Guidelines for

Setting up of Biodiversity Parks in Floodplains of Rivers of India, including River Ganga

Central Pollution Control Board
Ministry of Environment, Forest and Climate Change

October, 2020

GUIDELINES FOR SETTING UP OF BIODIVERSITY PARKS IN FLOODPLAINS OF RIVERS OF INDIA, INCLUDING RIVER GANGA

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ACKNOWLEDGEMENTS

We are grateful to the Principal Bench of Hon'ble NGT, New Delhi, for taking the initiative and for passing the order of 14.05.2019 (in O.A. No. 200/2014) to bring out the Guidelines for Setting Up of Biodiversity Parks in Floodplains of Rivers of India, including River Ganga.

We thank the support and encouragement received from the Chairman and Member Secretary of the Central Pollution Control Board during the preparation of Guidelines. We are also thankful to the Authorities of the Forest Department of Haryana and Shri V. K. Jain, Conservator of Forest, Saharanpur Division, Uttar Pradesh State Forest Department and his field staff of Haiderpur Wetlands and Hastinapur Wildlife Sanctuary for extending help during field visits to Kalesar National Park, Haiderpur Wetlands and Hastinapur Wildlife Sanctuaries, respectively.

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Members of the Committee

PREFACE

Delhi Biodiversity Parks have become models for urban environmental sustainability and resilience, and render a wide range of ecological services. These ecological services include: mitigation of air pollution, recharging ground water, buffering local weather, imparting climate resilience to the city, and several other functions beneficial to humans.

The rivers of India, particularly major rivers used to harbour a wide range of ecosystems, which not only contributed to purification of river water (water quality) and stream flows, but also generated ecosystem services and goods. In fact, the human communities living along the rivers used to eke out their livelihoods from these ecosystems. Due to increasing urbanisation, habitat conversion, damming up of water in upstreams, and other anthropogenic mediated activities, the river ecosystems are highly degraded and the rivers have become open sewers particularly in urban stretches.

The judiciary has been concerned with the massive degradation of river ecosystems, and the urgent need for rejuvenation of rivers of India. Realising the role of Biodiversity Parks not only in bringing back the degraded river ecosystems to their natural states that contribute to rejuvenation of rivers but also to sustain their health, the Hon'ble NGT has been passing orders from time to time on matters related to rejuvenation of rivers. In one of the orders passed by Hon'ble NGT (14 May 2019 in O.A. No. 200/2014) states that the Biodiversity Parks should be developed along the major rivers of India including the river Ganga, and also directed that the Central Pollution Control Board along with a representative from the Ministry of Environment, Forest & Climate Change and one expert, who developed Yamuna Biodiversity Park, should bring out the guidelines for setting up of Biodiversity Parks in flood plains of rivers of India, including river Ganga.

The present "Guidelines for Setting Up of Biodiversity Parks in floodplains of the rivers of India, including River Ganga" provides not only theoretical knowledge but also practical information on the river system and its network of river ecosystems, and Biodiversity Parks in riverscapes so that the stakeholders can easily implement the Guidelines for Development and Management of Biodiversity Parks as a part of rejuvenation of rivers of India. The Guidelines also includes general information on river systems and their ecology, floodplains and their ecological significance, besides a brief background. The bulk of Guidelines cover different facets of Biodiversity Parks and the planning, designing, development and management of Biodiversity Parks in riverscapes; it also includes how to prepare DPRs? and also provides information on the Institutional Mechanism needed for the development, management and sustenance of Biodiversity Parks, and possible source of funding for implementation of DPR; a schematic layout of a typical Biodiversity Park in the riverscapes is also given. The last chapter deals with Yamuna Biodiversity Park as an environmental sustainability model for replication in the riverscapes.

I am sure that the Guidelines will be useful to all the stakeholders in planning, designing, developing and sustaining Biodiversity Parks in riverscapes of rivers of India, and also useful for policy makers and regulators in conservation of rivers.

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FOREWORD

River rejuvenation is a step towards reversing the effects of ecosystem degradation, and to bring back the river ecosystems in their natural states and sustain them *via* improving the quantity and quality of river water. One such measure towards the river rejuvenation is the development of Biodiversity Parks. It is a holistic approach that involves the restoration of degraded river ecosystems in the riverscape, bioremediation of wastewater entering rivers, and use of natural floodplain wetlands for cleaning channel water as well as storage of floodwaters. Yamuna Biodiversity Park of Delhi is a proven and exemplified model rendering a number of ecological services such as mitigation of air pollution, recharging ground water, buffering local weather, imparting climate resilience to the city, and several other functions beneficial to human beings.

In pursuance to the directions of the Hon'ble National Green Tribunal, Central Pollution Control Board (CPCB) along with Ministry of Environment, Forest and Climate Change and Centre for Environmental Management of Degraded Ecosystems (CEMDE) brought out the guidelines for setting up of Biodiversity Parks in flood plains of rivers of India, including River Ganga.

The guidelines will provide comprehensive details on ecology of the river ecosystems, ecological significance of river floodplains and their biodiversity. These guidelines also provide a detailed account of systematic steps in planning, designing, development and management of Biodiversity Parks to restore degraded river ecosystems.

The contributions of Prof. C. R. Babu, Professor Emeritus, CEMDE, University of Delhi; Dr. Prashant Gargava, Member Secretary, CPCB and Dr. A. K. Vidyarthi, Additional Director, CPCB in developing the guidelines is highly appreciated. Hopefully, the guidelines will be useful to the concerned agencies and policy makers involved in rejuvenation and conservation of rivers.

(Shiv Das Meena)

October 29, 2020

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LIST OF ABBREVIATIONS

BSI : Botanical Survey of India

CBD: Convention on Biodiversity

CPCB: Central Pollution Control Board

DDA: Delhi Development Authority

DFO: District/Divisional Forest Office

DO: Dissolved oxygen

DPR: Detailed Project Report

EE: Executive Engineer

MoEF&CC: Ministry of Forest, Environment and Climate Change

MTS: Multi Task Staff

NGT: National Green Tribunal

NIC: Nature Interpretation Centre

NMCG: National Mission for Clean Ganga

O&M: Operation and Maintenance

PAH: Poly Aromatic Hydrocarbons

SPCB: State Pollution Control Board

STP: Sewage Treatment Plant

UNDP: United Nations Development Programme

VOC: Volatile Organic Carbon

ZSI: Zoological Survey of India

RET: Rare, Endemic and Threatened

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EXECUTIVE SUMMARY

The river system has a network of ecosystems that contribute towards sustainability of flow of water and its quality in the rivers. The diverse river ecosystems namely in-stream ecosystems, riparian ecosystems, floodplain ecosystems and adjacent upland ecosystems as well as the ecosystems of the catchments and watersheds - are highly degraded and some of them were extinct due to anthropogenically mediated activities. This degradation and loss of river ecosystems not only reduced flows in the rivers but also deteriorated the quality of river water and ground water.

One way to rejuvenate rivers and sustain the quantity and quality of water in rivers is to set up Biodiversity Parks in the riverscape. The Biodiversity Park approach is a holistic approach for the rejuvenation of rivers, as it involves the restoration of degraded diverse river ecosystems in the riverscapes, bioremediation of wastewater that enters into rivers and use of natural floodplain wetlands for cleaning channel water and storage of floodwaters. Biodiversity Parks approach for rejuvenation of rivers is a proven approach and is exemplified by the DDA's Yamuna Biodiversity Park of Delhi.

Realising the importance of Biodiversity Parks in riverscapes for rejuvenation of rivers, the National Green Tribunal (Principal Bench, New Delhi) not only ordered for the establishment of Biodiversity Parks along some of the rivers in Uttar Pradesh but passed an order on 14th May 2019 in O.A. No. 200/2014 that "The CPCB along with MoEF&CC to develop Guidelines for Setting Up of Biodiversity Parks. The CPCB can take the services of an external expert who has successfully guided DDA to set up Biodiversity Park in Yamuna Floodplain near Delhi".

The present "Guidelines for Setting Up of Biodiversity Parks in Floodplains of Rivers of India, including River Ganga" contains introductory chapters on the river systems, floodplains of rivers and their ecological significance, and Biodiversity and Ecosystems, besides the key chapter on 'Biodiversity Parks: A holistic approach for rejuvenation of rivers of India' which forms the backbone of the Guidelines. These contents of the Guidelines make it a ready reckoner for stakeholders interested in setting up of Biodiversity Parks in riverscapes and landscapes as a part of rejuvenation of rivers.

The second chapter on the "Introduction to River Systems" explains: (i) how rivers are formed?, (ii) how rivers create diverse ecosystems as they pass through different landscapes?, (iii) how the five elements of the riverscape (physical structure, water quantity, water quality, Biodiversity and floodplain and riparian zone) interact and determine the structure and function of river ecosystems?, and (iv) how their interactions along with the geology, geomorphology and climate influence the water quality. The answers to these questions are given in simple text and also *via* illustrations. The different riparian communities and their role in functioning of river ecosystems particularly with respect to water quality are explained.

The third chapter deals with the floodplains of rivers and their significance. It provides information about the different physical zones of the riverscape, definitions of floodplains, the kinds of floodplains and the diverse landforms of the floodplains. It also explains the functions of floodplains and diverse floodplain ecosystems such as wetlands, marshes, swamps, lakes, grasslands and floodplain forests. To make familiar with different river ecosystems, photographs of some stretches of riverscapes of River Ganga and Yamuna showing diverse ecosystems are included.

The fourth chapter on "Biodiversity Parks: A holistic approach for rejuvenation of rivers" has 9 sections. The first four sections explain the concept of Biodiversity Park with respect to riverscapes and landscapes, functions of Biodiversity Parks in riverscapes, the structural elements of Biodiversity Parks and size of Biodiversity Parks.

The section 5.4 on "Planning, Designing and Development of Biodiversity Parks in Riverscapes" gives all the details starting from the selection of site to the development of riverscape and landscape elements in different stretches of riverscape (headwaters, hilly tracts and plains). It also gives information how to restore the degraded river ecosystems and or recreate the lost ecosystems. Details on the development of in-stream ecosystems, riparian ecosystems, floodplain ecosystems including wetlands, marshes, swamps, lakes, grasslands and forests, upland grasslands and forest ecosystems as well as ecosystems of catchments and watersheds are provided.

This section also provides details on the development of other landscape elements such as Butterfly Park, Herbal Garden, Birding Area, Garden of fruit-yielding plants and kcfjvfjbhNature Interpretation Centre (NIC). The importance of biodiversity education and public awareness for river conservation is also emphasized.

The details on: (i) development of constructed wetland system for treatment of wastewater that enters into rivers, (ii) channelization of river water through natural wetlands for cleaning river water, and (iii) restoration of channels that connect the natural wetland to river water for storage of floodwaters are also included.

To implement the Guidelines at ease by stakeholder, schematic layout of "Biodiversity Parks in the riverscape and schematic layout of a typical constructed wetland system" for the treatment of wastewater that enters into river are given".

The section on DPR explains how to prepare the Detailed Project Report and includes all the activities for which costs have to be estimated. The possible sources for funding to establish Biodiversity Parks in Riverscapes are suggested in Section 5.8.

The last section 5.9 includes suggestions on the possible management strategies involving Irrigation Department, Forest Department and local Government Agencies, which would get maximum benefits from Biodiversity Parks, for long term management and sustenance of Biodiversity Parks.

The Guidelines ends with the chapter on the well-established functional Yamuna Biodiversity Park as an environmental sustainability model for replication. Some of the structural components of Yamuna Biodiversity Park that are fully functional and rendering ecological services to the city and its citizens, are illustrated.

Besides the above chapters, the Guidelines includes a Background Note, the Preface, the Foreword, Acknowledgments and References.

1.0 BACKGROUND

Delhi has lost its natural heritage which is critical for sustaining the environmental quality. To bring back the lost natural heritage of Delhi, the Delhi Development Authority (DDA) in joint collaboration with the Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi developed Biodiversity Parks for the first time in the world. The first Biodiversity Park established was Yamuna Biodiversity Park which harbour natural heritage of Yamuna river basin and include diverse river ecosystems that provide several ecological services.

The environmental degradation of river ecosystems of India is rampart leading to loss of their self purification systems and making them as open sewers, particularly in urban stretches. Urbanisation together with habitat conversion and construction of dams in the upstream are the prime causal factors of degradation of Indian river systems. The environmental degradation, particularly the pollution of water in Ganga and Yamuna has been taken up by the Supreme Court, High Courts and National Green Tribunal (NGT) through PILs and other legal cases filed by individuals. Mr. K. C. Mehta's PIL on Ganga (O.A. No. 200/2014) at Supreme Court and Mr. Manoj Misra's case (O.A. No. 06/2012) on Yamuna at NGT are well known and the judiciary has been passing various orders from time to time to rejuvenate the rivers Ganga and Yamuna and also other rivers of India.

Taking the cognizance of media coverage on the biodiversity Parks, the Hon'ble Chairpersons and some members visited Yamuna Biodiversity Park and Neela Hauz Biodiversity Park. Based on their visits and recommendations made in the Reports submitted by Hon'ble NGT constituted Expert Committees, the Hon'ble NGT took note of already developed functional Yamuna Biodiversity Park that harbour many river ecosystems of Yamuna. In its order of 14th May 2019 (in case of O.A. NO. 200/2014) Hon'ble NGT directed Central Pollution Control Board (CPCB) to formulate Guidelines for setting up of Biodiversity Parks in the floodplains of the Rivers of India including River Ganga with the Expert who was involved in the development of Yamuna Biodiversity Park, and also one member nominated by Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India.

Accordingly, the CPCB called a meeting where it was decided that Professor C. R. Babu would submit a proposal for the preparation of Guidelines for setting up of Biodiversity Parks. Professor Babu submitted the proposal and asked extension to submit the final Guidelines, as it involves taking of photographs from some riverscapes to illustrate representative river ecosystems in the Guidelines.

A meeting of the Committee was held on 27th September 2019 to discuss the progress achieved. Professor Babu explained the work done and outlined the chapters to be included in the proposed guidelines. Dr. Vidyarthi pointed out that the guidelines should be self explanatory and should facilitate the stakeholders to develop Biodiversity Parks on the ground without much difficulty. He suggested that the introductory paras of the interim report should include the treatment of waste waters (including sewage and industrial effluents) and restoration of self purification systems of rivers. Dr. A. A. Mao (Director, Botanical Survey of India) – a nominee of MoEF&CC in the committee – was also present in the meeting and informed that BSI would extend any help that is needed for finalizing the Guidelines.

The Interim Report on the Guidelines was submitted to NGT by CPCB. There was a delay in making field visits due to COVID-19 pandemic, and subsequently there was a lockdown Nation-wide from 23rd March 2020 to 31st May 2020. The final Guidelines are provided in the present document.

2.0 INTRODUCTION TO RIVER SYSTEMS

The information presented in this Chapter is mostly taken from the Chapters on 'River Ecology, Conservation and Restoration: A Theoretical Framework' written by Professor Brij Gopal and published in the edited volume on 'Restoring River Yamuna' (eds, Martin, P, Gopal, B and Southey, C. 2007). National Institute of Ecology, New Delhi, and also based on the field knowledge.

A river is a system of natural watercourse that originates as trickles of glacier or snowmelt or surface run-off of the precipitation, and is a link between the land and oceans; the primary, secondary and tertiary surface channels from different directions (surface run-off channels) merge together into a large river that may join another river or lake or ocean or any other large waterbody (Gopal, 2007). Springs also form streams in hills. Not all rivers, particularly the seasonal ones, discharge their contents into oceans.

Rivers are natural ecosystems and are unique in the sense that they change their forms, flows and other biophysical attributes as they pass through large landscapes before joining the oceans. The different river ecosystems found along the course of a river are depicted in Figure 1.

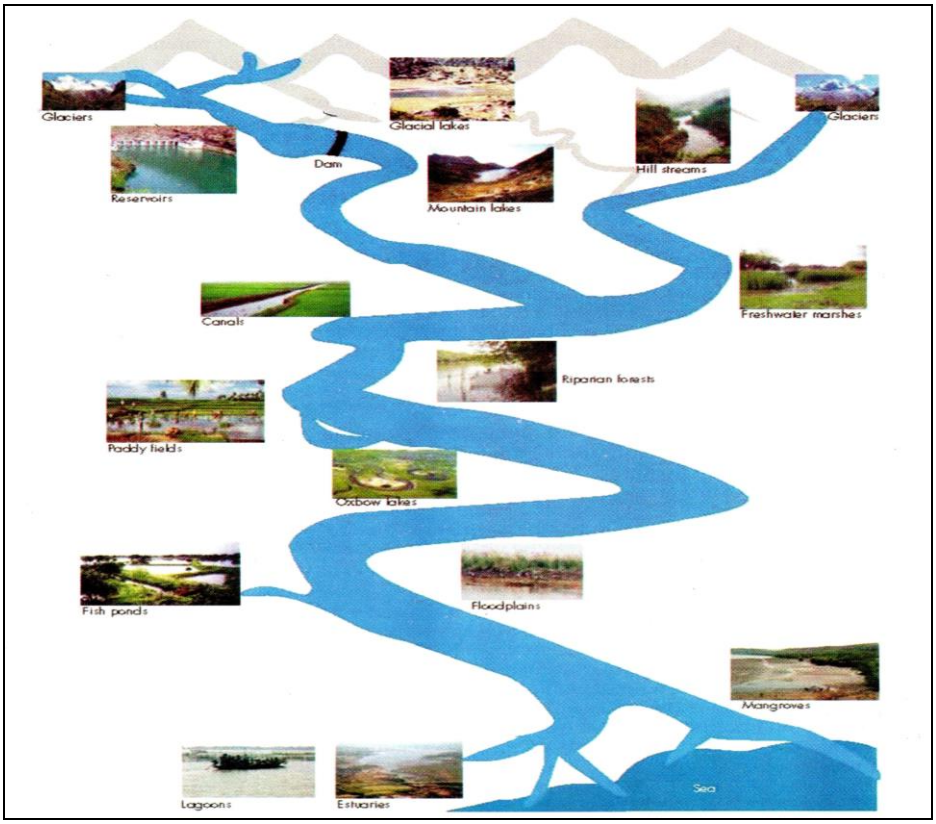

Figure 1: **Different river ecosystems in the riverscape starting from the source of the river to its mouth at sea. (*Source: Gopal, 2013*)**

River ecosystems form one of the major landforms of the planet Earth and are critical for sustenance of Biosphere by providing support to various lifeforms. The river system or riverscape includes the watercourses (channels), the riparian zone (the riverbed and adjacent floodplains), the floodway on either side of the main watercourse (floodplains), the embankments that hold flood waters and enclosed floodplains, and uplands adjoining embankments, together with entire stream network including interconnections with ground water flow pathways embedded in terrestrial setting.

The structure and function of river ecosystems is determined by physical structure of the riverscape, water quality, water quantity, biodiversity and floodplains including riparian zone. These five elements interact among themselves and any change in any one of them alters the structure and function of river ecosystems.

The interactions among these five elements are illustrated in Figure 2 and Figure 3.

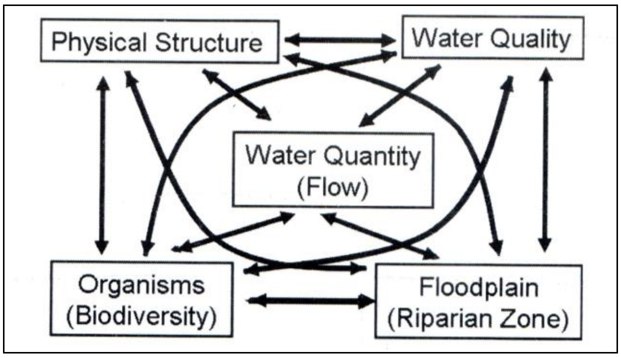

Figure 2: Five elements of the riverscape (river system) and interactions among them. ***(Source: Gopal, 2007)***

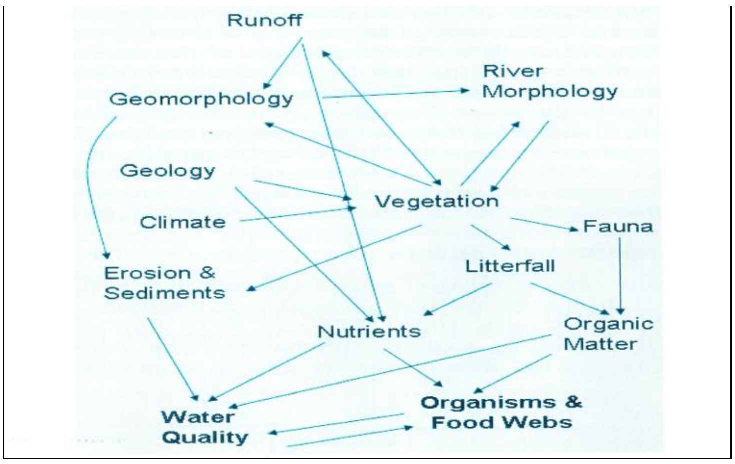

Figure 3: Illustration showing how the interactions among five elements of riverscape together with the geology, geomorphology and climate influence the water quality.

2.1 Physical Features of River System

The physical features of river system include: in-stream habitats such as substrate (rock/sand/silt), the geomorphic features (channel bars, pools, riffles), the depth and velocity of water, the in-stream vegetation and structures such as woody debris, pebbles and sandy patches. The habitat diversity changes along the river course from headwaters to the mouth. For example, the headwater streams are straight and meanders increase in downstream; mountain streams have fast and turbulent flows and are steep and unstable with bed composed of rocks or pebbles often with sandy patches; the channels in the flat plains are slow flowing, and beds of these channels are composed of sand and silt and meander over large areas; middle reaches are dominated by transfer of materials (sediment etc.), whereas the lower reaches are dominated by deposition of materials. These different stretches also differ in physical characteristics such as temperature and oxygen saturation. These diverse habitats are inhabitated by diverse plant and animal communities that contribute towards the self purification system of rivers. The communities of riverbed (not watercourse or channel) together with the adjacent communities of adjacent floodplain (marsh vegetation) constitute riparian ecosystems.

2.2 Flow of water

There is a substantial variation in the volume of water that flows among different rivers and depends upon the extent of catchments, annual rainfall, evaporation and infiltration. The size and frequency of flows, seasonal flow patterns, flow duration and the rate and rise of flow events also impact the habitat complexity and biotic communities. In some rivers, the stream flow has a component of base flow (ground water flow) into the stream which is critical in dry season for maintenance of in-stream and riparian ecosystems which in turn determine the quality of water (Gopal, 2007).

One of the features of the channel is the stream flow which is characterised in terms of quantity, quality and timing. There are two types of stream flows – one is storm flow which refers to flow resulting from precipitation that reaches to the channel over short time frame through overland and underground routes, and the second is base flow that refers to the flow resulting from the precipitation that percolates to the ground and reaches to the channel through substrate. The volume of water passing through channel per unit time is called the discharge and when it is represented graphically then the graphs are known as hydrographs. There are three categories of streams:

(i) Ephemeral streams are those that flow only less than 30 days in a year and flow during or immediately after period of precipitation;

(ii) Intermittent streams are those that flow for more than 30 days per year (seasonal flow) and flows only during certain times of the year; and

(iii) Perennial streams are those that flow continuously during both wet and dry periods (Gopal, 2007).

The stream flow determines the size and shape of channel (morphology). The variability in stream flow not only influences the diversity in biological communities but also maintain it in riparian ecosystems.

The hydrological features that influence the biotic communities through different ecological processes (interactions) are illustrated in Figure 4.

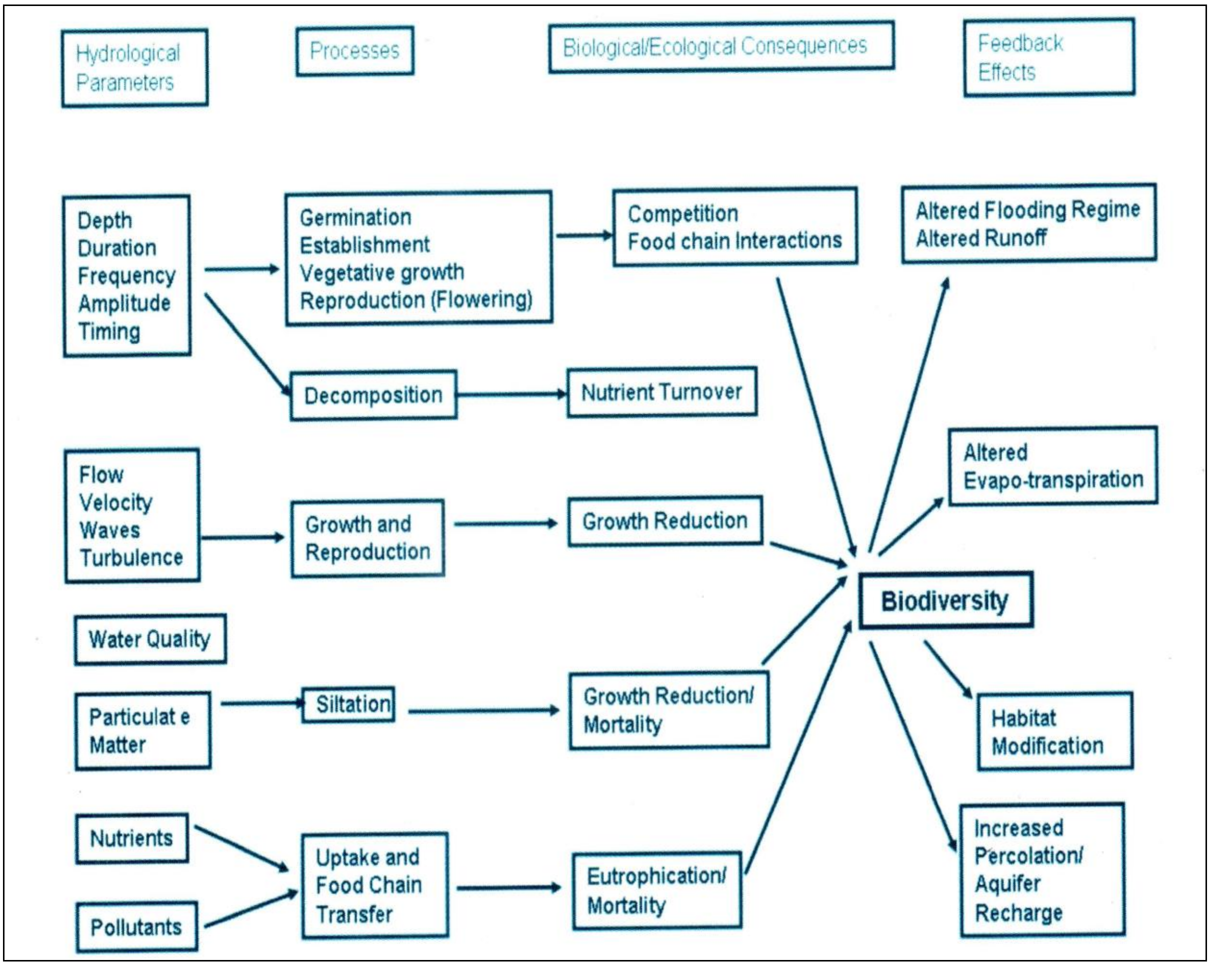

Figure 4: Different hydrogeological parameters (including water quality) of the river system and their impacts on biotic communities through ecological processes and the resulting feedback effects. *(Source: Gopal, 2007)*

2.3 Water Quality

The water quality changes along the course of the river and is governed by geological, geochemical and vegetational characteristics of the watershed. The concentration of nutrients increases gradually as variety of dissolved and particulate substances and plant litter enter the stream through runoff. Water temperature is critical for completion of the life cycles of aquatic and terrestrial invertebrates which are critical component of self purification system of rivers. Any change in water temperature results in significant changes in biotic communities; loss of riparian vegetation results in marked changes in water temperature. The change in water temperature brings out change in DO levels, and nutrient concentration, etc.

The decline in water quality due to adjacent land use, the presence of livestock, the kind and characteristics of the riparian zone, sewage effluents, urban storm water pollution and discharge of industrial waste water adversely impacted the biodiversity – complete loss to replacement of sensitive species of ecological significance to more tolerant species. The variability in flows regulates various ecological processes that influence the aquatic biodiversity. The same is illustrated in Figure 5.

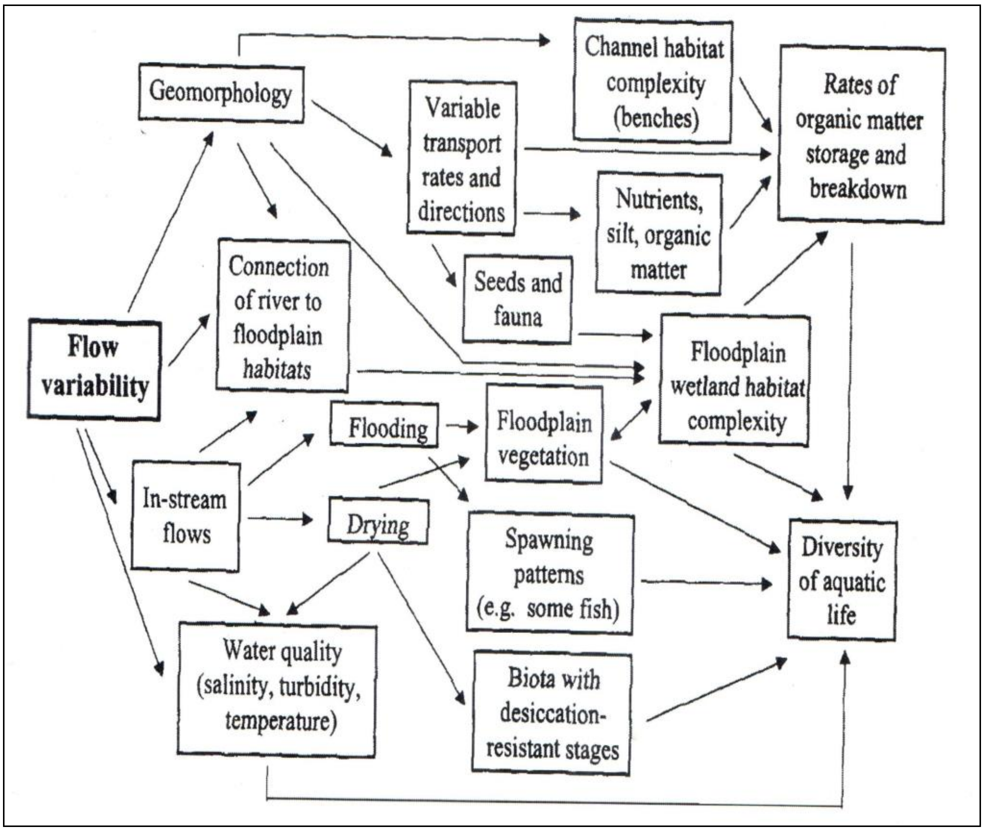

Figure 5: Impacts of flow variability on biodiversity of riverscape through ecological processes. (*Source: Gopal, 2007*)

2.4 Biotic Communities

The habitat diversity influences the biotic communities which vary along the course of river. Most of the animals, which are not attached to the channel bed are drifted to the downstream, although fish and birds swim against flowing water currents in hilly areas.

Species rich communities are confined to shallow slow moving streams or to margins (shores) where flow velocity is low, shallow pools and riffles. In the upper reaches of the stream, where turbulence is high, the biodiversity is not rich and is represented by poor plankton community, benthic algae attached to boulders, higher plants restricted only to banks, and shredders (invertebrates which feed on freshly fallen litter) found under boulders and pebbles near edges (Gopal , 2007) .

The community inhabiting the channel edges is different from that of the middle channel.

In the downstream the leaf litter is fragmented and converted into fine particles and benthic invertebrates that feed on particulate detritus are very common. With the increase in nutrient enrichment and greater availability of food niches, planktonic communities and faunal diversity also increase.

With reduction in flow velocity and change in substratum, the development of macrophyte community takes place. These communities are highly diversified in the river stretches of plains and also show zonation. The riparian communities include: deep water flora with emergent (cattails) plants growing along banks and shallow water communities having dense patches of reeds and cattails; the elevated areas, which are flooded occasionally, have different types of communities and these differ from those that occur in frequently flooded zones. The aquatic flora and fauna together play a major role in purifying water.

Plants not only provide food and habitat to fish, birds and invertebrates but also stabilize sediments against erosion, reduce flow velocity and improve water quality. The animals include: invertebrates such as snails, worms, shrimps, insects, and vertebrates such as fish, amphibians, reptiles, birds and even mammals. The trophic structures include autotrophs such as algae and aquatic plants; the herbivores include scrapers that feed on algae; the decomposers are represented by fungi and bacteria; the consumers are represented by shredders consume plant leaves or dead plant material and detritus, and snails, fresh water crayfish and a variety of larvae of insects, all of which are predated by larger invertebrates and animals such as fish, frogs, lizards and birds. The plants and animals together form complex food webs with algae and aquatic plants form the basis of food web and contribute to water quality.

2.5 Riparian communities

The riparian zone includes the areas (riverbed and adjacent flood plain) on either side of the channel and are flooded during high flows and influenced by the river. In other words the riparian zone is the floodplain located at lower elevation close to the channel and is contiguous with riverbed and is influenced by the river. Both riparian zone and floodplain are important riverine habitats and play a significant role in the ecology of the river environment. These are a critical link between terrestrial and aquatic ecosystems. Riparian vegetation includes the terrestrial vegetation (corridor vegetation) adjacent to the stream and as well as aquatic and semi-aquatic plants along the edge of the stream bank. The functions of riparian ecosystems include:

(i) sustain good stream habitat for fish;

(ii) serve as source of food in the form of leaves and branches and insects for aquatic animals;

(iii) provide sustainability to channel levees (banks) through root cohesion;

(iv) serve as filter for chemicals and nutrients entering into river from upslope sources;

(v) provide large wood to the channel for maintaining the channel form and improving in-stream habitat complexity;

(vi) ensure the stability of channel form and in-stream habitat through the restriction of sediment input or slowing of sediment movement through river system; and

(vii) moderate downstream flood peaks through upstream storage of water (Gopal, 2007).

The biotic communities and the role of floodplains in water quality are highlighted in the next chapter.

To sum up, the five elements – physical structure (habitat diversity), water quality, biodiversity, riparian zone and floodplain and water quantity determine the structure and function of river ecosystems. All these five elements have been greatly altered through anthropogenically mediated activities. Consequently, most of the river systems have lost their life supporting potential and have become either dead and or open sewers.

3.0 FLOODPLAINS OF RIVERS AND THEIR ECOLOGICAL SIGNIFICANCE

As has been pointed out in the earlier chapter, the river system is highly complex and has the following major physical structure that support a complete network of ecosystems: (i) the channel (water course), (ii) the riparian zone (adjacent to the channel and includes river bed and channel banks), (iii) the floodplain, (iv) the river embankments, and (v) adjacent uplands. The physical structure of river systems in the alluvial plains is illustrated below (Figure 6):

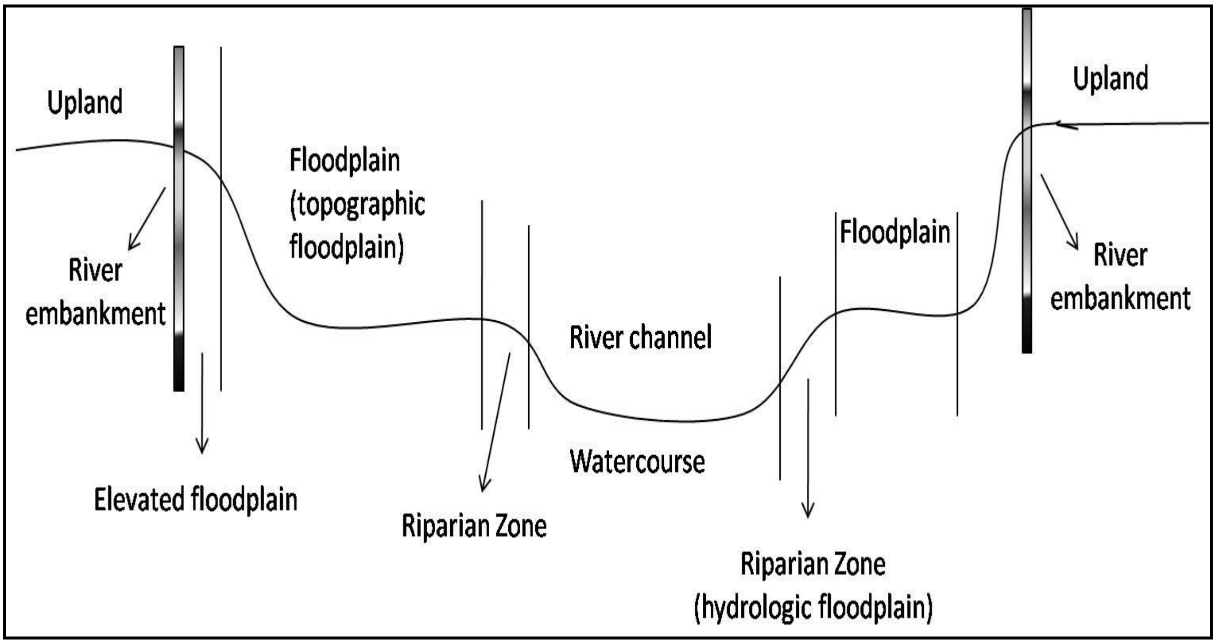

Figure 6: Diffenet zones of a typical riverscape of the rivers in plains.

The flooding results in movement of sediments to the downstream as well as laterally. The flooding of the area on either side of the channel enclosed between two banks/natural levees of the river constitute floodplain. The floodplain adjacent to channel and the dry channel bed (not watercourse constitutes riparian zone. The floodplain edges close to the channel are the levees of the channels, whereas the levees of river are the embankments of the river that enclose the floodplains. The functions of riparian zone have already been discussed.

In alluvial plains, the river migrates laterally across the valley floor and periodic flooding also causes movement of sediments both downstream and laterally. Both these two processes bring out changes in the floodplain continuously; there are two types of floodplains – the hydrologic floodplain that is the land adjacent to the base flow channel residing below the bankfull (water channel filled upto its levees) elevation, and this corresponds to riparian zone within the floodplain; the second type is the topographic floodplain that is the land adjacent to the channel and other bends upto the elevation where floodwaters of once in 100 years flood reaches, *i.e.* the river embankments.

The embankments are usually natural levees of the river but humans made into bund and bunds roads; guide bunds are made wherever bridges/ dams are constructed.

The floodplains provide temporary space for flood waters and sediment produced by water shed, and hence allows lag period between the peak run off caused by heavy rain fall and flood peak downstream (Gopal, 2007). If there is a reduction in floodplain, frequent and severe flooding and aggradation of the river channel take place.

Floodplains are a complex landforms within the riverscape and are formed by a complex interaction of fluvial processes, however, the characteristics and evolution of floodplains are mainly the product of stream's ability to entrain and transport sediment (stream power – ability to do work or shear stress) and the resistance of channel boundary to erosion, *i.e.* erosion resistance of floodplain alluvium that forms the channel boundary (Nansion & Croke, 1992). The geomorphology of the channel and floodplains is determined by the amount and texture of the sediment load.

3.1 Definition of floodplain

Floodplains are defined in different ways: For hydrologists and engineers, floodplains are defined as the surface areas next to the channel of the river and are inundated once a given return period (*i.e.* once in 25 years or 100 years) irrespective of the nature of surface area whether it is alluvial or not (Ward, 1978). According to Nanson & Croke (1992), the genetic floodplain is "largely horizontally – bedded alluvial landform adjacent to a channel, separated from the channel by banks, and built of sediment transported by the present flow regime". This is a contemporary floodplain or landform formed under present hydro-climatic conditions in contrast to ancient alluvial deposits formed under previous flow regime (elevated floodplain). The river can transport only a fraction of the total alluvium of a river valley over decades or centuries, and bulk of it is stored in floodplains.

Soni *et al.* (2019) discussed extensively the definitions of river floodplains in India. They also discussed the role of floodplains in maintaining good health of rivers and, hence the floodplains are often described as 'blue gold'. The floodplains of major rivers in India may store more than 20 times the volume of annual virgin flow in the river. These floodplains can be used to supply drinking water to several cities along the river annually. For example, the Palla well-field in the Yamuna floodplains of

Delhi supplies drinking water worth of Rs. 7500 million per year. About 40% of sand volume is water and hence floodplains store huge amount of water from rain and during flooding, and release some of this water into rivers in the lean period.

Soni *et al*. (loc. cit.) also suggested that the floodplain should be defined by its hydrogeomorphic character. In simple-terms, sand, silt and clay and the various geomorphic units associated with the depositional activity of the present day river should be used for demarcation of the floodplain.

The River Ganga (Rejuvenation, Protection and Management) Authorities Order (GOI, 2016) defines floodplain of the River Ganga as 'such area of River Ganga or its tributaries which comes under water on either side of it due to floods corresponding to its greatest flow or with a flood of frequency once in hundred years'.

Hon'ble NGT in its order on 13 January 2015 in O.A. No. 6 of 2012 on the Yamuna floodplain of Delhi stated "..... the floodplain zoning should be taken with reference to the flood of once in 25 years, as against other suggested figures of more years". Similarly, NGT's judgement on 17 November 2017 in case of O.A. No. 171 of 2015, based on the findings of a Committee constituted for demarcation of floodplains of Krishna river near the city of Amravati (AP), stated that "Therefore, it is evident that the flood from River Krishna does not cross the embankment/bund cannot be called as floodplains".

The layman's definition of a floodplain is that it is an area on either side of the channel and form natural levees of the channel and enclosed between the river embankments and flooded atleast once in 100 years flood. Floodplains are constructed by rivers and a number of floodplain deposition processes have been identified and explained in detail by Nanson & Croke (1992).

3.2 Floodplain depositional processes and classification

According to some workers (Allen, 1965), floodplains are formed entirely from lateral accretion deposits. Three main processes of floodplain formation are recognized. The lateral point bar accretion results from the progressive deposition of point bars on the convex bank of a meander and produce a variety of floodplain morphologies with some having little surface relief and others with well-defined scroll patterns. The overbank vertical accretion results from the overbank deposition of sediment during floods and provide levees, crevasse splays and backswamp deposits. The braid channel accretion is the product of a combination of processes including: (i) the shifting of primary braid channels to another part of the valley allowing the stabilization of previously active areas of braid-bars and riverbed; (ii) local aggradation and lateral channel incision resulting in the formation of abandoned braid-bars as partly erosional elevated features; and (iii) formation of extensive, elevated bars during a large flood forming a stable surface beyond the reach of regular flood events (Nanson & Croke, 1992). There are also three less common processes which also produce a variety of floodplain types. These include oblique accretion, counterpoint accretion and abandoned channel accretion. Island formation is a discrete process and is considered as the product of composite processes by involving the first two processes – later point-bar accretion and overbank vertical accretion.

Some of the floodplain types formed by depositional processes are illustrated in figure 7.

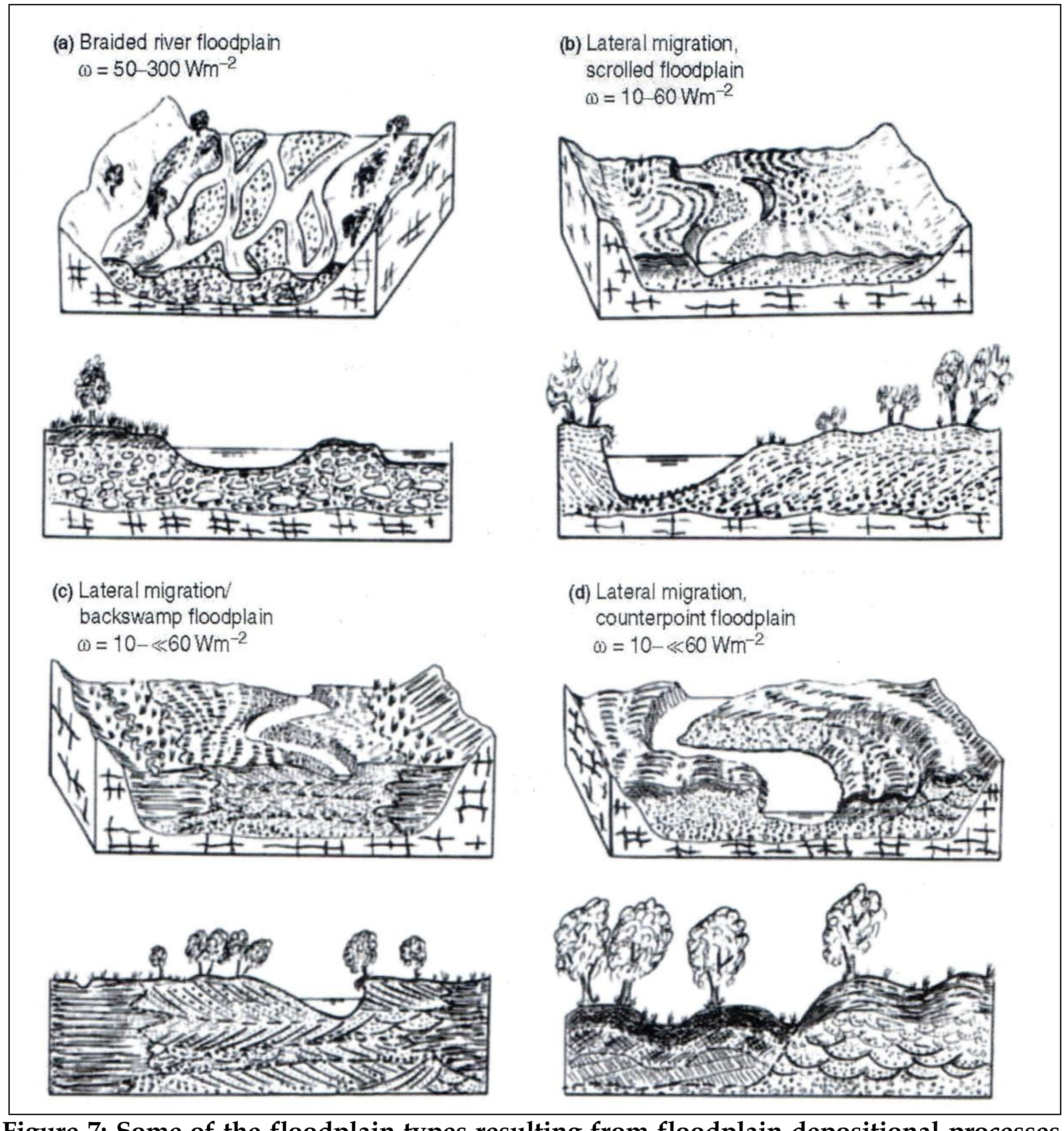

Figure 7: Some of the floodplain types resulting from floodplain depositional processes. (*Source: Nanson & Croke, 1992*)

There have been several classifications of floodplain types. These are broadly grouped under morphological, specific and genetic. These are extensively reviewed by Nanson & Croke (1992). They proposed the genetic classification of floodplains based on the interrelation between river processes and the floodplains they construct. The stream power or rate of doing work for unit length of channel (the power to erode and construct individual landforms) is used for classification of floodplain types. The erosive power/ resistance concept was used as the primary criteria in classifying river floodplains into classes. These classes were further subdivided into orders and suborders based on geomorphic factors. The three classes recognized are: (i) non-cohesive alluvium (gravel to fine sand), (ii) cohesive alluvium (silt and clay), and (iii) low-energy cohesive floodplains. The non-cohesive floodplains are grouped under two categories – high energy and medium energy environment classes. They have given an excellent Table which summarizes the classification of floodplains and gives details on order/ suborder, class, type of floodplains, specific stream power, erosional and depositional processes, landforms, channel planforms, and environment. Table 1 gives the order/ suborder, the type of floodplains, the sediment nature and the landforms.

Table 1: Floodplain types and characteristics of their sediments and landforms (*Source: Nanson & Croke, 1992*).

Order/ Suborder	Floodplain type	Sediment	Landforms
	Class A: High-Energy Non- Cohesive Floodplains		
A1	Confined coarse-textured floodplains	Poorly sorted boulders and gravel; buried soils	Boulder levees; sand and gravel splays; back channels, abandoned channels and scour holes
A2	Confined vertical accretion floodplains	Basal gravels and abundant sand with silty overburden	Large levees and deep back channels and scour holes
A3	Unconfined vertical accretion sandy floodplains	Sandy-strata inter-bedded muds	Flat floodplain surface
A4	Cut and fill floodplains	Sands, silts and organics	Flat floodplain surface; channel fills, swampy meadows
	Class B: Medium-Energy Non- Cohesive Floodplains		
B1	Braided-river floodplains	Gravels, sands and occasional silt	Undulating floodplain of abandoned channels and bars; backswamps
B2	Wandering gravel-bed river floodplains	Gravels, sands, silts and organics	Abandoned channels; sloughs; braid-bars; islands; back channels (see also figure 6)
B3	Meandering river, lateral-migration floodplains	Gravels, sands and silts	Flat to undulating floodplain surface; oxbows; backswamps (see also figure 6)
B3a	Lateral migration, non-scrolled floodplains	Gravels, sands and silts	Flat to undulating floodplain surface; oxbows; backswamps
B3b	Lateral migration, scrolled floodplains	Sands and minor gravels	Distinctly scrolled floodplains (see also figure 6)
B3c	Lateral migration/ backswamp floodplains	Sands, silts and organics	Central scrolled floodplain with flanking backswamps
B3d	Lateral migration, counterpoint floodplains	Sands with abundant silts and organics	Concave benches with scrolled floodplains (see also figure 6)
	Class C: Low-Energy Non- Cohesive floodplains		
C1	Laterally stable, single-channel floodplains	Abundant silts and clays with organics	Flat floodplains with low levees; backswamps
C2	Anastomosing-river floodplains	Gravel and sands with abundant silts and clays	Flat floodplains with extensive levees, islands and floodbasins crevasse-channels and splays
C2a	Anastomosing-river, organic rich floodplains	As for C2 with abundant organics and lacustrine deposits	As for C2 with lakes and peat swamps
C2b	Anastomosing-river, inorganic rich floodplains	As for C2 but with little or no organics	As for C2

Lateral migration of the stream channel creates a variety of topographic features on the floodplain.

Floodplains and river exchange the materials and energy through flooding forces. Such exchange is important for fisheries. For example, riverine fish migrate to floodplains for spawning and young larvae and fry feed on plankton, invertebrates and detritus; many animals complete their life cycles in different parts of floodplains.

Receding flood waters from the floodplains carry nutrients, organic matter and propagules and these influence the downstream communities – an important aspect of interaction between river and floodplains.

Different parts of the floodplain are subjected to differential flooding and vary from standing flood water (lentic) and flowing (lotic) with time. There is a spatial variation in hydrological pulses in the floodplains (geomorphic variation and topographic gradient), and as such there is a high diversity in biological communities inhabiting the floodplains.

Nutrient cycling within the floodplain (intracycling) is dominated by flooding from the river, runoff from upland forests or both. Vegetation exerts significant biotic control on intracycling of nutrients, seasonal patterns of growth and decay (Gopal, 2007).

Floodplains are links between rivers and upland, and the materials (water, sediments and nutrients) pass through floodplains before entering into the river. The biological communities of the floodplains control the fate of these substances. The water infiltrates through soil to the ground water or moves laterally to the stream; sediments are trapped and contribute to topographic changes in floodplains; organic matter get settled and decomposed and used by detritus feeding organisms. The nutrients undergo transformation and reduce their flux to the rivers. Many upland animals utilize the floodplains resources. Infact numerous insects of uplands pass their earlier stages of lifecycles in the floodplains.

Some aquatic animals like waterfowl depends upon the terrestrial landscape during some stages in the lifecycle. Consequently floodplains are considered as ecotones.

The most important functions of floodplains include:

(i) Regulation of river discharge by storing huge amounts of water derived from peak flow and storm run-off during the rainy season and subsequent releasing it to the stream gradually leading to uninterrupted stream flow for most of the year.

(ii) Recharge of ground water and improvement of its quality.

(iii) Production of valuable natural resources (timber, fuelwood, fodder and fish) beneficial to local communities.

(iv) Breeding and feeding habitat for fish and many other aquatic animals.

(v) Enhancement of water quality through retention and transportation of nutrients and other chemical substances. Natural floodplains have high rate of recycling of nutrients and usually accumulate nitrates and phosphates and other nutrients, and also sequester heavy metals and toxic compounds in anaerobic organic sediments. In this way floodplains have the capacity to process the wastewater flowing through them and regulate inputs of nutrients and organic matter to the river.

(vi) Reduce the velocity of runoff and traps sediments leading to reduction in siltation of river channels; the floodplains and its vegetation also check the soil erosion. The ecological processes in floodplains through which uplands interact with rivers are given in Figure 8.

The river basin is a landscape, and within which the rivers interact with floodplains, wetlands, and upland terrestrial ecosystems (Figure 8).

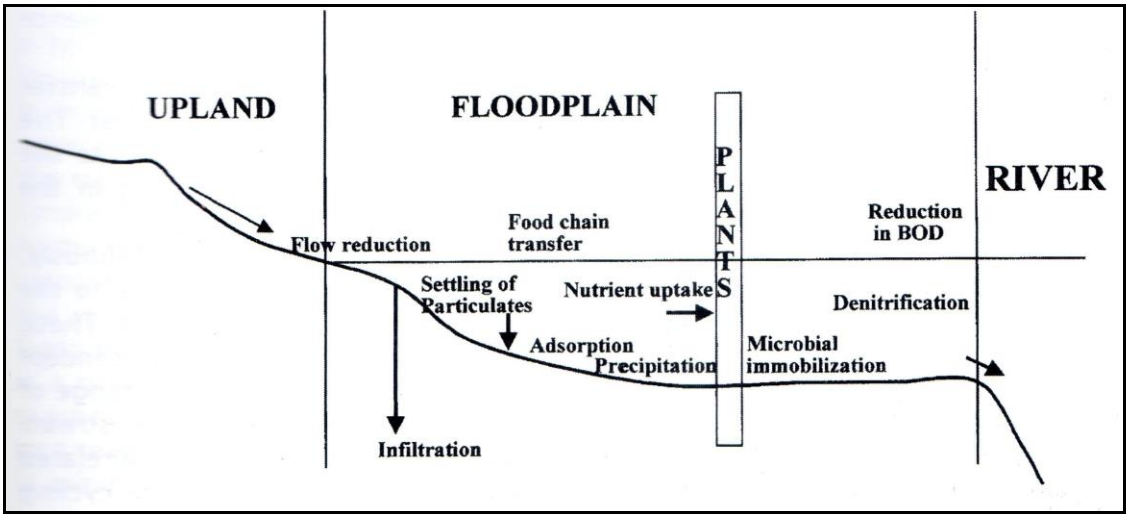

Figure 8: Interaction between uplands and river through ecological processes of the floodplains. (*Source: Gopal, 2007*)

It may be noted that major rivers in India form extensive floodplains during their course in plains, and these floodplains harbour a range of wetlands, swamps, marshes and even deep lakes, floodplain forests, and grasslands, all of which are integral part of the rivers. These different river ecosystems are critical in maintenance of ecological integrity of rivers and also ensure quality of water in the rivers.

3.3 Wetlands, marshes, swamps, lakes, forests and grasslands of floodplains

The natural landscape elements of the floodplains – wetlands, marshes, swamps, lakes, forests, grasslands – are river ecosystems and are integral part of floodplains of rivers. Wetlands are variously defined and the simplest practical definition of a wetland is that any natural lowlying area/depression in the landscapes/riverscapes that holds water atleast for some part of the year and has hydric soils with or without characteristic hydrophytes. Marshes are usually swampy areas and do not have hydric soils, and woody vegetation; it is often difficult to distinguish from wetlands. The inland swamps are marshy areas with clayey substratum saturated with water more or less throughout the year and have woody vegetation, besides Cattails, *Phragmites* and reeds. Often marshes and swamps are also included under wetlands. Lakes are deep water bodies and have an inlet and outlet and are usually undergo thermal stratification. Sometimes the lakes are so shallow that there is no thermal stratification in tropics. In general lakes in humid tropics rarely undergo thermal stratification because of absence of steep temperature gradient.

The ecological significance of floodplain wetlands, marshes, swamps and lakes and the ecosystem services rendered by them have been extensively covered in many publications. Wetlands are critical to sustain life in the Biosphere and the services rendered by the wetlands include : (i) provide water and water related ecosystem services such as fish, prawn, rice and many other plant and animal products ; (ii) purify water, including wastewater/ sewage and industrial effluents; (iii) store flood water and recharge ground water (hydrological regulation of floods and drought); (iv) sequester carbon and climate regulation; (v)storm protection; (vi) erosion control (vii) provide cultural and recreation facilities and (viii) provide livelihoods to local communities.

The structure and ecological processes of wetland and the ecological services rendered by it are illustrated in Figure 9.

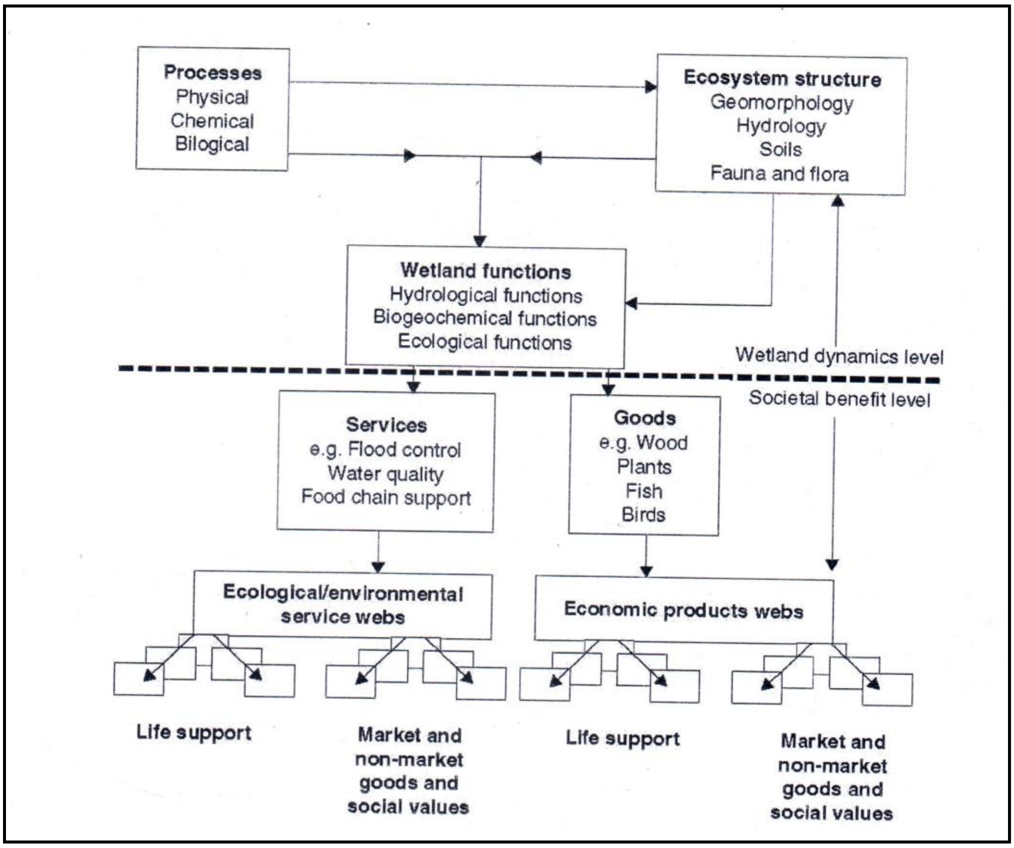

Figure 9: Structure and function of wetlands and the ecological processes that generate goods and services. (*Source: Gopal, 2007*)

The floodplain forests and grassland are also critical components of biodiversity of river systems and regulate several ecological processes, besides generating economic products to local communities. For example, the vegetation stabilise sediments, prevent erosion, reduce flood velocity, maintain water tables, regulate nutrient levels, purify water, immobilize heavy metals and toxic compounds, serve as grazing ground for terrestrial wildlife and also as habitat for completing life cycles of many aquatic animals, enhance the recharging capacity of floodplain, serve as sink for CO_2 and other pollutants, and provide livelihoods to local communities.

The Ganga and Yamuna rivers, in plains of India, form extensive floodplains often spreading for more than 10 km in width; some of the elevated floodplains already encroached and human settlements were developed; some floodplains have been converted into agricultural fields and orchards. The extensive floodplain forests along River Yamuna at Kalesar National Park and wetlands, marshes, swamps, lakes, grasslands, floodplain forests in the upstream and downstream of Madhya Ganga Barrage over Ganga and massive wetlands of Haiderpur (Muzaffarnagar) spreading over 1221 hectares and floodplain forests covering over an area of 1432 hactares along River Ganga, and the massive wetlands of Hastinapur Wildlife Sanctuary along River Ganga are illustrated in Figure 10 to 27. It may be noted that the entire Hastinapur wildlife sanctuary is a wetland spreading over 11,000 ha of area and is covered with water during monsoon but becomes dry during winter and summer months and are converted into agricultural fields during dry period; there are also extensive marshes and swamps in both Haiderpur Wetlands and Hastinapur Wildlife Sanctuary.

The figures 10 to 27 are included in the Guidelines primarily with the objective to bring to the attention of stakeholders about the different river ecosystems that already exist in riverscapes and such ecosystems can be restored/recreated in degraded stretches as a part of Biodiversity Parks in floodplains.

Figure 10: Overview of the riverscape of Yamuna river in the upstream of Hathni Kund reservoir at Kalesar National Park showing watercourses (channels), the riparian zone, the floodplain, and the islands.

Figure 11: Riverscape of river Yamuna showing floodplain forest with one of the dried channels of the river passing through it in the upstream of Hathni Kund Barrage at Kalesar National Park.

Figure 12: Riverscape of river Yamuna showing elevated floodplain that was converted into an Orchard in the upstream of Hathni Kund Barrage at Kalesar National Park.

Figure 13: Riverscape of river Yamuna showing floodplain grassland and forest in the upstream of Hathni Kund Barrage at Kalesar National Park.

Figure 14: Riverescape of river Yamuna showing in-stream habitat of the channel, riparian zone and floodplain forest in the upstream of Hathni Kund Barrage at Kalesar National Park.

Figure 15: Riverscape of the river Yamuna showing Acacia catechu dominated floodplain forest in the upstream of Hathni Kund Barrage at Kalesar National Park.

Figure 16: Riverscape of river Yamuna in the upstream of Hathni Kund Barrage at Kalesar National Park showing extensive riparian zone and floodplain forest.

Figure 17: Overview of the floodplain of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetland) showing wetlands, marshes, swamps, grasslands, forest and connecting channels.

Figure 18: Floodplains of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetalnds) showing luxuriant marshy vegetation, grasslands and floodplain forest.

Figure 19: Floodplain forest of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetland).

Figure 20: Planted forest on the elevated floodplain of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetland).

Figure 21: Floodplain of river Ganga in the downstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetlands) showing lake ecosystem.

Figure 22: Floodplain of river Ganga at Hastinapur Wildlife Sanctuary showing marshy grasslands.

Figure 23: Floodplain of river Ganga at Hastinapur Wildlife Sanctuary showing conversion of wetlands, marshes and swamps into seasonal agriculture.

Figure 24: Floodplain of river Ganga at Hastinapur Wildlife Sanctuary showing wetlands and marshes with rich aquatic flora.

Figure 25: Riverscape of river Ganga at Hastinapur Wildlife Sanctuary showing grasslands and marshes with a flock of Goose feeding in the floodplain grassland.

Figure 26: Riverscape of river Ganga showing in-stream habitat and riparian zone occupied by agricultural fields (wheat fields) at Hastinapur Wildlife Sanctuary.

Figure 27: Riverscape of river Ganga at Hastinapur Wildlife Sanctuary showing floodplain swamp with reeds, cattails and woody vegetation.

4.0 BIODIVERSITY AND ECOSYSTEMS

Biodiversity is critical for the existence of life on the planet Earth. The different gross landforms that include mountains, plains, rivers and oceans together with their rich ecological diversity support a myriad of life forms. The life forms and their environments together with interactions among life forms and between life forms and their environments constitute Biodiversity. Biodiversity is also often referred to as Biological Diversity (Diversity at all levels of Biological organization).

According to the Convention on Biological Diversity (CBD, 1992), Biological Diversity refers to "the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

The Biodiversity is broadly classified into three categories - (i) the genetic diversity (ii) the species diversity, and (iii) Ecosystem diversity; cultural diversity evolved by humans is also often considered as a component of Biodiversity. The genetic diversity includes diversity from gene level to population level; the species diversity includes the kinds and number of species at species level; and the ecosystem diversity encompass diversity at community and ecosystem levels of biological organisation.

In simple terms, Biodiversity or biological diversity refers to diversity at all levels of biological organisation ranging from genes to Biosphere.

The role of Biodiversity in the structure and function of river system has been discussed in the earlier chapters. The Biodiversity of river systems include plants, animals and microbes. The plants are represented by microphytes which include microscopic photosynthetic organisms such as algae and phytoplankton, and macrophytes that include macroscopic plants of aquatic environments which may be floating, submerged or rooted in sediments and emergents with rooting in the sediment. Terrestrial forest communities are also found on embankments, uplands and floodplains.

The animals include zooplankton, benthic fauna (macro-invertebrates) and dominant vertebrate groups such as fishes, birds, reptiles and amphibians. In the forest communities many animals belonging to diverse taxonomic groups are well-represented.

The microbial communities include protozoans, fungi, bacteria and viruses. The terrestrial communities have many soil borne microbes, including arbuscular mycorrhizae.

The relationships of hydrological features with the Biodiversity through different ecological processes (interactions) are previously illustrated in Figure 4.

4.1 Ecosystems and Ecological Services

Water, soil/rock, air and living organisms constitute environment. These four components of environment are also known as environmental resources or natural resources. These four environmental components interact within and between them in a given area/location and form a complex, self-sustaining, dynamic, functional natural system known as ecosystem. Ecosystem is the basic unit of ecological organisation in Nature. Ecosystem has many attributes and the most important ones are that: (i) ecosystem exists in more than one state, and (ii) the ecosystems have resilience. For example, natural forest is a natural state of ecosystem and when it is continuously grazed it becomes a shrubland and the shrubland becomes grassland if grazing is continued. There are three states of the ecosystem – the natural forest ecosystem, the degraded shrubland ecosystem and the degraded grassland ecosystem.

Resilience of the ecosystem refers to its ability to go back to its natural state if the disturbance regime (grazing) is within its threshold limits. If the disturbance regime crosses threshold limits, the ecosystem losses its resilience and convert from one state to another state. For example, if there is an intermediate grazing, the forest ecosystem goes back to original state, *i.e.* natural forest ecosystem because of resilience; but if there is an intense grazing, the forest ecosystem loses its resilience and degrades to a shrubland ecosystem.

The ecological processes resulting from interactions among four components generate a wide range of services and goods known as ecological services or ecosystem services.

The different ecological services rendered by ecosystems are classified into four categories: (i) the provisioning services that include the food that we take, the water that we drink, the shelter where we live in, the clothes that we wear and the drugs that we take for curing our diseases, all of which are derived from ecosystems; (ii) life supporting services like nutrient cycling, soil formation and primary productivity; (iii) regulatory services that include climate regulation, flood and drought regulation, disease control and water purification; and (iv) cultural services that include aesthetic, spiritual, educational and recreation values. All these services contribute to human well-being.

The different functions of river ecosystems, which have been discussed extensively in the earlier chapters, represent direct and indirect ecological services and goods belonging to above mentioned categories.

To illustrate the ecological services and goods provided by ecosystems, the ecosystem services rendered by Australia's tropical river systems are given in Table 2.

Table 2: Different ecological services with examples of goods, activities and benefits rendered by Australia's tropical river system. (*Source: Gopal, 2007*)

Ecosystem services	Examples of goods, activities and benefits provided
Provisioning	
Food	Production of fish, other aquatic terrestrial species, fruit, and grains for recreational and subsistence hunting and gathering
Fresh water	Storage and retention of water for domestic, ecological, aquaculture, mining, fishing, and agricultural use
Fibre and fuel	Production of logs, fuelwood, and fodder for building, cooking, and warmth
Biochemical	Production of biochemicals and medicines and industrial products
Genetic materials	Production of genetic material (genetic resource)
Regulating	
Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes
Water regulation (hydrological flows)	Groundwater recharge/ discharge; hydrological regime is key driver of ecosystem processes and food-web structure
Water purification and waste generation	Retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, storm protection
Biological control	Control of pests and diseases
Cultural	
Spiritual and inspirational	Source of inspiration for well-being and art; spiritual benefit; specific and unique indigenous spiritual and cultural values
Recreational	Opportunities for recreational activities and tourism
Heritage and sense of place	Cultural heritage and identity
Aesthetic	Many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Habitat provision	Provision of habitat for wildlife feeding, shelter, and reproduction
Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients

4.2 Changes in Ecosystems and their Degradation

Humans have been changing the ecosystems, and human induced changes that took place in ecosystems during the last 50 years exceeded all those changes that took place in the entire human civilization. Some changes (food production systems) benefited humans but most of the changes have adverse effects on ecosystems and manifested into 21st century environmental challenges. Loss of biodiversity is the major 21st environmental challenge that is a threat to human survival and existence of Biosphere. The River systems form the lifeline of human societies evolved over centuries, and today these life supporting systems are threatened with extinction. About 87 percent of wetlands were extinct due to land degradation. 100s of springs were dried up. Many Indian 3rd order tributaries were either vanished or become sewers or filled with solid waste. In fact, many rivers in urban stretches have become open sewers and lost their self purification abilities due to absence of microbial, algal, phyto and zooplankton, macrophytic and benthic faunal communities, all of which were extinct due to heavy pollution load. The loss of floodplains and their wetlands and riparian ecosystems also led to degradation of river ecosystems and deterioration of water quality.

Human activities that led to degradation of river ecosystems include: (i) damming up of water leading to diversion of river flows to agricultural, industry and domestic use; (ii) diversion of river flows for generation of hydropower; (iii) channelization by constructing embankments, bunds and bund roads for preventing flood waters entering into encroached human settlements on the floodplains; (iv) intensive sand and gravel mining from in-stream, riparian zone, floodplains and earthen embankments; (v) conversion of floodplains into agricultural fields; (vi) conversion of wetlands into paddy fields; (vii) loss of biodiversity along embankments, uplands, catchments and watersheds; (viii) dumping of solid waste into wetlands; (ix) filling up wetlands for human settlements; (x) dumping of solid wastes on the floodplains for human settlements; (xi) discharge of wastewater (domestic sewage and industrial effluents) into rivers and wetlands leading to death of riparian ecosystems; (xii) excess withdrawal of groundwater from the areas close to floodplain; (xiii) intensive grazing; (xiv) invasion of invasive alien species; (xv) excessive nutrient loading due to agricultural runoff; (xvi) contamination of water with pesticides and other chemicals used in agricultural and dairy farms, etc. The challenge is how to rejuvenate dying rivers?

5.0 BIODIVERSITY PARKS: A HOLISTIC APPROACH FOR REJUVENATION OF RIVERS

The river ecosystems across the country are highly degraded, and the pollution loads are so high that the water in most of the rivers, particularly in urban stretches are unsuitable even for irrigation. The challenge is how to rejuvenate river ecosystems which are highly complex. To achieve this goal, there is a need for holistic approach. One such approach is the establishment of Biodiversity Parks along the floodplains of rivers of India. The Biodiversity Park approach involves restoration of degraded river ecosystems and recreation of lost ecosystems, biological treatment of waste waters that enter into river, and use of natural wetlands for cleaning channel water and storage of flood water. The Biodiversity Park approach is detailed in the following pages:

5.1 Concept of Biodiversity Parks

Biodiversity Parks are unique landscapes/riverscapes of wilderness where ecological assemblages of native species are recreated over marginal/degraded landscapes/riverscapes. Biodiversity Parks are based on the ecological restoration principle and the underlying principle is to establish self sustaining ecosystems that have biodiversity and function that generate ecological services that contribute to well being of humans.

Biodiversity Parks in riverscapes include restored/recreated river ecosystems along degraded stretches of rivers for their rejuvenation.

The Biodiversity Parks of floodplains of rivers include the restoration/recreation of diverse landscape elements of floodplains such as wetlands, marshes, swamps, lakes, forests and grasslands, besides riparian ecosystems and in-stream communities. It also includes the development of greenways along embankments, forest communities on adjacent uplands and treatment wetlands for cleaning river water and constructed wetlands for treatment of sewage and industrial effluents that enter into rivers.

The Biodiversity Park concept ensures the original ecological integrity of the landscape/riverscape and prevents introduction of any external element in the landscape/riverscape that might affect native flora and fauna.

The Biodiversity Park approach is innovative approach or model for recreation of lost biodiversity or natural heritage and it is a conservation approach. It involves conservation of ecosystems, communities, species, populations, and simulate National Parks/Wildlife Sanctuaries/Nature Reserves/Wilderness.

5.2 Functions of Biodiversity Parks

Biodiversity Parks have wide range of functions and encompass almost all the four categories of ecosystem services rendered by ecosystems, and include: (i) enrich human microbiome as the parks harbour rich environmental microbiome which in turn reduces the human health risks and public health burden; (ii) serve as filters for point and nonpoint source of air pollutants; (iii) store flood water and recharge ground water; (iv) prevent soil erosion and stabilize floodplains; (v) reduce flood water velocity; (vi) serve as hub for conservation, educational and cultural activities; (vii) promote ecotourism; (viii) connect the city and its citizens to nature and biodiversity; (ix) provide livelihoods to local communities; (x) serve as living museum for understanding ecosystem processes and function; (xi) sequester CO_2 and impart climate resilience, buffer local weather and even cause local precipitation; (xii) serve as habitat for vanishing flora and fauna (xiii) purify water; (xiv) enhance biological productivity; (xv) sustain river ecosystem and, (xvi) rejuvenate rivers.

Biodiversity Parks of riverscapes have many other functions such as:

(i) contribute to self purification system of river water;

(ii) regulation of stream flows;

(iii) prevention of channel bank erosion;

(iv) uniform distribution of sediments;

(v) stabilization of floodplains;

(vi) trapping of sediments;

(vii) reducing flood water velocity;

(viii) immobilization of heavy metals and nutrients such as nitrogen and phosphates, including heavy metals;

(ix) regulation of nutrient cycle leading to enhanced water quality;

(x) storage of flood water;

(xi) recharge of groundwater and enhancement of base flow for sustained riverflow;

(xii) filtration of surface runoff from upland, embankments and watersheds;

(xiii) sink for CO_2 and buffer local weather;

(xiv) reduction in loss of water from surface evaporation;

(xv) provide diverse products to and livelihoods of local communities;

(xvi) provide recreation to the public;

(xvii) preservation and sustenance of diverse river ecosystems and the flora and fauna;

(xviii) promote ecotourism;

(xix) habitat for RET (Rare, Endemic and Threatened) aquatic and terrestrial plant and animal species;

(xx) regulate water temperature leading to enhanced water quality;

(xxi) bioremediate wastewaters that enter into river system; and

(xxii) cleaning of river water through treatment wetlands (natural).

These functions of Biodiversity Parks in riverscapes have already been discussed extensively in Chapters 2 and 3.

5.3 Structural Components of Biodiversity Parks

A Biodiversity Park can have wide range of landscape/riverscape elements, and it depends upon the space availability, nature of the ecosystems that used to exist before degradation, topography of the area and what the local communities need, besides the main goal of bringing back the lost pristine glory of the landscape/ riverscape and rejuvenation of rivers. An ideal Biodiversity Park has two zones: (i) the Nature conservation zone and (ii) the visitor zone. The nature conservation zone consists of terrestrial and aquatic ecosystems of the area where the natural forest ecosystems, floodplain wetlands, forests and grasslands, river channels and their interconnections with wetlands of floodplains are located. The visitor zone will have a number of elements such as representative ecosystems of the area, a herbal garden, an aquatic garden to preserve the aquatic resources, wetlands, butterfly conservatory, green ways along the embankment, diverse wetlands that attract diverse group of birds, NIC, constructed wetlands for treatment of wastewater, natural bathing sites for local community on specific festivals and Recreational Parks.

The Biodiversity Parks of riverscapes can have the following structural components:

(i) Forest communities along the river embankment and adjacent upland.

(ii) Greenways with walkways and cycleways long the river embankment/ bunds. The greenways have 3-storeyed native forest communities.

(iii) Greenways with Recreational Parks, where human settlements are located close to the river.

(iv) Floodplain forests and grasslands, marshes, wetlands and lakes on floodplains.

(v) A butterfly conservatory, an herbal garden, a recreational park and forest communities on elevated floodplains.

(vi) An NIC on the elevated floodplains/ embankment/ upland

(vii) Representative riparian ecosystems along the channel banks and riverbeds.

(viii) Natural bathing sites for local communities.

(ix) Natural treatment wetlands for cleaning of river water.

(x) Constructed wetlands for treatment of wastewater that enters into river.

(xi) An aquatic garden for conservation of aquatic flora.

(xii) Infrastructures for promoting awareness, education and training on the conservation of river ecosystems.

5.4 Size of Biodiversity Parks

The size of Biodiversity a Park depends upon the amount of land/the stretch of riverscape available. The minimum land required for biodiversity park is 100 acres, but 50 acres patch can also be developed into a Biodiversity Park. 10 patches of 10 acres each that are located in a cluster can also be used for development of Biodiversity Park. The Biodiversity Parks can be developed in linear fashion along Highways or rivers with stretches of 0.5-5.0 km wide. The upper limit of Biodiversity Park is similar to that of National Park, *i.e.* few hundred km^2.

The size of Biodiversity Parks in riverscapes depends upon the stretch (length) of the river available, the extent of floodplain width and the riparian zone, presence of wetlands and the extent of upland area. The stretch can be 1 km to 100 km long and 0.5-5 km or more wide on either side of channel. The Biodiversity Parks in riverscapes should be developed in linear fashion. Some of the major rivers of India, in the plains, have floodplains extending several 100 km stretch and include vast tracts of elevated floodplain forests.

5.5 Planning, Designing and Development of Biodiversity Parks in Riverscapes

Step-wise procedures involved in planning, designing and developing Biodiversity Parks in Riverscapes are outlined below:

1. Selection of the riverscape.

   Identify the stretch of river that is at least 1km long (the length may be anywhere between 1 and 100 km) that has lesser gradient, extensive floodplains (anywhere between 0.5 km – 5 km wide or more on either side of the water channel and the embankment/ bund) and an upland area of the size anywhere between 50 m and 500 m wide strip along the embankment/ bund.

   Stretches having threats, connectivity, services offered and potential of enhancing the integrity of the ecosystem considered and the potential of demonstrating an integrated approach for restoration may be preferred.

   The river stretch with high conservation values and under anthropogenic pressure should be identified for the Biodiversity Park. So that conservation of inhabiting species (e.g. Freshwater turtles) could be ensured through community engagement.

   There is a need to undertake the assessment of ecosystems, flora and fauna in the past and present at the site and its upstream and downstream areas. The past information can be obtained from the previous published information including floras and faunas and scientific papers, if any. The present information in the form of biodiversity mapping can be done by floristic and faunastic surveys. These surveys include the listing of kinds of species of plants and animals found, the vegetation types, the phytosociological features (dominance, abundance and frequency distribution of plants and birds), invasive species if found, and use of plant and animal species found in the area. This information is useful in selecting the species for community and ecosystem development.

   Proper environmental and ecological assessment of the proposed site taking into account the needs of local communities and participation of Panchayati Raj institutions should also be carried out.

   Regional Offices of Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) may be approached for identification of plants and animals found in the area/region. Both BSI and ZSI also have databases of the plants and animals of the area/region and such databases are useful in Biodiversity mapping.

Note: Please select the stretch where there is no agriculture in floodplains and human settlements on embankments and presence of a strip of upland close to the embankments. Location and design should not interfere with the hydrological, geomorphological and ecological connectivity. Biodiversity Park should follow all existing rules and regulations including those related to social and environmental impacts.

At higher elevations (headwaters zone), the Biodiversity Parks may include the restoration/ recreation of in-stream communities, riparian ecosystems and also adjacent upland ecosystems besides the ecosystems of catchments and watersheds. In these areas, the floodplain is either narrow or absent. In hilly areas, where the riverscapes have extremely narrow floodplains, Biodiversity Parks of such sites include restoration/ recreation of in-stream ecosystems, riparian ecosystems, adjacent upland ecosystems and ecosystems of catchments and watersheds.

2. Secure the area by fencing along the embankment/ upland area and the boundaries of floodplains at the upstream and downstream of the stretch selected.

   It may be noted that identification of wetlands and demarcation of land for interventions should be done based on the study of natural drainage patterns and connectivity analysis along with consultations with the local communities, keeping in view their existing rights and privileges. Restoration of wetlands should be done on the principles of wise use concept.

   Note: No fencing should be done along the water channel front.

3. Survey the vegetation of uplands located in the neighbourhood of the site selected for selection of plant species of trees, shrubs, herbs, and grasses that will be used for the development of terrestrial communities on uplands, embankments and elevated floodplains.

   Note: The propagules of the species selected (seedlings, seeds and ramets/ root slips of grasses) should be collected and raised and multiplied in a Nursery.

4. Development of a Nursery in 2 to 5 acre plot located in embankment/upland area (depending on the size of Biodiversity Park) for the maintenance of saplings and multiplication of saplings.

5. Development of forest plant communities on elevated floodplains, flat floodplains, embankments and uplands:

(a) Development of grasslands, to start with, on the upland, embankments and floodplains.

(b) Plantation of saplings of top canopy tree species.

(c) After 2-3 years of top canopy species plantation, plantation of underwood species should be done.

(d) After 4-5 years of plant community development, plantation of herbaceous plants should be done.

Note: The vegetation developed will prevent erosion/reduce sedimentation load, enrich nutrients in the aquatic ecosystems and improve the water quality. All plantation activities should be done using native plants only.

6. Survey of floodplains for location of the wetlands, marshes, swamps, lakes, grasslands and forests. A GIS based map of the area may also be developed for planning.

(a) The elevated areas in floodplains should be developed into floodplain forest communities. The shallow and undulating depressions should be used for grasslands.

(b) Different grassland communities should be developed based on the moisture gradient. The grass species required may be collected from already existing floodplain grasslands on undisturbed stretches of river close to the selected site.

Note: Propagules of some grass species may also be collected from upland grasslands located in the neighbourhood of the selected site.

(c) If there are already existing wetlands, marshes, swamps and lakes, these ecosystems should be restored. The first step in the restoration is desilting (in case of marshes and swamps desilting should be done less than 1 m depth; in case of wetland, desilting should be done upto a depth varying from 1 to 3 m; and in case of lakes, the desilting can be done upto a depth of 3 to 5 m). The silted material can be used for landscaping around the waterbodies. These landscaped areas should be grassed with native floodplain grassland species.

After desilting, introduce phytoplankton, zooplankton, benthic fauna, and fishes into the restored floodplain wetland ecosystems. The other vertebrates colonize these ecosystems on their own soon.

(d) If wetlands, marshes and swamps and lakes were vanished at the site, these have to be recreated on the sites where some hydrophytes such as Cattail and *Phargmites* exist.

(e) To provide seed material of animal communities, two nursery ponds should be developed in the elevated floodplains zone/ upland area.

(f) If there are silted connecting channels between water channel and the wetlands and lakes, these silted channels should be desilted upto a depth of 1 m or so and the excavated material should be used for landscaping. The channel should be lined with reeds and cattails.

(g) If channels were vanished, these channels have to be created. These channels should be shallow (4-8 m wide and 1-2 m deep). These channels should be lined with reeds and cattail plants.

(h) If there are habitats that support riparian communities and the habitats are degraded, restore them and introduce the planktonic, benthic and other plant and animal communities characteristic of riparian communities.

(i) If the riparian ecosystems were vanished, the ecosystems have to be recreated in the riparian zone. If such zones cannot be created along the channel, simulated riparian ecosystems have to be developed in the floodplains close to the water channel, using boulders, stones and pebbles.

(j) If the water in the channel has lost in-stream biotic communities, these have to be introduced.

(k) If the water quality is low due to discharge of sewage and industrial effluents, the water from the channel has to be treated by passing it through treatment wetlands to be developed in the floodplains and channels have to be created in a way that channel water pass through these wetlands from the upstream and then enters into the downstream. In fact such treated wetlands and channelization of water all along the river in floodplains may rejuvenate the rivers.

(j) If storm drains carrying sewage is passing through the floodplains, the treatment wetlands have to be developed for in-situ biological remediation of sewage before it is discharged into river.

(m) If natural wetlands do not exist for the treatment of storm drain sewage, constructed wetland system has to be developed. The constructed wetland system has the following units:

(i) One or two oxidation zones / ponds/ units separated by mini weirs of 1 m or 1.5 m high; this is connected to (ii) physical filter zone/pond/ unit that have 5 to 10 gabions of 1m high, 2' wide with boulders of 2' size embedded in iron mesh, and this unit is connected to (iii) constructed wetland unit consisting of 8-15 ridges and furrows; the ridges are 1 m high and 2′ wide and made of stones/ pebbles of 180-200 mm; the furrows are used for plantation. The length and width of each unit depends upon the length and width of drain, hydrological features such flow rate, volume and organic load of sewage.

It is important to prevent pollution at the source, particularly the drains that carry industrial effluent by having a common effluent treatment plant and STP for domestic sewage and then recycle the treated water. In case prevention of pollution at the source is not possible, in-situ remediation of sewage entering into river from clusters of villages should be carried out using constructed wetland as a part of rejuvenation of river.

(n) Aided regeneration/plantation of native species to develop and support native ecology will be undertaken wherever it is necessary.

(o) While designing the restoration/ recreation of wetlands, it is necessary to keep in view the wetland functions so that activities such as development of embankments and other topographic changes should not alter the natural flux of water, sediments and species.

7. Development of Butterfly Park

This should be developed on upland/ embankment, and suitably landscaped. About 70-100 host plants for larvae and 70-100 flowering native herbs, shrubs and trees that produce nectar bearing flowers seasonally and serve as host plants for adult butterflies should be planted. About 50-100 species of butterfly will be attracted to the Butterfly Park. The area required for development of Butterfly Park is about 2 to 5 acres.

There should be 2-3 small shallow waterbodies scattered over the area. Each waterbody should be 10 m X 10 m and 1 m depth. This is needed for maintaining relative humidity. There should be shelter belt around the periphery of Butterfly Park with 1 or 2 rows of bamboo.

8. Development of Herbal Garden

An area of 5-8 acres in the upland/ elevated floodplains can be developed into a herbal garden for the conservation of native medicinal plants. Plants that can be used in home remedies can be grown and can be provided to local communities. About 100-150 species of local plants of medicinal value can be grown. The cultivation practices, medicinal properties of plants grown should be provided on signages and should be also displayed in the Nature Interpretation Centre.

The area should be suitably landscaped depending on the site characteristics.

9. Fruit Yielding Garden (Orchard)

A fruit yielding plant garden can also be developed along embankment/ upland. About 25-30 acres can be used for the development of local varieties of popular fruit yielding species in the region.

10. Birding Area

Besides cultivated fruit bearing plant garden, wild shrubs and trees bearing fresh fruits should also be planted to attract birds. This should be designated as Birding Area. This should be located over an area of 25 -30 acres in upland /elevated floodplains.

11. A Nature Interpretation Centre (NIC) is critical in a Biodiversity Park for promoting awareness among public and students on the need for river conservation and sustenance of river ecosystems to sustain water quantity and quality. It also serves as a platform for undertaking other activities related to Biodiversity Education and training.

A modest building (aesthetically designed with built up area of 10,000-15,000 sq. ft.) is adequate enough. It should have Toilets and a small Seminar Room where visitors can sit to discuss the issues relating to river ecology and management. An office complex of 5000 sq. ft. and a minor laboratory of 5000 sq. ft. may be attached to NIC. This complex should be developed in the upland area.

The Biodiversity Parks, once established, provide opportunities to people to learn from the Park itself. To achieve this objective, the Biodiversity Parks should include the following provisions:

(i) Guided tours;
(ii) Awareness education on Biodiversity and environment among students and people;
(iii) Preparation of leaflets and training modules for different target groups;
(iv) Popular talks by experts; and
(v) Linkages with research centres in local Colleges and Universities, and also with BSI and ZSI.

12. A recreational garden should be developed in and around NIC without interfering with the hydrological and ecological connectivity of the riverscape, landscape or wetlands. The area required will be 1 to 2 acres. The area should be suitably landscaped.

13. A network of trails connecting different structural elements of Biodiversity Park should be developed. The width of major trails should be 8′ wide and secondary trails connecting major trails should be 6' wide and tertiary trails that connect secondary trails should be 4′ wide. This network of trails should pass criss-cross way across the riverscape. No concretization of trails should be permitted; No paver blocks should be used.

14. A field vehicle, a tractor and a golf cart are essential for the Park.

15. A recreational park on 5 acres of upland/ embankment/ elevated floodplains should be developed.

16. Use of nature-based solutions for water and waste management including composting of aquatic weeds/ leaf litter and floating reed beds and floating fountains for treatment of water should also be integral part of the Biodiversity Park.

17. A weather station may also be installed in the Biodiversity Park and also information on hydrology should be collected.

18. The Biodiversity Parks should have a provision for conservation of local fish species, and their importance in ecology and culture should also be displayed in the NIC.

19. The Guidelines is also applicable for the development of Biodiversity Parks in river reaches which are not embanked.

20. Various climatological challenges should be factored in while preparing the project proposal for Biodiversity Parks.

21. Only eco-friendly construction materials should be used in developing the Biodiversity Parks.

22. Biodiversity Parks, once developed, should be sustainably managed so that no solid waste and other waste should be dumped.

23. In case if legacy waste is located in the floodplains and upland areas, the legacy waste should be remediated and restored as a part of rejuvenation of rivers through the development of Biodiversity Parks.

24. Legacy waste is the solid waste dumped in the floodplains of rivers and has become part of elevated and upland zones of floodplains. These legacy waste zones of floodplains are very common along major rivers and its tributaries, particularly in stretches where urban centres are located.

These legacy waste zones can be remediated by the development of grasslands and or site specific forest communities.

Many grass species like *Saccharum, Sporobolus, Vetiveria, Eragrostis, Bothriochloa, Heteropogon*, *Chrysopogon, Paspalum* and *Panicum* not only uptake heavy metals and immobilize them in by complexing with organic matter/ humus but also biodegraded toxic pollutants with the help of rhizospheric microbial communities.

The broad leaved forest species (trees, shrubs and herbs) with rich and diversified microbial communities biodegrade even Volatile Organic Compounds (VOCs), *i.e.* Polycyclic Aromatic Hydrocarbons (PAHs), emergent pollutants and other toxic chemical pollutants but also uptake and immobilize heavy metals. It may be noted that the forest communities together with grasses play key role in changing the physical features of legacy waste that transform into substratum that hold moisture, recycle nutrients and recharge ground water. In other words the quality of river water is sustained by regulating nutrient cycling. In this way legacy waste over a period of time is biophysically transformed into a substratum that supports biological communities and render ecosystem services including rejuvenation of river.

5.6 Schematic Layout of a Typical Biodiversity Park in Riverscape and a Constructed Wetland

To facilitate how to implement the design of Biodiversity Park planned in the riverscape without any difficulty to the stakeholders, a schematic layout of a typical Biodiversity Park in the riverscape showing different structural elements is provided (Figure 28). A schematic layout of a typical constructed wetland for in-situ biological remediation of sewage that enters into the river is also given (Figure 29).

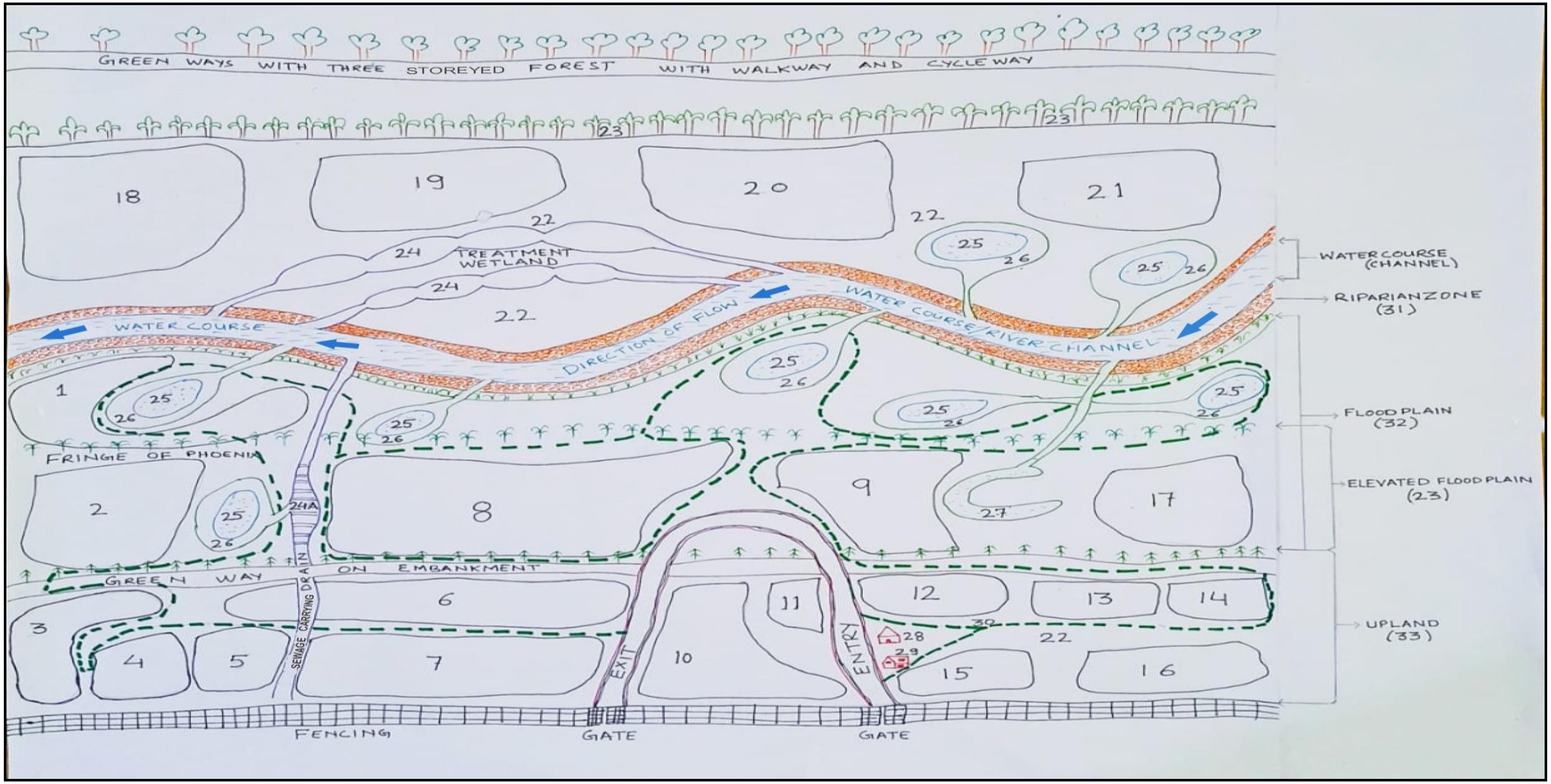

Figure 28: Schematic layout of a typical Biodiversity Park of the riverscape showing different structural components.

1 – Floodplain forest on the elevated ridge; 2 – Floodplain forest with *Acacia catechu*, *Bombax* and Ber, 3 – Wild fruit-bearing shrubs and trees (Birding Area), 4 – *Phoenix* groove, 5 – Shrubland, 6 – Orchard, 7 – Bamboo thickets, 8 – Grassland with scattered trees, 9 – Aquatic garden, 10 – Recreational Park, 11 – Butterfly Park, 12 – Herbal Garden, 13 – Nursery, 14 – *Sterculia* dominated community, 15 – *Butea* dominated community, 16 – *Holoptelea* dominated community, 17 – *Terminalia arjuna* dominated community, 18 to 21 – Different floodplain forest communities, 22 – Grasslands and marshes, 23 – Elevated floodplain, 24 – Treatment wetlands (natural), 24A – Constructed wetland, 25 – Catchment wetlands, 26 – Marsh, 27 – Oxbow lake, 28 – Nature Interpretation Centre, 29 – Office Campus, 30 – Dotted line (----) indicates trails, 31 – Riparian zone, 32 – Floodplain, 33 – Upland

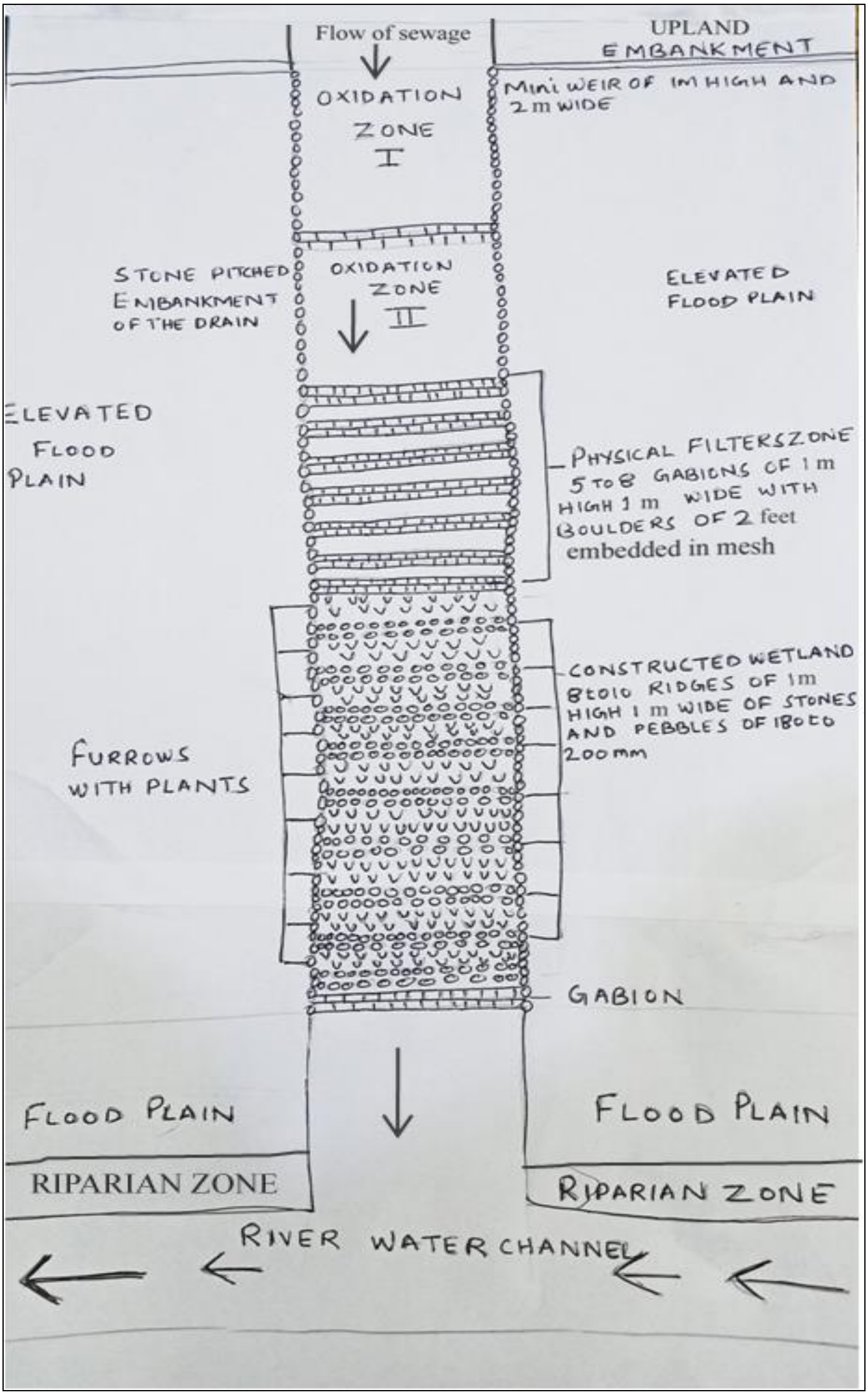

Figure 29: Schematic layout of a typical Constructed Wetland System for in-situ remediation of sewage/ industrial effluent of the drain that pass through Upland Elevated Floodplain of the riverscape.

5.7 Preparation of Detailed Project Report (DPR) for the Development of Biodiversity Parks in Riverscapes

After knowing the detailed procedural steps for planning, designing and developing of Biodiversity Parks in Riverscapes, it is important to know how to prepare DPR for approval of the Project by the Competent Authorities and for implementation.

The DPR should have the following details:

(1) A brief introduction to the Project. This should contain the background on the ecological issues of the stretch of river selected, and how Biodiversity Park would address the issues leading to the rejuvenation of the river stretch, and the benefits that the project can deliver to local communities. It should also include geomorphology and the hydrology of the river reach, in particular inflows and outflows.

(2) Contour map of the selected stretch with details in the upstream and downstream and upland area on either side of river banks; latitude and longitude, and topography of the selected site; demarcation of the area for Biodiversity Park on contour and also on Google Earth maps should be given.

(3) Description of site characteristics including the flora and fauna of upland area and embankment, details of floodplain landscape elements, riparian zone, in-stream characteristics such as flow rate, volume of water, depth of water, water quality, extent of fishing, aquatic flora and fauna, number of storm drains that carry sewage that enters into wetlands/ rivers, presence of wetlands/ swamps/ marshes/ lakes, and if present details of their vegetation and ecology, and land use of the site should be provided.

    It should also include information related to: (i) its historical and cultural significance of the riverscape/ landscape/wetland and of that particular site; (ii) its environmental significance in terms of maintaining the balance of a healthy ecosystem; (iii) its ecological significance in terms of dependence of different life forms & abiotic components (the aquatic life, the terrestrial life, riverine flora) on this river and its resources; (iv) its subsistence livelihood dependencies; (v) various climatological challenges the river is facing; (vi) various man-made challenges the river is facing).

    Regional Offices of BSI and ZSI can be approached for floristic and faunistic databases.

(4) Estimates for development of Nursery, which include costs of polythene bags, earthen pots, garden implements, a bore well, a polyhouse and fencing etc. and porta-cabin, should be given.

(5) Estimates for desilting or creation of wetlands/ marshes/lakes/swamps and use of desilted material for landscaping around the wetland /marshes/lakes/swamps (no transportation cost except in cases where it will be needed) should be provided.

The depth of wetlands /marshes/ swamps /lakes have already been specified in the earlier chapter; the width and length depends upon the existing wetlands/ marshes/ lakes or patches where hydrophytes (Cattails and *Phargmites*) are found.

(6) Estimation of costs for desilting of channels that connect the river/stream channel with wetland and lakes should be provided. The depth and width have already specified; the length depends upon the distance between the stream channel and the wetland/lake.

(7) Estimation of the cost of fencing as specified in the earlier chapters should be provided.

(8) Estimates for the restoration/recreation of riparian ecosystems, will involve the cost of stones and pebbles to be used in the area for diversification of habitat of the riverbed if the riverbed is not alluvial in nature, and desiltation, should be given.

(9) Estimation for the channelization and creation of treatment wetlands for treating stream water should be given. This depends upon the availability of area which cannot be submerged during low floods. The channelization should be atleast of 500m long and pass through a series of treatment wetlands.

(10) Estimates for the development of constructed wetland system for in-situ remediation of sewage that enters into channel through floodplains should be provided.

(11) Estimates for developing network of trails without concretization and paver blocks but lining on either side with stones should be provided.

(12) Cost of purchase of saplings from Forest Department nurseries and government nurseries for plantation should be given.

(13) Approximate cost of procurement of fish fingerlings of native fish species should be provided.

(14) Wages of atleast 20 Multi-Tasking Staff (MTS) as per the state government wages should be calculated.

(15) Salaries of 4 Scientists at the level of Scientist 'B' (one plant taxonomist, one animal taxonomist, one ecologist and one limnologist) should be included. Atleast 3 Field Supervisors at the level of Technical Assistant and one Administrative officer-cum-Accountant and one Office Assistant are required to develop and manage Biodiversity Parks. The salaries of these staff should be included in the annual recurring expenditure. The Biodiversity Park can hire a hydrologist as a consultant whenever his services are needed.

(16) Contingency and consumables are recurring grants, and these grants are also needed for day to day work and should be included in the budget.

(17) Costs of construction of NIC, toilets, office complex, and laboratory have to be estimated. Specifications have already been given in the earlier chapter.

(18) One Tractor with Accessories (about Rs. 8 lakhs), one field vehicle (about Rs. 4 lakhs) and one Motorbike (about Rs. 1 lakh) will be essential and should be included in the budget.

(19) Equipment for monitoring water quality will be required. This will cost about Rs. 5 lakhs.

(20) Estimates of one or two polyhouses of 20 m long and 10 m wide with exhaust fans should be provided.

(21) Depending upon the size of Biodiversity Parks, atleast 6-9 security staff will be required. The budget for engaging security staff should be provided.

(22) The duration of the project should be initially for 5 years.

(23) The DPRs should also include annual Operational and Maintenance (O&M) costs.

5.8 Source of Funding for Development of Biodiversity Parks in Riverscapes

The implementation of DPR of the Biodiversity Park depends upon the funds available. The major source of funding for development of Biodiversity Parks in riverscapes for rejuvenation of rivers should be from the National Mission on Clean Ganga (NMCG) for river Ganga and its basin which includes river Yamuna; and another primary source of funding is Ministry of Environment, Forest and Climate Change, Government of India. The other sources of funding for development of Biodiversity Parks in riverscapes for rejuvenation of rivers include:

> (i) Smart City Funds; (ii) Municipal Corporation; (iii) Village Panchayat; (iv) State Irrigation Department; (v) State Tourism Department; (vi) State Pollution Control Board; (vii) CSIR grants from PSUs and Public Sector Banks; (viii) Public and Private Sector Corporations; (ix) world bank and UNDP; (x) donations from individuals/ charitable trusts; (xi) International Agencies; (xii) Ministry of Housing and Urban Affairs, Government of India; (xiii) Departments of Urban Planning of State Governments; and (xiv) Minsitry of Jal Shakti, Government of India.

5.9 Management and Sustenance of Biodiversity Parks in Riverscapes

Riverscapes are dynamic systems and hence development, management and sustenance of river ecosystems require expertise, and continuous monitoring is a necessity. It is also important to document the lessons learned from the establishment of Biodiversity Parks.

About 4 scientists, 3 supervisors and 20 MTS are essential for the development of Biodiversity Parks in riverscapes. Atleast 6-9 security staffs are required. One Administrative Officer-cum-Accountant, one Office Attendant and one Documentation Officer are also needed.

An officer at the rank of Executive Engineer of Irrigation Department of the area or Divisional Forest Officer of the concerned Forest Division of the State Forest Department or a Special Officer on duty of the Municipal Corporation of the neighbouring town or urban centre should be the Incharge of the Biodiversity Park, and he/she will be responsible for the development and management of Biodiversity Parks. All the staff working in the Biodiversity Park will be reporting to him /her. A Technical Advisory Committee may be constituted with locally available experts (University/ College, BSI and ZSI) for providing technical help from time to time during the development of Biodiversity Parks.

Since the rivers and drains are under the control of State Irrigation Department, the management of Biodiversity Parks should be entrusted to state Irrigation department. Alternatively, the upland areas are mostly forest areas and belong to State Forest Department which has fairly large resources, and hence the state forest department jointly with Irrigation department should manage the Biodiversity Parks.

The State Pollution Control Boards (SPCBs) and CPCB should also be involved, as the Biodiversity Parks have role in improving the water quality and also in situ remediation of sewage that enters into rivers besides cleaning of river water through treatment wetlands.

A management committee consisting of senior representatives of Irrigation Department (Chief Engineer), Forest Department (Conservator of Forest of the concerned Division), Department of Fisheries (senior officer), Department of Tourism (senior officer), State Pollution Control Board (regional officer) and representative from the Municipal Corporation/Village Panchayat should be constituted to oversee the development of Biodiversity Parks.

The Chief Engineer of the Irrigation Department or Conservator of the concerned Forest Division will be the Chairman of the committee and EE or DFO (Incharge of Biodiversity Park) will be the member secretary of the Management Committee. The committee should be empowered one and should take all the decisions on the development and management of Biodiversity Parks.

It may be noted that any institutional arrangement to manage the Biodiversity Parks should involve local communities and the stakeholders in the riverscape and landscape because community driver participatory management of Biodiversity Park will link community livelihoods with the sustenance of the Park.

Periodical appraisal of developed Biodiversity Parks should be done to ascertain their effectiveness. The management should also evolve a financial mechanism to meet the annual O&M costs.

The Guidelines may be revised after a decade, by which time the limitations if any in the present Guidelines is known.

6.0 YAMUNA BIODIVERSITY PARK AS ENVIRONMENTAL SUSTAINABILITY MODEL FOR REPLICATION IN RIVERSCAPES

The concept of Biodiversity Park was successfully implemented for the first time in the world by Delhi Development Authority (DDA) in joint collaboration with the Centre for Environmental Management of Degraded Ecosystems (University of Delhi). DDA has notified so far 7 Biodiversity Parks (the Yamuna, the Aravalli, the Neela Hauz, the Tilpath Valley, the Northern (Kamla nehru) Ridge, Tughalaqabad and South Delhi Biodiversity Parks, besides the recent order for setting up of Riverfront Biodiversity Parks by DDA. Of these 7 Biodiversity Parks, the Yamuna and Aravalli Biodiversity Parks are fully functional and have become Nature Reserves of Delhi. Both the Biodiversity Parks have become global models for conservation of natural heritage and environmental sustainability. The Yamuna Biodiversity Park model is an appropriate model for replication in the floodplains of the rivers across India for rejuvenation of rivers.

6.1 Yamuna Biodiversity Park

The Yamuna Biodiversity Park is located over an area of 457 acres in the upstream of Wazirabad reservoir across Yamuna, and has inactive and active floodplains. The Biodiversity Park includes wetlands, marshes, flat active flood plains, salt bushlands, and elevated inactive flood plains. These different landscapes are interconnected by trails and support some 1200 species of plants that thrive in 30-35 communities and have three trophic levels including secondary carnivore (Leopard). The visitor area has several different landscape elements.

The Yamuna Biodiversity Park has two zones – the Nature Conservation Zone and the Visitors Zone.

6.2 Nature Conservation Zone

The Nature Conservation zone has forest communities interspersed with wetlands and grasslands on the elevated inactive floodplains which never receive floodwaters due to marginal bund.

There are altogether 25-30 forest communities, some of which are given below:

(i) *Mitragyna* dominated community

(ii) *Terminalia chebula* dominated community

(iii) *Adina* dominated community

(iv) *Acacia catechu* dominated community

(v) *Holoptelia* dominated community

(vi) Teak dominated community

(vii) *Terminalia tomentosa* dominated community

(viii) *Acacia nilotica* dominated community

(ix) *Dalbergia sisso* dominated community

(x) *D. lanceolata* dominated community

(xi) *Albizia* dominated community

(xii) *A. lebbeck* dominated community

(xiii) *Cordia* dominated community

(xiv) Jamun dominated community

(xv) Amla dominated community

(xvi) Grasslands (that include short, intermediate and tall grasslands)

(xvii) Mixed deciduous forest

(xviii) Wetland ecosystems (wetlands are fully functional and biologically rich and attract 1000s of migratory birds during winter months).

These communities have diversified food web and three trophic levels. These riverine forest communities provide a wide range of ecological services and harbour rich wildlife.

These diversified river ecosystems have been: (a) buffering ambient temperature, (b) preventing evaporation by keeping the air cool, (c) providing detritus (organic matter) to the biota that live in the river water and purify the water more effectively than RO plants, (d) preventing erosion/ gully formation on the floodplains, (e) enhancing recharging potential of the floodplains, (f) serving as filter for both point and non point source air pollution, (g) acting as shelter belt, (h) reducing the flood water velocity that ensures protection of infrastructure and communities in the downstream, and (i) harbouring rich wildlife having three trophic levels.

The wetlands are alone storing flood water of several million gallons annually, recharging ground water and even providing lateral flow to the river during lean period, clean waste water if it enters into the river system through storm drains. The wetlands are also serving as habitat for a wide range of animal species that form a rich trophic structure. These wetlands have been attracting 1000s migratory birds during winter months (Figure 30 to 33).

Figure 30: Wetland of Yamuna Biodiversity Park Phase-I.

Figure 31: Floodplain wetland of Yamuna Biodiversity Park Phase-II.

Figure 32: Floodplain wetland showing impounded flood water.

Figure 33: Floodplain wetland showing aquatic vegetation.

6.3 Visitors Zone

The purpose of Visitor Zone in the Biodiversity Park is to connect rivers to the people by walk through different river ecosystems and make them familiar with the services rendered by biodiversity to the people and the city. A butterfly Garden (Figure 34), a herbal garden (Figure 35), representative river ecosystems (Figure 36), a small ponds showing characteristic aquatic fauna and flora (Figure 37), threatened plants conservatory, amphitheatre, a Nature Interpretation Centre, a field gene bank, and a fruit yielding plant conservatory (Figure 40) and recreational park were developed on the inactive flood plain. About 0.2 million students visit the visitors zone every year as a part of environmental education curriculum. Several 100s of visitors from India and outside India visit the Park every year. Many Judges from different countries also visit the Park. A greenway with walkways and cycleway was also developed.

Figure 34: Butterfly Garden at Yamuna Biodiversity Park.

Figure 35: Herbal Garden at Yamuna Biodiversity Park.

Figure 36: Overview of river ecosystems at Yamuna Biodiversity Park.

Figure 37: Water lily pond at Yamuna Biodiversity Park Phase-I.

Figure 38: Mammals of Yamuna Biodiversity Park.

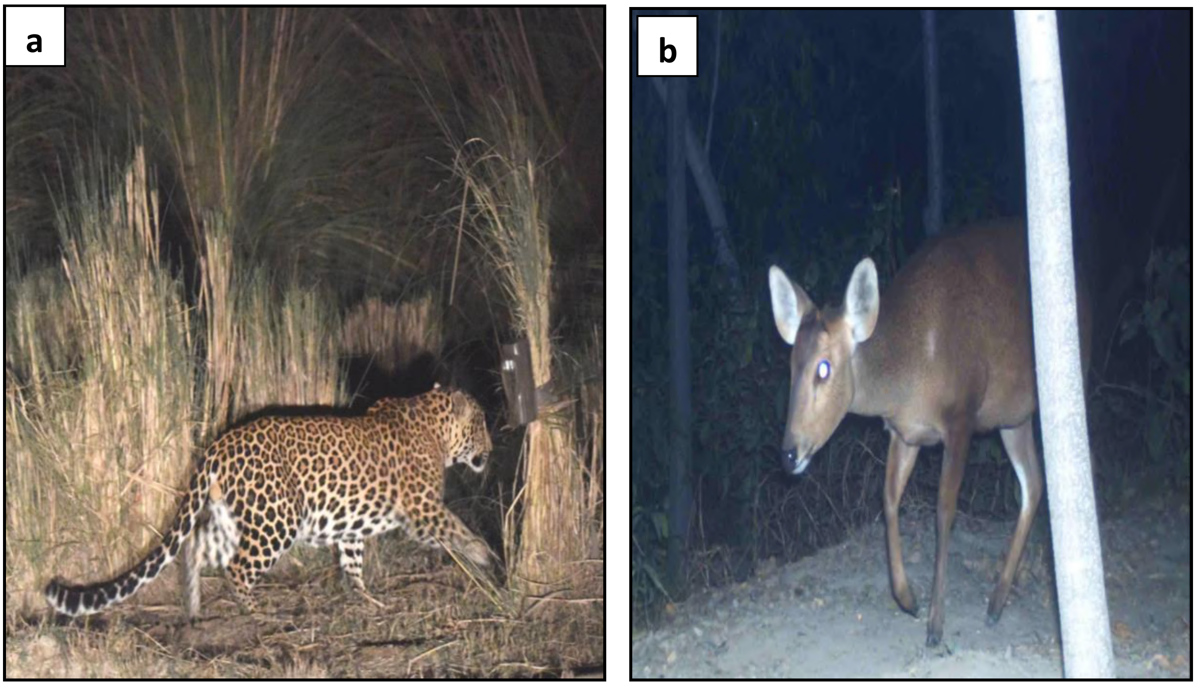

Figure 39: Carnivores (a) and Herbivores (b) in Yamuna Biodiversity Park.

Figure 40: Fruit yielding conservatory.

The model of Yamuna Biodiversity Park can be replicated along the floodplains of rivers in India. In some hilly areas and river valleys, the rivers may not have extensive floodplains, and for such river stretches, the Biodiversity Parks can be developed in the riparian zone, embankments and outside embankments and even in catchments and watersheds located close to the rivers.

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