural protection to a large variety of rare flora and fauna. Uttarakhand state has a network of PAs, including 6 NPs (total area 4915 km^2), 7 WLSs (2690 km^2), 4 CRs (212 km^2) and one Biosphere Reserve as listed in Table 31.

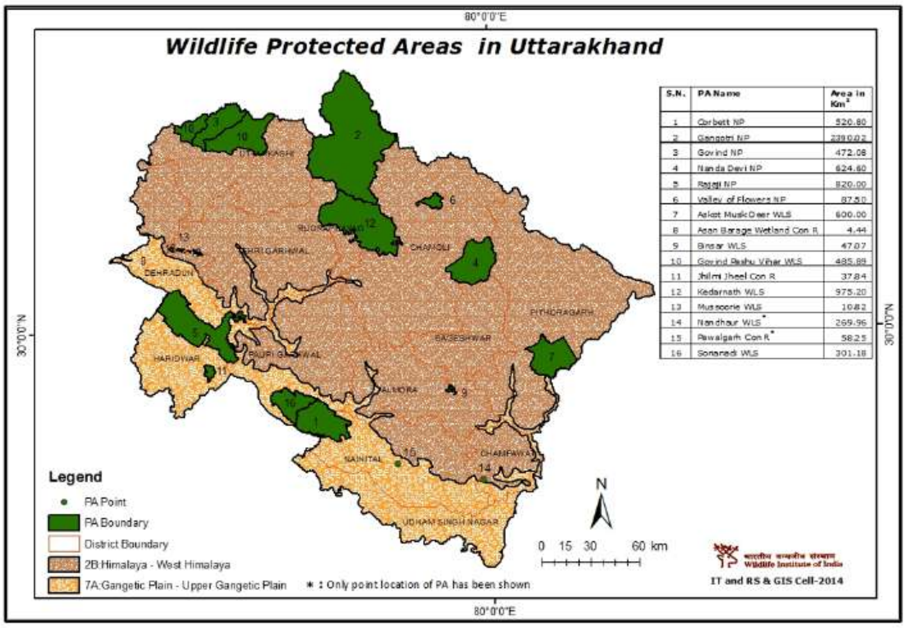
The region is home to India's first NP, the Hailey National Park, renamed as Corbett National Park in 1955-56. In 1974 it became India's first tiger reserve. The Gangotri NP is the third largest NP in India. Gaumukh, the snout of the Gangotri glacier which is the origin of the holy river Bhagirathi (Ganga), is located inside this park.

Table 31 : Protected Areas in the Upper Ganga Basin (India only)

S. No.	Name of the Protected Area	Location (District)	Year Estd	Area ($km^{2)}$	Remarks
Higher Himalaya					
1.	Govind NP	Uttarkashi	1990	472	See text
2.	Govind Pashu Vihar WLS	Uttarkashi	1955	486	See text
3.	Gangotri NP	Uttarkashi	1989	2390	See text
4.	Kedarnath Musk Deer Sanctuary	Rudraprayag and Chamoli	1972	975	See text
5.	Nanda Devi NP	Chamoli	1982	625	See text
6.	Valley of Flowers NP	Chamoli	1982	87.50	See text
7.	Nanda Devi Biosphere Reserve (NDBR)	Chamoli, Bageshwar & Pithoragarh	2004	6407	See text
8.	Askot Musk Deer Sanctuary	Pithoragarh, Uttarakhand	1986	600	See text
Lesser Himalaya					
9.	Binsar WLS	Almora, Uttarakhand	1988	47	See text
10.	Nandhaur WLS	Nainital and Champawat	2012	270	See text

11.	Benog WLS	Tehri Garhwal	1993	11	Near Mussoorie, popular with bird-watchers
12.	Naina Devi Himalayan Bird CR	Nainital	2015	112	Uttarakhand's newest PA.
Sub-Himalaya					
13.	Rajaji NP	Dehradun, Pauri & Haridwar	1983	820	See text
14.	Corbett NP	Nainital and Pauri Garhwal	1936	521	See text
15.	Sonanadi WLS	Nainital	1987	301	See text
16.	Asan Wetland CR	Dehradun	2005	4.44	See text
17.	Jhilmil Jheel CR	Haridwar	2005	38	See text
18.	Pawalgarh CR	Nainital	2012	58	See text

Source: Mainly Envis (WII)



Map 26 : Important Protected Areas in the Upper Ganga Basin

Source: WII

Conservation in the High Himalaya

The region is characterized by remoteness, a fragile and forbidding terrain, low and marginal populations and diversity. Altitudes range from just 600m above sea level in the valleys to several peaks over 7000m. The climate varies from warm summers in the valleys to severe sub-arctic winters along the mountain peaks. Large parts of the PAs in this region (Table 31) remain snowbound throughout the year with intense monsoon precipitation. Many important rivers like the Tons, Yamuna, Bhagirathi, Mandakini, Alaknanda, Rishi Ganga, Nandakini, Pindar, Dhauli Ganga (W) and Gori Ganga among others have their origins in the glaciers inside the PAs.

The tree line in the PAs ranges between 3000m to 3500m.The highest forests are dominated by Himalayan firs and stunted rhododendrons, birch or *bhojpatra* and junipers. Lower down, forests of *deodars* (cedar) gradually give way to oaks (*banj*) and rhododendrons (*buransh*) and *chir* pine on slopes with poor soils. Beyond the tree line are *bugyals* or alpine meadows which have a huge variety of flowering grasses. They are used by cattle herders to graze their cattle in the summer. The prominent *bugyals* in the PAs include Bedni, Auli, Panwali, Tungnath and Dyara.

The forests and bugyals in the PAs host a huge variety of herbs and medicinal plants, many of which are rare and endangered. Local inhabitants in the Nanda Devi Biosphere Reserve villages are said to use over 200 species as medicine, food, and animal fodder. The mythical *sanjeevani booti* of the Ramayana is locally said to be the plant *Selaginella bryopteris* found in the Valley of Flowers NP. A few other important medicinal plants include the atees or wolfbane (*Aconitum hetrophyllum*) a snake or scorpion bite antidote and analgesic, *tapasvini* or Indian nard (*Nardostachy jatamansi*) a body and mind calming herb and *somlata* (*Ephedra gerardiana*) source of ephedrine drug for treating asthma and cardiac disorders. Some of the globally threatened plant species such as the Himalayan poppy and *brahmakamal,* a medicinal plant for uro-genital disorders, are found in abundance in the Valley of Flowers.

The High Himalaya PAs shelter a number of rare and endangered wild animals, including the Snow Leopard, Musk Deer, Himalayan Brown Bear, Asiatic Black Bear, Bharal or Blue Sheep, Serow, Ibex and the Himalayan Tahr. The Musk Deer and the Snow Leopard are shy animals, photographed only in recent years by hidden cameras.

Several endangered avian species such as Uttarakhand's colourful state bird the Himalayan Monal, Cheer Pheasant, the Western Tragopan, Golden Eagle, the Himalayan Snow Cock, etc. exist in the High Himalayan PAs. The Govind Pashu Vihar WLS is one of the few remaining homes in the Himalayas of the Bearded Vulture, a vital ecological bird. Many species of butterfly and wild bees abound with the flowers in the Valley of Flowers.

More importantly, the limits of the distribution range of three highly endangered species lie in the PAs of the Alaknanda-Bhagirathi basin viz, (i) the Snow Leopard's southwestern-most distribution in Uttarakhand (ii) the Himalayan Brown Bear's eastern-most distribution in India and (iii) the pheasant Western Tragopan's eastern-most distribution in India.

The region is essentially a no-fish zone. Even micro-invertebrate species are limited.

People and Culture : The Tons valley in Uttarkashi district is Mahabharata country. Local communities believe that the Pandavas ascended to heaven from the aptly named Swaragarohini peak in the Govind Pashu Vihar WLS. Within this sanctuary the alpine meadows of Har-ki-dun valley are popular trekking destinations.

Nanda Devi (7816m) is Uttarakhand's highest peak and is worshipped as a regional deity. In 1962 the India-China War led to closure of the borders on both sides, affecting the native Bhotiya tribals who were engaged in border trade. To help enhance the local economy, Nanda Devi was later opened for mountaineering. It became the second most popular destination in the Himalayas next to Mount Everest. After noticing severe ecological damage in the region, however, in 1982 the old Nanda Devi Sanctuary was upgraded to a National Park and made a core part of the much larger, simultaneously notified **Nanda Devi Biosphere Reserve**[ii] around the Nanda Devi peak[iii]. The United Nations Educational Scientific and Cultural Organisation (UNESCO) selected the Nanda Devi NP as a World Heritage site in 1988. Tourists, trekkers and mountaineers were banned, to conserve it and allow the ecosystem time to repair itself.

Over 15,000 people live in about 100 villages with large Bhotia communities in the Biosphere Reserve. They practice subsistence agriculture, apiculture and horticulture, cultivate medicinal plants and rear cattle and sheep. The snow-clad peaks with over 30 glaciers, rare animals and birds, deep and vast river valleys and meadows have led to the evolution of a conservationist local culture.

Reni village, where Gaura Devi led the first Chipko protest to save forests in the region, is located in the NDBR. Though the fervour to save their forests is still strong among the village women in the area, they appear overwhelmed by the speed with which governments have sanctioned development projects in their valleys. The latter are a threat to the local communities and their conservationist way of life. Now the very existence of Reni village is under threat after the Raunthi Gad avalanche of February 1, 2021 which destroyed the downstream Rishi Ganga and Tapovan-Vishnugad HEPs.

Millions of tourists and some pilgrims annually visit the Char Dham shrines and Hemkund, the Sikh shrine. Religious tourism draws a lot of visitors to the Kedarnath WLS due to several important shrines located here at Madhyamaheshwar (3200m), Rudranath (2200m), Trijuginarayan (2200m), Tunganath (3750m), and Kedarnath (3400m).

Threats: Massive tree-felling, slopes' destabilization and muck dumping in rivers in the High Himalaya due to mega development projects – Uttarakhand's ambitious hydropower development programme and the 'Char Dham Pariyojana' to widen national highways leading to the Char Dham shrines threaten the survival of RET species in the PAs. The ecological destruction being wrought in the region has been detailed in the reports of two Supreme Court (SC) of India appointed bodies of experts (EB, 2014 and HPC, 2020).

Uttarakhand's state government tried to get the area of the Askot Musk Deer Sanctuary in the Gori Ganga valley reduced to facilitate the construction of HEPs. "The state's opposition has nothing to do with interests of wildlife or residents. They are just worried about not being able to utilise the area's hydro-electric potential," Pankaj Sekhsaria, editor of Protected Area Update, told a correspondent (Shrivastav K.S., 2015).

Besides endangering life and property, the massive tourism push by the state and central governments to the Char Dham shrines has added to the disaster proneness of the region's sensitive geology and ecology (See also Chapter 4). Thousands of restaurant operators, cooks, waiters, *chotus* (young restaurant helpers), horse-owners, porters, fodder gatherers, hawkers -- arrive to provide services to the visitors and earn a large part of their annual income (Chopra R., 2014). Forests are lopped for firewood and meadows are foraged for fodder. The waste is usually dumped over the slopes into the rivers. The Valley of Flowers NP, another popular tourist destination, faces similar threats.

Some years ago, the Gangotri NP suffered serious ecological degradation due to rapid annual increase in the number of *kanwariyas* arriving from the plains and leaving behind mounds of garbage and abandoned clothes. To curb this damage the Forest Department has now limited the number of daily visitors to Gaumukh to 150 persons and 20 ponies. Dogged efforts by Uttarakhand's well-known mountaineer, Dr Harshwanti Bisht, and her co-workers have helped regenerate *bhojpatra* (birch) tree patches between Gangotri and Gaumukh.

Flora and fauna in the region are threatened by smuggling and poaching. The diversity of threatened medicinal plant species is higher here than has been recorded in other Indian Himalayan protected areas. Collection of *yarsagumba (keerha jarhi)* or caterpillar fungus, said to be a physical performance enhancer with a large market in China, has become a major livelihood source in the higher altitudes of the Gori Ganga sub-basin. The Kedarnath Musk Deer Sanctuary has been under threat due to poaching of musk deer.

Global warming and its consequences pose a fourth set of hazards. Rising temperatures, frequent 'cloudbursts' or extreme and intense rain, such as the floods of 2013 (See Chapter 4 for the destruction caused by the 2013 Uttarakhand floods), declining snowfall in the winter and the appearance of vegetation at hitherto virgin elevations in the Gangotri NP are now being attributed by many scientists to climate change. Forest fires in the region have also become more frequent and widespread in the last two decades. As global warming increases these threats will be far more serious (UN, 2021). Scientists have suggested that the February 7, 2021 avalanche in the Rishiganga valley and the Girthi Ganga snow avalanche on April 23, 2021, both of which lie in the Nanda Devi Biosphere Reserve area and cloudbursts in the region could be due to the changing climate pattern (Sabin T.P., et al, 2020).

Conservation in the Lesser Himalaya

Most of Uttarakhand's mountain population lives in the Lesser Himalaya and lower regions. Four PAs are located in this region.

The small **Binsar WLS**, north of Almora town, in Kumaon's Middle Himalayas is heavily forested at altitudes ranging from 900m to 2500m. Oak and rhododendron forests dominate at higher altitudes and chir pine forests at lower heights. Its rare fauna include species like Himalayan Goral, Musk Deer, Himalayan Serow and Red Giant Flying Squirrel among others. It has 200 native and migratory bird species including Himalayan Monal, the state bird.

The **Nandhaur WLS** is a critical part in the central-western portion of the Terai Arc Landscape (TAL), that stretches from Himachal Pradesh to Nepal, for the movement of large body mammalians like tigers, elephants, leopards and sloth bears, etc. between India and Nepal. It was notified in 2012 to save the connectivity of TAL which was threatened by severe human pressures. Sal forests predominate in this sanctuary.

Threats: Poverty, inadequate employment opportunities and the exclusionary approach to conservation have led to a heavy, but risky, dependence on forests and illegal riverbed sand mining, leading to human-wildlife conflicts and resource degradation in the Nandhaur WLS. The proximity of Binsar to Almora and the rapid growth in the number of motor vehicles and motorable roads threaten the till recent pristine Binsar forests. **Benog WLS** too is under pressure from the tens of thousands daily summer visitors to Mussoorie.

Conservation in the Sub-Himalaya

The Corbett and Rajaji NPs are located in the Shivalik Range and the terai regions. They are large stretches of the TAL. Sal forests and rich grasslands dominate.

The **Rajaji NP** is best known for its elephant herds. In 2015 it was notified as a tiger reserve too. Its sal, *khair, sissoo* and Shivalik chir-pine laden forests provide excellent corridors for elephant movement. Besides elephants and tigers, it contains large and small mammal species like leopards, sloth bear, wild boar, cheetal, a variety of deer, nilgai (antelopes) and primates. A few Himalayan black bears and Himalayan goats exist on the higher slopes.

India's first NP and first tiger reserve, the **Corbett NP**, not only has Bengal tigers, Asian elephants, cheetal, and sambhar but also over 500 animal species, 488 plant species and an estimated 580 avian species. Otters, turtles and crocodiles are other prominent species in the Corbett stretch of the Western Ramganga. Gharials were introduced not long ago in the Ramganga dam reservoir. The Western Ramganga river is an anglers' paradise, famous for the golden Himalayan Mahseer, and the monster catfish (Goonch) – the only catfish in the world with teeth! Forests in, the Corbett NP, host around 110 tree species with *sal, haldu, peepal, rohini* and mango trees predominating. Migratory birds, Sarus cranes dot the wetlands in the Park.

Pawalgarh CR is a tiger conservation reserve but is also noted for its avian fauna. It has 375 recorded bird species, 160 butterfly and more than 150 species of moths. **Sonanadi WLS** is a critical habitat for the Asian Elephant species. It forms a corridor for large mammals between Corbett NP and Rajaji NP. It also has rich bird life. Two critically endangered species of vultures are found here.

Asan and **Jhilmil Jheel** are well-known bird conservation reserves. A large number of migratory birds visit Asan during the winter. Jhilmil Jheel hosts about 238 species of which 18 are on IUCN's Red List of threatened species (IUCN, 2016). It has mixed moist deciduous forest and grasslands. It is the only location in Uttarakhand where the Barasingha (swamp deer) can be seen (Mohan D., et al 2018).

Threats: Outside of the Char Dham shrines, the Corbett NP annually draws perhaps the largest number of tourists in Uttarakhand. But increasing human population in the towns and villages on the periphery of the two main NPs in the sub-Himalayan region and rapid infrastructure development pose the major threats to the parks. Close by are a number of towns including Dehradun near Rajaji and Ramnagar at one edge of the Corbett NP.

Wildlife in the Rajaji NP has been severely affected by a number of development projects. The construction of a canal for power generation in the 1970s made it impossible for the elephants to migrate and trapped them in the western part of the Park. Every year an elephant or two is mowed down in the Haridwar-Dehra Doon railway stretch. It is also disturbed by an Army shooting range inside the forest. The Delhi-Dehradun Expressway is the latest threat.

The Rajaji authorities blame the local populations for over-lopping, overgrazing, firewood collections, etc. On the other hand, Van Gujjars and other local communities, blame a century of 'destructive management practices of the Forest Department' as the main threat to sustaining ecological balance inside Rajaji. But all agree that poaching and illicit felling of timber by professional gangs constitute the Park's most serious ecological threat. Corbett NP forest officials say that the increasing population and the density of population within 1 to 2 km from the park present a challenge to the management of the tiger reserve. Incidents of tigers and leopards killing cattle have led to some acts of retaliation by the local population. Almost ten local villagers are reported to have been killed by tigers from the Park. The Indian government has approved the construction of a 12 km stone masonry wall on the southern boundary of the reserve to separate it from agriculture fields.

The National Conservation Tiger Authority (NCTA) has expressed serious concern that protection systems have weakened, and poachers have infiltrated into this park. Monitoring of wild animals in the prescribed format has not been followed. A cement road between Kalagarh and Ramnagar has been built through the Park, against a Supreme Court order. It has become a thoroughfare.

The Golden Mahseer is an endangered species in IUCN's Red List (WWF India, undated). Dams and barrages that reduce water flow in the river and prevent migration of the fish to their breeding grounds are big threats to its survival. Regulated Golden Mahseer angling has been introduced where the fish is released back into the river after anglers take pictures with their catch.

8.2.2 Conservation in the Indian Middle Ganga Basin

The middle stretch of the main stem of R. Ganga is taken from Haridwar to Varanasi. Therefore, this section, considers sub-basins in the states of Haryana, Rajasthan, Madhya Pradesh, Chattisgarh and Uttar Pradesh.

The left bank of R. Ganga in the middle basin is nourished by several important Himalayan rivers like the Ramganga (W), Sharda, Ghagara and W. Rapti. On the right bank the Yamuna brings a huge supply of water from Vindhyan drainages along with its own Himalayan water. At the Allahabad Sangam it has more water than the Ganga (Jain S.K., et al, 2016). The symbiotic forests and water relationship is evident in UP where many PAs recharge groundwater and base flows to rivers while flowing streams sustain the flora and fauna in the forests.

PAs in this part of the IGB include terrestrial areas and river stretches. The important ones are highlighted below sub-basin wise.

Yamuna Sub-Basin

Table 32: Important PAs in the Yamuna Sub-Basin

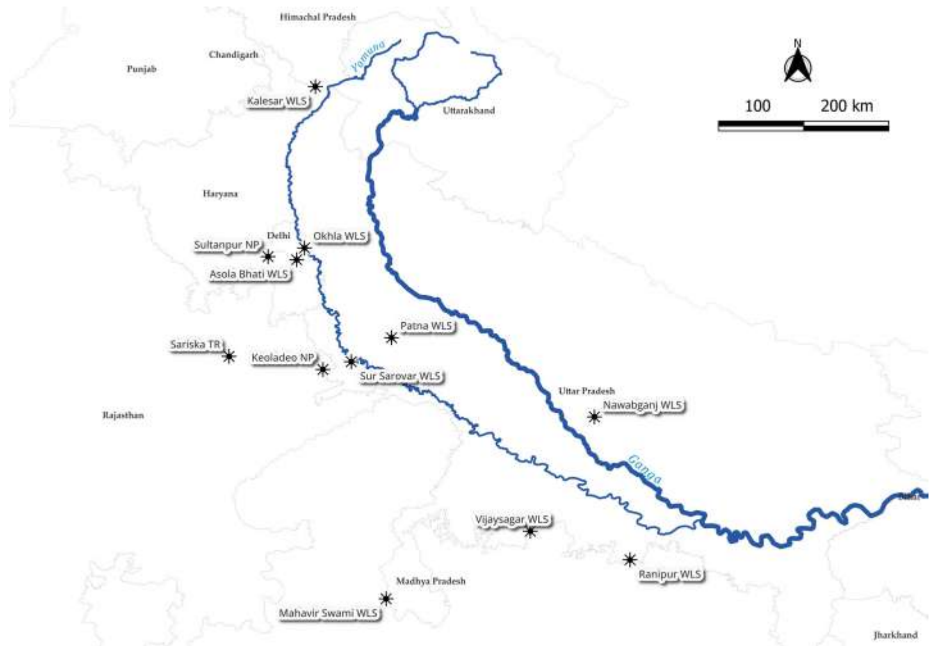
Sl. No.	PA Name	District, State	Year of Estd	Area (km^2)	Remarks
1.	Kalesar NP	Yamuna Nagar, Haryana	2003	53.00	See text
2.	Kalesar WLS	Yamuna Nagar, Haryana	1996	53.5	See text
3.	Sultanpur NP	Gurgaon, Haryana	1991	1.43	Bird sanctuary
4.	Sariska TR	Alwar, Raj.	1978	866	See text
5.	Keoladeo	Bharatpur, Raj.	1981	29	See text
6.	Nawabganj WLS	Unnao-Lucknow, U.P.	1984	2.25	Bird sanctuary
7.	Okhla WLS	Gautam Budh Nagar, U.P.	1990	4.00	Bird sanctuary. See text
8.	Asola-Bhati WLS	NCT Delhi	1986	27.82	Part of Aravalli Leopard Corridor
9.	Sur Sarovar WLS	Agra, U.P.	1991	4.03	Bird sanctuary
10.	Patna WLS	Etah, U.P.	1990	1.09	Bird sanctuary
11.	Mahavir Swami WLS	Lalitpur, U.P.	1977	5.41	On the banks of R. Betwa
12.	Ranipur WLS	Banda-Chitrakoot, U.P.	1977	230.32	
13.	Vijaysagar WLS	Mahoba, U.P.	1990	2.62	Bird sanctuary

Source: Mainly Envis (WII)

Haryana

Haryana is a small largely semi-arid state. Its notified forest area is only 3.9 per cent of its geographical area (Haryana Forest, 2019). Yamuna is the main river. There are three important PAs -- Kalesar NP, Kalesar WLS and the Sultanpur NP besides a number of small lakes in its Yamuna basin.

Kalesar NP (53 km^2) and **Kalesar WLS** (53.5 km^2) are Sal forest areas in the Shivalik foothills extending westward from the Yamuna. They are continuations of the Rajaji NP. They form the western frontier of the Asian elephant's distribution. West of them there are no elephants in the Himalayan region. The Kalesar forests provide important base flows to the Somb river which is the only tributary of the Yamuna in Haryana.



Map 27: Important PAs in the Yamuna Sub-Basin

The **Sultanpur NP** is a small wetland about 50 km from the centre of Delhi. It was originally established as a Bird Sanctuary in 1972 and upgraded to a NP in 1989. Besides a large number of resident bird species, it hosts over 100 migratory bird species in winter including Siberian cranes, flamingos, teals, pelicans and sandpipers among others. This wetland survives on borrowed water from River Yamuna.

NCT Delhi

The southern ridge areas of Delhi are an outcrop of the Aravalis. These were heavily quarried for stone till 1992, when the quarrying was banned by the Supreme Court. The area had earlier been notified as **Asola Bhati WLS** in 1986. With protection and plantation, the WLS is gradually becoming habitat to many species.

Rajasthan

The **Sariska Tiger Reserve** in Alwar district, an erstwhile hunting preserve of the Alwar royal family, was declared a wildlife sanctuary in 1955 and a TR under Project Tiger in 1978. It is the first reserve in the world to have successfully relocated tigers. It has dry deciduous and thorny arid forests, grasslands and rocky hills. In addition to the Bengal tiger and its prey species, it hosts a variety of animals and birds.

In January, 2005 no tigers were left in Sariska. A repopulation program was begun. Male and female tigers were brought in from other similar TRs. Wildlife Institute of India (WII) scientists had projected that STR could support 15 tigers. By the end of 2018, there were 18 tigers including five cubs.

Once known as the Bharatpur Bird Sanctuary, the **Keoladeo National Park (KNP)** is a Ramsar wetland (1981). It was declared a protected bird sanctuary in 1976. It was created as a royal game preserve by the legendary 18th century ruler, Maharaja Suraj Mal of Bharatpur (Wiki (a), 2019). He got the Ajan Bund constructed across the Gambhir and Banganga rivers.

Peter Scott, a founder of World Wildlife Fund, rated KNP as one of the best bird areas in the world. It shelters over 350 species of migratory and resident birds of which an estimated 230 are resident. The KNP is also a UNESCO World Heritage Site (1985). Its citation says, "[A] Habitat of rare and endangered species…. a wetland of international importance for migratory waterfowl." It attracts more than 100,000 tourists annually, mainly during winter to see the migratory birds. It was once the only regular wintering area in India for the critically endangered Siberian crane.

The KNP is an excellent breeding site for herons, storks and cormorants. Abundant terrestrial insects and a diverse fish population have a positive effect on the breeding of land birds. In recent years the great spotted eagle has been recorded breeding here, a first for the species in India. The sarus crane, with its spectacular courtship dance, is also found here.

The KNP's mix of dry grasslands, woods, wooded swamps and wetlands is home to nearly 380 floral species and dozens of species of fish, snakes, lizards, amphibians, turtles and other invertebrates. It has 27 identified mammalian species. Pythons basking in the sun on a winter day are a popular sight. Monitor lizards, porcupines, bats, poisonous kraits, cobras and Russell's vipers are also found in the Park.
Fish fauna of the Park comprises 43 species, of which 37 enter the park along with the water from Ajan Bund and six are breeding residents. In May and June, the entire area dries except for some depressions. Its 10 km^2 core wetland usually gets flooded during the monsoon. The alternate drying and wetting help to maintain the fresh water swamp ecology that is ideal for water-fowl and resident water birds. Four boreholes ensure that the marshes and water bodies do not dry out completely.

Threats: The Gujjar communities in the villages surrounding the Sariska TR mainly rear cattle. They are alienated because they have not been compensated for livestock loss and claim that they have been denied development. Marble mining in the vicinity also continues to threaten the local environment.

The old Bharatpur Bird Sanctuary was a grazing ground for the cattle of 15 surrounding villages before it was banned in November, 1982 resulting in a forced entry attempt, police firing and eight deaths. The absence of grazing is, however, causing management problems as profuse vegetation blocks the water channels. High pollution levels in Ajan Bund, particularly pesticides from surrounding farms, is said to have affected the bird population.

The KNP also suffers from water scarcity. Severe droughts and abandoning of the Park by nesting birds, as in 2007, have put it in danger of being removed as a World Heritage and a Ramsar site. The Park annually requires an estimated over 14 MCM of water to ensure flooding. Rainfall, the supply from the Ajan bund and a small canal dug from Khokhar Weir (Bees Mora) are usually inadequate. Efforts by the State and Central governments to supply water from sources outside the Park, have not yet succeeded.

Uttar Pradesh

The Yamuna sub-basin has a number of small bird sanctuaries at Nawabganj WLS, Okhla WLS, Sur Sarovar WLS, Patna WLS, Mahavir Swami WLS, Ranipur WLS and Vijaysagar WLS. **Okhla Bird Sanctuary** is a tiny (3.5 km^2) area at the Okhla barrage, where R. Yamuna enters UP. It was once a haven for over 300 bird species, with over 1 lakh winter migratory bird visitors. It has been recognized as one of India's 466 IBAs (Important Bird Areas).

Threats: Rapid urban development in the National Capital Region and massive pollution in the Yamuna have severely reduced the bird count in the Okhla BS. In 2013, the National Green Tribunal (NGT) ordered that no completion certificates be issued for building projects within a 10-km radius of the sanctuary or within its Eco-sensitive zone, until sanctioned by the National Board for Wild Life (NBWL). In June, 2014, the Supreme Court upheld the order. WII has recommended that the ESZ should cover the entire flood plain from Wazirabad barrage to Asgharpur in Uttar Pradesh. But with sky high land prices in the NCR no government is willing to expand it. This seriously depletes base flows into the Yamuna (Soni V., et al, 2009).

In 1974, the UP Forest Department launched a massive tree plantation drive after taking over the Nawabganj Priyadarshini Bird Sanctuary, once an open body of water, to attract more birds. Initially the wildfowl population increased dramatically. But large-scale plantation and the ban on grazing led to biomass accumulation. The wetland is now choked with water hyacinth, severely reducing dissolved oxygen levels and therefore the aquatic biota (IBCN, 2015). Pollution from nearby industries is another serious problem. The Nawabganj WLS can be restored to an open sheet of water by reducing the excess trees and allowing livestock grazing in summer.

Chambal Sub-Basin

Table 33: Important PAs in the Chambal Sub-Basin

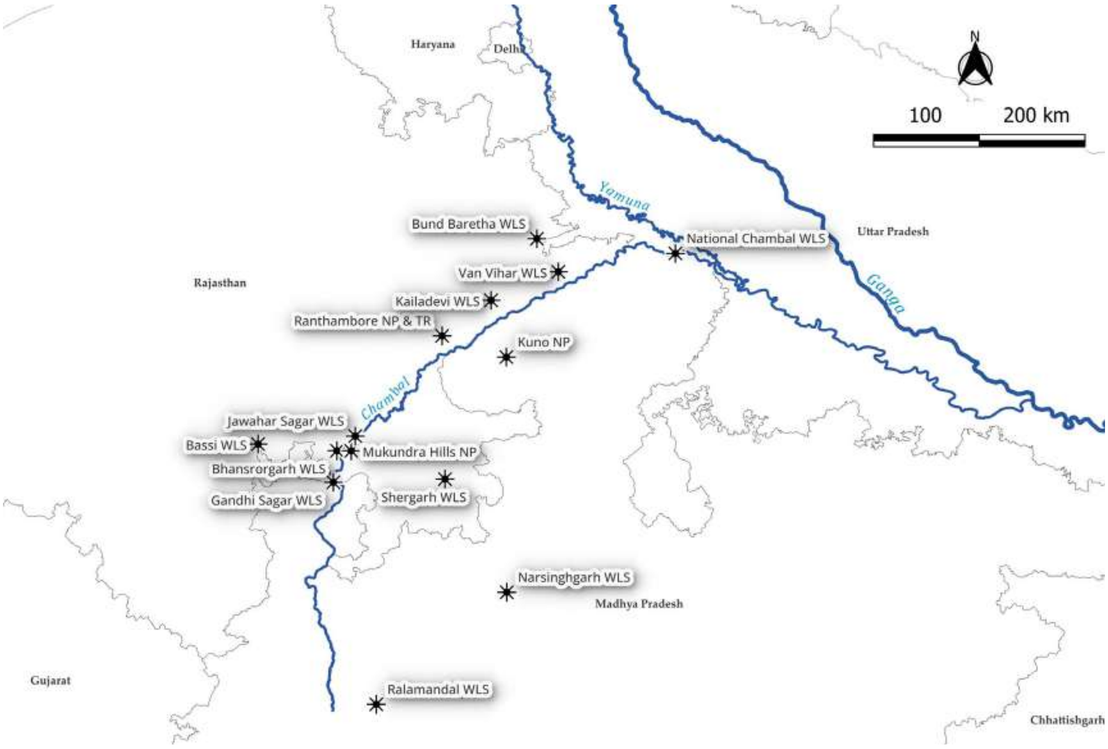
Sl. No.	PA name	District*	Year of Estd	Area (km^2)	Remarks
1.	Ranthambore NP & TR	Sawai Madhopur, Rajasthan	1955 1973, TR	1334	The core and buffer areas of the TR extend across more than 1300 km^2

2.	Bassi WLS	Chittorgarh, Raj.	1988	138.69	--
3.	Bund Baretha WLS	Bharatpur, Rajasthan	1985	199	Late 19th century bund on R. Kakund.
4.	Van Vihar WLS	Dholpur, Raj	1955	25.60	Nourishes Ramsagar lake.
5.	Kailadevi WLS	Karauli, Raj.	1983	676.30	Near R. Chambal on the Rajasthan-MP border
6.	Shergarh WLS	Baran, Rajasthan	1983	98.71	Several first and second order streams nourish nearby Parvan river
7.	Bhansrorgarh WLS	Chittorgarh, Rajasthan	1983	229.14	Near the confluence of Bamani and Chambal rivers.
8.	Mukundara Hills NP	Kota, Rajasthan	2004 2013, TR	760	The Darrah WLS inside this NP, was earlier the hunting ground of the Kota Maharaja.
9.	Jawahar Sagar WLS	Kota, Raj.	1975	153	Near the Jawahar Sagar dam.
10.	Gandhi Sagar WLS	Mandsaur & Nimach, M.P.	1974	368.62	--
11.	Narsinghgarh WLS	Rajgarh, M.P.	1974	59.19	--
12.	National Chambal WLS	Morena-Bhind, M.P.	1978	435	See text
13.	Kuno NP	Sheopur & Morena, M.P.	1981 WLS, 2018 NP	344.68	See text
14.	Ralamandal WLS	Indore, M.P.	1989	2.34	--

Source: Mainly ENVIS (WII)

Rajasthan

The **Ranthambore NP** (392 km^2) in Sawai Madhopur district is one of India's most visited PAs. It was originally established as a game sanctuary in 1955 by the GoI, notified as a Tiger Reserve (TR) in 1973, upgraded to a NP in 1980 and expanded to its present size by adding the neighbouring Sawai Man Singh and Kailadevi sanctuaries in 1991. The core and buffer areas of the TR lie between the Banas and the Chambal rivers. The TR's deciduous forests are dominated by *Dhak* trees -- also known as 'Flame of the Forest' -- for their bright flowers -- and interspersed with broad grasslands. Among the other prominent animals are leopards, nilgai, sambar, cheetal, wild boar, striped hyena, sloth bear, and crocodiles.



Map 28: Important PAs in the Chambal Sub-Basin

The Park and its three large lakes host a wide variety of birds and boasts of one of India's largest banyan trees.

The Mukundara Hills Tiger Reserve (MHTR), earlier National Park, is considered an extension of the Ranthambore TR. Tigers from the latter often stray into the MHTR. This 760 km^2 TR was notified in April, 2013. It includes the Darrah, Jawahar Sagar and Chambal WLSs. The densely wooded Darrah WLS near Kota city was once the hunting preserve of the Maharaja of Kota. The attempts to translocate tigers from other PAs have not been very successful.[iv]

Madhya Pradesh

The National Chambal WLS is perhaps the largest protected river stretch in India. Its 5400 km^2 area extends across the states of Rajasthan, Madhya Pradesh and Uttar Pradesh (See Box: India's Longest Protected River Stretch).

The **Kuno National Park**, established in 1981 as the Palpur-Kuno WLS was upgraded to a NP in 2018 with an enlarged area of 413 km^2. It has dry deciduous forests. Once it was selected for relocating lions but no relocation was done. Efforts to relocate cheetahs, however, have commenced in 2022. Its forests provide the base flows for the Kuno river which feed the Chambal and recharge several water bodies in and around the TR. They are also home to Saharia tribals.

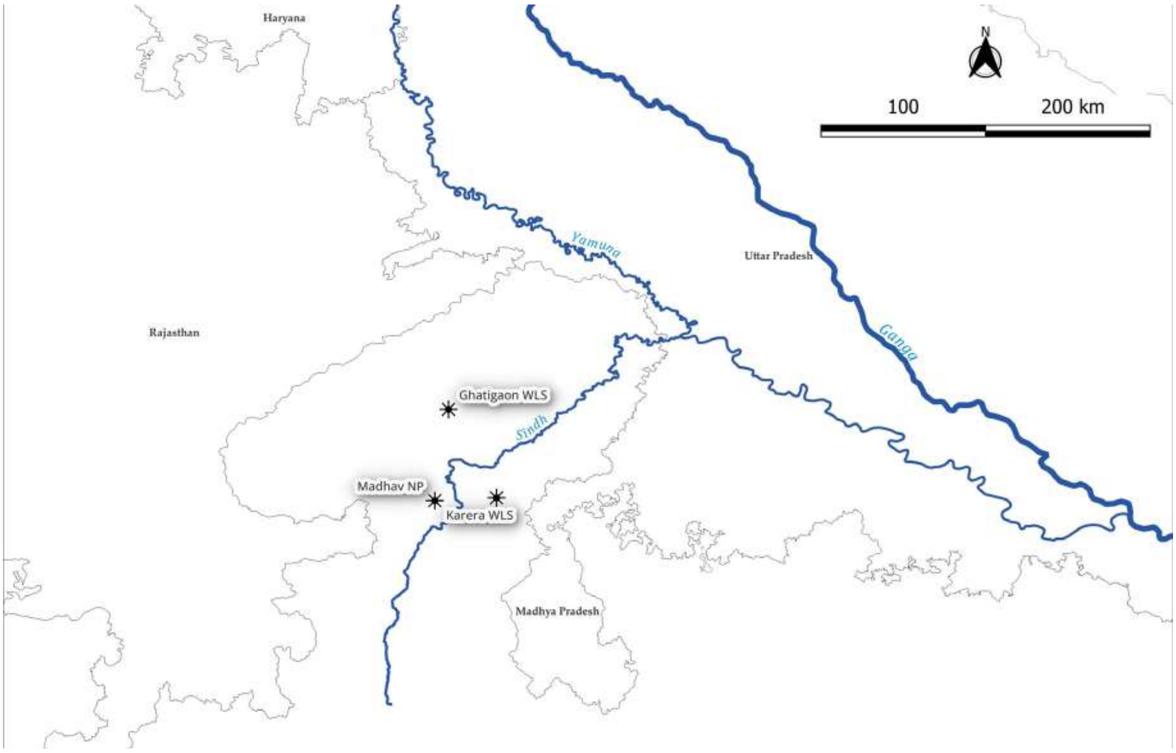
Sindh Sub-Basin

Table 34: Important PAs in the Sindh Sub-Basin

Sl. No.	PA name	District	Year of Estd.	Area (km^2)	Remarks
1.	Ghatigaon WLS	Gwalior, M.P.	1981	511	Protects Great Indian Bustards
2.	Karera WLS	Shivpuri, M.P.	1981	202.21	Protects Great Indian Bustards
3.	Madhav NP	Shivpuri, M.P.	1959	375.22	See text

Source: Mainly ENVIS (WII)

The Sindh sub-basin has three PAs of which the **Madhav NP**, named after Madho Rao Scindia a former ruler of Gwalior state, is the most prominent. Earlier its dense forests abounded with tigers and were the hunting grounds of Mughal emperors and Maratha royals. Lord Minto, India's Viceroy (1905-10) is said to have shot 19 tigers here. Later in 1916 Viceroy Lord Hardinge shot eight tigers in one day at Shivpuri. But tigers disappeared from the Park in the 1970s till the sighting of a female and a male tiger in 2007. The forests nourish the Sakhya Sagar Lake, an artificial lake within the Park. The lake area is a habitat for mugger crocodiles, pythons, monitor lizards and migratory birds in the winter.



Map 29: Important PAs in the Sindh Sub-Basin

India's Longest Protected River Stretch

The **National Chambal WLS** spread over 5400 km^2 is the second largest WLS in India and perhaps the longest protected stretch of any river in the country. It extends along a narrow 400 km stretch of R. Chambal downstream of the Kota barrage, across Rajasthan, Madhya Pradesh and Uttar Pradesh. It is primarily meant to protect three keystone species – the globally endangered gharials, red-crowned roof turtles and the National Aquatic Animal, the endangered, pollution- sensitive Ganges river dolphin.

Rampant poaching almost wiped out India's gharial population in the 1970s. The Sanctuary was notified by the three State Governments in December, 1979. Captive breeding and reintroduction of gharials in the Chambal started thereafter.

Besides the three keystone species the other important fauna are mugger crocodiles, tortoises, otters, striped hyenas, Indian wolves and many fish species. The Sanctuary's scrub-thorn forests mainly contain *shisham, babul* and *ber* trees. It is an Important Bird Area (IBA) and a proposed Ramsar site. Over 300 species of resident and migratory birds inhabit it, including migratory birds from Siberia. The vulnerable sarus cranes and flamingos are sighted here.

Human activities unintentionally harm wildlife and often destroy habitats or affect species behaviour by disrupting their feeding or breeding habits and even altering physiological processes. These disturbances, including mere human presence, can constitute 'predation risks' and create 'landscapes of fear' (Frid A. and Dill M.L., 2002) and (Ciuti S., et al, 2012). The increased vigilance required raises energy and reproductive costs for many species, leading them to avoid or abandon otherwise suitable habitats. Farming, expanding riverside cultivation, flattening of the Chambal ravines, illegal riverbed sand-mining, the increasing use of diesel pumps to water fields and the use of agro-chemicals pose such risks.

Unchecked illegal sand mining in the Chambal for years has led many local people to believe that its continued exploitation is their right and brazenly threaten, injure or even kill officials who try to stop this pillage (HT, 2016). Stone mining in the upper reaches of the river has destroyed otter holts and other habitats. The Sanctuary's wildlife is still at risk from blasting, the constant presence of people and the use of heavy machinery. "One of the main reasons for the sanctuary 'death' is the lack of inter-state coordination in conservation efforts, be it surveying, monitoring or enforcement," says WWF-India (WWF-India, 2007).

The Sanctuary has certainly helped gharials to recover and support all the established breeding populations today. Several thousand juvenile gharials have been released across north Indian rivers since the 1970s but their survival, movement and any potential breeding at the new sites have not been monitored.

Betwa Sub-Basin

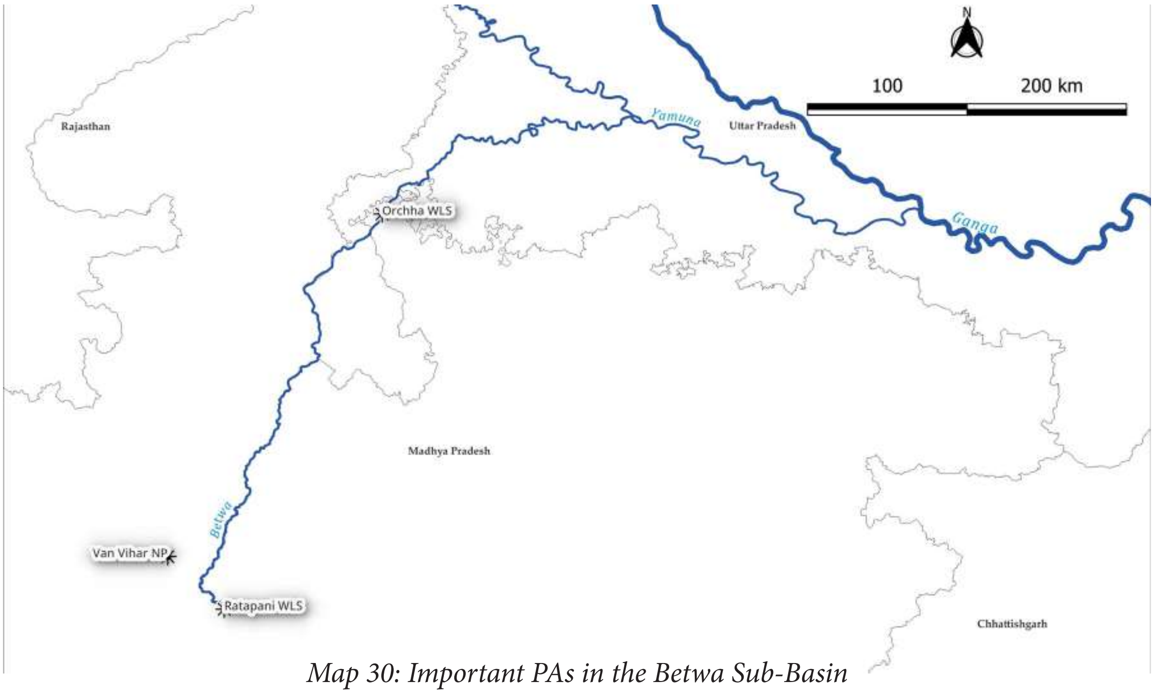
Table 35: Important PAs in the Betwa Sub-Basin

S. No.	PA name	River Sub Basin	District	Year of Estd.	Area (km^2)	Remarks
1.	Van Vihar NP	Betwa	Bhopal, M.P.	1979	4.45	Urban zoo, animals in enclosed natural habitats.
2.	Orcha WLS	Betwa	Tikamgarh, M.P.	1994	44.91	--
3.	Ratapani TR	Betwa	Raisen, M.P.	1978, 2013 TR	823.84	See text

Source: Mainly ENVIS (WII)

Van Vihar in Bhopal is an example of a successful urban attempt to save a wildlife habitat from degradation and encroachment. It is a modern zoological park with easy access for visitors to view the animals who remain within their natural but enclosed habitats.

The Ratapani WLS was established in 1976 and upgraded in principle to a Tiger Reserve in 2013. It has some of the finest teak forests in the state along with bamboo forests. Besides tigers and other carnivores, it has herbivore prey species, primates, reptiles, small animals and a large variety of birds. Seasonal streams and perennial pools recharge the Barna



Map 30: Important PAs in the Betwa Sub-Basin

Reservoir and the nearby Ratapani Dam. The famous Bhimbetka rock shelters, a UNESCO World Heritage Site, inhabited by early *Homo erectus* settlers (human predecessors) more than 100,000 years ago, are located within this TR. The rock paintings date back to about 6,000 BC (Habib I., 2001). The TR's proximity to Bhopal, about 50km away, draws many visitors. But in recent decades it has become vulnerable to increasing anthropogenic pressures.

Ken Sub-Basin

Table 36: Important PAs in the Ken Sub-Basin

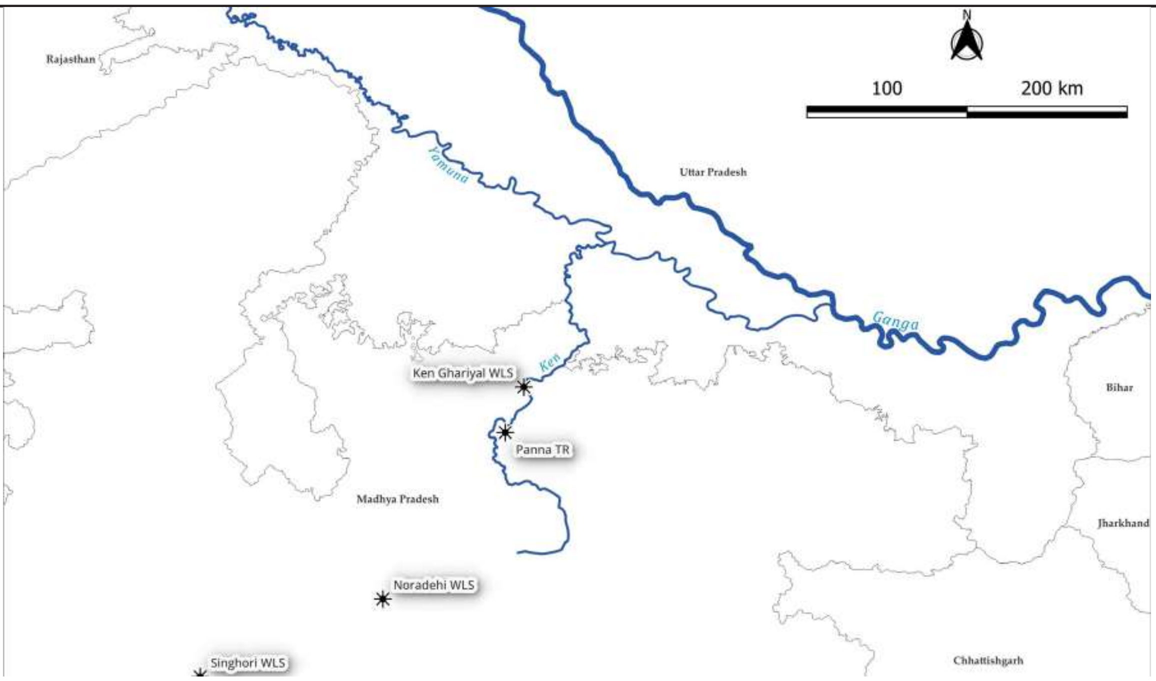
S. No.	PA name	River Sub Basin	District*	Year of Estd.	Area (km^2)	Remarks
1.	Panna TR	Ken	Panna-Chattarpur	1979	542	See text
2.	Ken Ghariyal WLS	Ken	Panna-Chattarpur	1981	45.2	Located by the Ken and Khudar rivers' confluence. Raneh Falls canyon located here.
3.	Singhori WLS	Ken	Raisen	1976	288	
4.	Noradehi WLS	Ken	Damoh, Sagar, Narsimhapur	1984	1195	

** All these protected areas are in Madhya Pradesh*

Source: Mainly ENVIS (WII)

The perennial Ken river and its feeder streams are lifelines for the **Panna Tiger Reserve**, the last remaining tiger habitat of northern Madhya Pradesh. This Yamuna tributary is one of India's least polluted major rivers. The south to north-flowing Ken cuts a deep gorge over 60 km long through the underlying rock of the TR. Many perennial springs emerge from escarpments in the TR. It is the northernmost tip of the natural teak forests and the northern edge of the great Central Indian forest belt beyond which the Ganga plains begin. Besides tigers there are other carnivores, omnivores like the sloth bear, various deer species, other ungulates and snake varieties. The avifauna consists of over 200 species including a number of migratory birds like storks, geese, buzzards, King Vultures and babblers.

Threats: Wildlife in the Panna TR and the **Ken Gharial WLS** faces a survival threat from the Ken-Betwa River Linking project (See Chapter 11). In a letter to the Expert Appraisal Committee (EAC) in August, 2015, several prominent environmentalists noted that, "… effectively only around 390 km^2 of the present 560 km^2 park will remain available for



Map 31: Important PAs in the Ken Sub-Basin

the wildlife…. [It] would sound the tigers' death knell." The Panna TR lost almost all its tigers in 2009 due to the poaching menace, a continuing concern. Today, however, the tiger population has been remarkably revived as a result of a pioneering great cat re-introduction project.

Sone Sub-Basin

Table 37: Important PAs in the Sone Sub-Basin

S. No.	PA name	River Sub Basin	District	Year of Estd.	Area (km^2)	Remarks
1.	Bandhavgarh TR	Sone	Umaria-Katni, M.P.	1968	1536	See text
2.	Sanjay TR	Sone	Sidhi, M.P.	1981	466	See text
3.	Sanjay Dubhri WLS	Sone	Sidhi, M.P.	1975	370	See text
4.	Panpatha WLS	Sone	Umaria, M.P.	1983	245	
5.	Bagdhara WLS	Sone	Sidhi, M.P.	1978	478	
6.	Sone Ghariyal WLS	Sone	Sidhi, Satna, Shahdol, M.P.	1981	41.8	--
7.	Kaimur WLS	Sone	Mirzapur-Sonbhadra, U. P.	1982	501	Stretches east-west, left bank of R. Sone

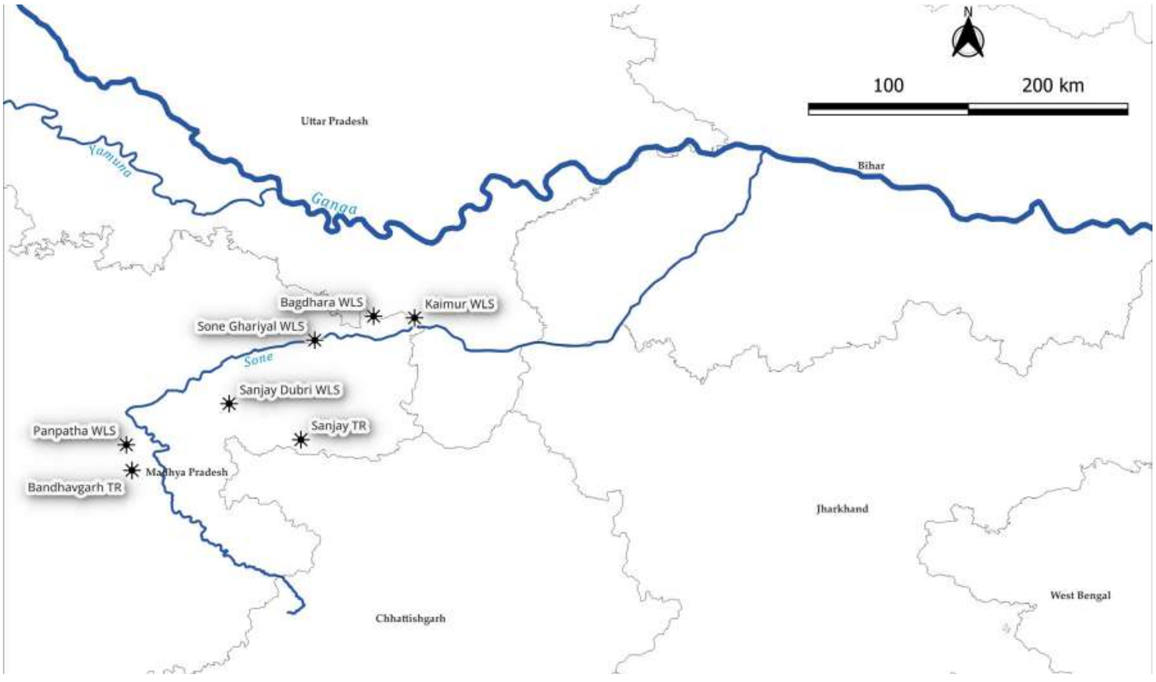
Source: Mainly ENVIS (WII)

The Sone sub-basin has two large Tiger Reserves, **Bandhavgarh TR (BTR)** spanning Umaria and Katni districts and the **Sanjay Dubri TR (SDTR)** in Siddhi district. The BTR was originally a royal hunting ground of the Rewa Maharajas. It was also once the home of white tigers in India. BTR's density of tigers being one of the highest known in the world, its area has been gradually increased to 1536 km^2. Rising mining activities around the Reserve, however, are a serious risk.

The SDTR has a core area comprising of the **Sanjay National Park** (466km^2) and the **Dubri WLS** (370 km^2) plus a buffer area of about 862 km^2 in Siddhi district. The SDTR forest is a connecting corridor for the Bandhavgarh and Palamau TR's wildlife. It was probably also the last known Asiatic cheetah territory in India.

The Umaria and Kodmar rivers in the SDTR and the Bijaur nala are perennial. They are the main sources of water to wild animals. Banas river flowing on the western side and the perennial Karjara and Khaini ponds are important water sources for wild animals.

The two TRs have Moist Deciduous Forests, mainly Sal. Besides tigers the major mammals they have are leopards, a variety of ungulate prey, wild boars and hyenas besides various primates and smaller animals. The BTR was densely populated with the gaur, or Indian bison, till it disappeared. In 2012, fifty gaurs were shifted here from Kanha National Park. Each Reserve is home to a few hundred bird species, butterflies and many reptiles including cobras, kraits, vipers and pythons. The rivers and streams contain many fish species.



Map 32: Important PAs in the Sone Sub-Basin

The **Sone Gharial WLS** is one of the few natural gharial habitats left in India.

Ganga Sub-Basin

The Ganga sub-basin (limited to River Ganga only) in the Middle IGB has only two large protected areas, the Hastinapur WLS and the Upper Ganga Ramsar stretch from Garhmukteshwar to Narora. Besides them it has several small scattered wetlands.

Table 38: Important PAs in the Ganga Sub-Basin in Uttar Pradesh

Sl. No.	PA name	District	Year of Estd.	Area (km^2)	Remarks
1.	Hastinapur WLS	Muzaffarnagar, Meerut, Bijnor, JP Nagar, & Hapur, U.P.	1986	2073	See text
2.	Upper Ganga Ramsar site	Hapur & Bulandshahar, U.P.	2005	266	From Garhmukteshwar to Narora. See text
3.	Sandi WLS (Dahar jheel)	Hardoi, U.P.	1990	3.09	Bird sanctuary. Nourished by R. Garra.
4.	Saman WLS	Mainpuri, U.P.	1990	5.26	Bird sanctuary
5.	Lakh Bahosi WLS	Kannauj, U.P.	1989	80.24	Bird sanctuary
6.	Samaspur WLS	Rae Bareli, U.P.	1987	7.99	Bird sanctuary
7.	Bhimrao Ambedkar WLS	Pratapgarh, U.P.	2003	4.00	Bird sanctuary
8.	Chandraprabha WLS	Chandauli, U.P.	1957	78.00	
9.	Suraha Taal WLS	Ballia, U.P.	1991	34.32	Bird sanctuary
10.	Kashi Turtle WLS	Varanasi, U.P.	1989	7 km	Relocated

Source: Mainly ENVIS (WII)

Hastinapur WLS, the largest (2,073 km^2) PA in UP, has almost 37 per cent of the protected area in the state. Lying near the western bank of the Ganga, it has swampy marshes between wet (lowlands) and dry (uplands) grasslands. Besides the Ganges river dolphin, the mammal species recorded here include swamp deer and smooth-coated otters. Since 2016, WWF-India and the UP-Forest Department have reintroduced captive-bred critically endangered gharials into the Ganga here to increase their wilderness population.

The Hastinapur grasslands attract a large variety of birds. The 2019 Asian Water bird Census (AWC) concluded that the bird diversity in the Sanctuary had been decreasing steadily in the last decade. Six migratory species are on IUCN's threatened Red List. T.K. Roy, AWC Delhi State Coordinator, listed Wooly-Necked Stork, Painted Stock, Spotted

Redshank, etc. among the IUCN Red-listed threatened birds (ToI, 2019). Other migratory birds from Central Asia and South and East Asia are also recorded here.

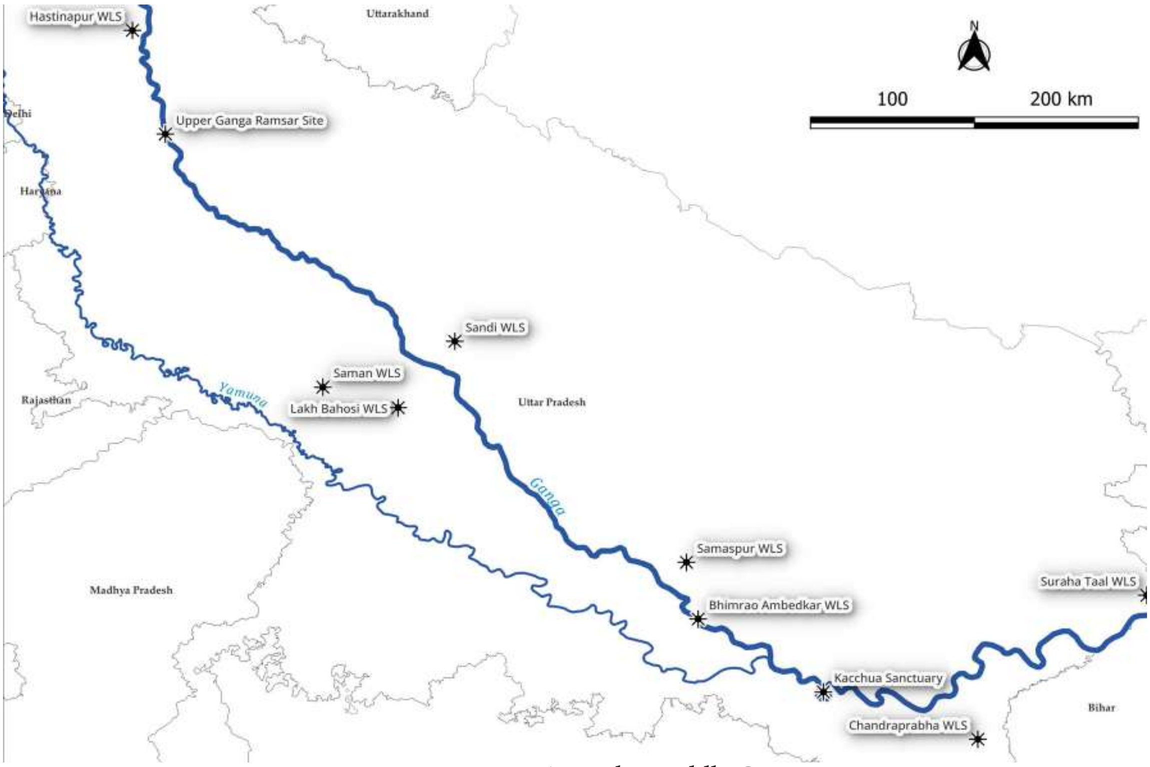
A 266 km^2 area covering the **Brijghat (Garhmukteshwar) to Narora** stretch of the Ganga was designated as a **Ramsar** site in November, 2005. It is largely shallow with intermittent deep pools and reservoirs upstream of barrages. It provides a habitat for the endangered Gangetic Dolphins, gharials, mugger crocodiles, turtles, otters, 82 fish species and hundreds of bird species (UP Forest Department, 2019). "A breeding population of gharials has been successfully established in this Ramsar stretch of river Ganga," says Dr. Sandeep Behera, consultant at NMCG.

The Ganga sub-basin has six bird sanctuaries: Sandi WLS (Hardoi district), Saman WLS (Mainpuri district), Lakh Bahosi WLS (Kannauj district), Samaspur WLS (Rae Bareli district), Bhimrao Ambedkar WLS (Pratapgarh district) and Suraha Tal WLS (Ballia district). The first two are small while **Lakh Bahosi**, the largest (See Table 38) is one of India's larger bird sanctuaries. Migratory birds arrive at all these sanctuaries between November and March each year. In the past, the rare Siberian white crane was sighted at the Sandi WLS.

Samaspur WLS and **Bhimrao Ambedkar WLS (Benti Lake)** are two small lake-based bird sanctuaries. Fish in the lakes nourish more than 250 varieties of birds reported at Samaspur. Winter migratory birds including Greylag geese, Pintail ducks and Common Teals, are said to fly in from more than 5000 km. The resident birds at Samaspur include various types of ducks, spoonbills, kingfishers and vultures.

Suraha Tal is a large natural lake. Its outflow discharges into the main R. Ganga. Floods in the Ganga or Saryu rivers during the monsoons cause a reverse flow into Suraha Tal. Suraha Tal recharges the local groundwater aquifer which enables year-round paddy cultivation.

In December, 1989 the UP-State Forest Department notified a 7-km stretch of R. Ganga in Varanasi as the **Kashi Turtle WLS**, as part of the Ganga Action Plan, as the world's only sanctuary dedicated to freshwater turtles. Freshwater turtles often act as keystone species. Their protection benefits other species too like the Gangetic River Dolphin, major carps like rohu, mrigal, katla, and tilapia among others, plus wintering birds. Though fishing and sand mining are prohibited in the Sanctuary, bathing, boating and cremation activities disturb the aquatic wildlife. The right bank of the Sanctuary provides a safe breeding habitat for the turtles. With the expected increase in river traffic on this stretch of National Waterway - 1, the Kashi Turtle Sanctuary has been denotified and a stretch of 30 km between Mirzapur, Prayagraj and Bhadohi has been notified as (the new) turtle sanctuary.



Map 33: Important PAs in the Middle Ganga Basin

Threats: A large part of the Hastinapur WLS is settled and under cultivation. Industrial activities in the region routinely violate environmental quality standards leading to air, water and noise pollution in the sanctuary and a consequent decline in the wildlife. Sewage discharge, agricultural chemicals runoff and intensive fishing threaten the Garhmukteshwar-Narora Ramsar site. Expanding populations pose risks to the lake based sanctuaries.

Sharda Sub-Basin

Table 39: Important PAs in the Sharda Sub-Basin

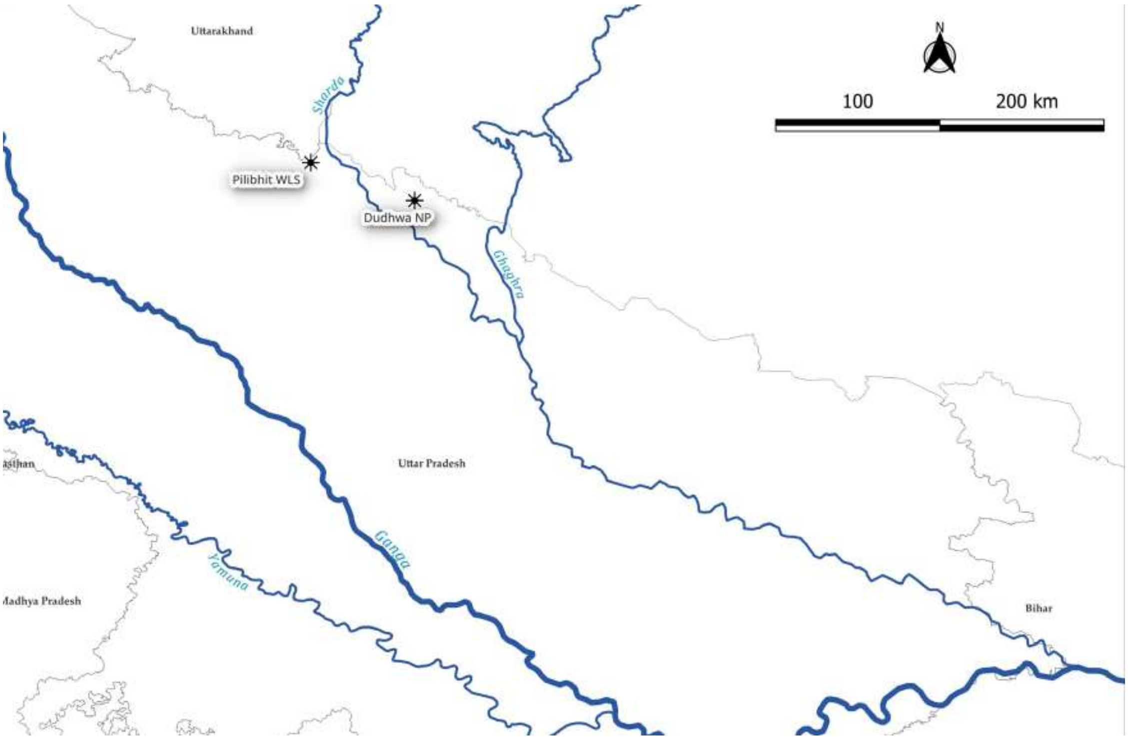
Sl. No.	PA name	Sub Basin	District	Year of Estd.	Area (km^2)	Remarks
1.	Pilibhit WLS	Sharda	Pilibhit, U.P.	2014	603	Tiger Reserve. See text
2.	Dudhwa NP	Sharda	Lakhimpur Kheri, U.P.	1977	490	Most well-known NP & TR in UP. See text

Source: Mainly ENVIS (WII)

The Pilibhit TR and the Dudhwa TR (including Kishanpur WLS, Dudhwa NP and the Ghagara sub-basin's Katarniaghat WLS) belong to the Terai forests and grasslands eco-region that stretches across the Indo-Nepal border. They are connected with one another through wildlife corridors which enable wildlife, especially large mammals, to move from one forest to another in search of new territories, mates or prey or water. They are home to four prized species, the Bengal Tiger, the One-horned Rhinoceros, the Asian Elephant and the Barasingha (swamp deer) and a habitat for hundreds of animal, bird and plant species (Wiki (b), 2019).

The rhinoceros was reintroduced into **Dudhwa** from the Pobitora Sanctuary in Assam and Nepal in March, 1984. Around half of the world's barasinghas (swamp deer) are present in the Dudhwa NP where the grasslands are a perfect camouflage. The Terai ecosystems provide vast open spaces and sufficient feed for major tiger populations and their prey base.

The Sharda river (Mahakali in Nepal) forms the northeastern boundary of the **Pilibhit TR**. The Dudhwa NP is bounded by the Mohana river in the north and the Suheli in the south. Their tributaries and lakes in the park nourish its diverse flora and fauna. Besides the prized species the other important fauna in this eco-region are leopards, four-horned antelope, sambar, cheetal, hog deer, barking deer, the sloth and Himalayan black bear, Indian pangolin, Himalayan goral, Gangetic River Dolphin, gharial and crocodile. There are over 70 ft (21 m) tall and 150 years old trees in this eco-region. Wet and dry grasslands comprise about 19% of the Reserve.



Map 34: Important PAs in the Sharda Sub-Basin

The **Dudhwa NP** and the **Kishanpur WLS** have between them over 350 bird species, including the threatened Bengal floricans and a range of winter migratory birds. They include among others, the endangered white-rumped vulture, painted storks, black and white necked storks, sarus cranes, woodpeckers, drongos, hornbills and varied night birds of prey.

Threats: Human settlements are present inside the core area of the Dudhwa NP. Numerous villages are clustered within a 2 km radius of its boundary. While the forest suffers from overgrazing, illegal logging and in extreme cases poaching using local snares, the villagers also suffer from wild animals raiding their crops and tigers preying on cattle (Ranjan S., 2017). Now most of the Kishanpur grasslands have been planted over by the Forest Department with sal, teak, mahua and other commercial species.

Ghagara Sub-Basin

Table 40: Important PAs in the Ghagara Sub-Basin

Sl. No.	PA name	Sub Basin	District*	Year of Estd.	Area (km^2)	Remarks
1.	Bakhira WLS	Ghagara	S. Kabirnagar, U.P.	1980	28.94	Bird sanctuary
2.	Katarniaghat WLS	Ghagara	Bahraich, U.P.	1976	400.09	A part of the Dudhwa TR. See text
3.	Parvati Arga WLS	Ghagara	Gonda, U.P.	1990	10.84	Bird sanctuary
4.	Sohagibarwa WLS	Ghagara (Gandak)	Maharajganj, U.P.	1987	428.20	See text
5.	Suheldeo WLS	Ghagara	Balrampur, U.P.	1988	452.57	See text

Source: Mainly ENVIS (WII)

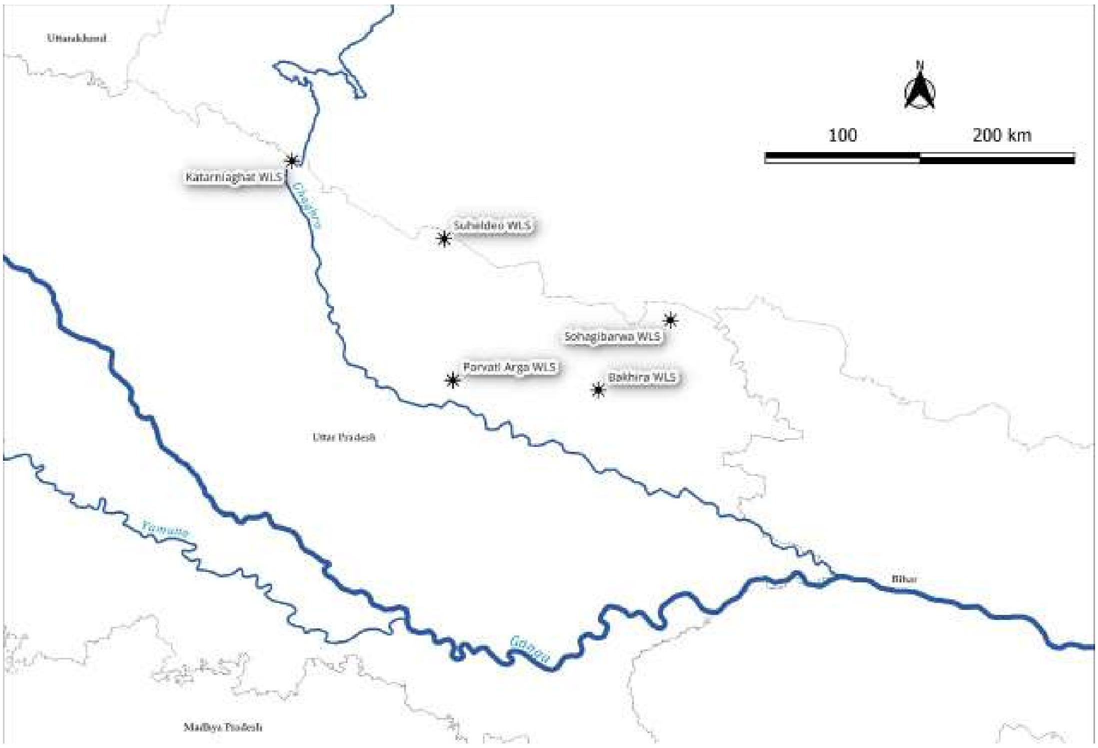
The Katarniaghat and Suheldeo WLS along the Indo-Nepal border and the Sohagi Barwa WLS on the UP-Bihar border lie near the middle of the Terai forests and grasslands eco-region mentioned above. This highly diverse and productive eco-region supports a large number of endangered species and tall wet grasslands. The vegetation is North Indian Moist Deciduous type, mainly sal and teak forests. The fauna in the PAs of this sub-basin are similar to that of the Sharda sub-basin.

The **Katarniaghat WLS**, a part of the Dudhwa TR, forms an important corridor between the Dudhwa TR in India and the Bardia NP in Nepal. Elephants and rhinos have migrated here permanently from Nepal. Lakes and wetlands host mugger crocodiles, otters and many winter migratory bird species. The Girwa river here sustains one of the few remaining wild gharial populations. Various rare snakes like the red coral kukri snake, banded kraits and Burmese rock pythons among others are found here.

The biodiversity rich **Suheldeo WLS** has two important reservoirs -- Chittaurgarh and Kohargaddi that sustain its wildlife in summer. Winter migratory birds visit these reservoirs. The avifauna includes cormorants, darters, herons, egrets, teals, eagles, white rumped vulture and sarus cranes besides migratory birds. Different types of buttlerflies are also found here. This Sanctuary is very rich in medicinal plants.

The **Sohagi Barwa WLS** is a vast alluvial plain spread across the sub-montane Terai in northeastern UP, and bordering Nepal in the north and Bihar's Valmiki Tiger Reserve in the east. It is a diverse complex of woodland forest (80%), grassland and swamp eco-systems. Highly diverse riparian forests, rich in transitional species, connect these habitats.

Sohagi Barwa WLS was established to protect large endangered mammalian fauna like tigers and leopards and their prey species. It has a high potential to rehabilitate tigers which are very few here now. The other important animals are the cheetal, bears, wild cats, wild boars and pythons. The *taals* or ponds can also support aquatic fauna such as mugger crocodiles and turtles. Monsoonal floods and waterlogging fill the grasslands along the rivers flowing through the Sanctuary. These grasslands *(phantas)* are covered by very tall grasses. Humans and animals depend on the grasslands. Properly managed, the critically endangered Bengal Floricans can survive here.



Map 35: Important PAs in the Ghaghra Sub-Basin

A number of rivers like the Gandak and Rapti tributaries Pyas and Rohini make many of the large wetlands perennial. Twenty-one *taals* in the Sanctuary provide food and water to the vast variety of fauna. Sohagi Barwa WLS is recognized as an “Important Bird Area” (Rahmani A.R., et al, 2015).

Situated in the terai plains of Gonda district, near the Tikri Reserved Forest, the **Parwati Arga** Bird Sanctuary consists of Parvati and Arga, two arms of a large oxbow lake left behind in a deep natural depression by the shifting Saryu river. It sustains more than 150 resident and winter migratory bird species, some of which are said to migrate across the High Himalaya ranges, flying over 5000km and above 8000m, from Tibet, China, Europe and Siberia. The important migratory birds include greylag geese, pintails, teals, pochards, gadwalls, and mallards. The local migratory and residential birds include sarus cranes, painted storks, waterfowls, peafowls, purple moorhen, white ibis, dabchicks, black drongos and bee-eaters.

The **Bakhira Bird Sanctuary** in eastern UP’s Sant Kabir Nagar district is said to be the largest (29 km^2) natural flood plain wetland of India. This vast lake is a winter habitat and staging ground for a large number of migratory waterfowls that come from Tibet, China, Europe and Siberia and a breeding ground for resident birds. BirdLife International estimates that more than 5000 Indian Purple Moorhen birds are common breeding residents here (Birdlife, Undated). More than 30 species of fish and macro-invertebrates provide food for the birds.

People: About 90 per cent of the population around Sohagi Barwa WLS is rural. It has more than 300 villages inside and outside the Sanctuary. The very poor Tharu and Musahar tribes live around the Sohagi Barwa forests. Forest produce provides them with sustenance. Villagers living around the Bakhira Bird Sanctuary earn their livelihood from its lake by fishing, farming and collecting fuelwood. A canal from the lake provides water for irrigation.

Threats: Much damage has already been done in the Terai forests and grasslands eco-region. Its rich natural vegetation has succumbed to agriculture and homesteads in the recent past. Prior to the establishment of the Sohagi Barwa WLS the area was under intensive management for maximum timber yield (Rahmani A.R., et al, 2015). Mixed forests were cleared and replaced by monoculture plantation by the Forest Department.

8.2.3 Conservation in the Indian Lower Ganga Basin

The Lower Ganga Basin contains 29 protected areas in Chattisgarh, Bihar, Jharkhand and West Bengal. The important ones are discussed in this section while the others are referred to in Table 41.

Underwater Vessel Noise And River Bottom-Dredging Harms Ganga River Dolphins

In a first study of its kind on the Ganga River Dolphin, scientists from ATREE have clearly demonstrated the negative impacts of vessel noise on the ecology and behavior of this species. It provides comprehensive evidence to show that the waterways development plans threaten the survival of the Ganga's biodiversity.

The National Waterways Act of 2016 of the Government of India (GoI) plans to initially "develop" 111 river stretches of the country for commercial transport (although now only 63 are being found viable), with the Ganga River from Haldia to Varanasi declared as National Waterway No. 1 (NW 1). Large-scale dredging, construction of ports and major increases in cargo and goods traffic are planned. Environmentalists have voiced serious concerns about the potentially disastrous ecological impacts of commercial waterways development, especially on the endangered Ganga River Dolphin, India's National Aquatic Animal and an IUCN Red List species.

The Ganga River Dolphin has undergone a regression of its eye lenses while evolving over millions of years in the murky, sediments-rich Ganga and Brahmaputra basin rivers. Consequently, the species is effectively blind. It uses high-frequency ultrasound clicks for navigation, communication, and foraging. Due to its almost total reliance on sound for survival, underwater noise generated by ships, vessels, and dredging activities poses a serious threat to the species. Nearly 90 per cent of the river dolphin's present distribution in the Ganga and Brahmaputra basins in India is a part of the proposed 111 waterways.

The ATREE study used passive acoustic recordings and comparative analysis of Ganga River Dolphin echolocation clicks when no vessels passed dolphins, and when vessels passed them, such that they were exposed to low frequency sounds from vessel engines and high frequency cavitation noise from propellers besides known information on the hearing range of these dolphins and other relevant scientific resources.

The most significant finding of the study was that the dolphins altered their acoustic click activity substantially when exposed to vessel noise, including changes in the repetition rate, frequency, and loudness of their clicks, significantly raising their metabolic stress. "In simple terms, this means that dolphins would have to spend 2.5 times more energy to do the same activities in noisy conditions, than they would normally spend in 'natural' conditions without vessel noise," says Nachiket Kelkar one of the study's authors. "As river flows reduce in the dry season the intensity of vessel traffic and corresponding ambient noise increase, leading to further intensification of these impacts on the dolphins," he adds.

An important lacuna in India's Noise Pollution (Regulation And Control) Rules, 2000 (with all amendments until 2017), is that there is no rule for underwater noise regulation and control. The present rules are only for noise in air and on land.

Edited extract from talk presented by Nachiket Kelkar at IRW 2018, November 2018

Table 41: PAs in the Lower Ganga Basin (Chhattisgarh, Bihar, Jharkhand & West Bengal)

Sl. No.	PA name	Sub Basin	District	Year of Estd.	Area (km²)	Remarks
1.	Guru Ghasi Das NP	Banas (Sone)	Koriya, Chhattisgarh	1981	1441	See text
2.	Tamor Pingala WLS	N. Koel (Sone)	Surguja, Chhattisgarh	1978	609	-
3.	Semarsot WLS	Kanhar (Sone)	Surguja, Chhattisgarh	1978	430	-
4.	Kaimur WLS	Sone	Rohtas, Bihar	1979	1342	See text
5.	Valmiki TR	Gandak	W. Champaran, Bihar	1989	336	See text
6.	Valmiki WLS	Gandak	W. Champaran, Bihar	1976	545	See text
7.	Udaypur WLS	Gandak	W. Champaran, Bihar	1978	8.87	A wetland located on an oxbow lake in the Gandak floodplain. It hosts many resident and migratory birds
8.	Bhimbandh WLS	Ganga	Munger, Bihar	1976	682	See text
9.	Vikramshila WLS	Ganga	Bhagalpur, Bihar	1990	50 km	Gangetic river dolphin protected stretch. See text
10.	Rajgir WLS	Ganga	Nalanda, Bihar	1978	36	~
11.	Gautam Buddha WLS	Ganga	Gaya, Bihar	1976	138	See text
12.	Barela WLS	Ganga	Vaishali, Bihar	1997	1.96	Salim Ali Bird Sanctuary
13.	Kanwar Jheel (taal) WLS	Ganga	Begusarai, Bihar	1989	63	See text
14.	Kusheshwar Asthan WLS	Ganga	Darbhanga, Bihar	1994	29	Bird sanctuary. See text
15.	Lawalong WLS	Sone	Chatra, Bihar	1978	211	~

16.	Topchanchi WLS	Damodar	Dhanbad, Jharkhand	1978	13	See text
17.	Parasnath WLS	Damodar	Giridih, Jharkhand	1981	49	Surrounds Parasnath Hill (1371 masl), the highest in Jharkhand. Nirvana sthan of Jain Tirthankar, Parsvanath.
18.	Betla NP	N. Koel	Latehar, Jharkhand	1974 TR	226	Notified in 1986
19.	Mahuadanr WLS	N. Koel	Latehar, Jharkhand	1976	63	See text
20.	Palamau WLS	N. Koel	Latehar, Jharkhand	1976	753	See text
21.	Gautam Buddha WLS	Ganga	Koderma, Jharkhand	1976	121	See text
22.	Koderma WLS	Ganga	Koderma, Jharkhand	1985	172	See text
23.	Hazaribagh WLS	Ganga	Hazaribagh, Jharkhand	1976	186	See text
24.	Mahananda WLS	Ganga	Darjeeling, W. Bengal	1959	158	See text
25.	Raiganj WLS	Ganga	Uttar Dinajpur, W. Bengal	1985	1.30	See text
26.	Ballabhpur WLS	Ganga	Birbhum, W. Bengal	1977	2.02	A popular Deer Park near Shantiniketan with 3 lakes, resident & migratory birds.
27.	Sundarbans NP	Ganga Delta	W. Bengal	1984	1330	See Chapter 5.
28.	Sajnakhali WLS	Ganga Delta	S. 24 Parganas, W. Bengal	1976	362	A part of the Sundarbans NP.
29.	W Sundarbans WLS	Ganga Delta	W. Bengal	2013	556	~

Source: Mainly ENVIS (WII)

Sone Sub-Basin

Chhattisgarh

The **Guru Ghasidas TR** was formed after bifurcation from the Sanjay NP when Chhattisgarh and M.P. became separate states. About 60 per cent of the original Park is now in Chhattisgarh. It is named after a well-known local Satnami reformer. The TR extends over the undivided forest. It lies between the Bandhavgarh TR (Madhya Pradesh) and Palamau TR (Jharkhand). It may have been the habitat of the last Asian cheetah. Several small rivers and streams in the TR -- the most important being the Banas in the west and the Bijaur nala in the north -- sustain the lush mixed deciduous forests with teak, sal and bamboo trees. The fauna consists of tigers, leopards, prey animals, reptiles and birds.

Bihar

Kaimur WLS is the second largest sanctuary in the entire Lower Ganga Basin. It is contiguous with the Kaimur WLS in Uttar Pradesh. It has several waterfalls and lakes. The main animals found in this Sanctuary are tiger, leopard boars, sloth bear, sambar deer, cheetal, four-horned antelope and nilgai. The common reptiles include cobra, krait and python. It is home to over 70 resident bird species. The number increases in the winters, when there is an influx of birds from the Central Asian region.

Gandak Sub-Basin

Bihar

The **Valmiki Tiger Reserve (VTR)** comprising of the **Valmiki NP** and the **Valmiki WLS** forms the eastern limit of the Himalayan Terai-Bhabar landscape (eco-region) in India. It is an extension of the Royal Chitwan Tiger Conservation landscape in Nepal. Its forests have a combination of *bhabar* grass and *terai* tracts. It is the only tiger reserve in Bihar. The VTR forest area has a substantial core area and low poaching pressure. Its vegetation is a mixture of moist deciduous vegetation in the alluvial plains and semi-evergreen forests in the upper sub-mountainous region.

River Gandak forms the western boundary of the Valmiki WLS. River Pandai flows into the eastern end of the Sanctuary from Nepal and meets the Masan River, originating inside the Valmiki forests, to form the Burhi Gandak river.

The VTR forests are also home to sloth bear, leopard, a variety of prey deer, wild boar and bison among other large mammals, besides common reptiles. Gharials swim in from R. Ganga via the Gandak. The VTR has almost 250 bird species consisting of resident and migratory birds. The more prominent species include Kaleej Pheasants, Hill Mynas, Paradise Fly- catchers, Himalayan Bulbuls, different types of storks and vultures.

People: The Tharu tribals are the dominant community in the region. They worship Hindu deities and their main festival is said to be Ramnavmi. They maintain cultural relations with the Tharus of Nepal. The Oraon, Munda, Lohra and Bhuiyan tribals were brought here as agricultural labour. They are collectively known as the Dhangars.

Ganga Sub-Basin

Bihar

Kusheshwar Asthan Bird Sanctuary is a 29 km^2 wetland in Darbhanga district (MoEFCC, 2016). It has a fresh water lake which receives the spillover from the Kamla Balan, Purani Kamla, Kosi, Bhutahi and Jeevachh rivers in flood. It stores the overflow and recharges the ground water. The Sanctuary is home to many species of water plants, fish, around 40 species of local birds and 15 rare and endangered winter migratory bird species from Afghanistan, Pakistan, Tibet, Nepal, Bhutan, China, Mongolia and Siberia among other countries. Some of the important bird species include the Dalmatian Pelican, various waterfowl species, Siberian Cranes, Purple Moorhen and Indian Darter.

The **Kanwar Taal** or **Kabar Taal** Lake in Begusarai district is said to be Asia's largest freshwater oxbow lake. It is the remnant of a meandering Gandak river. Ornithologist Salim Ali estimated it to be about three times the size of the Bharatpur Sanctuary. He counted about 60 winter migratory birds flying in from Central Asia and recorded around 106 species of resident birds. Many of them are vulnerable, endangered and threatened species.

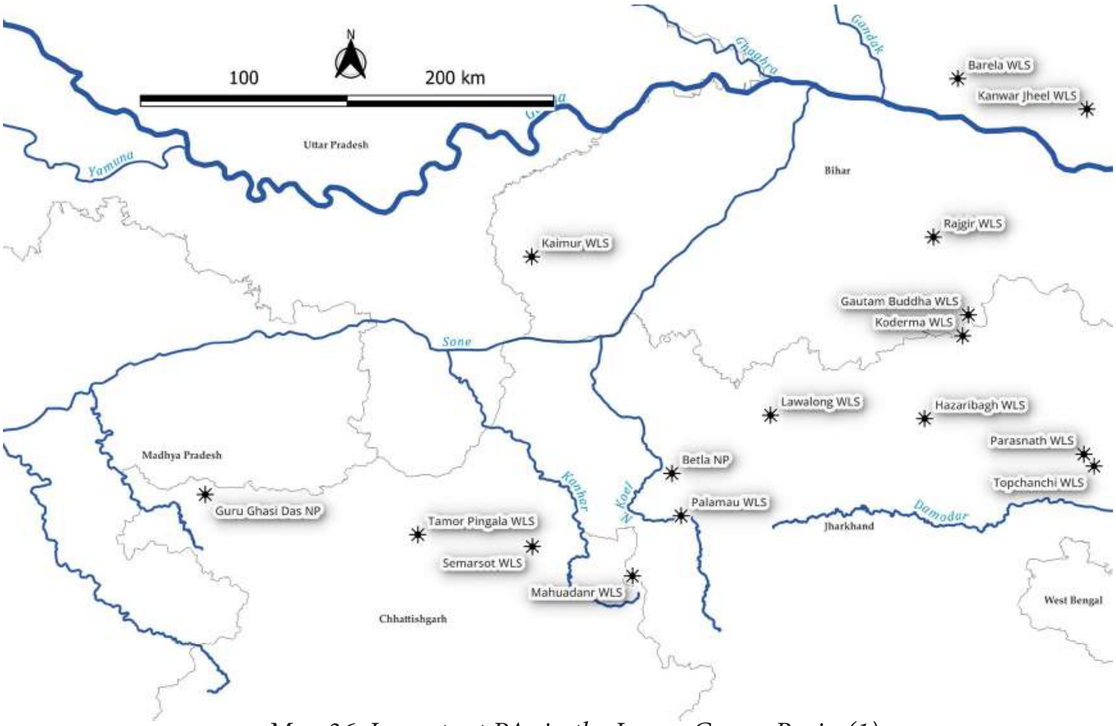
Threats: Now, however, Kanwar Taal is a dying wetland due to heavy encroachment by large land owners in the area, excessive hunting of birds and the use of poisonous pesticides by local farmers in the last two decades. The situation is further complicated by livelihood conflicts among the local farmers and fisherfolk (Sengupta S., 2015). Sanjiv Singh, head of Saviour Alluvial Ecological Establishment (SAEE) Society, a local voluntary organization has pointed to the decreasing depth of the lake due to massive deforestation and rapid siltation.

The **Bhimbandh WLS** in Munger district is known for its birds and hot water springs. These springs contain traces of radioactive matter. There are more than 250 natural hot springs between Bhimbandh forest and Sita Kund, about 25km away. Their sulphur content and other minerals are said to cure skin diseases and gastroenteric problems (Sarkar G., 2018). The distinctive flora of this sanctuary includes sal and semal trees besides a variety of creepers. The major animals are tiger, panther, sloth bear, wild boar, sambar deer, four horned antelope, cheetal and nilgai. In addition to more than 100 resident bird species the sanctuary is a winter home for migratory birds from Central Asia.

Vikramshila Gangetic Dolphin Sanctuary is a 50 km protected stretch of R. Ganga from Sultanganj to Kahalgaon in Bhagalpur district for saving the endangered Gangetic River Dolphins. About half of India's Gangetic river dolphin population is found in this Sanctuary. Other aquatic wildlife in this stretch includes waterfowl, otter, turtle and gharial.

Threats: Barrages, dams and other barriers hinder the free movement of dolphins. Another major hazard is heavy pollution of the river water by domestic and industrial wastewater, chemical fertilizers and pesticides from farms. A far more serious threat is the Haldia to Allahabad National Waterway 1 (See Box: Underwater vessel noise and river bottom-dredging harms Ganges River Dolphins).

Dredging activity in the area has increased manifold in recent years because of NW 1. Sunil Choudhary, Coordinator of Vikramshila Biodiversity Research and Education Centre (VBREC) at Bhagalpur University and a dolphin expert, told Down To Earth magazine, "Every year we do two surveys in the sanctuary. One thing is clear: 2015 onwards we see a declining trend of dolphin population" (Khan M.I., 2018). A joint survey conducted by VBREC, Ashoka Trust for Research on Ecology and Environment (ATREE) in Bangalore and Wildlife Institute of India (WII), Dehradun — found that the number of dolphins in the sanctuary had declined from 207 in 2015 to 154 in December, 2017 to 208 in June, 2022. This decline in the protected area is a serious concern. "We are still analyzing the exact reasons but the movement of big cargo vessels in the river and dredging activities have impacted the number of dolphins," says Choudhary.



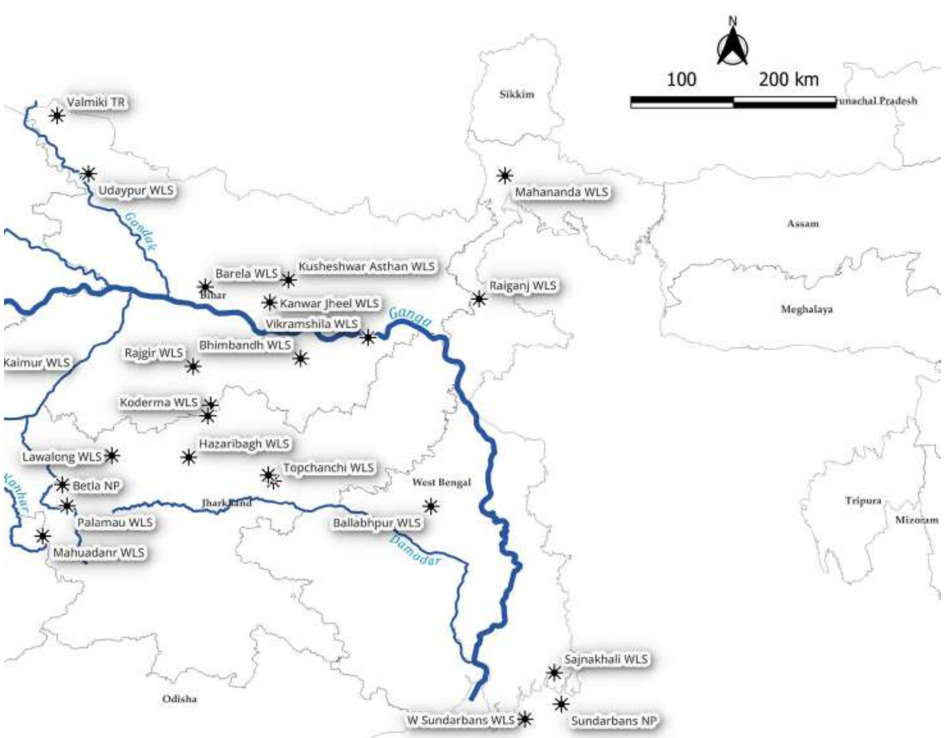
Map 36: Important PAs in the Lower Ganga Basin (1)

Other experts cite different reasons for the decline in the dolphin population in the Sanctuary. Dr. R.K. Sinha, also known as 'Dolphin Sinha' for his expertise, blames siltation, decreasing water flow and water level, human interference in the river, poaching or being trapped in fishing nets. D.N Choudhary, another dolphin expert at Bhagalpur University mentions increasing pollution as the main reason for the fall in dolphin numbers in the VGDS. "Fish production in the area is also witnessing a sharp decline mainly due to the river pollution, which also affects the dolphins," he told Down To Earth.

Gautam Budha WLS is spread across Gaya district in Bihar and the neighbouring Koderma district in Jharkhand. The Sanctuary's mixed biodiversity displays the Ganga plains and the Chota Nagpur plateau characteristics. It sustains moist deciduous forests of the Lower Ganga plains and dry deciduous forests of the Chota Nagpur plateau, with dry and moist Sal trees as the dominant species. The major fauna includes tiger, leopard, sloth bear, wolf prey deer species and many bird species.

Jharkhand

The Gautam Budha WLS (See above also) and the **Koderma WLS** lie in Koderma district. The latter WLS lies entirely in the northern dipping end of the Chota Nagpur plateau and houses dry deciduous forests. The prominent tree species are the sal, *mahua* and *palash*.
Hazaribag WLS was once home to tigers and leopards but due to unchecked human activities only some nilgai, cheetal, hyena, sloth bears, black bears and sambar are seen



Map 37: Important PAs in the Lower Ganga Basin (2)

now. Towers were constructed in the vicinity so that visitors could easily and safely see the animals.

Threats: In 2016 more than 100 stone quarries and crushing units, routinely using detonators for blasting rock, were operating on the periphery of the Hazaribagh WLS (Dey S., 2016) Such disturbances are forcing animals to leave the Sanctuary.

West Bengal

Spread over a wide altitudinal range from merely 150m to 1350m in the foothills of the Himalayas, the **Mahananda Wildlife Sanctuary** lies between the Mahananda and Teesta rivers in Darjeeling district. It was designated as a sanctuary in 1959 mainly to protect the Indian Bison and the Royal Bengal Tiger from extinction.

The forest types in the Mahananda WLS vary with the elevation, ranging from moist subtropical pine forests in the lower altitudes to dense broad-leaf temperate forests of the eastern Himalaya at the higher elevations. These variations sustain a large number of mammals, birds and reptile species. Very few tigers exist in the Sanctuary. Some other rare species are the Clouded Leopard, Himalayan Serow and the Himalayan Black Bear. Other important mammals are elephant, bison, sambar, barking deer, cheetal and leopard. The elephants migrate between Nepal, W. Bengal and Assam.

The Sanctuary houses some highly endangered bird species like the Oriental Pied Hornbill, Great Hornbill, the Rufous-necked Hornbill. Minvets, drongos, woodpeckers, etc. are abundant.

The **Raiganj Wildlife Sanctuary** in Uttar Dinajpur District is also known as **Kulik Bird Sanctuary** because the river Kulik flows by it. It is home to 164 species of birds and nearly 100,000 migratory birds visit it every year. In 2018, the State Forest Department's Census recorded 98,532 visiting birds. "What is encouraging is that the number of migratory birds is increasing every year," Dwiparna Kumar Dutta, Divisional Forest Officer (DFO), Raiganj, told The Hindu (Anon, 2018). It is a very popular picnic spot in Bengal.

During the monsoons the Kulik floods create many ponds and provide a variety of food for birds. Flocks of migratory birds from South Asian countries and coastal regions throng the Sanctuary from June onwards. They include open-bill storks, egrets, night herons and cormorants. The resident birds include drongo, kingfisher, kite, woodpecker, owl and flycatchers.

Amazingly, the Sanctuary was developed in the 1970s as a social forestry program by the West Bengal Forest Department. It was designated as a Sanctuary in 1985. It is a plantation of sisoo, eucalyptus and other dry deciduous trees, rather than a natural forest.

Raiganj WLS is an internationally recognized heronry that supports 30 to 40 percent of the existing population of Asian Openbills of South Asia. The other species in the heronry are Pond Heron, Night Heron, Little Egret and Little Cormorant.
Simply because of its location the Ganga delta is a unique ecoregion in the Ganga basin. Several other unique characteristics make the Sundarbans ecosystem of this delta a World Heritage Site, e.g., the Sundarbans forests constitute the world's largest contiguous mangrove blocks. The Sundarbans PA network is dealt separately in Chapter 5 of this Report.

North Koel Sub-Basin

Jharkhand

The **Palamau Tiger Reserve (PTR)** is one of the nine original TRs in India and the only one in Jharkhand, with the **Betla NP** (226 km^2), **Palamau WLS** (753 km^2) and **Mahuadanr Wolf Sanctuary** (63 km^2) as the core area. The dry and moist deciduous forests of the PTR constitute the catchments of the North Koel, Auranga and Burha rivers. They help minimize soil erosion and increase base flows to these rivers. The undulating terrain has a number of waterfalls and natural hot springs. Two historic forts are located inside the Betla NP.

The native biodiversity includes many RET flora and fauna species out of 47 mammal species, 174 bird species, 970 floral species and valuable medicinal plants species. The Bengal Tiger is the most important species in Betla NP and Palamau WLS. The Mahuadanr Wolf Sanctuary is the only one established in India to conserve the endangered wolf species. Other prominent endangered species in the PTR include Four-Horned Antelopes, Pangolin and Black-Necked Crane.

Threats: The integrity of PTR's area and its wildlife have been under severe threat since the 1980s. A CAG Report highlighted that between 1982 and 2014 the Jharkhand forest department had diverted 330.50 ha from the Reserve without obtaining the legally mandated prior permission of MoEFCC or the Supreme Court (Kukreti I., 2019). It also pointed out that the state government had not issued the final notifications for the PAs. Consequently, the claims of the forest dwelling communities in the PTR had also not been settled. The Mahuadanr Wolf Sanctuary has suffered degradation from a large number of stone-crushing units established within its buffer zone.

Damodar Sub-Basin

Jharkhand

There are two only small wildlife sanctuaries in this sub-basin, **Topchanchi WLS** in Dhanbad district and **Parasnath WLS** in Giridih district. The Topchanchi WLS nourishes the reservoir that supplies water to Dhanbad town. The Parasnath WLS surrounds Parasnath Hill (1371 masl), the highest in Jharkhand, where Parasnath, the 23rd Jain Tirthankar attained Nirvana.

8.3 BHAGIRATHI ECO-SENSITIVE ZONE [v]

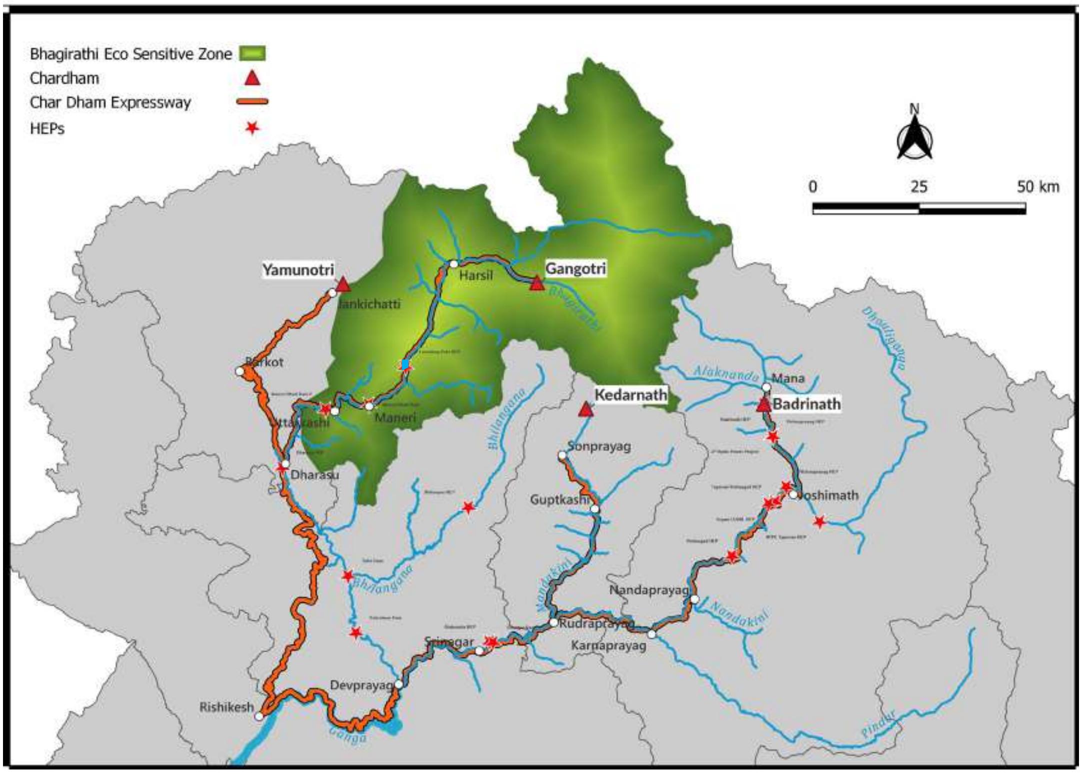
R. Bhagirathi emerges from the snout of the Gangotri glacier at Gaumukh (~4000 masl). A journey through its upper reaches is awe-inspiring as nature unfolds one breath-taking scene after another. The temple of goddess Ganga at Gangotri, 19 km downstream of Gaumukh, is among India's most revered and well-known shrines. An imaginative proposal by a few dedicated individuals convinced the Government of India of the need to conserve the upper Bhagirathi watershed for its incomparable landscapes, environmental values and natural resources. Since then, Indian scientists have confirmed the incomparable environmental value of this region by attributing the unique non-putrefying quality of Gangajal to the sediments and vegetative debris coming from its High Himalaya mountains (IMT, 2017).

Inception

In 2008, the roughly 100 km stretch from Gaumukh to Uttarkashi remained the least disturbed lengthy stretch of R. Ganga (Bhagirathi). One medium hydro-electric project (HEP) – Maneri-Bhali I (90 MW) was commissioned in 1984 at Maneri, about 8.5 km upstream of Uttarkashi and the large 600 MW Loharinag-Pala dam was then under construction at Loharinag, about 32 km upstream of Uttarkashi. But six HEPs were being planned for the Gaumukh-Uttarkashi stretch.

Between June, 2008 and August, 2010, Dr. G.D. Agrawal (See box later), one of India's leading environmental scientists, fasted three times demanding that R. Ganga be allowed to flow in its natural, unrestricted form, between Gaumukh and Uttarkashi. In October, 2009 at the first meeting of the National Ganga River Basin Authority (NGRBA) its non-governmental members proposed that the Gaumukh to Uttarkashi watershed of the Bhagirathi Ganga be designated as an Eco-Sensitive Zone. On November 1, 2010 the NGRBA formally accepted the recommendation.

The GoI notified the NGRBA decision on December 18, 2012 after overruling the objections of the Government of Uttarakhand (GoU) saying, "….. It has been decided that for the maintenance of environmental flows and ecology of the river Bhagirathi from Gaumukh to Uttarkashi with a total area of 4179.59 square kilometers covering the entire watershed



Map 38 : Map of Bhagirathi Eco-Sensitive Zone

of about 100 km stretch of the river Bhagirathi shall be declared as an Eco-Sensitive Zone from ecological and environmental point of view."

Zonal Features

Extent: The BESZ covers more than half the area of Uttarkashi district (8016 sq km). Its north-eastern boundary forms the Indo-China international border (Map 38). Just over 98 per cent of the area -- including forests, grasslands, wastelands, water bodies and glaciers -- is classified as forest and administered by the Forest Department (FD). Most of this area is under snow and glaciers. More than half the BESZ (2390 sq km) lies in the Gangotri NP

Image 25 : Sketch Showing Recession of Gangotri Glacier
Source - Wikipedia

protected area. About 67,000 people inhabit 89 villages, mostly lying in the south-western part.[vi] The population density of about 16 persons/sq km is well below the district (41 per/sq km) and state (189 pers/sq km) averages.

Physiography: After Malla village, about 26 km upstream of Uttarkashi town, the mountain slopes suddenly appear steeper. It indicates a geological cross-over from the Lesser Himalayan rocks in the southern part of BESZ to the Higher Himalaya rocks in the northern part. The seismically active Main Central Thrust (MCT) separates them.

The BESZ is a geologically fragile area prone to landslides, subsidence and earthquakes. Its north-eastern part lies in the seismically most hazardous Zone V and the remaining is in Zone IV.[vii] The Landslide Hazard Zonation Map classifies the BESZ into 'high' and 'very high' landslides hazard zones (Saha A. K., et al, 2002). Heavy monsoon rains often cause flash floods and landslides. Major landslides, often fatal, stall traffic every year on the Uttarkashi-Gangotri National Highway 34 (formerly NH 108).

Hydrology: About 225 glaciers (668 km^2) out of all the 238 glaciers in the Bhagirathi basin lie in the BESZ. The 30 km long Gangotri glacier (147 sq km) is the largest glacier while 70% of them are less than 5 km long.[viii] They provide perennial water discharge in the Bhagirathi basin. In the BESZ, the Bhagirathi's flows are mainly augmented by the glacier-fed Jahnvi, Jalandhri, Pilang *gads* (streams) and the snow-fed Kanodiya and Asiganga streams.

Lately there have been worldwide concerns about glacier recession as a result of global warming. The Gangotri glacier is estimated to have retreated at a rate of 26.5 m/yr between 1935 and 1971 and at a slower rate of 17.15 m/yr between 1971 and 2004 (Srivastava D., 2012). Data gathered by the National Institute of Hydrology (NIH) shows a decreasing trend between 2000 and 2016 in the monsoon season stream flow at Bhojbasa, about 10 km downstream of Gaumukh. This is most likely a result of the decreasing winter precipitation in recent years (GoU, 2018, p.77).

Along with water, glacial rivers also bring down very heavy sediment loads, as suspended sediments and bed load. Even a small glacier (5 km^2) can transport 4000 to 5000 tons of

The Raja of Harsil

In the 1840s, Frederick 'Pahari' Wilson, a deserter from the British Army in Afghanistan took refuge in Harsil village in the upper Bhagirathi valley and enriched himself selling deodhar logs for railway tracks. He introduced apple orchards and rajma cultivation in the region. He established the Bank of Mussoorie, minted his own coins, married two local Garhwali women, built several houses between Mussoorie and Harsil, hunted musk deer and acquired the epithet, 'Raja of Harsil'. He may have provided funds to the British Army during the 1857 War of India's Independence.

sediments during the monsoons. Such high sediment loads severely damage turbine blades and hamper the functioning of hydropower stations downstream (GoU, 2018 p. 85).

More global warming impacts are now visible in the BESZ glacial area (Mal S., 2015).[ix] The gradual fragmentation (breaking-up) of small glaciers and lake formation is a hazard with increasing potential for Glacial Lake Outburst Floods (GLOFs) and resulting risk for habitations and infrastructure downstream.

Lower elevation vegetation is becoming visible above the present tree-line and in the alpine meadows, due to warming temperatures, threatening the latter's herbaceous diversity. Rising stream temperatures will affect the temperature-sensitive aquatic biota.

Biodiversity: The tremendous altitudinal change from about 1150 masl (Uttarkashi town) to peaks of almost 7000 masl in the High Himalaya region gives rise to varied climatic regions in the BESZ and therefore to an amazing biodiversity. "The BESZ is a continuum between Govind NP in the west and Kedarnath Musk Deer Sanctuary in the east for many high-altitude mammalian, avifaunal, butterfly and floral terrestrial RET (rare, endangered and threatened) species," explains Dr. Sathyakumar, a senior scientist at the Wildlife Institute of India (WII) in Dehra Doon. Its alpine pastures, or *bugyals*, are rich in indigenous species of flora and fauna and are popular tourism sites.

High altitude temperate forests, alpine scrub meadows, moraines and glaciers in the Gangotri NP are home to five RET mammalian species (Himalayan Brown Bear, Asiatic Black Bear, Snow Leopard, Common Leopard and Himalayan Musk Deer) and three other rare species (Himalayan Tahr, Blue Sheep and Serow). The remote Jadhganga valley is an excellent habitat for snow leopards and their prey, the blue sheep. Forests in the warmer middle and southern parts host more than 30 different mammals.

The BESZ has several hundred floral species including the rare *bhojpatra* (Himalayan birch), *deodars*, coniferous evergreens and scores of zonal medicinal plants. The riverine forests in the lower stretch are rich in orchids. Hundreds of bird species in the region include four RET species (white-backed vulture, Egyptian vulture, chir pheasant and western tragopan) and the critically endangered Monal pheasant -- Uttarakhand's state bird.

The high altitude, cold, northern streams constitute a 'no fish' zone. Streams in the mid-zonal stretch host four threatened species: golden mahseer, snow trout, and two stone sucker species, among others. The Asiganga sub-basin in the southernmost stretch has recorded three fish species including the threatened snow trout (*Schizothorax richardsonii*) and the invasive brown trout. They migrate upstream to breed.

Though the biodiversity increases moving towards the warmer, lower end of the BESZ, much of it is threatened by development projects and increasing anthropogenic pressures.

Existing dams across R. Bhagirathi have nearly ended the upstream movements of the mahseer and snow trout species while allowing an invasive brown trout to expand its range.

Economy: Subsistence agriculture was the mainstay of the traditional economy in the BESZ along with some livestock rearing. The average landholding today is about 0.75 ha (GoU, 2018, p.111). Food grains like paddy, finger millets (*manduwa*), maize and amaranthus (*cholai*) are the main kharif season crops while wheat, barley (*jaun*), gram (*chana*) and mustard are the main rabi crops. In the mid-nineteenth century, Frederick 'Pahari' Wilson introduced apple orchards and rajma cultivation in Harsil village (See box: The Raja of Harsil). These two crops remain a large part of the rural cash economy. With the growing tourist influx to the Gangotri shrine, horticulture and floriculture production has picked up. Farmers are also supplementing their income with animal husbandry, especially for milk production, and some fishing in the villages by the river banks.

The rapid growth of automobile production in India in the last 25 years and the widening of the National Highway have made travel to the *Char Dhams* easier. Consequently, religious tourism has mushroomed in the BESZ. Lodges, rest houses and *dhabas* are scattered all along the National Highway to Gangotri and at other tourist locations like Dodital lake, Dayara bugyal and Harsil, giving a major fillip to the local economy while causing strip development along roads and also close to vulnerable river banks.

One visible impact of the mushrooming tourism is the rapid urbanization of the region even though it has only two designated urban areas – the Nagar Palika Parishad (Municipal Council) of Barahat (Uttarkashi town) and the Gangotri Nagar Panchayat. Both these urban areas host a massive number of tourists in the summer months, and now after the construction of the 'Chardham Expressway', in overwhelming numbers as also of passenger vehicles and supporting supply trucks. Gangotri Nagar Panchayat is snow bound for about five months of the year, when very few persons reside there. The 2011 Census recorded only 110 permanent residents in Gangotri. The addition of neighbouring Gram Panchayats to Uttarkashi town in November, 2017 resulted in a sudden jump of the town's area and population. The number of tourists visiting Uttarkashi district rose from 283,114 in 2015, to 801799 in 2017 (GoU, 2018). However, after the completion of 'Chardham Expressway', the number of visitors to Gangotri in 2022 was around 40 Lakh (Tourism Dept., Uttarakhand). The visiting hordes were conveyed in cars and buses causing massive gridlock and pollution. "The massive increase in economic activity, however, has left the Municipal officials struggling to provide basic services, particularly waste management," says Surat Singh Rawat, a senior Uttarkashi-based journalist. "All the urban sewage is released untreated into the Bhagirathi, in contravention of the existing laws," he revealed.

A Political Football?

The NGRBA decision to declare the Gaumukh-Uttarkashi watershed stretch of the Bhagirathi Ganga as an Eco-Sensitive Zone was strongly opposed by political leaders of the state's three leading political parties, the Congress, BJP and the Uttarakhand Kranti Dal. Soon after, then Chief Minister of Uttarakhand, Shri Ramesh Pokhriyal 'Nishank', piloted a resolution in the state legislature against the BESZ. Environmentalists criticized the legislators as being beholden to the contractors' and pro-dam lobbies that stood to lose thousands of crores of rupees upon the cancellation of many hydropower projects. Ultimately on December 18, 2012 the NGRBA decision was notified in the Gazette of India.

A key feature of the BESZ Notification required the State Government to prepare a Zonal Master Plan (ZMP) for improving the environment and the well-being of the local people. It specified that the ZMP was to be prepared in consultation with the local communities particularly women and the involvement of the relevant State departments and submitted to the MoEF, GOI for approval within two years. The Notification specified guidelines for developmental activities like land use changes, protection of green cover, natural springs, road construction, hydropower generation, tourism, etc. The Uttarakhand Government, however, chose to misrepresent the BESZ Notification as being anti-development. It made several written representations to the MoEFCC that were turned down, under the UPA and the NDA Governments.

In 2015, several people from the BESZ filed an application in the NGT demanding that a ZMP be prepared in compliance with the 2012 Gazette Notification. After many delays and on a direction from the National Green Tribunal (NGT) the State Government departments compiled various existing government schemes and projects, without any consultative process, and presented them as a ZMP in February, 2016. Several proposed activities in this draft contravened the basic guidelines in the BESZ Notification. After intense lobbying with MoEFCC, the Uttarakhand Government submitted a ZMP in October, 2016. This was opposed by the MoWR, RD&GR (GoI) as it violated the 2012 guidelines. On an order of the NGT, MoWR, RD&GR submitted an affidavit in the NGT in April 2017, rejecting the ZMP submitted by the Uttarakhand Government and calling for the appointment of a group of independent experts to prepare a fresh ZMP in accordance with the BESZ Notification.

The new committee too was thwarted by determined Uttarakhand officials led by the state's Chief Secretary in adopting a people-centric ZMP preparation methodology. Intense lobbying by the State Government with the Prime Minister's Office resulted in relaxing some restrictions in the 2012 BESZ Notification. But MoEFCC did not relax restrictions against constructing HEPs >2 MW capacities in the BESZ, among other key restrictions. Ultimately in June, 2018 the latter submitted a revised ZMP, incorporating some recommendations of the experts but without their approval of the Plan (GoU, 2018). The matter is under litigation before the Supreme Court.

Char Dham Pariyojana

The 2012 BESZ Notification had prohibited road construction and widening in areas of steep slopes (>35%), damage to natural springs and reduction of forests area, among other restrictions. It recommended several mitigation measures, including a proper

EIA study wherever hill cutting could cause environmental damage. But for the Char Dham Pariyojana to widen existing national highways to the four shrines at the ends of the Alaknanda, Mandakini, Bhagirathi and Yamuna valleys, MoRTH (Ministry of Road Transport & Highways, GoI) proposed five projects in the BESZ which involved:

1. Widening NH 108, Uttarkashi to Gangotri to 12.5 m width against the existing 7 to 8 m width. Extra cutting would be required for the slope protection wall on the mountainside.
2. Felling several thousand trees for widening 11 km through a pristine deodar forest.
3. Construction of a 5 km tunnel through the Sukhi Top hill, a bridge across the Bhagirathi and several smaller tunnels in the ~8 km Gangnani-Dabrani stretch.

On August 8, 2019 the Supreme Court ordered the formation of a High Powered Committee (HPC) to, “make special provisions (for the BESZ) in its report keeping in mind the guidelines given under the Notification of the Bhagirathi Eco-Sensitive Zone so as to avoid violations and any environmental damage,” among other tasks.

The HPC’s final report recommended that all the required clearances be obtained as per the 2012 BESZ Notification and its 2018 amendments for all the proposed five projects. It added that proper EIA reports be prepared by a competent and reputed organization, other than the DPR consultant (HPC, 2020). It recommended that alternate administrative and technological solutions be considered to avoid cutting the deodar trees and to undertake comprehensive geological studies before cutting any vulnerable slopes. The HPC would review them.

The Supreme Court accepted the recommendations of the HPC on September 8, 2020 and directed that the Char Dham Pariyojana roads be limited to an intermediate width (5.5m tarred surface), which would require minimal slope cutting in the BESZ. This decision was later challenged in the Supreme Court by the Union Ministries of Defence (MoD) and MoRTH. After much delays and a new MoRTH notification setting its desired width (10m tarred surface) as the standard for roads required for national security purposes, a new bench of the Supreme Court granted permission on December 14, 2021 for road widening in the BESZ, as demanded by MoRTH and MoD.

Conclusions: The BESZ has unique wilderness resources but is extremely vulnerable to natural upheavals. It was notified in December, 2012. Attempts to implement its guidelines, however, have been caught in a furious tug-of-war between pro-sustainable development forces and the forces of ‘business as usual’ which, in this context, implies development regardless of environmental cost. “Complex and powerful forces are ranged against the BESZ. Mobilizing the affected communities has been made difficult by the money power and political power of our opponents,” says Keshar Singh Panwar of Uttaron village who filed a case in 2015 before the NGT for implementation of the 2012 Notification guidelines.

The ZMP episode illustrates the need for selfless scientific and legal expertise and honest and determined officials to assist the local communities who are fighting to ensure the well-being of the ecosystems they are dependent on. The December, 2021 Char Dham Parijoyana case judgment, however, has increased the difficulties in protecting the fragile BESZ ecology.

The Bugyal and the Wedding

Auli, a Bugyal, or alpine meadow, endowed with a variety of endemic and rare flora and fauna, en route Badrinath, in Chamoli district of Uttarakhand is a popular destination for ski enthusiasts and trekkers.

Auli became the centre of attraction in June, 2019, when NRI businessmen Ajay and Atul Gupta were allowed to use the meadow for wedding celebrations, from 18 June to 22 June. The Rs 200 cr wedding was a huge affair being graced by the presence of political bigwigs and performances by celebrities like Katrina Kaif, Badshah and Kailash Kher. The only helipad at the meadow was turned into the mandap, and 8 helipads were to be constructed which was later struck down by the Nainital High Court. The Court had also banned the use of plastic, thermocol bags, glasses, plates, cups etc but the litter strewn by the organisers later tell a different story.

The grand, lavish was carried out despite a 2018 Uttarakhand High Court Order forbidding night stay at higher bugyals. The question arises, how and why did the government grant the permission for such a grand function on one of the most fragile ecosystems? On being questioned about the same by activists and media, the then CM Trivendra Singh Rawat dismissed the ecological concerns saying it would boost Auli's tourism potential. He was quoted as saying by the news agency PTI that he had asked businessmen at an investors summit, to explore Uttarakhand as a wedding destination instead of foreign locales.

On 18 June, hearing a PIL that claimed wedding preparations are damaging the environment, the Nainital High Court ordered the businessmen to deposit Rs 3 cr as security with the Chamoli district administration for any possible harm that may be inflicted but does this resolve the harm done to the environment, a concern, that authorities as well as local leaders have failed to address. A bugyal once disturbed, takes about 50-60 years to recover. The 2011 South Asian Winter Games, had already disturbed the meadows once, and before it could recover from the damages, the preparations to aggravate its condition were already made.

The function ended with a deadly aftermath for the environment. According to the reports, around 33,000 kg of garbage was littered not including the huge amount of human excreta strewn over the bugyal as only 4 makeshift toilets were constructed for the guests, and the workers engaged in the preparations were not provided with the toilets. The post-wedding clean up which was to be carried out by state administration did little to ameliorate the predicament, as the collected waste was burned in the Joshimath dumping ground on the banks of Dhauliganga, casting a smoky shroud over Auli and Joshimath for two days. The trash blown away by the wind made the clean-up attempts more difficult.

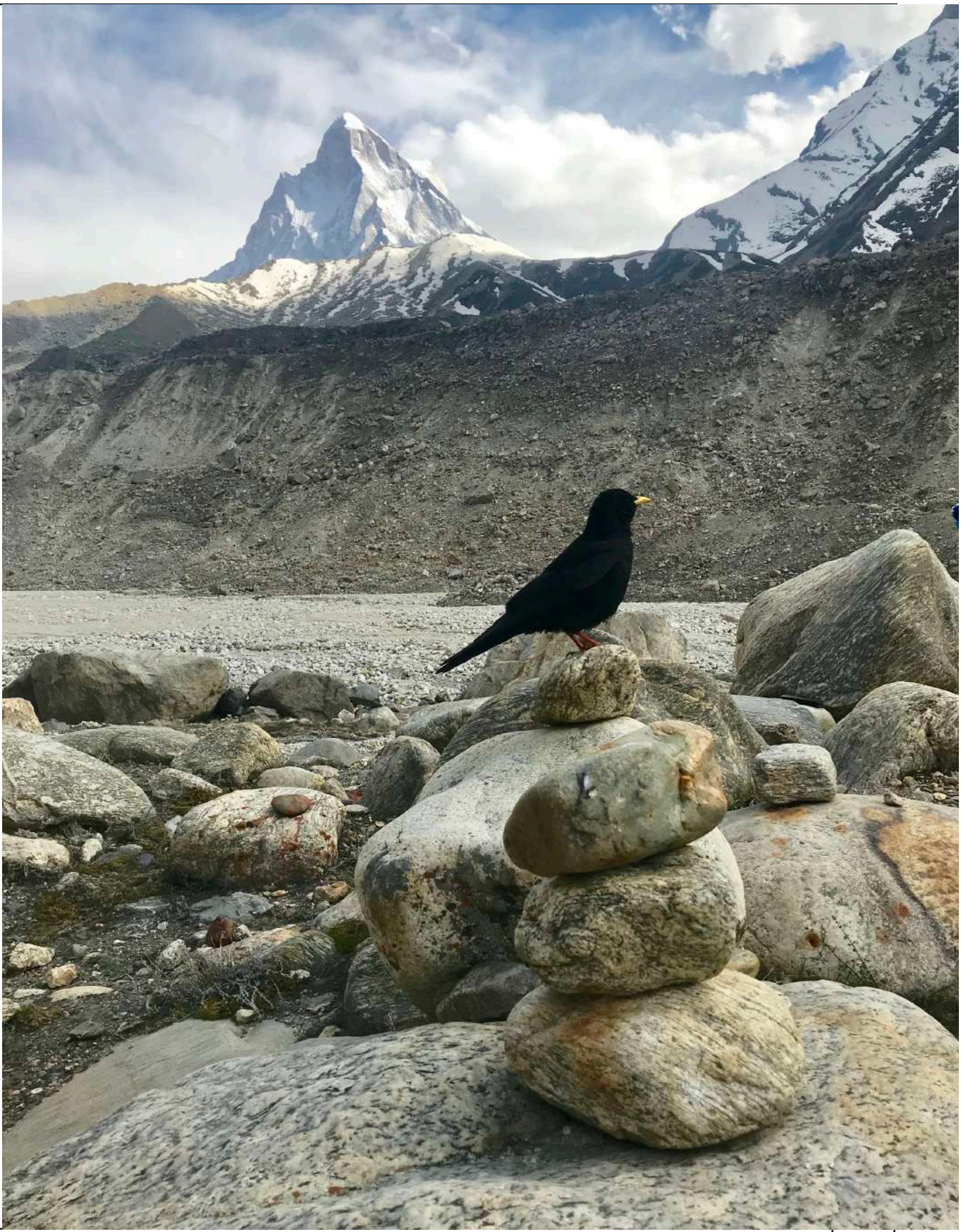
The High Court noted that the permission granted for the function set up wrong precedents by the government, but the statements of local leaders, terming the environmental concerns as anti-development and 'anti-national', should make us introspect the fact that how serious yet helpless are we when it comes to our natural heritage being damaged by unbridled money power for pomp and show.

8.4 LANDSCAPES AT RISK

The basin landscape is undergoing significant transformation towards a human-dominated and engineered landscape. Highways, dams, barrages, embankments, canals, sand mining, urban expansion, levelling of topographical relief features, encroachment of wetlands is all contributing to the disruption of landscape ecological processes.

Forests, hillocks, pasture lands are confined as small islands under pressure from human interventions and greed for land. Thus, corridors for faunal movements have almost vanished, soil productivity and permeability have diminished, forests canopy cover and density have generally declined. Around the headwaters, hill-cutting for roads, dams and tunnels is taking a toll on the integrity of the fragile bedrock. Compounding all this is the fact that tropical vegetation is advancing to altitudes which were earlier occupied by sub-alpine vegetation.

Thus, overall the ecosystem services generated by a ecologically functional landscape have shown a sharply declining trend. This is also reflected in climate changes at more local levels. It is unfortunate that there is no initiative to integrate broad perspective policy and programme approach for landscapes conservation in our spatial development.



CHAPTER 8B
CONSERVATION & PROTECTION MEASURES IN THE GANGA BASIN (PEOPLE & ORGANIZATIONS)

Source - PTI

8.5 CITIZENS' EFFORTS TO CONSERVE RIVERS AND WILDLIFE IN THE IGB

Since ancient times Indian traditions and scriptures have regarded water as sacred and rivers have been revered as goddesses or mothers (Chopra R., 2003). Conservation and protection of water bodies have been considered pious acts. Not surprisingly, therefore, individuals and organizations have been active in the Ganga basin to protect and conserve its rivers, watersheds, floodplains and flora and fauna, for over a century, against the onslaughts for rapid economic growth.[x] These efforts have focused on protecting river flows by opposing construction of big dams and reviving springs to enhance base flows,

G.D. Agrawal: Faithful to His Science and Scientific in His Faith

Dr. Guru Das Agrawal, aka Swami Sanand, sacrificed his life on October 11, 2018 after 112 days of fasting, seeking effective action from the Government of India, for the well-being of R. Ganga. Not receiving an acceptable response, he stopped drinking water on October 9th, 2018, and chose martyrdom.

Born on July 20, 1932 in Kandhla (U.P.), GD, as he was affectionately called by his friends and associates, matured into young adulthood in the early 1950s, fired by a dream of nation-building. He obtained a B.Sc. degree from Banaras Hindu University, a B.E. in civil engineering from the University of Roorkee (now IIT-Roorkee). He joined the irrigation department in Uttar Pradesh state in 1953 as a design engineer at the Rihand Dam in Mirzapur (now Sonbhadra) district. Once asked what he thought then about being a dam builder, he answered, "I did not think I was building a dam. I thought I was building a nation."

Dr. Agrawal had a phenomenal intellect, a logical mind and an amazing memory. In 1960 he joined the faculty at IIT-Kanpur. Sent to the U.S.A. in 1963 for postgraduate studies, he obtained his M.S. and Ph.D. degrees from the University of California at Berkeley in less than three years. He always credited his Ph.D. advisor, Dr. Erman Pearson, for his understanding of modern ecological science.

Dr. Agrawal was fiercely independent. As Dean of Student Affairs at IIT-Kanpur in 1977, he invited Jayprakash Narayan to address the students. When he was reproached by the Institute's Director, GD tendered his resignation and returned to farm in Kandhla.

In 1980, Dr. Agrawal joined India's Central Pollution Control Board as its first Member-Secretary, on the invitation of its Chairman, Dr. Nilay Chaudhry. At CPCB he guided a team of scientists to develop environmental standards specific to Indian conditions rather than blindly borrow them from abroad. But he quit in 1983 when he differed with Dr. Chaudhry over an issue of the Board's autonomy. He refused to bend science to the will of political masters.

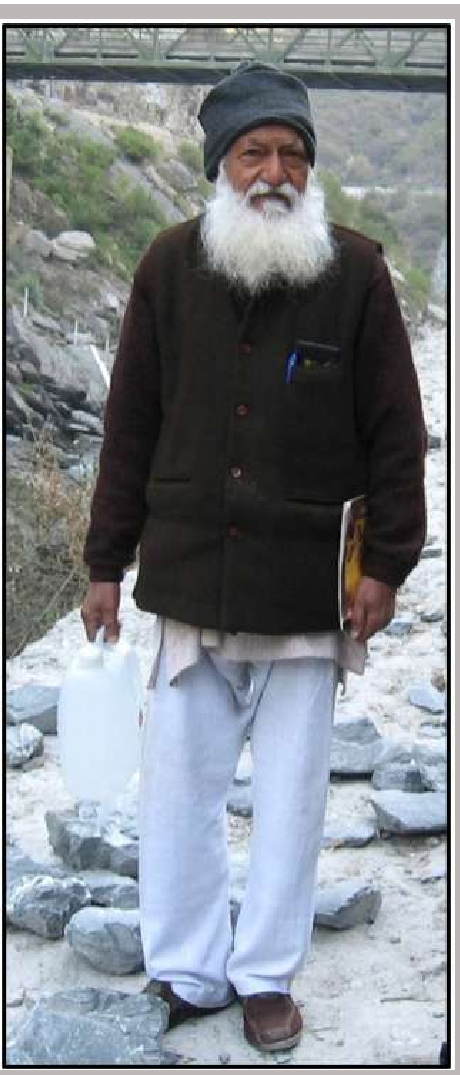
Thereafter Dr. Agrawal joined a few of his former students from IIT-Kanpur to set up a company to manufacture air quality monitoring instruments. He developed procedures for air quality monitoring. He emphasized consulting local people to identify and understand air pollution problems. In the early 1990s he moved to Chitrakoot (M.P.) at the invitation of Nanaji Deshmukh to teach at the Mahatma Gandhi Grameen Vishwavidyalaya in an honorary capacity. Dr Agrawal was a legendary and inspiring teacher. He is the only faculty member, so far, to receive the Most Distinguished Teacher Award from IIT-Kanpur alumni,. Senior professionals sought his help to solve difficult technical problems.

GD's signal nation-building contribution was to mentor many young activists, (and institutions) like Dunu Roy (IIT-Bombay,'67) who set up the innovative Vidushak Karkhana in Anuppur (M.P.) and later The Hazards Centre, New Delhi; Dr. Ravi Chopra (IIT-Bombay,'68) of People's Science Institute; Anil Agrawal (IIT-Kanpur, 1970) who established the Centre for Science & Environment in New Delhi and Rajendra Singh, a Magsaysay awardee and founder of Tarun Bharat Sangh. Prominent institutions that he mentored included People's Science Institute (PSI) in Dehra Doon and Banwasi Sewa Ashram in Sonbhadra district (U.P.) among many others.

Dr. Agrawal saw R. Ganga as an ecosystem with water, sediments and aquatic biota. In 2007, on a visit to Gangotri, he learnt of plans to build three HEPs upstream of Uttarkashi town, besides the existing Maneri-Bhali I dam. He realized that they would destroy the only remaining pristine stretch of the Ganga.

After considering a number of options, GD began a fast-unto-death from Ganga Dussehra Day in June, 2008 demanding that all HEPs on the Ganga between Gangotri and Maneri be permanently cancelled and the natural flow of the river restored. It was the start of a decade-long struggle to unshackle his Maa Ganga. During this period, he went on six hunger-strikes, which he called *tapasyas*, with varying degrees of success (See main text). He limited his opposition to dams and barrages on the Himalayan headstreams of the Ganga. For the others he demanded the release of environmental flows. GD was often asked why he was opposing dams and barrages on the Ganga. "Ganga is no ordinary river. It has unique properties of self-purification," he would say.

Like most Indians Dr. Agrawal grew up with the belief that Gangajal is unique because it does not putrefy even when kept in a closed bottle for years. But as a scientist, he wanted evidence. In the 1970s, he conducted experiments on Gangajal with graduate students at IIT-Kanpur. These experiments showed that the Ganga's self-purifying capacity – including its ability to destroy coliform bacteria –was higher than the Yamuna's, which in turn was higher than other rivers that had been studied elsewhere, including the mighty Mississippi in the United States. This special characteristic of the Ganga was attributed to the Himalayan sediments and rare vegetative debris in the river.[xii]



Dr. Agrawal therefore opposed the construction of hydropower dams, tunnels and barrages on the Ganga and its Himalayan tributaries because such structures obstruct the flow of water and sediments down the river - thereby diminishing its unique self-purifying ability. Experiments conducted under Dr. Agrawal's guidance at People's Science Institute (PSI), Dehra Doon, in 2008 established that the self-cleansing and self-purifying capacities of the Bhagirathi decreased progressively after each dam.[xiii]

In February, 2018, after waiting for almost four years for election promises to be fulfilled to rejuvenate Maa Ganga, Dr. Agrawal, now known as Swami Sanand, wrote to the Government of India to fulfill four demands or he would fast-unto-death from June 22nd. These were (i) Present a comprehensive Bill in Parliament to conserve and protect R. Ganga, based on a draft prepared by Ganga Mahasabha in 2012; (ii) Cancel all under-construction and proposed HEPs in the upper reaches of the Ganga and its six headstream tributaries; (iii) Ban river-bed sand mining in the main stem of the Ganga, particularly in the Haridwar Kumbh Mela area, and (iv) Form an empowered autonomous Authority of capable persons with demonstrated commitment to ensure R. Ganga's well-being.

On September 9th, owing to unfulfilled promises, Swami Sanand announced that he would give up drinking water from October 9th, the first day of the Navratras. Negotiations thereafter with government officials, cabinet ministers and senior political leaders were unproductive. The GoI did not concede a single one of Swami Sanand's four demands. In the face of the government's obstinacy the iron-willed Swami Sanand chose martyrdom hoping that it would awaken the conscience of the Government and the people of India. "I think my body will last for another six weeks. But don't worry about me. I am satisfied with what I have done and my going will only give you more strength to do what needs to be done," he told Dunu Roy and Ravi Chopra on August 24th, 2018.

Dr. Guru Das Agrawal remained faithful to his science and scientific in his faith till his end.

monitoring and improving river water quality, opposing unscientific river-bed sand mining, wildlife conservation and celebrating river cultures. They have included conservation activities, campaigns, research and documentation, information dissemination and legal actions. A sampling of these efforts is discussed in this section.[xi]

8.5.1 Conservation Campaigns and Struggles

Citizen's Conservation Efforts in the Upper Ganga Basin

In the midst of towering mountains and evergreen forests, tempestuous streams and torrents, and rare flora and fauna, the mountain communities of Uttarakhand have over centuries revered nature, respecting its furies and bounties. Unrestricted control of the local communities over their natural resources ensured sustenance of these traditions. In the early part of the 20th century a popular movement succeeded against the steady usurpation of community forest rights by British administrations and local rulers (Guha

Matri Sadan: A Home for Unrelenting Ganga Tapasvis

On the right bank of Neeldhara, one of R. Ganga's many channels in Haridwar is a large, unpretentious *ashram* called Matri Sadan. It is a spiritual outpost amid the proliferating ostentatious *ashrams* of Haridwar. It was established in 1997 by Swami Shivanand, a chemistry postgraduate from Bihar, and his associates. Over more than two decades, the *sanyasis* of the *ashram* have established a reputation as spiritual non-violent warriors fighting against corruption and the desecration of R. Ganga. Specifically, it seeks the nirmal and aviral flow of R. Ganga by zero discharge of polluted water into it, decommissioning dams on it and a ban on illegal riverbed sand mining.

In 1998, Swami Shivanand, adopting Mahatma Gandhi's satyagraha approach to combat wrong doings, undertook a fast against illegal sand mining in the Kumbh Mela area. His evidence-based protest forced the authorities to give in. Since then, Swami Shivanand and his young disciples have repeatedly gone on hunger strikes and sought judicial intervention to force officials to act against illegal sand miners.

Matri Sadan came into national focus in 2011 when its young sanyasi, 35-year old Swami Nigmanand Saraswati, died suddenly after fasting for 68 days against the district authorities turning a blind eye to illegal riverbed sand mining in the Kumbh Mela area. According to Matri Sadan's website a pathology report of his serum revealed that Swami Nigmanand had succumbed to organophosphate poisoning. Gokulanand Saraswati was another seer at Matri Sadan who died fasting for the well-being of R. Ganga.

Swami Sanand, aka Dr. G.D. Agrawal, found a kindred spirit in Swami Shivanand and his disciples. This meeting of hearts and minds encouraged him to sit on fasts-unto-death at Matri Sadan where he was often guided and counseled by Swami Shivanand on the science of long duration fasts.

R., 2005). This spirit of conservation in Uttarakhand was strengthened in later decades by the two prominent British followers of Mahatma Gandhi, Mira Behn and Sarla Bahen.

Chipko Andolan: The proud tradition of protests to safeguard their traditional rights and conserve natural resources was renewed in the 1970s by the Chipko Andolan. After the devastating Alaknanda river valley flood in 1970 (See Chapter 4), relief workers from Dasholi Gram Swaraj Mandal (DGSM) observed that the destruction had been severest in the valleys most heavily deforested for commercial interests. They demanded an end to tree-felling in the sensitive Himalayan river valleys.

In 1973, after local officials failed to curb tree-felling, DGSM launched a non-violent protest in Chamoli district against the clear-felling of Himalayan forests and the oppression of the local forest-dwellers. In 1974, women in Reni village in the Rishiganga valley carried out a Chipko protest – hugging trees – to prevent woodcutters of Symonds Sports Goods Company of Allahabad from cutting trees in their forest. A fact-finding committee headed by Dr. Virendra Kumar, a botanist from Delhi University, appointed by the U.P. state government recommended that no clear-felling be allowed in the Alaknanda basin.

The quick successes of the Chipko Andolan were followed by seasonal eco-development camps of mountain women to afforest degraded valleys. A study conducted by the Indian Institute of Science (Bangalore) in the early 1980s found a survival rate of 20 to 50 per cent in the Forest Department's plantations and over 68 per cent for DGSM's people-based efforts (Pahari R., 1997). Later a remote-sensing study by the Space Applications Centre (Ahmedabad) showed that the local women's forests rejuvenation efforts, guided by DGSM, had significantly covered the earlier barren slopes and checked soil erosion and landslides (Kimothi M.M. & Juyal N., 1996).

As knowledge of DGSM's pioneering work spread, it fired people's imagination the world over.

Anti-Tehri Dam Movement: In recent decades dams have been extremely contested development projects in India and other parts of the world. Beginning in the 1980s, protests against the Tehri dam on R. Bhagirathi and against dams on R. Narmada in Central India, dominated environmental discussions in India for over two decades (See also Chapter 11). The Tehri reservoir submerged over 100 villages and the historic town of Tehri, displacing nearly 100,000 persons. It consumed forests, destabilized the surrounding slopes and damaged the unique self-purifying capacity of river Ganga (IMT, 2017). Lying on a major fault in a highly earthquake-prone region, the dam is a disaster threat. The anti-dam protests highlighted these issues to educate people about who bore the real costs of development.

Several fasts undertaken by Shri Sunder Lal Bahuguna forced the GoI to appoint committees

Image 26 : Br. Atmabodhanand and Swami Shivanand

of experts to examine the seismic threats and other issues. Over time, dam proponents, construction industry lobbies and government officials pushed the decision-makers to sanction the dam's construction, in violation of the government's own procedures and the experts' recommendations.

In September, 2003 India's Supreme Court dismissed a writ petition filed by Shri N.D. Jayal and Prof. Shekhar Singh in 1992, after the Uttarkashi earthquake (1991) asking reconsideration of the safety and environmental aspects of the Tehri dam. After hearing final arguments, by a 2:1 judgement the Court ruled that the dam's sanction had not contravened the clearance conditions. It brought down the curtains on the anti-Tehri dam movement, though local protests continued as fresh problems arose once the dam was commissioned.

The rejection of the people's protests and subterfuge in decision-making processes left the local people feeling ignored, defeated, sullen and apathetic to later protests against similar development projects (Sethi H., 2001). Since then, dam-builders and other 'developmentalists' routinely label protests against the destruction of rivers as being anti-development or even anti-national.

Partial Victory At Phalenda: In May, 2006, residents of Phalenda and Saruna villages in Tehri Garhwal district struck a blow for mountain villagers when they forced the state and Swasti Power Corporation, the 22.5 MW Bhilangana HEP developer, to concede that the villagers' existing use of the river water for irrigation had priority over hydro-power generation.
In March, 2004 the residents of Phalenda, Saruna and other neighbouring villages became aware of a proposed project on the Bhilangana river and that it would dry up an 8km

Extracts from the proceedings of the meeting of Phalenda and Saruna Gram Sabhas and invited institutions / social activists with the Commissioner (Garhwal Division) on Bhilangana Hydropower Project on 04.05.2006.

1. The District Administration will hold the responsibility of making water available to villagers for irrigation as per need in accordance with 02.12.05 agreement and ensure the said arrangement from the company management. After assessment of water (requirement) for agriculturally-fit area by the Minor Irrigation Department, water will be primarily and firstly given to villagers as per need and will be available to the project thereafter.
2. If there is any adverse impact from the project on drinking water in the future, then the District Administration will ensure making of alternative arrangement by the Company concerned.
3. All civil utilities and facilities under the project area will be marked, video graphed and photographed and if there is any adverse effect on these due to project construction, then the District Administration will ensure alternative arrangement from the Company management. The expenses will be borne by the Company.
4. The District Administration would refer to the State Government along with its recommendation, for a hanging ropeway bridge, upgrading of a junior high school and the internal motor road in the village, and will monitor the same from time to time.
5. The issue of providing free of cost electrical power to the affected villages is a policy-related matter and will be referred to the administration.
6. The issue of giving Project shares free of cost to the villagers is a policy-related matter and will be referred to the State Government.
7. Amount given for compensatory afforestation for grass, fodder and fuel would be utilized in the affected villages through the gram sabhas.
8. If any land is taken for the project in the future, then the Company will make payment as per the highest rate given in the village.
9. ADM, Ghansali, who was present at the meeting, apprised that there is no case of disturbing peace (disrupting law and order) presently pending in the SDM's court, Ghansali, against any villager of Gram Phalenda / Saruna.

stretch of the river, affect their irrigation supply, forests, springs, habitations and even their cremation ghats. Further, the construction of a diversion tunnel could destabilize the mountain slopes.

The villagers registered their objections before the company's officials and the district administration but to no avail. Their 'Bhilangana Ghati Baandh Pariyojana Virodhi Sangathan' then began an agitation to prevent the company from starting work. The district administration resorted to repeated arrests and repression. On November 22, 2005 six women and four men were badly beaten, bloodied and their clothes torn before being jailed.

Apna Jungle, Apna Pani: The demands of the UNBA

1. No further construction, approval or sanction of dams in Uttarakhand till a publicly accepted hydropower policy is in place.
2. An independent commission should evaluate dams' proposals and monitor construction activities.
3. The focus should be more on micro-hydel projects (less than 1MW).

a) The quality of EIAs needs to be improved through legal provisions and enforcing punitive measures for defaulters.

b) A basin scale EIA, along with project-based EIAs, should become a minimum criterion for granting environmental clearances.

c) All probable oustees (esp. women) should be informed well in advance about the nature of the project and its probable impacts. They should be made part of the decision-making process. Honest public hearings need to be held and proper follow up actions have to be taken. The project-affected should also receive free power (from the state's share of 12% free power) and monetary benefits arising out of projects.

4. Constitute an independent and interdisciplinary team of experts to scientifically determine the minimum in-stream flows requirement for Himalayan rivers in order to maintain an environmental flows regime.
5. Uttarakand needs a clear Resettlement and Rehabilitation policy. Implementation should be strictly monitored. 'Provision of land-for-land' should become an important criterion for compensation.
6. Compensatory afforestation at the project sites should be promoted through CAMPA funds, which should be released directly to the Gram Sabha.

The woeful villagers received a sympathetic hearing from Shri Saifuddin Soz, then Union Minister for Water Resources. Faced with a threat of mass civil disobedience, on May 4, 2006 Shri Subhash Kumar, the Garhwal Division Commissioner, met the villagers and their representatives along with the developer.

After discussions, the Commissioner agreed to most of the villagers' demands, particularly for according priority to irrigation over hydropower generation and that the amount given for compensatory afforestation for the loss of grass, fodder and fuel be utilized only by the gram sabhas of the affected villages. He referred the remaining demands to the State Government for action.

The agreement reached with the villagers of Phalenda provides a framework for village communities to protect their prior use rights over natural resources (See Box). It is an important example for resolving disputes due to hydropower projects. But it was only partially fulfilled and remained a one-time agreement.

Uttarakhand Nadi Bachao Abhiyan (UNBA): Almora town is completely dependent on River Kosi for its water supply. But R. Kosi has been steadily drying for many years. In the

Matu Jan Sangathan

Vimalbhai, a Gandhian activist, cut his activist-teeth during the anti-Tehri dam agitation. He established Matu Jan Sangathan (MJS) to ensure transparency and demand that the regulatory processes are duly followed.

MJS has organized project-affected people to fight for their rights and entitlements, by educating them about the public hearing procedures and the fraudulent processes often followed. It has used forums like public hearings and village meetings, pamphlets and books to educate villagers about EIA and SIA reports and the FRA provisions. It has successfully challenged illegal actions of project developers at public hearings, before the EAC and the courts. Vimalbhai's case against environmental approvals for the Pala-Maneri and Loharinag-Pala HEPs led to the formation of the National Green Tribunal (NGT).

Faced with an aware and angry populace, public hearings have often been cancelled or illegally managed by district administrations.

- January, 2007 public protest at a public hearing for the Kotli-Bhel IB project on the Alakananda led to cancellation of its environmental clearance.
- Since 2009, public opposition against dams on the Pindar at public hearings twice led to their cancellation. Till today these dams have not received sanction.
- In June, 2018 the Jakhol-Sankri HEP public hearing was cancelled. In March, 2019 a harried district administration used police force to hold a closed door 'public hearing'.

MJS gave evidence to a Supreme Court-ordered Expert Body investigating the 2013 Uttarakhand floods disaster, regarding damages caused by dams at various locations. The EB's scientific data and conclusion that the Srinagar HEP was responsible for heavy property destruction in Srinagar town led to the NGT ordering that Rs. 10 cr compensation be paid to various victims of the disaster. Similarly, based on MJS's complaint, THDC was fined Rs. 50 lakhs for directly dumping muck into river Alakananda at the Vishnuprayag-Pipalkoti HEP.

MJS has taught people to use environmental security mechanisms, however weak, to reduce destruction in development's name.

summer of 2003 when there was very little water in the river, the district administration prohibited its diversion for irrigation, upstream of Almora. It was a time of peak irrigation need to prepare nurseries for the main paddy crop.

In response, activists of Kasturba Mahila Utthan Mandal (KMUM - also known as Laxmi Ashram), a Gandhian organization of women established by Sarla Bahen in Kausani -- educated village women in the upper Kosi catchment about specific steps to conserve the river water, from protecting forests to limiting water use. They prevented hotel-owners from diverting sustenance water resources of villages for commercial use. Laxmi Ashram also initiated dialogues between the villagers and government officials. In May, 2007 around 300 villagers undertook an awareness-raising *padyatra* along the Kosi, with other activists, mahila mandals, villagers, panchayat representatives, ex-MLAs and even forest officials.

On July 8, 2007 at an annual meeting of state level activists gathered at Laxmi Ashram to commemorate the 25th death anniversary of Sarla Bahen, Sureshbhai a Gandhian activist from ‘Himalayee Paryavaran Shiksha Sansthan’ (Uttarkashi), told the participants about the State and the Union Governments’ plans to build a series of dams on River Bhagirathi (Ganga) starting from near its source.

Many concerned persons met again at Laxmi Ashram in October, 2007 and formed the ‘Uttarakhand Nadi Bachao Abhiyan’ (Save the Rivers Campaign). They declared 2008 as the ‘Nadi Bachao’ Year. On January 1, 2008 they launched simultaneous *padyatras* in 14 different river valleys to highlight the problems arising from hydropower projects in the state. En route the *padyatris* held discussions with the local communities about their rights to the local natural resources, including rivers, and responsibilities. State-wide media coverage of the protests pushed the then Chief Minister, Maj-Gen (Retd) B.C. Khanduri to announce that the State Government favoured small dams over large projects.


Image 27 : Kosi valley Padyatris reach Ramnagar

At the end of their marches, they converged in Ramnagar town on the banks of the Kosi for a two-day convention. Alerted by the news coverage, representatives of the leading political parties in the state attended the convention, uninvited. In Ramnagar the *padyatris* explained that the price of being a major hydropower producing state was being borne by the mountain people and the fragile ecology. Wherever these dams had come up, complaints of loss of springs, access to forests, livelihoods and income and displacement followed. This violated the basic right to life of the local people.

In February, 2009 the UNBA organized a ‘River Padyatra Week’ which concluded in Dehradun with a public gathering and a rally at the Secretariat to present the campaign’s demands (See Box: Apna Jungle, Apna Pani). Media reports led to public attention and interactions with concerned citizens of Dehradun. Voices critical of the campaign also emerged in the local media and many debates ensued.

The campaign gained momentum and support from within and outside Uttarakhand. River valley communities better understood their rights over their local resources. Beyond Uttarakhand too the 'Nadi Bachao Abhiyan' was able to highlight the conflict over conserving rivers and hydropower.

But project promoters also learnt lessons from the anti-Tehri and anti-Narmada dams protests. After the initial campaign successes, the developers and the state government evolved strategies to drive a wedge in the local communities and succeeded in wearing out the campaign. They offered some benefits including jobs at the construction sites to a few local youths. As at Tehri and Phalenda, district administrations and the state governments viewed the protests as law-and-order problems. They simply wore out the protestors.

Challenging the Loharinag-Pala HEP: Opposition to the 600 MW Loharinag- Pala river diversion HEP, about 50 km downstream of Gangotri, began in 2005 (Lafaye de Micheaux F., 2019). Matu Jan Sangathan (MJS) and the Gram Pradhans of two affected villages challenged the environmental clearance (EC) given in February, 2005 by the MoEF. They claimed that the Uttarakhand State Pollution Control Board had not given sufficient notice to the affected population before the public hearing of the EIA Report. The National Environment Appellate Authority rejected their plea in February, 2007.

Later MJS highlighted several irregularities by the project developer, National Thermal Power Corporation (NTPC), like illegal disposal of muck and excavated material into the Bhagirathi, and other harmful impacts of the project (Matu Jan Sangathan, 2009). An important concern was that the project would deny downstream villagers, up to almost Uttarkashi town, access to the river to perform prayers and rituals. Arya Vihar, an *ashram* located at Maneri on the right bank of R. Bhagirathi initiated 'Ganga Aahvan', a campaign to save the river.

Dr. G. D. Agrawal's struggles to save River Ganga: In 2008 Dr. G.D. Agrawal (later known as Swami Sanand), a distinguished scientist and professor at IIT-Kanpur and a former Member-Secretary of India's Central Pollution Control Board, initiated an effective campaign to save R. Ganga from complete destruction by hydropower projects.

Between 2008 and 2018 he fasted six times with varying degrees of success (See Box: G.D. Agrawal: Faithful to His Science and Scientific in His Faith):

- June 2008, 18 days fasting – led to the formation of a High-Level Expert Group (HLEG) and designation of River Ganga as India's National River
- January 2009, 38 days fasting – resulted in the establishment of the National Ganga River Basin Authority (NGRBA) with the Prime Minister as its Chairman
- July 2010, 34 days of fasting led to the cancellation of the Bhairon Ghati (400 MW), Loharinag-Pala (600 MW) and Pala-Maneri (380 MW) projects, declaration of the

Gaumukh to Uttarkashi Bhagirathi river stretch watershed as an Eco- Sensitive Zone (ESZ) and the formation of a consortium of seven IITs to prepare a comprehensive Ganga River Basin Management Plan

- 2012, more than a hundred days of fasting
- 2013, over 110 days fasting
- June 2018, 112 days fasting before his unexpected death on October 11, 2018.

Swami Sanand's martyrdom was to galvanize many of his supporters.

Matri Sadan Carries on the Struggle: Once Swami Sanand announced his intention to give up drinking water after the start of Navratras in October, 2018, the *sanyasis* of Matri Sadan *ashram* (See box on Matri Sadan), where he was fasting, promised to keep the satyagraha alive by undertaking fasts-unto-death, one after the other, until his demands were fulfilled

The first to take up the cause after Swami Sanand's martyrdom was Brahmachari Atmabodhanand, a 26-year-old former IT engineer from Kerala. Br. Atmabodhanand began his fast on October 24, 2019 just days after Sanand breathed his last. He believed that a South Indian fasting was desirable given the Ganga's pan-Indian character. "From the day I started the *anshan* (hunger fast), I was fully prepared to sacrifice my life. I had no illusions about being heard," he told a visitor.

On May 4, 2019 on the 194th day of his marathon hunger strike, Br. Atmabodhanand suspended his fast upon receipt of a written committment from Mr. Rajiv Ranjan Mishra, the Director General of the National Mission for Clean Ganga (NMCG), promising to act against illegal sand mining in the Ganga and to look into the demand for scrapping all proposed and under-construction hydro-electric projects in the Bhagirathi, Mandakini and Alaknanda valleys.

A young Sadhvi Padmavati is another courageous Ganga-warrior at Matri Sadan. She went on a fast-unto-death from December 15, 2019 against the pollution in River Ganga. She was forcibly removed from the Matri Sadan campus on January 30, 2020 and confined at Doon Hospital in Dehra Doon. Ill-treatment during her incarceration has physically impaired her. She is unable to walk without support and her voice is severely enfeebled.

Himdhara: is a young campaigning organization, based in Kandbari village, Kangra district (H.P.). During the time of the UPA-II government in New Delhi, Himdhara worked with other organizations to successfully demand a review of the proposed Renuka dam on the Giri river in the upper Yamuna catchment. Himdhara was presented the Bhagirath Prayas Samman award at the India Rivers Week in 2016.

Citizens' Efforts to Conserve Rivers and Wildlife in the Middle Ganga Basin and the Lower Ganga Basin (India only)

Several conservation campaigns have been initiated in the Middle Ganga Basin. They pertain to protection of important aquatic species like gharials, Gangetic dolphins, turtles and otters; campaigns against encroachment of the floodplains; preservation of forests and wildlife habitats and against illegal riverbed sand mining.

A large number of industrial units in the vicinity of the Hastinapur WLS are affecting its flora and fauna with air, water and noise pollution, in open defiance of laws and court orders. Local activists like advocate **Ravindra Shukla** and organizations like Paryawaran Sachetak Samiti with the support of national organizations like People For Animals and WWF have organized campaigns to protect the Sanctuary.

The massive pollution in River Yamuna and its floodplain in Delhi has received the attention of well-known organizations like WWF-India, Centre for Science and Environment, Development Alternatives, Gandhi Peace Foundation, and a host of individuals like the late Naval Commander Sureshwar Sinha (more in Legal Battles).

Yamuna Jiye Abhiyaan (Living Yamuna Campaign): "Yamuna Jiye Abhiyan is an important voice for India's rivers," says Manoj Mishra, its founding spirit. It was organized in February, 2007 as a civil society campaign by a number of Delhi-based NGOs to counter impending threats to R. Yamuna's floodplains in Delhi. It is best known for its opposition to the encroachments on the Yamuna floodplain in Delhi for the Commonwealth Games Village and other infrastructural infractions. It conducted an advocacy campaign, direct action activities and filed legal cases in the NGT where the case entitled 'Maili se Nirmal Yamuna' resulted in several positive directions for the river's conservation but have seen snail paced progress owing to feet dragging by intransigent government authorities.

Between 2009 and 2013 YJA, with its host organization -- PEACE Institute, devised a People's River Health Index (PRHI) and implemented a riverside communities' mobilization project to establish 'Nadi Mitra Mandalis' (Friends of the River groups) at 10 locations along the river. They are now functional NGOs working for the restoration of their stretch of R. Yamuna.

Since 2014, YJA (PEACE Institute) and other NGOs like INTACH, SANDRP, Toxics Link, WWF-India and Dehra Doon-based People's Science Institute (PSI) have formed a consortium that organizes an India Rivers Week (IRW), a forum to bring together river conservationists. Later, Veditum based in Kolkata, SOPPECOM in Pune and ATREE and IIHS both in Bengaluru, joined the effort which was renamed India Rivers Forum. It recognizes and celebrates the good work of individuals and organizations for rivers in the form of the Bhagirath Prayaas Samman (BPS) award. It has also instituted the annual Anupam Mishra Memorial Medal for a deserving media person.

"The simultaneous worship and pollution of R. Ganga defies logic," said Rakesh Jaiswal, founder of the Kanpur-based **Eco Friends Organization** which has been working for about 25 years on critical issues of environmental degradation, though its prime concern is to protect R. Ganga from various sources of pollution. Eco Friends aims to generate mass awareness and deepen public debate on pollution-related issues, mobilize the local communities for sustained campaigns, initiate public interest litigation and undertake advocacy with media, and opinion makers and other stakeholders.

Given the miserable condition of R. Ganga, the **Ganga Mahasabha** was restructured and revived in Varanasi in 2005. In 2012 a committee of experts under the banner of Ganga Mahasabha headed by Justice (Retd.) Girdhar Malaviya, a grandson of Pandit Madan Mohan Malaviya, and including eminent experts like Dr. G.D. Agrawal, Shri Paritosh Tyagi, a former Chairman of the Central Pollution Control Board and Shri M.C. Mehta the renowned Supreme Court lawyer, drafted the National River Ganga Ji (Conservation & Management) Act, 2012 for enactment by the Parliament of India. It called for a paradigm shift in the way R. Ganga is governed. It specified 'prohibited activities'. Violation of the river's sanctity would invite punitive action as in the case of other national symbols. To avoid the pitfalls of past attempts to rejuvenate the river, it proposed establishing an empowered National River Ganga Authority of persons with proven commitment to the well-being of R. Ganga to manage the health of the main stem, rather than the entire basin.

The Sankat Mochan Foundation (SMF) was established in 1982 by Prof. Veer Bhadra Mishra, former Head of the Civil Engineering Department at IIT(BHU) and the *Mahant* of the famous Sankat Mochan temple in the city to restore the Ganga's environmental health. SMF has advocated the implementation of the Advanced Integrated Wastewater Pond Systems (AIWPS). A typical AIWPS facility consists of a minimum of four ponds in series that store sewage for 45 days, using bacteria and algae to eliminate waste and purify the water. Performance data provided by SMF indicates that AIWPS is cost and energy-efficient. It has proposed this system for treating the sewage water that is being let in to the Ganga River in Varanasi. Though the proposal is supported by the Varanasi Nagar Nigam, it has still to see the light of day.

In 1992, the United Nations Environment Programme (UNEP) awarded Prof. Mishra its "Global 500 Roll of Honour". He served on various government committees including the National Ganga River Basin Authority (NGRBA). Prof. Mishra passed away in March, 2013. The Foundation continues with its regular monitoring of Ganga water quality and campaigns for effective government policies and programs to ensure the purity of Gangajal.

In 2010, students at the Mirzapur campus of Banaras Hindu University started the **Vindhya Bachao Abhiyan (VBA)** to prevent the destruction of forests, natural resources and wildlife habitats in the dry deciduous landscape of the Vindhya mountain ranges in Mirzapur district.

In 2012, VBA registered a trust named Vindhyan Ecology & Natural History Foundation (VENHF) and added the Eco One initiative to focus on environmental issues in and around the BHU campus. With Eco One, VBA enrolled hundreds of students, faculty members, security staff and shopkeepers as volunteers for a mass campaign to clean waterfalls on River Khajuri adjacent to the Mirzapur campus. Its advocacy relied on scientific research. It created a stewardship of local people towards the river and made Eco One the river's guardian.

More recently, VBA opposed the construction of barrages and dredging in R. Ganga to facilitate the National Waterway-1. Along with other activists and experts, it highlighted the harmful effects of NW-1 and against the denotification of the Kashi Turtle Sanctuary.

Dakshinbanga Matsyajibi Forum (DMF): "Inland fisheries in India accounts for about two-third of the country's total fish production and total fish workers, about half of whom are women…….. a population of almost 30 million is dependent on the well-being of our rivers," says Pradip Chatterjee, President of DMF, a trade union representing fishworker communities in West Bengal since the early 1990s. It has more than 10,000 members spread over East Midnapore, South 24 Parganas, North 24 Parganas, Howrah and Hooghly districts.

For almost three decades now DMF has campaigned for saving rivers and aquatic biodiversity in the Ganga basin, particularly the Lower Ganga basin. It has campaigned against the use of mosquito nets for fishing. The latter destroy fish seeds, juveniles and other small aquatic life, devastating the food cycle and biodiversity. It is now mobilizing people to revive Buriganga, an old course of the Ganga. A flood in 2000 silted the channel and stopped the flow of Ganga water in it. Fish are no more found in it. Its women's wing campaigns for a just compensation for Tiger Widows, women whose husbands have been killed by tigers while fishing in the Sundarbans. DMF has helped mobilize the National Platform for Small Scale Fish Workers (Inland), representing small fishers from seven states. It has demanded a National Policy on Inland Fisheries.

8.5.2 Legal Battles

Many organizations and individuals have taken the public interest litigation (PIL) route to seek judicial support for conserving rivers, e.g., the earlier-mentioned court battles of Matu Jan Sangathan. Perhaps the most celebrated case is the long-running case, since the 1980s in the Supreme Court, by the lawyer M.C. Mehta seeking cleaning and conservation of R. Ganga.

Cleaning R. Ganga: Kanpur city on the main stem of R. Ganga has a population of over three million people. In 1985, M.C. Mehta filed a case in the Supreme Court to prevent the municipal authorities and the leather tanneries from releasing the municipal sewage and untreated effluents into the river (Law Times Journal, undated).

The Court held the municipal authorities responsible for the release of raw municipal sewage into the river and thus negligent of its mandated duties. It directed the Kanpur Nagar Mahapalika to take appropriate actions under the Uttar Pradesh Nagar Mahapalika Adhiniyam (1959) for the prevention of river pollution. Dairies in the city were directed to move out of the city or dispose their wastes outside the city area. New industries would be required to establish adequate effluent treatment facilities before being issued licenses. These orders were made applicable to all urban bodies having jurisdiction over areas through which the Ganga flowed.

The Court noted that besides the tanneries, effluents from paper and textile mills were adding to the toxic pollution load and that the State Pollution Control Board had not taken any effective steps to prevent the discharge of (untreated) effluents into the Ganga in violation of the Environment Protection Act. It ordered the tanneries to establish at least primary treatment plants, irrespective of the financial costs or face shut down.

Under Article 52A of the Indian Constitution, the Court directed educational institutions throughout India to introduce weekly lessons on improving the natural environment up to Class 10. It further directed the Central Government to get appropriate text books written and distributed free of cost to the educational institutions.

Uttarakhand's Hydropower Projects: In the 1980s, the then Uttar Pradesh State Electricity Board (UPSEB) had planned a 200 MW HEP on Alaknanda river at Srinagar. The MoEF granted the required clearances in the same decade. Later UPSEB enhanced the capacity to 330 MW and received clearances for the same. After liberalization in 1992, UPSEB transferred the project to a private company, M/s Duncan Industries Limited. ECs were also transferred to the latter by MoEF.

When Duncan Industries transferred the project to the Alaknanda Hydro Power Company Limited (AHPCL), Shri Anuj Joshi of Srinagar, Dr. Bharat Jhunjhunwala and others challenged the clearances granted by the MoEF to AHPCL in the Nainital High Court. They also noted that the increased installed capacity of the Srinagar HEP and the height of the dam would submerge the revered Dhari Devi temple. The subsequent order of the Nainital High Court directing the MoEF to hold a public hearing was challenged by AHPCL in the Supreme Court. The respondents, Anuj Joshi and others, filed counter pleas seeking stoppage of the project till the procedures in the 2006 EIA Notification were complied with, including the conduct of a public hearing. The SC in its order of August 13, 2013 set aside the direction of the Nainital High Court ordering the public hearing and directed MoEF and the state of Uttarakhand to stay all further environmental or forest clearances to HEPs in Uttarakhand till further orders.

In the same judgement the SC also took suo moto note of the June 2013 floods disaster in Uttarakhand and directed MoEF to constitute an expert body (EB) consisting of official and other experts to determine (i) whether existing and under construction HEPs had contributed to environmental degradation in Uttarakhand and (ii) whether they had contributed to the June 2013 floods tragedy. It also ordered MoEF to examine the recommendation of the Wildlife Institute of India (WII) that 24 projects in the Alaknanda and Bhagirathi river basin would cause significant impact on the basins' biodiversity.

Based on reviews of available scientific studies, official documents, field visits and representations and presentations by officials, project developers and affected citizens, the EB concluded that existing and under-construction HEPs had (i) caused environmental damage in Uttarkhand; (ii) they had aggravated the impact of the 2013 floods disaster, and (iii) the 24 proposed projects would significantly impact the basins' biodiversity. It also recommended that 23 out of the 24 projects be dropped while one could be built after implementing the modifications recommended.

Among the 23 HEPs recommended for cancellation were six that had earlier received the necessary MoEF clearances. Their promoters appealed to the Supreme Court against the EB's recommendation. This led to the appointment of another committee, headed by Dr. Vinod Tare of IIT-Kanpur, to investigate whether due processes had been followed in clearing the six projects. The Tare Committee concluded that due processes had been followed but recommended that the six projects be cancelled as they would significantly harm the region's pristine environment

This adverse recommendation was unacceptable to the Union and State Governments. MoEF then appointed a third committee which had no known ecologists or activists to review the WII recommendation regarding the 24 HEPs in the Alaknanda-Bhagirathi basins. The EB-II concluded that all the environmental impacts could be minimized with appropriate mitigation measures. The SC is still to give a final ruling in this case.

In 2008, the Uttarakhand State Government (GoU) invited bids for allocation of 56 hydro power projects of up to 25 MW capacities. The subsequent allotments came under the scanner since many projects were allotted to companies with no prior experience in hydropower generation. An Almora-based organization, **AMAN**, filed a PIL in the Nainital High Court seeking a CBI inquiry into the allotment process. The State government cancelled all the 56 allotments on the eve of the court hearing.

Cleaning Delhi's Yamuna: Since R. Yamuna flows through the capital city of Delhi, the Supreme Court of India has been sensitive to its condition. In 1992, **Sureshwar Sinha**, a retired Naval Commander, petitioned the SC demanding that adequate water be released in the river to revive its ecology. In 1999, the Supreme Court ordered Haryana, Delhi and Uttar Pradesh to ensure minimum 10 cumecs fresh water flow in the river. It directed a

High Powered Committee to monitor the implementation of this decision and other short term and long term measures recommended by it for maintaining the ecology of the river. In 1994, the Supreme Court took suo moto cognizance of pollution in R. Yamuna and issued orders to the Chief Secretaries of Delhi, Haryana and Uttar Pradesh to ensure that no industrial effluent be discharged directly or indirectly into the river Yamuna with effect from November 1,1995. In May, 2000 a fine of Rs 10,000 was levied on the Government of Delhi for non-compliance of the Court's orders (Dutta R., 2009). But despite all these orders Yamuna remains polluted in Delhi which controibutes 75% of its pollution load.

After the completion of the 2010 Commonwealth Games, the YJA filed a number of petitions relating to the Yamuna with the NGT. In a landmark order in January 2015, the NGT directed the relevant state agencies to improve the state of R. Yamuna and its floodplains in Delhi. It appointed a Monitoring Committee to supervise the implementation of plans (See also Chapter 11, Yamuna Riverfront Development).

In 2016, YJA successfully challenged the organization of a cultural festival by the Art of Living Foundation on the Yamuna's active floodplain, contending that it violated an earlier NGT order prohibiting any such activity. NGT held AOL "responsible for causing damage and environmental degradation of the flood plain of river Yamuna" and, "responsible for restoration and restitution of the flood plain" in the disturbed area to its condition prior to the event (India Environment Portal, 2017). The Foundation was also ordered to deposit a sum of Rupees 5 crores for the purpose.

Ken-Betwa Linking Project: This important controversial project is discussed in Chapter 11.

Cleaning R. Ganga: Appalled by the continuing pollution of R. Ganga at Kanpur, Eco Friends has filed public interest litigation cases in the Allahabad High Court since 1997. It has secured several important orders from the Court for curbing pollution and the encroachment of the floodplains.

Saving Vindhyan Ecology: In 2013, Vindhya Bachao Abhiyan, through its Trust VENHF, disputed the EAC clearance given to Welspun Energy's 1320 MW coal fired thermal power project near the BHU campus. VENHF's research showed that the project would ruin the region's ecology. The project, however, got Environmental Clearance from the EAC in August, 2014. VENHF challenged the Environmental Clearance in the NGT and in December, 2016 the NGT quashed the clearance, terming the entire process tainted and ordered Welspun Energy to restore the area to its original condition.

In 2014, VBA supported tribal communities in neighbouring Sonebhadra district to oppose the Kanhar Irrigation Project which would destroy almost 1000 ha of dense forests and displace 10,000 largely tribal families – without even a valid Environment and Forest

Clearance. But the NGT did not stop the project, citing fait accompli, and ordered a post facto Environmental Management Plan for ensuring remedial measures and proper R&R. A small number of lawyers, whose services are regularly sought by campaigners seeking legal redress, usually provided gratis, has helped set legal precedents for conservation in the Ganga Basin. In the Supreme Court of India, Ritwick Dutta, Sanjay Parikh, Colin Gonsalves, Prashant Bhushan and M.C. Mehta have made a mark in Public Interest Litigation (PIL) cases.

8.5.3 Conservation in Practice

Citizen's efforts to conserve forests and their wildlife in the Ganga basin have had a long history as described earlier. Direct action to cleanse rivers or revive their flows is of recent vintage.

One of the most well-known river conservation efforts in India is the revival of the 45 km long Arvari river in Alwar district, Rajasthan. The latter is a small stream in the catchment of the Gambhir river which joins the Yamuna. In 1986, **Tarun Bharat Sangh**, led by Rajendra Singh, began mobilizing villagers to build *johads* – traditional water harvesting bodies -- in the Arvari catchment. Several years after it went dry and after 375 *johads* were built, the Arvari began to flow again in 1990. By 1995, it had become a perennial stream. In 1998, Rajendra Singh and his colleagues formed the Arvari Sansad (Parliament) to manage the river. Rajendra Singh was awarded the Magsaysay Award in 2001. Since then, he has become a popular crusader for the well-being of rivers in India.

A large fraction of the water that flows through the rivers in the Ganga Basin comes from base flows or ground water recharge. This can be enhanced through watershed or spring shed treatment works. In Uttarakhand, the pioneering efforts of **Doodhatoli Lok Vikas Sansthan** in Pauri Garhwal district have led to the revival of a dry mountain stream (See Box: The Magical Talaais of Doodhatoli). The flow is adequate to provide water for irrigation.

In the present decade major non-government agencies like Arghyam, Tata Trusts and WWF-India have successfully promoted spring shed development (SSD) in the Himalayan region. Arghyam has supported Springs Initiative (SI), an association of NGOs, communities and government agencies around the country, to innovate best practices and develop participatory models, undertake applied research and advocacy for springs rejuvenation and protection. People's Science Institute (PSI), CHIRAG, Himalaya Seva Sangh (HSS) and Himmotthan, with the hydrogeological guidance by ACWADAM of Pune, are Uttarakhand-based partners of SI and Megh Pyne Abhiyan in Bihar.

Making a Difference by Being the Difference (MAD) is a group of youngsters working primarily for the protection of the environment in Dehradun valley, since 2011. Over the years MAD has emerged as an active pressure group by organising numerous clean-up,

YAMUNA BIODIVERSITY PARK

Yamuna Biodiversity Park is a river front area developed by Delhi Development Authority (DDA) with the technical assistance of Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi. It is meant to be a habitat for migratory and resident birds, to enhance groundwater recharge, augment freshwater availability and to conserve wild genetic crop resources.

Relentless and unplanned urbanization had reduced Delhi's onetime 400-odd wetlands to a mere handful. In 2005 the Delhi Development Authority (DDA) began restoring sodic soils in Delhi's inactive Yamuna floodplain by establishing wetlands, a grassland and a forest on them – Yamuna Biodiversity Park, Phase I. By 2014, it had an estimated 900 species of native plants, snakes, mammals, butterflies and migratory birds from Central Asia, Europe and Siberia. Now, Delhi University scientists are engaged in developing six other biodiversity parks in the city environs.

A highlight of the project's successful restoration was the capture on camera of a young, hungry leopard that had strayed into the Park in late 2016. "Though there have been claims of people seeing leopards in Delhi, this is for the first time that we have pug marks, photographs and videos of the leopard's presence," Faiyaz Khudsar, the scientist in charge at the Yamuna Biodiversity Park, told journalists. The leopard was later caught by the Wildlife Department.

Today, the Yamuna Biodiversity harbour 2000 species of plants and animals living in some 20-25 biotic communities having 3 trophic levels and diverse food web including 60 species of butterflies, 50 species of dragon and damselflies, 200 species of birds and mammalian herbivores and carnivores. The Park has attracted a specialist herbivore – Barking deer and a top carnivore – the Leopard suggesting that ecosystem is functional. The mosaic of wetlands is home for hundreds of resident and migratory birds. The green cover together with large water reservoir buffers the ambient temperature and also influences the local weather patterns. The wetlands which are already functional harbour luxuriant aquatic vegetation, phyto- and zooplanktons and fishes. These floral and faunal features of the wetland offer food base for the resident and migratory ducks. Wetlands of YBP attract more than 5000 migratory ducks from Siberia, central Asia and Europe, each year in winters

awareness-raising and plantation drives among other activities. More recently MAD has begun a campaign to revive Dehradun's dying streams that feed Rivers Ganga and Yamuna.

Delhi Residents Revive Waterbodies: In recent years residents of Delhi have been working to revive their water bodies. The newly-restored water bodies have become idyllic recreation spots in the crowded city and help recharge the ground water aquifers.

Since 2013, residents of Dwarka locality in Delhi have revived three dry water bodies. In 2019, they revived the third and the deepest water body, Dhul Siras (ToI, undated). "Work on this particular water body began four years ago," reveals Diwan Singh, an activist and convener of **Natural Heritage First**, who has been actively involved in the revival process. DDA provided earth-moving equipment to alter slopes of rain water drains and channel rain water into the pond.

Professor Emeritus, C.R. Babu of Delhi University and a team from DU's Centre for Environmental Management of Degraded Ecosystems (CEMDE) have restored the long-neglected 10-acre Neela Hauz using raw sewage discharged by Kishangarh, a nearby village. Prof. Babu and the CEMDE team have constructed a wetland system (Down To Earth, Undated). It uses natural processes involving wetland vegetation, soil and microbes to improve water quality.

The constructed wetland system treats the sewage in two stages. In the first stage, raw sewage water is stored in an open pond for about 24 hours for oxidation. The oxidized water is then led through a channel with pebbles in it to filter out organic matter from the water. The sewage water is then treated in a wetland system, where a variety of aquatic plants cleanses the toxins from the water. Clean water is finally released into the lake.

8.5.4 Research and Documentation for Advocacy

Common people, whose lives are affected by threats to their local biodiversity or environmental resources, typically lead conservation campaigns. Their problems and activities are researched, understood and reported by scientists, activists, writers and journalists. Wide-spread concerns, thereafter, lead to conservationist policies, laws and programs. Research, information documentation, its analysis and dissemination are thus critical elements of conservation efforts. They often require field work to gather data firsthand, accessing and analyzing relevant project documents and then disseminating them effectively to a target audience.

Two persons can be undoubtedly credited for the upsurge of environmental activism in India after the 1970s, Anupam Mishra and Anil Agrawal. Anupam wrote in Hindi and Anil in English. Both first caught the attention of their readers first with articles on the Chipko Andolan in the Upper Ganga basin.

Few people are aware that Anupam Mishra was instrumental in bringing the Chipko Andolan to the attention of the nation through a special issue of Dinman, the Hindi magazine from The Times of India stable, in 1973 (Joshi S., 2017). Later he also brought to public knowledge the conservation work of younger activists like Sachhchidanand Bharti (See Box: The Magical Talaais of Doodhatoli) and Farhad Contractor (Sambhaav Trust). His books on traditions of rainwater harvesting are not only educational but also gems of Hindi literature.

In 1975, Anil Agrawal revealed the Chipko movement to the English-reading world through

The Magical Talaais of Doodhatoli

Doodhatoli (meaning 'milk vessel') is the name of the highest mountain range in Pauri Garhwal district of Uttarakhand. Its forests and alpine meadows are favoured pastures for cattle in the region.

Ufrainkhal (*Ufrain* means upper and *khal* means pond) is a small village in the Doodhatoli range. During his student days, Sacchidanand Bharti a native of Ufrainkhal, was an active participant in the Chipko movement to save forests in Chamoli district. When he returned to Ufrainkhal in 1979 he was struck by the destruction of its forests and its dry *khals.* He plunged into a local struggle to save a large tract of Doodhatoli's virgin forest from being auctioned to loggers. In 1980, he established the Doodhatoli Lok Vikas Sansthan (DLVS). Organizing annual afforestation camps became its first major programme.

The drought of 1987-88 was a turning point. Many saplings withered away. Sacchidanand then led the local people to dig over 1500 small *talaais* (trenches) to harvest rainwater. The dug earth was piled upslope of the trench and used for planting saplings and grass. The survival rate increased and the slopes became green with the plant cover.

Ufrainkhal now has oak, rhododendron, alder, mountain cherry and cedar trees covering its once-barren slopes. Four small rock masonry dams have been built to harvest the surface runoff. Its old dry stream has revived. DLVS and the local people have dug over 7000 trenches and ponds in 10 villages.

an article in New Scientist, "Ghandi's Ghost Protects the Himalayan Trees" (Agrawal A., 1975). He was a prolific and crusading writer who went on to establish Centre for Science & Environment (see below) in New Delhi. His writings influenced activists, particularly the young, and decision-makers. An IIT-Kanpur trained engineer-turned-journalist, his articles were at once passionate and evidence-based. Many Indian environmentalists today credit him for their chosen vocation.

Centre for Science & Environment: CSE is one of India's leading environmental research and advocacy organizations. It is based in New Delhi. It was established by Anil Agarwal in 1980. It is most well- known for its State of India's Environment Reports. Its fortnightly magazine Down to Earth is the most widely read environmental periodical in India.

CSE believes that millions of Indians live within a biomass-based subsistence economy at the margins of survival. Rapid industrialization for India's economic growth, however, has led to a toxic environment and stressed land, water and forest resources so critical for the survival of the marginalized millions. Hence, it advocates new ways of building national wealth that does not degrade the environment or increase destitution and poverty.
Its efforts focus on (i) Communication through periodicals, publications, films, videos,

briefing papers and web and e-news bulletins; (ii) Research and Advocacy; (iii) Education and Training for professionals, public administrators, private sector executives, NGO professionals, students and others on environmental issues and (iv) Pollution Monitoring through its own laboratory. CSE has a significant web presence through its India Environment Portal which has over 400,000 cross-referenced research reports and government documents

WWF-India: "River conservation is complex and requires a multi-disciplinary, multi-stakeholder approach," says Dr. Suresh Babu of World-Wide Fund for Nature-India (WWF-India). Among its many activities WWF-India conducts research, advocacy and action programmes to restore the health of the Ganga and other rivers in its basin and to provide long term water security to nature and local communities and businesses.

Perhaps its most significant contribution till now in helping rejuvenate rivers in the Ganga basin has been to collaborate with well-known institutional partners like IITs Kanpur & Delhi, People's Science Institute (PSI), International Water Management Institute (IWMI), Central Inland Fisheries Research Institute (CIFRI) and HNB Garhwal University to (i) adapt the internationally accepted Building Blocks Methodology to assess EFlows for Ganga and Ramganga rivers; (ii) assess river flows requirements in the Ganga for ecological purposes during mass events like the Kumbh and other Melas and (iii) begin mapping wilderness stretches in the Ganga's headwaters for sustaining them. The UP Irrigation and Water Resources Department is formally reviewing WWF-India's Ramganga EFlows recommendations.

Since 2010, WWF-India has collaborated with State and Central Government agencies to initiate research and action programmes for conserving endangered and endemic species like the Gangetic Dolphin, Gharial and Mahseer among others in the Ganga and Ramganga rivers with financial support from Hong Kong and Shanghai Banking Corporation (HSBC). It is an active member of the District Ganga Committees at Moradabad, Bareilly and Shahjahanpur.

"Water is a shared resource with shared risks—pollution, unreliable supply and increased regulatory pressure, for people, businesses and nature," says Nitin Kaushal of WWF-India. "WWF-India has therefore evolved multi-stakeholder groups like the Ganga/Ramganga Mitras to tackle these shared challenges," he adds. With several thousand Ganga/Ramganga Mitras in Moradabad, Meerut, Bijnor, Bareilly and Shajahanpur districts, WWF-India has done regular River Health Assessments and helped more than 1500 households in Moradabad district to reduce their water consumption.

WWF-India has demonstrated sustainable and resilient agriculture practices to thousands of farmers in Uttar Pradesh. It works with tanneries in Kanpur and MSMEs in Moradabad to use clean technologies and reduce water use and pollution.

WWF-India is partnering with the Swarovski Waterschools programme to influence the behaviour and attitudes of communities in biodiversity rich freshwater ecosystems in the Ganga Basin. Its Ganga Interpretation Centre in Hastinapur provides knowledge about the aquatic biodiversity of the region. The Ramganga Choupal action centre has reached out to 1700 schools in Moradabad district.

Peoples' Science Institute (PSI): Based in Dehra Doon, PSI is one of India's leading non-profit science and development organizations. Over the last three decades, it has established a reputation in empirical science and natural resource management through a host of community-centred action projects and research reports. Its work has proved the effectiveness of evidence-based advocacy and action. PSI colleagues have often served on important official committees.

As a WWF-India partner, PSI's River Conservation Group has pioneered an ethnographic approach to determine river flows required for spiritual and cultural purposes in the Ganga and Ramganga rivers, by incorporating the needs of local communities for more inclusive river management (Lokgariwar C., et al, 2013). It is also engaged in regenerating river flows by reviving springs and mountain streams. Along with other partners it has so far regenerated over 800 springs in the Himalayan states.

A dedicated team at PSI's Environmental Quality Monitoring Laboratory has conducted several studies on rivers in the Ganga Basin. With CPCB scientists, it has monitored the water quality of the Ganga, Bhagirathi and Alaknanda rivers in Uttarakhand, using benthic invertebrates. It has conducted water quality studies in the Hindon, Kali, Ramganga and Kosi rivers in Uttar Pradesh. Its study on the Bhagirathi water quality, led by Dr G.D. Agrawal, revealed a progressive decline in the river's self-purification and self-cleansing ability after each successive hydroelectric dam. It has studied the impact of Kumbh Melas on R. Ganga.

INTACH is an 10,000 volunteer members strong organization established in 1984 to conserve the heritage of India. Its Natural Heritage Division has focussed on water issues since 1996. It has several initiatives to its credit like lake revival, river conservation planning, documentation of traditional water bodies and high-altitude lakes, demonstrating sustainable agriculture practices and water policy among many others.

INTACH has prepared a major proposal for the revival of Hindon River through a basin approach. The basin landscape was studied through satellite imagery and field work to prepare a basin water budget. The latter shows the points of intervention for taking the basin towards sustainability and the revival of the Hindon's lean season flows. The initiative has been well-received by the Uttar Pradesh Government and the National Mission for Clean Ganga (NMCG). A similar basin plan is being prepared for the Betwa river.

Demonstrating innovative bioremediation interventions for pollution abatement in Varanasi's Assi River is another feather in INTACH's cap. INTACH is working on the revival of the Najafgarh Jheel in the Sahibi Nadi catchment through advocacy and public interest litigation. It has also supported a public interest litigation for clearing the Ganga floodplains in Patna based on the Ganga River authorities notification. It has completed the documentation of the natural, cultural and architectural heritages along R. Ganga from Gaumukh to Ganga Sagar.

INTACH's revival of the Hauz Khas lake in Delhi is a pioneer example of the use of highly treated wastewaters for urban lake revival and groundwater recharge.

For NMCG, INTACH has carried out documentation of natural, built and cultural heritage along the main stem of the Ganga, over a distance of 2,525 km from Gaumukh to Gangasagar comprising 51 districts. The documentation has yielded information on unknown and unusual aspects related to the river. INTACH has also drafted a position paper for the riverine islands of the Ganga.

For several years INTACH has been associated with organizing India Rivers Week highlighting various rivers- related issues and contributing to the research and policy papers issued by India Rivers Week.

Research Institutions: Most research in India is confined to government research institutions and academia. Generally, they do not directly engage in environmental conservation advocacy. But their published research often informs environmental advocacy.

Among the leading government institutions whose research includes a large focus on the Ganga Basin are the IITs, particularly the ones at Kanpur, Delhi, Kharagpur and Roorkee. In 2010, the NGRBA mandated a consortium of seven IITs (Kanpur, Delhi, Madras, Bombay, Kharagpur, Guwahati and Roorkee) to prepare a comprehensive Ganga River Basin Management Plan 'for restoration of the wholesomeness of the Ganga ecosystem and improvement of its ecological health, with due regard to the issue of competing water uses in the river basin.' The effort was coordinated by Dr. Vinod Tare of IIT-Kanpur.

Though the GRBM Plan has specified seven thrust areas, namely Nirmal Dhara (clean river), Aviral Dhara (uninterrupted flowing river), Swach Kinara (Clean River Front), Capacity Building, Research & Monitoring, Biodiversity Conservation and Awareness Creation, programmatic funds have later been primarily sanctioned for construction of sewage treatment plants and other structures.

Other important governmental research and academic institutions whose work has directly impacted conservation in the Ganga Basin are Wildlife Institute of India (WII, Dehra Doon), Central Inland Fisheries Research Institute (CIFRI, Barrackpore, W. Bengal), National Institute of Hydrology (NIH, Roorkee), Indian Institute of Soil & Water Conservation (IISWC, Dehra Doon), Gobind Ballabh Pant Institute of Himalayan Environment & Development (GBPIHED, Kosi-Katarmal, Uttarakhand) and the International Water Management Institute (IWMI). In 2012, WII submitted an important assessment report "Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins, Uttarakhand" to MoEF (GoI). In 2016, IWMI scientists produced a book, "The Ganga River Basin", a comprehensive compilation of research on the basin and its inhabitants.

Other Researchers: India is fortunate that several senior researchers undertake research that educates public and official decision-making. The late Prof. Brij Gopal, a former professor of Environmental Sciences at Jawaharlal Nehru University in Delhi, played a leading role in advocating policy and regulatory changes for better management of Ganga Basin rivers and other water bodies based on his research work. He was a member of many state, national and international bodies and official committees. He headed or advised important research and advocacy organizations and academic institutions in India and abroad. Dr. Brij Gopal was a dedicated supporter of IRW and India Rivers Forum.

In recent years Dr. Brij Gopal was actively associated with N**ational Institute of Ecology (NIE)** in Jaipur and the **Centre for Inland Waters in South Asia (CIWSA)** established by **Pragya Education and Environment Trust** with its own research and training facilities, in Peera village near Khajuraho (Madhya Pradesh). At NIE he led several major research projects focused on rivers, lakes and other water bodies in the Ganga Basin, including a comprehensive one for the restoration of the Yamuna River Basin. At CIWSA he focussed on ecosystem services provided by R. Ken and studies to conserve them.

Prof. C.R. Babu is Professor Emeritus at Delhi University and Distinguished Professor at the School of Human Ecology, Ambedkar University, Delhi. Earlier he established the Centre for Environmental Management of Degraded Ecosystems (CEMDE, see earlier section) and the School of Environmental Studies at the University of Delhi. As Project-in-charge of the Biodiversity Parks Programme of Delhi Development Authority (DDA) at DU, he and his students worked successfully on ecological restoration of degraded ecosystems in and around Delhi. Prof. Babu has been honoured with three National Awards.

Based on his research studies, Dr. Vikram Soni, Professor Emeritus, Jawaharlal Nehru University and Jamia Milia Islamia University in New Delhi, has advocated the conservation of R. Yamuna's floodplains for ground water recharge and sustaining environmental flows. He has been a driving force in the formation of Natural Heritage First (referred to earlier) and has guided activists in restoring water bodies in Delhi.

Prof. A.K. Gosain of the Department of Civil Engineering at IIT-Delhi and his colleagues from Integrated Natural Resources Management Consultants Pvt. Ltd. (INRM), an early start-up from IIT-Delhi, have worked with the WWF-India led effort to determine E-flows in R. Ganga. In 2017, he was a member of the NGT-appointed expert committee that gave a highly critical report on the impact of the massive concert on the Yamuna floodplain in Delhi organized by Sri Sri Ravishankar's Art of Living Foundation.

There are several other academic researchers whose support is regularly sought for conservation in the Ganga Basin. They include Prof. Rajiv Sinha, a geomorphologist at IIT-Kanpur (See Chapters 2 and 4 in this report), dolphin experts such as Prof. R.K. Sinha of Patna University and Prof. Sunil K. Choudhary (both referred to earlier in this Chapter) of Tilka Manjhi Bhagalpur University, and Prof. Prakash Nautiyal (HNB Garhwal University) who focuses on Himalayan cold water fishes.

South Asian Network for Dams Rivers and People (SANDRP): Established in 1998 by Himanshu Thakkar, an IIT-Bombay graduate, SANDRP has emerged as an effective public interest research and information dissemination organization (See Box and the Ken-Betwa Link Project section in Chapter 11). Over the years it has actively supported various struggles against dams by monitoring the processes of EC, forest clearance, techno-economic

SANDRP: A Fierce Monitor

Before setting up SANDRP, Himanshu Thakkar – an IIT-Bombay graduate, was associated with the Narmada Bachao Andolan for six-and-a-half years. That experience has helped SANDRP to analyze the likely social, economic and political impacts of proposed water development projects and influence decision-making.

SANDRP has provided inputs to the World Commission on Dams (WCD) and also advocated implementing its recommendations. It was the first to demand that all HEPs release environmental flows. Later it convinced a responsive Environment Secretary in Himachal Pradesh, to implement an environmental flows policy for HEPs in H.P. It ensured the release of a minimum of 15% of the lean season flows.

For a public hearing of the Allain-Duhangan HEP in H.P., SANDRP secured the participation of three external civil society members in the presiding panel to ensure a fair process. Between 2008 and 2016 SANDRP successfully intervened with the EAC in several hydropower projects. After the EAC decided in 2016 to accept submissions from civil society only during public hearings, SANDRP began media critiques to push for correct decisions.

In 2016, the Government of Bihar appointed Himanshu Thakkar to a committee to investigate the role of silt accumulation behind the Farakka barrage in flooding Bihar. SANDRP is now working on the impact of projects on riverine fish. It has recently published a fisheries primer, created by Nachiket Kelkar of ATREE, for the Ganga.

clearance by the CWC and the activities and decisions of the Expert Appraisal Committee (EAC). SANDRP disseminates its reports to activist groups around the country and the world through a regular bulletin and a blog. The latter is widely read by water activists and scholars in many parts of the world.

PAHAR: Enlish language documentation of the Ganga basin is well-publicized. PAHAR is a unique non-profit organization in Nainital that has focused its efforts on documenting and publicizing material in the Hindi medium. Simultaneously it is dedicated to bringing together scientists, social activists, and common people to save the fragile environment of the Ganga headwaters' Himalayan region. Every ten years since 1974 its core team of Himalaya enthusiasts and friends led by Dr. Shekhar Pathak, also known as 'Uttarakhand's walking-talking encyclopedia', has walked across Uttarakhand state from Askot in the east to Arakot in the west. The annual publication PAHAR draws contribution from scientists, activists, environmentalists, litterateurs, journalists, artists, mountaineers and others committed to a scientific understanding of Himalayan society, culture, history and environment. It also publishes small booklets and posters in Hindi and English on the major problems of the Himalaya.

A large number of independent persons have devoted life-times to studying, documenting and reporting changes that have impacted the well-being of Ganga Basin river systems. The most voluminous work perhaps is that of Dr. D.K. Mishra, a graduate of IIT-Kharagpur, on floods in the rivers of Bihar, particularly Kosi. His studies and writings are enriched by first-hand field report and interviews with the affected people, activists, political leaders, engineers and administrators. Mishra's use of the vernacular idiom in Hindi and English has won him a wide readership. Dr. Mishra received India Rivers Week's prestigious Bhagirath Prayas Samman award in 2016.

Our knowledge of the histories of conservation efforts, especially in the Upper Ganga Basin, has been enriched by the research-based writings of Dr. Ramchandra Guha and Dr. Madhav Gadgil.

The Himal Prakriti team based in Munsiyari, Uttarakhand documents the rich biodiversity resources of the Gori Ganga valley and the larger north-western region of the Uttarakhand Himalaya. In 2014, naturalist and river-enthusiast Emmanuel Theophilus, a founder of Himal Prakriti and his son Zorawar, paddled in a kayak from the Mahakali's (Sharda) Himalayan headwaters and down the Ganga, almost 2000 km, to the Bay of Bengal.

It is tragic that English writings on Ganga receive wide circulation among Indian opinion and decision-makers but not those in Indian languages. **Arun Tiwari**, a journalist and author of stories and plays has become well-known for his writings on Ganga, other rivers and related themes. His association with water-related activists and their campaigns has helped him write from first-hand knowledge of ground realities. A signal contribution has been his serialization of conversations with Swami Sanand, later compiled into a book, “Swami Sanand ki Atmakatha”. Arun Tiwari has received several awards for his work, including the 2018 prestigious Anupam Mishra Memorial Medal presented by India Rivers Week.

A young addition to the growing tribe of river conservationists in the Ganga Basin is Siddharth Agarwal, an IIT-Kharagpur graduate. In 2016, he completed a 3000 km walk along River Ganga from Ganga Sagar to Gangotri. He established the Veditum India Foundation, a research and media organisation. It painstakingly gathers primary information in projects designed around walking. Two important projects are Moving Upstream and City Water Walks. It has also created a media for parallel online participation.

8.6 CONCLUSION

The rich biodiversity of India’s Ganga Basin is under grave threat today. The conservation ethos preached by India’s ancient civilization seems to have been pushed into the background by the onrush of rapid economic growth. Unsustainable modernization pursued in recent decades has not only endangered rare flora and fauna but also the local communities and their conservationist cultures.

In the midst of the dust left behind by the modernization juggernaut are emerging tenacious efforts to save the country’s natural heritage. This chapter has compiled numerous efforts where conservation-minded people have pushed and prodded officialdom to protect and sustain the Ganga basin’s rich biodiversity. Since Independence considerable official efforts have been initiated to conserve it. The chapter has highlighted the important role that forests in PAs play in sustaining the base flows of many small streams in the Ganga basin. But the PAs legal status also betrays an exclusionary or fortress approach (Pande N. and Sharma K.A., 2015). Considering nature as external or separate from humans has privileged officials and scientific knowledge over local people and their lived experiences. It has often led to local conflicts, undemocratic use of the state’s force and an erosion of human rights.

There is a need to learn from inclusive conservation practices that have been demonstrated elsewhere (Wiki (c), Undated). Conservation of a river’s aquatic biodiversity requires a comprehensive approach that considers the required discharge in the river, its geomorphology and water quality. Here too the experiences of the local people and their programmatic involvement are essential.

India’s modernizing officials view Himalayan hydropower as a key component of the nation’s energy basket. Led by the Union government, Himalayan state governments have sought to harness the region’s free-flowing rivers with ambitious programmes to build hydro-power projects. This is at a time when hydropower generation costs twice as much as solar power generation (Seetharaman G., 2019) and consumers pay higher price for hydropower against solar and wind energy sources. The myriad irreversible impacts of hydropower threaten the survival of the river ecosystems and also imperil the lives and livelihoods of people who live in these river valleys. The latter threats, more than the threat to the ecosystems, have generated a lot of anxiety and protests against the hydro projects. Some of the protests have succeeded in changing national policies in favour of protecting critical stretches of rivers.

But even the establishment of Eco-Sensitive Zones has failed to restrict the current rush of development projects. "The uppermost stretch of the Bhagirathi is an extremely sensitive region," says Chandi Prasad Bhatt, the progenitor of the Chipko Andolan in Uttarakhand. "If the various emergent problems are not tackled soon, the very existence of R. Ganga will be threatened," he adds, referring to the continuing recession of glaciers in the Bhagirathi Eco-Sensitive Zone.

Swami Sanand's decade-long struggle to save R. Ganga and his martyrdom has provided fresh energy to activists engaged in saving the river system. Several other examples in this chapter, of recent conservation efforts in the Ganga basin, have highlighted the need for selfless scientific and legal expertise and honest and determined officials to assist the local communities who are fighting to ensure the well-being of the ecosystems they are dependent on. These campaigns have raised larger questions about India's development pattern: Who ought to make decisions on development policies and how? Whose vision and whose voice should count?

Rapidly emerging climate changes are adding fresh urgency to temper modernization with limiting consumption. The ancient wisdom of reverence for nature needs to be imbibed and to prevail.

ENDNOTES

i. An authoritative Census of fisher population of India is long overdue. The Handbook of Fisheries Statistics (2020) gives an all-India total of over 23 million inland fishers. It is therefore safe to assume an estimated figure of 10-13 million in the Ganga basin.

ii. Wherever a particular PA is discussed in some detail. It has been written in a bold font in the para.

iii. GoU (2018): (Draft)Zonal Master Plan of Bhagirathi Eco-Sensitive Zone. Government of Uttarakhand, Dehradun, p.77.

iv. Mukundra Hills TR has received male and female tigers from other PAs. In late 2020 only one female tiger was left in the Park.

v. This section has benefitted from the data reported in various drafts of the Zonal Master Plan of BESZ prepared by officials of the Government of Uttarakhand (GoU) in 2018 and the EB-I Report (Ref 5a). Most statements in quotes in the chapter are personal communications to Ravi Chopra.

vi. The original Notification of December 2012 listed only 88 villages. Later the village of Harsil was added. The BESZ area has increased to 4182.25 sq km as a result.

vii. The BESZ experienced a devastating earthquake in October 1991 which killed over 650 persons.

viii. The 147 km^2 extent of the Gangotri glacier includes a collection of several small glaciers.

ix. In the last few years increasing evidence -- in the form of geomorphic disasters like debris flow, flash floods, avalanches, etc. -- has validated the predicted terrain response to rising temperatures over the western Himalayan region. "The 7th February 2021 Rishi Ganga flash flood, the 23rd April 2021 Girthi Ganga snow avalanche, 27th April 2021 avalanche in Siachen (Karakoram), the 4th May 2021 cloudbursts in Chamoli, Almora, Tehri, Rudraparyag (Uttarakhand) and in Chamba (Himachal Pradesh) indicate that possibly the triggering factor is regional" (See Sharma S., et al (2021). "The 23rd April '21 Snow Avalanche, Girthi Ganga post the 7th February '21 Rishi Ganga Flash Flood: Are these Events Linked to Climate Warming in the Western Himalaya?". J Geol. Soc. India. pp 975-979.).

x. By 1905, Pt. Madan Mohan Malviya had become apprehensive about the possibility of the British completely damming the flow of R. Ganga at the Bhimgauda barrage in Haridwar. He established the Ganga Mahasabha and mobilized massive public protests against damming River Ganga. Finally, in 1916 the British government made a formal agreement with the Mahasabha that:

(a)The unchecked flow of Ganga would never be stopped (even) in the future.
(b)No decision on Ganga would be taken without the consent of the Hindu community.

This agreement was signed by the British government, the then Indian princes and Ganga Mahasabha. This agreement is legally binding even today under Article 363 of the Indian Constitution. See: http://www.gangamahasabha.org/

xi. It is not possible to do justice to the vast citizens' conservation efforts in the Ganga Basin, therefore references to the work of some individuals and organizations are largely to bring out the flavour of these efforts.

xii. In 2013, a research report from NEERI (National Environmental Engineering Research Institute) confirmed the earlier work done by Dr. Agrawal and his researchers at IIT-Kanpur. It explained that the Himalayan sediments provided sites for bacteria-destroying phages (viruses) to adsorb and proliferate and that 90% of the sediments in the river were stopped behind the Tehri dam.

xiii. A research report released by the Institute of Microbial Technology (Chandigarh) in 2017 concluded that reservoirs and tunnels reduced sunlight penetration and dissolved oxygen in the river water and thereby the river's self-cleansing ability.

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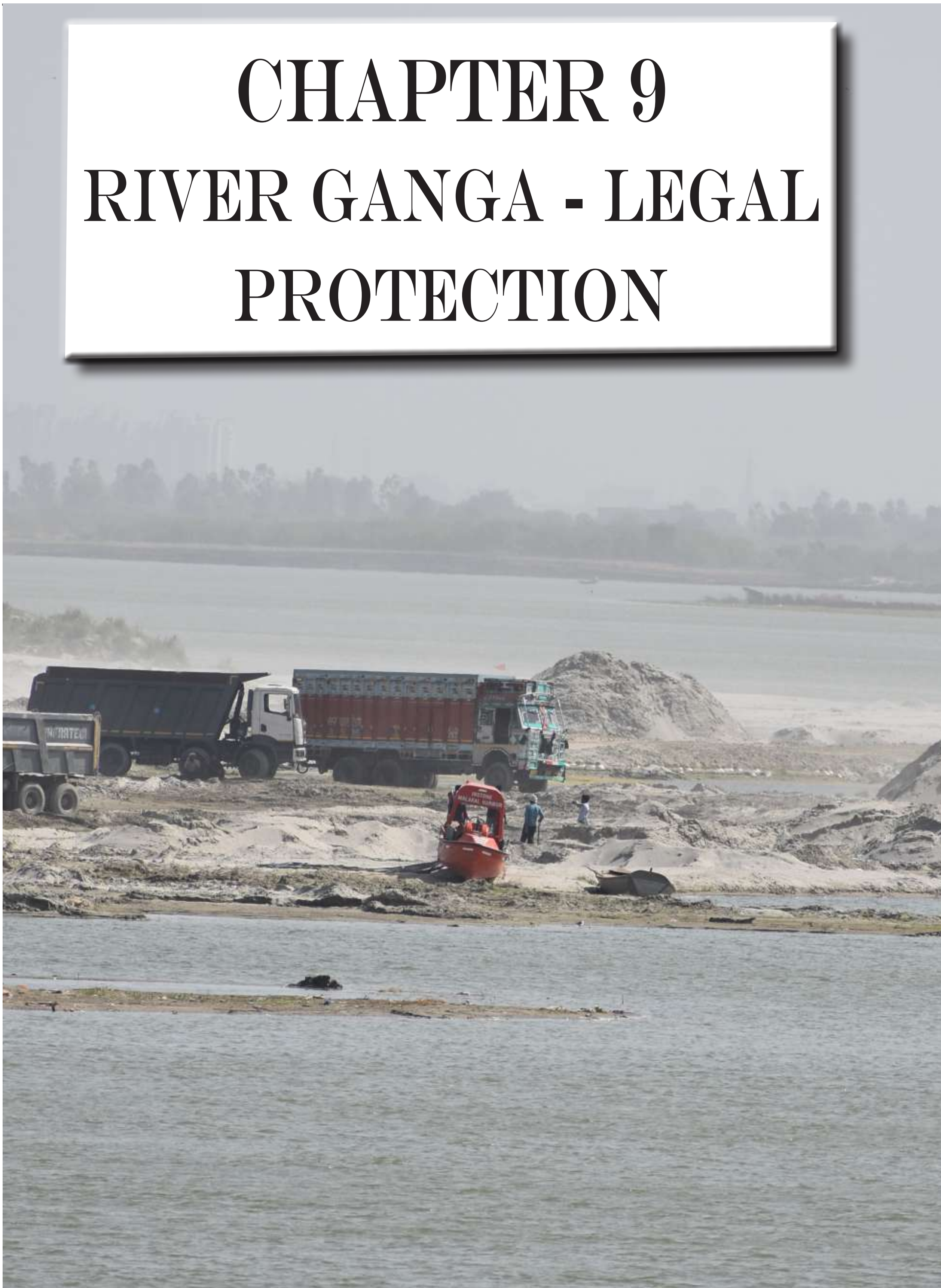
CHAPTER 9
RIVER GANGA - LEGAL PROTECTION



9.1 BACKGROUND

River Ganga, India's National River, is not only an integral part of the country's natural heritage but it is also deep-rooted in its cultural and spiritual ethos. It is India's civilizational identity. The Ganga, thus, deserves much better care and protection than provided hitherto by Indian society and the state.

The Ganga sustains the lives of some 500 million people in India. Unfortunately, it is among the most threatened ecosystems in the world. Its waters are diverted and extracted to a point where large stretches of the river are nearly dry for much of the year. The National River, crucial for India's vitality, is polluted with billions of litres of sewage and toxic chemicals every day (See Chapter 7). As a result, the basic human right to life, guaranteed by Article 21 of the Indian Constitution, inter alia the right to clean water, is violated every day.

The Indian Constitution has not been very kind or appreciative of the nation's rivers. They are seen as no more than providers of water and carriers of pollution loads. The term 'water' has routinely been used to denote 'rivers' in the few sections where rivers are referred to, as cited below (GoI 2020).

Entry 56 of List I (Union list) of the Seventh Schedule[i]

"Regulation and development of inter-state rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest"

Entry 17 of List II (States' list) of the Seventh Schedule

"Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to the provisions of Entry 56 of List I"

Article 262

In case of disputes relating to waters, Article 262 provides that:

1. Parliament may by law provide for the adjudication of any dispute or complaint with respect to the use, distribution or control of the waters of, or in, any inter-state river or river valley
2. Notwithstanding anything in this Constitution, Parliament may, by law provide that neither the Supreme Court nor any other court shall exercise jurisdiction in respect of any such dispute or complaint as is referred to in Clause 1)

That rivers are ecological entities and consequently could suffer from overuse or abuse was not envisaged by the founders of newly independent India. It was only in the mid-1970s when rivers, as entities within the natural environment, got Constitutional protection. The 42nd amendment to the Indian Constitution in 1976 first brought the 'natural environment' within the ambit of the Constitution through Articles 48-A and 51-A(g).

Article 48-A of the Directive Principles of State Policy

"The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country."

Article 51-A(g) Fundamental Duties of the Citizens

"To protect and improve the natural environment including forest, lakes, rivers and wildlife, and to have compassion for living creatures."

Environment (Protection) Act, 1986

India's Parliament enacted the Environment (Protection) Act, 1986 (EPA) as "An Act to provide for the protection and improvement of environment and for matters connected therewith."

Section 3 in Chapter II of EPA defines the power of the Union Government to take measures to protect and improve the environment (CPCB 2021).

Section 3 (3) states that "The Central Government may, if it considers it necessary or expedient to do so for the purposes of this Act, by order, published in the Official gazette, constitute an authority or authorities by such name or names ...."

A Landmark Judgement

In a landmark judgement (M.C. Mehta vs Kamal Nath & Ors, WP 182/1996), the Supreme Court of India emphasized that protection of India's natural resources was a legal duty of the Indian State. The judgement authored by Justice Kuldip Singh stated:

"Our legal system - based on English Common Law - includes the public trust doctrine as part of its jurisprudence. The State is the trustee of all natural resources which are by nature meant for public use and enjoyment. Public at large is the beneficiary of the sea-shore, running waters, airs, forests and ecologically fragile lands. The State as a trustee is under a legal duty to protect the natural resources."

In a later case reviewing the above judgement (ELAW, 2011), Justice D. Raju reiterated, "The public trust doctrine, as discussed by us in this judgment is a part of the law of the land."

Public Trust Doctrine

The Public Trust Doctrine is perhaps the strongest legal principle for the protection of India's rivers. It makes the Indian State legally duty-bound to protect India's natural resources (SCI, 1996). It is a part of the law of the land (See box: A Landmark Judgement).

Despite the legal provisions that could have been invoked to revive and sustain India's National River Ganga, in all her eons-old majesty, it is unfortunately emasculated – fragmented and dried in stretches by a large number of dams and barrages for excessive diversion of water, and the destruction of its catchment forests, floodplains, wetlands and marshlands.The ever increasing efforts of the decision makers continue to fall short of the expanding gamut of problems ailing Ma Ganga. The economic development model being pursued is exploitative of the river and its basin well beyond its sustaining capacity. Their practical actions since 1986 have mainly focused on constructing Sewage Treatment Plants (STPs) and *ghats* at various locations where the Ganga's devotees gather periodically (See also Chapter 12). The landmark "River Ganga (Rejuvenation, Protection & Management) Authority Order, 2016, is followed only in the breach.

9.2 THE RIVER GANGA (REJUVENATION, PROTECTION AND MANAGEMENT) AUTHORITIES ORDER, 2016

In October, 2016 the Union Government approved a Subordinate Legislation – "River Ganga (Rejuvenation, Protection & Management) Authority Order, 2016, under the Environment (Protection) Act, 1986 laying down a new institutional structure for policy and 'fast track' implementation of projects to rejuvenate River Ganga. It converted the National Mission for Clean Ganga (NMCG), a registered society till then, into an Authority to discharge its functions in an independent and accountable manner (PM India, 2016). It also set up authorities at the State and District levels to ensure effective actions for reviving the river. The basic features of the Order of 2016 are outlined in this section.

The introduction to the Order states:

"Whereas it is necessary to constitute authorities at Central, State and District levels to take measures for prevention, control and abatement of environmental pollution in River Ganga and to ensure continuous adequate flow of water so as to rejuvenate the River Ganga to its natural and pristine condition and for matters connected therewith or incidental thereto" …………. the Central Government hereby..................

I. constitutes the authorities by the names mentioned in this Order for the purpose of exercising and performing such of the powers and functions (including the power to issue directions under section 5 of the Act and for taking measures with respect to the matters as mentioned in this Order;

II. directs, subject to the supervision and control of the Central Government and the provisions of this Order, such authority or authorities as specified in this Order that shall exercise the powers or perform the functions or take the measures so mentioned in this Order as if such authorities had been empowered by the Act to exercise those powers, perform those functions, or take such measures;

III. directs that all its powers and functions (except the power to constitute any authority under sub-section (3) of section 3 and to make rules under the sections 6 and 25 of the Act) under any provision of the Act shall, in relation to River Ganga and matters connected therewith, be exercisable and discharged also by the authorities constituted by this Order and by the officers specified in this Order, subject to such conditions and limitations and to the extent as specified in this Order.

9.2.1 Salient Features of the River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016

Applicability:

This Order shall apply to the States comprising River Ganga Basin, namely, Himanchal Pradesh, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, Haryana, Rajasthan, West Bengal and the National Capital Territory of Delhi and such other States, having major tributaries of the River Ganga as the National Council for Rejuvenation, Protection and Management of River Ganga may decide for the purpose of effective abatement of pollution and rejuvenation, protection and management of the River Ganga

Definitions:

The Notification provides, perhaps for the first time, legal definitions for river related terms like ‘Basin’; ‘Buffer area’; ‘Catchment’; ‘Flood plain’; ‘River bed’ and ‘Stream’.

Principles:

The Notification, again for the first time, sets legally mandated ‘Principles’ to be followed for rejuvenation, protection and management of River Ganga.

1. The River Ganga shall be managed as a single system;
2. The restoration and maintenance of the chemical, physical, and biological quality of the waters of River Ganga shall be achieved in a time bound manner;
3. The River Ganga shall be managed in an ecologically sustainable manner;
4. The continuity of flow in the River Ganga shall be maintained without altering the natural seasonal variations;
5. The longitudinal, lateral and vertical dimensions (connectivities) of River Ganga shall be incorporated into river management processes and practices;
6. The integral relationship between the surface flow and sub-surface water (ground water) shall be restored and maintained;

7. The lost natural vegetation in catchment area shall be regenerated and maintained;
8. The aquatic and riparian biodiversity in River Ganga Basin shall be regenerated and conserved;
9. The bank of River Ganga and its flood plain shall be construction free Zone to reduce pollution sources, pressures and to maintain its natural ground water recharge functions;
10. The public participation in rejuvenation, protection and management, revision and enforcement of any regulation, standard, effluent limitation plan, or programme for rejuvenation, protection and management shall be encouraged and made an integral part of processes and practices of River Ganga rejuvenation, protection and management.

Ecological Flow to be maintained:

1. Every State Government, shall endeavour to ensure that uninterrupted flows of water are maintained at all times in River Ganga as required........
2. Every State Government shall also endeavour to maintain adequate flow of water in River Ganga in different seasons to enable River Ganga to sustain its ecological integrity and to achieve the goal, all concerned authorities shall take suitable actions in a time bound manner.

Prevention, control and abatement of environmental pollution in River Ganga and its tributaries:

1. No person shall discharge, directly or indirectly, any untreated or treated sewage or sewage sludge into the River Ganga or its tributaries or its banks;
2. No person shall discharge, directly or indirectly, any untreated or treated trade effluent and industrial waste, biomedical waste, or other hazardous substance into the River Ganga or its tributaries or on their banks;[ii]
3. No person shall construct any structure, whether permanent or temporary for residential or commercial or industrial or any other purposes in the River Ganga, Bank of River Ganga or its tributaries or active flood plain area of River Ganga or its tributaries; [ii]
4. No person shall do any act or carry on any project or process or activity which, notwithstanding whether such act has been mentioned in this Order or not, has the effect of causing pollution in the River Ganga.

Emergency Measures in Case of Pollution of River Ganga or its Tributaries:

If any poisonous, noxious or polluting matter is present or has entered into the River Ganga due to any accident or other unforeseen act or event, and it is necessary or expedient to take immediate action, the National Mission for Clean Ganga shall take immediate action for carrying out such operations or direct for carrying out such operations by the specified State Ganga Committee or specified District Ganga Committee or local authority or any other authority or Board or Corporation, as it may consider necessary

Power to issue directions:

The National Mission for Clean Ganga shall, in the exercise of its powers and performance or its functions under this Order, issue such directions in writing as it may consider necessary for abatement of pollution and rejuvenation, protection and management of the River Ganga to the concerned authority or local authority or other authorities or Board or Corporation or person and they shall be bound to comply with such directions.

Ganga safety audit:

Every District Ganga Committee shall cause the Ganga safety audit to be carried out by such Ganga Safety Auditors within such time frame and in accordance with such protocols as may be specified by the National Mission for Clean Ganga for the area of the River Ganga abutting such district.

Pollution in River Ganga and its tributaries to be monitored:

The pollution in River Ganga and its tributaries shall be monitored by the National Mission for Clean Ganga on its own or by directions through various State and Central Government agencies by use of satellite imagery and other remote sensing technologies as well as physical stations, online monitoring and independent agencies at a periodicity to be specified by it.

Constitution of National Council for Rejuvenation, Protection and Management of River Ganga:

With effect from the date of commencement of this Order, there shall be constituted an authority by the name to be called the National Council for Rejuvenation, Protection and Management of River Ganga, (hereinafter in this Order called as the National Ganga Council) for the purposes of the Act and to exercise powers and discharge functions as specified in this Order and the Act.

The National Ganga Council is headed by the Hon’ble Prime Minister of India.

Constitution of Empowered Task Force on River Ganga as Authority:

With effect from the date of commencement of this Order, there shall be constituted an authority by the name to be called the Empowered Task Force on River Ganga for the purposes of the Act and to exercise powers and discharge functions as specified in this Order and the Act.

The Empowered Task Force is headed by the Hon’ble Union Minister for Water Resources, River Development and Ganga Rejuvenation.

Constitution and Composition of Specified State Ganga Rejuvenation, Protection and Management Committees as Authorities:

With effect from the date of commencement of this Order, these shall be constituted, in each State as specified in paragraph 2, an authority to be called the State Ganga Rejuvenation, Protection and Management Committee, which shall consist of a Chairperson and other members as specified in the Schedule to exercise powers and discharge functions as specified in this Order and the Act.

Constitution of National Mission for Clean Ganga as an authority:

With effect from the date of commencement of this Order, the National Mission for Clean Ganga, a society registered under the Societies Registration Act, 1860 (21 of 1860), shall be an authority constituted under the Act, by the same name for the purposes of the Act and to exercise powers and discharge functions as specified under this Order and the Act and the rules made or directions issued thereunder.

Constitution of District Ganga Protection Committees:

The Central Government shall immediately after the commencement of this Order, in consultation with concerned State Ganga Committee, by notification constitute, in every specified District abutting River Ganga and its tributaries in the States mentioned in paragraph 2, the "District Ganga Committees" for the prevention, control and abatement of environmental pollution in the River Ganga.

9.2.2 Analysis of the October 2016 Order

This Order is the first serious attempt by the Central Government to address the issues of *aviralta* (continuous or uninterrupted flow) and *nirmalta* (without contamination) through legislation albeit a subordinate legislation. Till its approval, earlier attempts had been mainly limited to providing administrative and financial assistance to create sewage and other infrastructures.

The possible efficacy or otherwise of the 2016 Order, in accomplishing its objectives, can be understood in terms of its thrust, provisions, empowerment of the Authorities created and its geographical reach.

The comprehensive list of principles (identified in the previous section) to be followed to rejuvenate, protect and manage R. Ganga notwithstanding, the thrust of the 2016 Order distinctly emphasizes pollution abatement through treatment of sewage and industrial effluents and prevention of solid waste from draining into the river or being dumped on the river side. Clause 41 specifying the powers of the NMCG clearly identifies prevention and abatement of pollution in river Ganga as its main activity. Similarly, the duties and responsibilities of State and District Committees are largely to prevent pollution.

The Order refers to the need to maintain adequate flows but does not outline an action plan to achieve the same. In the absence of a distinct time frame to ensure adequate flow of water in the river, the Order is being observed in violation or non-compliance of the direction to ensure ecological flows and treating the river as an ecological entity. It is obvious that pollution abatement alone will not achieve the main objective of rejuvenating the river.

The Order does not even adequately empower the Authorities to create deterrence for the polluters to refrain from polluting the river. It has been issued under the Environment (Protection) Act, 1986 which mainly deals with regulations to prevent pollution and environmental degradation. All activities that result in non-compliance of the Act or Subordinate Legislation under it, are identified as criminal, to be adjudged in the appropriate Courts. The experience so far in ensuring compliance with pollution laws and regulations has been extremely disappointing as it takes the Courts years to decide cases registered against the polluters. More often than not, the polluters go scot-free or escape with an insignificant penalty. Consequently, urban local bodies and industrial polluters discharge untreated or partially treated effluents into the river, with impunity.

Closure of factories on frequent violations clearly does not deter industries from repeating the offence. The number of times that pulp and paper factories, sugar units, distilleries and tanneries located in the Ganga Basin have been closed on the orders of Pollution Control Boards, bears testimony to this. Complicity by officials of the Pollution Control Boards further encourages industries either not to set up effluent treatment facilities or bypass them even when they are set up. Nor has the Environment (Protection) Act or any regulation under it, been effective in controlling or preventing discharge of urban sewage which is the main contributor of pollution, by volume, in R. Ganga.

Urban Local Bodies (ULBs) are responsible for collecting, conveying and treating sewage to the required standards, notified from time-to-time by CPCB, before being discharged in the river or drainages leading to the river. The 2016 Order does not prescribe any timeline on ULBs to set up sewerage infrastructure to collect and treat sewage generated in the towns located along the river Ganga and its tributaries. Consequently, ULBs have not taken effective tangible actions for getting the sewage collected, conveyed and treated. Past experience provides little hope that the Authorities set up under the Order will ever initiate penal action against the ULBs' officials for non-compliance.

In 2014-15, CPCB undertook a study in Uttarakhand, UP and Bihar and found that the State Jal Boards were mainly interested in constructing STPs but not in their effective operation. Thereafter, the Central Government set up a financing mechanism to establish major STPs only in a PPP mode under a hybrid annuity process wherein selected private parties with their own resources would set-up STPs, operate and manage them. They would be paid an annuity for 15 years based on the treated water meeting the prescribed standard. This financing mechanism, under Namami Gange, for the first time emphasizes performance.

The fact remains, however, that the 2016 Order does not create any deterrent for individuals, companies or corporate bodies to comply with its provisions within a timeline. How will the Authorities under this Order punish or act against the offenders who continue to pollute the river? Or, how will it ensure adequate environment flow in the river, protect the flood plains, wetlands, marshlands and upper catchment areas, or restore the river's connectivity to the ground water? There is no clause in the Order that directs different authorities to restore *aviralta*, or ecological flows, without which rejuvenation of River Ganga will only remain a pipe dream.

Though the Order mentions protection, rejuvenation and management of the entire Ganga basin, the thrust seems to be on the main stem of R. Ganga and not its tributaries. Besides the Prime Minister and a few Union Ministers, the steering National Ganga Council only has the Chief Ministers of the main-stem Ganga states as Members. CMs from the remaining Ganga basin states may be coopted, if their states have major tributaries feeding into R. Ganga.

Finally, unlike NGRBA that had non-official expert members, the National Ganga Council may only 'consult' experts and expert organizations or institutions. This is contrary to the spirit of people's participation in superintending and guiding the functioning of Authorities responsible for the restoration of the National River.

9.3 RIGHTS OF RIVERS: A NEW APPROACH TO CONSERVATION OF RIVERS

The present laws framed under the Environment (Protection) Act, 1986 basically regulate the harm being done to ecosystems. They do not render adequate regard or special consideration due to River Ganga as a revered National River and its tributaries.

It is necessary to establish a fundamentally new relationship between people and nature which recognizes the inalienable rights of ecosystems, and the interdependence of humans and other natural communities. There is, therefore, a need to progress from regulation to rights-based systems of environmental protection and thereby protect and restore R. Ganga, as well as the basic rights of millions of people who depend upon it. This will require that River Ganga be first legally recognized as a living ecosystem and then develop comprehensive and effective legislation to restore its rights and rejuvenate it.

In this context the March, 2017 order of the Hon'ble High Court of Uttarakhand in Mohd. Salim vs State of Uttarakhand & Ors, currently stayed by the Hon'ble Supreme Court, assumes importance. It gives legal status to Rivers Ganga and Yamuna as living persons

and therefore legal entities. The background of the order underlines the deep faith Indians have in rivers Ganga and Yamuna and they collectively connect with these rivers. Both these rivers are central to the existence of over a third of the Indian population, their health and well-being. They provide physical and spiritual sustenance.
It is worth quoting para 19 of the above-mentioned High Court judgement order which affirms, "Accordingly, while exercising the *parens partie* jurisdiction, the Rivers Ganga and Yamuna, all their tributaries, streams, every natural water flowing with flow continuously or intermittently of these rivers, are declared as juristic/legal person/living entities having the status of a legal person with all corresponding rights, duties and liabilities of a living person in order to preserve and conserve river Ganga and Yamuna."

An effective legislation to preserve, conserve and rejuvenate R. Ganga will require recognizing its rights and accordingly drafting an appropriate legal framework. It could include the following basic rights

1. The right to exist, thrive, flow, regenerate, and evolve in its natural form covering the catchment areas, natural forests, 100-year flood plain, wetlands, marshlands, sediments, distributaries, estuaries, delta and its mangrove forest and biota, etc.;
2. The right to perform all its natural functions;
3. The right to be free from pollution;
4. The right to feed and be fed by sustainable aquifers;
5. The right to its native biodiversity;
6. The right to restoration.

Arguments are advanced *ad nauseam* that the economic benefits through development projects like hydroelectricity generation, irrigation or flood control, far outweigh maintaining a river or restoring it to a pristine state. Often it is presumed that ensuring *aviralta* would mean foregoing economic benefits from hydropower, intensive agriculture, rapid urbanization and industrialization, etc. The truth, however, is quite the opposite.

An honestly calculated monetary value of an *aviral* river in terms of its ecological goods and services like aquifer recharge, flourishing fisheries, fertilization of its flood plains, the medicinal worth of plants and animals harboured by it, dilution of poisons that enter it naturally or through human agency, formation of and stability provided to the delta regions, revitalizing tired minds and the physical health of people through its cultural, aesthetics, spiritual, religious and recreational offerings and above all maintenance of climate stability – would be far greater than the value of all other human economic activities using the same waters. Unfortunately, the economic benefits that people derive from *aviral* rivers are taken for granted and hence poorly valued, since rivers ask for no upfront financial investment to be made for the same.

All over the world a new understanding is emerging that preserving, conserving and restoring natural ecosystems offer more benefits than their reckless destruction in the name of economic growth or development. Governments are increasingly realizing that rights-based legislations are the most appropriate means to restore ecosystems to their pristine condition. India will not be the first to enact rights-based legislation for restoration of ecosystems. Similar Acts and mandates which apply a rights-based legal framework for Nature exist in countries like Bolivia and New Zealand. The Constitution of Ecuador has a chapter on the Rights of Nature. Serbia has drafted a rights-based legal framework for restoration of riverine ecosystems. Indian people and the government should study these legislations and then evolve a justiciable rights-based legislation for the restoration, preservation and conservation of the National River Ganga. Political persons, irrespective of their political affiliation, have expressed support for the rejuvenation of River Ganga. With such a political consensus in place it should be possible to enact a justiciable rights-based legislation for Ganga's rejuvenation.

The process can begin with reaffirming River Ganga as India's cultural, spiritual and above all civilizational identity and correcting a mistake done in 2008 by the UPA government. The latter declared River Ganga as India's National River under the Environment (Protection) Act of 1986 instead of doing so under the far more stringent National Symbols legislations. The latter carries severe penalties for injury, damage, or destruction of the National Symbols. On the other hand, by declaring Ganga as the National River under EPA, 1986 the Union and States governments are only bound to regulate and improve the condition of the National River, without the threat of severe punishment on failing to do so.

It is shocking that the National Portal of India on the official india.gov.in website does not even list the National River Ganga in the National Identity Elements which are described as symbols intrinsic to the Indian identity and heritage. The website is owned, designed and developed by National Informatics Centre (NIC), Ministry of Electronics & Information Technology, Government of India. Nothing could be more ironic.

9.4 CONCLUSIONS AND RECOMMENDATIONS

In India's environmental law framework, rivers have been recognized as little more than sources of water and carriers of pollution loads. Ecologists describe rivers as landscape-scale ecosystems. There is no river-specific statute in India that imposes a legal duty on the State to protect and conserve riverine ecosystems. Only the Public Trust Doctrine imposes such a legal duty on the State but it defines no deterrent penalty or punishment for non-compliance.

The focus of the existing legal orders, rules and regulations to protect and conserve the National River Ganga, from 1986 till now, and the efforts since then have mainly been on cleaning the river. But their implementation has been feeble and inadequate flowing water in large stretches of the river have rendered them ineffective. Failure to ensure ecological flows in River Ganga have left large stretches dry, destroying its ecosystem. Even the October, 2018 Notification on E-Flows in River Ganga prescribes 'minimum environmental flow' without citing any scientific basis for the levels recommended. And these flows are recommended only for a limited portion of the river.

A consortium of IITs, eminent researchers, scholars, spiritual leaders, concerned individuals, civil societies and politicians, among others, have from time-to-time raised concerns and deliberated on Ganga-specific legislation that can ensure *aviralta* and *nirmalta* to rejuvenate River Ganga. But the October, 2016 Notification does not include concerned and knowledgeable non-official persons to help guide the rejuvenation efforts, as members of the National Ganga Council. The guidance and monitoring is primarily left to transient and often unenthusiastic officials. And the woes of River Ganga continue.

It now requires every effort – legal, regulatory, administrative, financial, and social to restore the ecological health of the National River Ganga and ensure its revival. Fortunately, there is enough political agreement on the need to enact Ganga-specific legislation that will guarantee the entire river's ecosystemic revival and therefore its rights to satisfactorily perform all its natural functions. In a National River specific legislation, there can be time-bound provisions for restoration and rejuvenation measures, with accountability for non-compliances. A beginning can be made by making Ganga the National River under the appropriate National Symbols law.

ENDNOTES

i. The Seventh Schedule defines and specifies the allocation of powers and functions between the Union and the States.
ii. Exemptions cited in the Order

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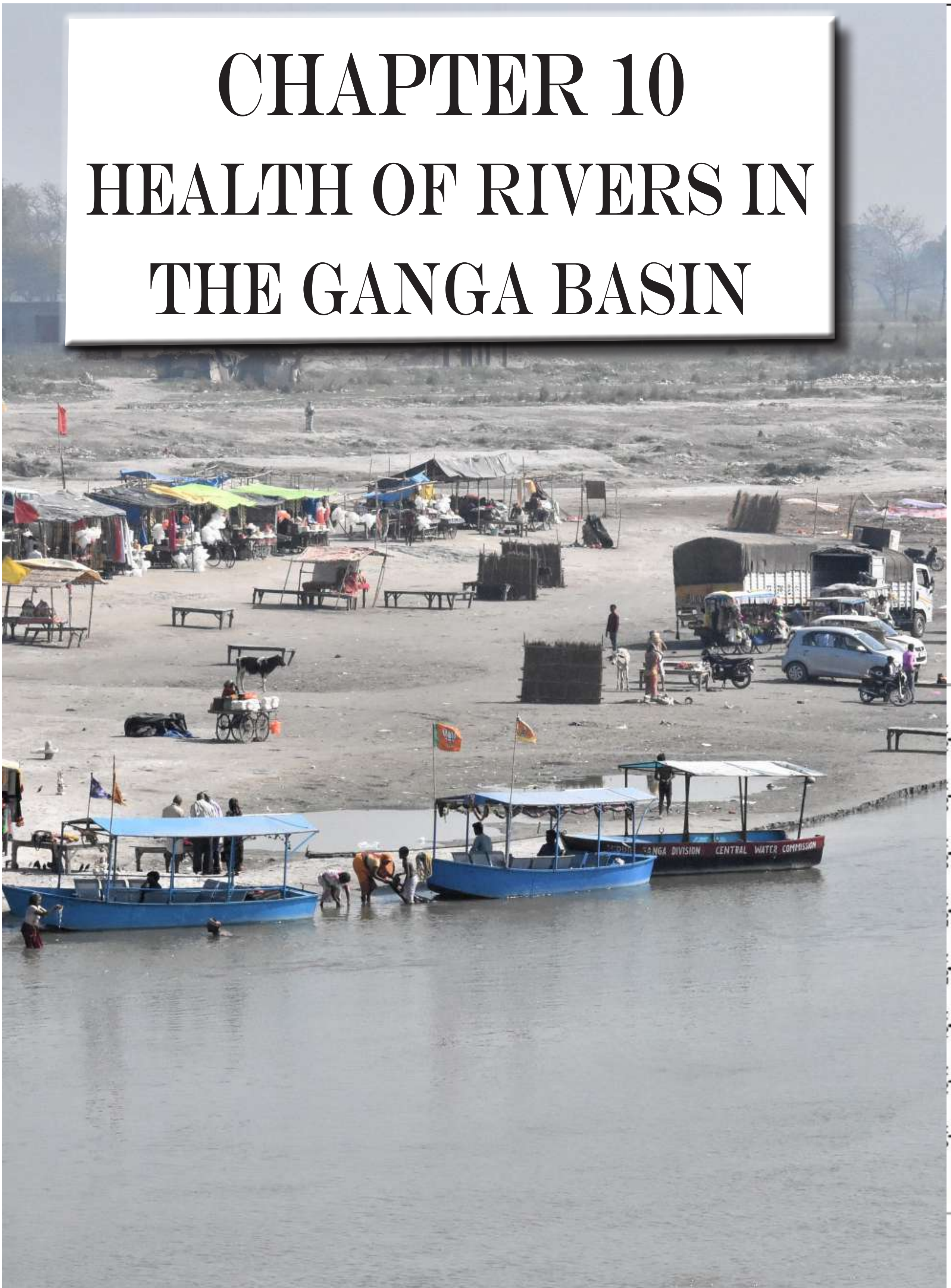
CHAPTER 10
HEALTH OF RIVERS IN THE GANGA BASIN



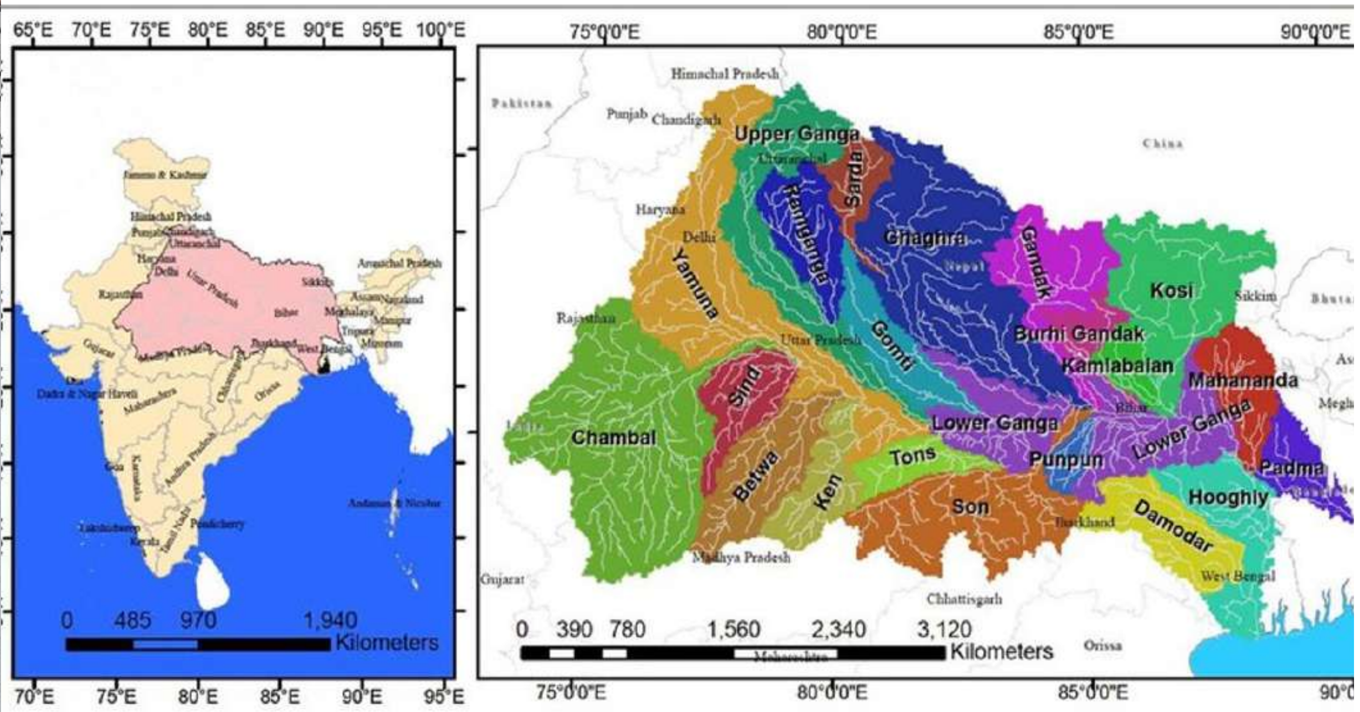
10.1 INTRODUCTION

Ganga's Health Is A Function Of The Health Of Its Tributaries

Ganga, as is popularly known, flows about 2525 km starting at Gaumukh in Uttarakhand (UKD) and meeting the Bay of Bengal at Ganga Sagar (W Bengal). But is Ganga only that stretch? Would it still be the same river if all its tributaries draining their sub-basins spread over 7, 48, 241 sq km in different states of the union were not there?

It may surprise some readers that the river Ganga that we usually think of and which, in technical language, is called the main-stem of the river, has a basin spread of 1,13,163 sq km which comprises only 13.14 per cent of the total Ganga basin in India (Table 10.1). Although it is the main-stem where all the tributaries merge, any assessment that limits itself only to the health of the main stem of river Ganga does not provide us the complete picture.

Thus, effectively, planning rejuvenation measures for the main stem of Ganga, addresses only a small part of the whole problem. It is a mistake that the planners have persisted with till today.



Map 38 : - Sub Basins in the Ganga River Basin

Source - Anand. J et al, 2018

10.2 GANGA BASIN

Table 42 : Basin Spread of Various Tributaries of River Ganga

S No	River	Basin area (Sq Km)	%
1	Ganga Main-Stem	113163	13.14
2	Yamuna	363082	42.15
3	Sone	71259	8.27
4	Ghaghra	57647	6.70
5	Ramganga	32493	3.77
6	Damodar	31220	3.62
7	Gomti	30435	3.53
8	Rupnarayan etc	23760	2.76
9	Mahananda	17440	2.02
10	Tons	16860	1.96
11	Kiul-Harohar	16661	1.93
12	Tidal rivers	15650	1.82
13	Kosi	11070	1.29
14	Burhi-Gandak	10150	1.18
15	Mayurakshi-Babla	8530	0.99
16	Punpun	8530	0.99
17	Gandak	7620	0.89
18	Ajoy	6050	0.70
19	Jalangi	5640	0.65
20	Badua-Chandan	4840	0.56
21	Bagmati	3720	0.43
22	Kamla-Balan	2980	0.35
23	Adhwara	2600	0.30
	GANGA	**861404**	**100**

Source: NIH 1998-99

Thus, unless the rejuvenation needs of all the tributaries of R. Ganga are not addressed, there will be little gain in trying to restore only its main stem. This chapter briefly reviews past efforts that considered the health of its major tributaries as well.

10.3 HEALTH OF A RIVER

There are several ways to assess the health of a river. These range from detailed scientific assessments taking various factors into account to subjective assessments made by knowledgeable persons.

Any stream big or small begins its journey as a trickle and gathers flow as it moves downstream, getting fed by tributaries which merge into it along its course. Thus, a stream is continuously changing in terms of its geography, geological terrain, flow or the composition of what is flowing in it as it races downstream to meet a higher order stream, water body or the sea. For analytical purposes then, most rivers can be divided into small segments which can be considered uniform in most of their individual attributes.

The overall health of a river shall then be the sum of the health of its various segments.

The best indicator of the health of a river is a change, if any, over time, against a benchmark, in its seasonal flow assessed at various points along its length and that of its tributaries. This is because it is the flow down a stream that determines all its varied functions in nature.

An indirect indicator could of course be the status of flora and fauna at critical junctures in the river, since the river's biota is mainly the result of its flow. Yet another feature that could indicate the health of a river is its behavior during the times of floods. For it is the manner in which the river spreads over its flood plains and beyond during floods that generally determines whether the river is healthy (limits itself within known bounds) or not (turns unusually devastating). A stream with a healthy catchment will not spread itself beyond its flood plain in normal floods.

10.4 RECENT STUDIES

Three separate studies by the IIT-Consortium (2014), a World Bank consultant (2015) and by knowledgeable experts for the India Rivers Week in 2016, have been considered to highlight and compare their results.

10.4.1.1 IIT Consortium Report, 2014

A Flow Health Tool (developed in 2012 by the International Water Centre) was used to arrive at the Flow Health Score at 146 locations within the river Ganga basin under four scenarios:

a) In its virgin state (without any human interventions)
b) In its present state of water diversion and management
c) With improved irrigation efficiency
d) Due to implementation of future projects

The Soil and Water Assessment Tool (SWAT) and weather data spread over 29 years (1974-2002) were used to establish the hydrologic flow regime for the above mentioned four different scenarios.

A categorical finding of the study is that "in general the hydrologic flow health has been considerably affected at several stretches of Ganga due to the present state of water management."

More interestingly, the study concluded (page 23) that even with scenarios (c) and (d) not much improvement in the hydrologic flow health could be expected.

While the language of the report is guarded, the clear implication is that a threshold in the overall health of R. Ganga has already been crossed, through human interventions, and that any minor tinkering either way with the status quo will not make a difference to its health.

Thus, the attaining of *aviralta* (uninterrupted flow) in river Ganga is a pipe dream for the present. Unless major decisions regarding abstracting structures and lowering the current levels of water extractions from it are taken and implemented, there is little hope of rejuvenating of river Ganga to full health.

The report has analyzed and discussed the Hydrological Flow Health Status at 35 selected locations (out of the total 146). These are summarized in Table 10.2.

Table 43: Hydrologic Flow Health

S. No	Segment	Location	Hydrologic Flow Health	Comment*
1	Upper Ganga (Till Rishikesh)	Rishikesh (Ukd)	Good	
2	Upper Ganga (Till confluence with Ramganga)	Garhmukteswar (UP)	Poor	
3	Upper Ganga (Till confluence with Ramganga)	Fatehgarh (UP)	Poor	
4	R Birma	Bewar (UP)	Moderate	
5	R Ramganga	Bareilly (UP)	Poor	
6	R Ramganga	Dabri (UP)	Poor	
7	Middle Ganga (Till Yamuna confluence)	Bhitaura (UP)	Poor	
8	Middle Ganga (Till Yamuna confluence)	Allahabad (UP)	Poor	
9	Upper Yamuna	Paonta (HP)	Moderate	
10	Middle Yamuna	Baghpat (UP)	Poor	

S. No	Segment	Location	Hydrologic Flow Health	Comment*
11	Middle Yamuna	Mohana (UP)	Poor	
12	Middle Yamuna	Agra (UP)	Poor	
13	Middle Yamuna	Etawah (UP)	Poor	
14	R. Banas (Chambal)	Baranwada (Raj)	Moderate	In IRW's opinion the flow should have been assessed Poor, due to the large number of hydrological structures in the basin
15	R. Kali Sindh (Chambal)	Mandawara (MP)	Moderate	
16	R. Kali Sindh (Chambal)	Barod (MP)	Moderate	
17	Chambal	Mandrail (Raj)	Moderate	
18	Chambal	Udi (UP)	Moderate	
19	Lower Yamuna	Kalpi (UP)	Poor	
20	R Betwa	Mohana (UP)	Poor	
21	R Gomati	Raibareli (UP)	Moderate	
22	R Gomati	Jalalpur (UP)	Moderate	
23	R Gomati	Lucknow (UP)	Moderate?	In IRW's opinion the flow should have been assessed Poor
24	R Gomati	Jaunpur (UP)	Moderate?	In IRW's opinion the flow should have been assessed Poor
25	R Sone	Chopan	Poor	
26	R Ghaghra	Paliakalan (UP)	Moderate	
27	R Sarju	Ayodhya (UP)	Moderate	
28	R Ghaghra	Turtipur	Moderate	
29	R Gandak	Triveni (Bihar)	Moderate	
30	R Gandak	Lalganj (Bihar)	Moderate	
31	R Kosi	Baltara (Bihar)	Moderate	
32	Lower Ganga	Sikandarpur (Bihar)	Moderate to Good	
33	Lower Ganga	Sripalpur (Bihar)	Moderate	
34	Lower Ganga	Patna (Bihar)	Poor	
35	Lower Ganga	Farakka (W Bengal)	Poor	

**Comments are additional and were not part of the report* *Source: IIT-Consortium, 2014*

Though the small number (35) summarized in Table 10.2 is not truly representative in a vast river basin like the Ganga, it is worth noting that the Hydrological Flow Health has been assessed as 'Good' at only one out of the 35 locations. In all, 22 stations were assessed as 'Good', 44 were 'Moderate' and 80 were 'Poor'. Almost all the 'Good' stations are located in the upper basins of the Ganga (12), Yamuna (7), Ghaghra (2) and Kosi (1). It points to a dismal situation.

10.4.1.2 World Bank Consultant's Report, 2015

The World Bank in Delhi commissioned a private consultant for hydrologic modeling of the Ganga Basin using the SWAT model. It has looked at the entire Ganges basin upstream of Farakka (INRM, 2015). These include the basin segments in India, Nepal and Tibet. According to the report, "Any effort to restore the hydrological status of the basin requires the information on the basin that prevailed before the water resources development, which is usually not available. However, generation of such information is possible only through hydrological simulation and the same has been adopted." Two scenarios have been constructed:

Scenario A (Reference): Pre-development flow in the absence of water resources infrastructure including water diversions but reflecting catchment hydrology corresponding to the current land use.

Scenario B (Current regime): Representing existing major water resources infrastructure, current management, operation practices and existing irrigation water demand.

Flow Health Score

A major input required for the flow health tool is the monthly or daily flow hydrograph (observed or simulated) continuously available for a period of time.

The flow health is derived from nine different hydrological sub indicators: High Flow (HF); Low Flow (LF); Highest Monthly (HM); Lowest Monthly (LM); Persistently Higher (PH); Persistently Lower (PL); Persistently Very Low (PVL); Seasonality Flow Shift (SFS) and Flood Flow Interval (FFI). (Gippel et al, 2012). These nine indicators are closely related to the basic flow components of a natural flow regime. The Flow Health Index combines the scores of the nine sub indicators.

The final results shown in Table 10.3 are for the entire Ganga basin, including the portions in Tibet (China), Nepal and in India.

Table 44 : Median Flow Health Scores Of Sub Basins Based On 31 Years (1976-2005) Simulated Monthly Flows

S. No	Sub basin	Size (Sq km)	Score	Variation from Reference	*Comments
1	Upper Ganga (Before Hardwar)	23,209	0.72	Small	Since the high dam at Tehri (Phase 1) was commissioned in 2006, this score would now be different/lower.
2	Upper Ganga (Before confluence with Ramganga)	26,837	0.42	Moderate	
3	Upper Yamuna (Before confluence with Chambal)	80,185	0.44	Moderate	On the lines of R. Ganga this basin size should actually be assessed as two sub-basins. One till the barrage at Hathnikund. The other till the confluence with R. Chambal.
4	Ramganga	24,943	0.53	Moderate	
5	Gomti	31,050	0.60	Moderate	
6	Chambal	141,814	0.20	Very Large	This highlights the result of major hydrological interventions in almost all the tributaries of Chambal.
7	Lower Yamuna (Before confluence with Ganga)	29,639	0.31	Large	
8	Sindh	28,301	0.33	Large	Again this highlights the result of major hydrological interventions in the basin
9	Betwa	43,892	0.42	Moderate	Should have been Large. Although borderline, this does not truly reflect the many hydrological interventions in the basin

S. No	Sub basin	Size (Sq km)	Score	Variation from Reference	*Comments
10	Ken	28,665	0.45	Moderate	
11	Tons	17,446	0.46	Moderate	
12	Sone	67,501	0.34	Large	This reflects the result of major hydrological interventions in the basin. Would have been Very Large, if recent high dam (Bansagar) were to be taken into consideration.
13	Ghaghra	133,365	0.23	Large	
14	Gandak	42,310	0.23	Large	
15	Burhi Gandak	12,524	0.46	Moderate	
16	Koshi	91,287	0.38	Large	
17	Punpun	8,900	0.53	Moderate	
18	Kiul-Harohar	17,598	0.51	Moderate	
19	Lower Ganga (At Farakka)	20,277	0.14	Very Large	This reflects the ill effects of the barrage at Farakka
20	Damodar	37,568	0.23	Large	
21	Lower Ganga (Hoogly)	70,008	0.20	Very Large	This reflects overall the result of a highly hydrologically interfered basin.

Source: INRM Consultants, report to The World Bank, 2015

Flow Health Score: Very Large (0.0-0.2); Large (0.2-0.4); Moderate (0.4-0.6); Small (0.6-0.8); Very Small (0.8-1.0).
**Comments are additions and were not part of the cited report.*

The Report says that "It can be observed that Chambal, Lower Ganga (Farakka) and Lower Ganga (Hoogly) perform the poorest on the Flow Health Score". The Lower Yamuna, Sindh, Sone, Ghaghara, Gandak, Koshi and Damodar have large deviations from the reference.

Since a river's delta is a geo-hydrological health report of the basin it can be surmised that even in 2005 the Ganga basin was in a very poor state in terms of its flow deviation from the reference or pristine (no structural intervention) stage.

10.4.2 India Rivers Week, 2016

'State of India's Rivers' was the theme for the India Rivers Week held in New Delhi between November 25-27, 2016. To produce a nationwide assessment of the present condition of India's rivers, well known experts and organisations in different states of the Union were identified and commissioned to prepare statewide reports (IRW, 2016). They were given a generic format of the report.

One of the tasks requested from the experts was to assess the state of health of the various river stretches in their respective states ranging from Good (Blue color), Sick (Yellow) to Dying (Red). The experts were asked to make the assessment based on their own understanding of the ground realities, although presence/absence of structures on the river, quality of water, threatened flood plains, presence/absence of biota, etc. were the obvious bases for the assessment. Good or degraded status of the health of the catchment, although a critical factor, could not be assessed for lack of information and time.

The IRW16 did try and arrive at a methodology to holistically assess the health of rivers. But this exercise was carried out at the IRW conference itself and hence the reports prepared by the experts did not get the benefit of this exercise.

The assessment of the local expert(s) for the river Ganga and its tributaries spread over the states of Himachal Pradesh, Uttarakhand, Uttar Pradesh, Haryana, Delhi, Rajasthan, Madhya Pradesh, Chattisgarh, Bihar, Jharkhand and West Bengal are summarized in Table 10.4. Various experts took different factors into consideration, in addition to pollution as a factor, while assessing the various rivers. These included structures (dams, barrages, embankments), sand/boulder mining, falling base flows, reduced biota, etc.

Table 45: Summary of Findings

State/ River	**HP**	**UKD**	**UP**	**HAR**	**NCTD**	**RAJ**	**MP**	**CG**	**BH**	**JH**	**WB**
Ganga		PINK	RED						PINK		
Yamuna	RED	PINK	RED	RED	RED						
Bhagirathi		RED									
Alaknanda		RED									
Ramganga		BLUE	RED								
Kaliganga		PINK									
Gomti			RED								
Ghaghra			PINK								
Banas						RED					
Chambal						RED	RED				
Banganga						RED					
Sahibi						RED					

State/ River	HP	UKD	UP	HAR	NCTD	RAJ	MP	CG	BH	JH	WB
Sindh							RED				
Betwa							RED				
Ken							RED				
Sone							PINK	BLUE	RED		
Tons							RED				
Gandak									PINK		
Budhi Gandak									PINK		
Baghmati									PINK		
Kamla-Balan									PINK		
Kosi									RED		
Mahananda									NA		PINK
Karmnasa									PINK		
Punpun									PINK		
Kiul-Harohar									PINK		
Badua									PINK		
Chandan									PINK		
Damodar										RED	
Koel (N)										PINK	
Mahananda											PINK
Bhagirathi/ Hoogly											RED
Tidal Creeks											PINK

Note: Details can be seen in the Appendix .

10.4.3 Comparison And Analysis

The three assessment reports have looked at almost similar segments of the river Ganga basin. Hence, despite differences in their approach to the issue, it is by and large possible to compare and contrast their findings.

Table 46 : Comparative Assessments of River Health Status

Segment/ Studies	IIT Consortium	WB Report	IRW2016
Upper Ganga (Till confluence with R Ramganga)	Good till Rishikesh, Poor later on	Small variation	Sick
Upper Yamuna (Till confluence with R Chambal)	Moderate till Paonta and Poor later on	Moderate	Sick in UKD & later Dying
Middle Ganga (Till Confluence with Yamuna)	Poor	NA*	NA*
Lower Yamuna (Till confluence with Ganga)	Poor	Large	Dying
Ramganga	Poor	Moderate	Good in UKD later Dying
Gomti	Moderate	Moderate	Dying
Ghaghara	Moderate	Large	Sick
Chambal	Moderate	Very Large	Dying
Sindh	NA	Large	Dying
Betwa	Poor	Moderate	Dying
Ken	NA	Moderate	Dying
Tons	NA	Moderate	Dying
Sone	Poor	Large	Good in CG & Sick later, Dying in Bihar
Gandak	Moderate	Large	Sick
Burhi Gandak	NA*	Moderate	Sick
Kamla-Balan	NA*	NA*	Sick
Koshi	Moderate	Large	Dying
Mahananda	NA*	NA*	Sick in WB
Punpun	NA*	Moderate	Sick
Kiul-Harohar	NA*	Moderate	Sick
Lower Ganga	Poor at Patna & Farakka	Very Large	Dying
Damodar	NA*	Large	Dying
Hooghly	NA*	Very Large	Dying

NA: Not assessed*

The correspondence between the rated conditions are as below:
Good (IIT) = Small Variation (WB) = Good (IRW);

Moderate (IIT) = Moderate Variation (WB) = Sick (IRW);
Poor (IIT) = Very Large Variation (WB) = Dying (IRW).
The World Bank report also had an intermediate category, 'Large', with no correspondence in the other studies.

There appears to be a general similarity of results amongst the different reports, despite the fact that the IIT consortium and the WB consultant's reports based their findings on objective consideration (hydrology) and the use of the relevant software, while the IRW report was based on subjective understanding of the ground situation (structures, diversions, sand mining, reduced base flows, high pollution, etc.) by knowledgeable persons.

This exercise would have become more interesting to record and compare if the IRW experts also had access to reports on the state of biodiversity in different tributaries of R. Ganga as an indicator of river health.

10.5 RIVERS OF HIGH CONCERN

The following rivers of the Ganga basin call for urgent attention:

1. Yamuna sub basin (Yamuna, Tons, Giri, Pabbar, Sindh, Betwa, Ken)
2. Chambal sub basin (Chambal, Banas, Kalisindh, Parbati)
3. Ramganga
4. Gomti
5. Tons (Direct tributary of Ganga)
6. Sone
7. Gandak
8. Kosi
9. Damodar
10. Ganga at Farakka

10.6 CONCLUSIONS

In the Ganga basin, in many a case, tributaries brings more water at the confluence with the trunk river. Thus the Himalayan Tons in Uttarakhand carries a greater discharge than the trunk river Yamuna at their confluence near Kalsi in Uttarakhand. Similarly the Yamuna has a greater discharge than the Ganga at Sangam (Allahabad). In such cases it is easy to realize that the health of the trunk river could be largely determined by the health of the tributary. Hence the statement at the start of this chapter, "Ganga's health is a function of the health of its tributaries."

The overall picture that emerges from this chapter is grim. None of the 146 locations studied by the IIT Consortium was rated 'Very Good' under the present (2014) conditions. Only the 22 stations of the Upper Ganga, Upper Yamuna and Ghagra basins in Uttarakhand were rated 'Good'. And even these would have deteriorated with the construction of more dams and tunnels in the high Himalayas. The IRW assessments were generally more sombre. The knowledgeable local experts consulted by India Rivers Week rated only small streams like the Aglar (Yamuna basin), Ramganga (E) and Ladhiya (Ghaghra basin) and the Uttarakhand stretch of the Ramganga (W) as 'Good'.

The Union Government's new mega-projects for rapid economic growth like the National Waterways and the Inter-Linking of Rivers pose new threats to the health of the main stem and several tributaries.

Although a list of seven thrust areas indicates a broader awareness, the National Mission for Clean Ganga's flagship 'Namami Gange' programme is still largely focused on sewage treatment (See Chapter 12). The National Ganga Council which guides NMCG must energise the thrust areas of NMCG other than sewage treatment alone.

It is clear that a herculean effort based on a comprehensive understanding of the role of tributaries is now needed to restore the ecological health of the National River Ganga and ensure its revival. The existing political consensus must be expanded to enact a Ganga basin-specific legislation that will guarantee the entire river basin's ecosystemic and hydrological revival. Expanding the political consensus is a major challenge for all who are interested in restoring the health of India's rivers.

10.7 REFERENCES

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APPENDIX

Findings at the India Rivers Week, 2016

State	River Basin	Tributary river	State of health	Comments/ Key Threats
HIMACHAL PRADESH	Yamuna		Dying	All tributaries are assessed as dying
		Giri	Dying	Dams, Ind. pollution, Sand mining
		Tons	Dying	Dams, Ind. pollution, Sand mining
		Pabbar	Dying	Dams, Ind. pollution, Sand mining
UTTARAKHAND	Yamuna		Sick	Water quality is fine. But existing barrages and dams (planned/under construction) are key threat for flow, biodiversity and landslides
		Tons	Dying	Dams
		Rupin	Sick	Dams
		Asan	Sick	Untreated Ind. waste
		Aglar	Good	Proposed Dam at Lakhwar on R Yamuna would turn healthy Aglar into Red
	Bhagirathi		Dying	Series of dams have destroyed the free flow. Water quality is fine.
		Jadh Ganga		Proposed dams
		Assi Ganga		Proposed dams
		Jalkur		-
		Bhilangana		Dams including the dam at Tehri

State	River Basin	Tributary river	State of health	Comments/ Key Threats
	Alaknanda		Dying	Water quality is fine. But dams at Vishnuprayag and Srinagar are key threats to flow, biodiversity and unstable banks
		Dhauliganga (W)	Dying	Under construction Dams
		Nandakini	Sick	Dams planned
		Pindar	Sick	Dams planned
		Mandakini	Dying	Dam at Singoli-Bhatwari
	Ganga		Sick	Dams at Kotli-Bhel II and Bhimgouda and pollution downstream of Rishikesh
		Nayar	Dying	River is drying up due to lack of base flow and sand/ boulder mining
		Song	Sick	Pollution
		Suswa	Sick	Pollution
	Ramganga (W)		Good	River is fine within the state upstream the dam at Kalagarh, after which the river enters UP
		Gagas	Dying	River is drying up due to lack of base flow and sand/ boulder mining
		Kosi	Dying	River is drying up due to lack of base flow and sand/ boulder mining
	Kaliganga/ Mahakali		Sick	Water quality is Good. But planned Dam at Pancheswar would detroy free flow and biodiversity
		Dhauliganga (E)	Dying	Drying up due to Dams
		Goriganga	Dying	Shall dry up due to dams
		Ramganga (E)	Good	-
		Saryu	Sick	Pollution
		Ladhiya	Good	-

State	River Basin	Tributary river	State of health	Comments/ Key Threats
HARYANA	Yamuna		Dying	Barrage at Hathnikund and heavy diversion of water into WYC and EYC. River is dry or carrying heavily polluted water. Heavily reduced biodiversity. Sand mining.
		Somb	Sick	Barrage regulates water flow. Water quality is fine.
		Sahibi	Dying	River has dried from lack of base flow and barrage. High pollution from Gurgaon city.
NCT OF DELHI	Yamuna		Dying	Barrages, high pollution, floodplains encroachment, sand mining.
		Storm water drains (201)	Dying	Pollution, covering and encroachment
UTTAR PRADESH	Ganga		Dying	High fragmentation and extraction of water due to barrages at Bijnor, Narora and Kanpur. Lift irrigation schemes and high Ind. and domestic pollution. Sand mining.
		East Kali	Dying	Drying from low base flows and High pollution
		Pandu	Dying	Drying from low base flows and High pollution
	Ramganga		Dying	Dam at Kalagarh and barrage diverts all its waters. High pollution.
		Khoh	Dying	Barrage
		Dehla	Dying	Reduced base flows and Ind. pollution
		Gangan	Sick	Pollution
		Kosi	Dying	Diversion at barrage and Ind. pollution

State	River Basin	Tributary river	State of health	Comments/ Key Threats
		Baigul (W)	Dying	Fragmented due to water impoundment at several places
		Aril	Dying	Heavy Ind. pollution
		Baigul (E)	Good	-
	Yamuna		Dying	Barrages at Okhla and Gokul and pollution. Sand mining.
		Katha	Dying	River has completely dried. No base flow. Only channel remains.
		Hindon	Dying	Reduced base flows. High pollution. Barrage at Ghaziabad.
		Karwan	Dying	Reduced base flows. High pollution.
		Banganga	Dying	Fragmented due to dams.
		Gambhir / Utangan/Khari	Dying	Fragmented due to dams.
		Sengur/Sirsa	Dying	Reduced base flows. High pollution.
		Non	Sick	Reduced base flows.
		Arind	Sick	Reduced base flows.
		Sasur Khaderi	Sick	Reduced base flows.
		Chambal	Sick	Reduced flow. Lift irrigation.
		Sindh	Sick	Reduced flow.
		Betwa	Dying	Dams and water diversion
		Ken	Dying	Barrages and proposed Ken-Betwa link.
	Gomti		Dying	Reduced flow and high pollution. Several large cities (Lucknow, Sultanpur, Jaunpur) on it.
		Sarayan	Dying	High pollution.

State	River Basin	Tributary river	State of health	Comments/ Key Threats
	Ghaghra		Sick	Formed by confluence of Mahakali(Sharda)/Chauka and Karnali/Kauriyali/ Ghaghra and Rapti, the latter two originate in Nepal. Major barrage (Sharda Sahayak Irrigation Project) on Sharda diverts water away. Water quality is fine. Biodiversity is fine.
		Sharda/ Mahakali / Chouka	NA	-
		Karnali/ Kauriyala	NA	-
		Sarju	NA	-
		Kuwana	NA	-
		Rapti	NA	-
		Choti Gandaki	NA	-
		Jharah	NA	-
		Daha	NA	-

State	River Basin	Tributary river	State of health	Comments/ Key Threats
RAJASTHAN	Banas		Dying	Dams (7 major, 33 med and 1219 minor irrigation projects), Mining, Pollution.
		Berach	Sick	Pollution
		Dain	Good	Low pollution
		Guria	NA	-
		Kalisil	NA	-
		Khari	NA	-
		Kothari	Sick	Pollution
		Mashi	Good	Low pollution
		Morel	NA	-
		Sodra	NA	-
	Chambal		Dying	Reservoir dams (3), pollution
		Banas	Dying	Dams, pollution, mining
		Kalisindh	Sick	Dams and pollution
		Parbati	Sick	Dams and pollution
	Banganga		Dying	Dams (One major,10 med, 177 minor IP), mining, pollution, river bed encroachment
		Gumti	NA	-
		Suri	NA	-
		Sanwan	NA	-
		Palasan	NA	-
	Sahibi		Dying	Barrage, reduced base flows, high pollution

State	River Basin	Tributary river	State of health	Comments/ Key Threats
MADHYA PRADESH	Chambal		Dying	Dams, Lift projects, pollution, sand mining
		Chamla	NA	-
		Maleni	NA	-
		Kshipra	Dying	Reduced base flow, pollution
		Choti Kalisindh	NA	-
		Shivna	NA	-
		Retam	NA	
		Kali Sindh	Dying	Dams, pollution
		Parbati	Sick	Dams, pollution
		Banas	Dying	Dams, Mining, pollution
		Kuno	Good	Unaffected by human intervention, wildlife sanctuary
	Sindh		Dying	Dams, pollution, sand mining
		Parbati	Dying	Dams, sand mining
		Mahuar	Dying	Dams, pollution
		Vaisali	NA	-
		Pahuj	Dying	Dams, pollution
		Kunwari	NA	-
	Betwa		Dying	Dams (3 major), pollution, sand mining
		Bina	Dying	Barrage, low base flow, pollution, sand mining
		Kethan	Dying	Dams, pollution, sand mining

State	River Basin	Tributary river	State of health	Comments/ Key Threats
		Orr	Sick	Dams(under construction), sand mining, low base flow
		Jamni	Dying	Dams, sand mining, low base flow
		Dhasan	Sick	Dams (planned), low base flow
		Birma	Dying	Dams, sand mining, low base flows
	Ken		Dying	Planned K-B link, low base flows, barrages
		Patne	Sick	Dams (minor IP), pollution
		Sonar/Bearma	Sick	Dams, reduced base flows
		Mirhasan	NA	-
		Banne	Sick	Low base flows
		Urmil	NA	-
		Kail	Good	-
		Chandrawal	NA	-
	Sone		Sick	Major dam (Bansagar), reduced flow
		Kevai	NA	-
		Johilla	Dying	Dam, low base flows
		Katni	Sick	Pollution, reduced flow
		Mahanadi	Good	-
		Banas	Good	-
		Mahan	Good	-
		Gopad	NA	-
	Tons		Dying	Dams, barrage, low base flows,
		Satna	Dying	Dam, pollution
		Bihar	NA	-
		Keoti	Good	-
		Belan	Dying	Dam, reduced base flows

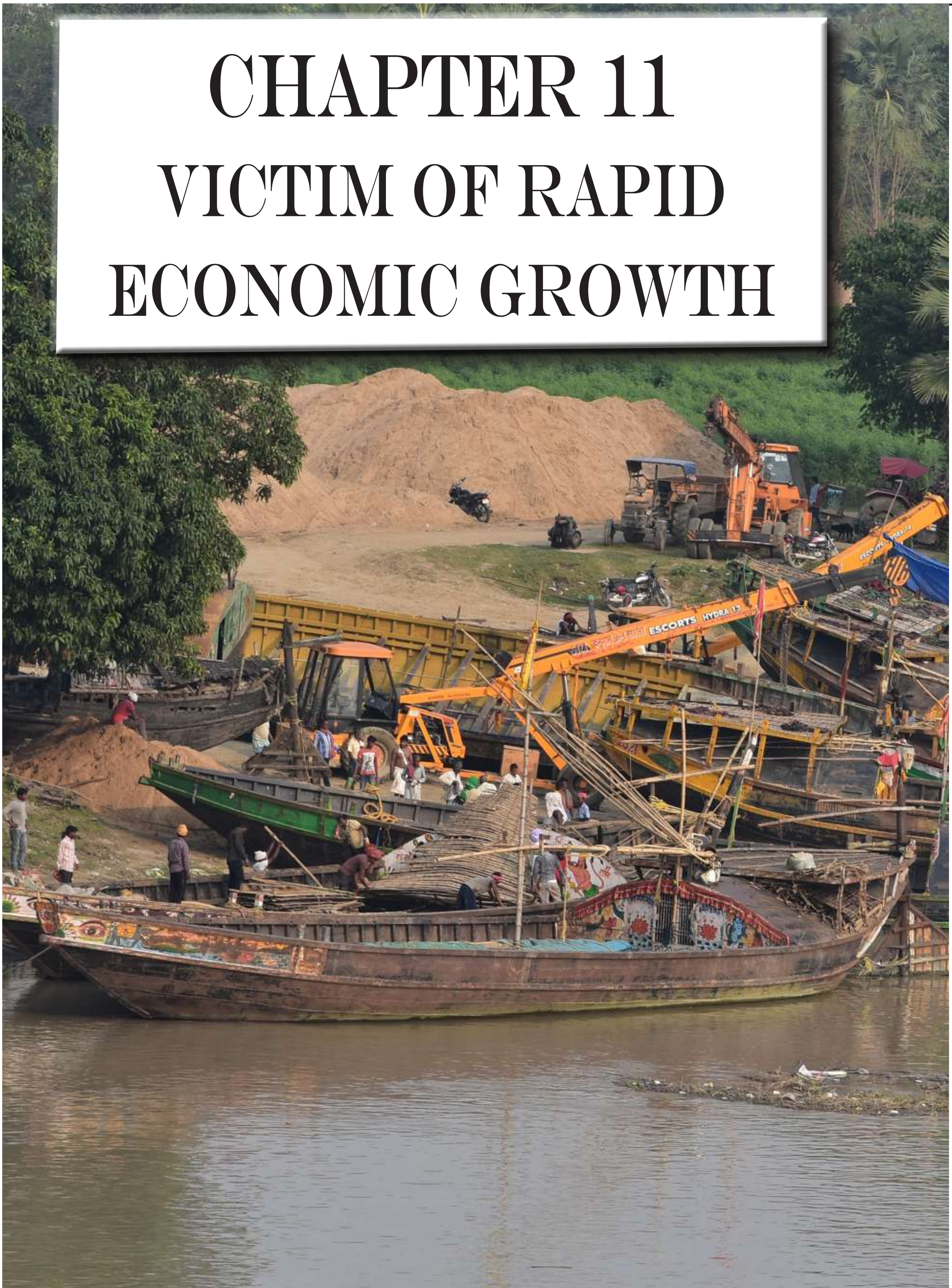
State	River Basin	Tributary river	State of health	Comments/ Key Threats
CHHATTISGARH	Sone			Sone has its origin and a small catchment portion in North CG
		Banas	Good	Tributary of R Sone
		Gopad	Good	Tributary of R Sone
		Rihand	Good	Tributary of R Sone
		Kanhar	Good	Tributary of R Sone

State	River Basin	Tributary river	State of health	Comments/ Key Threats
BIHAR	Ganga		Sick	Bihar is drained by R Ganga. Reduced flows, pollution.
	Gandak		Sick	North Bihar river. Water quality is fine. Threatened by barrage and embankments.
	Budhi Gandak		Sick	North Bihar river. Water quality is fine. Embankments threat.
	Baghmati		Sick	North Bihar river. Water quality is fine. Embankments threat.
	Kamla-Balan		Sick	North Bihar river. Water quality is fine. Embankments threat.
	Kosi		Dying	North Bihar river. Water quality is fine. Embankments threat.
	Mahananda		NA	North Bihar river.
	Karmnasa		Sick	South Bihar river. Dam in upper reaches.
	Sone		Dying	Inter-state river. Reduced flows due to dams on tributaries like Rihand, Kanhar (under construction).
	Punpun		Sick	South Bihar river. Dam in upper reaches.
	Kiul-Harohar		Sick	South Bihar river. Dams in upper reaches.
	Badua		Sick	South Bihar river. Dam (major) in upper reaches.
	Chandan		Sick	South Bihar river. Dam (major) on upper reaches.

State	River Basin	Tributary river	State of health	Comments/ Key Threats
JHARKHAND	Damodar		Dying	Dams, Barrages, high pollution
		Barakar	Dying	Dams, high pollution
	Koel (north)		Sick	A tributary of river Sone. Threatened by Koel project (under construction).
WEST BENGAL	Mahananda		Sick	High pollution
	Bhagirathi (Hooghly)		Dying	Barrage at Farakka has dramatically transformed the geo-morphology of the river. High Pollution
		Mayurakshi	NA	-
		Ajoy	NA	-
		Damodar	Dying	Dams, Barrages, pollution
		Dwarakeswar	NA	-
		Silai	NA	-
		Kansai	Sick	Pollution
	Tidal creeks		Sick	Pollution, Climate change

NA – Not Assessed

CHAPTER 11
VICTIM OF RAPID ECONOMIC GROWTH



11.1 INTRODUCTION

Most rivers worldwide have fallen victim to various pressures of rapid economic growth. These pressures are in the form of water diversions - to meet water requirements for power generation, agriculture, industries and urbanization; changes in water flow patterns; river morphology; loss of vegetation (due to land use change or deforestation) in their catchments and pollution of river courses from urbanization, industrialization, encroachment of riparian areas and chemical farming practices. River Ganga is no exception to these pressures.

The most telling impact of these pressures is the net reduction of flows over the years in the rivers with the consequent damage to the rivers' ecosystems, the loss of aquatic and riparian biodiversity and dependent human livelihoods.

Recent estimates using models (since flow data is not available in the public domain) reveal that River Ganga and its tributaries have witnessed drastic reductions in annual and seasonal flows over 31 years between 1975-2005 (INRM, 2015).

Table 47 : Estimated Annual Flow Reduction In The R. Ganga Sub Basins

S.No.	Sub Basin	% Flow reduction 1975 to 2005
1	Upper Ganga before Haridwar	7
2	Upper Ganga (before confluence with Ramganga river)*	36
3	Ramganga (before confluence with Ganga river) - Left Bank	37
4	Upper Ganga (after confluence with Ramganga river)*	41
5	Upper Ganga (before confluence with Yamuna river)*	49
6	Upper Yamuna	51
7	Chambal (before confluence with Yamuna river) - Right Bank	63
8	Sind (before confluence with Yamuna river) - Right Bank	81
9	Betwa (before confluence with Yamuna river) - Right Bank	56
10	Ken (before confluence with Yamuna river) - Right Bank	48
11	Lower Yamuna (before confluence with Ganga river) - Right Bank	60

12	Ganga (after confluence with Yamuna river)	56
13	Tons (before confluence with Ganga river) - Right Bank	41
14	Gomti (before confluence with Ganga river) - Left Bank	31
15	Ganga (after confluence with Gomti river) - Left Bank	54
16	Ghaghra (before confluence with Ganga river) - Left Bank	34
17	Ganga (after confluence with Ghaghra river)	47
18	Sone (before confluence with Ganga river) - Right Bank	58
19	Gandak (before confluence with Ganga river) - Left Bank	34
20	Punpun (before confluence with Ganga river) - Right Bank	48
21	Kiul (before confluence with Ganga river) - Right Bank	51
22	Burhi Gandak (before confluence with Ganga river)	48
23	Kosi (before confluence with Ganga river)	27
24	Farakka*at lower Ganga (before bifurcation to India and Bangladesh)	45
25	Damodar (before confluence with Ganga river) - Right Bank	62
26	Lower Ganga at Ganga Sagar (India)	57

Source: INRM, 2015

** This location is generally accepted as Middle Ganga*

The clear message in Table 47 is that River Ganga has lost 45% of its flow before reaching Farakka and 57% before it reaches Ganga Sagar, in just over 30 years. But for a few left bank tributaries – primarily the Ghaghra, Gandak and Kosi rivers, the Ganga would be in more dire straits than it is today since almost all its major right bank tributaries – the Yamuna, Chambal, Sindh, Betwa, Sone, Kiul and Damodar rivers are also heavily compromised.

The extent of flow disruptions varies over time (seasons) and space in the basin. During the monsoon months the flow reduction varies in the different sub-basins of the Ganga. The Ganga's right bank or southern tributaries have higher reductions (the maximum, 75%, being in the Sind sub-basin) in comparison to the northern tributaries (the maximum reduction is 40% for the Upper Yamuna sub-basin). However, the situation is drastically different during the non-monsoon period. A very small fraction of flow is left during the non-monsoon months in the non-glacial tributaries especially in the southern sub-basins of R. Ganga. Reduction is also considerable in the flows of the northern sub-basins, ranging from 44% to 94% (INRM, 2015).

The flow reduction could possibly arise from two factors:

(i) A substantial reduction in rainfall in the last one century that has caused water flow reduction in the river? Or,

(ii) The adverse impact of the economic growth model that the country has adopted.

The second factor raises two further questions:

(a) Has the green revolution (flood irrigation) approach to agricultural production for food security adversely impacted flows in the rivers? Or,

(b) Has relentless urbanization and unplanned industrialization reduced river flows to the current critical levels?

Published scientific literature on historical rainfall trends in the Ganga River basin suggests that historically annual precipitation in the Ganges basin has remained stable, despite localized variations which lack basin-wide significance (Nepal S. and Shrestha A.B., 2015). On the contrary some sub- basins have seen an increase in annual rainfall. Clearly, the massive volume of water that is consumed in India's rapid economic growth has enormously shrivelled flows in the Ganga River basin and in the process grievously wounded the river basin's ecosystem. WWF has rated it as one of the 10 most threatened rivers in the world (WWF, 2007).

More recently mega-plans have been pushed in the name of development such as the mushrooming of hydroelectric projects (HEPs) in the Upper Ganga Basin, the proposed inter-linking of rivers, fanciful concretization of river fronts, the opening of a large number of river stretches to inland commercial transportation and relentless mining of sand from the rivers, among many others.

Therefore, it is important to understand the impact of all these interventions on the health of R. Ganga and beneficiaries and victims of these projects. Such an understanding is critically needed to guide future river management in view of the emerging alterations in the flow patterns due to global warming and climate change.

11.2 CONTROVERSIAL DAMS

There are almost 1000 structures and systems in the Ganga basin that significantly affect the flows of the rivers in the basin. They include 784 dams, 66 barrages, 92 weirs and

45 functional lift schemes (Mohan V., 2018). Assuming that the total river length of all the streams in the basin is about 25,000 to 30, 000 km, if these flow impediments were uniformly distributed, there would be one structure every 25 to 30 km of river length! Hundreds more are on the drawing board.

Dams and barrages are constructed to meet human needs and economic growth. But they also have serious negative environmental and social costs across their life-cycles. Some of the critical impacts are listed in Table 48, below :

Table 48 : Life-Cycle Environmental And Social Impacts Of Dams And Barrages

ACTIVITY		IMPACT
I. Pre-Project Construction		
1.	Land acquisition	• Land acquisition (displacement, loss of lands, homes, and livelihoods)
2.	Construction of approach roads	• Deforestation (loss of tree cover, access to CPRs, soil erosion and landslides, loss of flora and fauna, changes in micro-climate) • Disposal of debris and earth (loss of trees, river water pollution)
3.	Construction of housing for staff and labour	• Deforestation • Pollution due to sewage releases
4.	Quarrying, blasting	• Noise pollution, slopes destabilization, disruption of underground seepages and damage to buildings
II. Project Construction		
5.	Tunneling, blasting	• Air and noise pollution, destabilization of slopes, damage to buildings, disturbing wildlife, drying of springs, disposal of muck into the river, psychological trauma to people and animals due to the repeated blasts
6.	Dam/barrage construction	• Disruption of river flows (biotic changes, disruption of natural functions, e.g., sediments transport, land shaping, nutrient cycling), river pollution, loss of aesthetic, cultural, economic and recreational values • Using blasted material, landslide debris in various aspects of construction • Disposal of muck in sensitive zones
III. Project Operation		
7.	Seepage from canals	• Water-logging and salinization
8.	Testing of tunnels	• Slope destabilization (loss of tree cover, land, livelihoods, water sources and access to CPRs)

9.	Water storage and release	• Altered river flows
		• Sedimentation (effect on river water quality), scouring of river bed • Severe bio-diversity disruptions • Secondary effects (increase in emission of greenhouse gases, warming of valleys, melting of glaciers, increased earthquake risks, floods, downstream urban and industrial development pollution due to runoff from agricultural fields) • Destabilization of slopes along the perimeter of storage reservoirs due to the draw-down effect • Major changes in cropping patterns leaning towards water intensive mono crops like paddy, sugarcane, cotton, etc. at the cost of traditional multi-cropping • Leaching of soil nutrients and increased dependence on synthetic fertilizers, pesticides, etc. • Major impacts on monsoon period flows and drying of aquifers downstream impacting later the aquifer fed base flows • Major unnatural diurnal flow variations resulting from hydropower dam releases for peaking power, impacting both aquatic life and dependent livelihoods and often leading to accidents involving loss of life
10.	Laying of Power Lines (HEPs)	• Deforestation (loss of wild life habitat), soil erosion

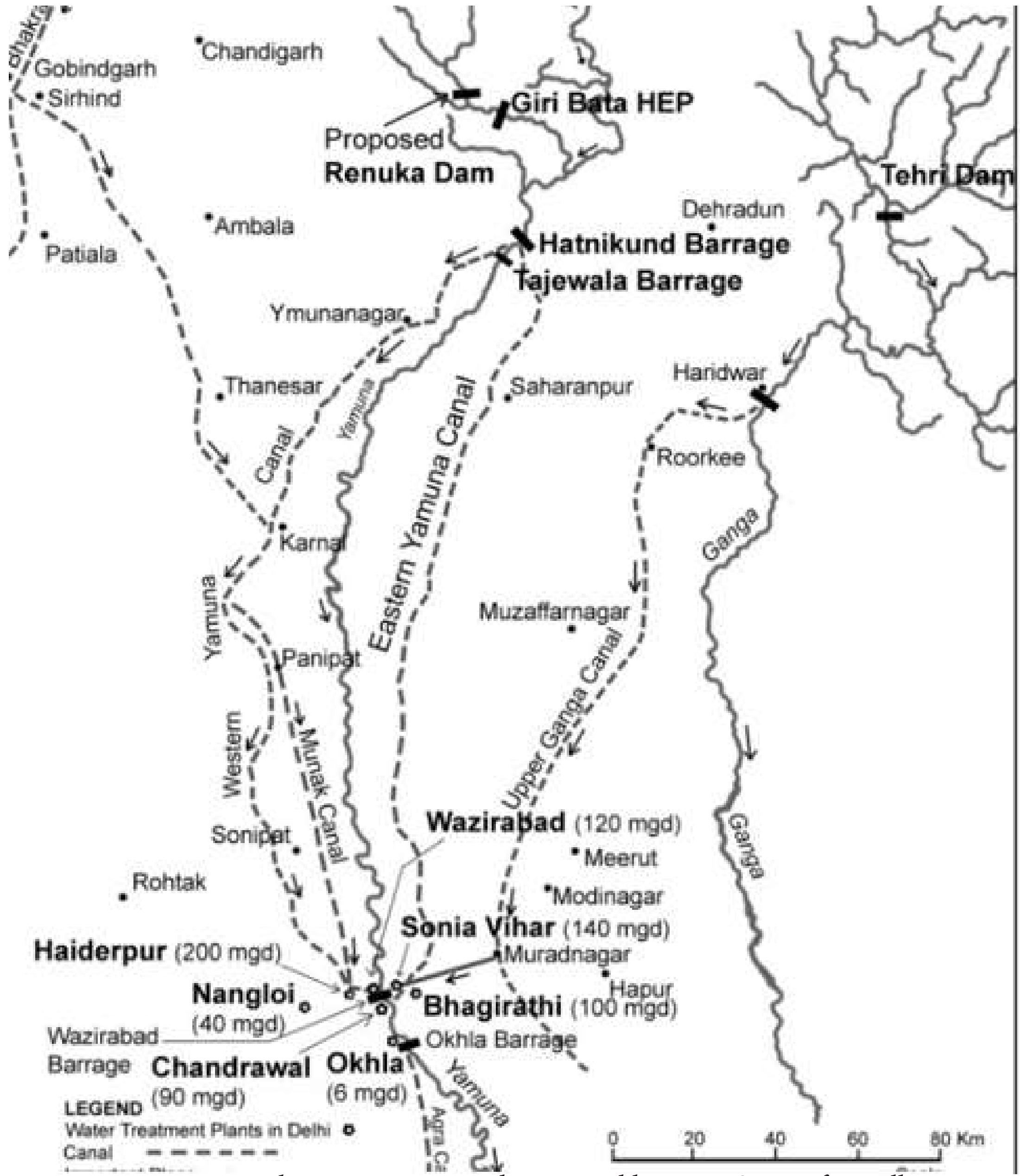
Source: Modified from EB Report, 2014, p.33.

The impacts of hydropower projects are hard to mitigate. They can result in permanent scarring of nature and society. Many of them are not even seen or felt immediately. They emerge over time. Thus, dams and barrages are hotly contested projects all over the world today.

Much has been written about the dams and barrages in the Ganga basin, such as the Tehri dam or the HEPs in the Upper Ganga basin in Uttarakhand (MoEF, 2014). This section focuses on five recent controversial HEPs, i.e., Renuka dam (R. Giri), Kishau HEP (R. Tons), Lakhwar and Vyasi HEPs (R. Yamuna) and the Pancheshwar multi-purpose project (R. Kali aka Mahakali).

11.2.1 Renuka Dam: Who really wants it?

A 40 MW Renuka dam project, on the confluence of the Giri and Jogar ka Khala, was first conceived in the 1960s by the State Government. The current project developer is Himachal



Map 39 : - Renuka Dam is proposed as a Potable Water Source for Delhi

Source - SANDRP

Pradesh Power Corporation Ltd (HPPCL), the state's electricity generation body. Renuka dam was one of two hydropower projects to be built on R. Giri in Sirmaur district of Himachal Pradesh. The 60MW Giri HEP, downstream of the Renuka dam, was commissioned in 1978.

In 1994, in order to make the project economically more viable, the Renuka dam project was reconceived as a 148 m high dam and a reservoir stretching for 24 km, to supply 23 cumecs of drinking water to Delhi, in addition to generating 40 MW of power. It would also help generate 93.83 MU additional power from the 60 MW Giri-Bata HEP further downstream (Asher M., 2017).

Yet, in November, 2015 Kapil Mishra, then Minister for Environment in the Delhi State Government, told an audience at the India Rivers Day fuction that Delhi did not require any more water from external sources such as the Renuka dam or the Sharda Yamuna River link (HT, 2015). The Draft Water Policy for Delhi, framed by the Delhi Jal Board stated, "The construction of large reservoir dams like the Renuka Project is not only planned without any assessment of options, it also runs contrary to the stated objectives of the reviving and preserving of the Yamuna river system" (Dutta R., 2015).

Environmental Concerns And Social Protests

In 2005, the National Wildlife Board and later (2006) the Supreme Court cleared the diversion of the protected area subject to certain conditions. In October, 2009, MoEF gave the Renuka dam project Environmental Clearance (EC).

In the EC letter MoEF (MoEF, 2009) noted, "The total land requirement is about 1477.78 ha. Out of which 901 ha. is forest land & 576.78 ha. is private land. Out of total land 1197.60 ha (761.60 ha. forest land + 436 ha private land) will be submerged. Around 49 ha. of Renuka Wildlife Sanctuary will be submerged. The Supreme Court has accorded approval on 17.11.2006 for diversion of forest land. Thirty-two (32) villages consisting of 308 families are likely to be affected due to this project. Out of 32 villages, people from 24 villages will lose their land." It also said, "Prior approval under Forest (Conservation) Act, 1980 for diversion of forest land should be taken. No physical work will be initiated without forest clearance for this project." Against the original project cost estimate of Rs 1284 crores, MoEF cited a total project cost of Rs.2687.33 cr and a completion time of six years.

Despite these clearances, the project generated protests and remained mired in controversies. The EC was challenged by the local people in the National Green Tribunal, saying that it was based on insufficient assessment of impact on local ecology, inaccurate data, low estimates of the amount of land that would be submerged and the absence of any social impact assessment. They estimated that the total agricultural land to be diverted for this project was 1,231 hectares in the 32 villages (Asher M., 2017). The Giri valley is well known for its ginger production. Though cash crops like ginger, garlic, tomatoes and peas are common, subsistence agriculture based on maize and wheat cultivation and livestock rearing dominates the largely agrarian rural economy.

The ecologically important Renukaji lake, recognized as a Ramsar site in 2005, is located close to the proposed dam site. It also has religious importance for local communities and beyond. The lake is already under threat as siltation is shrinking its size.

Image 28 : An Early Protest by Local People and Environmental Organisations in Renuka Valley

Source - Sumit Mahar

Dutta (2015) describes the freshwater fish assemblage in the Giri River as having a high level of endemicity, richness and diversity. He cites an excerpt from the project's EIA Report which states, "Most common and predominant fish present in the catch was endemic golden mahseer (*Tor spp*) followed by other fishes including *Schizothorax spp., Barilius spp., Channa spp., Glyptothorax spp, Bagariusspp, Puntius spp* and *Mastecemblus spp* (Plates 6.16-6.18). All are endemic species and no exotic species were recorded in the river." Sustenance of the Golden Mahseer's abundance in this stretch of the Giri River is critical as it is classified as an endangered species in the IUCN Red list because of its declining population. But the EIA report glibly claims, "None of the fish species recorded from the study area are listed in various schedules of the Indian Wildlife (Protection) Act 1972 or listed in the IUCN Red List as Threatened Animals (2006)."

Another controversial aspect of the project was the invocation of Section 17-4 of the Land Acquisition Act of 1894, which enabled the government to seize land for the dam and make compensations later (ICTA, 2019). Since its invocation, the affected families launched protests to get fair and adequate compensation.

Citing an earlier clearance granted by the Supreme Court, in February, 2016 the NGT rejected the petition to quash the EC granted to the project by MoEF in 2009. In its judgement, the NGT observed, "It is seen from the records that there has been inconsistent and contradictory disclosure of the land requirement for the project from the stage of submission of the application for ToR, to the stage of granting of the environment clearance" (Kohli K., 2016) and added, "In such circumstances, it can only be found that the appraisal of the project was not sufficient." It, however, constituted an experts' panel to study environmental aspects and the rehabilitation policy of the project.

Rising social and economic costs

In January, 2016 the State Government (Himachal Pradesh) requested the Central Government for the release of Rs 1981.35 cr to meet the costs of rehabilitating the people whose lands were acquired. After a commitment to the Supreme Court in August, 2016, the Central Government released Rs 446.96 cr to the state in October, 2016 to pay compensation for the land acquired. Thereafter, even while the final project approval was pending with the Central Government, the land acquisition process began. By April, 2017 only some ten villages were left to be paid the compensation money (Asher M and Mahar S., 2017). In a region with a largely spartan economy, monetary compensation has been a big allurement for many men to part with their land. But with their fields and forests gone, women in the affected villages are worried about their families' future, notwithstanding the monetary compensation. The landed class among the affected, who have alternate lands and livelihoods, will benefit the most.

According to documents drawn up by HPPCL, 149 families will lose their homesteads and be rendered landless by the dam. Against 135 ha to be purchased for the dispossessed families only 35 ha had been identified by April, 2017 (Asher M and Mahar S., 2017). Many of these resettlement locations were unacceptable to the displaced families. Dalit and Nepali families who have been tilling fields here for decades as share-croppers stand to lose their livelihoods.

In January, 2019, six north Indian states – Himachal, Haryana, Uttar Pradesh, Uttarakhand, Rajasthan and Delhi -- signed a memorandum of understanding to construct the dam and share the benefits. In December, 2019 the technical advisory committee of the Ministry of Water Resources, River Development and Ganga Rejuvenation, approved the Renuka dam project proposal for ₹6,946.99 cr. Ninety per cent cost of the irrigation and drinking water costs of the project will be borne by the Central Government and the rest by the six states. Towards the end of 2021, the Renuka Dam National Project, received the final approval from the Central Government at the cost of Rs 6946.99 cr (Anon, 2021a).

11.2.2 The Kishau Hep: A Project In Limbo For Almost 60 Years

The Kishau Multipurpose Project is a 236m high concrete gravity dam proposed on the Tons River, the main tributary of R. Yamuna in Uttarakhand. Its site straddles the Himachal Pradesh and Uttarakhand border. Its primary purpose is power generation, irrigation and domestic water supply in downstream states. With a live storage of 1324 MCM, the dam has a potential to irrigate around 97000 ha and generate 660 MW power (Anon, 2020). The project was stalled for 12 years as a result of differences between Himachal and Uttarakhand over water sharing. In 2013, the Centre agreed to bear 90% of the cost estimated at Rs 7193cr at 2010 prices (ET, 2013). It is expected to be completed by March 2028 (UJVNL, Undated).

A cost-benefit analysis of this project for both the states suggests that in the long run the project could become unfeasible for Himachal Pradesh. The state will not get any share of water for irrigation and will be provided with only 50 % of power. Himachal Pradesh will also lose 177 hectare of cultivated land and 1321 hectares of forest land, resulting in displacement of hundreds of families and wildlife. This has caused lot of friction between the governments of both the states. The signing of an MoU between the state governments for this project was repeatedly postponed though the states had agreed to the project's terms (Singh R.S., 2019).

If the Pancheshwar dam is built, the Kishau dam will become the third highest dam in Uttarakhand (and India) after Pancheshwar and Tehri dams. The Kishau's submergence area of 2950 ha will be about 75 per cent that of the Tehri dam. It will directly impact 5498 people belonging to the Jaunsar Bawar region of Dehradun district. The latter is a Schedule-V area and all large projects here require the formal consent of the *gram sabhas*. These villagers have strong religious, cultural and economic ties with the forests. Agriculture and animal husbandry being the main source of income, the villagers stand to suffer massive economic and cultural deprivation (Himdhara, 2018).

The submergence area includes 512 ha cultivated private land and 2438 ha forest land (Anon, 2018a). Roughly 15 lakh trees will be felled, a huge biodiversity loss that will disrupt the forest-based livelihood and food systems of the region (Bhandari P. and Thakur K., Undated).

The technical feasibility and safety of the dam is questionable, as it lies in close proximity of the Tons thrust. The thrust forms a tectonic boundary between two geological formations, the Krol nappe and the Simla Group of rocks. In the Himalayan region, areas proximate to thrusts are extremely vulnerable to landslides. Frequent movements along the thrusts, have pulverized, fractured and crumpled the local rocks, making them vulnerable to slope failures, especially during the monsoon months (MoEF, 2014, p.62). Researchers have observed a large number of active landslides in the area.

The impoundment of four huge dams - Tehri, Lakhwar, Kishau and Renuka in almost parallel and nearby valleys of the Himalayan region is going to put a huge geological stress on the mountains. The destabilization of slopes witnessed along the perimeter of the Tehri reservoir due to the draw-down effect of the annual raising and lowering of the water levels in the reservoir, has been ignored (MoEF, 2014, pp. 66-68). In addition, the reservoir pressure in the fragile area, can cause reservoir induced seismicity (Srivastava V. et al, 2015).

The Kishau dam was originally conceived in 1940 (Bhandari P. and Thakur K., Undated). It was actively pursued after 1963 as part of a plan to develop the Upper Yamuna basin. The start of construction was, however, repeatedly delayed due to different reasons each time, such as its location in a seismically active region, disagreement among the potentially benefitting states, paucity of funds, local opposition. Each reason is good enough to abandon the project. Given the absence of any popular demand for the construction of the HEP, the persistence of the concerned governments is hard to understand.

11.2.3 The Lakhwar-Vyasi Multi-Purpose Project

The Lakhwar-Vyasi twin HEPs were originally conceived in 1976 as one multipurpose project on the Yamuna River in western Dehradun district in Uttarakhand. It included the Lakhwar HEP (300 MW) meant to be a peaking power station to help meet high power demands, the 120 MW Vyasi HEP about 5 km downstream with its surface power station at Hathiari and the Katapathar barrage another 2.75 km downstream from Hathiari. The main purpose of the three structures was to generate 927 MU hydroelectricity and irrigate

Image 29 : A large Landslide at the Proposed Lakhwar Dam Site

Source - Bhim Singh Rawat

almost 34,000 ha, mostly in western Uttar Pradesh (UJVNL, Undated). The entire project will impound 580 MCM of water during the rainy season. It will release over 78 MCM to meet the domestic and industrial water needs of Uttarakhand, Uttar Pradesh, Haryana, Rajasthan, Himachal Pradesh and Delhi (Nandi J. and Pillai S., 2021). The Delhi Jal Board, however, had earlier announced efforts to reduce the city's dependence on the Yamuna River (See Section 11.2.1 on the Renuka dam).

Though construction work began in 1987, the projects suffered enormous delays, first due to lack of funds and later due to inadequate environmental clearances. Construction work resumed at the Vyasi HEP in 2014. The UJVNL website states that the Lakhwar project will be completed six years after its construction begins. The cost of the Lakhwar and Vyasi projects is now estimated at Rs 7524 cr (UJVNL, Undated).

Around 50% of the land to be submerged by the Lakhwar-Vyasi project is forest land (Nandi J. and Pillai S., 2021), rich in floral and faunal diversity. The livelihood of all 32 villages in the region is predominantly dependent on forest-based agriculture or animal husbandry. Experts have highlighted several violations of forest clearances given to the project in the past. The biodiversity and associated ecological balance have changed significantly in the last three decades, rendering the limited older clearances outdated. Continuing climate change is causing changes in the rainfall pattern, landslides, flashfloods, glacial melt and increased peak flood profiles. All these factors needed to be reconsidered while assessing the projects' environment impact.

The break in the natural river flow will immensely impact its aquatic life. The golden mahseer (*Tor putitora*), once common across the Himalayas, is now listed as an endangered species in the IUCN Red List. Adrian Pinder of Bournemouth University and the director of the Mahseer Trust says, "The ongoing dam construction throughout the Himalayas is systematically chipping away at the Mahseer's habitat by preventing the movement of this long-range migratory species to critical spawning habitats in tributary streams with the potential to extirpate local populations" (Dutt B., 2020).

Lakhwar HEP

The Lakhwar dam is the biggest high dam on river Yamuna. It has a 22 km long reservoir across Dehradun and Uttarkashi districts. The project has been stalled for over three decades primarily due to environmental and geological factors. The local people and environmentalists have raised a number of serious social, geological and ecological concerns. In January, 2019, after hearing a petition filed before it, the National Green Tribunal directed the EAC to reappraise the Lakhwar project in terms of the EIA notification of 2006 and impose additional general and specific conditions as necessary.

A major geological concern is the instability of the mountain slopes around the dam sites. Several researchers and the local people have highlighted that it is a seismically active area and the valley's proneness to flash floods enhances the threats of toe-erosion and landslides. A large landslide on the right bank of the river was documented at the site of the Lakhwar dam (Rawat B.S., 2019). The local people say that many of the landslides at and around the location have become perennial.

Manoj Mishra a retired IFS officer and convenor of the Yamuna Jiye Abhiyan, strongly believes that, the dam is a future hazard for Delhi. He argues that in the event of a dam break at Lakhwar, Delhi will be submerged. The intensity of water gushing from a height of the 204m high dam will be tremendous. Unlike cities like Panipat, Sonepat, Karnal etc. which are a few kilometers away from the river, Delhi is sprawled by the river banks and may not have enough time to take safety measures (Nandi J. and Pillai S., 2021). Mishra also adds that holding the Yamuna's water during the monsoons may hinder the natural aquifers' rejuvenation downstream. This could lead to water shortages and drought-like situations. Dam authorities, however, simply brush aside these concerns.

The life of the villagers residing in the submergence zone has been heavily impacted by the lack of development of basic facilities like water and power supply and roads since the dams were planned. In Kona village, just 1 km upstream of the dam site, villagers have to climb 2 km uphill to access transportation for the nearby market. Their development has been totally ignored for the last three decades. The compensation provided to them is far from being adequate to sustain themselves (Rawat B.S., 2019).

In December, 2020, MoEFCC's expert appraisal committee (EAC) recommended the 300MW Lakhwar HEP for environmental clearance. The NGT and MoEFCC followed up quickly with a green signal on February 2, 2021. The finance committee of the Jal Shakti Ministry gave approval for the budget of Rs 5747 cr on September 22, 2021. Ninety per cent of the cost will be met by the Centre, while the beneficiary states will provide the remaining ten per cent (Azad S., 2021). In December, 2021, the Union Government gave the final clearance for the Lakhwar HEP (Anon, 2021b).

Image 30 : Vehicles, Machines Flooded at the Vyasi HEP Power Station

Source - Bhim Singh Rawat

The green signal by the MoEFCC was contested at the NGT and the NGT vide its order dated 20.01.2022 constituted an Expert Committee to advise it on various issues before it takes a final decision on it.

Vyasi HEP

The 120 MW Vyasi HEP, presently under-construction, is the first major HEP being built on the main stem of the Yamuna River in the Upper Yamuna Himalayan basin. Originally a part of the 420 MW Lakhwar-Vyasi Multipurpose Project, the 86 m high Vyasi dam diverts the flow of the Yamuna into a 2.7 km long tunnel and drops the water into the power house at Hathiari village. The project is located in a landslide prone, seismic region.

Image 31 : Yamuna Ghati (Lakhwar-Vyasi) Bandh Prabhavit Samiti, Lohari Residents, Demanding Promised Rehabilitation and Compensation

Source - Social Media

Around 30 percent of the Vyasi HEP was said to have been completed during the 1990s. In 2007, the Uttarakhand state government re-allotted the project to the state-owned generating company Uttarakhand Jal Vidyut Nigam Ltd (UJVNL) for completion. UJVNL started the construction work on the project in 2014 with an estimated budget of Rs. 950 crore and a completion target of December, 2018. The current projected completion date is 2022-23 and the construction cost has escalated to Rs. 1777.30 crore (Rawat B.S., 2021).

During construction, there have been complaints of the developer dumping muck along and in the river and excessively mining the riverbed in the project area among other violations. Muck dumping upstream has not only polluted the river, but the dust swirling around has degraded the air quality around the Vyasi dam. According to local residents, particulate matter from the muck dumped along the banks is picked up by high-speed winds in the valley and suspended in the air, polluting it and impacting their health (Rawat B.S. 2019). However, in the absence of adequate compliance monitoring mechanism in India's environment and hydro sector, UJVNL has managed to escape accountability for the violations.

The unpreparedness of the project in coping with existing and emerging disasters was highlighted during intense rainfall in the area on August 25-27, 2021 (Rawat B.S., 2021). A deluge after a series of about seven cloud burst events in quick succession in western Dehradun district, affected the under construction Vyasi HEP. The power station area at Hathyari was flooded with muck and debris damaging or burying several vehicles and machines.

Rajiv Agarwal, Executive Director, Vyasi HEP, UJVNL told SANDRP that Early Warning System (EWS) had not been installed at the project. Since the Vyasi HEP is the first major project on the Yamuna, it often faces the threat of extreme rainfall leading to flash floods. A break in the massive Lakhwar dam a few kilometres upstream from it could demolish the Vyasi HEP.

Residents of Lohari village, upstream of the dam at Vyasi, sat on a *dharna* from June 5, 2021 demanding adequate rehabilitation for their lands that were acquired for the project. On October 2nd, Mahatma Gandhi's birth anniversary, district and police officers removed them from the site and arrested 17 persons for 14 days, indicating that the government was pushing ahead with the project. The next day hundreds of villagers joined a protest march against the project led by the leader of the opposition in the state assembly. They were arrested and released at the end of the day.

Lakhwar and Vyasi are just two of many projects proposed in the upper Yamuna valley. **There has been no cumulative impact assessment of this cluster of projects**. "The Lakhwar HEP is a part of a larger composite development of the upper Yamuna stretch. This lack of a basic (river) management plan is a disastrous consequence of allowing projects based on outdated clearances," says Himanshu Thakkar of South Asia Network on Dams, Rivers & People (SANDRP).

11.2.4 The Pancheshwar Multipurpose Project (PMP)

The Pancheshwar Multipurpose Project (PMP) is presently the most controversial HEP in India's Upper Ganga Basin (UGB). It is a bi-national project since much of the Kali's (Mahakali in Nepal) Himalayan stretch forms a boundary between India and Nepal. This hydropower-cum-irrigation project is a joint venture between the governments of Nepal and India, one of a series of projects planned by the two countries in the Mahakali basin. It was first conceptualized in 1961 and its pre-feasibility was done in 1971 (Everard M. and Kataria G., 2010). The PMP was formally agreed to in the Mahakali treaty, signed in 1996. But 25 years later, the DPR of the project is yet to be finalized (DoWR, 2020).

The project has been stalled due to objections by Nepal over water and electricity sharing as detailed in the Treaty and following political unrest there. It was re-invigorated in 2014 following the visit of the Indian Prime Minister, Shri Narendra Modi, to Nepal and the formation of the Pancheshwar Development Authority (PDA). Despite opposition from local communities and other concerned citizens, the Government of India is trying to push ahead with the project ignoring significant evidence that it is economically unviable, socially disruptive and an ecological hazard.

Technical specifications

The main Pancheshwar dam is located near the Pancheshwar temple, about 2.5 km downstream of the confluence of the Saryu and the Mahakali rivers. At 311 m, it will be the world's second highest dam, after the 335 m high Rogun dam in Russia (Everard M. and Kataria G., 2010). A second 95 m high re-regulating dam, at Rupaligad 27 km downstream, is also planned as a part of the project. Its purpose is to reduce flow variations due to the main dam releases and to maintain continuous river flow.

The installed capacity of the PMP is 5040 MW -- 4800 MW at Pancheshwar dam and 240 MW from Rupaligad station (PDA, 2017). It will be the largest HEP in South Asia. Its reservoir has a capacity of 11.35 BCM and covers an area of 11,600 ha (116 km^2). According to the Environmental Impact Assessment, the PMP has an irrigation potential of over 70,000 ha in Nepal and 259, 000 ha in India. The original cost of the project was estimated at INR 33,108 crores. Of this India was to bear 65%. By January, 2017 it had climbed to Rs 40,184 cr, but it was expected to reach Rs. 500 billion (Rs 50,000 crore) by the start of the project (Aggarwal M., 2018).

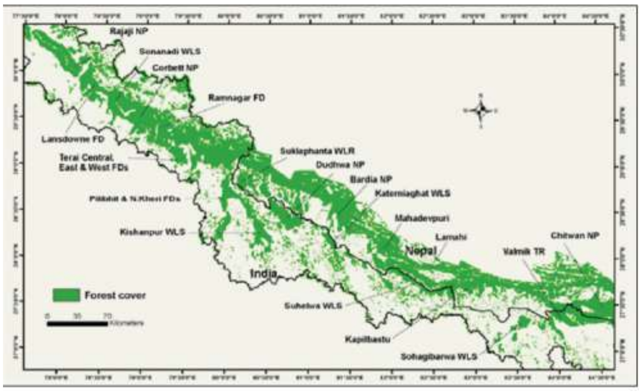
Major Concerns

Local people, experts and activists have raised a variety of concerns about the likely impacts of the PMP project. These are outlined below.

Geological Issues

- The project is located in Zone IV of India's seismic zonation map. Several currently active faults around the proposed site increase the seismic hazard (Sati S.P. et al, 2019).

The seismically active North Almora Thrust (NAT) passes 5 km north of the dam site, whereas the South Almora Thrust lies ~20 km south of the dam. Two major earthquakes have occurred in the area in recent history, of magnitude 6.5 in 1980 and magnitude 7.5 at Lohaghat in 1833, barely 15 km from the site of the project (Thakkar H., 2018). Between 1992 and 2006, multiple earthquakes measuring over 5 on the Richter scale have been recorded within a 10 km radius of the proposed site (Everard M. and Kataria G., 2010).



Map 40 : The Terai Arc Landscape

Source - Maurya K. and Borah J.

- The Pancheshwar reservoir will extend over the NAT and thereby increase the probability of Reservoir Induced Seismicity (RIS).
- The geology of the PMP region is very similar to the area where the Tehri dam is located. The latter is also very close to the NAT.
- In a storage dam, like the proposed Pancheshwar dam, the colluvium-laden slopes around the reservoir become super-saturated during the high reservoir level. As water is withdrawn from the reservoir, water seeps out of the slope, along with the colluvium grains back into the reservoir, causing land subsidence and ground fissuring. The perimeter of the Tehri reservoir is riddled with fresh landslides and ground fissures indicating that the slopes are still adjusting to a new equilibrium angle of repose. This may take a long time in the tectonically active region of the PMP (Sati S.P. et al, 2019). Such slope instability effects may require relocation of threatened villages after the project has been commissioned.

Environmental Impacts

- It is feared that the PMP will radically alter the Mahakali River, in terms of daily flows volumes, seasonal rhythms and connectivity, serious upstream and downstream environmental impacts far beyond the impoundment, or a 10 km terrestrial periphery (Mahakali Lok Sangathan, 2018).
- The flood control objective of the PMP threatens the rare fauna of the Terai Arc Landscape, a transboundary network of 14 protected areas (PAs) in the Terai regions of India and Nepal (See Map 11.4). Spread across 5 Mha this conservation unit sustains some of the most endangered wildlife like tigers, rhinos, elephants, the gharial and mugger crocodiles, the Barasingha or Swamp deer and the hispid hare, among many others. The 300 sq. km. Shuklaphanta Wildlife Reserve has 424 bird species, including the very rare Bengal Florican, the Swamp Francolin and the Grass Owl. These fauna of the riparian marshland and grassland savannah are threatened with

extinction because the biomass productivity of the marshes, swamps and grasslands is completely dependent on the monsoonal floods in the Mahakali River. Floods also provide hydrological connectivity and seasonal isolation for these animals to breed.

- About 4687 ha of forest land — reserved, protected and *van panchayat* forests – will be submerged. It will drastically reduce the connectivity between the forests of the Terai Arc PAs. More forests will be diverted for "relocation" of displaced families in the Terai, a crucial habitat for the endangered wildlife. Two wildlife sanctuaries are located at the head and toe of the proposed project area. The Askot WLS is barely 300 m from the tip of the submergence area in Pithoragarh district. It is home to several endangered species like the Himalayan musk deer, snow leopard, Assamese macaque and now probably the tiger. The Nandhaur WLS to the south, is just 10 km away from the re-regulating dam at Rupaligad. Leopard, small prey including jackal and small deer, all the three species of otter found in India, i.e., the Eurasian otter, the smooth-coated otter and the small-clawed otter are often sighted in the project area.
- Natural flow variability of the Mahakali is critical for fish in the river. The Mahakali is home to 124 species of fish (Mahakali Lok Sangathan, 2018). Its confluence with the Saryu at Pancheshwar is famous for its mahseer, where large golden mahseer weighing up to as much as 50 pounds (22.7 kg) are still caught. Angling and wildlife tourism contribute substantially to the local economy.

Social Impact

- The social, cultural and livelihoods impacts of the PMP will be colossal. Close to 250 villages will be directly impacted in both the countries; 9100 ha of land in Uttarakhand and 6000 ha in Nepal will be acquired for this project. About 31,023 families will be affected in Pithoragarh, Almora and Champawat districts of Uttarakhand. The Nepal EIA estimates 41,330 people will be displaced as a direct result of the project, the number of those indirectly affected is likely to be much higher.
- The Social Impact Assessment report proposes a Rs 9000 cr rehabilitation plan. It reveals that 3735 hectares of agricultural land will be acquired at a compensation of Rs. 6000 cr. Almost 84 per cent of these funds will benefit only 23 per cent of the affected villages since the circle rates vary hugely from village-to-village. The dependence on forests and livestock rearing has not been assessed and there is no land-for-land provision.
- The number of displaced persons in Uttarakhand will be higher than due to the Tehri project. That experience was one of delays, corruption and conflicts.
- The EIA reports do not mention the primitive tribal group, van rajis or van rawats, who have been co-existing with the area's forests for centuries.
- Forests are critical for protecting the Himalayan environment. They also provide many provisioning services for the local communities, including fuelwood and fodder – leaf litter, medicinal plants, oil, wood for agricultural implements and housing, etc. Though the counting is yet to be done it is estimated that more than 5 lakh trees will be impacted by the submergence and deforestation.

- The region has several culturally significant, historic and religious worship places like the famous Pancheshwar and Rameshwar temples besides several sacred groves.

Environment Impact Assessment Studies

A report prepared for the Institution of Environmental Sciences, a London-based professional body, found that the net ecosystem services provided by the PMP failed all seven strategic priorities identified by the UN's World Commission on Dams (WCD). The latter is meant to guide more sustainable and equitable water resource development. The Pancheshwar proposals and process, "therefore cannot be assumed to be sustainable, fair or economically sound" concluded the report (Everard M. and Kataria G., 2010).

The project EIA was conducted by WAPCOS, a Ministry of Jal Shakti (MoJS, GoI) entity, instead of by an independent third party. WAPCOS, far from being an independent impartial entity, has been involved with the project since 1961. On the Nepal side too, the EIA was conducted by the Department of Electricity Development, the main Nepalese proponent of the project. A joint mechanism for the EIA and SIA studies would have been better. Public hearings were timed during the rains so many affected families could not attend them. There have been reports of violations of the Forests Rights Act by district authorities in the process of obtaining No Objection Certificates (Aggarwal M., 2018).

The environment and social impact assessment studies conducted by WAPCOS do not contain all the information they are legally required to have. They do not provide enough baseline information on the basic aspects like demography, ecology, geology and socio-economic. The EIA misses out major topics such as a disaster assessment of the project area despite the concerns of earthquakes and reservoir induced slope failures. Landslide hazard assessment was not done for the reservoir area. It also fails to take into account climate change related uncertainties, both in terms of disaster potential and future viability of the dams. Several basic factual errors have been pointed out in the EIA document, raising questions about its credibility. The map of the project region displayed on the WAPCOS website is grossly inaccurate (Thakkar H., 2018). The PMP project requires environment, forest and wildlife clearances from the MoEFCC but they have not been secured so far. The Social Impact Assessment (SIA) has not assessed the local people's dependence on forests and livestock rearing, which will be seriously affected by the loss of forests.

Economic Viability

The economic viability of the PMP has been questioned by civil society and academicians. The highly likely ecosystems' destruction and the loss of many associated ecosystem services supporting the livelihoods of thousands of families, will result in substantial costs which are not considered in terms of mitigation, compensation or the retrospective price of damage. The issue of the primitive *van rajis* tribe mentioned earlier, could lead to compensation costs. Although the planned life of the project is 100 years, it has been speculated by scientists that the actual life may be close to 25 years due to the heavy silt load of the Mahakali River. It is most likely that above the inundation level, landslides will increase around the reservoir due to the 'draw-down effect', as experienced around the Tehri reservoir (Kumar B., 2007). Estimates made by SANDRP have shown that the power generated by the project will be far more expensive than the prevailing solar power price, which is much lower.

Conclusion

It has been mentioned earlier that PMP is the centrepiece of the Mahakali Treaty which was signed by India and Nepal in 1996. Twenty-five years later, however, the DPR of the project which was prepared in 2016 is still to be finalized.

Since its inception, the Mahakali Treaty has been strongly criticized in Nepal as a sell-out to India. In 1999, Dipak Gyawali and Ajaymani Dixit two well-known Nepali water experts charged the ruling leadership with signing and pushing the Treaty through the Nepali Parliament in extreme haste (Gyawali D. and Dixit A., 1999). Gyawali, a hydropower engineer and economist, was Nepal's Minister for Water Resources in 2002-03.

The controversies in Nepal apparently revolve around:

1. A perceived Indian strategy to legitimize its unilateral construction of the Tanakpur barrage;
2. Interpretation of the Treaty's Article concerning equal entitlement to water; and
3. The extent of existing irrigation use on the Indian side and its direct implication on benefit assessment and proportional cost sharing (Bagale D.R. and Adhikari K.D., 2020).

To anyone familiar with Indo-Nepal water negotiations, the delay and the controversies are not surprising. One only has to look at the history of the negotiations over the proposed Barakshetra Dam to be built in Nepal on River Kosi to provide a flood cushion and with irrigation and power generation for India and Nepal. The proposal was first mooted in 1937. Sixty years later, in 1997, an agreement was reached to prepare its DPR. An Indian team worked on preparing it till 2004 when it was replaced by a joint Indo-Nepal team. That DPR still awaits finalization!

Given the above history, and the escalating costs, it appears nearly impossible that the Pancheshwar Multipurpose Project will be completed in the near future or if ever.

11.3 FARAKKA BARRAGE

To call Farakka Barrage, a barrage, is misleading. It is a large dam according to the International Commission on Large Dams (ICOLD), World Commission on Dams (WCD) and Central Water Commission(CWC) definitions, with associated large dimensions and impacts. Work on the Barrage first began in 1962-63. It was completed in 1971. This 2.25 kms long structure was commissioned to flush the sediments silting up the Hooghly River and make it navigable for Kolkata port and stretches further upstream. It has 112 gates, and a 38.4 km long feeder canal carrying Ganga water to the Hooghly (FBP, Undated).

The colonial rulers built Calcutta port about 140 km upstream of the mouth of the river, but it could not be approached by large vessels due to continuous sedimentation in the estuary. Britain's famous irrigation engineer, Sir Arthur Cotton, first proposed construction of the Farakka Barrage in 1853 to divert river Ganga's water to the Bhagirathi-Hooghly River.

The idea of the Farakka Barrage was revived after independence, but Kapil Bhattacharya, then a superintending engineer with the Irrigation and Waterways Directorate of West Bengal, raised objections to its plans. Kapil Bhattacharya's original critique of the barrage had three main contentions. The first was that there would not be enough water in the river to flush out the Kolkata port. The second, was that flows towards Bangladesh, then East Pakistan, would be greatly reduced. The third argument was that the barrage was not adequately designed for flood control. Consequently, it would lead to severe flooding in the upstream districts of Malda and Murshidabad and parts of Bihar through which the river flowed (Chari M., 2016). But his concerns were brushed aside, and he was forced to resign after being branded a traitor for his opposition to the project.

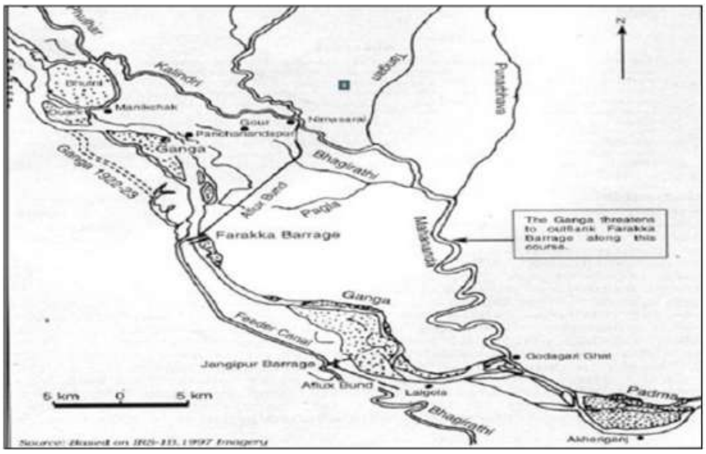
More than half-a-century later, it is apparent that Bhattacharya's concerns were correct and that the Government of India should have heeded them. River expert and Chairman West Bengal Pollution Control Board, Dr. Kalyan Rudra, says that the objective of flushing silt from the mouth of the Hooghly has been "frustrated" (Dandekar P., 2014). The freshwater added to the Hooghly is just too meagre to flush the sediments from the estuary. The Kolkata port's bulk cargo operations have shifted downstream to Haldia.

Impacts

Geomorphological Impacts

Geomorphological changes upstream and downstream of Farakka Barrage after its construction have worsened the river's ecology for India and Bangladesh. Exceptionally high sediment generation in the tectonically active Himalayan ranges and the monsoon rains in the mountain region feed the Ganga and its Himalayan tributaries with one of the highest sediments loads in the world. Estimates of the annual sediment load brought down by the Ganga at Farakka, vary between 700-800 million tons, a large portion being deposited upstream of the Barrage. "(This) is compounded by the regulation of the non-monsoon flows upstream and disruption of the longitudinal connectivity by the Farakka Barrage," adds Prof. Rajiv Sinha of IIT-Kanpur (Sinha R. 2018). This causes shifting and meandering of the river in its lower basin (LGB). Consequently, the Ganga and its tributaries are endlessly eroding land somewhere and building it elsewhere.

IIT-Kanpur researchers have recently determined that about 3000 MCM silt has accumulated between Buxar and Farakka, of which 1700 MCM may be extractable. Sediment accumulation in such huge volumes has led to major morphological changes, causing migration of rivers and unexpected floods, in several lower Ganga stretches. The Ganga has shifted several kilometres from its banks in towns like Farakka, Bhagalpur, up to Patna.



Map 41 : Location of Farkka Barrage

Source - https://slideplayer.com/slide/6615929/

The Ganga has widened enormously upstream of the Farakka Barrage due to the sediment impoundment. "When Farakka Barrage was built, the engineers did not plan for such massive silt. But it has become one of the biggest problems of the Barrage now," Dr P.K. Parua, a former General Manager of the Farakka Barrage Project (FBP), told SANDRP in an astounding admission of poor planning (Dandekar P., 2014).

Over time, the sediment settled behind the Barrage raised the river bed. Shoals formation in the Ganga and along its banks, exacerbated its natural tendency to meander and braid. The river developed an eastward meander. In the absence of proper sediment management, the river may outflank the barrage entirely and shift to a new course along the Kalindri-Mahananda channel

Land Erosion: Constant shifting of the Ganga leads to annual erosion in densely populated rural areas and flooding (See box: Raat ko zamindar, savere ko bhikari). By 2006, it had engulfed 267 km^2 of land in Malda district (Rudra K., 2010). Crores of rupees are spent every year on anti-erosion measures such as spurs, boulders and embankments that simply prove to be futile and poor investments.

The shifting nature of River Ganga and the rapid creation of shoals has resulted in conflicts between Jharkhand and West Bengal over ownership of these temporary islands. The main victims of the conflict are people whose lands have been consumed by the river and are not recognized as residents by either state. It affects their access to services such as ration cards, government schemes, education and job applications. Rehabilitation, to which the victims of Farakka are entitled, is contentious and ignored by the states and the Centre. Captain Sherwill's almost 200 years old description of the tragedy (Sherwill W., 1858) is still apt, "Islands become inhabited, cleared and cultivated; population increases, large village(s) start up, land revenue is collected for ten or twelve years; then (the) fabric will disappear within one rainy season."

Raat ko zamindar, savere ko bhikari

The Ganga's braided distributaries, before it reaches the Bay of Bengal, have historically allowed the hinterlands to trade through the bay. The river deposits a lot of its massive load of rich fertilizing Himalayan silt in these channels, often filling one and shifting to another, and enables the cultivation of rice, millet, mustard and greens.

After Independence the Indian government implemented Sir Arthur Cotton's idea of a barrage at Farakka and flushing the Hooghly to make it navigable. But there was simply not enough water in the river to push out the sediment that the tides brought back every day. Thus, the Barrage failed to make the Hooghly navigable.

The Ganga enters West Bengal downstream of Rajmahal town in Jharkhand. Here the Farakka Barrage blocks its sediments. With time the river-bed has kept rising higher and the river has kept pushing its way out through newer channels, eroding land in its path. Tarikul Islam, a jewellery store owner from Malda district, tells a visiting journalist, "Everyone in this area of West Bengal has lost everything to the river."

Source - Arati Kumar Rao

Prof. Kalyan Rudra, chairman of the West Bengal Pollution Control Board, who has studied the geomorphology of the area warns, "The mighty river even threatens to outflank the Farakka Barrage and open a new route through the presently moribund channels of Kalindri and Mahananda." The Kalindri is a dry river bed with paddy fields, while a thin Mahananda flows through Malda town. If the Barrage forces the Ganga into taking these dried paths, it could destroy NH 34 and threaten nearly four million people in Malda district. Malda has already lost about 250 sq. km of land—more than half the size of the city of Chennai—to the river. Erosion has damaged a school building on the banks of the Ganga in Murshidabad, West Bengal.

Prof. Rajiv Sinha of the Indian Institute of Technology in Kanpur, blames the neglect of the sediment loads of the Ganga and its Himalayan tributaries for this looming disaster. Prof. Rudra highlights the problem numerically: if a truck carries seven cubic meters of sediments, the number of trucks needed to dredge the Farakka Barrage could go around the equator 126 times!

The people of Malda are caught between the sediment and the eroding river. But the bureaucracy does not consider steady land erosion as a disaster worth compensating. "We lose our world," explains Tarikul, "Everything goes into the river, leaving us empty-handed. And the government does not consider this a disaster.....Raat ko zamindar, savere ko bhikari (We go to sleep as landowners and wake-up as beggars)," he says.

Instead, the government pumps crores into fortifying the banks with boulders to stem erosion. It costs over ₹ 1 lakh to protect 1m of riverbank, without any guarantee against erosion, according to Prof. Rudra. The river washes away the boulders, but the effort continues. "Often, they start this useless work in the monsoon, which is stupid. How can you work on fortifying the bank-line when the soil is already wet with rain?" asks a bewildered Tarikul.

A CAG report of March, 1999 agrees with Tarikul: "Implementation of anti-erosion scheme suffered all through from recurring weakness in planning, execution and monitoring at senior level of the Department and also the Government...... hasty execution of work, appointment of large number of small contractors and work during full monsoon in unfavourable weather condition resulted in frequent and repeated failure of the work leading to wasteful and unfruitful expenditure."

The local people and the experts agree that only the government fails to see the obvious and do what is right for the people.

Based on an article, "The nowhere people" by Arati Kumar-Rao. Her research was funded by Asia Foundation and thethirdpole.net.

The displaced often try to carve out a new place for themselves in nearby *chars* (large shoals). Their new settlement usually has poor access to basic medical facilities, sanitation, drinking water and livelihood opportunities. Such displacements have unequal impacts. The better off are able to buy land elsewhere, but most are not. The impacts are also gendered, with women bearing the greater brunt of the hardships. Among women too, the impacts are differentiated. Caste, class, education, presence of male family members, religion, age, and factors like the number of times displaced and the conditions of the displacement largely determine the degree of hardship they face. Rehabilitation strategies and policies are often insensitive to gender-related issues. They worsen the conditions created by the inequitable distribution of resources between the genders (Mukherjee J., 2011).

Biodiversity Impacts

The anadromous Indian shad, *hilsa* (*Tenualosa ilish*), is the most dominant fish in many large Indian rivers, particularly in the monsoon season, when they ascend the rivers from the sea for spawning. In river Ganga, they ascend in shoals from the Bay of Bengal through the Hooghly-Matlah estuary travelling up to 1500 km above the estuary. The collapse of the *hilsa* fisheries due to Farakka Barrage has been devastating for fisheries in the middle and upper Ganga stretches, since *hilsa* is very popular among the fish-eating populations (Mukherjee A. and Suresh V. R., 2007). Fish catch data from major landing centres upstream of the barrage (Bhagalpur, Buxar and Allahabad) also revealed a sharp decline in the fish catch post-Farakka. Fish passes built into the Barrage have not functioned.

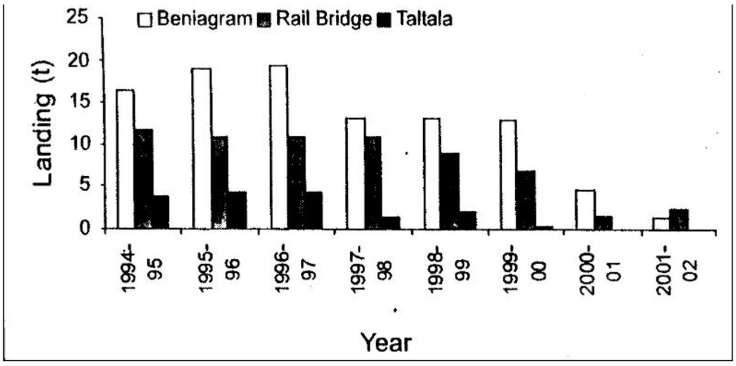


Image 32 : Hilsa Landing at Beniagram, Rail Bridge and taltala Landing Centres at Farakka

Source - Mukharjee A. and Suresh V.K., 2007

Research scientists from the Central Inland Fisheries Research Institute (CIFRI) collected annual fish landing data downstream of Farakka at Beniagram, at Farraka (Rail Bridge) and upstream of Farakka at Taltala between 1994 and 2002. The mean annual landing was maximum at Beniagram (Malda) (12.47 tons), followed by Rail Bridge (8.01 tons) and lowest at Taltala (Kolkata) (1.94 tons). The year wise landing from all these landing centers also showed a gradual declining trend (Fig. 11.5) with no *hilsa* at Taltala landing center from 2000 to 2002.

Increased freshwater inflow from the Farakka Barrage into the Hooghly River has significantly changed the salinity regime, nutrient load, suspended sediments, water transparency and the freshwater fish assemblage downstream of the barrage, according to Wildlife Institute of India (WII-GACMC, 2018, p. 90). Freshwater fish like *cheeng* (*Apocryptes bato*), *suhia* or Ganges River gizzard shad (*Goniolosa manmina*) and *rohu* (*Labeo sp*), that were earlier found only between Nabadwip and Nawabganj are now found as far south as Uluberia, indicating a 60 km southward shift of the freshwater zone (WII-GACMC, 2018, p.90).

"The Farakka Barrage not only acts as a barrier to the upstream migration of the prized *hilsa* fish, but can also have negative impacts on Ganges River dolphins, India's national aquatic animal," says Nachiket Kelkar, Member, IUCN Cetacean Specialist Group. He has referred to recent research by Imran Samad, at the National Centre for Biological Sciences-Bangalore, who has observed that the reduction in flows downstream of the barrage in the dry-season (March-April) may increase the risk of mortality of dolphins by entanglement in fishing nets.

Using satellite imagery data, Sonkar & Gaurav (2020) have determined that the Farakka Barrage has adversely affected the lower Ganga's ecosystem, leading the Gangetic River dolphin to abandon the stretches immediately upstream and downstream of the Barrage (Sonkar G.K. and Gaurav K., 2020). Changes in the river morphology, hydraulic geometry and flow conditions, appear to be the main causes for the changes in the distribution and habitation of the species.

Impacts on Indo-Bangladesh Relations

"The consequences of the Farakka barrage on southwestern Bangladesh have been devastating, driving migration into Assam and West Bengal, and inflaming ethnic conflict," argues Ashok Swain, professor of peace and conflict research at Uppsala University, Sweden, and director of the Research School for International Water Cooperation (Swain A., 2017).

Reduction of downstream flows to Bangladesh and other severe downstream impacts in Bangladesh due to Farakka Barrage have dominated diplomatic relations between the two countries. In 1996, after several decades of wrangling over this issue, the Ganges Water treaty was signed between India and Bangladesh. Essentially, it deals with the apportionment of water from Farakka Barrage. India has been given the right to extract 40,000 cusecs from the Barrage from January to May every year. If the flow of water falls below 70,000 cusecs, then both nations are entitled to equal halves of the available water, and a minimum of 35,000 cusecs for ten days alternatively from March 11th to May10th. The treaty does not contribute much to interstate river basin cooperation beyond this.

Though the Ganga Water Treaty has helped improve bilateral relations between the two countries, analysts have identified several flaws in its details. The most significant is that it relies on limited hydrological data collected between 1949 to 1988. Analysts claim that this has resulted in Bangladesh often not getting its apportioned share of Ganga waters due to increased abstraction for agriculture and other uses upstream reducing the available lean season flows. The lack of openly available Ganga flow data, which is treated as information vital to national security by India, has raised doubts about the Treaty's effectiveness.

The reduced water inflow into Bangladesh has affected its agricultural and industrial production, disrupted domestic water supply, fishing and navigation, and changed the hydraulic character of the rivers and ecology of the delta in the downstream areas (Swain A., 2017). Salt water intrusion has increased and livelihoods that depend on freshwater have been seriously curtailed. Large scale riparian tree deaths have been observed, including in the Sundarbans. Agriculture has been impacted due to changes in the river's morphological and hydrological regimes and falling groundwater tables. Bangladesh's food shortage in 1982 was attributed to the diminished flows in the river (Swain A., 1993). Swain has identified other problems including (i) reduced water flow diminishing the river's ability to cleanse decaying organic matter and agricultural and industrial run-off; (ii) nutritional deficiencies due to the sharp decline in fish availability, a staple food in Bangladesh; and (iii) less inland transport, which is highly dependent on the dense network of river channels.

Conclusion

Kolkata Port continues to decay with Haldia, further downstream, emerging as the major port for international trade. Meanwhile, the severe and unforeseen impacts of the barrage on the environment and the people of India and Bangladesh are leading to increasing demands for a review of the entire Farakka Barrage scheme.

Political opposition has come from Nitish Kumar, the long-time Chief Minister of Bihar. Speaking at a conference after the devastating flood in August, 2016, he is reported as saying that, "The current flood situation has been caused by siltation of river Ganga, ….. This situation is the result of silt getting deposited in Ganga after construction of Farakka dam. The only way to remove silt from the river is to remove the dam" (Chari, M., 2016). By targeting silt management, Nitish Kumar has highlighted the need for a new paradigm for river management which focuses on river ecosystems rather than just water.

11.4 INTERLINKING OF RIVERS

Unequal distribution of water resources in India across space and time and simultaneous droughts and floods in different parts of the country have been a matter of concern for Indian policy makers.

The Inter-Linking of Rivers Program (ILRP) has been advocated as a solution to India's regional water imbalances. The original proposal was to physically transfer monsoon flood surpluses from the Himalayan rivers to the peninsular ones. But over time the idea has undergone several changes. The ILRP has separate components for the Himalayan and peninsular rivers. Many of the links are inter-state links.

This section focuses primarily on the Himalayan links and one peninsular link – the Ken-Betwa Link which lies in the Ganga river basin.

11.4.1 Background

The idea of river linking is not new. In the 19th century, Sir Arthur Cotton, the well-known British engineer, proposed linking rivers in south India for inland navigation. This idea may also have been suggested by Bharat Ratna M. Visveswarya, India's much-honoured civil engineer (Rajendran C.P., 2017). After Independence, Captain Dinshaw Dastur, an airline pilot presented the idea of a Garland Canal – a name that caught the public's imagination. It proposed transferring Himalayan flood waters to central and southern peninsular rivers using a system of lakes and canals (See Map 43).

In 1972, a proposal by Dr. K.L. Rao, the high-profile civil engineer and Minister for Power and Irrigation in Smt. Indira Gandhi's cabinet, recommended the creation of a Ganga-Cauvery Link and a few other links (See Map 43). It was examined and rejected as being impractical due to its high energy requirement (Iyer R.R., 2002). Dr Rao had proposed pumping 20-million-acre ft. of water during the monsoon from R. Ganga to irrigate four million ha (Mha).

In 1980, India's Ministry of Irrigation and the Central Water Commission formulated a National Perspective for Water Development. It was advocated as "the greatest water development projects of the world" (NWDA, Undated). Its principal objective was to transfer water from water 'surplus' to water 'deficit' basins by building dams and canals to inter-link the major rivers. The Himalayan component included plans to construct storage reservoirs on the Ganga and Brahmaputra and their main tributaries -- in India, Bhutan and Nepal -- to transfer surplus (monsoon) flows from the eastern rivers to the western basins.

The National Perspective led to the establishment of the National Water Development Agency (NWDA) for planning the storages and transfer links. By 2015, NWDA had prepared pre-feasibility reports, feasibility reports for the 14 Himalayan links and 16 peninsular ones. Only two Detailed Project Reports (DPRs) had been completed till then (See Box: The ILRP).

The National Commission on Integrated Water Resources Development Plan (NCIWRDP) examined the initial proposals prepared by NWDA but was unable to comprehensively analyse the Himalayan links as the data for the international rivers was not given to it. Given the serious knowledge gaps concerning Himalayan rivers and the political implications of these international rivers it simply noted, "The Himalayan component would require more detailed study using systems analysis techniques" (Bandyopadhyay J. and Perveen S., 2003). On the peninsular links it said, "There seems to be no imperative necessity for massive water transfers. The assessed needs of the basins could be met from full development -- an ominous idea! --and efficient utilisation of intra-basin resources except in the case of Cauvery and Vaigai basins…" (Iyer R.R., 2002). It recommended further studies for the ILRP.

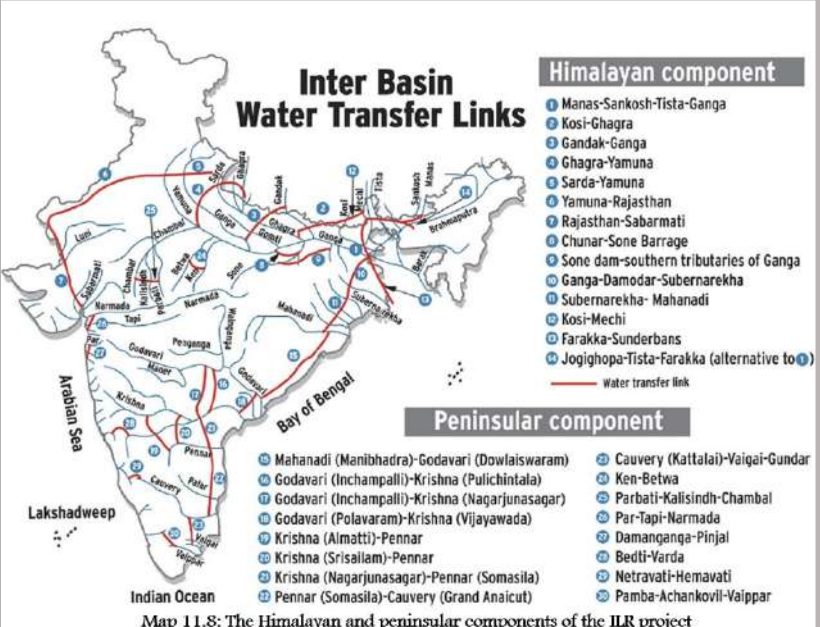
The then President of India, Dr A.P.J. Kalam, endorsed the ILRP in his pre-Independence Day speech of 2002 despite the lack of enthusiasm of the NCIWRD. Soon after, the Supreme Court expressed its support on October 31, 2002 on a lawyer's petition, recommending

The Inter-Linking of Rivers Project*

The ILRP may perhaps be the largest infrastructure project ever undertaken in the world, transferring water from 'surplus' river basins to ease the water shortages in central, western and southern India and mitigate the impacts of recurrent floods in eastern India. It proposes to build 30 links and approximately 3,000 storages to connect 37 Himalayan and Peninsular rivers to form a gigantic South Asian water grid. The canals will be wide and deep enough to facilitate the navigation of water. Complicated engineering is planned to transport water across different terrains and elevations.

The original program estimated a staggering US$123 billion investment (INR 560,000 crore at 2002 prices) to transfer 178 BCM of water /per year, build about 15,000 km of canals, add 35 Mha irrigated areas, create about 35 GW hydropower capacity and navigation potential. Approximately 3,700 MW would be required to lift water across major watershed ridges by up to 116 meters.

Knowledgeable people agree that it may not be completed even by 2050, contrary to a Supreme Court's earlier recommendation that the Program be completed by 2016. B.G. Verghese, a staunch non-government supporter, thought that completion could take 50 to 100 years.



Map 11.8: The Himalayan and peninsular components of the ILR project

Map 42 : The Himalayan and Peninsular Components of the ILR Project

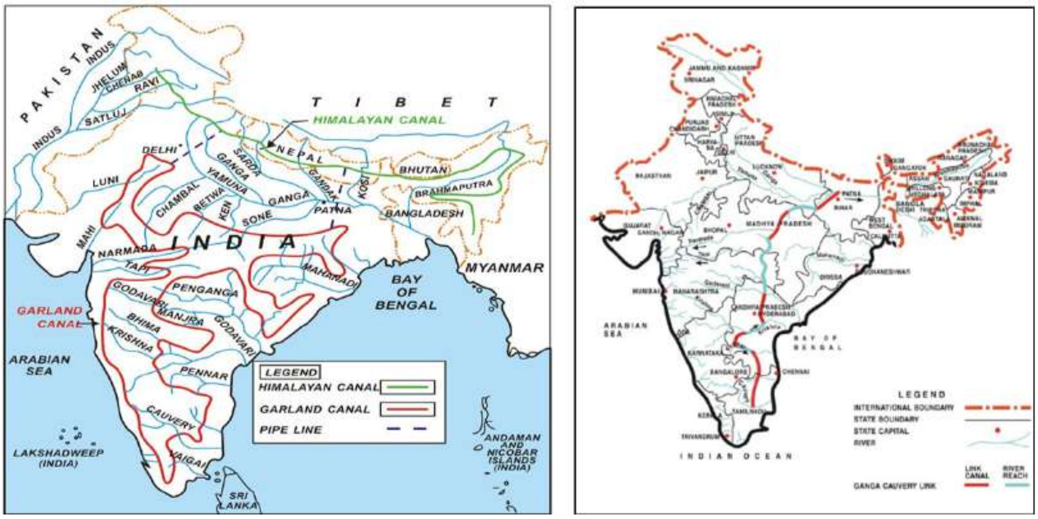
The Himalayan and the Peninsular components are meant to transfer 33 BCM and 141 BCM of water respectively through a combined 14,900 km canal network. The Himalayan Component, has two sub-components: the first will transfer the 'surplus' waters of the

Ganga and Brahmaputra rivers to the Mahanadi Basin. From there the water will be relayed to Godavari, Godavari to Krishna, Krishna to Pennar and Pennar to the Cauvery. The second sub-component will transfer water from the flood-prone eastern Ganga tributaries to provide the western parts of the Ganga and the Sabarmati river basins with irrigation and water supplies.

The Himalayan component needs several large dams in Bhutan and Nepal to store and transfer flood waters from the tributaries of the Ganga and Brahmaputra rivers, and also within India to transfer the surplus waters of the Mahanadi and Godavari rivers. The Peninsular component proposes 16 major canals including the Ken-Betwa and Parbati-Kalisindh-Chambal links in the Ganga basin.

The projected cost of Rs.5,60,000 crores included three components: 1) the Himalayan component costing US$ 41 billion (Rs.1,85,000 cr); 2) the peninsular component costing US$23 billion (Rs.1,06,000 cr); and 3) the hydroelectric component costing US$59 billion (Rs. 2, 69,000 cr). The Program proposes to generate about 30 GW and 4 GW in the Himalayan and the Peninsular components, respectively.

** Edited and extracted from T. Shah, U. Amarsinghe & P. McCornick (2008): "India's River Linking Program: The State of the Debate" in Strategic Analyses of the National River Linking Program (NRLP) of India Series 2", IWMI, Colombo, pp.1-21*



Map 43 : (Left) Garland Canal Links Proposed by Captain Dastur; (Right) Links Proposed by Dr. K.L. Rao

that the GoI complete the Program by December 31, 2016. The NCIWRDP had estimated that it would take about 43 years to complete the ILRP!

Seizing the opportunity, Prime Minister Vajpayee appointed a Task Force (TF) headed by the Union Minister Suresh Prabhu to initiate the Program activities. With all due respect to the Hon'ble Supreme Court, it appeared that its support had been politically managed. In the face of the outcry that followed, the successor UPA government at the Centre closed down the TF in December, 2004. Some planning activities continued. Later, at the instance of the UPA government, NWDA identified 37 additional smaller intra-state river linking projects.

On February 27, 2012 a three-judge Bench of the Supreme Court directed the Central Government, to constitute a special committee for inter-linking of rivers and enjoined GoI to take expeditious decisions to complete the Program in the national interest. The judgment left many concerned persons bewildered. More than 60 eminent citizens expressed their concerns over the propriety of the order and the Program.

In 2014, the NDA government revived the ILRP without reviewing the problems highlighted till then. By March, 2018 NWDA had completed pre-feasibility reports (PFRs) for all the 30 links and the FRs of 14 Peninsular and two Himalayan links. The DPR of the Ken-Betwa Link Phase I (KBLP) was completed. The Ken-Betwa link project was approved as a National Project (MoJS, 2018). On December 8, 2021 the Union government approved the Ken-Betwa Link Project at a cost of Rs 44,605 cr (Anon, 2021c).

11.4.2 Major Apprehensions

The ILRP involves multiple ecological, economic, political and social challenges. But first, the justifications put forth by its champions are briefly summarized.

Justifying ILRP

Low per capita availability of utilizable water, highly variable rainfall in space and time and the associated droughts and floods are the main reasons put forth for the ILRP by its proponents. The utilizable per-capita water availability in India is far below the internationally accepted standard of 1,700m^3/person/year for comfortable living.

As India's population continues to increase during the rest of this century, this problem will become increasingly severe and may lead to food insecurity. Water scarcity is likely to increase in western and peninsular India in the coming decades.

The spatial distribution of rainfall in India varies from 10,000 mm annually around Cherrapunji in the east to 150-200mm at Jaisalmer in the west. Several hundred million Indians live with less than 1,000 m^3/ per year in the water scarce arid and semi-arid parts. The Brahmaputra basin is considered 'surplus' in water resources whereas all the peninsular basins suffer over-exploitation. The ILRP is meant to augment the natural flows of the peninsular rivers and attenuate the floods in the Ganga-Brahmaputra basins.

Annual floods, on an average, affect more than 7 Mha with 3 Mha cropped area and over

34 million people in eastern India. The annual damage is said to cost several thousand crore rupees. Recurrent droughts affect 68 % of India's cropped area and 12 % of the population. The ILR storages and canal diversions are expected to reduce flood damages by 35% and ease drought-proneness in the semi-arid and arid parts. It is also argued that India has created less large storage to supply its arid and semi-arid areas compared to the USA, China or Australia.

IWMI researchers claim that large water development programs often have side benefits, such as (i) New roads, which provide improved access to markets and (ii) Clean water supply – which reduces the drudgery of women and children who trek hours daily to fetch potable water. Large irrigation programs enhance the livelihoods of farming families in the command area and have substantial regional and national multiplier impacts. Irrigated farming in India's Indus basin, meets more than 80 % of the food production deficits of other basins in India.

Major Objections

'Surplus' water, an unsound concept

The ILRP is based on a conceptually unsound calculation that some river basins have 'surplus' water. The official methodology for determining the water availability in a basin simply ignores the environmental flows, required by a river to perform all its vital ecosystem functions, including transporting water and sediments to the sea.

Every river is a natural ecosystem which performs a variety of specific functions within the web of life on planet Earth. Unnatural changes can have profound impacts, even though they may be delayed and therefore not apparent in the present. Sudipta Sen describes rivers as tireless dynamos of nature that erode, transport and deposit sediments to continually reshape Earth's surface. A river is not just a clearly defined object – with a beginning, a middle, and an end. He illuminates the ecological locus of a river, "As a natural phenomenon it is a part of the earth's water cycle, the endless succession of clouds, rain, snow and glacial melt that merges into other rivers, lakes, or the ocean" (Sen S., 2019).

Bandyopadhyay and Perveen explain the ecological losses due to inter-basin transfers of river waters, "At the macro level, the flood flows flush the silt from the riverbeds in the plains to the delta areas free of cost. They support the rich fisheries in the estuaries and keep away the saline incursion from the sea. When flood-water is diverted away from a basin, the reductionist hydrology sees it as a 'harmless' transfer, which has all gains and no losses. From an ecohydrological perspective such transfer of flows affects the processes of many ecosystem services" (Bandyopadhyay J. and Perveen S., 2003). Other losses include lower groundwater recharge and the loss of a medium for fish movements and conservation of biological diversity. 'Surplus' flows in rivers therefore simply reveal a poor understanding of rivers as ecosystems.

India's Ganga basin landscape – with large floodplains and delta -- has evolved over millennia with the natural flow of water. "Pushing rivers around through ILR disrupts the supply of sediments and nutrients downstream," says Dr. V. Rajamani at Delhi's Jawaharlal Nehru University (Padma T.V., 2016). The impact will be severe on the Ganga-Brahmaputra delta and disastrous for the millions living in the Sundarbans.

A World Bank Report highlights the disastrous impact of river water extraction on the Aral Sea saying, "This ecological disaster is the consequence of excessive extraction of water for irrigation from the Amu Darya and Syr Darya rivers, which feed the Aral Sea. Total river runoff into the sea fell from an average 55 cubic kilometres a year in the 1950s to zero in the early 1980s" (Bandyopadhyay J. and Perveen S., 2003).

River basins cannot be designated 'surplus' for all times. Their water resources may be underutilized today, but as populations increase or as the basin gets industrialized, urbanized, or land uses change, water demand can shoot up in the future. It is most likely that in the future riparian states within the 'surplus' basins will have their own plans to use the river water for economic growth in their own 'under-developed' regions. Several state governments like Odisha, Madhya Pradesh, Chhattisgarh, Maharashtra and Gujarat have rejected the NWDA's claims that their basins have surpluses.

Different parts of Bihar in the Ganga basin often experience floods or droughts simultaneously. Can Bihar's Ganga basin then be called surplus? Almost half of the Ganga's annual discharge in Bihar originates in Nepal. Once Nepal's plans to exploit these water resources become operational, the Ganga's discharge in Bihar will reduce significantly.

A climate modelling study published by IIT-Bombay and Madras scientists predicts a significant decrease in the monsoon rainfall over major water surplus river basins in India. Their computer simulations show increasing water yield in the deficit basins. "What may appear as water deficient today may become water surplus in the future due to climate change." says study author Sachin Gunthe at IIT-Madras and adds, "So how do you justify inter-linking?" (Padma T.V., 2016).

The eco-hydrological perspective is now being implemented in several countries. To enhance river flows, the Murray-Darling Basin Commission in Australia has repurchased irrigation water rights granted earlier to farmers. In the USA, hundreds of dams are being decommissioned to revive river flows and their ecosystems. A $8 billion plan has been passed in California to revive some of its rivers. Popular protests have stalled the second phase of water transfer from Spain's Ebro River to the country's south (Anon, 2003).

Technical Issues

Maj-Gen. (retd.) S. G. Vombatkere highlights a second basic concern, based on systems analysis, saying, "Any system can fail. It is axiomatic that the consequences of system failure become more serious as the system gets more complex" (Vombatkere S.G., 2019).

In its barest engineering essence, the ILRP is a system of sequentially connected reservoirs and canals. Its success depends on the functioning of the canals system, in which northern river basins supply water to river basins that are to their south (or west) by link canals forming a "chain of supply" (See Map 42).

As mentioned earlier, however, the NCIWRD had expressed concern that, "on the basis of public information, it appears that the Himalayan River linking component is not feasible for (the period of its review) up to 2050." Vombatkere then raises the question, "If the Himalayan sub-system is not feasible, then what is the source of water to feed the Subarnarekha basin and onward to the river basins to its south (Mahanadi, Godavari, and so on) for each basin to supply water to the next basin?" Three link canals have pumped lifts within them. "For water to reach Cauvery, all the links have to function as a system, conveying water from North to South," adds Vombatkere.

Vombatkere's analysis also shows that during the monsoon months the canal carrying Ganga water to the southern Subarnarekha River (via the Damodar), can at most divert 2000 cumecs or about 4% of the average flood discharge at the take-off point, while the Brahmaputra off-take canal can only divert 3 per cent. Therefore, these hugely expensive diversions will not provide any significant relief from the floods. On the contrary, during the remaining non-monsoon months every year the Subarnarekha-link canal will divert about 38% of the average flows in the Ganga with possibly serious socio-economic consequences for Bihar.

The Feasibility Reports prepared by NWDA consider each link as a separate stand-alone project. It is unlikely that NWDA or the ILR TF considered all of them together as one system. "In sum," says Vombatkere, "the ILR system is delicate, failure-prone and ….. the risk of system failure is high. Thus, from a system standpoint, the entire ILR scheme is unworkable."

Ecological Concerns

Serious concerns regarding the environmental effects of the ILR Program on river ecosystems have forced intermittent rethinking and delayed construction activities.

In May, 2003 MoEF listed 23-concerns about the environmental implications of the ILRP, including the submergence of forests and cultivable areas, displacement and resettlement and biodiversity loss (Bandyopadhyay J. and Perveen S., 2003). The ILRP is likely to repeat some of the Green Revolution excesses, e.g., growing water-intensive crops in water-short areas. The ILRP's reservoirs will lead to harmful methane emissions.

A basic concern is that reduced river flows into the sea will disrupt the balance between fresh water and the sea. The Ganga and the Brahmaputra deposit over one billion tons of sediments every year into the Bay of Bengal, the highest sediment load of any river system in the world (Wasson R.J., 2003). A University of Colorado research study shows that ILRP will considerably reduce water discharge in 23 out of 29 rivers (Rao M. M. 2018). The Ganga's discharge will fall 24 per cent. Its tributaries, Gandak (-68%) and Ghaghara (-55%) will be worse-affected. The Brahmaputra tributaries will suffer massive losses: Manas (-73%), Sankosh (-72%) and Raidhak (-53%). Reduced water flow and trapping of silt in reservoirs will decrease the sediments deposited by the rivers. Aggradation in the Ganga-Brahmaputra delta will decrease by 30% to 2.5 mm per year on an average, causing a loss of land in the delta where the estimated sea level will rise annually by 5.6 mm on average. "Rare ecosystems and vital agricultural areas would become more vulnerable to storm surges, river flooding, and heightened salinity," warns the study.

Linking rivers through large storage reservoirs and an extensive network of canals will destroy river ecosystems, aquatic diversity, forests, wildlife habitats and refashion the ecology of the country with unimaginable consequences. About 30 per cent of the Panna Tiger Reserve (PTR) will be submerged by the reservoir of the Ken-Betwa link – the first link stated to be undertaken (See also Chapter 8). Nearly 50 per cent of the breeding tigresses in PTR presently reside in the submergence area and the forests to the west that will be cut off by the proposed reservoir.

The complex geology and ecology of the Himalaya demands approaches based on reliable data, especially of seismic hazards, floods and sediments transport, and climate change impacts. Floods in the Himalayan foothills and the adjoining plains are the result of complex ecological processes, many of which are not well understood. But there are worrisome knowledge gaps for the Himalayan component, such as those related to the stated benefits of flood control. Dr. Bharat Singh, Professor Emeritus and former Vice-Chancellor of IIT-Roorkee and Member, NCIWRD has remarked, "Any water resources engineer will immediately discard the idea of the ILR as a flood control measure" (Iyer R.R., 2012).

Very little data regarding the Program has been shared in the public domain. Even though the Himalayan component involves international rivers it does not appear that detailed data has been shared with the affected neighbouring countries. Recognizing the urgent need for open professional evaluation of the Himalayan component, the (NCIWRDP, 1999) stressed that, "hydrological data of all the basins need to be made available to the public on demand".

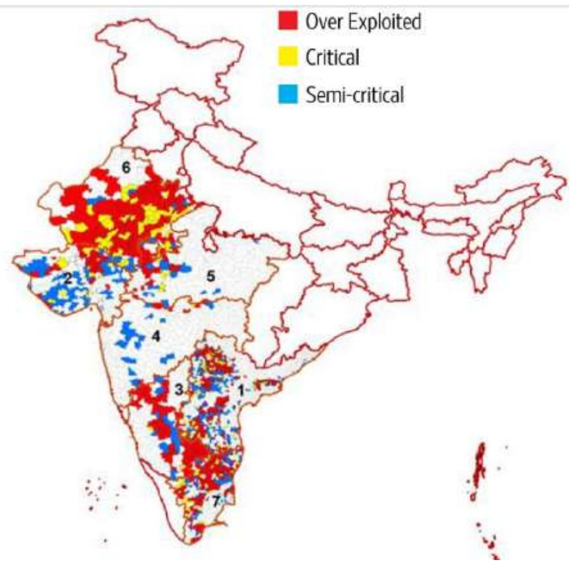
Social Concerns

The ILRP's network of canals and storage structures in India and its neighbouring countries will displace tribal people and farmers on a massive scale. Details of the official figure for the people to be displaced are not available. Unofficial estimates vary. IWMI estimates displacement of 583,000 people. For 'the largest construction program ever in the world', this figure seems to be an understatement. Vombatkere states that canals alone will displace 5.5 million people in India and occupy about 600,000 ha, whereas SANDRP estimates a figure of 3.47 million displaced persons and 1.675 Mha area required for the ILRP.

Displacement is generally involuntary and it causes economic, social and cultural hardships for the displaced communities. After Independence, millions of people, mainly rural and poor, have often been violently displaced. India's past record of rehabilitating project affected people does not inspire confidence that the process will be fair or empathetic. Displacement often destroys livelihoods. Few are restored. IWMI researchers point out that multi-purpose water transfer programs require both skilled and unskilled labor. Such opportunities are usually available only for the duration of the program and for comparatively fewer persons. Tribal communities and women generally can do only unskilled labour. Success stories of retraining unskilled displaced persons for skilled jobs are rare.

Food Production and Higher Water-Use Efficiencies

A major justification for the ILRP put forth by NCIWRD was the need to rapidly and massively enhance India's food grain production to meet the demands of its growing and increasingly prosperous population (Shah T., et al 2008). It estimated a grain demand of 450 to 494 MT in 2050 (against the 1999-2000 annual production of about 210 MT) and called for increasing the country's irrigation potential. The ILRP aims to add 35 Mha of irrigated land in the country. Of this area, 30 per cent will be for non-food crops. NCIWRD's figures of possible productivity increases suggest an addition of about 80 MT of food grains production by 2050, in the ideal case.



Map 44 : Ground Water Exploitation in India

Source - IWMI

Of the proposed 35 Mha increase in irrigated area, 25 Mha will come from surface irrigation and the rest from ground water. But Himanshu Thakkar, a member of the official Special Committee for Inter-linking of Rivers, has estimated that in two decades after 1991-92, the net area irrigated by major and medium irrigation projects actually declined by 1.5 Mha despite an investment of over Rs. 200,000 cr on large irrigation projects (Thakkar H. 2012).

Such a poor performance record does not inspire confidence in large surface irrigation projects. “The way India plans irrigation is divorced from the way Indian irrigation actually functions,” remarks Tushaar Shah, Principal Researcher at IWMI (Shah T., 2008).

But the groundwater irrigation component of ILRP is shrouded in mystery. “No data has been presented to explain how the target of 10 Mha for ground water irrigation will be achieved,” says Himanshu Thakkar. As Map 44 shows, the western and southern parts of India suffer from ground water shortages. The largely hard rock peninsular states have small aquifers with low capacities and uncertain or varying yields. Hence their ground water resources are very limited. NWDA has not presented any plans to undertake watershed development or rain water harvesting to recharge existing aquifers. “NWDA simply claims that this target will be achieved due to groundwater recharge from the canal systems,” says Himanshu Thakkar. There is no accounting either for the loss of ground water resources in the donor basins due to diversion of rivers or cutting of forests for the different links.

Economically and environmentally, the alternative of achieving greater grain productivities per unit volume of water is a far better proposition than targeting greater production by expanding the irrigated area. NCIWRD had proposed increasing irrigation water use efficiency from 0.35 in 1998 to 0.60 in 2050. China has adopted this approach. With less arable area than India it achieved cereals yield of 6081 kg/ha in 2018 against only 3248 kg/ha in India (World Bank Group, Undated).

In recent years, Indian farmers have been experimenting with several low-cost approaches to increasing productivities. Micro-irrigation is a major component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). Since 2000, the System of Rice Intensification (SRI) or its extension to a variety of other crops -- the System of Crop Intensification (SCI), has been spreading steadily across India. With less external inputs – about 30 per cent less water and without chemical fertilizers, SRI achieves better yields and profits for farmers. By 2013, SRI had taken firm roots in over 1Mha in India (Varma P., 2017). Finally, there is the highly neglected but more nutritious option of a mix of coarse and fine grains in our diet. It substantially reduces the water required for growing food grains (Chopra R.- and Sen D., 1993).

This brief analysis makes it clear that though the main justification for the ILRP is the claim of providing an extra 173 BCM of water primarily for India’s food security, much less expensive and minimally disruptive options are available.

Geopolitical Issues

The ILRP involves managing storages and diverting the waters of international rivers that are shared between China, Nepal, Bhutan, India and Bangladesh. Bangladesh being a major downstream stakeholder in the Ganga-Brahmaputra-Meghna (GBM) basin fears that the Manas-Sankosh-Teesta-Ganga link could have deleterious impacts on its economy. It can dry up the Brahmaputra-Jamuna channel, destroying irrigated paddy in eastern Bangladesh.

It will be equally hard to get Bangladesh to accept diversion of the Ganga basin water. Bangladesh is likely to object to the diversion of about 38 per cent of the average lean season flows in the Ganga for the Subarnarekha-link canal, unless the diversion is adequately compensated with water from other resources. In August 2004, after the UPA government had taken office in New Delhi, the Foreign Minister of Bangladesh announced that India had assured Bangladesh that it would not implement its proposed river-link Program without consulting the concerned regional countries (Khalequzzaman M., 2012). Nepal and Bhutan would have to agree to the construction of dams, for the Himalayan component of the ILRP, in their territories. Agreements may not be easy to obtain. Construction of the Barahakshetra dam in Nepal to control floods in Bihar's stretch of the Kosi river was proposed in 1954 as a part of the Indo-Nepal Kosi Agreement. While other projects in the Agreement have long since been implemented, the Barahkshetra dam remains in a limbo, despite decades of discussions, negotiations and agreements (See also Section 11.2.4).

Other Issues

Inter-state disputes: Water sharing of inter-state rivers is a highly contested political issue in India, water being a state subject in the Indian Constitution. Maj-Gen (retd.) Vombatkere asserts, "No state would like to spare water even though every state is keen to receive water. Inter-State consensus regarding water sharing can only be a pipe dream," (Vombatkere S.G., 2007). Currently there is no mechanism to deal with important institutional and legal issues concerning inter-basin transfers. As mentioned earlier, Orissa, Madhya Pradesh, Chhattisgarh, Maharashtra and Gujarat have denied that their rivers have 'surplus' waters. From time-to-time, some states have expressed their reluctance to share their water with other states.

High Costs and Resource Mobilization: NWDA's (National Water Development Agency) initial cost estimate was Rs. 560,000 cr (US$123 billion) at 2002-03 prices. It was about 2.5 times India's then annual tax collection (Anon, 2003). Commenting on the cost of the Program, Tushaar Shah et al wrote, "(The original budget) will require a larger investment than the sum total of all irrigation investments made by the governments of colonial and free India since 1830" (Shah T. et al, 2008). Since then, the costs have kept ballooning. By 2016, the ILR Program budget was estimated at almost Rs.12 lakh cr (US$ 168 billion), about twice the original cost (Ramachandran S., 2016). Can the Indian government afford such sums? The annual interest on such huge borrowings would itself be enormous. **NWDA has never presented a comprehensive assessment of its financial viability.**

The budget details are not easily available and it is not clear whether the land acquisition, rehabilitation and resettlement costs are based on the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 or not. It is also not clear whether the budget is only for construction-related expenses or does it include compensation for loss of forests, pastures, or other community resources. Sustainability and equity require including such environmental resource losses in the Program budget. Such infrastructural projects also have attendant security costs. Adding them could make the whole ILR Program economically unviable.
User charges for irrigation or power provided by ILRP would probably be unaffordable for many potential customers. They may end up serving only well-off consumers and add to inflationary pressures. Politically too it may be difficult to collect high charges from farmers.

The recent IPCC Reports on global warming warn about uncertain rainfall patterns with greater likelihood of shorter and more intense rainy spells. It may require re-assessing river flows and may make the ILRP unviable. That could lead to the nightmarish possibility of a future government abandoning the Program after investing thousands of crores in it. Tushaar Shah et al write, "The maintenance cost and physical position of the dams, canals, tunnels, and captive electric power generation will also involve huge financial burdens. This certainly requires financial assistance from the private sector as well as global capital agencies" (Shah T. et al, 2008).

11.4.3 The Ken-Betwa Link Project

In an alarming move on December 8, 2021, the Union Cabinet Committee approved funding and implementation of the Ken-Betwa Link Project (KBLP) at a cost of Rs 44,605 cr, 2020-21 prices (Anon, 2021c). The decision was in complete violation of the law of the land, as the final environmental, forest and wildlife clearances for the project were still pending. On December 8, 2021 the Cabinet Committee for Economic Affairs (CCEA) of the Union government approved the funding and implementation of the KBL project.

In July, 2017 the MoEFCC granted KBLP Environmental Clearance (EC) despite several lacunae in the EIA Report presented by NWDA, the project proponent, and several violations of the provisions of the 2006 EIA Notification. Himanshu Thakkar, coordinator of the South Asia Network on Dams, Rivers and People (SANDRP), challenged the EC approval before the National Green Tribunal's (NGT) New Delhi Bench in August, 2017. The case is still pending before NGT.

The forest clearance is yet to be granted. Many conditions set down by the Forest Advisory Committee, under MoEFCC, for 'Stage I Forest Clearance' have not yet been addressed (Perinchery A., 2021). One condition for the clearance is that no power generation project can be located inside a protected area, the PTR in this case.

In 2019, a Central Empowered Committee (CEC) appointed by the Supreme Court said the wildlife clearance granted by the National Board of Wildlife (NBWL) had no merit since the project proposal had not considered more sustainable and cost-effective alternatives and it appeared to be economically unviable. The major findings of the CEC were stated as:

1. The large block of 6017 ha of forest land involved in diversion to non-forest use is a part of the National Park and core critical tiger habitat of Panna Tiger Reserve and will result in total loss of wildlife habitat of 10500 ha on account of submergence and fragmentation;
2. The forest land involved in submergence is a unique ecosystem of morphological significance with rare and rich biodiversity, which ecosystem cannot be recreated;
3. The Standing Committee of NBWL (SC-NBWL) has considered the impact of the project only in terms of the tiger habitat, ignoring the fact that the project is located within the core of the National Park and it has not taken into account the entire flora and fauna and the unique ecosystem;
4. The very objective of declaration of this unique ecosystem with special morphological significance and unique biodiversity as a National Park to ensure operation of laws of nature including natural evolution unhindered by human intervention will be defeated and will result in complete breakdown of the evolutionary process of millions of years;
5. The diversion of 6017 ha of wildlife habitat, as approved by the SC-NBWL, for the implementation of the Ken-Betwa Link Project Phase I, has not been found necessary for improvement and better management of the wildlife therein as provided in Section 35 (6) of the Wildlife (Protection) Act, 1972. The assumption of NWDA, SC-NBWL and MoEFCC that the project will have positive impact on the tiger population is flawed as the large flood plains vacated by the villagers on relocation will remain under water even during summer, by their being located 240 M below the dead storage level.
6. The mitigative measures are grossly insufficient to mitigate the loss of habitat and the unique ecosystem of KNP and the threat of PTR losing the status of "source area". Without any reliable "source area" in the proposed landscape, the viability of the tiger population in the entire landscape will be at risk.
7. The alternative low cost options to attain the main objectives of the project proposal of irrigation and alleviation of poverty have not been examined by the project proponents.
8. The impacts of the project on the downstream Gharial Sanctuary and the vulture nesting sites have not been examined by the SC-NBWL and no mitigative measures in this regard are forthcoming in its recommendations.
9. The critical observations of the Committee constituted by the SC-NBWL were:

a) No developmental project should destroy the ecology of the remnant fragile eco systems and an important tiger habitat in the country. ln an ideal situation, it would be best to avoid such projects in such wilderness areas with protected area status and specifically when it runs the risk of providing justification or unhealthy precedence for more such developmental projects within protected areas that will not be in the interest of wildlife and the overall well-being of the society in the long term. The present proposal may not be the best possible option for addressing livelihoods and development of the region using water resources from the River Ken. Ideally, a team of independent experts on surface water hydrology drawn from leading scientific institutions should be requested to examine the hydrological aspects of the Ken-Betwa River Link as this involves submergence of a significant core area of a tiger reserve, hitherto considered as sacrosanct for conservation and a 'no-go' area for development.

b) The adverse impact of the KBLP on the ecology and environment of the Panna National Park, PTR and the Ghariyal Sanctuary are irreversible.

c) The disturbance to wildlife during the construction phase will extend beyond the 6071 ha of the forest proposed for diversion and will last for more than a decade exerting tremendous biotic pressure on the core of the National Park and the critical tiger habitat.

d) The SC-NBWL while giving wildlife clearance to this project has not taken into account the decision of the Supreme Court of India in IA No. 100 in WP (C) No. 337 of 1995 with IA No. 3452 wherein it is held that the approach should be ecocentric and not anthropocentric and must apply the "species best interest standard" as all species have equal rights to exist on earth.

The Supreme Court has still to consider the CEC report.

The Project

The Ken River flows 427 km from the northern slopes of the Kaimur hills in Katni district (M.P.) to its confluence with the Yamuna in Banda district (U.P.). It has a catchment area of 28224 sq. km. The Betwa, a perennial river, originates in Raisen district of M.P. (southwest of Bhopal) and flows about 590 km to meet the Yamuna in Hamirpur district in U.P. Its basin is contiguous to the Ken basin and its catchment area is 43895 sq. km. The KBLP proposes constructing a dam on the Ken for storing and transferring its water through a link canal to the Betwa. Its main components are:

- A 77 m high and 2,031 m long Daudhan dam, across the Ken inside the PTR. It will have a gross storage capacity of 2853 MCM (million cubic meters).
- Lower Orr Dam
- Bina Complex Project
- Kotha Barrage
- Two powerhouses of 60 MW and 18 MW capacities.
- Two tunnels and a 221 km long Ken-Betwa link Canal Phase-I on the left bank of the river.

A Problematic Project

NWDA has justified the need of KBLP in order to alleviate frequent drought conditions in the Bundelkhand region. But its DPR (Detailed Project Report) clearly states that its basic objective is to facilitate water transfer to the Upper Betwa basin which is already a well-endowed region outside Bundelkhand, with over 900 mm of average annual rainfall. This crucial issue has been ignored in the EIA Report as also by the Environment Appraisal Committee (EAC) and MoEFCC while granting environmental clearance to the project. It will displace at least 10 villages and have other downstream impacts.

A flawed claim of transferring 'surplus' water: The project claims that River Ken has 'surplus' water while the Betwa is water 'deficit'. It proposes to irrigate parts of three districts in M.P. and three districts in U.P. Hydrological data used by NWDA to conclude that Ken is 'surplus' and Betwa is a 'deficit' basin are not available for public scrutiny. NWDA did the water balance calculations for this project in the 1990s with limited data. It is now out-dated in the context of India's changing climate pattern. The hydrology chapter of the KBP Feasibility Report (FR), available on NWDA's website, ignores groundwater issues.

An independent study led by the late Dr. G.D. Agrawal (former Professor of Civil Engineering at IIT-Kanpur and Member-Secretary of CPCB – one of India's most respected civil engineers) compared 25 years rainfall data of the two basins. The analysis revealed that on an average, the Ken basin does receive slightly higher average rainfall than the Betwa basin. During low rainfall years, however, which are critical from a water availability point of view, the rainfall difference between the two basins is not significant and both basins have simultaneously faced drought conditions. The average rainfall in the Betwa basin has in fact been higher during some of the low-rainfall years. Thus, during low rainfall years, the Ken basin cannot alleviate shortages in the Betwa basin. The groundwater table in both regions is similar. Both the basins have large numbers of traditional tanks which, however, are being neglected and falling into disuse.

The upper Ken basin being largely forested, is neither urbanized nor industrialized and presently does not use much water. But in the future when the Ken basin also gets 'developed' there will be conflicts between the people of the two basins. In 2007 the then District Magistrate of Panna highlighted this issue stating, "…To say that the Ken Basin is a "Water Surplus" basin is not only totally erroneous, it holds disastrous implications for the residents of Panna district as also other districts of the Ken river basin. The basin is supposedly water surplus only because there has been scant utilization of upstream/midstream water… The plan (Indicative Master Plan of the Ken Basin), made way back in the year 1983, has outlined detailed small, medium and major projects for the districts in the Ken river basin which, if actually constructed, will need more water than is actually available in the basin. Thus it is clear that not only is the Ken river basin not water surplus, it is in fact water deficient!..." (Thakkar H., 2017).

Up to 60% of the land in both the basins is cultivable. It is already cultivated in the Betwa basin. Soils in both the basins are generally poor in nutrients. With water availability, farmers have shifted from cultivating crops like legumes, which are ideal for these soils, towards more water intensive crops and practices. With proper land use management, including a shift to nutritious but low water-consuming crops and reviving their traditional tanks for harvesting rainwater, sufficient water would be available in both basins to meet their agricultural requirements without transfer.

In the face of these arguments, the KBLP is an injustice to the people and ecology of the Ken basin.

An Invalid Sanction

Thakkar's August, 2017 affidavit in the NGT highlighted several shortcomings in the EIA process and Report and serious errors committed by MoEFCC and its committees.
These included:

Misleading EIA Report: The EIA Report submitted by NWDA contains wrong, misleading and contradictory information. It has failed to assess the project's impact on three prized and endangered species – tigers, gharials and vultures. Among its critical flaws are:

1. Different figures on different pages for the Full Reservoir Level (FRL) of the Daudhan Dam, the forest land required and the number of trees to be cut make the EIA Report's data unreliable.
2. The EIA did not assess the environment flows required in the Ken but its Report cited different figures on different pages. It proposed to release 'minimum ecological flows' of 2 cumecs from Daudhan reservoir during May, violating Condition No. 11 of the in-principle Forest Clearance that the water flow downstream would be regulated in line with the natural flow regime and in the lean period, 100% of the existing flow regime would be maintained.
3. The Report ignored the impact on the Ken Gharial Sanctuary. The NBWL Sub-Committee Report stated that the biggest loss due to the project would be the riverine species and the unique habitats.
4. It displayed a complete lack of understanding about fish migration or movement and that the Daudhan reservoir is not available for fisheries development since the reservoir is a protected area.
5. The EIA Report data about the affected PTR area differ widely from the assessments by the PTR Field Director, National Tiger Conservation Authority and NBWL.
6. The irreversible loss of shelter sites occupied by wild mammals for breeding and resting, cited by NBWL and the FAC Sub-Committee, is ignored. It is silent about the project's impact on the rare and endangered vulture species in the PTR. It does not discuss any climate change impacts.

Faulty EIA Processes Followed: The major violations and shortcomings are listed below.

- **Violations with regard to the public hearing:** The EAC approved the KB Link Project and MoEFCC granted it clearance despite several violations of the provisions of the EIA Notification of 2006 with regard to the public hearings process and outcomes which were pointed out to it.

- **EC granted the 78 MW power house being inside the forest area breaching the in-principle Forest Clearance (Condition No. 17)** issued by MOEFCC on May 25, 2017.
- **No cumulative impact assessment done for the Ken or Betwa basins:** The Ken and Betwa basins have multiple existing projects. But no cumulative impact assessment and carrying capacity studies for either basin had been done as required under the Ministry's Notification of May 2013.
- The EAC cleared the Project without the clearances required under the Ganga (October 7, 2016) Notification despite being informed of the same.
- **EAC Chairman and other members had a conflict of interest:** A new EAC, chaired by newly-appointed Shri Sharad Jain, met for the first time on December 30, 2016 and cleared the KBLP without analyzing rejections by the previous EAC. Thereafter, Shri Sharad Jain was appointed Director-General of NWDA, the project proponent, indicating a clear conflict of interest.

The GoI's recent decision to grant funding and implementation approval to the KBL Project, even as it awaits statutory clearances has shocked water experts, wildlife conservations and scientists and environmentalists throughout the country. That the Central government can so casually disregard the law of the land is ominous. Bundelkhand's water security, the successful reintroduction of tigers in the Panna Tiger Reserve and the gharials breeding in the Ken Gharial Sanctuary have been gravely imperilled by politicians desperate to retain state power.

Earlier, the shoddy EIA Report hid more than it revealed. Its ready acceptance rather than rejection ordering of a fresh impartial impact assessment is what is called for in the interest of environmental justice.

If options such as irrigation efficiency in both Ken and Betwa basins are pursued, the water requirement in both basins can be vastly curtailed, nullifying the need for the project.

11.4.3 Conclusions

Inter-linking of rivers ranks among the most controversial developmental projects proposed in independent India. It has been dogged by controversy right from the start. The early suggestions of Captain Dastur and Dr. K.L. Rao were dismissed by official bodies and critics as ill-conceived, a boondoggle, 'a pipe dream' or a 'pie-in-the-sky' project. Dr. Bharat Singh, a member of the NCIWRD, one of India's most respected civil engineers and former Vice-Chancellor of Roorkee University (now IIT-Roorkee), bluntly said, "There really seems to be no convincing argument or vital national interest which can justify taking up the river linking project in its entirety" (Bandhopadhyay J. and Perveen S., 2011). This review has highlighted that the core assumptions of the ILRP are conceptually, ecologically, technologically, economically and politically unsound. The concept of 'surplus' rivers or river basins is based on a myopic engineering view of rivers. It ignores the ecosystem and only sees the water. Destruction of vast forest areas, at a time of global warming, will be a self-destructive self. The worst affected will be the displaced millions and the ecology.

Trans-boundary controversies are likely to arise with respect to the Himalayan component of the ILR Program. Submergence makes storage dams hotly contested development projects all over the world. Building storage reservoirs in Nepal and Bhutan as planned, is likely to meet with local opposition. Another trans-boundary dispute will most likely arise due to higher saline sea water ingress into the fertile and densely populated Ganga-Brahmaputa delta that spans Bangladesh and India. Bangladesh and India both need adequate discharge of water and sediments into the Ganga delta to ward off this intrusion. Millions living in the Sundarbans will become more vulnerable to storm surges, river flooding, and high salinity.

A very significant issue is the lack of project information in the public domain. According to the currently available information, the economic feasibility of the ILRP as a whole has not been done. By 2016, the ILR Program budget was estimated at almost Rs.12 lakh cr (US$ 168 billion), more than twice the original cost. With the project completion expected to take at least several decades, this cost will keep ballooning, as has been seen in the case of the Ken-Betwa link. Interest costs and the cost of providing security for the project will make it further uneconomical. It is not known how this huge amount will be mobilized. How will the Indian government mobilize such sums? What social budgets will be sacrificed and who will bear those consequences? Will it privatise the individual projects? Even the private sector may not find it economical to borrow such huge capital.

With global-warming and the changing climate patterns, much of the crop-water requirement and hydrological data used so far will become irrelevant and may make the ILRP unviable. Would a future government then abandon the Program after investing lakhs of crores in it? Or, would it invite MNCs who may demand privatisation of India's water resources? Would it then enslave India to foreign capital?

The GoI appears determined to implement the ILR Program despite all the negative impacts. In approving the first proposed link, the Ken-Betwa link, it has shown a baleful willingness to ride roughshod over norms, rules and regulations painstakingly crafted by conscientious officials and environmental activists and notified by legislatures over the last few decades.

Critics of the ILR Program are highly aware of the gravity of India's rapidly widening water scarcity in western, southern and elsewhere in India. Their basic argument is that there are more effective, cheaper and easier solutions which should be considered. On the other hand, ILRP will be an expensive 100 years boondoggle project.

Practical and much cheaper alternatives for speedily enhancing water availability in both the basins like protecting forests and traditional water-harvesting systems, springshed development, afforestation and watershed development and treatment of polluted water and its reuse, etc. are known and practised in different parts of the country. Combined with cultivation of traditional and more nutritious, low water-consuming crops, sustainable agriculture and participatory groundwater management have provided resilience against droughts and equitable economic uplift in dryland farming areas like Ralegan Siddhi and Hivre Bazar in Maharashtra.

11.5 INLAND WATERWAYS IN THE GANGA BASIN

The story of Kevat ferrying Lord Rama, Sita and Lakshman across River Ganga at Prayag is perhaps the earliest reference to water transport on River Ganga. Much later, Megasthenes the Greek scholar-diplomat during the Mauryan era wrote that the Ganga and its tributaries were used for navigation in the 4th century BCE (Sen S., 2019). The Laws of Manu (c. 200–100 BCE), within the Hindu law tradition, obligated rulers to protect public waters and collect fees for crossing waters (Cullet P. and Gupta J., 2009). Throughout later history there are recorded references to navigation on the Ganga and its tributaries and canals for travel, trade and warfare.

The mapping of the Ganga in 1781 by Major James Rennell, the first Surveyor General of India, heralded the golden age of navigation on the Ganga (Sen S., 2019). The British East India Company introduced steamships in 1822 and by the mid-19th century, huge volumes of goods were being transported via waterways. Private steamboat companies during that period plied as far as Garhmukteshwar, about 650 km upstream of Allahabad. From time-to-time the British introduced rules and laws to regulate ferries and the use of canals for navigation purposes. The golden age, however, did not last long due to the emergence of railways and construction of the Ganga and Yamuna canals which reduced the flow in the river. The volume of river borne cargo traffic declined significantly.

There are various estimates of the total navigable length on India's rivers, canals and estuaries, extending over 20,000 km. But the continuing abstraction of water by dams and irrigation canals after independence, constricted navigation in India as well as in the Ganga basin. At the all-India level, freight carried by inland water transport (IWT) is only 0.5%, compared to 8.7% in China, 8.3% in the USA and 7% in Europe (IWAI, undated).

The Ganga-Brahmaputra Water Transport Board, set up in the First Five Year Plan, was the first IWT institution established in independent India. Passage of the Inland Waterways

Authority of India (IWAI) Act, 1982 led to the formation of the Authority in 1986 to develop, maintain and regulate National Waterways (NWs) for shipping and navigation. Mechanically propelled vessels of over 300 tons capacity can ply on the first five NWs, each established by a separate Act of Parliament between 1986 and 2008 (See Map 45). They pass through and serve more than one state. A 1620 km stretch of the Ganga from Haldia to Allahabad was designated as the National Waterway-1.

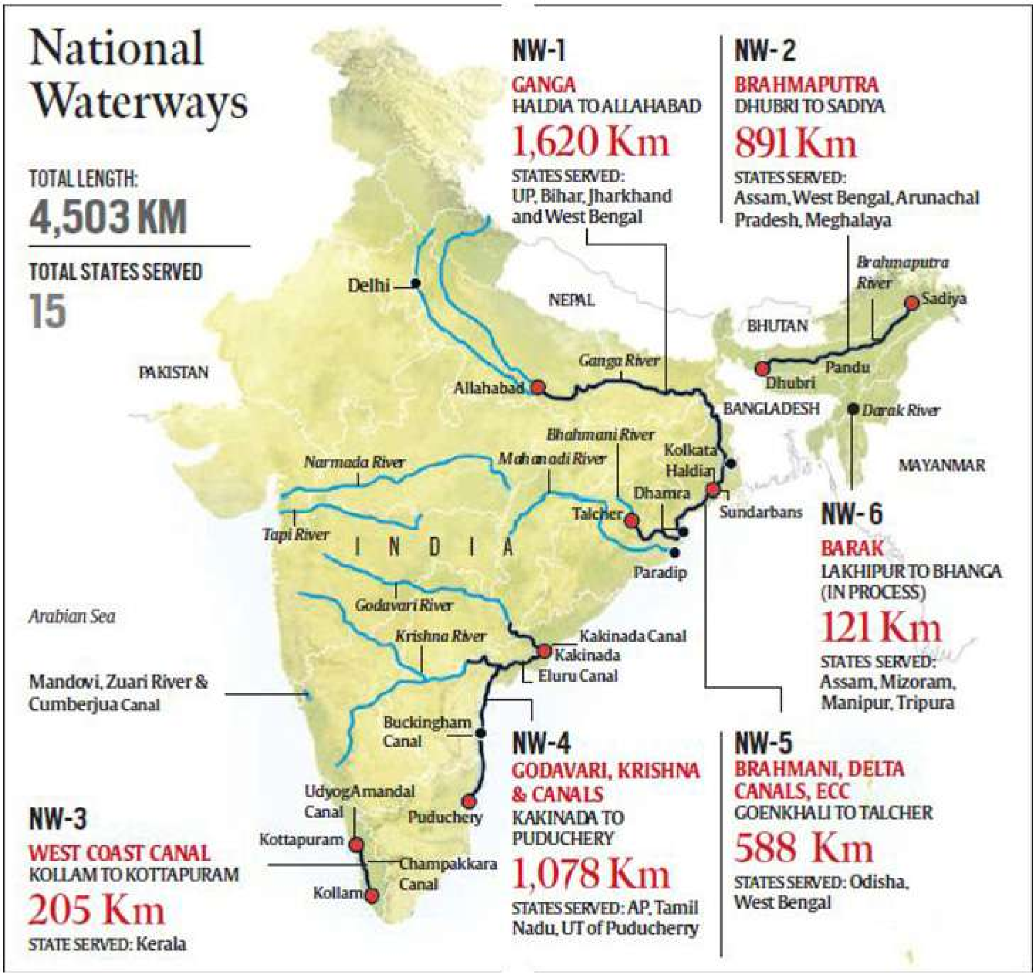
Inland Water Transport Policy: The Inland Water Transport Policy, 2001 is India's only formal policy document dealing with IWT (Dharmadhikary S. and Sandbhor J., 2017). It describes IWT as being an economic, fuel-efficient and environment friendly mode of transport. It states that 5200 kms on major rivers and 485 km in canals are suitable for mechanised crafts out of India's 14,500 km navigable waterways (Sharma K., 2017). It estimated the total potential for cargo movement on inland waterways at 50 billion ton-km. According to this policy most of the waterways suffer from navigational hazards like shallow waters and narrow width of the channel during the lean season, siltation, bank erosion, absence of infrastructure facilities like terminals and inadequacy of navigational aids. It noted that the safety record of waterways was not encouraging. It proposed a number of measures for financing IWT development, including large-scale private sector participation. Some of these measures are outdated.

National Waterways Act, 2016: In addition to the five pre-existing NWs, this Act provides for the development of another 106 new inland NWs for shipping and navigation purposes and also for their regulation. It repealed the five National Waterway Acts, enacted between 1986 and 2008, notifying the first five NWs. The 106 waterways are to be developed for commercial navigation by large vessels of up to 3000-ton capacity to transport bulk and hazardous goods, and passengers (although already the number of viable waterways has come down to 63). In the first three years only 37 NWs were to be taken up for development (Dharmadhikary S. and Sandbhor J., 2017). More than 25 tributaries of Ganga have been declared as National Waterways.

Table 49: National Waterways in the Ganga Basin

Sl. No.	National waterway	Length (Km)	River(s)/Canal	States
1.	NW 1	1620	Haldia - Allahabad stretch of the Ganga	UP, Bihar, Jharkhand, West Bengal
2.	NW7	96	Ajay	West Bengal
3.	NW12		Asi River	UP
4.	NW15	137	R.Bakreshwar-R. Mayurakshi	West Bengal
5.	NW19	68	Betwa River	UP
6.	NW24	60	Chambal	UP

7.	NW29	135	Damodar	West Bengal
8.	NW34	130	DVC canal	West Bengal
9	NW35	113	Dwarakeswar	West Bengal
10	NW36	121	Dwarka	West Bengal
11	NW37	300	Gandak	Bihar & UP
12	NW38	62	Gangadhar	Assam & West Bengal
13	NW40	340	Ghaghara	Bihar & UP
14	NW42	518	Gomti	UP
15	NW44	64	Ichamati	West Bengal
16	NW47	131	Jalangi River	West Bengal
17	NW54	86	Karmanasa	UP & Bihar
18	NW58	236	Kosi	Bihar
19	NW60	77	Kumari	West Bengal



Map 45 : National Waterways 1-5

Source - Aspirant Forum

20	NW65	81	Mahananda	West Bengal
21	NW81	35	Punpun	Bihar
22	NW86	72	Rupnarayan	West Bengal
23	NW92	26	Shilabati	West Bengal
24	NW94	160	Sone	Bihar
25	NW96	314	Subarnarekha	Jharkhand, West Bengal & Odisha
26	NW97	654	Sundarbans waterways	West Bengal
27	NW103	73	Tons	UP
28	NW108	53	Varuna	UP
29	NW110	1089	Yamuna River	Haryana, UP & Delhi

Source: National Waterways Act, 2016

Besides NW-1, only NW-37 (Gandak), NW-40 (Ghaghara), NW-58 (Kosi), Rupnarayan (NW-86) and NW-97 (Sundarbans) in the Ganga basin have been prioritized for development. Several waterways in the Ganga basin will cater to international transport. They include extending the Gandak, Kosi and Ghaghra waterways into Nepal, augmenting the existing Indo-Bangladesh Protocol routes through the Sundarban and Rupnarayan waterways, and linking NW-1 and NW-2 through Bangladesh.

Benefits and Costs

The National Waterways Bill, 2015 justified inland NWs by stating, "…inland water transport is recognized as fuel efficient, cost effective and environment friendly mode of transport, especially for bulk goods, hazardous goods and over dimensional cargos. It also reduces time, cost of transportation of goods and cargos, as well as congestion and accidents on highways." Other benefits listed by proponents of IWT include:

- CO_2 emissions from container vessels are significantly less than from road transport vehicles.
- IWT has a much greater capacity to carry bulk cargo, coal, etc. than road transport vehicles.
- Inland waterways development will reduce the cost of moving cargo and passengers between ports and hinterland and thereby stimulate industrial growth, trade and tourism.
- Inland waterways will reduce traffic congestion and accidents on highways.
- Inland waterways can provide better access to remote areas of the northeastern states.

"But these advantages are neither unqualified, nor automatic. They will manifest only when certain conditions are met, and only under certain circumstances," argue Dharmadhikary and Sandbhor (2017). They cite an IWAI consultancy report which says, "In respect to operating costs per ton-km, IWT shows the lowest costs compared to rail and especially road. "

However, this cost argument has to be put into perspective, as it is generally true for single mode carriages but not for door-to-door transports including cargo transfer and pre/end haul……… Among the most visible weaknesses of IWT are the low transport speed and its limited area of operation, depending on the infrastructural premises and depth of the waterways. Moreover, there are very few cases in which IWT can offer door-to-door transport of cargo."

Economic Costs

A RITES (Rail India Technical and Economic Service Ltd) Report has compared the costs of IWT, rail and road transport as given below (PIB, 2016 and RITES, 2014):

Table 50: Cost Comparison Between IWT, Rail And Road Transport

Mode	Pre-tax freight (Rs/ ton-km)	Post tax freight (Rs/ton-km)
Railways	1.36	1.41
Highways	2.50	2.58
IWT	1.06	1.06

Source: RITES, 2014

Here water transport appears cheaper than rail and road transport. But this is only the vehicle operation cost. An Asian Development Bank study (Rangaraj N. and Raghuram G., 2007) on the viability of IWT in India notes that, "Freight handling in IWT involves movement to and from the water mode, including loading and unloading of material, and storage. IWT offers medium batch size possibilities, slow but secure movement, limited door-to-door opportunities and cheap rates. In comparison, road offers small load options, faster movement, door-to-door service, but higher rates. Rail offers large batch economies, quick movement, partly door-to- door service, and medium rates…… The geographical advantage of freight transport by IWT is strongest if the entire movement is across a river…... (or) when one or both terminal points are near a river. For transport of material (construction material and equipment) relating to a particular river-based project activity (e.g., river bridges, hydroelectric plants), IWT is most attractive."

Estimating Direct Costs: Unlike rail and road routes, which follow straight lines for long stretches, rivers meander. Thus, the River Ganga stretch from Prayagraj to Haldia is about 1620 km as compared to only 955 km by railway and 884 km by road. Based on the actual distances travelled from Prayagraj to Haldia and the per ton-km cost from the above Table, the table below shows that transportation by NW-1 is costlier than rail. Waterways being the slowest mode of transport, they also increase the opportunity costs.

Table 51: Distance-Wise Transport Mode Cost Comparison on NW 1

Mode	Total distance (Km)	Total Cost before tax (Rs)	Total Cost including tax (Rs)
Railways (via Howrah)	955	1299	1346
NH-19	884	2210	2280
NW-1	1620	1717	1717

Debadityo Sinha, founder of Vindhyan Ecology and Natural History Foundation, Mirzapur, argues that, "The actual cost of transport on NW1 may be higher because of large investments that need to made by the Inland Waterways Authority and other agencies in making multi modal transport terminals like at Varanasi, Barh and Haldia. For full-fledged commercially feasible waterways, there will be requirement of other infrastructure as well to support the ships such as riverside jetties, ports, handling sites, godowns, barge repairing & service stations, parking, fueling stations etc." (Sinha D., 2019).

Goods transported via waterways usually require railways or road transportation for door-to-door delivery from ports, the cost of which and the associated infrastructure requirements are additional. To facilitate the movement of 1000 to 2000 DWT cargo vessels, the navigational channel should be at least 45 m wide, 3 m deep and dredged periodically (Sinha D., 2019). These capital and maintenance costs are high. If just the annual maintenance costs are added to the waterways' operational costs, then the cost of transportation per ton-km could exceed that of road and rail transportation. Therefore, the economic feasibility and ecological sustainability of the 106 proposed NWs is doubtful.

Ecological Costs

Waterways require adequate water flowing in a fairway (navigation channel) with adequate width and depth throughout the year, for vessels to sail. The natural flows in most Indian rivers vary significantly during the year and many do not naturally have the required depth or width for a fairway. In such cases river conservancy works like bandalling, dredging or building of upstream dams or barrages are needed to develop a fairway. Each of these processes have a significant impact on the natural morphology and ecology of the rivers' ecosystems.

Dredging: The need for frequent dredging, especially in the Himalayan rivers, increases their maintenance costs far above the maintenance costs of railways and roadways. For instance, a project worth Rs 4,200 cr was proposed by IWAI to remove silt by dredging from the Ganga between Varanasi and Haldia for developing an "integrated river water freight corridor" (Joshi S., 2015). In 2017, the Assam government proposed a project worth Rs 40,000 cr for developing NW-2 (Kaur B., 2017). The utility of such projects is highly doubtful as the Ganga-Brahmaputra River system annually brings down about a billion tons of sediments.

Apart from financial constraints, dredging damages the river ecosystems. The foremost problem is the increase in turbidity, which greatly impacts benthic organisms like worms, clams, crabs, lobsters, sponges, etc. and the fish population. These creatures live in and on the bottom of the river floor. Due to scouring of the river floor, their habitat is destroyed. The populations' recovery rates depend on local conditions and the periodicity of dredging. Generally, opportunistic species recover faster than sensitive species (Rehitha T.V. et al, 2017). Fish feed on benthic organisms and several fish populations diminish in their absence. The increasing need for dredging for enhancing navigability in the Columbia river (USA) led to the loss of its salmon population, leaving the fishing tribes unemployed (Lokgariwar C., 2013).

Large ships sailing on a river cause a lot of noise pollution. Along with fishes, such noise severely impacts the Gangetic river dolphins. The latter are effectively blind because they inhabit the shallow, sediment rich, murky waters of the river Ganga. So, they use echolocation to swim around. The high frequency sounds from the ships disrupts their delicate SONAR and greatly affects their life cycle (See Chapter 6, related box item).

A Dubious Environmental Clearance

Dredging and ports are included in the EIA Notification 2006 (as amended from time to time) as works that require environmental clearance. Yet these works in River Ganga for NW-1 have been exempted from the requirement of prior environmental clearance on the grounds that the dredging in the Ganga is only maintenance dredging. According to the amended EIA notification of 2006, however, maintenance dredging is exempted only if it is included in the Environmental Management Plan and environmental clearance has been obtained for the project, which is not the case for NW-1. An exemption from EC has also been obtained for the Varanasi multi-modal terminal on grounds that also appear legally untenable.

In October, 2016 the Ministry of Environment, Forests & Climate Change (MoEFCC) submitted to the NGT that environment clearance for NW-1 was not required (Ghanekar N.M., 2017). In June, 2017, however, it informed IWAI that an Expert Committee of MoEFCC had recommended appraisal of the NW-1 as a Category 'A' project. But in October, 2017 at an Inter-Ministerial meeting headed by the Cabinet Minister for Road Transport & Highways, Shipping and Water Resources, in which the Minister for Environment Forest and Climate Change was also present, it was concluded that "per the extant legal position, no prior EC is required for maintenance dredging for navigational channel for Inland Waterways". No independent expert was present at this meeting (Junjhunwala B., 2021). The Shipping Ministry argued that the Environment Protection Act, 1986 and the EIA Notification, 2006 were not applicable to the Jal Marg Vikas Project (JMVP). On January

3, 2018, the Union Cabinet Committee on Economic Affairs (CCEA) approved the JMVP after the MoEFCC backed off from its stand that maintenance dredging in the Ganga for NW-1 required prior environment clearance. In response to an earlier petition filed by Dr Bharat Jhunjhunwala before it, in December, 2018 the NGT asked MoEFCC to clarify its stand. This case is still pending a decision by the NGT. Dr. Jhunjhunwala has challenged the Ministry of Shipping's authority to decide what requires environmental clearance.

Other native species of Ganga that will be affected by NW-1 development are turtles (See below) and the fish-eating gharial crocodilian. The population of gharials in the Varanasi-Haldia stretch of Ganga is negligible, but the tributaries like Gandak and Ghaghra have a significant population. Since Gandak has been declared as NW-37, environmentalists have become more apprehensive about the future of these endangered species. The big ships will not only disturb the water but dredging will destroy the mid-channel islands / sand bars vital for the gharials for basking and regulating their body temperatures (Lokgariwar C., 2013).

Dredging activities also impact people severely. Dredging significantly increases erosion rates at the banks. Consequently, cases of people drowning near the banks have drastically increased. As a result of dredging, the depth of the riverbed increases abruptly, causing people to drown (Kelkar N., 2016). In Bhagalpur district, previously safe *ghats* are now marked dangerous, requiring patrolling by of the National Disaster Response Force (NDRF). The larger steamers and vessels often cut into the fishing nets, causing huge losses for the fishing families.

Dams: In order to maintain the required water depth for large vessels, several dams/ barrages were proposed to be constructed on the river Ganga and its tributaries. Environmentalists pointed out that dams would cause rapid upstream siltation, reducing the river bed's depth and increasing the need for dredging. Large scale ecological damages have been recorded after the construction of Farakka barrage in 1975. The population of migratory fishes like *Hilsa* has reduced significantly. In the Sundarbans delta, dredging has enabled large mechanized fishing vessels to enter the shallower waters. The worst affected are the fishers' communities as their fish catch has fallen (Sinha D., 2016). In view of these negative effects the proposal to build dams and barrages was dropped.

Jal Marg Vikas Project (JMVP): The JMV Project aims to develop the Varanasi-Haldia stretch of river Ganga (earlier NW 1) for navigation of large vessels weighing 1,500 to 2,000 tons (Anon, 2018b). It involves the construction of (i) six multi-modal terminals, (ii) five roll-on-roll-off (Ro-Ro) terminal pairs and (iii) a new navigation lock at Farakka in West Bengal. The project will also undertake assured depth dredging and river training, establish an integrated vessel repair and maintenance facility, a differential global positioning system (DGPS) and a river information system (RIS). The Prime Minister has inaugurated India's first multi-modal terminal on November 12, 2018 at Varanasi and a second one at Sahibganj (Jharkhand) in September, 2019.

The estimated project cost of Rs 5,369.18 cr, is to be shared between the Government of India and the World Bank (World Bank, 2017). But it has been contended that NW-1 (and other waterways) cannot be commercially successful in isolation unless it is linked with other waterways and other transportation modes which could invite major environmental damages by altering the river ecosystems in the country (Sinha D., 2019)

NW-1 passes through two wildlife sanctuaries. First is the 7 km long Ramgarh Turtle Wildlife Sanctuary near Varanasi in Uttar Pradesh, which was denotified in 2019 and a stretch of 30 km between Prayagraj, Mirzapur and Bhadohi has been notified as (the new) Turtle sanctuary. The second is the 50 km long Vikramshila Dolphin Sanctuary in Bhagalpur district, Bihar. Increased river traffic will severely impact the ecology of these sanctuaries (Lokgariwar C., 2013).

The harm done by dredging to the Gangetic River Dolphin – India's National Aquatic Animal – has also been discussed in Chapter 8 (See Box). Nachiket Kelkar, a wildlife expert, has highlighted the specific impact of dredging on the Gangetic River Dolphin, saying, " Over 90 per cent of the Gangetic dolphin population distribution in India overlaps with the extent of the proposed waterways. ……. In Bihar, the surviving 1,200-1,500 dolphins are highly vulnerable to dredging and navigation impacts……. Vessels of the Inland Waterways Authority of India have been regularly dredging inside the Vikramshila Gangetic Dolphin Sanctuary (on NW-1), in Bihar – possibly without environmental or wildlife clearances. 'Unprotected' reaches of the Ganga and its tributaries also hold viable dolphin populations, but environmental impact assessments for the NW-1 wrongly assume that mitigation measures apply only to Protected Areas such as Vikramshila" (Kelkar N., 2017).

The World Bank's decision to sanction a $375-million loan for the JMVP violates its own operational policies on environment and social assessment. They categorize the JMVP as a Category A (maximum impact) project. The World Bank did not respond to media queries on why it overlooked the environment clearance process while clearing the loan (Manoj P., 2018).

The NW-1 project is being implemented with very little involvement of the local population. Its Detailed Project Report (DPR) has not been made public. DPRs available for tributaries of the Ganga -- Gandak (NW-37), Kosi (NW-58), Ghaghara (NW-40) also leave several important questions unanswered from the perspective of disposal of dredged material, solution to the problem of silt in these alluvial rivers, and to tackle their notoriously shifting channels.

Conclusion

The scale on which NW-1 is planned will severely damage the ecosystem of about two-thirds

Riverfronts: Developers' Paradise*

In all riverfront projects, generally a weir, dam or barrage is constructed upstream and downstream of the urban stretch to retain water in that segment of the river at a designated level all year round. This means impounding water for a limited stretch, ponding water even in lean periods. The river bed is then allowed to dry and dredged to give it a uniform slope. Weirs hold the water on both ends of the riverfront stretch and a steady perennial river level is maintained. Sometimes, water is imported from some other river. The river banks are then heavily concretised to provide spaces for social and public infrastructure such as car parking, plaza, walkways, restaurants, theme parks and gardens. Commercial activity by the river even late at night, with high mast lights, attempts to make riverfronts 'vibrant hearts of the urban fabric'. The active floodplain becomes a developers' paradise. Sometimes a parallel road strip is built to ease urban traffic congestion.

*excerpted from Dutta V. (2018): "The Demise of Rivers", Down To Earth, March 13, 2018.

of the Ganga's main stem. The NWs on its tributaries, like the Kosi, Gandak and Ghaghara will be equally destructive of their ecosystems. Such projects merit open public debate before approval. Truly participatory and transparent EIA processes and Environment Management Plans that give primacy to the river's ecosystem must be mandatory for all waterways. "In earlier times, we shaped our boats to fit our rivers. Now, we are shaping our rivers to fit the size of our vessels," say Dharmadhikary and Sandbhor. It is time to begin living within the limits of natural ecosystems. Moving towards sustainable economies has enough room for India's economic growth.

11.6 RIVERFRONT DEVELOPMENT

The waterfront of a city on the banks of a river or a lake or the sea offers an open space and recreation opportunities. In most parts of India people worship rivers as divine manifestations and perform religious rituals by the riverside. Devotees gather in towns and cities along rivers to celebrate festivals. Since ancient times rulers and subjects have built temples and *ghats* at such locations for the convenience of the worshippers. Commerce has often followed such construction. Traditionally, rivers have been seen as sources of clean and fresh water and people have used the river banks for drinking water, bathing and washing clothes. Riverfronts are also used for crossing the rivers by boat.

For decades now urban rivers in India have suffered abuse. Their waters have been diverted up stream for irrigation, hydropower generation, water supply for human habitations and industries, reducing them to thin braided streams and storm water drains in the cities. Untreated liquid wastes and solids flowing into them have turned them into sewers. Local administrations facing shortages of funds, motivation and ideas have tended to neglect the maintenance of river fronts. The general impression is that river fronts are places of hard surfaces – built facades, stone or concrete walkways and steps leading to the water edge. There does not appear to be any place for natural features and hence no ecological processes as a result. These river fronts are a celebration of concrete with a sprinkling of regimented and manicured greens as a token gesture towards eco-friendliness. The natural shoreline/bank of the river has been completely obliterated wiping out habitats and the transition zone between water and land. (INTACH, 2022).

In recent decades, however, with the Indian state championing rapid economic growth, cash-strapped administrators have identified river banks as undervalued properties that can be monetized for revenue generation. In the name of improving the quality of urban life concrete riverside promenades are being promoted as urban renewal projects, to attract commercial investments and convert the river banks into revenue banks for local and state agencies and commerce. In the process rivers are converted into canals, their aquatic biota is grievously wounded and their life-supporting floodplains are destroyed. Anticipated financial returns trump ecological factors in approving such projects.

River bank boundaries are not well-defined. Their integrity is naturally maintained through the drought and flood cycles. Encroachment of the river banks is usually followed by encroachment of the floodplain with the growth of commercial activity in a wider area. This severely damages the river ecosystem (See Box item: “Concept of River Space”, in Chapter 4) and locally available groundwater resources. Flood plains store huge amounts of water derived from peak flows and storm runoffs during the rainy season. The stored groundwater is gradually released back to the river, thereby helping sustain its lean season flows and ecosystem. Left in their natural state, dynamic riverbanks help sustain riverfront vegetation and edge habitats.

Riverfront development projects, routinely and disingenuously circumvent environmental laws and regulations by defining them as “building and construction projects or township and area development projects” to obtain No Objection Certificates from the environmental regulators (See Patna and Gomti riverfront development below). The developers usually submit only the built-up area as the project affected area, ignoring the plethora of very significant environmental and social changes.

Image 33 : (Left)Sabarmati River Front : A Celebration of Concrete on Borrowed Narmada Water (India Water Portal
(Right)Gomti River Front : Inspired from Sabarmati River Front (Usha Devani)

The rush to promote riverfront development projects in India started with Ahmedabad's Sabarmati riverfront development project in 2005. Concrete walls along 10.4 km on both banks converted the river's natural channel into a canal with wide promenades on both embankments. Water for this usually dry stretch of the seasonal Sabarmati is imported upstream from River Narmada. The downstream Vasna barrage ensures pondage.

The project was officially publicized as a model of river restoration. Logically, a restored river transforms a previously unsatisfactory state of the river into one that reflects its natural state and fulfils its ecological functions of transporting sediments to the confluence or the sea, land-forming, sustaining aquatic biota, groundwater recharging, etc. (Lokgariwar C. V., 2014). However, the Sabarmati river front is not on a flowing river but on a artificial linear lake bereft of any ecological component or process.

In a natural river, mineral sediments and vegetative debris flow into it from its watershed to feed the micro-organisms (benthos) on the riverbed that in turn become food, along with algae, for fish, other aquatic animals and birds. The benthic organisms and the larger beings that feed upon them need natural surfaces like sand, silt, clay and pebbles in which to feed, shelter and breed. Wildlife can hardly survive in a concrete pond.

A few riverfront development projects in the Ganga basin are described below.

11.6.1 Ganga Riverfront Development in Patna

The Ganga Riverfront Development Project Phase I at Patna, launched in February, 2014 has been officially promoted as an urban renewal project. Over the years a large part of River Ganga's course has shifted away from Patna and flows by its edge usually only during the monsoon season or during important festivals like the Chhath puja when water is specially released from upstream dams.

The initial Phase I proposal involved the development of 20 *ghats* along a 6.6 km promenade connecting the ghats and including kiosks, community and cultural centres, landscaping of spaces between the ghats, improvement of approach roads, electric crematoria, eight interceptor drains for the city sewage, and toilet complexes among other facilities (Anon, 2014a). The estimated cost was about Rs 243 cr. Phase II began in January, 2018 to extend the riverfront with a 6.5 km promenade at an estimated cost of Rs 218 cr (Anon, 2018c).

In terms of the upgradation of the river's ecosystem Phase I plans included restoration of its riparian vegetation and interception of eight sewage drains. Two sewage treatment plants were constructed separately under the National Clean Ganga Mission activities so that untreated domestic waste water would not be released into the Ganga.

Though an EIA study was done, the project did not submit to a formal EIA process by resorting to the subterfuge of a low built-up area (Anon, 2014). Dr Venkatesh Dutta, who teaches environmental science at the Babasaheb Bhimrao Ambedkar University in Lucknow, was not sanguine about the project's environmental impact when he wrote, "Even the Wildlife Protection Act, 1972, is not applicable to the project, despite the presence of the Gangetic Dolphins in the river……Strangely, only the built-up area is considered as the project affected area, ignoring the upstream and downstream consequences of riverfront projects" (Dutta V, 2018).

Dr R.K. Sinha of Patna University, also known as 'Dolphin' Sinha, wrote guardedly, "The entire stretch of river along the city of Patna has been a good habitat for the Gangetic River Dolphin. Currently, half of the river front has been lost as Ganga shifted away from the city…. I understand that there will be not much impact of the RFD Project on dolphin habitat in the Ganga at Patna………Detailed research on the impact of the RFD project on dolphin habitat may be concluded in due course of time" (Sinha R.K., 2014).

Overall, the riverfront development area is highly concretised with negligible ecological elements. Additionally, the Ganga Expressway, skirting the city is passing through the river with its piers in the river course, thereby, intruding into the river bed, and concealing and isolating all the heritage buildings along the riverfront from the river.

11.6.2 Gomti Riverfront Development

Work on the 8.5 km long Gomti riverfront development project in Lucknow -- estimated cost over Rs. 1500 cr -- began in April, 2015. As in other riverfront development projects, EIA requirements were bypassed by camouflaging it as a 'township and area development project' and understating its built-up area.

Groundwater is fundamental to sustaining water flow in the Gomti during lean seasons. The flux of water between the river and the aquifer has been affected by a vertical concrete wall that goes 11 m below the river bed level. It has disturbed the river bed, the river bank sediments and the extent to which the channel of the river intersects the saturated part of the aquifer. The channelisation has also resulted in the removal of several public *ghats.*

"The widespread ecosystem degradation caused by filling of wetlands, channelisation and concretisation of the floodplains has led to a physical, mental and spiritual disengagement with the cultural landscape of the Gomti riverfront," said Dr Venkatesh Dutta (Dutta V. et al 2018). A state level special expert committee (SEAC), however, quietly accepted the proponent's submission despite its obvious environmental, social and cultural shortcomings. The submission ignored the loss of breeding sites for turtles and the presence of crocodiles upstream of the riverfront.

11.6.3 Delhi's Yamuna Riverfront Development Saga

River Yamuna flows 52 km through the National Capital Territory of Delhi, including portions of UP, while its urban stretch in Delhi city is 22 km, from Wazirabad Barrage in the north to Okhla Barrage in the south.

The idea that Delhi could have a riverfront, popular with tourists, like the Thames in London, fascinated British planners almost a century ago. But so far, the Yamuna riverfront has managed to avoid the channelization fate of the Sabarmati and the Gomti, though administrations and developers have steadily nibbled away the river's banks and floodplains. In the process the floodplains and river banks have been encroached for mega event sports facilities (Asiad 1982 Player's hostel since reused as Delhi Secretariat, indoor and outdoor stadiums), a massive cultural-cum-temple complex, buildings to house the well-off, riverside parks behind concrete embankments, metro stations, rail lines and residential and commercial developments, a few thermal power stations, cement-concrete *ghats*, crematoria, fly ash ponds and landfill sites among other invasive projects.

A plan for developing the riverfront was first proposed in 1913, soon after the establishment of Delhi as the new capital of British India. It featured a riverfront from Wazirabad to its exit in the south. The town planning committee believed that it would enhance the attraction of the new capital and therefore deserved full support. It included a scheme for water treatment. An Interim General Plan for Delhi framed in the 1950s, presented a riverfront plan for recreational activities like playgrounds, beaches, swimming pools and fishing areas besides bathing *ghats* and other structures. But not much happened besides building embankments on the eastern bank to contain floods (Sharan A., 2015). Some of the riverfront development ideas from the 1950s plan were reiterated in Delhi's first Master Plan (1962-1981). In the late1970s, the Delhi administration's attention shifted to the construction for the 1982 Asian Games. It brought in lakhs of migrant workers to build stadia and other Games associated structures. As Delhi's population rapidly outstripped the city's ability to treat its wastewater, by the 1980s attention centered on the Yamuna's worsening water quality.

The Delhi Improvement Trust (DDA's precursor) in the 1950s leased out large chunks of river flood plains to two local villager's cooperative societies (Delhi Peasants and Jhil Khuranja Milk developers) for farming and grazing purposes. Later many of the farmers and graziers sub-leased their lands to migrant farmers who can be found farming even today. DDA disputes the validity of the said leases post 1970s. The matter is in the courts.

Delhi's second Master Plan (1981-2001) while acknowledging the annual flow cycles of Yamuna river and the groundwater potential of its floodplains, said that the land uses and aesthetics of the designated riverfront 'should be more fully integrated with the city and made more accessible – physically, functionally and visually' (Sharan A., 2015). It also recommended channelization of the river, development of the riverfront and enforcement of water pollution laws (Babu C.R. et al, 2014). But reality turned out differently. A large number of the migrant labourers had by then obtained on lease dry riverbed land from farmers who had been granted the same in the 1950s, as explained above, to cultivate vegetables and flowers. Summers yielded abundant crops of thirst-quenching melons.

Meanwhile, the Yamuna itself was dying in Delhi. Untreated domestic sewage flowed into the river, its natural flow sapped by upstream dams and barrages. Industrial effluents from local factories and thermal power plants and pesticides from upstream agriculture added to the pollution load. The migrant labourers were blamed for the biological contamination of the river water. Unmindful of their labours in building the new stadia and other facilities a chorus arose for their eviction, beautification of the city and riverfront development.
Economic liberalization of the 1990s fed the aspirations of the burgeoning, upwardly-mobile middle classes wanting to live in a 'world-class city'. It found an expression in the third Master Plan of Delhi (2001-21). With its sights set on the 2010 Commonwealth Games and the vision of Delhi as a world class city, the Delhi state government began the task of reclaiming the riverfront. The first step was the eviction in 2004 of about 350,000 persons living in *jhuggis* along the Yamuna embankments, with the help of votes-seeking local politicians. By selective use of facts, defecation along the Yamuna became the reason for the demolition of their homes (Baviskar A., 2011). A Delhi High Court ordered their removal, ignoring that most of the pollution load came from homes in the authorized colonies.

In 2007, the Prime Minister set up a High-Powered Committee for the Yamuna's rejuvenation. Chief Minister Sheila Dikshit's administration proposed an ambitious plan in 2009-10 to channelize the Yamuna and construct a waterfront with recreational facilities, parking lots and promenades etc., conveniently forgetting the river's tendency to spread its sediments-laden flood waters in the monsoons.

The rapid, almost unopposed, usurpation of the Yamuna floodplains and the prevailing ignorance towards their importance, led several local organizations to come together in February, 2007 and establish the Yamuna Jiye Abhiyaan (Living Yamuna Campaign). In 2012, Manoj Misra, convenor of YJA, filed a petition in the NGT against the Union of India and others for the deterioration of River Yamuna. An expert committee appointed by the NGT to examine the Yamuna River Front Development Scheme of the Delhi Development Authority (DDA) recommended that the DDA's ambitious scheme be scrapped since it would reduce the river's flood-carrying capacity and increase flooding and pollution. It recommended that the Yamuna's entire 52-km stretch in the NCT of Delhi (including parts of UP), be declared a 'conservation zone' and that developmental activities in its active floodplains be banned for restoring the river's ecological functions.

With the Lieutenant-Governor of Delhi and the Vice-Chairman of DDA taking an interest, the DDA proposed plans in 2017 to develop the Yamuna riverfront following the guidelines set by the NGT expert committee. In the first phase, it launched biodiversity parks on 200 ha from Old Railway Bridge to ITO Barrage and the national highway (NH 24) to DND flyway on the western bank, to revive the ecology, with native flora and fauna in a biodiversity park and wetlands, water conservation and a 2.5-km long riverfront walkway (Sultan P., 2020). The DDA also proposed a water treatment solution for the Yamuna under a separate plan. In November 2020, DDA officials said that about half the work was done and that the remaining would be completed by June 2021. Prof. C.R. Babu, Chairman of the expert committee was guiding the project. The DDA is also working on restoration and rejuvenation of about 1,500 hectares of the Yamuna floodplain on its eastern bank.

More recently a plan has been announced to extend the proposed Central Vista to the western banks of the Yamuna. A 20.22 acres Nav Bharat Udyan will replace the existing trees and shrubs along the Yamuna (Tiwari A., 2020). Faiyaz Khudsar, scientist-in-charge of the north Yamuna Biodiversity Park and the under-development south Yamuna Biodiversity Park has identified plum, guava, eucalyptus, *jamun* and mulberry trees and *saccharum munja*, typha and other grasses and shrubs along the floodplains of the river. "The riverbanks experience huge floods once every 15-20 years, when entire floodplains are covered for around a fortnight. Native species of plants tend to survive floods, such as jamun trees," he said (Tiwari A., 2020). According to an official, the Nav Bharat Udyan will not extend all the way to the river as an embankment runs parallel 50 metres from it. YJA has opposed these plans as violative of the 2015 NGT Yamuna judgment titled 'Maily se Nirmal Yamuna'.

If executed on ecological principles, the DDA revised restoration plan for the Yamuna floodplains can potentially be a template for urban river stretches elsewhere in the country.

11.6.4 Dehradun's Riverfront Development Plans

Dehradun, the provisional capital of Uttarakhand, lies in the Doon valley almost midway between the Ganga in the east and Yamuna in the west. Two small rivers, the Rispana and the Bindal flow through it to join the Song river, a tributary of the Suswa, which flows into the Ganga. In a report submitted to the Union Ministry of Water Resources, The National Institute of Hydrology had described the Bindal and Rispana as 'perennial streams' (Anon, 2014b). Presently, the Bindal and Rispana river banks are heavily encroached and the rivers themselves are sewage drains. They are naturally flushed every year during the monsoons.

In October, 2015, the Mussoorie Dehradun Development Authority (MDDA) announced a 30 km long river front development project on the Bindal and the Rispana, along the lines of the Sabarmati Riverfront Development Project in Ahmedabad, Gujarat. An Interim (Project) Report submitted by WAPCOS for 'long term conservation and at the same time restoring the environmental and ecological balance of rivers and their surroundings' proposed the following works: (i) Re-sectioning / Channelization & Abatement of

Pollution, (ii) Additional infrastructure for sewer and industrial effluent treatment, (iii) Bank Protection Works, (iv) Construction of weir and series of check dams and (v) Parks & Recreational Centers.

The WAPCOS report was severely criticized by concerned citizens, who had earlier put forth suggestions for rejuvenation of the rivers during public consultations on Dehradun's Smart City programme proposal. Reviewing the WAPCOS report, A.K. Roy, Director of the Hazard Centre in New Delhi, who was born and raised in Dehradun, said, "All these (structures) seem to treat the river/stream as a tame smooth-flowing entity that does not carry gravel, sand, and small boulders with tremendous erosive impact, and can be confined within the two banks of a channel and behind check dams and weirs. In addition, the banks are assumed to be stable enough to become recreation spots. And the sewage treatment plants are assumed to be able to adequately treat the increasing waste waters with both their biological as well as chemical content. But there is no data within the report – flow volumes, velocity of streams, silt quantification and content, bank stability, nature of sewage, and sewage treatment processes – and that makes such simplistic assumptions untenable."

Till the end of 2019, MDDA neither had a Detailed Project Report nor ownership of the land required for the project estimated by it to cost about Rs 750 cr. Meanwhile it has sought technical assistance from Sabarmati Riverfront Development Corporation Limited and selected NBCC (India) Ltd, a blue-chip Central PSU as its construction contractor.

11.6.5 Conclusion

Riverfront development as proposed by Indian planners is nothing more than encroachment of a river's regime and its conversion into expensive real estate for commerce, pleasure and recreation. The state, funding agencies, consultants and riverfront developers are all fully aware of the injurious environmental and social impacts of their riverfront channelizing projects. Yet they cynically publicize them as river restoration projects. Environmental laws and regulations are circumvented as uncritical regulatory agencies look away.

"The river, the slum dwellers, the urban elite and the public authorities all covet the same parcels of land on either bank, as floodplain, as a fragile site for informal housing, as spaces for constructing monumental buildings, and for building public infrastructure," explains Awadhendra Sharan of the Centre for the Study of Developing Societies, New Delhi (Sharan A., 2015). In their contests the river, like the powerless, becomes a victim.
Rivers make their own waterfronts. Genuine riverfront development can be done in harmony with what nature has already done. Planners would do well to invest in sustainable ecological and social well-being by consulting with the various stakeholders, including those who try to survive along the river banks and eke out meagre livelihoods. Delhi's Yamuna Jiye Abhiyan (YJA) has shown that strong protests backed by well-

researched scientific evidence and arguments can move the courts to thwart the frontal assaults on the natural riverfront by the developers and develop a riverfront that is in tune with Nature's rythyms.

11.7 CONCLUSIONS AND RECOMMENDATIONS

Since Independence, India's decision-makers opted for planned economic development with industrialization as the engine of growth of the tiny national economy. Poverty eradication had been a key promise of the freedom struggle. The decision-makers piously hoped that as the size of the national economy improved the benefits would trickle down to everyone.

The early focus was on food security and installing the motive power to drive machinery. Hence the emphasis on building dams for irrigation and hydropower generation. But without adequately institutionalizing equity and sustainability, Nature was devastated and the rural masses who were almost totally dependent on their immediate surroundings for the daily resources of food, fodder, fuel and water were impoverished. The present shrunken, emaciated and defiled state of India's National River, also worshipped as a divine manifestation, mirrors the devastation of Nature.

Once liberalization set in, the increasing availability of financial credit for investment from international capital seeking newer and bigger markets, and growing Indian technological prowess replaced planned economic development with the objective of rapid economic growth. It also inflated the ambitions of decision-makers – politicians, bureaucracy and the business and other upwardly mobile classes.

In the push for rapid economic growth, this nexus of political, administrative and commercial power has pushed mega projects in the last three decades. A dangerous trend that has emerged in the last decade, is the disdain of the power nexus for environmental regulations painstakingly crafted by those mindful of the harmful repercussions of unbridled growth and desirous of sustainable and equitable development. This nexus has succeeded in subjugating legislatures, courts and the media as elaborated in the preceding sections. These developments portend greater, more rapid and perhaps irreversible damage to the Ganga river system.

The massive June 2013 floods in India's Upper Ganga basin, the swift decimation of the Tapovan-Vishnugad HEP and the avalanches in the Dhauliganga valley in April 2021, the repeated and powerful storm surges in the Ganga delta are warning signals from a rebellious river system that the threshold levels for climate change are not uniform all over the world. It is well-known that the Himalaya, the sentinels of the northern Ganga sub-basin, are more sensitive to climate change impacts than most other parts of the world.

Practical and much cheaper alternatives for speedily enhancing water availability in both the basins like protecting forests and traditional water-harvesting systems, springshed development, afforestation and watershed development and treatment of polluted water and its reuse, etc. are known and practised in different parts of the country. They are critically important for enhancing the base flows in the rivers. Combined with cultivation of traditional and more nutritious, low water-consuming crops, sustainable agriculture and participatory groundwater management have provided resilience against droughts and equitable economic uplift in dryland farming areas like Ralegan Siddhi and Hivre Bazar in Maharashtra.

Past efforts in the above-mentioned activities have met with limited and localized successes. What is desired is systemic change that incorporates these ideas. For this people must have a sense of ownership of the natural resources in their habitations. This calls for a complete review of the governance of our natural resources, particularly rivers, groundwater, forests and grasslands. India's natural resources are very-underproductive. A pre-requisite for community ownership of natural resources leading to equitable and sustainably high productivity is the observance of democratic norms of governance at all levels.

11.8 ENDNOTES

i. In 2016, scientists from WII recorded the presence of a tiger in this PA at an elevation of 3,274 metres. This is the first time a tiger has been found at this altitude in the country. The Mahakali basin has historical records of the tiger but information is scanty.

ii. This section is based on an analysis by Maj-Gen (retd) S. G. Vombatkere, a Ph.D. in Structural Dynamics from IIT-Madras and an Adjunct Associate Professor at University of Iowa, USA. in (Vombatkere S.G., 2019).

iii. Presumably, the Brahmaputra inflows into the Ganga will be downstream from the Subarnarekha link off-take so that the water supply to Bangladesh is maintained. The addition of the Brahmaputra water, however, may cause serious erosion problems, but no details on this aspect are in the public domain.

iv. The study team included Dr. Agrawal's engineering peers and researchers from People's Science Institute, Dehra Doon and Tarun Bharat Sangh, Alwar.

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CHAPTER 12
NAMAMI GANGE

12.1 BACKGROUND

On October 16, 2008 a delegation led by Shankaracharya Swami Swaroopanand Saraswati met the then Prime Minister, Dr Manmohan Singh, to impress upon him the need to assess the state of River Ganga, since the Ganga Action Plan had been in place since 1984. It was by then well-known through government and non-government reports that the Ganga and Yamuna Action Plans had failed to meet their objectives and the health of both the rivers was going from bad to worse (CAG, 2000 and Shankar U, 1993).

Subsequently on November 4, 2008 the Central Government declared River Ganga to be India's National River. It was also decided to set up a National Ganga River Basin Authority (NGRBA) as an empowered planning, implementing and monitoring body, chaired by the Prime Minister. NGRBA was constituted under the provisions of the Environment (Protection) Act, 1986 (See also Chapter 7 in this book). The NGRBA was formally constituted on February 20, 2009 to effectively abate pollution and conserve R. Ganga.

Later, on August 12, 2011, the National Mission for Clean Ganga (NMCG) was registered as a society under the Societies Registration Act, 1860. It was created to act as the executive arm of the NGRBA. The NGRBA and the NMCG were both hosted by the then Ministry of Environment & Forests (MoEF).

On 31 July, 2014, the new government at the Centre decided (through a Gazette Notification) to transfer the work related to Ganga and its tributaries from the Ministry of Environment, Forests and Climate Change (MOEFCC) to the Ministry of Water Resources, River Development and Ganga Rejuvenation (MOWR, RD & GR). Accordingly, the administrative control of NMCG was also transferred and the NGRBA was reconstituted on 29 September, 2014.

Earlier, in June, 2014 the Union Government approved the "Namami Gange" program as an integrated conservation mission, and in May, 2015 approved an indicative five-year budgetary outlay of Rs 20,000 crores to accomplish a) effective abatement of pollution and b) conservation and rejuvenation of National River Ganga. It was clearly a step in continuation of the various measures planned previously and taken for arresting and improving the deteriorating condition of river Ganga.

What was new about Namami Gange was a large dedicated budget and a broader objective to 'rejuvenate' the river instead of just 'cleaning' it. A worthy intent had certainly been put in place. An air of great expectancy has since been created around the Namami Gange program.

National Council for Rejuvenation, Protection and Management of River Ganga

On October 7, 2016 a National Council for Rejuvenation, Protection and Management of River Ganga was constituted by the River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016. Its Notification, issued under the provisions of Environment (Protection) Act 1986, also dissolved the NGRBA.

The NMCG now has a two-tier management structure, comprising of a Governing Council and an Executive Committee. Both of them are headed by the Director General, NMCG. The Executive Committee is now authorized to accord approval for all projects up to Rs.1000 cr.

Similar to the structure at the national level, State Programme Management Groups (SPMGs) act as implementing arms of the State Ganga Committees. Thus, the newly created structure attempts to bring all stakeholders on one platform to take a holistic approach towards the task of Ganga cleaning and rejuvenation. For effective implementation of the projects under the overall supervision of NMCG, the state level SPMGs are headed by senior officers of the respective States.

NGRBA'S Achievements

NGRBA was meant to be a participatory and collective endeavour that would address the issues facing the Ganga in a comprehensive manner, based on a river basin management plan and an estimated outlay of Rs 15,000 cr over a 10-year period. Among its notable actions were:

- Creation of the Bhagirathi Eco-Sensitive Zone (BESZ) covering an area of 4179.56 sq. km., the entire watershed from Gaumukh to Uttarkashi town – the initial 100 km stretch of river Bhagirathi, to preserve its pristine Himalayan ecology.

- The creation of BESZ led to the cancellation of three major hydroelectric projects, including the 600 MW under-construction Loharinag-Pala project, and 10 small hydropower projects.

- Designation of the Gangetic River Dolphin as the National Aquatic Animal of India.

- Commissioning a consortium of seven IITs to prepare a Ganga River Basin Management Plan.

- Negotiating financial assistance of US $1 billion from the World Bank for pollution abatement and river conservation.

Despite these initial achievements, NGRBA made inadequate progress towards its larger goals, before it was dissolved in 2016.

To implement measures for prevention, control and abatement of environmental pollution in R. Ganga and to ensure continuous adequate flow of water for rejuvenating it, the Ganga Authorities Order, 2016 mentions the following five tier structure at the national, state and district levels:

1. National Ganga Council under the chairmanship of the Prime Minister of India.
2. Empowered Task Force (ETF) on R. Ganga under the chairmanship of the Union Minister of Water Resources, River Development and Ganga Rejuvenation.
3. National Mission for Clean Ganga (NMCG).
4. State Ganga Committees and
5. District Ganga Committees in every specified district abutting R. Ganga and its tributaries in the states. (These have been formed in all the river basin districts having monthly meetings)

Expert Committees

Since its restructuring in 2014, NMCG has created a number of standing as well as temporary expert committees to advise it on various matters. These are:

a) Standing Expert Committee on Technologies for Ganga Rejuvenation (22 Sep, 2014)

b) Expert Committee for Improving the existing guidelines on sand mining (11 Nov, 2014)

c) Expert Committee for preparation of guidelines for works on desiltation from Bhimgauda (UKH) to Farakka (WB) (21 July, 2016)

d) Expert Committee on Ganga Act (21 July, 2016)

e) Expert Evaluation Committee for wastewater treatment technologies (20 Sep, 2016)

f) Expert Committee for suggesting measures for revival of river Bhagirathi (28 Sep, 2016)

g) Expert Committee for demarcating the flood plain (once in 25 year floods) of river Ganga from Haridwar to Unnao (1 Aug, 2017)

h) Expert Committee on minimum E Flow in river Ganga (1 Aug, 2017)

i) Standing 'Think Tank' Committee for Ganga Rejuvenation (5 July, 2017)

However, no reports of these committees are available on NMCG's website.

12.2 ACTIVITIES UNDER THE NAMAMI GANGE PROGRAMME

The NMCG website has identified the following key pillars of the Namami Gange programme (NMCG 2020):

a) Sewerage Treatment Infrastructure
b) River Surface Cleaning
c) Afforestation
d) Industrial Effluent Monitoring
e) River Front Development
f) Bio-Diversity
g) Public Awareness
h) Ganga Gram

Identified Thrust Areas And Action Points

Namami Gange has identified seven thrust areas and 21 action points for the rejuvenation of Ganga and its tributaries, as below (NMCG Undated-a and NMCG Website):

Thrust Area 1 - Nirmal Dhara

- Rehabilitation and upgradation of existing sewage treatment facilities and initiating new sewage infrastructure projects along with the Ministry of Urban Development
- Treatment of sewage and other effluents flowing directly into the river through various drains by adoption of suitable technology and financial models
- Tackling industrial pollution in collaboration with MoEFCC and with the active involvement of CPCB and the concerned SPCBs.
- Promoting sanitation in rural areas along the banks of R. Ganga together with MoRD and development of select village panchayats as model panchayats to be christened as "Ganga Grams"
- Tackling agricultural pollution from chemical fertilizers and pesticides by promotion of organic farming in the villages adjacent to R. Ganga along with the Ministry of Agriculture.
- Tackling 'pious refuse' entering the river; removal of floating solid waste; development of model Dhobi Ghats
- Creating model cremation ghats on the river banks and promoting ecofriendly cremation methods with the help of religious leaders

Thrust Area 2 - Aviral Dhara

- Implementing comprehensive measures to determine and maintain environmental flow, which is site, season and river specific and ensuring longitudinal connectivity

Thrust Area 3 - Jan Ganga - People's participation and creating awareness

- Creation of Ganga Vahini/Ganga Vichar Manch
- Communication and Public outreach activities

- Training of citizen volunteers as 'Ganga Praharis', 'Ganga Mitras' and 'Ganga Doots' in the riparian districts
- Organisation of 'Ganga Utsav' (River Festival), Ganga Quest (International Quiz Competition), Cleanathons, plantation drives etc

Thrust Area 4 - Gyan Ganga - Research, Policies, Knowledge Management and Monitoring

- G.I.S. and spatial mapping of Ganga basin
- Research projects such as those relating to assessment of the special properties of Ganga water; study of communities traditionally dependent upon Ganga for livelihood and study to formulate guidelines for scientific sand mining
- Establishment of a National Ganga Monitoring Centre
- Establishment of Ganga Institute of River Sciences (cGanga) at IIT Kanpur
- Commissioning studies for documentation of heritage along the Ganga, riverine islands, biodiversity mapping and rejuvenation of tributaries

Thrust Area 5 - Arth Ganga

Self-Sustainable Economic Model based on Symbiotic Relationship between Nature and Society, by strengthening people-river connect, adopting an ecologically conscious development framework - The six thrust verticals are:-

a. Zero-Budget natural farming
b. Monetisation of sludge and treated wastewater reuse
c. Promotion of livelihood opportunities
d. Revival of cultural heritage and tourism
e. Public participation
f. Instituiton building

Thrust Area 6 - Protection and Beautification of Riverfront and Development of Public Amenities

- River front and ghats development at seven selected places and also at other places of cultural significance
- Development of public amenities in Char Dham Yatra and at Ganga Sagar.
- Engagement of a Ganga Task Force

Thrust Area 7 - Inter-Ministerial Coordination, State's participation and Capacity building

- Providing support to states for preparation of DPRs of projects under the Ganga rejuvenation program
- Coordination between various Ministries of the Central Government and concerned State Governments; capacity building of State Governments, urban local bodies and Panchayati Raj Institutions

Key Achievements under Namami Gange Programme, 2022

1. **Creating Sewage Treatment and Sewerage Capacity:** Out of a total of 183 sanctioned projects, 102 sewerage and sewage treatment projects are complete and 47 are under implementation in Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Delhi, Himachal Pradesh, Haryana and Rajasthan. Work is under construction for creating a sewage treatment capacity of ~4949 (MLD).

2. **River-Front Development:** 102 projects have been initiated for construction, modernization and renovation of 254 *ghats*, crematoria and kunds, ponds, of which 77 have been completed and 17 are in progress.

3. **River Surface Cleaning:** Collection of floating solid waste from the *ghats* and river surface and its disposal at 11 locations.

4. **Bio-Diversity Conservation:** One of NMCG's long-term visions for Ganga rejuvenation is to restore viable populations of all endemic and endangered biodiversity of the river and restore the integrity of the Ganga river ecosystems. Consequently, Wildlife Institute of India (WII), Central Inland Fisheries Research Institute (CIFRI) and the Uttar Pradesh State Forest Department have been awarded projects to develop science-based aquatic species restoration plan for Ganga River by involving multiple stakeholders along with conservation & restoration of aquatic biodiversity. WII researchers have identified high biodiversity areas in river Ganga for focused conservation action. It has established rescue & rehabilitation centers for the rescued aquatic biodiversity and trained 'Ganga Praharis' to support conservation actions in the field. It has established interpretation centres for developing awareness on biodiversity conservation and Ganga rejuvenation and developed an assessment framework to strengthen the environmental services in the river basin. CIFRI has mapped and recorded the available fish species in the Ganga basin. It is conducting ranching and awareness programmes at various locations in the river basin for conservation and restoration of Indian Major Carps (IMC) & Mahseer in Ganga. It is also studying the migration pattern of important fish species like the Hilsa. The Uttar Pradesh State Forest Department is implementing a programme for conservation breeding of freshwater turtles and gharials at Kukrail Gharial Rehabilitation Centre, Lucknow.

5. **Afforestation:** NMCG is providing financial support to State Forest Departments in Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal to implement 'forestry interventions' to enhance the productivity and diversity of the forests in head water areas and all along the river and its tributaries and improve the flow in the river (aviralta). The interventions are based on a five-year plan (2016-2021) prepared by Forest Research Institute (FRI) to afforest 1,34,106 hectares at an estimated cost of

Rs. 2293.73 cr.* The works are planned for natural, agriculture and urban landscapes among other conservation interventions.

6. **Public Awareness:** Workshops, seminars, conferences, rallies, campaigns, exhibitions, shramdaan, cleanliness and plantation drives, competitions, and development and distribution of resource materials have been organized to involve communities in the Namami Gange programme. NMCG has ensured the programme's presence on Social Media and publication on platforms like Facebook, Twitter, You Tube, etc. For wider publicity, electronic, digital and print media advertisements, advertorials, featured articles and a Gange Theme song have been released.

7. **Industrial Effluent Monitoring:** Regulation and enforcement through regular and surprise inspections of Grossly Polluting Industries (GPIs) are carried out to ensure compliance of environmental norms. Annual third-party inspections of GPIs for compliance verification of the pollution norms and process modification orders, led to 215 units being self-closed, out of 961 GPIs inspected in 2018, while 110 non-complying GPIs were issued closure directions. Online Continuous Effluent Monitoring Stations (OCEMS) connectivity with CPCB has been established in 885 out of 1072 GPIs.

8. **Ganga Gram:** Rs. 578 Crores were released to MoDW&S for construction of toilets in 1674 Gram Panchayats of 5 Ganga Basin States. It has constructed 8, 53,397 toilets out of the targeted 15, 27,105 units. A consortium of seven IITs is preparing a Ganga River basin Plan and 13 IITs have adopted 65 villages as model villages. UNDP is executing a rural sanitation programme and has been engaged to develop Jharkhand as a model State at an estimated cost of Rs. 127 cr.

NMCG has signed MoUs with various Central Ministries for synergizing Government schemes. It is also negotiating with countries like Australia, United Kingdom, Germany, Finland, Israel etc. that are interested in collaborating for Ganga rejuvenation.

*This amounts to a Rs 1,71,038/hectare.
-excerpted from https://nmcg.nic.in/NamamiGanga.aspx

Projects

The programme implementation is divided into Entry-Level Activities (for immediate visible impact – three years), Medium-Term Activities (to be implemented within a five-year time frame) and Long-Term Activities (to be implemented within 10 years). Till now, 423 projects worth more than US$ 4 Billion have been sanctioned against which 225 projects have been completed, while the remaining are under various stages of execution. About 176 projects roughly worth over US$ 3 Billion have been sanctioned just to create/ rehabilitate a cumulative treatment capacity of 5,270 MLD and laying of 5,214 km sewer network in the basin. The other projects pertain to the areas of industrial pollution abatement; solid and liquid waste management; conservation of biodiversity, wetlands; afforestation; groundwater management; rejuvenation of small rivers and springsheds; floodplain management etc.

Introduction of innovations such as Hybrid Annuity based PPP Model and One-City-One-Operator model have been a game changer in Indian wastewater sector. They have enhanced accountability in wastewater infrastructure creation, service delivery and accountability, along with significantly increasing private sector participation in the sector.

NMCG launched "Rivers Cities Alliance" to provide its 100 member cities a platform to discuss and exchange information related to sustainable management of urban stretches of rivers. It is expected that the 'Alliance' would go a long way for building river and water-sensitive cities of the future.

2.3 E FLOWS NOTIFICATION

NMCG published a Notification on October 10, 2018 specifying (a) Minimum environmental flows at locations in the Upper Ganga Basin stretch and (b) Minimum Flow releases (d/s of barrages) in the Haridwar to Unnao stretch of the main-stem of R. Ganga. These values are shown in Tables 52 and 53.

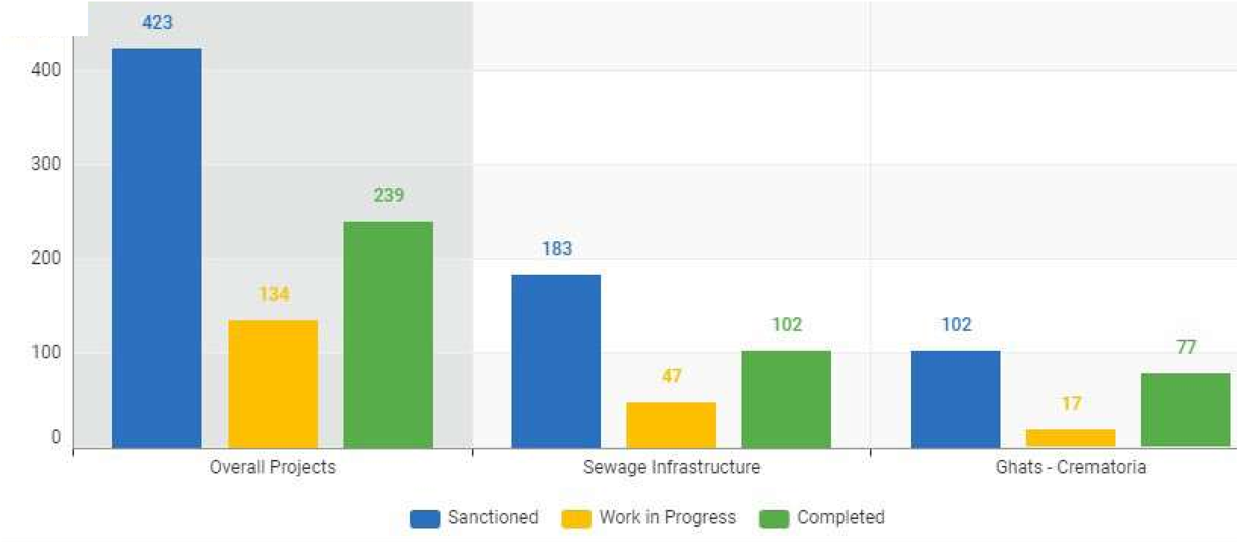

Image 34 : Number of Projects Sanctioned by Namami Gange and their Progress

Source -NMCG Website

Table 52 : Minimum environmental flows in the Upper Ganga Basin Stretch

S No	Season	Months	Percentage of monthly average flow observed during each of preceding 10-day period
1	Dry	November - March	20
2	Lean	October, April, May	25
3	High Flow Season	June to September	30

Source: https://nmcg.nic.in/writereaddata/fileupload/46_Notification.pdf

Table 53 : Proposed Minimum Flow releases (d/s of barrages) in the Haridwar-Unnao stretch of the main-stem of R. Ganga

S No	Location of Barrage	Minimum Flow release immediately downstream of Barrages (cumec) in Non-monsoon (Oct – May)	Minimum Flow release immediately downstream of Barrages (cumec) in Monsoon (June – Sep)
1	Bhimgoda	36	57
2	Bijnor	24	48
3	Narora	24	48
4	Kanpur	24	48

Source: https://nmcg.nic.in/writereaddata/fileupload/46_Notification.pdf

The above ecological flows are subject to the following stipulations:

a) The compliance of minimum ecological flow is applicable to all existing, under construction and future projects.

b) The existing projects which currently do not meet these environmental flows norms, shall comply and ensure that the desired environmental flow norms are complied with, in a period of three years from the date of issue of this order.

c) Projects which are at different stages of construction, where physical progress on the ground has been initiated and made and reported to the appropriate authority shall also make necessary provisions to maintain the stipulated environmental flow before and after commissioning of the project.

d) Mini and micro projects which do not significantly alter the flow characteristics of the river or stream are exempted from these environmental flows.

e) To ensure the release of desired quantities of water to maintain environmental flows, flow conditions in these river reaches shall be monitored at hourly intervals from time to time.

f) The Central Water Commission shall be the designated authority and the custodian of the data, and shall be responsible for the supervision, monitoring and regulation of flows, and reporting of necessary information to the appropriate authority as and when required and also authorised to take emergent decisions about the water storage norms in case of any emergency. The Central Water Commission shall submit flow monitoring-cum-compliance reports on quarterly basis to NMCG.

g) The concerned project developers or authorities shall install automatic data acquisition and data transmission facilities or required necessary infrastructure at project sites within six months from the date of this order. The installation, calibration and maintenance of flow monitoring facility shall be the responsibility of the project developers or authorities and they shall submit the data to the Central Water Commission from time to time.

h) The Central government through NMCG may direct release of additional water in river Ganga to meet special demand as and when required.

Moreover, as per the 2nd Quarterly EFlows Report of 2020, Tehri Dam and the Kanpur Barrage failed to provide the flow data in the desired format of hourly basis, with Tehri Dam providing data on daily basis and Kanpur Barrage on two-hourly basis. Although most of the HEPs have complied with the EFlow norms, Pashulok Barrage in Rishikesh did not comply with the norms for the month of April. The Srinagar HEP performed dismally, not complying with the desired EFLows during the entire quarter. One of the main concern is the erratic submission of data, primarily due to lack of automatic data acquisition and transmission system in most of the HEPs except Tehri dam, Koteshwar dam, Bhimgoda barrage and Narora barrage which, even after the Notification of 2018 and requests during inspections have been blatantly ignored.

12.4 WHITHER NAMAMI GANGE?

12.4.1 Findings of the Lok Sabha Estimates Committee

Dr Murli Manohar Joshi, MP and chairperson of the Estimates Committee of the Lok Sabha, presented the 24th report of the Committee on December 21, 2017, regarding actions taken by the government on the observations / recommendations contained in the fifteenth report of the Committee (2016-17) on rejuvenating River Ganga (Lok Sabha 2017). Some of the key observations of the Committee, which are still relevant, are excerpted below:

1. Gap between installed and actual utilization capacity of STPs

(a) “The Committee fails to understand the pitiable condition of various STPs, inspite of strong directions given by the Chairman, CPCB in the backdrop of Hon’ble Supreme Court directions. The Committee strongly emphasizes for having mechanisms to fix accountability where there is slackness on the part of officers/contractors or anybody involved in the implementation of various works/projects.”

2. Ideal location for STPs

So far as the recommendation of the Committee to set up STPs on the sand bed site of the river being economical and sustainable, the Ministry has not recommended to this part of the recommendation."

3. Lack of scientific and technical resources

(a) "The Committee highly deprecate(s) that despite huge shortage of manpower particularly scientific and technical man power in CPCB, urgent steps have not been taken to fill up the vacancies."

(b) "What is more worrying is the problem being faced in the retention of young manpower being recruited. The Committee concludes ……. a sorry state of affairs with regard to recruitment and handling of manpower in CPCB which calls for urgent and immediate action."

4. Incentives to Small Scale Industries for ZLD (Zero Liquid Discharge)

(a) "While taking note of some of the incentives being given to SSI for ZLD, which include meeting all the financial liabilities arising out of preparatory studies for 20 MLD ZLD and a project for management of waste water from textiles clusters through NMCG fund, the Committee would like to be apprised about the status of setting up of these projects."

(b)These Small Scale Industries need more government support as recommended by the Committee viz., (i) tax and non-tax incentives may be offered to the units which are adopting new technologies with considerable amounts of investments to become Zero Liquid Discharge (ZLD) units; (ii) availability of easy finance may be ensured at affordable rates from the banks……..; (iii) these units may be provided technical knowhow from government owned academic and research institutes at subsidized rates so that they become ZLDs."

(c)It has been stated that …………based on inspection of 355 units during the last one year the waste water generation from GPI has been found reduced……………."

5. Nirmalta and Aviralta of the River

(a) "The Committee had desired the government to furnish the details and outcome of the Report submitted by expert body appointed under the direction of the Hon'ble Supreme Court to find out the environmental degradation, impact of HEPs on environment including landslides and biodiversity. The Committee is unhappy to note that the Ministry has not furnished the information with respect to action taken or proposed to be taken on the recommendations contained in the above report."

(b) "In pursuance of the other part of the recommendation the Ministry has furnished the decadal data of lean season and non-lean season flows in the Ganga from the date of opened site to October, 2016 from points of origin to Haldia."

6. Arsenic in Ganga Basin

(a) "The Committee are appalled to note the way the different arsenic genesis studies proposals have been dealt with by the Government."

12.4.2 Findings of CAG

The Comptroller & Auditor General (CAG) of India conducted a performance audit of the Namami Gange programme activities during the period from 2014-15 to 2016-17. Projects sanctioned prior to the announcement of the Namami Gange programme but continuing during 2014 to 2017 were also audited. (MoWR, RD&GR 2017)

During this period 145 projects (sanctioned amount about Rs 10,974 cr) were under various stages of construction. Of these, 128 were infrastructural projects, sanctioned at a cost of about Rs 10638 cr. CAG audited 87 projects, including 70 infrastructural projects and all the institutional, afforestation and biodiversity projects. Of these 87 projects, 73 were continuing, 13 were completed and one was an abandoned project.

The audit concluded with the following important observations:

1. Financial Management

"There were deficiencies in preparation of budget estimates as only eight to 63% of the funds were utilized during 2014-15 to 2016-17 as compared to Revised Estimates……. Huge unspent balances were lying with NMCG, SPMGs, EAs and state governments and the entire amount of Clean Ganga Fund was lying idle."

2. Planning

"NMCG has not finalized the Ganga River Basin Management Plan (GRBMP) for initiating long term intervention on the Ganga. Approvals of DPR for Ganga Rejuvenation suffered from inordinate delays. Ganga Knowledge Centre (GKC) has not been established as of June 2017. River Conservation Zones were not identified in the states of Uttar Pradesh, Bihar, Jharkhand and West Bengal." **Knowledge centre has since been established**b nn

3. Pollution Abatement and Ghat Development

"NMCG missed the target of preparation of DPR for STPs as per the cabinet approval of Namami Gange program. Untreated sewage was found to be discharged into the river Ganga in the selected towns of Bihar, Jharkhand and West Bengal. The projects executed by SPMG/EAs relating to sewerage systems and sewage treatment suffered from delays in execution ………In case of projects relating to ghats and crematoriums which are being executed by CPSUs, projects suffered due to delay in start of work……. lack of coordination among NMCG and CPSUs……." **Subsequently, much progress has been made in the last 6 years . The data in Image 34 indicates that significant progress has been made towards construction of STPs. Initiatives like the River Cities Alliance offer hope for pollution abatement in the Ganga basin rivers.**

4. Rural Sanitation

"The main objective of Rural Sanitation program to make all Ganga river basin villages ODF could not be achieved despite repeated extension of time. There were deficiencies in planning and laxity in spending of available funds by the state governments .... The work related to Solid Liquid Waste Management was not initiated in Uttar Pradesh, Bihar, Jharkhand and West Bengal. There were discrepancies in data of targets / achievement reported under MIS and in the records of Gram Panchayats." **As per NITI Aayog in 2019-20, India has become open-defecation free. However, achievement of open defecation status is related to the construction of toilets in homes and education alinstitutes. There are many reports that many of these toilets are not used because of lack of water for sanitation.**

5. Conservation of Flora and Fauna and Maintenance of Ecological Flows

"The number of projects for conservation of flora, fauna and river flow were very limited as compared to projects for pollution abatement and river front development. The long-term action plan for Ganga Rejuvenation was yet to be finalized based on Ganga River Basin Management Plan. As such ecology and biodiversity conservation efforts of NMCG were at a very initial stage and (they) suffered from deficiencies in program implementation. There was short release of funds for forestry interventions, coverage on ground for biodiversity conservation and non-sanction of any projects for study of the maintenance of ecological flow."

6. Human Resource Management

"The organization framework created under the National Ganga River Basin Authority (NGRBA) for implementation of Ganga Rejuvenation programmes suffered from shortages of human resource at NMCG, SPMG, and CPCB/SPCBs."

7. Monitoring and Evaluation

"Meetings of various bodies, committees created under NGRBA framework, Societies Act and order of Government of India to monitor and evaluate programs have not been held as per the prescribed frequencies. There was slow implementation of projects sanctioned to CPCB for water quality monitoring, strengthening of regulators, inventorization, etc. Establishment of Ganga Monitoring Centers was still in conceptual and planning stage. The use of remote sensing data and mobile applications were at nascent stage.................."

12.5 NMCG PRIORITIES AND E FLOWS NOTIFICATION

NMCG's vision for Ganga rejuvenation calls for restoring the wholesomeness of the river defined in terms of ensuring "Aviral Dhara" (continuous flow), "Nirmal Dhara"(unpolluted flow), geologic and ecological integrity (NMCG Undated-b).

The aims and objectives of NMCG, as listed on its website, appear to be dated, harking back to the NGRBA period, which ended in October 2016. It states (NMCG Undated-c):

1. To ensure effective abatement of pollution and rejuvenation of the river Ganga by adopting a river basin approach

2. To promote inter-sectoral co-ordination for comprehensive planning and management

3. To maintain minimum ecological flows in the river Ganga with the aim of ensuring water quality and environmentally sustainable development.

Against the above objectives, it would appear that the effort has been greatly weighted in favour of the first objective i.e. pollution abatement. The emphasis has been upon the main stem of the river and mainly on pollution abatement through STPs.

The second objective, i.e. to promote inter-sectoral co-ordination for comprehensive planning and management, is a far more complex exercise involving vast sectors such as agriculture, urban planning, water resources, biodiversity, transport, fisheries, mining and climate change. It would be fair to say that the efforts towards this objective are at a very early stage.

The vital third objective i.e. to maintain minimum ecological flows in the river Ganga, has yet not made progress. Perhaps, even more than pollution, it is anaemic flows which truly ail the river.

Thus, looking at the activities being implemented under the Namami Gange programme, coupled with the observations and comments made by the Lok Sabha's Estimates Committee as well as the CAG there is a real danger that the Namami Gange programme is going to become a clone of the Ganga and Yamuna Action plans. The latter failed largely on account of ignoring the key rejuvenation need of any Indian river, namely to ensure its flows with all their seasonal variations. The budgetary allocations revealed by the CAG audit of Namami Gange in 2017 showed that almost 97 per cent of the allocations were for infrastructural projects (MoWR, RD&GR 2017).

The EFlows Notification

The so-called EFlows Notification issued on October 10, 2018 (just a day before Swami Sanand made the supreme sacrifice of his life for river Ganga) by NMCG is woefully inadequate and problematic.

It appears that this Notification, which in its effectiveness reads like a post-dated cheque, is the result of the now late Prof. G.D. Agrawal's unrelenting fast from June 22, 2018 till his unfortunate death on October 11, 2018. (See Table 52 and Table 53).

A Brief Assessment

The EFlows Notification is briefly assessed below in terms of its good, bad and ugly (or downright undesirable) aspects.

Good

a) In the EFlows Notification preamble, the Central Government

i) reveals its awareness of 'significant temporal and spatial flow variation' in river flows, and voices a commitment to 'restore and maintain the wholesomeness of the rivers', ensuring 'appropriate environmental flows' and 'uninterrupted flows of water' and simultaneously preventing 'pollution ingress into the said river (Ganga)'.

ii) Reiterates the constitution of NMCG for, among other purposes, determining 'the magnitude of ecological flow(s) in the River Ganga and its tributaries required to be maintained at different points in different areas at all times' and 'devising a system for continuous monitoring of flow in the River Ganga and its tributaries'.

b) The EFlows Notification mandates all existing, under construction and planned structures on river Ganga to observe the flow conditions specified by it.

c) It also directs the concerned Central and State governments to implement demand side management plans by adopting practices like efficient irrigation, reuse and recycling of water and monitoring and regulation of ground water withdrawal, etc. for various purposes. Presumably, the latter also include the primary purpose, i.e., of enhancing the volume of water flowing in the river.

Bad

a) Specifies just 20%, 25% and 30% as 'minimum environmental flows' during the dry, lean and high flow seasons.

The term 'minimum environment flow' is unscientific. It betrays a lack of honesty in the government's above-stated commitment to 'restore and maintain the wholesomeness of the rivers', or even 'ensuring appropriate environmental flows.'

No scientific bases have been provided for how these figures have been arrived at, nor is there any mention or reference to comparative figures to show that it is an improvement over the current state of affairs. It may be noted that an MoWR Report of 2015 had suggested E flows in the main-stem of R.Ganga as nowhere less than 60% of the 90 % dependable flow, with the monsoon season being more than the lean season (MoWR, 2015).

The minimum releases below the existing barrages from Haridwar to Unnao are again ad hoc figures and the notification provides no indication of how these figures were arrived at and in what manner are they an improvement over the present situation.

b) CWC alone has been given the responsibility for data collection, monitoring and reporting. The monitoring track record of CWC and its guarding of Ganga flow data as a national secret does not inspire any confidence to entrust it with this responsibility. Hence, an independent expert body should have been given the said responsibility. Public involvement in simple monitoring methods and reporting the data to an independent body of experts for validating CWC reporting is essential and would provide reassurance.

Ugly

i) The Notification provides enough scope for construction of more projects on the river Ganga, fighting against which the late Prof. G.D. Agrawal (aka Swami Sanand) sacrificed his life.

ii) The Notification applies to only a part of the Ganga's main-stem (Gaumukh till Unnao) and is silent on the remaining main-stem and its numerous major tributaries namely, Yamuna (Tons, Giri, Asan, Chambal, Sindh, Betwa, Ken), Ramganga, Gomti, Ghaghra (Mahakali, Karnali, etc), Kosi, Sone, Damodar, Hooghly, etc., most of which also suffer from lack of flow due to diversion for myriad uses.

The big issue that has yet not been seriously addressed is the enforcement of the EFlows rules. This responsibility was assigned to CWC. The latter's own performance, however, has been woefully inadequate and unacceptable, particularly as there is no independent monitoring of its efforts.

In a detailed review of CWC's monitoring reports of all four quarters of 2019, SANDRP concluded that all the eleven projects that were being monitored in the Ganga basin had violated the mandatory EFlows in each of the four quarters of 2019 at different times (SANDRP Bulletin). Yet no punitive action was initiated for any violation.

Basic rules had been violated. For example, as late as in December, 2019 none of the 11 projects monitored, other than Tehri dam, Koteshwar dam, Bhimgoda barrage and Narora barrage, had installed automatic data acquisition and data transmission facilities or the appropriate infrastructure at the locations specified by CWC, though the installation had to be done within six months from the date of the October, 2018 notification. In most of the HEPs, even after the Notification of 2018, requests for installation of the equipment have been blatantly ignored.

The Tehri dam authorities and the Koteshwar HEP downstream of the Tehri dam, blithely reported water released from the penstock, i.e., through the turbines, as Eflows. By not citing this blatant misrepresentation of data, CWC betrayed its own lack of understanding of the EFlows concept.

12.6 SEEKING A WAY FORWARD

According to the CPCB report on polluted river stretches of November, 2022, the BOD levels in the main stem of the Ganga have greatly moderated except for a few stretches in UP and Bihar. While these very generic claims are welcome, the occurence of reports to the contrary, from time to time show that there is a requirement for independent third party validation. The CPCB report shows that the water quality parameters in several tributary rivers and streams continue to be well above the norms and, thus, unacceptably high.

Although the ground evidence and independent and official assessments show that measurable progress has been made in pollution abatement (*Nirmalta*), the current NMCG programme has miles to go in the restoration of minimum flows, ecological integrity and instituting basin management. A lot needs to change. While there are no doubts that funds, infrastructure, technology, laws and institutions are necessary, it is also clear that more of what has been done in the past alone is not going to help.

There is a crying need to address the central issue of governance, to make the governance of everything related to the river more transparent, more accountable and more participatory. Comprehensive Ganga-centric legislative proposals have been presented to NMCG, including ones from the IITs-consortium, the Ganga Mahasabha headed by retired Justice Girdhar Malaviya and a People's Ganga Bill endorsed by more than a dozen MPs. These draft bills await discussions and wide public debates.

In the meantime, the first step for NMCG should be to assess the 35-plus years efforts to clean and rejuvenate the rivers of the Ganga basin and the emergent lessons, through an inclusive consultative process where the voices of people whose lives and livelihoods are directly dependent on the rivers' health are also seriously heard. The aim must be to try and evolve river-centric, ecologically sound, sustainable and just answers to the questions of what needs to be done, and more importantly, how it will be done.

While the NMCG has generally moved in the right direction, however, the enforcement of regulations, particularly regarding EFlows, remains weak. Further, there is negligible movement towards a basin approach or basin governance. Several other agencies such as CPCB and SPCBs have greatly underperformed. Other agencies such as ULBs and Town Planning Departments have also turned a blind eye to encroachments of the floodplains. The restoration of the ecological integrity has yet to be addressed.

The present top down approach needs to be integrated with a bottoms up approach. The process should lead to the establishment of an inclusive, transparent and accountable mission (or autonomous commission like the Election Commission) that has all the required authority and resources to deliver the desired results in a time-bound and cost-effective manner. Such a structure must analyze all available options for the question of what needs to be done, from regenerating springs, watershed management, reduction and reuse of water, nature-based sewage treatment options, decentralized STPs and above all recognizing ground water aquifers as the lifelines of river flows in the lean season. We also urgently need a national urban water policy considering the increasing foot print of urban areas on Ganga and other rivers.

The real issue, perhaps, is how can NMCG coordinate the large gamut of agencies, which are often functioning under political pressure, and obtain their cooperation for speedy enforcement of various directives and regulations laid out for the rejuvenation of Ganga.

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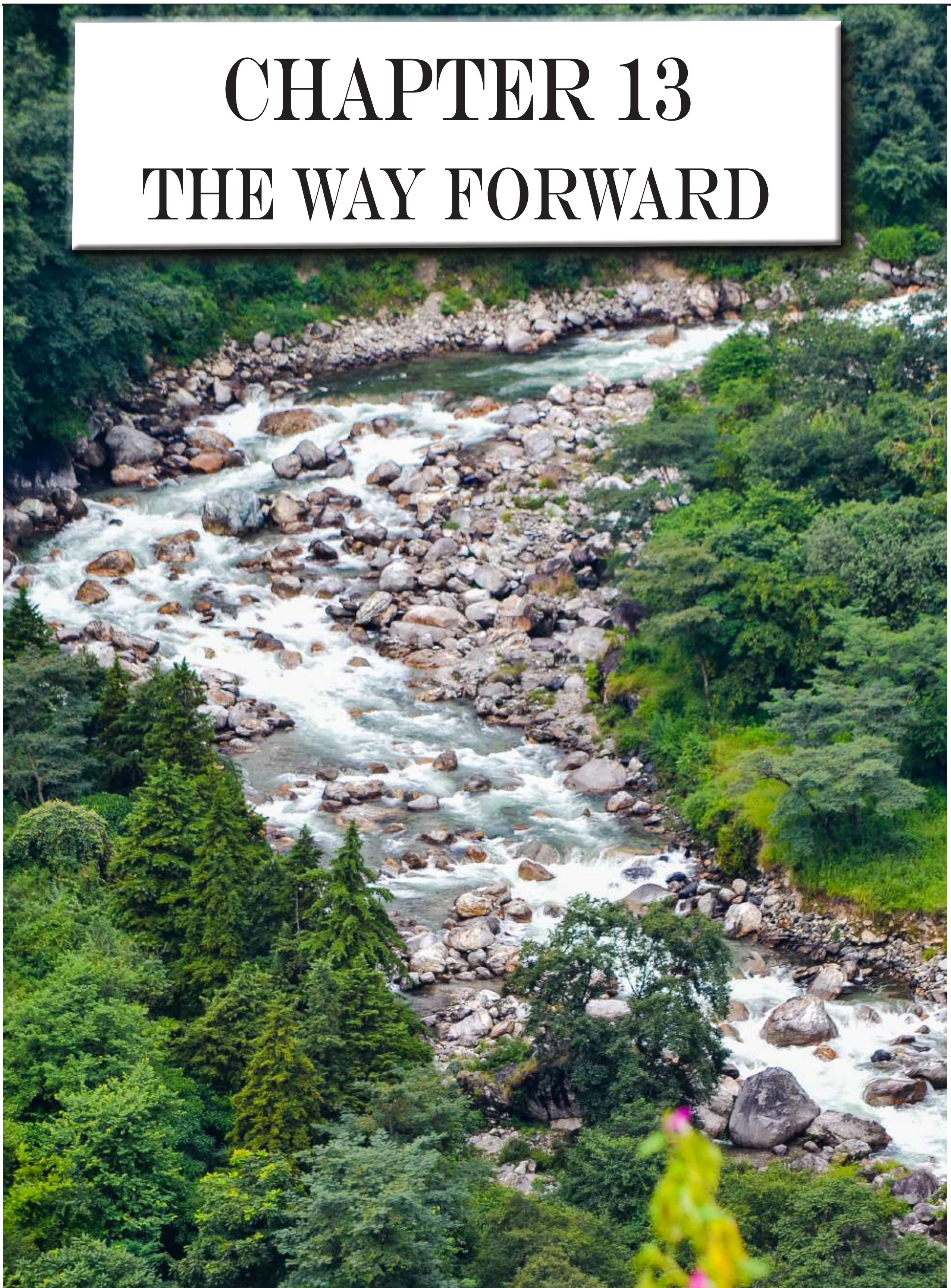
CHAPTER 13
THE WAY FORWARD



13.1 INTRODUCTION

The tour de force undertaken in the previous chapters has provided us with a bird's eye view of the history of Ganga rejuvenation, the actors, the institutional landscape, the current initiatives and the interrelated spectrum of concerns. Whilst many activities to rejuvenate the Ganga are afoot much distance remains to be traversed. The growing pollution in the river was the trigger for the rejuvenation efforts but even as pollution is being grappled with several other critical dimensions have surfaced on the radar. The problem has, even as it is being tackled, grown larger and more complex.

Thus, the restoration of adequate flows is a critical issue which has no easy solution without political will. Sand mining, in a rapidly modernizing economy can be regulated, but there is no sign of it happening. Tributaries, springs, local water bodies, paleochannels, fading streams, shrinking wetlands are all crying for attention and nurture. Riparian and instream biodiversity, which are voiceless, call for restoration of habitats, and fishing and boating communities along the banks deserve protection of their livelihoods. Some other existing threats with increasing dimensions include dams and hydro projects, increasing groundwater extraction, encroachments and dumping of wastes. Among the new threats to the river can be counted the attempts to push navigation, river front development, river linking, increasing urbanisation and its impacts, among others. Looming large is the spectre of climate change and its malefic threat to the Himalayan glaciers. Most notably, there is no sign of change in governance mindset to democratise the river governance.

In the following sections this book offers recommendations for the way forward. The recommendations are interlinked and overlapping, each targeting multiple objectives. Presently, the decision-making structures are both dynamic and receptive and much of what is offered herewith is beginning to receive consideration. However, the journey is going to be arduous, with no easy solutions, and requiring an enormous scale of effort, basin wide and on more than a decadal time scale and more.

13.2 RIVER MANAGEMENT

River management in India has always been dominated by water allocation (considers rivers as 'conduits' of water) and pollution problems (considers rivers as 'sinks'). There is a strong need to consider a river as a 'live natural system' meant for supporting not just human civilizations but also act as complete eco-systems. This means that we need to understand how a river functions as a system and how it maintains the 'dynamic equilibrium'. The time is ripe to move from 'river control' to 'river management' which necessitates the appreciation of the role of geomorphology – the science of form and processes of rivers and the concepts of threshold, lag and complex response in river adjustment.

Further, the impact of engineering structures on river systems must be assessed primarily focusing on natural equilibrium and assessment of degradation due to anthropogenic factors; this may include geomorphic assessment of rivers as well as the impact on the ecosystem. Alternatives to embankments for flood management with an emphasis on 'living with the floods' concept must be emphasized; this may include floodplain zoning and other non-structural approaches.

It is high time that we recognize that the era of climate change is upon us. The most recent report released by the Intergovernmental Panel on Climate Change (IPCC), highlighting the resulting disasters, has been described as a 'Code Red' alert for humanity by the United Nations. Unprecedented heat spells and extreme rainfall events resulting in flash floods are being witnessed all over the world. Recent experiences in the Himalayan part of the Ganga basin have shown that floods in small Himalayan streams are far more destructive than floods in the main trunk rivers, especially in the paraglacial zones of the Upper Himalaya. Such stream valleys and high riverbed slope stretches of the larger rivers, past the confluences with the small streams, need to be kept free of engineering structures like dams to avoid loss of life and property, including public infrastructure.

Hence, it is essential to do long-term cost-benefit analyses of major interventions in the river basins and their utility in the present context. Such analyses should include the benefits accrued as well as the impact on livelihood and ecology. Basin scale flood-risk maps should be prepared based on scientific data and reasoning; such GIS-based, interactive maps may be based on historical data analysis as well as modeling approaches and can be linked to an online data base and flood warning system. Drainage improvement and land reclamation in low-lying areas should be taken up on an urgent basis; several successful case histories are available from different parts of the world but they need to be taken up seriously and systematically.

13.3 DATA COLLECTION

Data collection regarding flows and other river health parameters at various points even at the level of 2nd and 3rd order streams needs to be instituted urgently. Currently, all riverine hydrology data is collected by the CWC. The same agency is also responsible for policy making, monitoring, sanctioning, development, dams, hydropower projects, river diversion projects and river linking projects. There is a clear conflict of interest as the data can be subjected to manipulation to justify exploitative projects which cannot be justified on the grounds of benefit/cost ratio. Even outdated data can be used which is no longer valid under climate change circumstances. The data generation arm of CWC must therefore be insulated and made independent of the project wing even if an independent agency for this task cannot be immediately formed. Procedures of data collection and real time data must be readily and promptly available on the website. Alternatively, there could be an independent, autonomous body engaged in collection of data relating to rivers. Urgent steps need to be taken to implement some of the recommendations of the Mihir Shah Committee (2016) so that CWC and CGWB start to function in more integrated manner.

13.4 BASIN MANAGEMENT AND GOVERNANCE

Despite the National Water Policies (1987, 2002 and 2012) stressing the need to adopt basin management for rivers, no concrete steps have yet been taken towards setting up of empowered basin management organizations with bottoms up governance. Reliance has been placed upon the existing administrative structures, i.e., districts and states, which are simply not geared towards basin management.

Basin boundaries are not coincident with administrative units. Therefore, data collection is on administrative unit basis and not on basin area basis. Therefore, a first requirement for basin management would be to reorganize the data and align it along basin and sub-basin lines. This would have to be done for each tributary sub-basin upto watershed level and the cumulative data would present the dynamic picture of the higher order stream basin. Some of these tributaries would be intra-state hence easier to address and others would have some more complexities owing to their inter-state nature. Thus, if R. Ganga is a 5th order stream, then the sub-basin data should be organized for 3rd order streams and above.

Data Collection: This would require that relevant statistics which are collected at village, block and district level be color coded for their pertinence to a particular basin. Thus, for e.g., if a district falls in 2 basins then statistics of villages falling in one basin would be color coded according to the color code imparted to that basin whereas statistics pertinent to a different basin would be color coded as per the assigned color code of that basin. Watershed maps, overlaid with district and block boundaries would become common currency as river basin-based administration maps. This exercise is not difficult to carry out and would start building the picture of the basin and its water issues while at the same time embedding a basin driven approach in the outlook of the decision makers and administrators at all levels.

Basin Water Budget: The next step in this regard would be to establish the water budget of a basin and its sub-basins. The basin's resource side ledger includes rainfall endowment, further assigned to surface flows, aquifer recharge storage, soil moisture, surface water storage of all water bodies, evaporation [including trans evaporation] losses, recycled water [if applicable] and, in some cases, existing water import from another basin. On the consumption side the ledger would include agriculture and irrigation requirements [variable], domestic [including rural and livestock] [increasing] and industrial consumption [variable] and, in some cases, export to other basins. The budget would thus show whether the basin/sub-basin is living within its resources sustainably or overexploiting its resources or drawing upon other basins for its activities/sustenance or exporting water to other basins or a combination of these. In these calculations, virtual export/import of water may also be counted at a later stage.

The subsequent step would be analysis of the water budget which would reveal areas of intervention. These could be related to cropping pattern, water saving agronomic practices, domestic/industrial water efficiencies, use of recycled water, enhancing forest cover in catchments, enhancing aquifer recharge, creating rainwater storages, rejuvenating local water bodies, wetlands, soil moisture, regulating groundwater use, monitoring and regulating surface water storages, regulating import/ export of water, ensuring river flows, pollution management. Ensuring a scientifically determined adequate water for different uses, sections, reaches and seasons would be an underlining requirement of the basin water management budget. The agro-climatic zone data, changing rainfall patterns assessment and a sophisticated weather and rainfall forecasting system would aid in the management and monitoring of the water budget.

The final step would be to insert the basin management organization [BMO] at sub-basin level of say 3rd order streams and thereafter to the highest order stream basin within the administrative hierarchy. For intrastate rivers this may require a state level administrative reorganization whereby districts and parts of districts falling in a particular basin/sub basin would report to its BMO for hydrological compliance of development activities and impact on the water budget on both the resource availability and consumption side. At interstate level this may require the Central Govt to intervene and perhaps even constitutional changes may be required to enable interstate BMOs.

The role of basin managers would be decisive in allowing/disallowing developmental projects based on their impact if any on the basin water budget and river health. Cumulatively, the sum of basin management of tributaries would aggregate to basin management of the highest order stream (finally Ganga River in this case) in due course. All information about the BMOs and their quarterly and annual reports must be promptly placed in the public domain. The BMO should have 50% representation from non-government persons.
Much friction and resistance can be foreseen on the part of the political and administrative hierarchy in subordinating themselves to the water-sensitive diktats of empowered BMOs. However, a start has to be made somewhere.

13.5 IMPLEMENTATION OF RIVER GANGA (Rejuvenation, Protection and Management) Authorities Order, 2016

The principles laid down in the River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016 for rejuvenation, protection and management of River Ganga were far reaching and if implemented vigorously and robustly can yield manifold enhancement of the riverine system of the Ganga basin. Let us revisit these principles below:

i. River Ganga shall be managed as a single system;
This is a welcome idea which shows no signs of being translated into practice.

ii. the restoration and maintenance of the chemical, physical, and biological quality of the waters of River Ganga shall be achieved in a time bound manner;
Useful steps have been made in this direction but still there is a long distance to cover

iii. the River Ganga shall be managed in an ecologically sustainable manner;
Scientific documentation of the river ecosystem is called for to make appropriate interventions. Efforts have been made in this direction but vast knowledge gaps persist

iv. the continuity of flow in the River Ganga shall be maintained without altering the natural seasonal variations;
Some measures to enhance flows have been instituted. They are neither adequate nor fully implemented

v. the longitudinal, lateral and vertical dimensions of River Ganga shall be incorporated into river management processes and practices;
The implementation of this principle faces the most hurdles as dam construction, aquifer depletion continues unabated while floodplains are increasingly vulnerable to encroachments

vi. the integral relationship between the surface flow and sub-surface water (ground water) shall be restored and maintained;
Easier said than done. Falling water tables have lowered groundwater contributions to base flows. It is a Herculean task to bring up the water table and enhance base flows

vii. the lost natural vegetation in catchment area shall be regenerated and maintained;
This principle needs to be precisely defined. Moreover, large scale restoration of natural vegetation, given pressures to colonize natural landscapes and resultant unavailability of land make this difficult to achieve

viii. the aquatic and riparian biodiversity in River Ganga Basin shall be regenerated and conserved;
This requires improvement in water quality, flows, restoration of linear and lateral connectivity, restriction of rampant sand mining, a truly tall order. Riparian areas are becoming bereft of aquatic grasses owing to cultivation being extended to the lean season active channel. The resultant baldness of the banks makes them erosion prone.

ix. **the bank of River Ganga and its flood plain shall be construction free Zone to reduce pollution sources, pressures and to maintain its natural ground water recharge functions;**

Pressures to colonize floodplain lands are only increasing and attempts, such as the Bihar Building Byelaws Amendment Act of 2022, which allow construction as close as 15m from the water channel, are being brought in to subvert this notification. Court orders to enlarge no-construction bank widths are routinely ignored. Sanctioning of riverfront development projects, without even the requirement of EIAs, makes a mockery of this principle. It is routinely ignored in favour of economic growth.

x. **The public participation in rejuvenation, protection and management, revision and enforcement of any regulation, standard, effluent limitation plan, or programme for rejuvenation, protection and management shall be encouraged and made an integral part of processes and practices of River Ganga rejuvenation, protection and management.**

The activation of Ganga Praharis and Ganga Mitras is a welcome initiative in this direction which needs rapid upscaling

xi. **Ecological flow of water in River Ganga to be maintained.**

Determining the ecological flow for different reaches and in different seasons is a humongous task which has yet to be undertaken. Once established it is no mean task to obtain such flows.

xii. **Every State Government, shall endeavour to ensure that uninterrupted flows of water are maintained at all times in River Ganga**

Thus far State Governments have shown no interest in this matter

xiii. **Every State Government shall also endeavour to maintain adequate flow of water in River Ganga in different seasons to enable River Ganga to sustain its ecological integrity and to achieve the goal, all concerned authorities shall take suitable actions in a time bound manner.**

Thus far the State Governments have shown no interest in this matter

xiv. **For the purposes of this paragraph, the average flow of water shall be determined by such Hydrology Observation Stations at such points of the River Ganga, as may be specified by the National Mission for Clean Ganga: Provided that the average flow of water in River Ganga may, having regard to ecology, be determined by the National Mission for Clean Ganga for different points of River Ganga.**

Much progress is required in establishing the necessary database and its implementation

xv. **No person shall construct any structure, whether permanent or temporary for residential or commercial or industrial or any other purposes in the River Ganga,**

Bank of River Ganga or its tributaries or active flood plain area of River Ganga or its tributaries

State Governments have not shown adequate interest in regulating such construction particularly in urban settings where real estate pressures influence land use decisions

13.6 DEMAND MANAGEMENT

Climate change impacts are felt, both, in the form of sudden extreme events as well as by way of creeping long term impacts. The latter have far graver implications for river basins. Global warming resulting in excessive average temperature increases which will have several primary and secondary impacts. Amongst the former are receding glaciers and their impact on flows, higher evaporation losses from waterbodies, wetlands and rivers, greater trans-evaporation losses resulting in higher water inputs to maintain agricultural productivity and also higher demands for Municipal and industrial uses. On the secondary side there will be compulsions to abstract more water from surface waters and aquifers even as rivers need to maintain adequate flows and aquifer need to contribute to river base flows.

To combat climate change impacts on hydrology, demand management will need to be taken up on priority. **Agriculture uses 70%-80% of all water used in India and our water related agricultural productivity is most inefficient amounting to just 35%, while irrigation efficiency of surface water schemes are even lower than 35%.** Thus, any increase in water efficiency in agriculture will greatly conserve water resources.

Micro-irrigation techniques are useful for certain kinds of crops. Micro-irrigation techniques are useful for certain kinds of crops. Moreover, many a times it is not as effective as it is claimed to be. Micro-irrigation also requires specialised equipment that has higher capital cost, higher maintenance cost and most farmers find it difficult to operate it.

But the real gains are to be made through soil improvement. Reduction of or elimination of chemical inputs, improvement of soil texture enables the soil to better absorb and store rain water. Soil texture and health are improved by capturing carbon in soil, in formation of humus - that ensures better water holding capacity of soil and in slow release of nutrients for plants to grow. The most efficient way of storing harvested rain water is in the sub-soil. It is said that for every 3 cm of carbon rich soil, 1 cm of water is stored and bound, to be released in dryer situations for roots to draw on. This measure significantly decreases the requirement for irrigation by increasing the reliance on stored subsoil rainwater which is immune to evaporation losses. **Field practise and documentation shows that irrigation water requirement can be halved by improving the soil's water holding capacity and by improving percolation in the soil profile**. Water efficiency in agriculture, thus, goes hand-in-hand with soil health restoration. [Economies thus obtained can increase the farmers' margins by increasing the gap between market price and input costs].

The push for enhancing area under millets along with creating demand for the same is a serious water conserving initiative. Millets being naturally water efficient crops do not require as much irrigation inputs as other cereals - particularly hybrid varieties do. Yet, in this new found push for higher area under cultivation and higher yields in millets many high-yield and hybrid seeds of millets are being developed that require irrigation as well as fertilizers, a path similar to wheat and rice took under green revolution. One needs to be aware of and make the distinction between native seed varieties of millets and hybrids. Similarly, processing of millet-based value-added products is usually water intensive and, thus, highly processed off-the-shelf food products of millets will probably be equally unsustainable - both in cultivation and in processing.

System of Rice intensification (SRI), a technique of rice cultivation that works best in organic conditions, can not only reduce the water requirement in rice cultivation, it can also help increase the yields and thus farmer incomes, while reducing costs. This technique has also shown promise for a number of crops other than rice. When adopted in conjunction with increased carbon content in soil, SRI will give even better results.

There is also a case for reducing water intensive sugarcane cultivation. India has been exporting huge quantities of sugar in most years, providing export subsidies! This is tantamount to providing subsidies for water export! And when much sugarcane cultivation happens in drought prone areas like Marathwada (Maharashtra), North Karnataka and Cauvery belt area in Tamil Nadu. Similarly in Ganga basin too large quantities of sugarcane ltivation and resultant sugar export is tantamount to subsidising exporting Ganga water while we do not have water for environment flows in Ganga.

There is, thus, a need for a massive program of water saving agronomic practices, efficient irrigation technologies, effecting changes in cropping patterns through strategic orientation of MSP for water saving. The target would be to almost entirely irrigate crops through rain, groundwater and soil moisture. If this is done then there are possibilities of first, halting further construction of dams and barrages, and then restoring base flows and adequate river flows.

Domestic water demand is also major claimant on water resources. Here, much water goes down the drain in flushing, bathing, laundry. Over and above this is the utilities need to supply sufficient water to flow the sewage to the large centralized STPs [sewage treatment plants]. Much can be done in this theatre. Many are the remedies held in abeyance whose time has come. Water efficient fixtures, efficiency rating of water using devices, bulk installation of flow reducers on taps, plugging conveyance losses, dry lavatories wherever possible, nature based decentralized wastewater treatment systems – this last would require bold urban planning changes.

The water footprint of Urban India is increasing in multiple ways, but the sector has no Urban Water Policy to guide. There is urgent need to have a National Urban Water Policy that will also guide what is a water smart city and hold periodic competitions to declare and honour water smart cities.

The judicious use of financial instruments for pricing can discourage promiscuous use of water – this combined with metering of all points of consumption would enable this instrument to be truly effective. Above all the citizenry needs to be made far more water literate so that conservation of water resources becomes a mass movement.

Existing thermal power plants, so long used to drawing surface waters copiously, must adopt the cogeneration model and a closed cycle of water. There is no case for new such plants in any case. Industries, too, must be incentivized to adopt zero discharge models and disincentivized to become water neutral. Water efficiency in steel plants, for eg., has brought down the consumption of water from 15 tons per ton of steel to just 4 tons over the past three decades.

13.7 TRIBUTARIES

The Indian part of Ganga river basin (GRB) is the most populated, large river basin in the world. But R. Ganga is very highly regulated in its journey to the sea. Four important tributaries, the Yamuna, Ghagara, Gandak and Kosi provide about 60 per cent of the annual flow at Farakka, where the main R. Ganga branches and a part flows into Bangladesh. The Yamuna is also highly regulated in its upper stretch and is rejuvenated by its Vindhyan tributaries. Hence the maintenance of the integrity of R. Ganga's tributaries is a sine qua non for a healthy R. Ganga.

Conserving the health of tributaries would cumulatively improve the health of the higher order streams, the Ganga, in this instance. However, if we examine just the Yamuna, which is the largest tributary, its plight is notable for pollution and anaemic flows. The Yamuna gets revived after Etawah when the healthier Chambal, Sindh, Betwa and Ken rivers add their waters. A reinvigorated Yamuna then injects life into the insipid flow of the Ganga at Prayagraj Sangam.

Several more dams are proposed on Yamuna, on Mahakali [Sharda], Ken, northern tributaries flowing from Nepal to UP and Bihar and other tributaries which will divert water from the river system and thus debilitate Ganga further. This will put paid to all the idealistic intent for eco-restoration, adequate flows and biodiversity conservation.

While a vigorous implementation of these measures on a large scale can help get us ahead of the curve, there is no gainsaying the fact that declining contribution to river flows from receding glaciers has no ready answers.

The recommendation is to plan the water budgets sub-basin wise for each major tributary with emphasis on demand management particularly through water saving agronomic, urban and other practises.

13.8 THE RIVER CHANNEL

The management and restoration of degraded stretches of rivers should focus on (a) identification of baseline (pre-disturbance) conditions, (b) mapping of 'hotspots' of degradation and (c) development of site-specific and nature-based mitigation measures.

There is a paucity of geomorphic studies and data for rivers in the southern Ganga basin. This deficiency must be made up first to ensure a process of rational river management.

High sediment yield has emerged as the most crucial issue in several Himalayan rivers. Modelled soil erosion rates and sediment load values are essential inputs for quantifying sediment balance and understanding the overall sediment dynamics of these river basins which in turn influence river related hazards such as landslides and floods. Given the spatial inhomogeneities, this should be done periodically at a higher resolution.

Sediment management should become an essential part of river management strategies and this has to be based on a strong understanding of sediment dynamics. In particular, the framework should be based on estimates of silt accumulated, identification of hotspots of aggradation, mechanisms and techniques for desilting and finally a plan for utilizing the excavated silt. In this context a wider network of sediment load measurements should be established, and periodic surveys of critical sections must be a part of the standard operating protocol (SOP) for river management.

Strategic desilting of river channels in several Himalayan rivers may be necessary to increase their water holding capacities and lower the flood risks. However, desiltation in the river channel should be done carefully to avoid any disturbance in the hydro-geomorphic regime and loss of riverine biodiversity.

13.9 AQUIFERS

The Ganga is a perennial river. The Indian GRB is estimated to receive over 80 per cent of its annual rainfall in the monsoon season. Base flows and glacial and snow melt, though comparatively small in volume, remain crucial for sustaining river flows in the non-monsoon months.

Recent studies, however, show that massive over-extraction of ground water for irrigation in the alluvial plains of the GRB is rapidly depleting the adjoining aquifers, leading to a sharp decrease in the base flows – about 59 per cent between the 1970s and 2016 -- in parts of the lower basin. The resulting decline in the river water availability threatens the survival of the basin's ecosystems and water security for hundreds of million people. Climate change impacts pose additional undetermined threats.

The National Project on Aquifer Management [NAQUIM] is steadily yielding detailed scientific information on the aquifer parameters and related hydro-geology apart from churning out aquifer management plans. Finally, what matters is that more rain water should nourish the aquifers than is extracted. And it may be emphasized that groundwater is immune to evaporation losses unlike surface storages and is available in a dispersed manner for decentralized usage without recourse to massive storage and conveyance infrastructure involving huge social, environmental and economic costs.

A leaf can be taken from **Mission Kakatiya**, a programme of the Government of Telangana to restore over 40,000 derelict tanks in the states. The program has indicated a positive impact on groundwater recharge and is recognized as a good practice by India's national policy think tank-NITI Aayog. A recent report shows that hydrographs of monitoring wells reflect a rising trend of 0.80 m/year to 2.87 m/year in different watersheds in Telangana with an average of 1.27 m/year. The trends have demonstrated an 19% additional rise (average) in the influence zone as compared to the wells in a non-influence zone.

For nurturing aquifers in the Ganga basin the following measures are of utmost importance:

a. Rapid adoption of water-saving agronomic practises including by ensuring higher percolation of rain water into the soil in farm fields, protection and rejuvenation of wetlands, local water bodies and forests in the catchments

b. Reviving and conserving waterbodies in the Ganga basin, in an integral manner with their catchments, would greatly help in aquifer recharge. The ground situation shows that most of the floodplain lakes of the Ganga basin are still to be notified under Wetlands (Conservation and Management) Rules, 2017 and hence remain unprotected. These are being rapidly encroached and, hence, it is not sufficient to notify them but to physically protect them.

c. Freeing floodplains of advanced embankments which jacket the river channel and isolate floodplains from the river flood impact

d. Avoid river front development projects which are destructive of the ecology

e. Identifying paleochannels and ensuring that they are filled with floodwaters and, in proximity to urban areas, filled with treated recycled waters on a regular basis

f. Using tertiary level treated waste water in urban areas for aquifer recharge through stormwater channel beds, waterbodies and paleochannels

g. Desealing excessive pavement and premises concretization in cities to allow rainwater percolation

13.10 RECYCLING WASTE WATERS

The time has come to take wastewater recycling seriously. With the looming constraints on dam construction in the Himalayan region and peninsular region dam building already approaching high densities, recycled water presents a serious option on the supply side for urban areas. Recycling also means having a closed loop of water resources. With treatment standards of STPs, mandated by NGT, to be tertiary level [likely to be achieved in next few years if governance issues addressed] the percentage of recycled water can increase significantly. Ultimately, the target should be to attain potable standards for acceptability in the domestic sector as that is the largest consumption sector in urban areas. Attaining acceptability may be a gradual process but it is essential to reduce the impact on fresh water sources including groundwater.

13.11 WETLANDS

Surveys along the Ganga have shown that pressure on wetlands through reclamation is on the increase and wetlands seem to be a systematic target for destruction. Smaller waterbodies, too, need to be conserved, rejuvenated and even created as their cumulative contribution to the hydrological cycle can be significant. Another field observation has shown that several farm ponds are low on performance as they are not aligned with the farm topography, a factor in their underperformance.

State Wetland Authorities have so far not implemented either the Wetlands (Conservation and Management) Rules, 2017 nor the earlier Wetlands (Conservation and Management) Rules, 2010 requiring all wetlands noted in the National Wetland Atlas [2010] to be notified for protection nor several rulings of the Hon'ble Supreme Court such as in Balakrishnan & Ors. v. Union of India & Ors. [(2017) 7 SCC 805] nor orders of the NGT in O.A. No. 351/2019 [Raja Muzaffar Bhat v. State of Jammu and Kashmir & Ors]. The Hon'ble Supreme Court orders apply to 200,205 wetlands above 2.25 ha spread as noted in National Wetland Atlas [2010].

The recent 'Water Bodies - Ist Census Report' released by the MoJS in March, 2023 lists 2,424,540 waterbodies under various categories. The contribution of wetlands to aquifers and of floodplain lakes to the river flow regime are well known. Hence, the recommendation can only be to rapidly notify wetlands and conserve them scientifically with an emphasis on hydrology and ecology.

13.12 FLOODPLAINS

River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016 has posited that the 100 years floodplain will be mainly free of construction other than existing structures or permissible structures like jetties.

However, it is observed that, particularly in urban areas the floodplains are vulnerable to encroachment and unauthorized construction. Under river front development, they also become target of official encroachment. A case in point is Patna's floodplains. Here the Bihar Govt. has brought in the Bihar Building Byelaws Amendment [2022] to circumvent the Ganga Authorities Order of 2016. The said Amendment permits construction to within as close as 15m of the river channel, a clear case of the fence eating the grass.

It is recommended that the 100 years floodplain be demarcated and geo-tagged on the main stem of the river and the tributaries, with adequate publicity to raise awareness about the notification. The satellite imagery of November, 2016 is to be kept as a bench mark which would show the extant constructions of that date and subsequent constructions are to face the implementation of the law. The relevant clause of the Bihar Building Byelaws Amendment [2022] must be contested and removed from the books on the grounds that a subsequent State level Act cannot override a prior Central notification.

13.13 RIVER BANKS

Beyond the floodplains are the river banks. The riverbanks need urgent definition and demarcation for Ganga and all tributaries right from source to sea. River banks are being cultivated to the edge of the floodplain leaving no space for riparian vegetation and associated habitats. In the absence of the stabilizing effect of riparian vegetation many vulnerable banks are facing severe erosion. Furthermore, the banks are, at many places, used for open cremations with half burnt bodies floated into the river. Thus, bald banks and open cremations present severe drawbacks.

It is recommended that a strip of bank should be maintained with riparian grasses for bank stabilization and for habitat provision. Further, gas/electricity based crematoria need to be promoted and the 'shamshan ghats' need to be screened from the river channel by appropriate vegetation.

13.14 DAMS

Indian Himalayas, despite having a fragile geology, have a very high density of dams and hydropower projects. The adverse impacts of dams and barrages on rivers has already been highlighted in an earlier chapter. Their construction in the fragile Himalayas is a massively disruptive exercise which is destructive of the local ecology and often causes landslides.

Dams kill the flow downstream and then generate sudden releases of water in synchronization with the electricity demand in the plains. These massive releases scour the river bed and banks destroying habitats but the intermittently dry bed is destroys aquatic life and instream migration and spawning. The structures retain sediment which should have spread on the floodplain in natural circumstances but by effecting the rapid reduction in flow velocity enable deposition in the river bed, creating several sandbars and shallowing the river depth.

If the water use efficiency gains, outlined in the earlier recommendations, are implemented, particularly in agriculture, and dispersed groundwater storage is enhanced further dams are rendered unnecessary and the decommissioning of some brought into consideration. Similarly, efficiency gains in electricity usage, the massive increase in contribution from renewable energy sources, the existing excess thermal power capacity, the likely induction of superconductors may put some brakes on HEPs.

Hence, it is recommended that further dam construction in the Himalayan region may be frozen, including work on under-construction dams which are less than half built. Existing dams may be reassessed based on cumulative environment impact criteria as well as benefit cost ratios being calculated with monetization of negative environmental impacts being factored in.

13.15 INTERLINKING OF RIVERS

The old scheme of interlinking Himalayan rivers with Peninsular rivers for transferring water from the former to the latter is a dead letter. The schemes cannot be justified on either economic, social, environmental or ecological rationale. Moreover, with supply side constraints, interlinking proposals are only opening a Pandora's box of interstate disputes between upper and lower riparian entities.

It is recommended that every effort should be made to optimise the intra-basin water resources through various water use efficiency measures before considering any inter-basin transfer. Moreover, climate change induced hydrological factors should be an integral part of assessment studies.

In general, this report recommends, on the basis of arguments elaborated in Chapter 11 and the flawed rationale, based on spurious EIAs and non-transparent water balance data in the Ken-Betwa case entailing massive destruction of Ken river, Panna Tiger Reserve and millions of trees and wildlife habitats, that inter-basin transfer schemes may be dropped from further consideration.

13.16 DATA COLLECTION OF TRIBUTARIES AND LOWER ORDER STREAMS

The health of tributaries contributes to the health of higher order streams. While a fair amount of data is available regarding the main stem of the Ganga and Yamuna rivers, data regarding the hydrology of other major tributaries and their tributaries is mostly absent. In fact, ecological data, floodplain demarcation, livelihoods, fisheries and several other aspects of sub-basins have still to be researched, thoroughly studied, and monitored regularly.

NMCG should consider enlisting, without delay, local academic institutions and an expert body to guide the institutions for gathering essential data of R. Ganga's major tributaries and their tributaries. Ultimately, an independent hydrology data collection institution with mandate across the country will need to be set up as soon as possible.

13.17 THE WATERWAY

Ganga River has been declared National Waterway I from Ganga Sagar to Prayagraj in the National Waterways Act of 1982. Sections 5 (b, c, d, e & f) of the Act permits the authorities [Inland Waterways Authority of India/IWAI] to remove any impediment to opening up new navigable channels, clearing, widening and deepening existing river channels, setting up infrastructural facilities and to remove any obstruction or impediments in the national waterway. Thus, the Act enables drastic changes in river morphology and instream landforms for the purpose of navigation. Such changes can be destructive of both riparian and instream habitats, biodiversity and also livelihoods of large sections of population, besides making the river itself hazardous for cultural, aesthetic and religious objectives. No credible social and environmental impact assessment or public consultation has been done of the waterways project.

Moreover, it has been amply demonstrated (see Chapter 11) that the financial viability of operations is adverse and does not justify large cargo transport operations via inland waterways. It is for this reason that there are no bidders for IWAI terminals and despite all efforts there has been no substantial movement of cargo by the river route. Further, the continuous requirement of dredging is damaging in terms of social and ecological impacts whilst weighing adversely on the financial viability.

It is therefore recommended to have honest, participatory EIAs for the waterways and rigorous financial viability studies rather than taking the double hit of subsidizing operations that whilst simultaneously damaging the river ecosystem.

13.18 SANDMINING

Unregulated sand mining is destroying riverbed, islands, sandbars, floodplains, biodiversity, livelihoods, habitats and banks and structures along the rivers. Enforcement of sand mining rules needs to be carried out on the ground through strict patrolling and decisive say for the local communities in monitoring and decision making. The Ganga

Praharis may be involved in monitoring sand mining in their respective districts. This must happen on all the tributaries as well.

13.19 BIODIVERSITY

While Gangetic Dolphin is being celebrated as the National Aquatic Animal we have forgotten the Hoogly river shark [Glyphis gangeticus] which is highly endangered if not near extinction, among other species. There are severe losses in native fish species and the presence of exotic species. Pollution, anaemic flows with resultant shallow depths, destruction of river bed habitats through sand mining, destruction of riparian habitats, increased sound pollution through motorized river traffic, loss of resource base, are taking a huge toll on aquatic fauna populations and showing up as stunted growth of the same.

Here, it must be mentioned that the October, 2018 Ganga E-flows notification has neither any scientific basis, nor any credible monitoring or compliance mechanism. Nor is the notification comprehensive and applicable across the basin. This needs to be replaced by a science based E-flow notification which includes a credible monitoring and compliance mechanism.

The riverine ecosystem is an integral dynamic composition of natural conditions, processes and populations of various organisms. Restoring the natural conditions towards their original state insofar as possible alone can revive the river biodiversity. Migration of fish must be enabled by effective engineering mechanisms so as to enable spawning. Further, the Wildlife Act must be rigorously implemented in the river sanctuaries and more such sanctuaries may be identified and notified in the Ganga as well as tributaries. Greater efforts at monitoring and supporting scientific research on the riverine biodiversity are required to mitigate the impact of human interventions.

Riverine heritage needs to be recognised and protected through law. For example, the mini canyon downstream of Panna Tigar Reserve along the Ken River is a case in point.

13.20 FISHERS' COMMUNITIES AND OTHERS

The livelihood of riverside communities dependent on capture fishery has hugely and silently suffered owing to the impact of river deterioration. Surveys have shown decline in numbers, size and weight of catch. Little can be done to restore the fish landings of earlier times unless the several measures recommended earlier are implemented. Even if just e-flows are maintained and pollution controlled, the situation can greatly improve.

Boatmen communities are at a disadvantage as plying boats to transfer cargo or transport passengers has suffered on account of inadequate draft in many reaches. This limits employment of boats to lower reaches of the river or seasonally in the upper plains reach.

Minimum flows may be also derived considering the requirement of draft for smaller flat-bottomed boats and barges.

Both communities constitute a reservoir of knowledge about the river based on direct observation and firsthand experience of the river constant and shifting conditions. Basin managers need to draw upon their knowledge for local improvements.

Their livelihood dependence on the river must also be recognised, and impact on the same assessed of any intervention affecting the river and they be compensated/rehabilitated when affected.

13.21 PEOPLES' PARTICIPATION

The Ganga Authorities Order, 2016 states: "Public participation to be made an integral part of processes and practices of River Ganga rejuvenation, protection and management". While Ganga remains a provider of spiritual succour to millions, the people display little interest in its well-being or even a stake in it. This is because the state has usurped its management role from the local people and their institutions. It is to be noted that when the colonial government wanted to create a structure over River Ganga at Haridwar, it went through a consultation process before an agreement (1916) with local people's representatives was arrived at.

All efforts should be made to involve the local community in river management. Regular programs for capacity building should be organized by experts at regular intervals. Knowledge dissemination should become an essential part of the standard operating procedure for river management and success stories should be advertised to instill confidence in the local community.

NMCG initiatives (https://nmcg.nic.in/index.aspx): Identification and training of GANGA PRAHARI and GANGA MITRA are two of the activities that NMCG has promoted with the following objectives:

- Ganga Praharis are self-motivated and trained volunteers from among the local communities working for biodiversity conservation and cleanliness of the Ganga River with the ultimate objectives of restoring the Nirmal and Aviral Dhara.

- Ganga Mitras is a Task Force of urban, suburban, and rural grass root level people living on the banks of river Ganga to help rejuvenate the Ganga and its associated water bodies.

While these initiatives are laudable, it remains to be seen if they get translated into a people's movement and more importantly if they lead to cementing local people's critical role in the actual governance of River Ganga. Moreover, these Praharis and Mitras need to be extended along the main tributaries as well.

The Ganga Mitras need to be involved in monitoring the performance of every STP and every drain discharging into the river. The people whose lives and livelihoods depend on river including fisherfolk, boat people, riverbed cultivators, local sand miners, communities depending on the river for different water needs have to be represented in such monitoring systems.

Since the aim of River Ganga rejuvenation is multifarious and complex and cannot be achieved just through the mechanism primarily of pollution abatement measures, there is a need to constitute a GANGA ASSEMBLY/assemblies of standing nature with a wide representation (academicians, scientists, researchers, sociologists, administrators, technologists, spiritual leaders, legal experts, authors, media persons, legislators, representatives of local people with livelihood dependence on the river, and NGOs) for a period of, say, 5 years, so that various issues regarding River Ganga rejuvenation are threshed out in a transparent and participatory manner. Such assemblies may be appointed for each watershed of say 5000 sq km. These legally empowered monitoring mechanisms should have the right to get all the information and inspect offices and facilities related to the river and make binding recommendations. A person of considerable eminence and scholarship (if need be, a former Judge of the Supreme Court of India) may be requested to convene the Ganga Assembly. It would be expected that the Ganga Assembly provides clear drafts, guidelines and action plans on following and related matters: a) Legal measures including draft of a People's River Ganga Rejuvenation Bill (Draft as proposed by late Swami Sanand (Prof. GD Agarwal) to form the basic draft) b) Governance and Institutional measures including publication of river data c) Ecological, scientific and technological measures needed to restore the health of River Ganga and its tributaries d) Measures to restore the spiritual, cultural aspects of River Ganga

It would be useful for the NMCG to take up following measures to support informed decision making by the Ganga Assembly/assemblies:

i. Establish the consensus situation with regard to the likely impact of climate change on various components of the River Ganga Basin with special emphasis upon enhancing the longevity of glaciers and the sustainability of current precipitation levels

ii. Define terms like Ganga Rejuvenation to its natural and pristine R. Ganga Basin Management Plan (RGBMP)state and decide on a reference past

iii. Establish the rejuvenation needs of all the tributaries to a near natural and pristine state

iv. Review and establish sound method(s) for monitoring the health of River Ganga

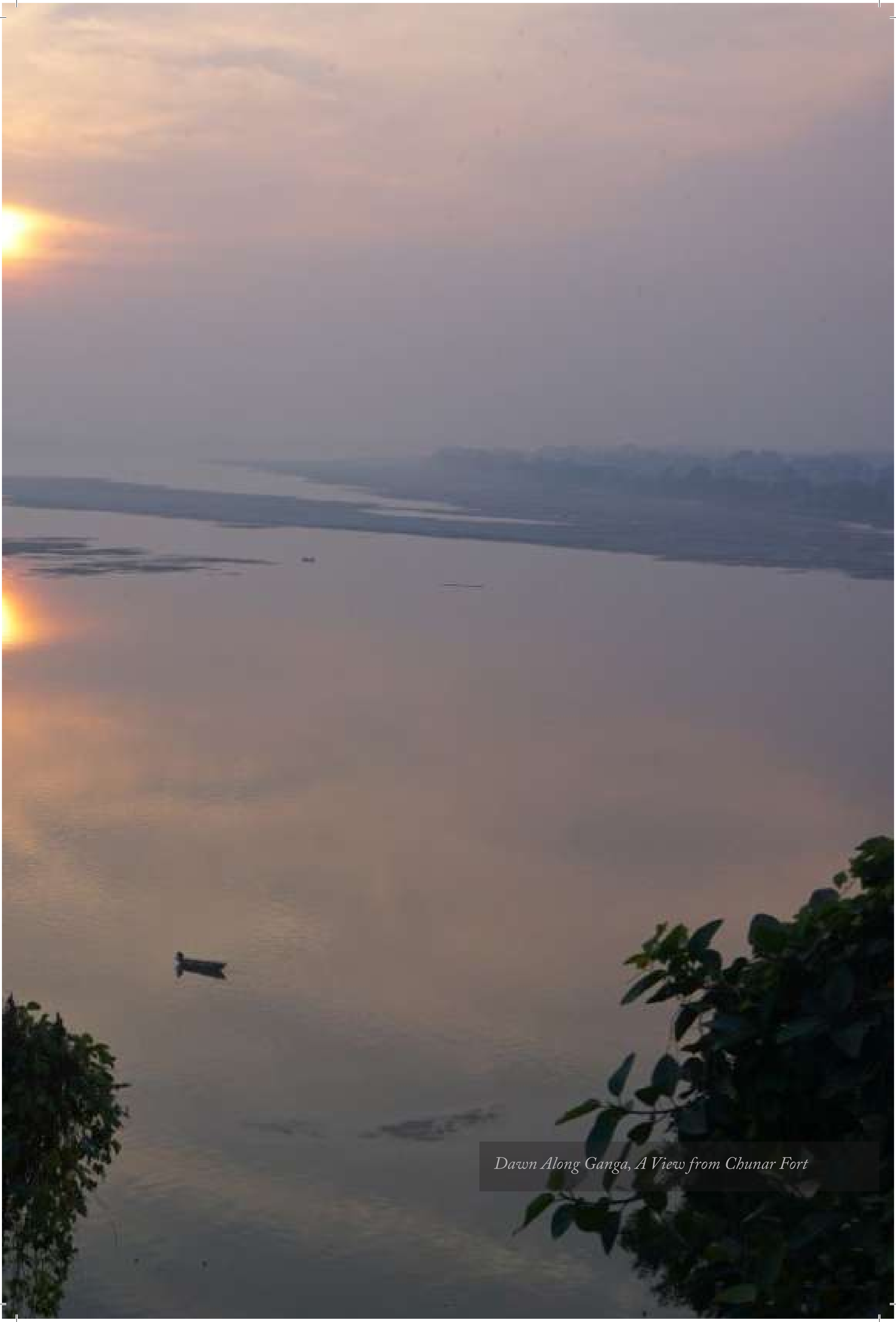
v. Direct the IIT-Consortium to complete the task of the preparation of the and commission a peer review of the same

vi. Establish the actual rate of evapo-transpiration in the River Ganga Basin

vii. Determine E-flow regime in every sub-basin within River Ganga Basin

Inter-alia, riverine heritage needs to be recognised and protected through law. For example, the Raneh Falls canyon downstream of Panna Tigar Reserve along the Ken River is a case in point.

While a vigorous implementation of the above recommendations on a large scale can help get rejuvenation efforts ahead of the curve, there is no gainsaying the fact that declining contribution to river flows from receding glaciers has no ready answers.



Dawn Along Ganga, A View from Chunar Fort

*Satellite Imagery of Gaumukh,
the snout of the Gangotri Glacier*