BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
EASTERN ZONAL BENCH, KOLKATA
IN
O.A. NO. 20/2022/EZ

IN THE MATTER OF:

SUPROVA PRASAD **...APPLICANT**

VERSUS

MINISTRY OF ENVIRONMENT FOREST & CLIMATE CHANGE & ORS.
...RESPONDENTS

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Mrinal Kanti Biswas
Regional Director
CPCB, RD, Kolkata

Filed Through Counsel

Chittaranjan Ghosh
High Court Calcutta
REGN NO. [illegible]
Expiry Date 31.12.23

Dated: 18/08/2022
Place: Kolkata

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AFFIDAVIT ON BEHALF OF THE RESPONDENT NO. 5 i.e. CENTRAL POLLUTION CONTROL BOARD

I, Mrinal Kanti Biswas, S/o Shri Saroj Biswas, aged about 41, by Religion – Hindu, by Occupation Service, having office at the Regional Directorate, Central Pollution Control Board, 1582, Rajdanga Main Road, Kolkata-700107 do hereby solemnly affirm and declare as under:

1. That I am working as the Regional Director in the Central Pollution Control Board (hereinafter referred to as 'CPCB'), Regional Directorate Kolkata and have been authorized to file the present affidavit on behalf of CPCB, Respondent No. 5 and I am well conversant with the facts of the application from the records maintained by the offices of the CPCB hence, I am competent to swear this independent response on behalf of the CPCB.

2. That I have read and understood the contents as mentioned in para 17, 18 and 19 of the Order dated 12.07.2022 passed by the Hon'ble Tribunal.

3. That the following is mentioned in para 17 of the order dated 12.07.2022 -

> *"Counsel appearing (in Virtual Mode) for Respondent No.5, Central Pollution Control Board, states that the Central Pollution Control Board does not want to file a separate counter-affidavit since they were part of the Committee constituted by the Tribunal and they adopt the report of the Committee. He further states that there are no allegations against the Central Pollution Control Board and, therefore, he has instructions not to file counter-affidavit."*

   The statement made by the Counsel for CPCB during the hearing on 12.07.2022 was not in consultation with the officers of CPCB.

   CPCB is humbly praying for unconditional apology for not submitting the Counter Affidavit earlier. However, as per the direction, CPCB is providing the status of the water quality of river Ganga at the upstream and downstream of alleged ghats, monitoring status of the relevant STPs and drains.

4. That the Hon'ble Tribunal vide order dated 16.02.2022 was pleased to constitute a committee comprising of the following members:-

   i. *A Senior Scientist from the Central Pollution Control Board, Regional Office, Kolkata;*

   ii. *A Senior Scientist from the Ministry of Water Resources, River Development and Ganga Rejuvenation;*

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iii. *Dr. Tapas Kumar Gupta, Chief Technical Advisor, West Bengal Pollution Control Board.*

It is submitted that after receiving the above mentioned order of the Hon'ble Tribunal, officer was nominated as a member of the committee to represent CPCB.

5. That accordingly, the Committee inspected the impugned ghats as per the direction of the Hon'ble Tribunal and the Report has been duly submitted by West Bengal Pollution Control Board (hereinafter referred to as 'WBPCB'), being the Nodal Agency in this matter.

6. That in connection to this, the data available on water quality of the river Hooghly (lower stretch of river Ganga) (hereinafter referred to as 'river Ganga'), drains discharging directly into river Ganga and compliance status of STP's from Dakshineshwar to Garden Reach (as the impugned 5 ghats are located within this stretch) is given below:-

   - CPCB is monitoring river water quality on fortnightly basis under National Water Quality Monitoring program (NWMP) through West Bengal Pollution Control Board (WBPCB) at two locations (1. Dakshineshwar & 2. Garden Reach), 8 STPs on quarterly basis and 19 drains discharging directly into river Ganga on half-yearly basis under Namami Gange program along with WBPCB and other state agencies (KMC & KMDA).

   - As per the NWMP data, water quality of river Ganga during 2021, the respective median values of DO, BOD and Fecal Coliform were 5.5 mg/l, 2.7 mg/l and 79000 MPN/100 ml and

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5.5 mg/l, 2.65 mg/l and 70000 MPN/100 ml at Dakshineswar and Garden Reach respectively.

- Also, the recent observation from January to June, 2022, the respective median values of DO, BOD and Fecal Coliform were 6.3 mg/l, 2.8 mg/l and 79000 MPN/100 ml and 5.65 mg/l, 2.7 mg/l and 70000 MPN/100 ml at Dakshineswar and Garden Reach respectively.
- The notified primary water quality criteria for bathing is pH-6.5-8.5, DO>5mg/l, BOD 3mg/l or less, FC 500 MPN/100 ml (desirable), 2500 MPN/100 ml (maximum permissible). The data revealed that the water quality of river Ganga at the mentioned locations are within the notified primary water quality criteria except Fecal Coliform.
- Out of 19 drains, 15 drains carry domestic and 4 drains carry both domestic and industrial effluent. The total flow and BOD load from the drains discharging into this stretch were 3254 MLD and 69 TPD respectively during post monsoon- 2021-22 and associated BOD and COD concentrations are varied from 16-402 mg/l and 20-1376 mg/l respectively.
- The water quality of 16 drains are exceeding the inland surface water discharge standards of BOD 30 mg/l and COD 250 mg/l.
- Further in compliance in the matter of Manoj Mishra Vs UoI & Ors, in OA 06/2012, a report namely **Alternative Treatment Technologies For Wastewater Treatment In Drains** was submitted by CPCB before Hon'ble NGT in Principal Bench

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which is providing various technologies available to treat the Drain water.

The said report is annexed and marked as **Annexure- I.**

- The 08 STPs namely, Bangur, Howrah, Hatisur, Haridevpur, Bagajatin, Garden Reach, Baranagar-Kamarhati and Kona are having capacity to treat 361.5 MLD of sewage, whereas, the utilization capacity is only 138 MLD.

  Also, the compliance status of the mentioned STPs is given in the following table:

Sl. No.	Name of STP	Capacity of STP (MLD)	COD	BOD	TSS	TN	TP	FC	Status as on 15.07.2022	Discharging into River
1	Baranagar Kamarhati	60	New STP is being erected; STP is under construction							Ganga
2	Bangur	52	C	C	C	NC	NC	NC	Operational	Vidyadhari
3	Garden Reach	57.5	NC	C	NC	C	NC	NC	Operational	Ganga
4	Hatisur	10	NC	NC	C	NC	NC	NC	Operational	Vidyadhari
5	BaghaJatin	15	Chlorination facility is being installed and currently STP is not in operation							Vidyadhari
6	Haridebpur	45	C	C	C	C	NC	NC	Operational	Ganga
7	Howrah	60	New STP is being erected; STP is under construction							Ganga
8	Kona	40+22	New STP is being erected; STP is under construction							Ganga

C= Compliance, NC= Non-compliance

CPCB is following up the matter with concerned agencies, responsible for operation and maintenance of the STPs, where non-compliance were observed.

A line diagram of Hooghly River showing NWMP locations, drains and STPs is annexed and marked as **Annexure-II**.

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7. It is also submitted that the National Mission for Clean Ganga (hereinafter referred to as NMCG) has prepared a **"Guidance Note for Environmentally Sensitive, Climate Adaptive and Socially Inclusive Urban Riverfront Planning and Development"** for the stakeholders including urban local bodies, service providers, project financing organization etc. who are involved in planning and / or developing any urban riverfront projects. A copy of the Guidance Note is annexed and marked as **Annexure-III**.

8. Further, in the matter OA 200/2014, a Guideline was prepared & submitted by CPCB before Hon'ble NGT namely **"Guidelines for Setting up of Biodiversity Parks in Floodplains of Rivers of India, including River Ganga"** annexed and marked as **Annexure- IV.**

9. In view of the above facts indicated in earlier paras, it is respectfully prayed that the Central Pollution Control Board shall abide by any Order or direction as the Hon'ble Tribunal may deem fit and proper.

DEPONENT

CHITTARANJAN GHOSH
Advocate cum Notary
E WB 235/2005
REGN NO.- 13801
High Court Calcutta

VERIFICATION

I, Mrinal Kanti Biswas, the above named deponent do hereby verify that, the contents of the above Counter Affidavit are true and correct to my knowledge based on official records, no part of it is false and nothing material has been concealed therefrom.

Signed and verified on this 17th Day of August, 2022 at Kolkata.

DEPONENT

Solemnly Affirmed and Declared
before me on Identification
CHITTARANJAN GHOSH
Regn. No - 13801/31.12.18
Notary

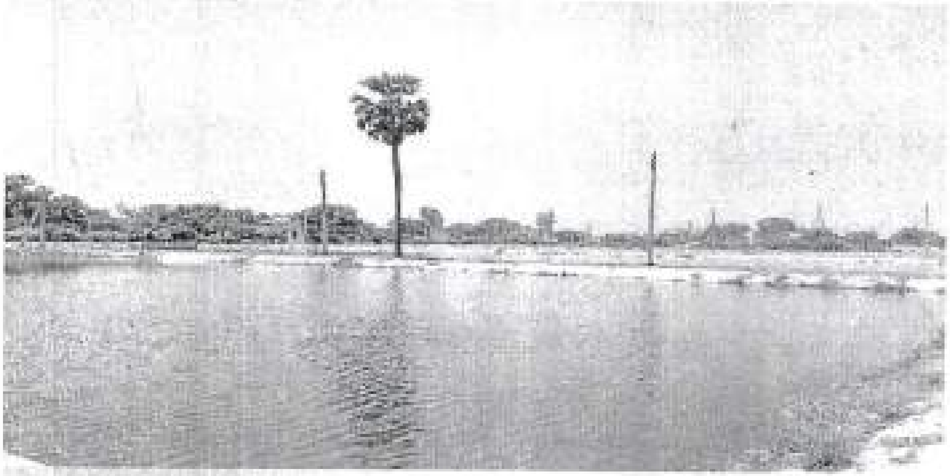
Adv

17 AUG 2022

Annexure- I

ALTERNATIVE TREATMENT TECHNOLOGIES FOR WASTEWATER TREATMENT IN DRAINS

In Compliance to Direction of Hon'ble NGT in the Matter of OA No. 06/2012
Titled Manoj Mishra Vs Union of India & ORS



NOTARY
GOVT. OF INDIA

February, 2020

CENTRAL POLLUTION CONTROL BOARD, DELHI

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LIST OF ABBREVIATIONS

BOD- Biological oxygen demand

COD – Chemical oxygen Demand

CPCB – Central Pollution Control Board

CW- Constructed wetland

DO – Dissolved oxygen

EL – Elevation

EM – Electromagnetic

ICT- Institute of Chemical Technology

IIT- Indian Institute of Technology

MLD- Million liter per day

MSL- Mean sea level

N – Nitrogen

NEERI- National Environmental Engineering Research Institute

NGT – National Green Tribunal

NH_3-N – Ammonical Nitrogen

NO_3-N – Nitrate Nitrogen

O&M - Operation & Maintenance

OL- Organic load

OLR – Organic loading rate

P- Phosphorus

PO_4-P – Phosphate

STP – Sewage Treatment plants

TERI- The Energy and Resources Institute

TSS – Total dissolved solids

V – Volume

WSP- Waste stabilization pond

REPORT ON ALTERNATIVE TREATMENT TECHNOLOGIES FOR WASTEWATER TREATMENT OF DRAINS IN COMPLIANCE TO DIRECTION OF HON'BLE NGT IN THE MATTER OF OA NO. 06/2012 TITLED MANOJ MISHRA VS UNION OF INDIA & ORS.

1. BACKGROUND

The verbatim of Hon'ble National Green Tribunal in the matter of OA No. 06 of 2012 titled; Manoj Mishra Vs Union of India & Ors. vide order dated 22.01.2020 at para 25 is as follows:

> *"Since the above report does not mention the generic and representative models which could be customised, adapted and adopted to the natural scenario including the drains in question, let CPCB furnish such a report containing at least ten generic and representative models which are techno-economically feasible and can be implemented after customization to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in.*
>
> *CPCB furnish a report in terms of Para 25 above to the YMC by 07.02.2020 and the YMC may include the report with its comments in its report to be submitted to this Tribunal before the next date by e-mail at judicial-ngt@gov.in."*

A meeting was convened on 27.01.2020 to consult experts including representatives from NEERI, TERI, Delhi University and other stakeholders. During the meeting, apart from in-situ remediation, low cost decentralised treatment systems (waste stabilization pond, oxidation pond, anaerobic lagoon) were also discussed, which can be adopted as ex-situ treatment. Another meeting was convened on 29.01.2020 wherein consultation was held with experts from IIT-Roorkee, IIT-BHU and ICT - Mumbai.

2. ADVANTAGES AND ECOLOGICAL SERVICES OF ALTERNATIVE BIOLOGICAL TREATMENT TECHNOLOGY

In situ treatment methods such as constructed wetland system, phytoremediation, Eco Bio Block system, microbial bio remediation are most favorable methods for alternative biological treatment technology of drains. Although above treatment systems are temporary provision but it may be adopted for further polishing of STP effluent. Alternative biological treatment technologies are not only useful in improving water quality of drains / rivers but are also helpful in rejuvenation of the ecology of a river system. Benefits of alternative biological treatment technologies are highlighted below:

- Alternative biological treatment technology methods such as phytoremediation or wetland systems are efficient in terms of nutrient removal such as removal of nitrogen and phosphorous.

- All alternative biological treatment technologies are low in energy incentive and not only reduces carbon footprint thereby minimizing climate change impact but also contributes to carbon sequestration.

- Constructed Wetlands have highest microbial diversity that will biodegrade not only organic but all emergent pollutants including odor producing substances & gases, antibiotic, detergent, pharmaceutical products, etc.

- The technologies provide benefits like increase in the biodiversity and biomass production apart from habitat conservation.

- Constructed Wetlands may attract migratory birds, as well as provide aesthetic and recreational services to the public.

- Studies indicate that there is massive reduction in pathogenic microbes in alternative biological treatment technology as compared to conventional treatment.

- In-situ remediation technique does not require much energy, its maintenance cost is relatively low, it is easy to develop, operate and manage as compared to conventional technology. Besides high reduction efficiency of BOD, different alternative treatment technologies are efficient in increasing Dissolve Oxygen (DO) and reducing Fecal Coliform (FC) e.g. Phytoremediation technique can reduce FC by 50% and increase DO from 0 to 5 mg/l; Oxidation Pond can reduce FC by more than 95% and increase DO from 0 to 5mg/l; similarly, lagoons are efficient in reduction of FC by 50-70%.

- The cost of alternative biological treatment technology is extremely low.

- In-situ remediation is more efficient in restoring self-purification system of river and also immobilization of heavy metals.

- Constructed wetlands contribute to groundwater recharge as well as results in buffering of ambient temperature and odor.

3. WATERSHED PATTERN – STREAM ORDER

Based on the drainage pattern, all drains traverse towards recipient water body located downstream of drains. Drains which directly discharge into recipient water bodies such as rivers, rivulets, ponds, lakes etc. are called as first order drain. Drains which join into first order drain are called as second order drains. Similarly, third and fourth order drains could be defined. The first and second order drains which confluence directly with River system are relatively larger with continuous flow.

Generally, drain emerging from urban centers/ rural habitats are third or fourth order drains which confluence into larger second or first order drains finally meeting into river/ pond/lakes.

Third and fourth order drains are rather narrow, very shallow, located at higher gradient, usually shorter in length and often covered / or passed beneath roads. Similarly, due to unplanned growth, untreated sewage/ industrial discharge into such drains, which ultimately meets first and second order drain (Figure – 1).

This sort of order of drain is defined as classic stream order, also called Hack's stream order. Drains usually carry wastewater from Urban/Rural centers called domestic sewage or effluent from Industrial activities and surface runoff including agricultural runoff.

Therefore, drains could be broadly categorized as sewage drains carrying only sewage and mixed drains carrying sewage and industrial effluent.

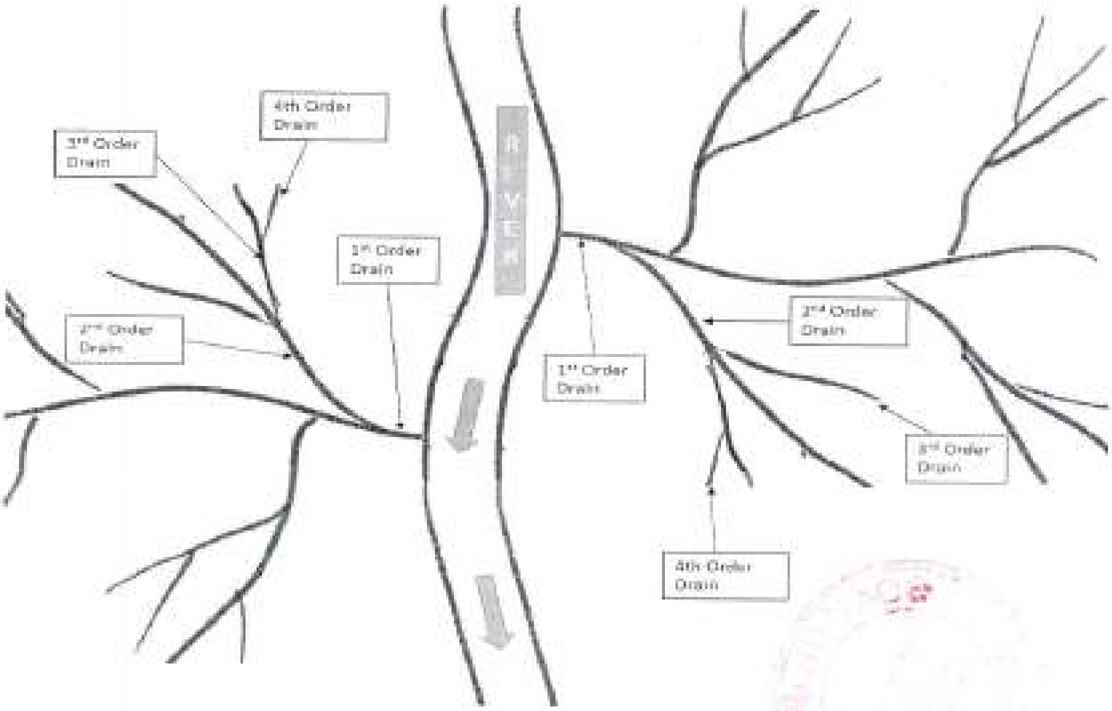

Figure 1 Drainage pattern of any city/town

Based on drain data available for River Ganga and its tributaries, categorization of drains has been made considering their hydrological characteristics namely, flow, pollution load and physical characteristics, which may influence selection of drain wastewater treatment technology.

Flow – Based on flow drain can be classified as,

- <20MLD – Minor Drain
- 20 – 50 MLD – Medium Drain
- >50 MLD – Major Drain

Pollution Load – Based on pollution load in terms of BOD concentration, drains can be classified as,

- <50 mg/l – Low Pollution Load
- 50-100 mg/l – Modern Pollution Load
- >100 mg/l – High Pollution Load

Width – Based on channel width, drains can be classified as,

- <3m – Narrow Drain
- 3 – 15m – Wide Drain
- >15m – Broad Drain

Drain could also be characterized based on the criteria such as drain traversing through hilly terrain, rocky terrain, plain, marshy area and draining into different recipient water body like river, lakes, pond and sea.

4. ALTERNATIVE TREATMENT TECHNOLOGIES

4.1 IN-SITU BIOREMEDIATION TECHNIQUES

In-Situ bioremediation techniques involve treatment at the site using aquatic plants and/or microbial remediation methods. *In-Situ* treatment systems can be commissioned in lower time duration (few months only), is easy to operate, and requires less energy as compared to conventional treatment technologies. *In-situ* treatment, depending on effluent characteristics, site conditions, and type of treatment systems, may either provide desired quality of treated effluent or act as supplementary to conventional treatment technologies. In any case, wherever feasible, it can be used as an interim remedial measure and help in reducing pollution load or polishing of treated effluent from Sewage Treatment Plants. The common *in-situ* treatment systems are Microbial Bioremediation, Phytoremediation, Constructed Wetland System and Root Zone Treatment. Adequate space and appropriate flow are general requirements for adoption of these technologies. Details of above mentioned *In-situ* bioremediation techniques indicating methodology, parameters for the feasibility assessment, existing experiences, etc. are as follow:

4.1.1 Phytoremediation

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. Phytoremediation involves the removal of organic compounds and nutrients from wastewater through bio-sorption/uptake by pollution-tolerant aquatic plants (such as algae, water hyacinth, duckweeds, etc.) growing in the wastewater. Quite often such plants grow along the littoral zones on either side of the drain.

4.1.2 Constructed Wetlands (CWs)

CWS also uses principle of Phytoremediation techniques. It integrates microbial bioremediation, phytoremediation and root-zone treatment in addition to providing the benefits of oxidation pond and physical filters.

Constructed wetlands (CWs) are scientifically proven and widely adopted across the world as alternative and complementary technology to conventional technologies for sewage treatment. A well-designed constructed wetland system will work on the same principle as that of STP but with greater microbial diversity associated with diverse plant species that effectively biodegrade organics and other pollutants in sewage and without energy.

A constructed wetland is highly versatile and can be designed for drains that have different topography hydraulics and physical characteristics of the drain (width, length, height). A constructed wetland system can be used as primary/ secondary/ tertiary treatment and with continuous flow. Figure 2 depicts schematic flow diagram of a Constructed Wetland System.

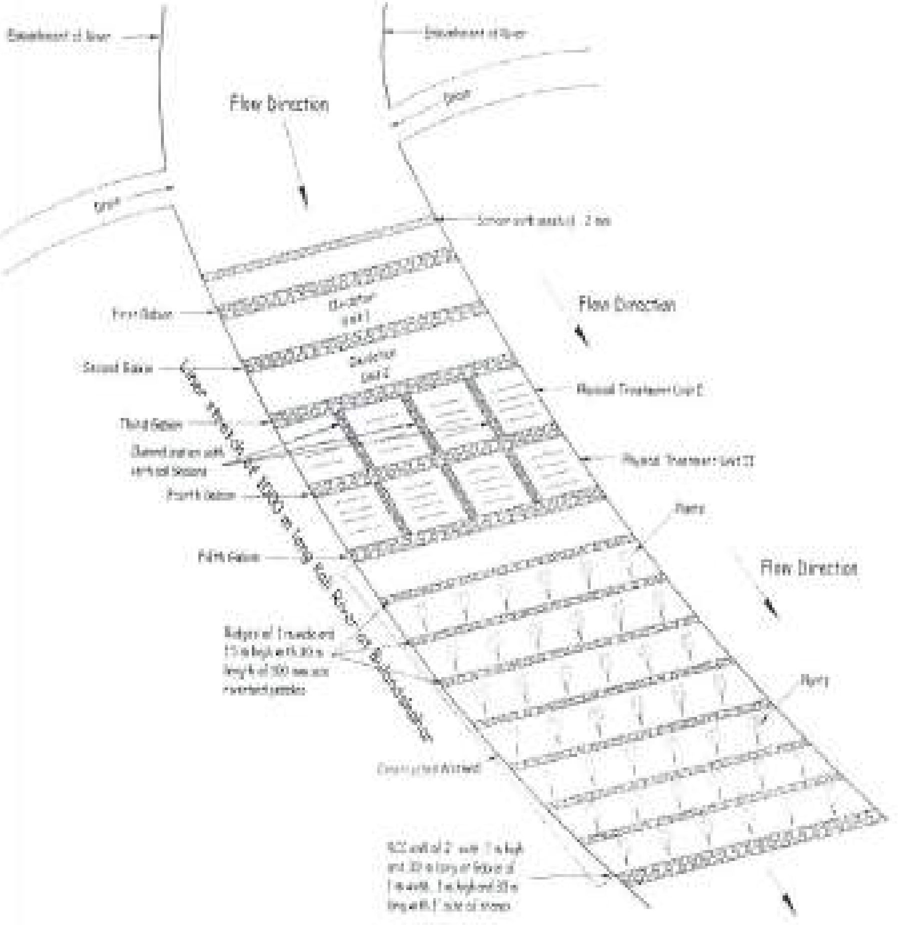

Figure 2 Schematic Diagram of Constructed Wetland Systems

A typical CW system should have the following components:

i. An aerobic oxidation pond with depth of water ranging from < 1m to 5m; water may be retained for at least 8-10 hours and consequently there may be slight rise in the water level (up to 30cm) from the normal water level in the drain.

(a) there may be a screen (iron mash having 4-10 mm aperture) before the oxidation pond to remove solid waste and another screen (2-4 mm aperture) before water enters into two physical filter tanks / chambers/ zones/ channels from oxidation pond.

ii. Three physical filter tanks/ chambers/ channels/ zones are ideal for efficient functioning; the physical filter chambers are separated by gabions of boulders of different sizes and embedded in iron mesh.
   (a) the first chamber/ channel/ zone is separated from the second chamber by a gabion made of boulders of 2' within the chamber channel and there will be 3 ridges made of stones/ pebbles of 200 to 250 mm.
   (b) The second chamber is separated from third chamber by a gabion made of boulders of 1' size with 3-4 ridges of pebbles of 180 mm.
   (c) The third chamber is separated from the constructed wetland by gabion made of boulders of 1' size with 3 to 4 ridges of river bed pebbles of 150 -120 mm.

iii. Constructed wetland having 5-10 furrows of 1 to 4 m width separated by ridges of 1 m high, 0.5m wide and composed of river bed pebbles of 80-50 mm size.

iv. Cascade outlet is made of boulders, stones and pebbles with gentle slope from the overflow of the constructed wetlands. Water coming out from the cascade can be recycled /stored in stagnant water bodies / wetland or channelized into the downstream of the drain or river.

Note:

i. The height of gabions should be 1.0 m 1.5 m high and usually above the water level in the channels/ chambers/ ponds/ zones.

ii. The typical CW system outlined above is for in situ biological remediation where the sides of the chambers/ ponds/ channels / zones are the embankments of the drains.

iii. For ex-situ biological remediation, the four sides of chambers/ponds/ tanks should be made of stone meshed walls of 1.5 -2 m high and 0.5 m – 1 m wide and all the components should be contiguous with gradient so that water flows on its own. If a gradient does not exist, a gradient channel has to be constructed.

4.1.3 Microbial Bioremediation

Microbial bioremediation involves periodic or continuous dosing of special waste-treating microbes, fungi and /or plants and their products (such as enzymes) in adequate quantity to the wastewater mass. The effectiveness of bioremediation depends on both the wastewater characteristics, the microorganisms and products that are used for dosing, the dosing amount, frequency of dosing and the environmental conditions.

Microbial bioremediation could be intrinsic (within the drain using natural consortia of microorganisms) or in vitro (using an engineered treatment system).

Microorganisms are used to treat mainly the organic matter; small quantity of inorganic materials and metals are also consumed as nutrients. Direct use of enzymes is done in biochemical treatment. It may be noted that aerobic microbes need less time, whereas anaerobic microbes need more time to degrade the waste.

Flow and retention time: This type of bioremediation requires retention time of 20 -30 hours, therefore may be suitable for drains with low flow.

Output of the process could vary where flow rates are variable and high, which could partly be due to rapid wash out of the material dosed from drains during high flow pulses. Drains often need interventions to slow down the flow rates. Also, the process being inherently slow will achieve good performance in larger span of time.

Domestic wastewater also gets mixed with the effluents from industries which invariably carry inorganic pollutants thereby impacting the microbial load. While there have been claims of successful treatment of municipal wastewater by bioremediation with various microorganisms and inoculums, these claims require reverification for a sustained period.

The system requires a kind of bio-reactor to meet the retention time and as such it requires a large area /stretch to provide the requisite retention time and the microbial diversity is limited and is composed of consortia of known microbes. There is recurring cost for maintaining microbial consortia as bio-media has to be added in running stream at regular intervals.

Further, the successful use of this bioremediation technique for in-situ treatment of wastewater-carrying drains, would necessitate periodic removal of bio-sludge generated over time from the drains to avoid choking of the drains and/or addition of pollution load on the receiving water body by transporting the sludge generated.

There is a requirement for well-defined specifications in case of this type of bioremediation since the microbial composition and doses are usually trade secrets and claims are unverifiable and comparable.

Current application of microbial bioremediation carried out by NMCG in 144 drains depicts better results in drains having flow less than 10 MLD. Therefore, such intervention can be applied in low hydraulic load and its expected outcome shall be within 50 %.

4.2 Ex-Situ Remediation Techniques

Ex-situ remediation technique includes constructed wetland, waste stabilization pond, aerated lagoon and oxidation pond. Design and performance details are attached as Annexure-I. Details of ex-situ techniques are given below:

4.2.1 Waste stabilization pond

Waste or Wastewater Stabilization Ponds (WSPs) are large, man-made water bodies in which Blackwater, greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds,

(1) anaerobic,
(2) facultative and
(3) aerobic (maturation),

each with different treatment and design characteristics. WSPs are low-cost for O&M and BOD and pathogen removal is high. However, large surface areas and expert design are required. Effluent contains nutrients (e.g. N and P) and is therefore appropriate for reuse in agriculture, but not for direct discharge in surface waters.

4.2.2 Mechanically Aerated Lagoon

Mechanically aerated lagoons are earthen basins generally 2.5 to 5m deep, provided with mechanical aerators installed on floats or fixed columns. Raw sewage is fed from one end into lagoon (after screening) and it leaves from the other end after desired period of aeration. Aerated lagoons are smaller in size (less than 10-20%) compared to waste stabilization ponds. Three types of aerated lagoons can be distinguished as mentioned below:

1. **Facultative aerated Lagoons**

Facultative aerated lagoons consist of a shallow basin in which settleable solids introduced by the wastewater settle to the bottom to form a sludge layer that decomposes anaerobically. Biodegradable organic materials that do not settle are degraded aerobically. The term facultative aerated describes the aerobic-anaerobic nature of the lagoon - an anaerobic bottom region covered by an aerobic top layer. Process of oxygenation is enhanced through floating aerators in upper section of lagoon. Lower section of lagoon maintains anaerobic conditions. The power input per unit volume is only sufficient for diffusing required amount of oxygen into liquid, but not sufficient for maintaining all the solids in suspension (Figure – 3).

Consequently, some of the suspended solids entering the Lagoon and some of the new solids produced in the lagoon as a result of substrate removal tend to settle down and undergo anaerobic decomposition at the bottom. They are capable of giving 70-90% BOD removal from domestic sewage.

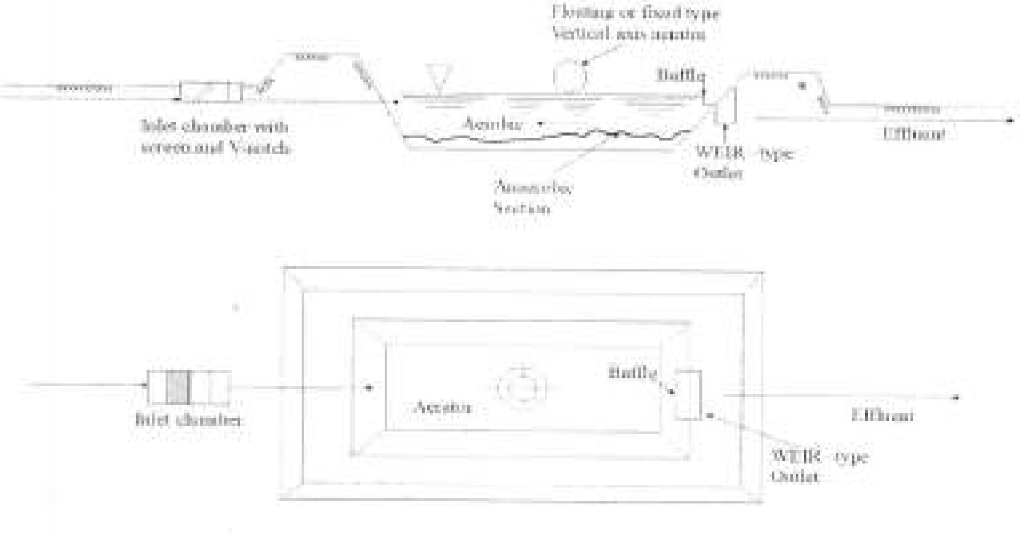

Figure 3: Mechanical aerated facultative lagoon

2. Aerobic flow-through Lagoons

Aerobic flow-through lagoons use aerators to mix the effluent in the pond and add oxygen to the wastewater. In aerobic flow through lagoons, oxygen transfer is maintained throughout the depth of the lagoon. The power level is high enough not only to diffuse adequate oxygen into the liquid but also to keep all solids in suspension as in an activated sludge aeration tank (Figure – 4). Additional treatment (such as stabilization pond) is necessary if better BOD and solid removal is desired.

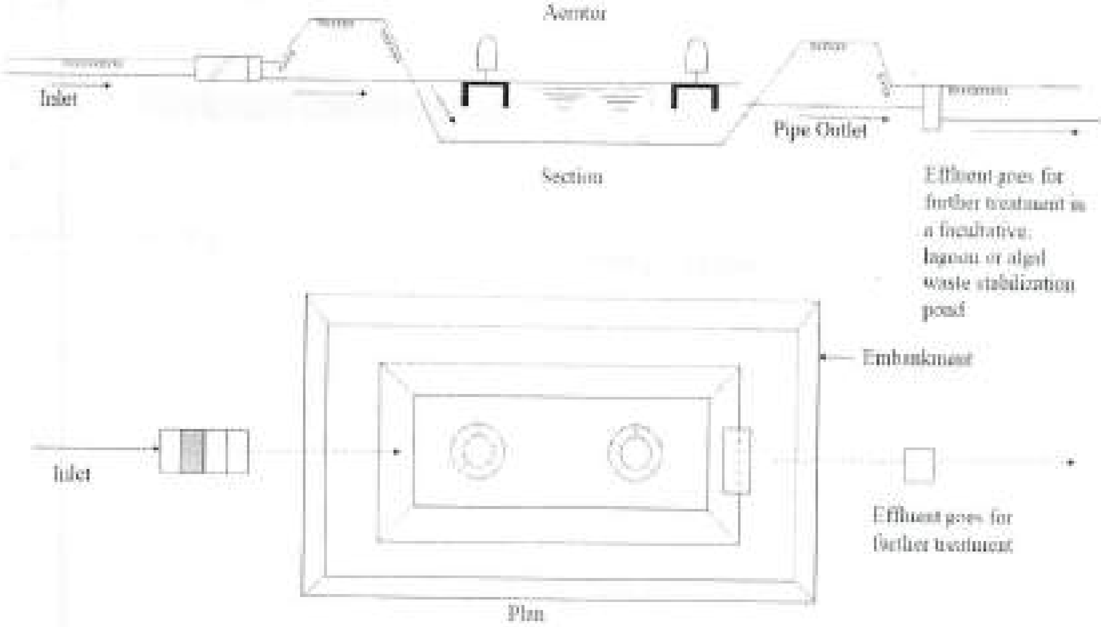

Figure 4 Mechanical aerated flow through type lagoon

3. Aerobic lagoons with recycling of solids

In aerobic lagoons, oxygenation of effluent and retention of recyclable solids is carried out. In these lagoons, power input level is sufficient to meet the oxygen requirement as well as to keep all solids in suspension. The efficiency of BOD removal in these types of lagoons can be as high as 95-98%. and nitrification can also be achieved (Figure – 5).

Figure 5: *Typical mechanical aerated lagoon system*

5. CRITERIA FOR SELECTION OF ALTERNATIVE TREATMENT TECHNOLOGIES FOR REJUVENATION OF DRAINS

The effective biological *in-situ* treatment system should need the following requirements:

i) *In situ* treatment should be different from conventional centralized or de-centralized treatment system.
ii) It should be a rapid system having commissioning time of less than six to twelve months.
iii) The *in situ* treatment system should have the ability to treat the sewage in a continuous manner throughout the year.
iv) The treatment system must have a well-defined inlet and outlet along with minimum modification in natural drain structure.
v) The treatment system should work on zero/negligible power consumption.
vi) The treatment system should have a designed life and minimum operational constraints.
vii) It should not have high capital cost and recurring cost as compared with conventional *ex situ* treatment technology currently in practice.
viii) The design life should be up to 15 years at optimum operation condition.
ix) In case of drains having flow >20 MLD, the system may be developed in modular form having 2-3 blocks of treatment within one treatment stretch.
x) The treatment system must be capable of degrading/reducing the soluble and insoluble organic materials.
xi) Removal efficiency of soluble BOD at the final designated outlet should not be less than 60% in terms of organic load reduction with treated wastewater quality at designated outlet of pH 6.5-8.5, DO ≥5mg/land BOD ≤ 20 mg/l, whichever is stringent.
xii) *In-situ* treatment shall be accompanied with pre-treatment/ physical solid liquid separation as drains carry large quantity of solid waste.
xiii) The generated sludge must be quantified and cleaned based on requirement preferentially at every 15 days within the defined stretch. If required, dredging should be done to maintain the depth.
xiv) The system must not hinder the flow and not result in ponding at the upstream site of the drain.
xv) Flow measuring device (such as V-notch, EM meter etc.) may be installed at the inlet/outlet of the treatment stretch so as to control the treatment based on flow and assessment of daily treated volume.
xvi) Treatment system shall be installed at such a location/manner and for such volume of drains that the treated effluent quality at defined outlet shall be maintained throughout the entire downstream stretch of the drain till confluence with the river. If required, treatment system could be set up in series in entire drain stretch.
xvii) Treatment system shall be set up for inlet wastewater quality of BOD≥40mg/l.

6. SCHEMES/MODELS FOR DIFFERENT ORDERS OF DRAIN

Categorization of drains are made based on the experience of drain monitoring in Ganga Catchment. Schemes/ Models defined for treatment are generic and suggestive in nature and any application of such model requires specific design as per site requirements. The land requirements mentioned are indicative and it shall be worked out as per the design criteria. Summary of different treatment schemes is shown in table 1

6.1 Model 1: Minor sewage drain with moderate pollution load & broader channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 6). In *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

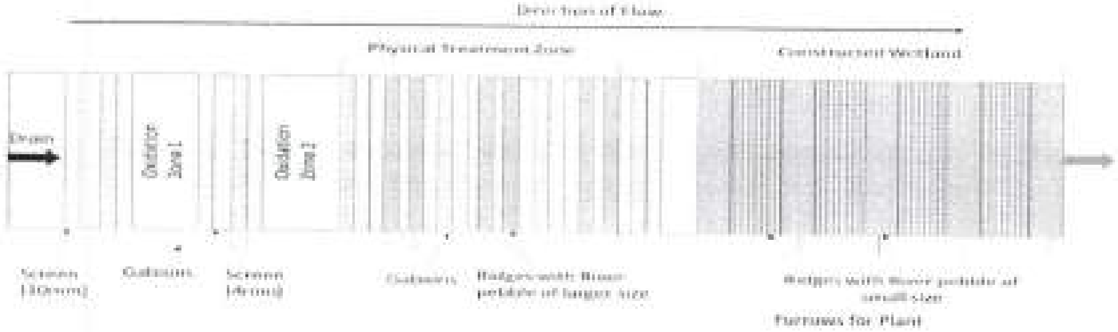

Figure 6 Schematic layout of *in-situ* Biological Remediation

6.2 Model 2: Minor sewage drain with moderate pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

  Width of Drain : 3-15 Meter

  Depth of Flowing Water : 1 - 3 Meter

- Organic Loading

  BOD : < 100 mg/l

- Hydraulic Loading

  Flow : < 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 2nd and 3rd order drains. For hilly areas, such system has to be developed in the marshy depressions/valleys. In other words, it will be developed at the confluence of the drain with depression /low lying area in the valley.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 7).

e) **Schematic diagram:**

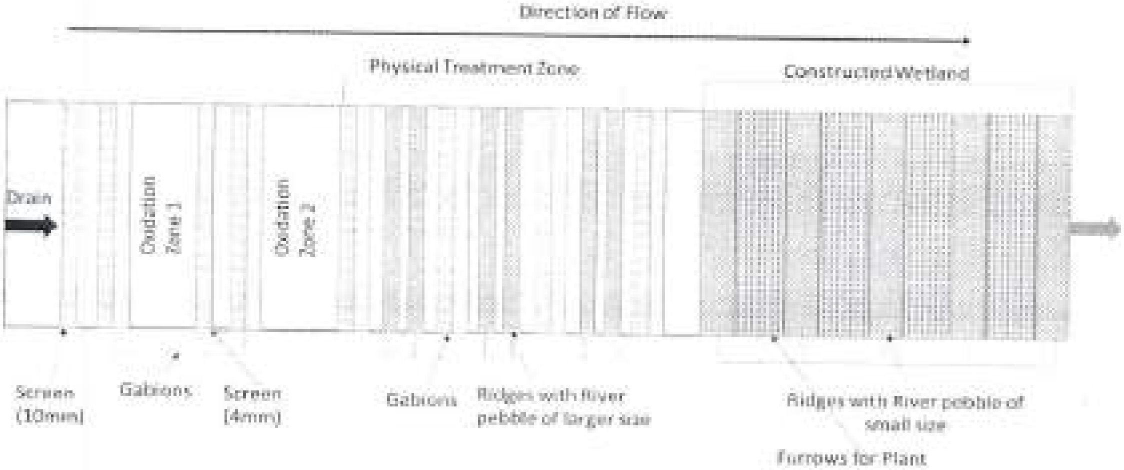

Figure 7 Schematic layout of *in-situ* Biological Remediation

6.3 Model 3: Minor sewage drain with moderate pollution load & narrow channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System

Width of Drain	:	< 3 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation ponds/ Facultative pond (1-2 no.) + Physical Treatment unit + wetland/phytoremediation or waste stabilization pond or Ex-Situ Activated Sludge Method

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with channel width of less than 3m. This type of model is suitable for 3rd or higher order drains. For hilly areas, such system has to developed in the marshy depressions/valleys. In other words, it will be developed at the confluence of the drain with depression /low lying area in the valley.

d) **Design aspect:** Due to less flow width, In- situ treatment is generally not feasible in these categories of drains. Ex situ model may be best suitable for providing sufficient hydraulic retention time in oxidation pond + wetland system or Waste Stabilization Pond as per the space available. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 8).

e) **Schematic diagram:**

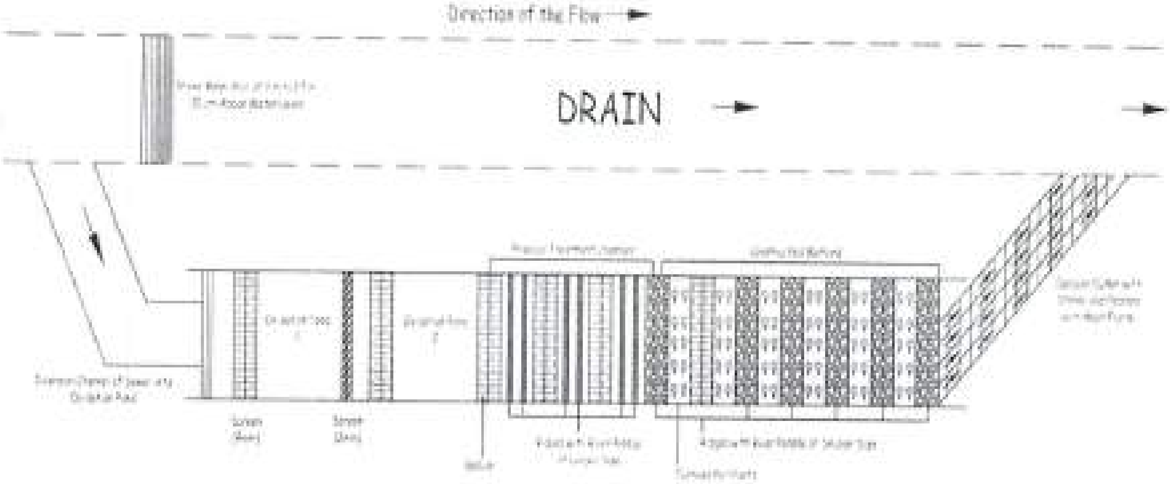

Figure 8 Schematic layout of *ex-situ* Biological Remediation

6.4 Model 4: Minor sewage drain with high pollution load &broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

  Width of Drain : > 15 Meter

  Depth of Flowing Water : 0.5 - 2 Meter

- Organic Loading

  BOD : >100 mg/l

- Hydraulic Loading

  Flow : < 20 MLD

b) **Treatment scheme:** Oxidation pond + Physical Treatment unit + constructed wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with channel width more than 15 m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 9). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

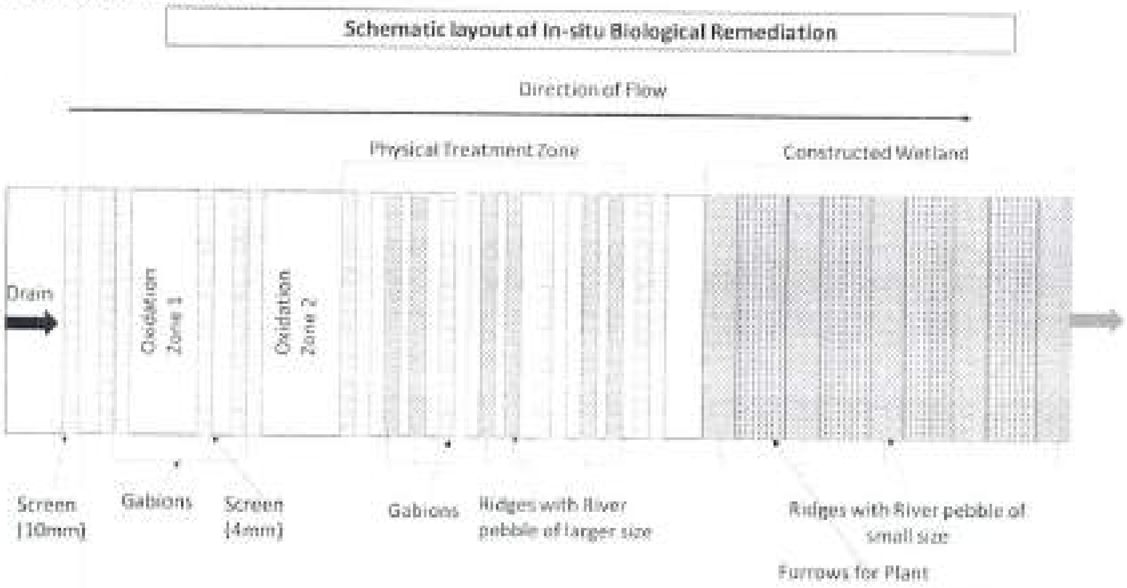

Figure 9: Schematic layout of *in-situ* Biological Remediation

6.5 Model 5: Minor sewage drain with high pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	3- 15 Meter
Depth of Flowing Water	:	0.5 - 2 Meter

- Organic Loading

BOD	:	>100 mg/l

- Hydraulic Loading

Flow	:	< 20 MLD

b) **Treatment scheme:** Oxidation pond + Physical Treatment unit + constructed wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with channel width 3-15 m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure 10).

e) **Schematic diagram:**

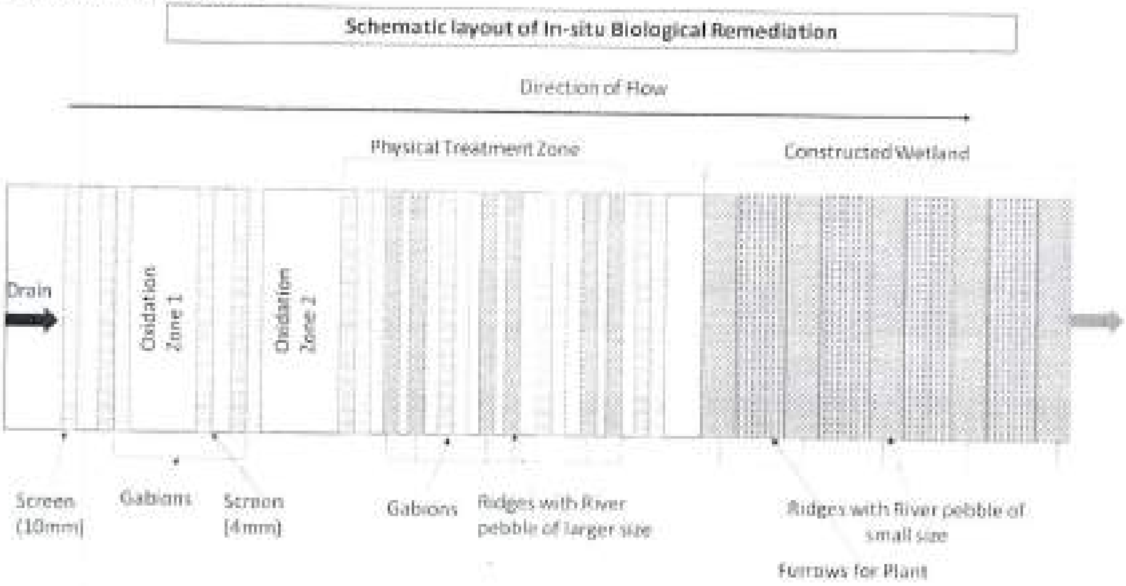

Figure 50 Schematic layout of *in-situ* Biological Remediation.

6.6 Model 6: Minor sewage drain with high pollution load& narrow channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System
  Width of Drain : < 3 Meter
  Depth of Flowing Water : 0.5 - 2 Meter
- Organic Loading
  BOD : >100 mg/l
- Hydraulic Loading
  Flow : < 20 MLD

b) **Treatment scheme:** Oxidation pond + wetland system or Waste Stabilization Pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load untreated sewage with channel width of less than 3m. This type of model is suitable for 3rd or higher order drains.

d) **Design aspect:** Due to less flow width, In- situ treatment is generally not feasible in these categories of drains. Ex situ model may be best suitable for providing sufficient hydraulic retention time in oxidation pond +wetland system or Waste Stabilization Pond as per the space available. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 11).

e) **Schematic diagram:**

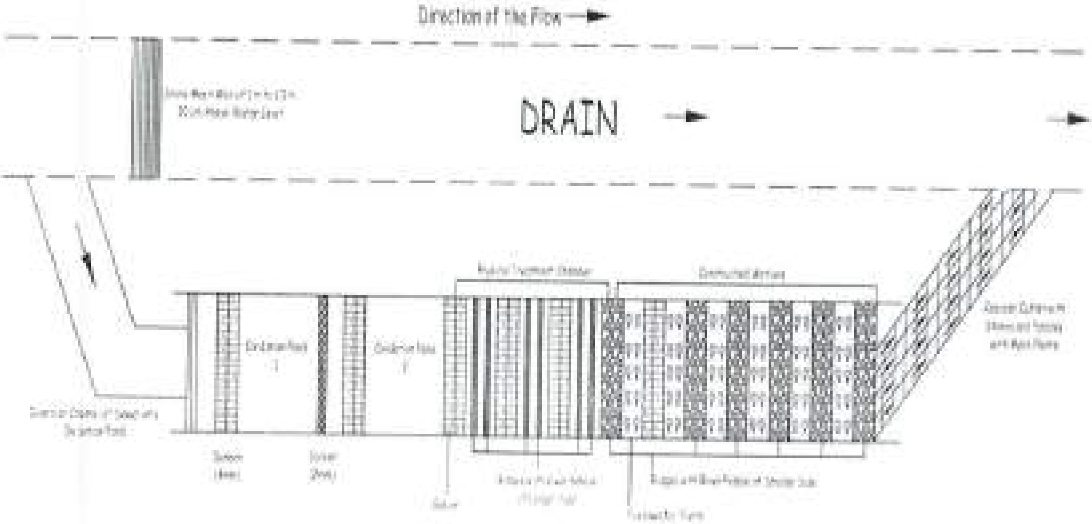

Figure 11: Schematic layout of *ex-situ* Biological Remediation.

6.7 Model 7: Medium sewage drain with low pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

  Width of Drain : > 15 Meter

  Depth of Flowing Water : 1 - 3 Meter

- Organic Loading

  BOD : < 50 mg/l

- Hydraulic Loading

  Flow : < 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 12). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

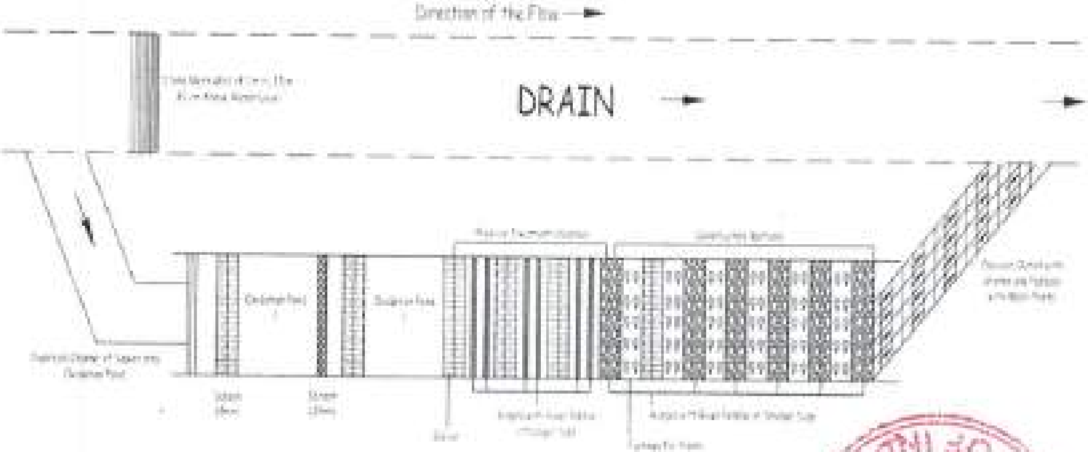

Figure 62 Schematic layout of *ex-situ* Biological Remediation

6.8 Model 8: Medium sewage drain with low pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

  Width of Drain : 3- 15 Meter

  Depth of Flowing Water : 1 - 2 Meter

- Organic Loading

  BOD : < 50 mg/l

- Hydraulic Loading

  Flow : < 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying only low pollution load untreated sewage with channel width of 3-15m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised as In-situ/ Ex-situ based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 13).

e) **Schematic diagram:**

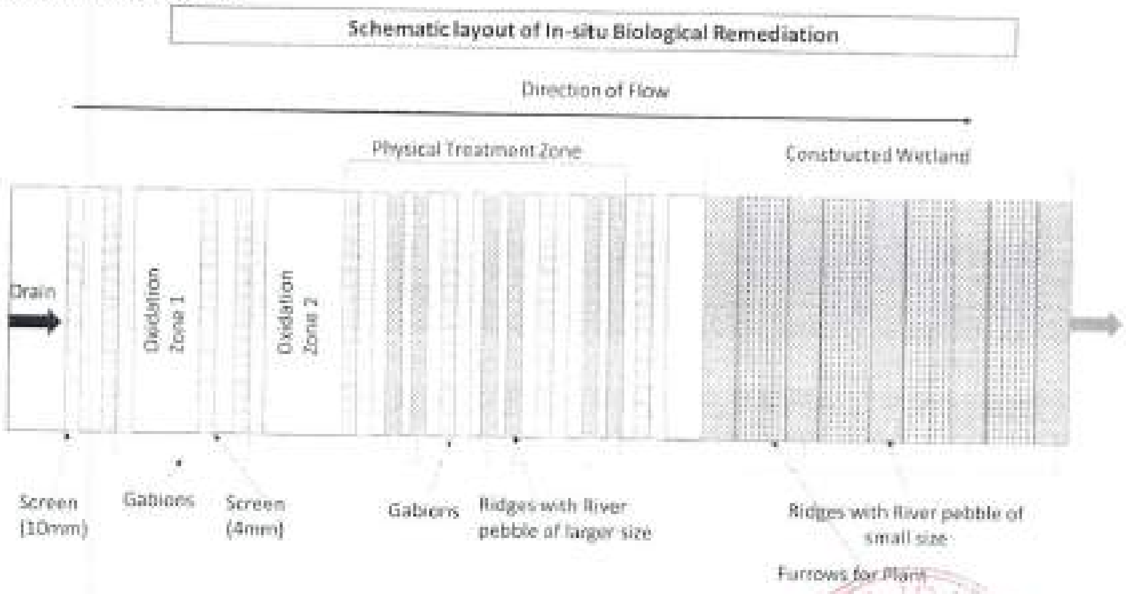

Figure 13 Schematic layout of *in-situ* Biological Remediation.

6.9 Model 9: Medium sewage drain with moderate pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load sewage with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 14). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

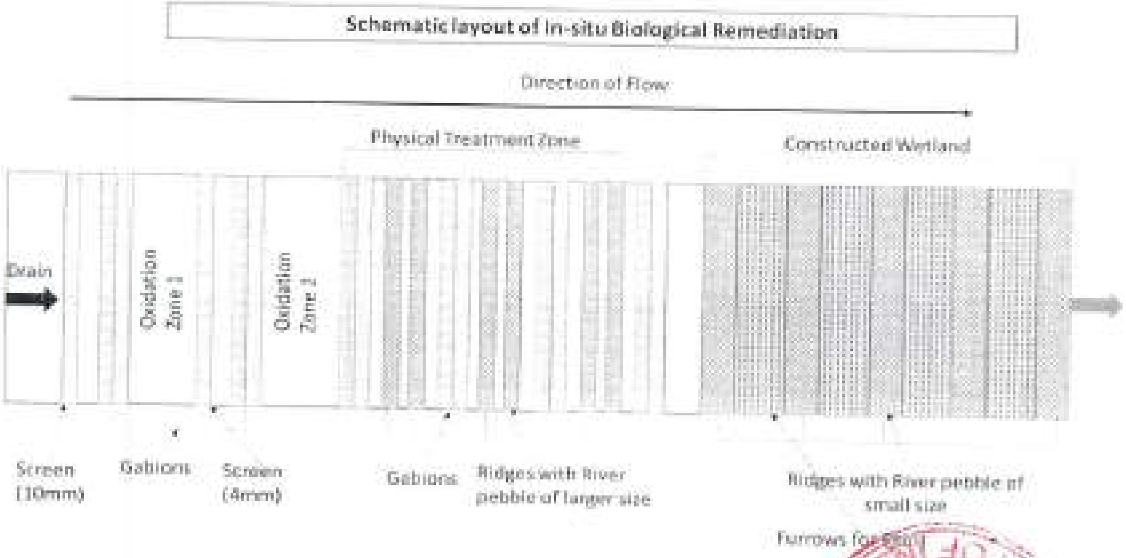

Figure 14: Schematic layout of *in-situ* Biological Remediation.

6.10 Model 10: Medium sewage drain with moderate pollution load & wide channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

  Width of Drain : 3- 15 Meter

  Depth of Flowing Water : 1 - 2 Meter

- Organic Loading

  BOD : < 100 mg/l

- Hydraulic Loading

  Flow : < 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond (2 no.) + Physical Treatment unit -2 no.) + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying moderate pollution load untreated sewage with channel width of 3-15m. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 2nd and 3rd order drain, dimensions of oxidation pond and a wetland need to be customised based on the available flow width to provide the required hydraulic time of at least 20 hr in oxidation pond and wetland system. Treatment scheme configuration may be customised as *In-situ/ Ex-situ* based on the flow width. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 15).

e) **Schematic diagram:**

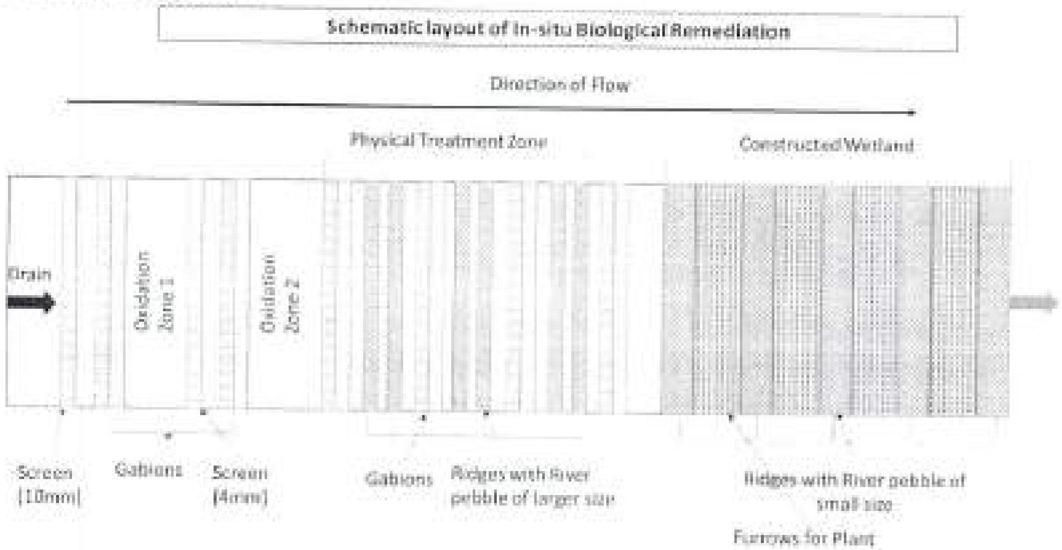

Figure 15: Schematic layout of *in-situ* Biological Remediation.

6.11 Model 11: Medium sewage drain with high pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	> 100 mg/l

- Hydraulic Loading

Flow	:	< 50 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + wetland/phytoremediation or Oxidation pond + Physical Treatment unit + Constructed wetland or waste stabilisation pond

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 16). **In** *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

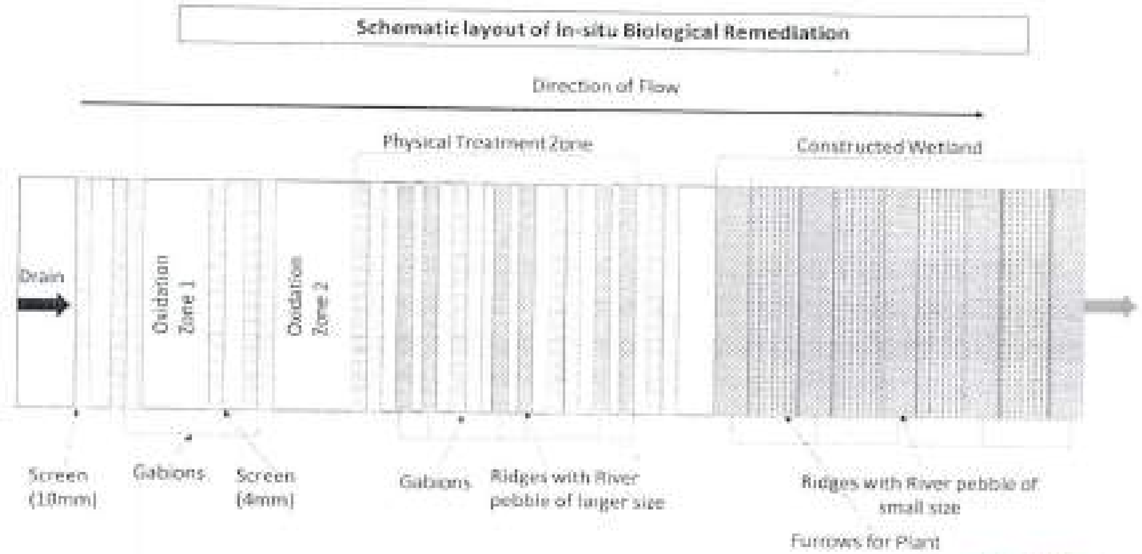

Figure 76: Schematic layout of *in-situ* Biological Remediation

6.12 Model 12: Medium sewage drain with very high pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System
  Width of Drain : > 15 Meter
  Depth of Flowing Water : 1 - 3 Meter
- Organic Loading
  BOD : > 200 mg/l
- Hydraulic Loading
  Flow : < 50 MLD

b) **Treatment scheme:** Pond with mud ball technology + Facultative ponds (1-2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond + Physical Treatment unit + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying high pollution load (untreated sewage + industrial effluent) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 17). In *in-situ* treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

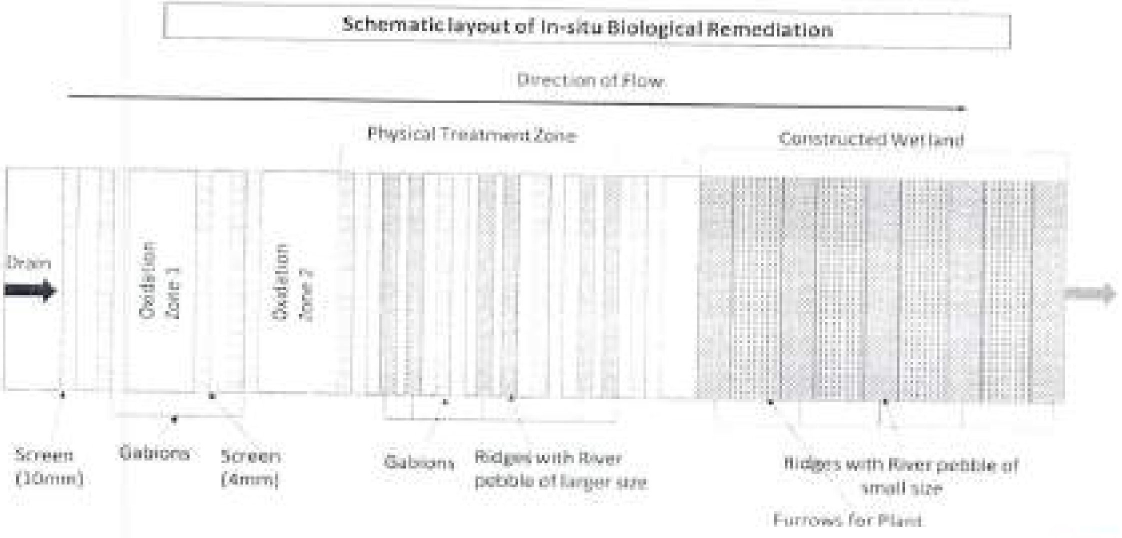

Figure 8 Schematic layout of *in-situ* Biological Remediation.

6.13 Model 13: Major sewage drain with low high pollution load & broader channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 50 mg/l

- Hydraulic Loading

Flow	:	50 -100 MLD

b) **Treatment scheme:** Facultative ponds (1-2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond + Physical Treatment unit + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying low pollution load (untreated sewage only) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 18). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

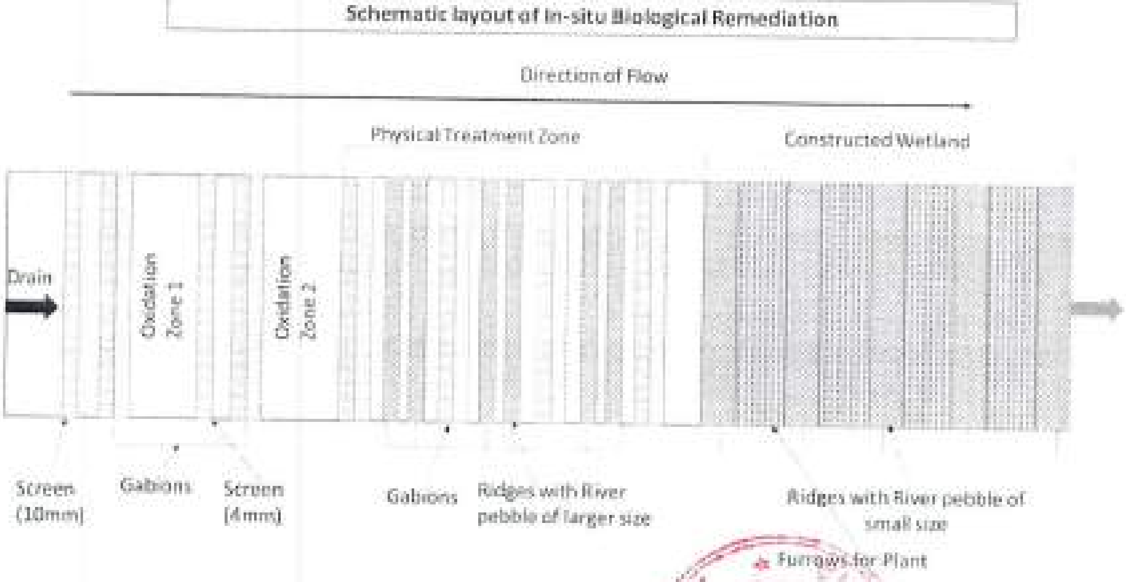

Figure 18: Schematic layout of *in-situ* Biological Remediation.

6.14 Model 14: Major sewage drain with moderate pollution load & broader channel

a) **Drain hydrological characteristics:**

- Physical Characteristics of Drainage System

Width of Drain	:	> 15 Meter
Depth of Flowing Water	:	1 - 3 Meter

- Organic Loading

BOD	:	< 100 mg/l

- Hydraulic Loading

Flow	:	50 -100 MLD

b) **Treatment scheme:** Facultative ponds (2 no.) + Lagoon + oxidation pond + Lagoon+ wetland or Oxidation pond (2 no.) + Physical Treatment unit (2 no.) + Constructed wetland

c) **Applicability:** This type of treatment scheme is suitable for drains carrying low pollution load (untreated sewage only) with wide channel suitable for in-situ construction. This type of model is suitable for 1st and 2nd order drains.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure 19). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

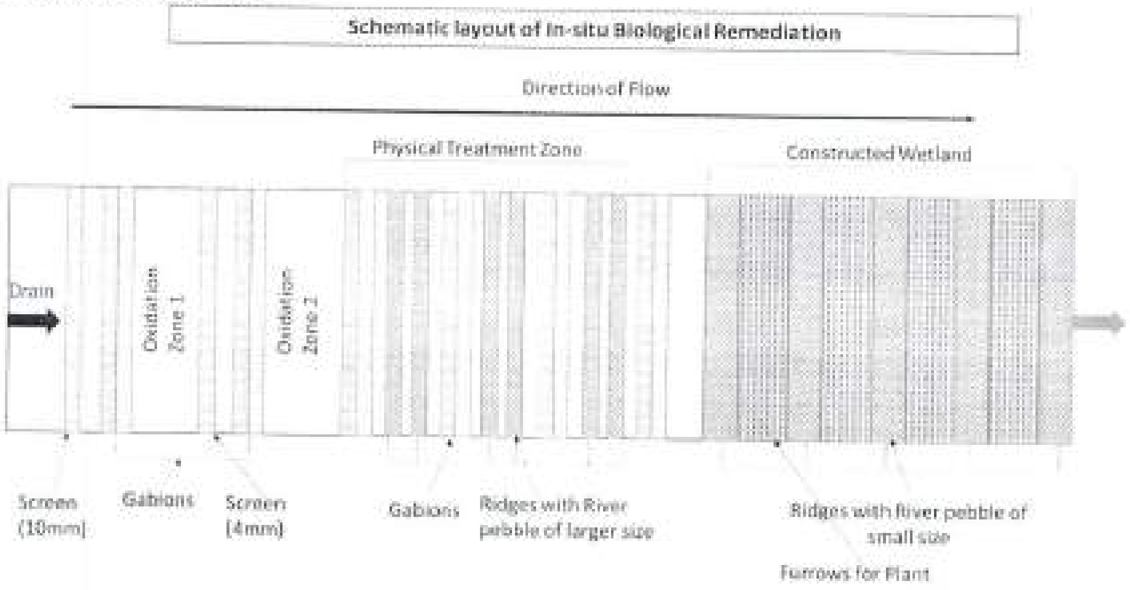

Figure 19: Schematic layout of *in-situ* Biological Remediation.

6.15 Model 15: Major sewage drain with low pollution load & broader channel

a) Drain hydrological characteristics:

- Physical Characteristics of Drainage System
  - Width of Drain : > 15 Meter
  - Depth of Flowing Water : 1 - 3 Meter
- Organic Loading
  - BOD : < 50 mg/l
- Hydraulic Loading
  - Flow : >100 MLD

b) **Treatment scheme:** Facultative ponds (2 no.) + Lagoon + oxidation pond (2 no.) + Lagoon+ wetland or Oxidation pond (2 no.) + Physical Treatment unit (2 no.) + Constructed wetland

c) **Applicability:** This type of treatment scheme can be used for biological remediation of polluted rivulets /rivers/major storm drains of cities by channelizing the drain bed up to 15 channels (distribution channels) and the CW stretch may extend up to 1000 m (1 km) and there may be more than 15 such stretches across a distance of 500 km (linear). The width of gabions should be at least more than 4m, as the river carry storm water.

d) **Design aspect:** Depending on the space availability and the flow rates of the 1st and 2nd order drain, oxidation pond, and a wetland with furrows and ridges should be developed. The ridges are made of stones/ pebbles specified in the typical model. Area and depth requirement for such system shall be worked out as per design criteria (Figure – 20). In in-situ treatment techniques, length of the drain is only variable parameter for area calculation whereas available width of drain will remain fixed. Therefore, any design for *in-situ* is dependent on length of the drain.

e) **Schematic diagram:**

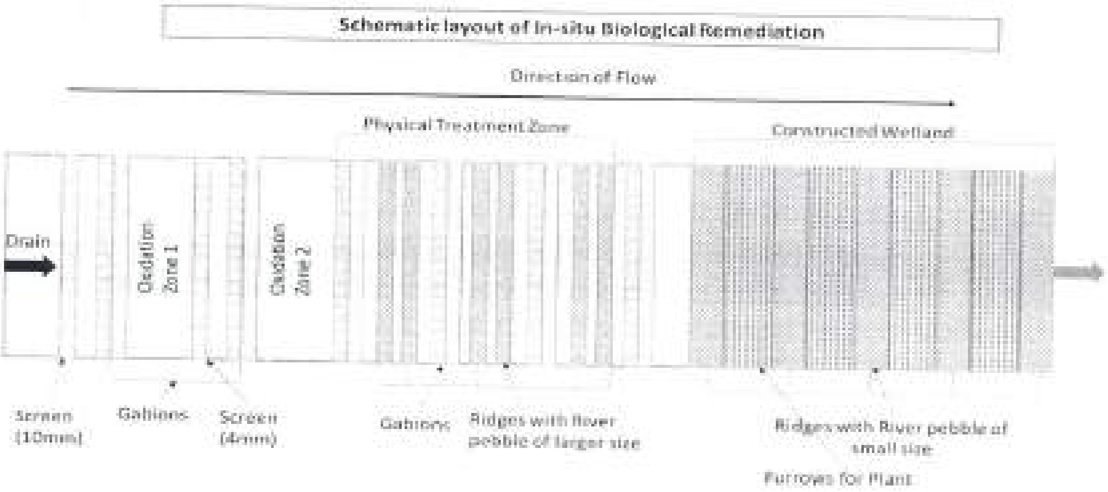

Figure 20: Schematic layout of *in-situ* Biological Remediation.

Table 1: Decision matrix for design of In-Situ / Ex-situ remediation techniques

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
1.	Minor sewage drain with moderate pollution load & broader channel	< 20	< 100	> 15	Oxidation pond/ Facultative pond+ Lagoon+ Wetland or Waste Stabilization Pond or In-situ Activated Sludge Method	In situ	Lagoon sludge removal frequency – every 3 month, ponds HRT 20 hr min.
2.	Minor sewage drain with moderate pollution load & wide channel	< 20	< 100	3-15	Oxidation pond/ Facultative pond + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Treatment unit may be in situ/ex situ as per available space
3.	Minor sewage drain with moderate pollution load & narrow channel	< 20	< 100	< 3	Oxidation pond/ Facultative pond + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Oxidation pond will be ex situ & wet land may be in situ/ ex situ
4.	Minor sewage drain with high pollution load & broader channel	< 20	> 100	> 15	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ	Sludge may be recycled partly in Facultative Trickling filler. Toxic sludge need to be disposed as per guideline

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Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
5.	Minor sewage drain with high pollution load & wide channel	< 20	> 100	3-15	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment units may be in situ/ex situ as per available space
6.	Minor sewage drain with high pollution load & narrow channel	< 20	> 100	< 3	Facultative pond/Trickling filter + Lagoon Wetland/phytoremediation or Constructed Wet Land (CWS)	In situ/ Ex situ	Pond/filter/Lagoon will be ex situ & wet land may be in situ/ ex situ
7.	Medium sewage drain with low pollution load & broader channel	< 50	< 50	> 15	Facultative pond + Lagoon + Oxidation pond +Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months
8.	Medium sewage drain with low pollution load & wide channel	< 50	< 50	3-15	Facultative pond + Lagoon + Oxidation pond +Wetland or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment unit may be in situ/ex situ as per available space
9.	Medium sewage drain with moderate pollution load & broader channel	< 50	< 100	> 15	Facultative pond + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum

Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
10.	Medium sewage drain with moderate pollution load & wide channel	< 50	< 100	3-15	Facultative pond + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ/ Ex situ	All Treatment units may be in situ/ex situ as per available space
11.	Medium sewage drain with high pollution load & broader channel	< 50	> 100	> 15	Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
12.	Medium sewage drain with very high pollution load & broader channel	< 50	> 200	> 15	Pond with mud ball technology Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
13.	Major sewage drain with low high pollution load & broader channel	50-100	< 50	> 15	Facultative pond + Oxidation pond (1-2 no.)+ Lagoon + +Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months
14.	Major sewage drain with moderate pollution load & broader channel	50-100	< 100	> 15	Facultative pond + Oxidation pond (1-2 no.)+ Lagoon + +Wetland or	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum

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Model no.	Description	Flow (MLD)	BOD Conc. (mg/l)	Drain Width (m)	Treatment Technology	Technology Type	Remarks
					Constructed Wet Land (CWS)		
15.	Major sewage drain with low pollution load & broader channel	> 100	< 50	> 15	Facultative pond (2 no.) + Lagoon + Oxidation pond (1-2 no.) + Lagoon+ Wetland or Constructed Wet Land (CWS)	In situ	Lagoon removal efficiency – 1-3 months, pond HRT 20 Hr minimum
Note: All above models are generic in nature and actual design may vary as per actual site specific requirement							

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7. CHALLENGES WITH APPLICATION OF ALTERNATIVE BIOLOGICAL TREATMENT TECHNOLOGY

- Application of any *in-situ* bioremediation of wastewater requires obstruction wall (check dam / weir) to slow down the velocity of flowing water. Any flowing wastewater in storm water drains carry huge volume of floating material (solid waste, plastic waste etc.) and silt. Such obstruction to slow down of the velocity of wastewater results in trapping of floating material and deposition of silt.
- Siltation of drains will result in ponding of wastewater in upstream of such structures that may also result in flooding of upstream areas. Therefore, provisions must be made for regular removal and proper disposal of deposited silt. Floating matter collected also need to be disposed off in scientific manner.
- Spacing between the gabions need to be cleaned on regular basis as it may get choked with silt and floating materials.
- Efficiency decrease in monsoon due to high flow.
- It needs regular harvest of biomass and cleaning of physical filters.
- Difficult to operate when depth of water in drain is more than three feet.
- Slow process as compared to conventional treatment.
- Not effective in backwater, flood water from river on high tides.

8. CASE STUDIES ON DIFFERENT ALTERNATIVE TREATMENT TECHNOLOGIES

Case studies of some of the wastewater interception, diversion and treatment facilities based on alternative treatment technologies namely constructed wetland, soil biotechnology, oxidation pond, trickling filter and aerated lagoon are as under:

8.1 Constructed Wetland

a) Constructed wetland has been established at Neela Hauz lake near Sanjay Van by Centre for Environmental Management of Degraded Ecosystems (CEMDE), Delhi University in collaboration with DDA. The lake is fed by discharge from drain having 01 MLD flow. The constructed wetland effectively results in 90% reduction in BOD and has resulted in restoration of the Neela Hauz lake which was practically dead due to high pollution load. The project was started in November, 2016 and is currently in operation; it was constructed at a cost of Rs. 10 lakhs and requires annual harvest of dead biomass and annual cleaning of physical filters and removal of sludge from oxidation ponds.

b) In-situ constructed wetland system at Rajokari water body was installed by Irrigation and Flood Control Department, Delhi with a project cost of Rs. 77.19 lakhs. The water body is fed by a drain having flow of 600 KLD. There is 84% reduction in BOD in the water body post construction of the wetland. The wetland is currently in operation.

c) Ex-situ remediation for water body rejuvenation through Phytorid technology developed by CSIR-NEERI. This project has been implemented Pan India in 300 sites and is currently in operation in all the sites. The cost of the project was Rs 2.2 crore per

MLD for civil construction and O&M of Rs 20 Lakhs per MLD (including manpower, consumables, electricity, testing, contingency and miscellaneous items). The land requirement for the project is 1500 m2 per MLD. The technology is highly efficient with BOD and TSS of treated water reduced to ≤ 10 mg/l and ≤ 30 mg/l respectively.

d) In-situ restoration of drains viable for flow between 1-10 MLD through RENEU Technology developed by CSIR-NEERI. The restoration of six drains in Jhusi, Prayagraj was undertaken through this technology while work order has been received to implement RENEU in 10 drains at Gorakhpur. For implementation of this technology, drains having 1-10 MLD require a stretch of 180-200m while for drains having flow greater than 10 MLD, the stretch required will be 200-600m. The cost of the project was Rs Rs835 Lakhs per MLD for civil construction and O&M of Rs Rs255 Lakhs per MLD (including manpower, consumables, electricity, testing, contingency and miscellaneous items). The technology demonstrates 40% reduction in pollution with BOD and TSS of treated water reduced to ≤ 30 mg/l and ≤ 30 mg/l respectively.

e) Constructed wetlands are under commissioning at Bithoor to treat 2.4 MLD sewage generated from seven drains directly discharging in River Ganga from Bithoor town. The constructed wetlands are designed for in-situ treatment of sewage. During the last visit by CPCB officials, the wetlands were found to be under construction.

8.2 Soil Biotechnology

a) In Bah Bazar STP at Devprayag, soil biotechnology is adopted for treatment of 1.4 MLD sewage. An inspection of the STP by CPCB officials revealed that through soil biotechnology, a BOD and COD reduction of 80% and 76.39% respectively was achieved while TSS levels reduced by 78.53% and ammonical nitrogen showed a reduction of 66.66%. Thus, soil biotechnology is an effective treatment technology with only one drawback being that TDS reduced by only 6.48%.

8.3 Waste Stabilization Pond

a) In Anupshahar, an STP of 1.75 MLD at STP Zone B has adopted waste stabilization pond technology with five ponds in series for sewage treatment. The analysis report of treated samples from the STP indicated 96.77% reduction in BOD, 92.27% reduction in COD and 100% reduction in TSS. Phosphate and sulphate content also reduced by 52.67% and 35.71% respectively. However, it was observed that nitrate content reduced only by 3.84% and there was no reduction in TDS, faecal coliform. Thus, treated samples were found to comply with general discharge standards.

b) At STP of 0.85 MLD situated in Zone A of Anupshahar, U.P., the treatment technology is waste stabilization through five ponds in series for sewage treatment. The analysis report of treated samples from the STP indicated 74.48% reduction in BOD, 59% in COD and 81.39% in TSS. Also, there was marginal reduction in TDS (3.08%), sulphate (20.51%), chloride (10.2%) and phosphate (5.91%). However, there was increase in ammonical nitrogen by 22.72% and faecal coliform levels remained unchanged. The treated effluent complied with general discharge standards thus indicating that the in-situ treatment technology is effective despite increase in ammonical nitrogen.

c) At the Vindhyachal STP of 4 MLD capacity located in Mirzapur, U.P., waste stabilization pond technology has been adopted with a total of four ponds (with three different functions); first pond is anaerobic (28.4 mx49.6x5.5m), second is facultative (75.4 m x 148.5 m x 2.0 m), and two are maturation ponds (Maturation-1: 55.45 m x 150.4 m x 1.45 m; Maturation – 2: 56.5m x 150.4 m x 1.55 m). Analysis of samples from final outlet indicated a reduction of 77.5% in BOD, 75% in COD and 63.69% in TSS.

8.4 Oxidation Pond

a) In the Fatehgarh STP of 2.7 MLD capacity, situated in FARRUKHABAD, the in-situ sewage treatment technology adopted involves primary oxidation ponds (2 in number) each of dimension 100m × 150m × 1.2 m, followed by secondary oxidation pond. The treated effluent is discharged into river Ganga. As per analysis report, the STP was found non-complying w.r.t general discharge standards for pH, BOD and TSS. However, BOD and COD showed a reduction of 53.98% and 34.95% respectively while ammonical nitrogen and phosphate levels reduced by 95.1% and 97.36% respectively.

b) In the 6 MLD capacity STP at Baidyabati in West Bengal, there are a total of three lagoons in series for treatment of sewage before maturation pond. The analysis of treated sample indicated BOD and COD reduction of 78.57% and 27.3% respectively. However, during inspection by CPCB officials, it was observed lagoons are eutrophicated while baffle walls and embankment are partially damaged.

9.0 AN EXAMPLE OF PROPOSED TREATMENT SCHEME

A typical first order drain having flow of 500 MLD with physical characteristics like length – 20 km, width of drain varying between 30-90 meter and organic loading of 100-250 mg/l of BOD may adopt *in-situ* constructed wetland system with horizontal and free-flowing system. This system will have two oxidation ponds, two physical treatment units and a constructed wetland.

The two oxidation units of 100 m long each are separated by three gabions; the two physical treatment units of 75 m long each and have vertical channels separated by gabions. The constructed wetland is of 150 m length and has 15 furrows of 8 m width, separated by 15 ridges of 2 m width. The schematic layout of the proposed constructed wetland is given in figure-21. Depending upon the width of the drain, the number of vertical channels varies and also length and height of gabions varies from site to site. Further design details of each unit are mentioned below:

1. Oxidation Pond:

   Depth: Gabions of 4m width with height of 2.5 meter;

   Width: As per availability (15-90 meter)

   Length: 100 meter

   Number of Oxidation Pond: 02

2. Physical Filters:

Vertical channels: Width upto 8 meter, height 1-5 meter, length 75-100 meter and number of channels varies as per width of drain

Depth: Gabions of 2m width with height of 1.5 meter;

Number of Physical Filters: 02

3. Constructed Wetland Systems

   Depth: Gabions of 2m width with height of 1.5 meter;

   Length- 150 m long

   15 furrows of 8 m wide separated by 15 ridges of 2 m wide

Actual design may vary as per available physical characteristics and organic loading of drain

- Expected Outcome

  BOD removal: 50-70 % reduction

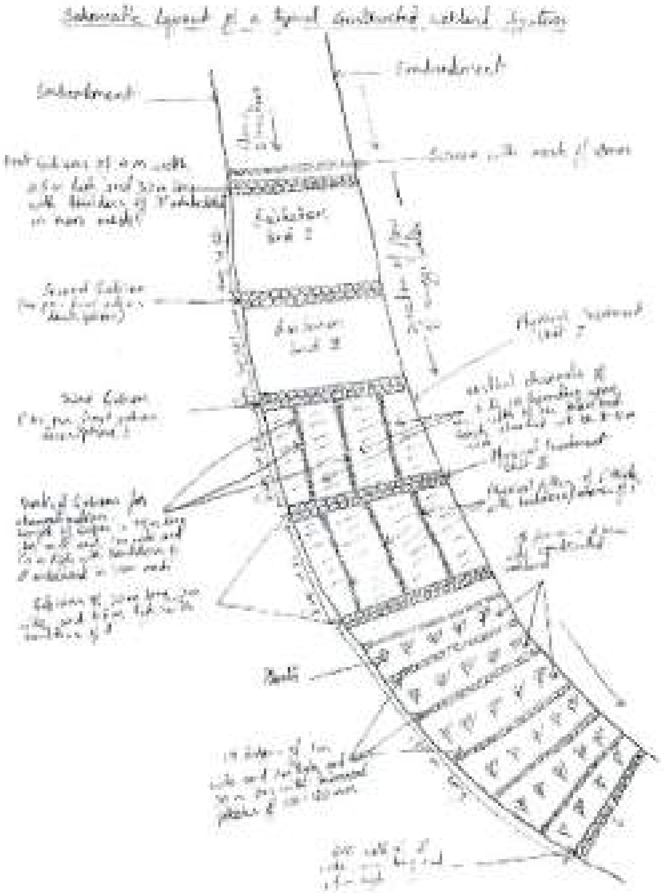


Figure 21: Schematic diagram of In-situ Remediation

9. ACKNOWLEDGEMENT

Inputs provided in the preparation of models alternate biological treatment techniques for drains by Prof.C.R. Babu, Professor Emeritus, Centre for Environmental Management of Degraded Ecosystem, University of Delhi, Prof. P. K. Mishra, Head, Department of Chemical Engineering & Technology, IIT-BHU, Varanasi; Prof. S.N. Upadhyay, Ex Director, IIT-BHU, Varanasi and Prof. C.B. Majumdar, Head, Department of Chemical Engineering, IIT Roorkee are acknowledged.

ANNEXURE-I

DESIGN AND PERFORMANCE DETAIL OF EX-SITU TREATMENT TECHNOLOGY

Design Criteria

- **Requirement of Physical Characteristic of Drainage System**

Length of drain	: 2-20 Km
Width of drain	: 2-15 m
Depth of flowing water	: 0.5 2 m

- **Organic Loading**

BOD	: 100-250 mg/l
COD	: 150-500 mg/l

- **Hydraulic Loading**

Flow	: 2-20 MLD
Volumetric loading	: 100-400 BOD g/m3.day

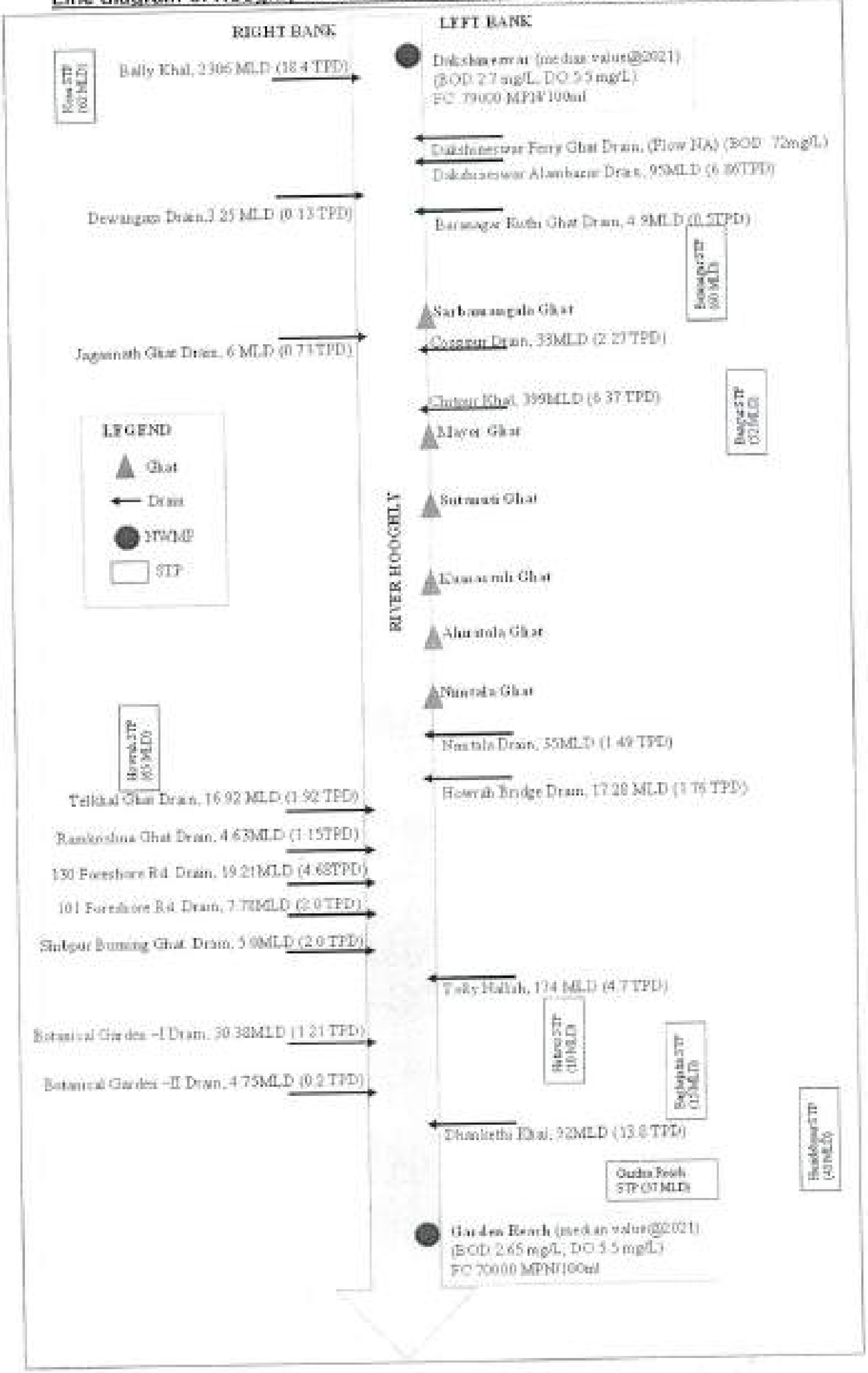
Typical characteristics of different types of Ex-Situ treatment technologies for treating domestic sewage are mentioned in table below:

SL. No	Characteristic	Facultative type Lagoon	Aerobic flow through type Lagoon	Aerobic with solids recycling Lagoon	Oxidation Pond
1.	Suspended solids concentration , mg/l	50-150	100-350	3000-5000	-
2.	Sludge age or mean cell residence time , days	High (because of settlement)	Generally 5	Warm:10-20 Temperate:20-30 Cold: over 30	-
3.	Overall BOD removal rate K_L per day at 20 ^{0} C	0.6-0.8	1-1.5	20-30	-
4.	Temperature coefficient,	1.035	1.035	1.01-1.05	
5.	Detention time, days	3-12	Generally 5	0.5-2	7-15 days
6.	BOD removal efficiency, %	70-90	50-60	95-98	80-90%
7.	Nitrification	None	Non favorable conditions	Likely under	-
8.	Coliform removal, %	60-99	60-90	60-90	99%
9.	Depth, m	2.5-5	2.5-5	2.5-5	1-1.5 m
10.	Land requirement, m^2/MLD	2200	2200	1111	8800
11.	Power requirement,	12-15	12-14	18-24	-

SL. No	Characteristic	Facultative type Lagoon	Aerobic flow through type Lagoon	Aerobic with solids recycling Lagoon	Oxidation Pond
	KW/Person -year				
12.	Minimum power level, KW/1000 m³ lagoon volume	0.75-1	2.75-5	15-18	-
13.	Sludge	Accumulates in lagoon; manual removal after some years	No accumulation; solids go out with effluent	Surplus sludge withdrawn continuously (daily) and disposed off suitably	Accumulates in Oxidation Pond; manual removal after some years
14.	Outlet management	Effluent flows over a weir	Partially or fully submerged pipe outlet	Weir or pipe	Weir or pipe

Annexure-II

Line diagram of Hooghly River showing NWMP locations, drains and STPs



Annexure - III

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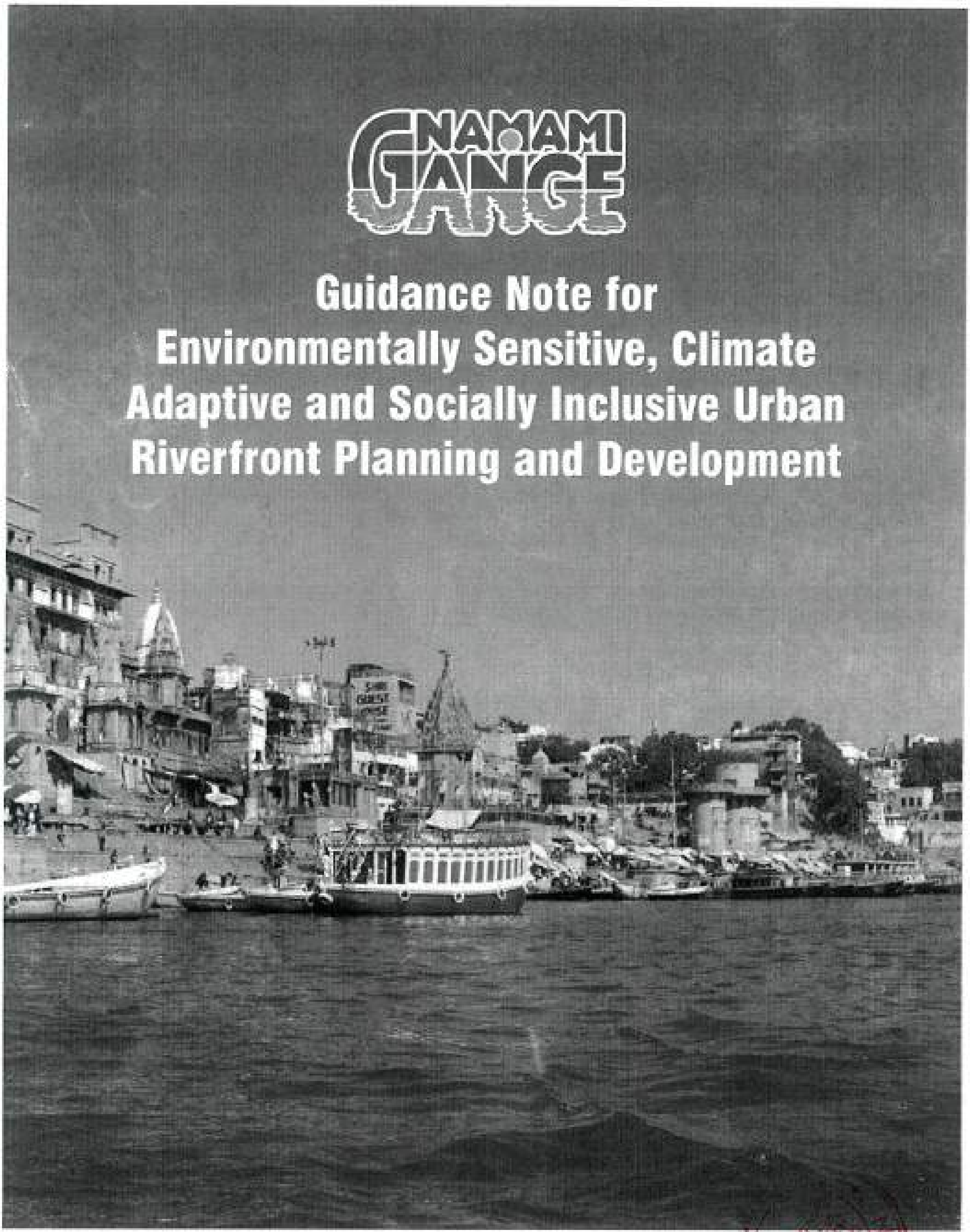

NAMAMI GANGE

Guidance Note for Environmentally Sensitive, Climate Adaptive and Socially Inclusive Urban Riverfront Planning and Development

NOTARY
INDIA

FOREWORD

Cities in India have historically developed near major water bodies such as rivers to ensure water access and accrue additional benefits of proximity to these natural resources.

India's rivers and their many tributaries have been the source of physical and spiritual sustenance of Indian civilization for eons. Rivers holds immense cultural and religious significance in India and the cities and locales on riverbanks are typically important cultural centers. Flowing rivers support agriculture, industry, trade and urbanization in India and are critical for a robust economy to thrive. In addition, rivers also support a plethora of flora and fauna along their courses such as fish, birds and larger species.

Despite India's reverence for rivers these natural resources are facing urgent and rapid challenges which have brought them and their ecologies to the brink of collapse. Constantly increasing demand on the finite water available in the river, pollution from urban areas, industries and agricultural runoff are some of the key stressors for rivers today in India. In addition, the deep connection that humans had forged with rivers, with a multitude of religious and cultural practices and community and individual rituals are lost today. Cities and towns are turning their backs to rivers, which are now too polluted, with too little water or too flooded.

The picture of degradation of rivers and riverfront is ubiquitous as there is a constant struggle to achieve a balance between urban development and environmental sustainability. Added to the developmental challenges comes the growing uncertainty and risk wrought by climate change. To manage risks brought about by unprecedented and unmanaged urbanization, increasing population and growing climatic whiplash, it is critical that restoration and conservation of rivers, local water bodies and other related ecosystems become a co-equal goal in a city's development. There needs to be a revolution in planning to improve how we make policy and investment decisions and implement solutions. The climate challenge is not only urgent—it is also pervasive across virtually all sectors of the economy.

National Mission for Clean Ganga (NMCG) has been prompted to develop a balanced approach to urban riverfront development (URFD), where ecological, environmental and social concerns are addressed harmoniously along with development to accrue multiple benefits to people and riverine ecosystems and also generate economic dividend for cities. This guidance note on URFD is to provide a broad framework in order to plan and develop environmentally sensitive, climate adaptive and socially inclusive approach to urban riverfront projects. It can be considered as a primer for multiple stakeholders including urban local bodies, service providers, project financing organizations etc. who are involved in planning and/ or developing any urban riverfront projects.

Governments, development agencies, service providers, subject matter experts and civil societies are needed to collaborate to strengthen knowledge and capacity for managing the complex process of urban riverfront development especially at a time when climate risks and water challenges are becoming prevalent and are resulting into serious social, financial and environmental losses.

Save water, Save rivers, Save earth, Save humankind!

Shri Rajiv Ranjan Mishra
Director General
National Mission for Clean Ganga
Department of Water Resources, River
Development and Ganga Rejuvenation
Ministry of Jal Shakti

ACKNOWLEDGEMENTS

The National Mission for Clean Ganga (NMCG) presents this guidance document on planning and development of environmentally sensitive, climate adaptive and socially inclusive urban riverfronts.

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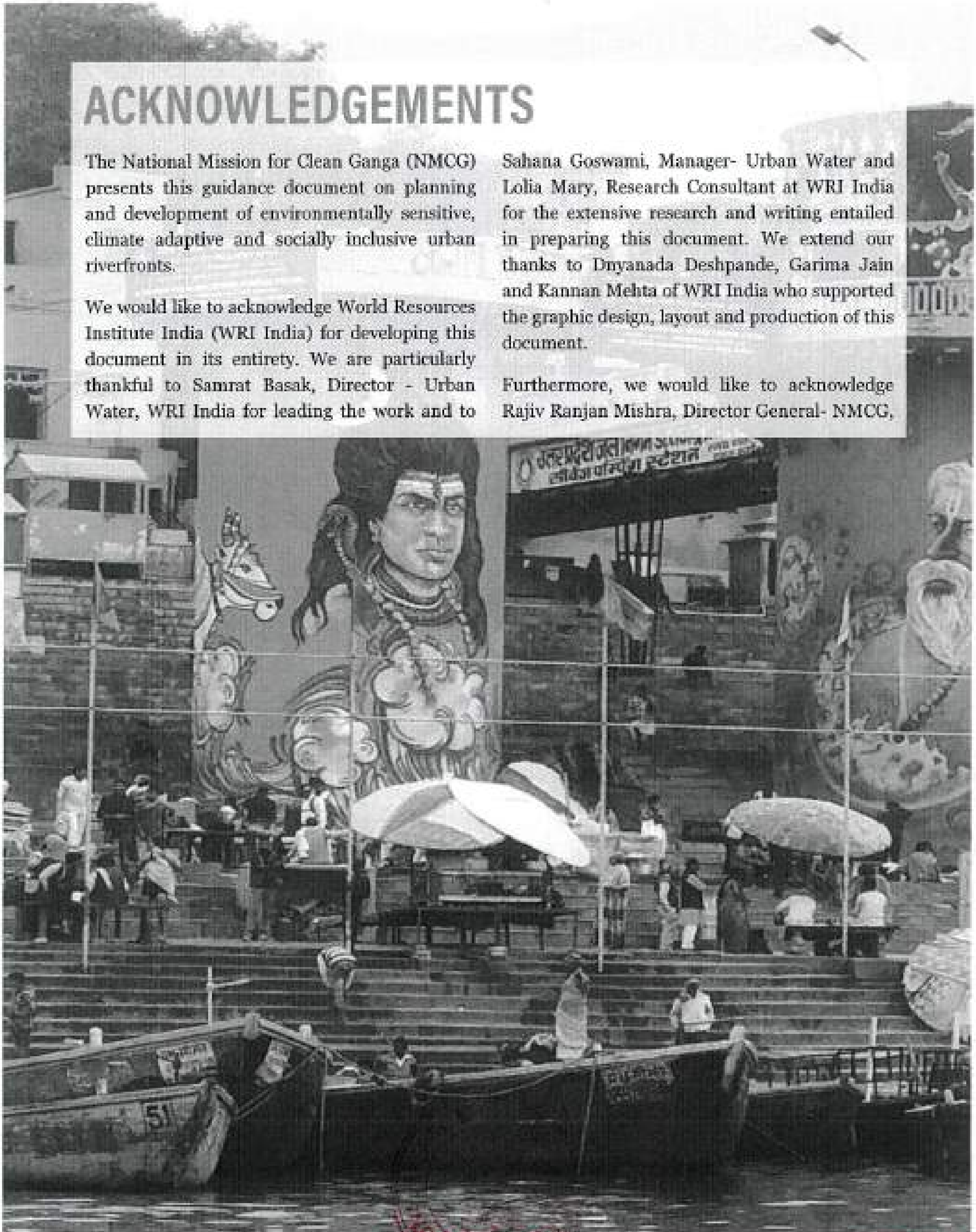

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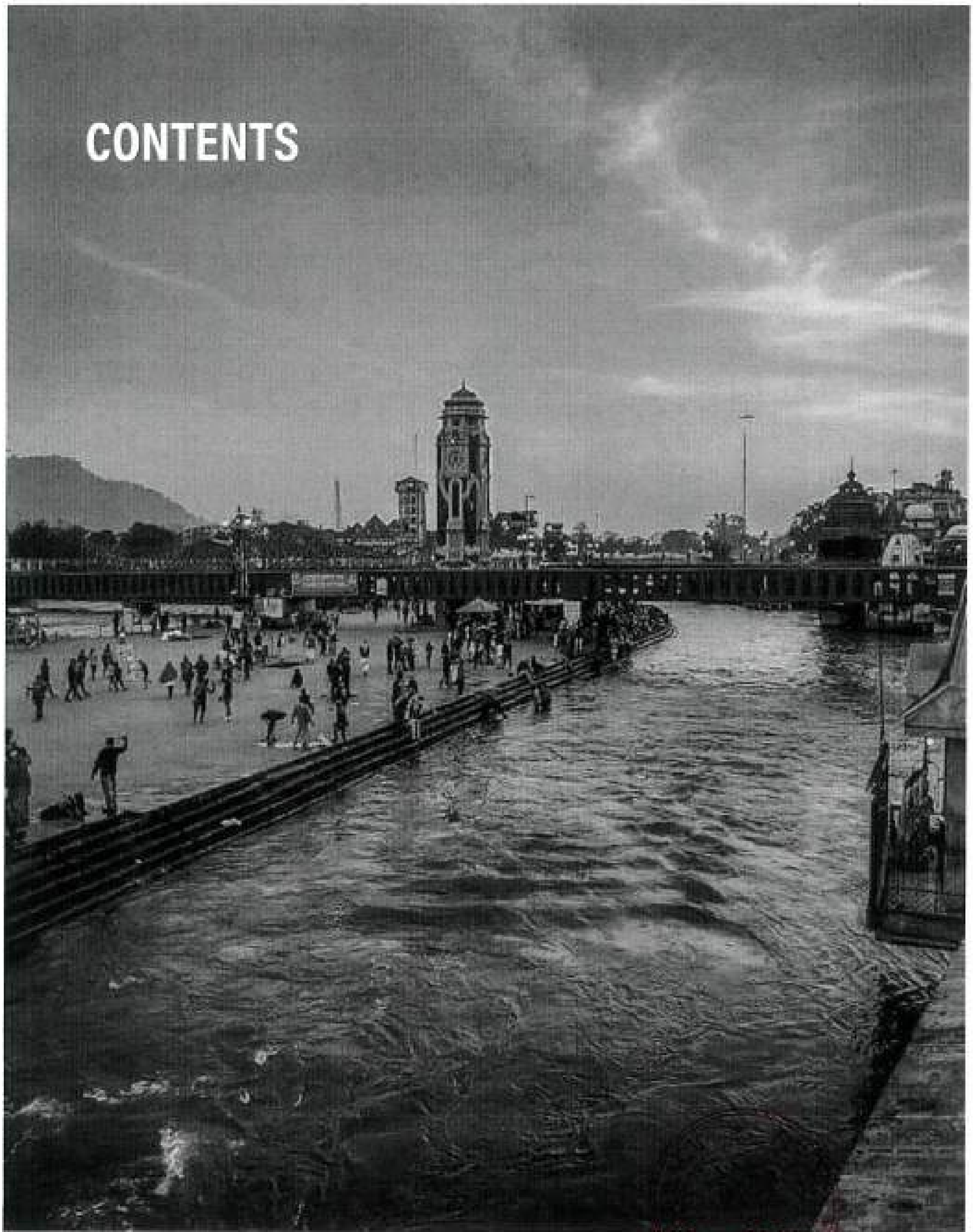

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SUMMARY

Urban Riverfront Development (URFD) and planning in India currently focuses on the built environment (construction, landscaping and beautification) and the potential economic benefits to be derived from these projects. There are limited considerations of the social, hydrological, environmental and ecological impacts of these projects as well as impact on the project itself. Also, erratic climatic events like flood and drought has direct impact on riverfront projects. Discounting these aspects of riverfront planning and development has time and again led to failed outcomes, hydrological/ ecological/ environmental stresses and disasters like floods with loss of life and property.

With this context, National Mission for Clean Ganga (NMCG) has requested World Resources Institute India (WRI India) to develop a guidance note integrating water, ecology, environment and climate resilience related considerations within the existing framework of urban riverfront planning and development. Responding to NMCG's request, WRI India has developed this high-level guidance note by bringing in relevant hydrological, ecological, environmental, social and climate resilience considerations.

This document is a primer for all stakeholders who wish to implement urban riverfront projects; to be able to plan and develop projects which are environmentally sensitive, climate adaptive and socially inclusive. The document, as envisaged, has three broad objectives as presented below.

Appraisal tool to support decision-making on urban riverfront development based on environmental and social indicators

Informs project proponent, decision makers and other stakeholders about **environmentally sensitive, climate adaptive and socially inclusive** riverfront developments

Guidance to various service providers on design and planning and implementation of ecological URFD

A BROAD STRUCTURE OF THE GUIDANCE NOTE IS AS FOLLOWS:

CHAPTER I is an introduction into the history of urban rivers and their present condition in urban India.

CHAPTER II outlines the existing environmental and social regulatory framework and the interrelationship between Urban River Management Plan (URMP) and URFD.

CHAPTERS III AND IV detail the protocols for appraisal, implementation process and governance for riverfront developments. These two chapters also include a range of case studies which are provided to demonstrate how cities across the world have worked to integrate a variety of ecological and social measures in URFDs.

CHAPTERS V outlines mechanisms to ensure smooth Operations & Maintenance (O&M) in URFD projects and financing mechanisms that can be used.

APPENDIX A presents a checklist to help all stakeholders follow various steps as suggested in Chapter III, IV and V.

1 Appraisal framework

Project Screening
High-level Plan Report

- Type of URFD
- Existing Plans
- Site Selection
- Connections
- Financial Plan
- Key Performance Indicators

Detailed Project Report
Detailed action and management plans

- Hydrological Assessment
- Climate Change scenario
- Environmental Impact Assessment
  - *Ecological and environmental setting*
- Social Impact Assessment
  - *Socio-economic analysis*
  - *Stakeholder identification and mapping*
  - *Participation and outreach plan*
- Design Strategy

Planning and Institutional Strategy
[illegible]

2 Guidance Note for Implementation

Implementation of Management/ Action Plans

- Approved Construction Design and Plans
- Environmental and Social Management Plans
- Land Acquisition and Resettlement Action Plan
- Indigenous Peoples Plan
- Hydrological Impact Management Plan
- Biodiversity Management Plan

Change Management

- Project Reviews
- Stakeholder Engagement Register

Monitoring and Evaluation

- Bi-annual Audits
- Correction/prevention plans
- Performance Improvement

Training

- Roles, Responsibilities and duties
- Compliance training
- Impacts of Procedural Lapses

Information Disclosure

- Information Dissemination
- Comments Period
- Feedback

Grievance Redressal

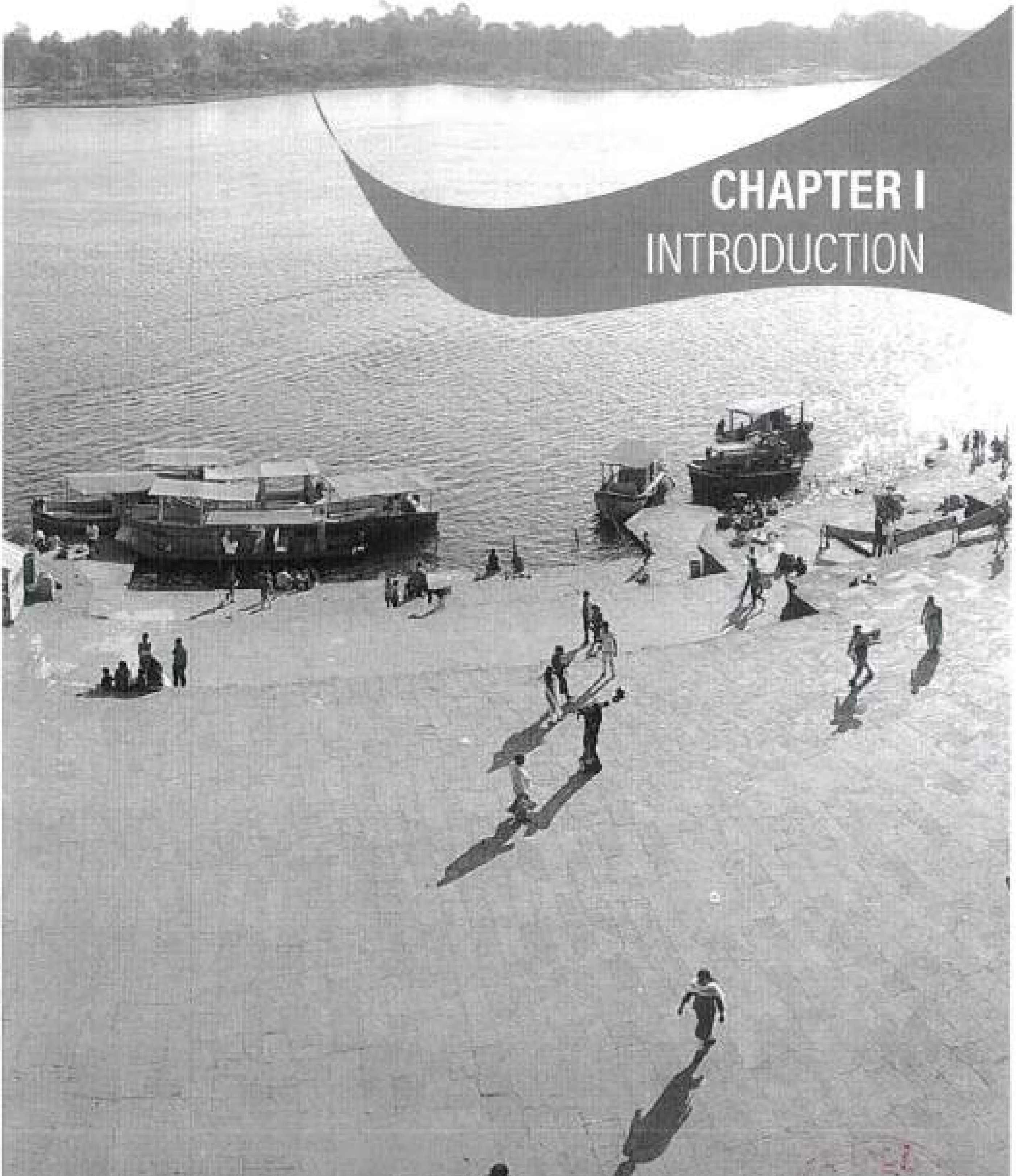
- Grievance receipt and acknowledgement
- Investigation
- Response

3 Operations, Maintenance and Financing

Operations

Maintenance

Financing



CHAPTER I
INTRODUCTION

CHAPTER I: INTRODUCTION

Historically, human settlements have clustered along riverbanks and developed into large urban centres when supplemented by plentiful resources (food and water), trade and commerce. The industrial era with its growing urban populations and economic activity saw urban rivers change from freshwater sources to polluted water streams carrying industrial and human wastes away from urban centres. In the 20th century, a resurgence of urban riverfront development came about as commercial, retail and residential use, along with vibrant public spaces, competed to establish themselves on prime riverfront properties.

Climate change driven extreme weather events place built infrastructure, property and human lives at risk. As extreme events increase in frequency, urban areas are looking beyond economic benefits and renewing their relationship with water systems to make cities resilient, such as in Rotterdam (Mackenzie 2010) and to improve the quality of life of citizens such as in Cheonggyecheon, Seoul (Landscape Performance Series n.d.). Urban design and planning strategies and water management policies are integrating concepts such as water-sensitive cities, sponge cities and blue-green infrastructure, allowing cities to respond better to urban hydrological cycles and extreme weather events.

Living beside and building along riverfronts remains fraught with various challenges such as the risk of loss of life and property due to floods and spread of insects and disease due to contaminated water. In India and other developing countries, such risks are disproportionately borne by economically weaker sections of society who reside in such areas due to the lower costs of land in these unimproved areas. Development plans often

Figure 1 | Evolution of waterfront development

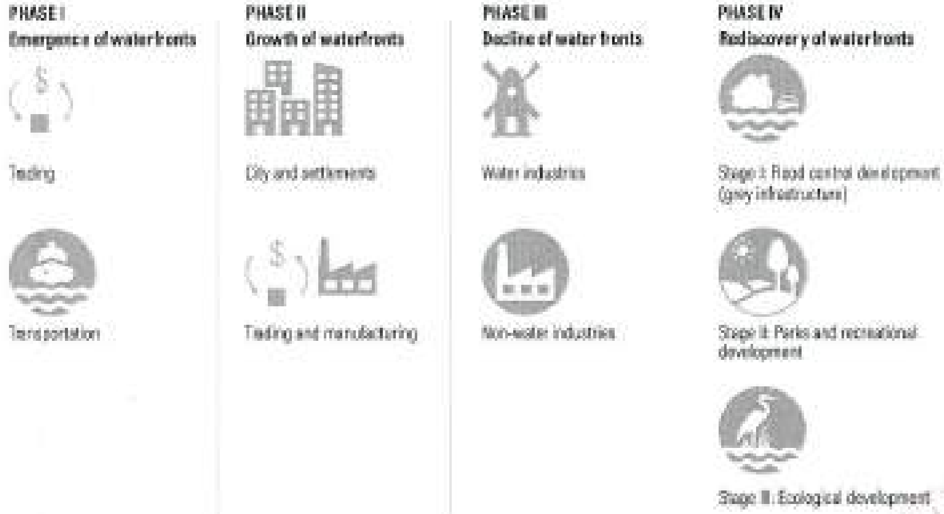


Image adapted from (Redzuan and Latip 2016)

Box 1 | Urban riverfronts must respond to key challenges of current times

The environment in terms of river catchment and upstream areas have rapidly changing land-use profiles; this has drastic impacts on sediment loads and runoff volumes entering water bodies as well as local biodiversity. Climate change driven weather variability impacts the extent and frequency of extreme events such as floods and drought leading to infrastructure damage and loss and disruption of services. Finally, changing population and demographic patterns impact the socio-cultural connections and associations that communities have with rivers, often leading to the loss of river custodian communities. These three interacting themes lead to higher stress on urban river ecosystems with increased pollution, extreme events and lack of care of the river.

To manage for the uncertainty brought about by climate change, existing planning concepts need to be transformed so that climate risk can be mainstreamed, and adaptation practices can be integrated into urban and regional planning. Improved data analytics and forecasting tools must be developed which can ensure robust decision making for climate uncertainty. Participation of communities, particularly of vulnerable and most impacted groups in the planning process must be ensured so that the benefits of climate adaptive planning can percolate to such groups (GCA 2019).

With the emerging global focus on environment, climate and social issues this document asserts that there are 3 primary concerns that must be addressed in combination as new urban riverfront development projects are conceptualised and implemented to respond to critical and rapid changes. **Thus, this guidance note has been developed to support project proponents to develop environmentally sensitive, climate adaptive and socially inclusive urban riverfronts.**

Environmentally sensitive urban riverfronts refer to concepts and projects which are sensitive to local hydrology, environmental and ecological considerations by putting primary focus on conservation, restoration and enhancement of river and associated ecosystems.

Climate adaptive urban riverfronts are riverfronts which have adequate planning/ design buffers to deal with future climatic variabilities by limiting and/ or mitigating any social, ecological and capital loss as well as damage to natural and built assets.

Socially inclusive urban riverfronts are riverfronts with adequate considerations of the needs and aspirations of all local stakeholders, custodians and users of river and riverfronts throughout the planning, development and operational phases of such riverfronts.

do not factor in the socio-economic impacts of displacement of these existing residents.

Urban riverfront development projects focus primarily on the built environment (construction, landscaping and beautification) and the potential economic benefits to be derived from these projects. There is limited consideration of the social, hydrological, environmental and ecological concerns of these projects. Discounting these aspects of riverfront development has time and again led to severe hydrological/ ecological/ environmental impacts as well as disasters like urban floods and loss of life and property.

Additionally, riverine ecosystems provide many benefits such as groundwater recharge, microclimate control, increasing biodiversity and controlling floods where intact floodplains and wetlands are present. Further, healthy urban rivers can also support fishing, recreational activities and water activity-based tourism as livelihood options for citizens.

India, with its many urban rivers and culturally important sites such as the ghats (like Varanasi on River Ganga), is well poised to demonstrate the benefits of water and eco-sensitive urban riverfront developments. Urban riverfront development projects along various rivers

Box 2 | How to use this document

This guidance note on environmentally sensitive, climate adaptive and socially inclusive urban riverfront planning and development has been developed as a primer for urban local bodies which are contemplating the rejuvenation and restoration of their urban rivers. This note intends to offer key points that project proponents should consider before embarking on and during the project implementation phase.

As the local context of each URFD project site is different, this document is not intended to provide pre-defined solutions on methods and technologies that can be undertaken to develop URFDs. Also, various solutions are described as part of case studies but this document is technology agnostic and does not prefer any specific technological solution. Rather this document provides a checklist of relevant and critical aspects, tasks and activities that a project proponent (URFD authority) must consider while developing an environmentally sensitive, climate adaptive and socially inclusive URFD project.

This document also provides a range of global and national case studies of riverfront developments; examples of both good practices and unsuccessful implementation and provides a project framework that future riverfront developments in India can follow.

This document has drawn extensively from an existing publication *Ecological Riverfront Design: Restoring Rivers, Connecting Communities to develop the framing and approach to be followed to develop ecological URFDs.*

However, this document goes beyond the theory and conceptual frameworks of the above-mentioned primary publication and provides an India-specific, documented, high-level guidance note by bringing in relevant hydrological,ecological,environmental,socialandclimateresilienceaspectsthatneedtobeconsideredduring planning, development and operational phases of riverfront development projects. This document is a primer for all stakeholders who wish to implement urban riverfront projects; to be able to plan and develop projects which are environmentally sensitive, climate adaptive and socially inclusive.

This guidebook is an **addendum to any existing reports and guidelines** on urban riverfront developments and is designed to include a broad framework on an **environmentally sensitive, climate adaptive and socially inclusive** approach to riverfront projects.

This document **does not include** guidelines on architectural detailing, technical details and heritage conservation practices.

are already attracting significant investments (Mumbai alone is investing INR 685 million to develop the Mithi Riverfront (Das 2017)).

A balanced approach to urban riverfront development (URFD), where ecological, environmental and water concerns are addressed harmoniously along with development can accrue multiple benefits to people and riverine ecosystems and also generate economic dividend for cities.

Historical Context and Significance

Urban centres in the Indian sub-continent have a long and intertwined history with river valleys and river basins. Beginning with the ancient Indus Valley civilization to later periods such as the Maurya, Chola and Mughal eras, cities have grown and flourished along the banks of rivers and in the fertile deltas of river basins. Indian tradition holds all Indian rivers sacred and considers them as the purifier, life giver, symbol of fertility and destroyer of evils.

Being close to rivers brought easy access to water for domestic, agricultural and fishing purposes. The added access to waterways for navigation, trade and commerce allowed these settlements to connect with each other and enabled the growth of large urban centres (Gupta 2017). Alongside the tangible impacts brought about due to the proximity to rivers, a deep cultural significance for rivers emerged in India where rivers came to be associated with community and individual rituals. These cultural practices mirrored natural rhythms such as the hydrological cycle of the river, the change of seasons and the associated flowering/ fruiting of trees which dictate

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agricultural sowing and harvest times.

Since industrial times rapid urban population growth in cities across the world and in India has changed the intimate relationship cities and citizens had with urban rivers (Otto, McCormick and Leccese 2004).

Improved road, rail and air transport services and advancements in science and technology removed dependence on local resources like rivers. Water was sourced and transported from distant rivers and reservoirs to meet urban needs in many cities and this trend continues today (IIHS 2014).

Rapid increase in urban population has led to greater extraction of surface water from the river as well as groundwater (that supports base flow in rivers). Additionally, dumping of municipal and construction waste on the riverbanks adds to pollution levels. Industrial pollution, wastewater and fecal sludge, agrochemical runoffs and waste had turned many urban rivers into settling drains or cesspools.

Across India, rivers continue to be revered and their cultural significance is embedded into festivals and rituals, but the deep connections engendered by daily access and use of local rivers for domestic and economic purposes has dwindled. This has in turn led to a reduction of local activities that enabled river protection and rejuvenation.

While in India river restoration still focusses on

Figure 2 | Ghat of Varanasi

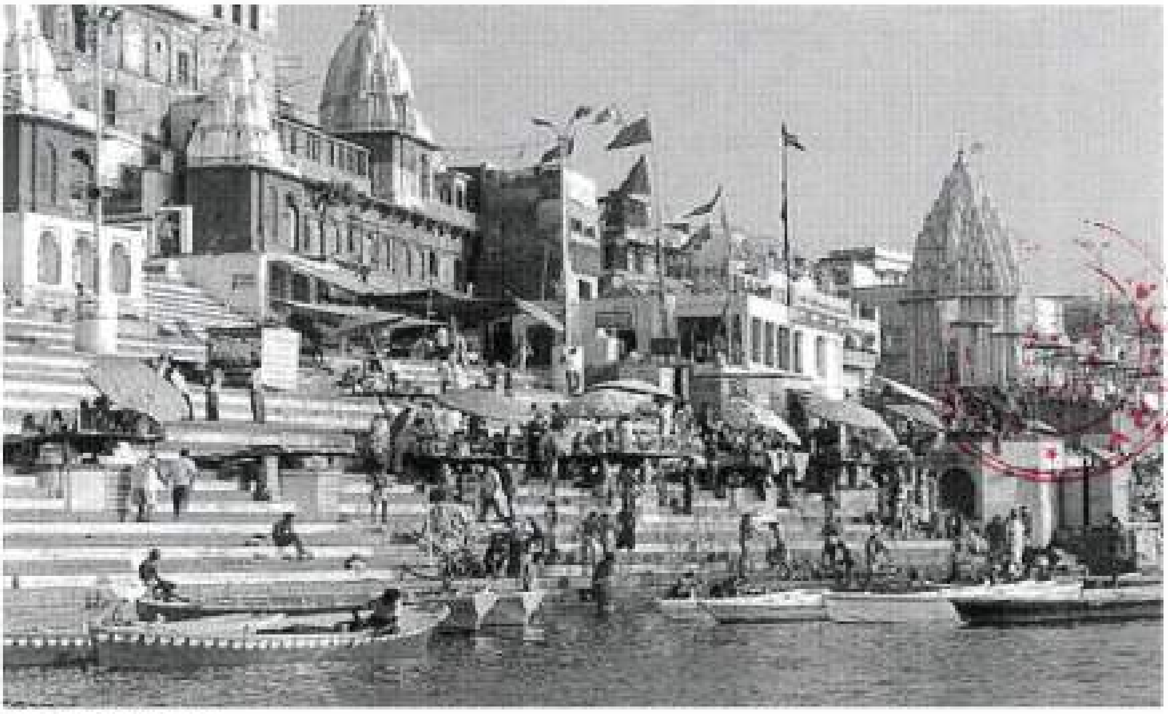

Image Credit: Sheldon Kirshner

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Figure 3 | Ghats in Patna City

Image Credit: WRI India

river cleaning and aesthetic appeal, the concept of clean rivers on a global level has shifted towards the creation of healthier rivers which are able to sustain a wider diversity of fish, birds, and other wildlife. An ecologically improved and healthy river draws the public to the water's edge for various recreation activities such as to walk, bike, boat, fish, and observe wildlife. People returning to the river and the increased and deeper connection with water leads them to express a stronger interest to protect and restore natural areas and wildlife habitats along rivers and elsewhere in the catchment (Otto, McCormick and Leccese 2004).

Urban Riverfronts Today

Urban riverfront development in India is thus far limited to commanding and controlling river waters and exploiting its floodplains for the use and convenience of people as well as for commercial gains realized from real-estate development. The modern concept of urban riverfront development in India has originated with Sabarmati riverfront development in Ahmedabad, which involved a grey infrastructure-based development for a stretch of around 10 km (AMC n.d.). Following this, several other urban riverfront

Figure 4 | Stormwater infiltration changes over undeveloped and developed areas

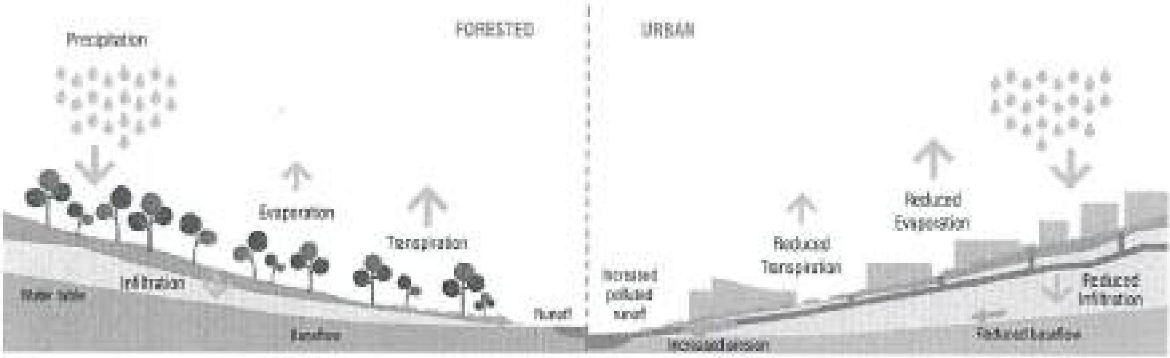


Image Credit: Melbourne Water

1. Stormwater is usually water from ice/snow or water from a nearby stream, river or runoff surface.
2. Natural sediment such as soil and forests absorb most of the stormwater. In developed areas such as in cities, unmanaged stormwater can create 2 types of problems: flooding and water pollution.
3. Water pollution is due to contaminants on the impervious surface of the materials used to construct parking lots, roads and buildings that prevents stormwater from being absorbed into the ground. Therefore, generating more runoff than natural sediment and introducing pollutants to the water. Flooding is due to objects being transported to drains and blocking them.
4. To combat stormwater, a storm drain is installed at various points in cities. It is designed to drain excessive stormwater from impervious surfaces.

development projects have been approved. This list includes Godavari riverfront development in Maharashtra, Patna riverfront development in Bihar, Dravyavathi riverfront development in Rajasthan, Gomti riverfront development in Lucknow, etc., besides similar development proposals for other rivers across India.

But as more studies indicate the wide range of benefits of urban riverfront development projects, river management practices have shifted towards river protection and restoration of degraded areas. Cities today increasingly recognize the value of ecological services provided by natural river (courses) such as flood control, groundwater recharge, etc. Natural river functions (e.g., flood storage, water purification and supply, wildlife habitat, and safe fishing and recreation) once they are lost or degraded are extremely costly to replace Incorporating river protection measures in URFDs can significantly reduce the costs of recreating these ecological services.

Urban riverfronts today must fulfil a range of services from recreation to economic activity and ecological functions. Urban rejuvenation along riverfronts when done right is a powerful tool for cities to renew core city areas and revitalize commercial and business districts. Furthermore, there is great insistence for greater proximity to the river, as citizens increasingly want to view biodiversity, engage in recreation activities and learn of the cultural and natural history of rivers. The pressures to rejuvenate urban rivers is paralleled with rapid development across the watershed which compromises water quality as increased runoff and untreated sewage enters water courses. Urban riverfront developments must protect and improve of river health as a co-equal goal with economic and area revitalization efforts (Otto, McCormick and Leccese 2004).

Principles of Ecologically Sound Riverfront

This section below is derived extensively from "Ecological Riverfront Design: Restoring Rivers, Connecting Communities by Betsy Otto, K McCormick, and M Leccese of the American Planning Association".

How urbanization affects streams

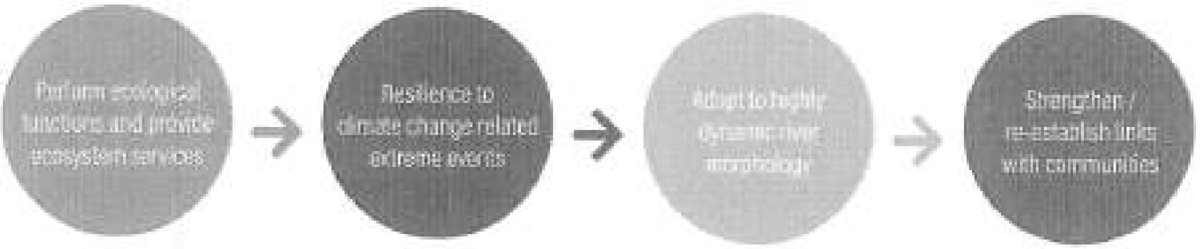
Changes in stream hydrology resulting from urbanization include the following (Caraco 2000):

- Increased peak discharges compared to predevelopment levels
- Increased volume of urban runoff produced by each storm
- Decreased time needed for runoff to reach the stream, particularly if extensive drainage improvements are made
- Increased frequency and severity of flooding
- Reduced streamflow during prolonged periods of dry weather due to reduced level of infiltration in the watershed
- Greater runoff velocity during storms due to the combined effects of higher peak discharges, rapid time of concentration, and the smoother hydraulic surfaces that occur as a result of development.

The following principles can be considered as guiding pillars or anchors to evolve guidance for urban river front development. These principles are for the fundamental purpose of creating environmentally sound river front developments and lists the critical functions that the urban river front should perform in the context of intense and rapid urbanisation and climate change scenarios.

Guiding Principles

To translate these guiding principles into planning and design strategies and actions on ground the planning objectives and design objectives mentioned below will be useful.



Planning objectives based on the guiding principles

Plan for a larger scale	Plan for a scale larger than the riverfront to include immediate micro watershed and integrating streams/rivulets flowing into the river
Use development regulations	Ensure spatial connectivity with city's open spaces
Connect to green network	Provide for public access, connections, and recreational uses
Enable public access	Manage river resources which are directly accessed by communities through participatory stewardships
Participatory stewardship	Plan for a scale larger than the riverfront to include immediate micro watershed and integrating streams/rivulets flowing into the river
Formal management authority	Establish and formalise management bodies within the urban local body and community/neighbourhood

Design objectives based on the guiding principles

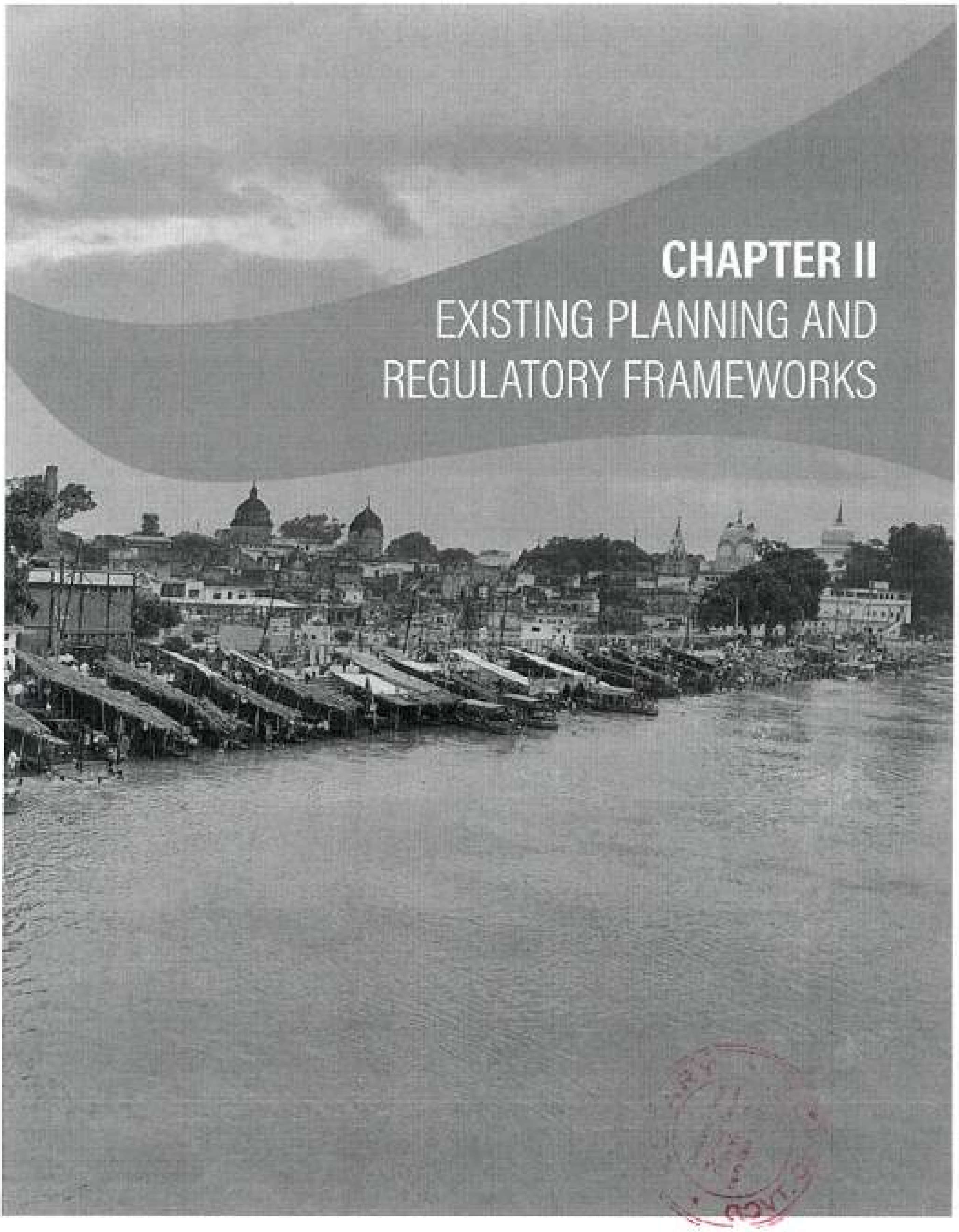
Unique characteristics	Demonstrate characteristics of the city's unique relationship to the river in the riverfront design
Pollution removal	Design for filter strip and gross pollutant traps at the city side of RFD
Low impact design	Adopt low impact design and construction measures like bio-engineering and landscape interventions to restore natural riparian
Non-structural alternatives	Use nonstructural alternatives to manage water resources
Reduce hardscape	Reduce hardscape within the RFD area
Manage stormwater	Manage stormwater on site and use nonstructural approach such as retention ponds, swales and wetlands
Inundation sinks	Design for inundation sinks to carry or hold any inundation from the river
Use development regulations	Ensure spatial connectivity with city's open spaces
Ghat design	Design ghats which are not continuously built along the banks at intervals
Natural and cultural history	Incorporate information about a river's natural resources and cultural history into the design of riverfront features, public art, and interpretive signs
Restrict river channelisation	Do not channelise the river at the RFD stretch by continuously running walls

In the context of this guidance note, a few scientific terms have been used throughout the document. The definitions of such scientific terms are presented below. These definitions have been primarily drawn from River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016.

Basin	the entire catchment of a water body or water course including the soil, water, vegetation and other natural resource in the area
Buffer area	an area which extends beyond the floodplain or stream
Catchment area	is the entire land area whose runoff from rain, snow or ice drains into a water body or water course
Channelization	a method of river engineering that widens or deepens rivers to increase the capacity for flow volume at specific sections of the river
Floodplains	the area of a river or tributary 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 (100) years
Ghat	sloped part of river or its tributaries with artificially constructed steps or ramp to provide easy human access to river for religious or other related activities
Hardscape	all such built elements which do not allow for the infiltration of water into the ground
Runoff	flow of water that occurs when excess stormwater, meltwater, or other sources flow over the Earth's surface
Stream	includes river, watercourse (whether flowing or intermittently dry), inland water (whether natural or artificial) and subterranean waters
Wetlands	distinct ecosystems where water meets land which are inundated seasonally or perennially and are characterized by uniquely adapted aquatic plants and other flora

CHAPTER II

EXISTING PLANNING AND REGULATORY FRAMEWORKS



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CHAPTER II: EXISTING PLANNING AND REGULATORY FRAMEWORKS

Existing Environmental and Social Regulatory Framework: Policies and Regulations with influence on Riverfront Development

Currently, river management is not empowered by an Act or Policy that focuses on it exclusively. Having said that, there are several acts and policies aimed at regulating and managing many of the environmental and social components of a river system. Water quality, environment, biodiversity and disaster risks are aspects addressed through specific acts and policies. The following table presents few key environmental and social regulations applicable to urban riverfront development projects (MoEF&CC n.d.). Please note that this list may not present ALL relevant and applicable national and state-specific environmental and social regulations that may be applicable to a URFD project. The URFD project proponent and consulting service providers must undertake a detailed compliance assessment of relevant and applicable environmental and social regulations.

Act/ Rules	Purpose	Applicability	Authority
Jal Jeevan Mission (URBAN), 2021	This mission's primary objective is to provide universal coverage of water supply across 4,378 statutory towns in accordance with United Nations Sustainable Development Goal 6. This mission takes an integrated approach and recognizes that rejuvenation of water bodies and sustainable aquifer management will be critical to augment sustainable fresh water supply.	Urban green spaces and sponge cities will mitigate flood impact and support development of urban water assets (surface and groundwater) through circular practices for recycle and recharge of treated wastewaters.	Ministry of Housing and Urban Affairs, urban local bodies
River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016	This order is for the purpose of effective abatement of pollution and rejuvenation, protection and management of the River Ganga, maintain ecological flows through its entire length, impose restrictions as required on industries and processes abutting River Ganga and to make provision for inspection of premises, plants, machinery, etc., to assess their impact on the river.	This Order shall apply to the states comprising the River Ganga Basin and its tributary rivers and streams and will guide during plan, implementation and evaluation phases.	Ministry of Jal Shakti, State Ganga Basin Authorities
National Water Policy, 2012	The National Water Policy, 2012 is envisioned as a framework law that can support essential legislation on water governance at State and Union level. This law enshrines the value that water be considered as element that sustains life and ecology and not merely as a scarce resource that has to be divided among various competing uses.	Section 8 about 'Conservation of River Corridors, Water Bodies and Infrastructure' details the value of urban rivers. Section 8.2 elaborates: Encroachments and diversion of water bodies (like rivers, lakes, tanks, ponds, etc.) and drainage channels (irrigated area as well as urban area drainage) must not be allowed. Wherever encroachment has occurred, restoration to the extent feasible should be undertaken and maintained properly.	Government of India, State governments, Ministry of Jal Shakti, Ministry of Housing and Urban Affairs

Act/ Rules	Purpose	Applicability	Authority
Environment (Protection) Act, 1986	To protect and improve overall environment.	As all environmental notifications, rules and schedules are issued under this umbrella act.	Ministry of Environment, Forests and Climate Change, DoE, State Govt. Central Pollution Control Board, State Pollution Control Boards
Coastal Regulation Zone (CRZ) Notification 1991 (2011)	Protection of fragile coastal belts.	If project location is located along coastal belt.	
Land Acquisition Act, 1894 (as amended)	Sets out rules for acquisition of land by government.	Applicable in case of acquisition of land.	Revenue Department, State Government
Environmental Impact Assessment Notification 14th Sep-2006 (as amended)	Mandatory environmental clearance to a certain category of new development activities following environmental impact assessment.	Applicable in case built up area of the project is more than 20,000 sq.m and the total construction area is more than 1,50,000 sq.m	State Pollution Control Boards, State Environment Impact Assessment Authority
Wildlife (Protection) Act, 1972	To protect wildlife in sanctuaries and national parks.	This act is applicable if any sanctuary/ national park exists within 10 km radius of project site. This act will be applicable, if there are any points of protected wildlife crossings in proximity to project locations like River Dolphin, which is a schedule-I animal.	Chief Conservator Wildlife, Wildlife Wing, State Forest Department, Ministry of Environment, Forests and Climate Change
Air (Prevention and Control of Pollution) Act, 1981	To control air pollution by controlling emission of air pollutants as per the prescribed standards.	This act will be applicable during construction phase and may be applicable during operational phase (for e.g., if the project has any diesel generator set of more than 15 kVa capacity or a crematorium).	State Pollution Control Boards
Water Prevention and Control of Pollution) Act, 1974	To control water pollution by controlling discharge of pollutants as per the prescribed standards.	This act will be applicable during construction phase and may be applicable during operational phase.	State Pollution Control Boards
The Noise Pollution (Regulation and Control) Rules, 2000	The standards for noise for day and night have been promulgated by the MoEF&CC for various land uses.	This act will be applicable during construction phase.	State Pollution Control Boards
Central Motor Vehicle Act, 1988	To check vehicular air and noise pollution.	This act will be applicable during construction phase and may be applicable during operational phase.	Motor Vehicle Department
National Forest Policy, 1988	To maintain ecological stability through preservation and restoration of biological diversity.	This policy will be applicable if any eco-sensitive feature exists in and around the project.	Forest Department, State Government and Ministry of Environment, Forests and Climate Change

In addition, there are a few empowered agencies that can provide or have provided directions for urban riverfront development projects. Few of them are presented below:

National River Conservation Directorate (NRCD), under MoEF&CC - the objective of NRCD is to improve the water quality of the rivers, which are the major water sources in the country, through the implementation of pollution abatement works (NRCD 2014).

National Green Tribunal (NGT) – a special judicial entity equipped with the necessary expertise to handle environmental disputes involving multi-disciplinary issues. They also have power to issue orders in cases where legalities and regulations are compromised or are not abided by individuals or entities including government agencies (NGT 2016).

City and Regional Land use plans and Building regulations are local-level development management mechanisms, under the purview of Development Authorities and the respective State-level Town Planning Departments along with the urban local bodies. These land use regulations, building regulations and activity regulations have the greatest role in influencing the condition of the river and its watershed in the long-term.

This tool allows the formulation of building coverage regulations, create zoning regulations through participatory planning which can reduce surface runoff, increase percolation, etc.

Projects under SPVs and National Missions such as HRIDAY, PRASAD, SMART CITY, AMRUT, etc., are development plans and projects which target towns, cities and tourist hubs/corridors and religious hubs. If the location of these proposed projects are along or near a river, these projects will need to look at riverfront development guidelines to inform their project proposals to avoid any conflict (HRIDAY n.d.); (AMRUT n.d.); (Ministry of Tourism 2016).

Therefore, concerned authorities in charge of preparing and implementing these other mission-based projects such as HRIDAY, SMART CITY, AMRUT, etc., near riverfronts should ensure that there is no conflict.

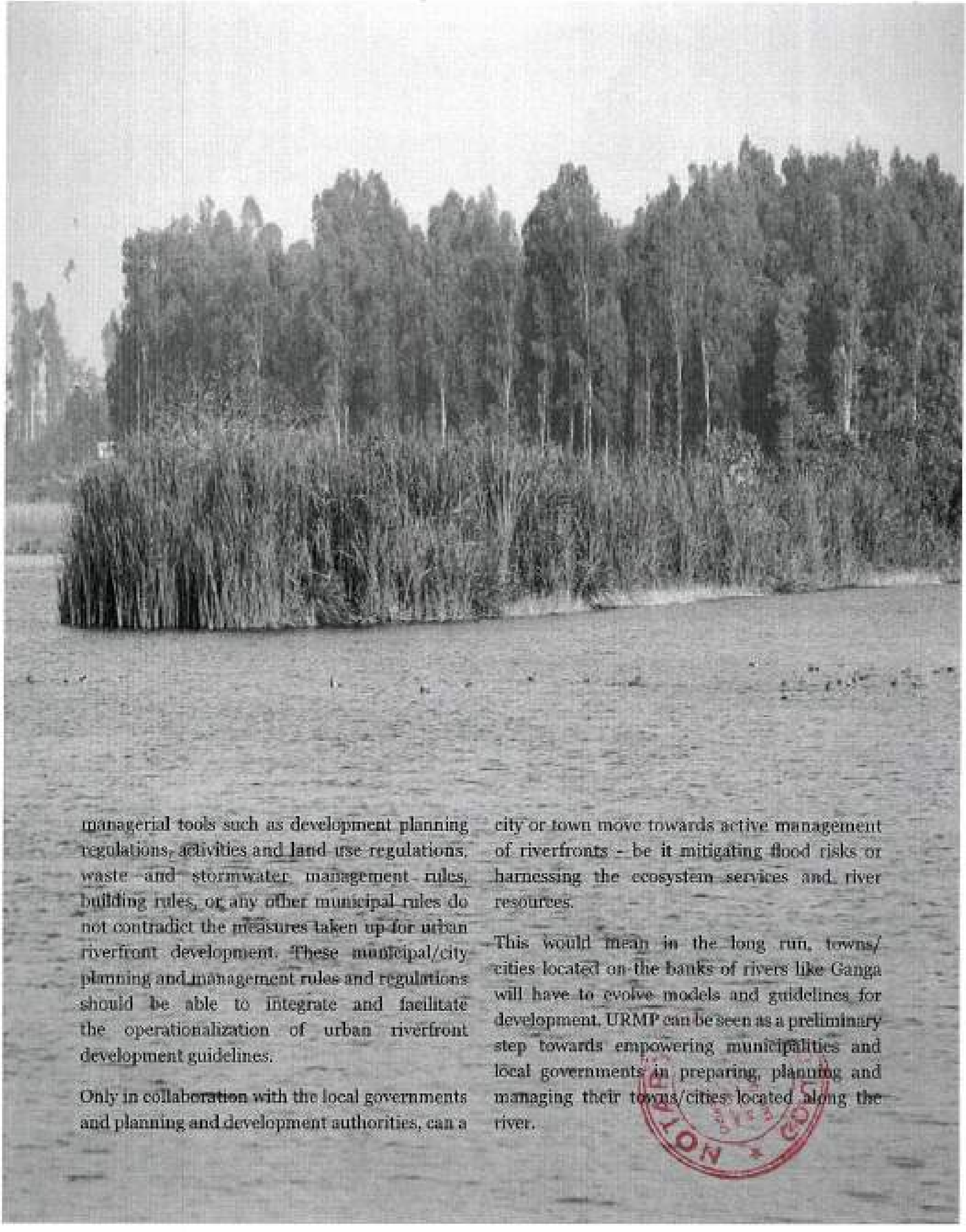
Interrelation between URMP and URFD

Urban River Management Plan (URMP) (NGRBA 2010), which is a city specific comprehensive planning document meant for better management of urban rivers (as well as water bodies and associated ecosystems), should ideally inform Urban Riverfront Development proposals. This is because URMP provides the following plans and information which are critical considerations for URFD projects:

- Runoff from urban watershed
- Waste and effluent discharge from the city to the river
- Access, use and management of riverine and riparian edges and buffers; have direct environmental and social impact on the health of the river and its ecology

Regulatory or management measures for the river therefore cannot be limited to the river, or its immediate edge/buffer but has to extend to the source, especially the watershed of immediate impact and gradually the entire basin itself.

It is also important that administrative and



managerial tools such as development planning regulations, activities and land use regulations, waste and stormwater management rules, building rules, or any other municipal rules do not contradict the measures taken up for urban riverfront development. These municipal/city planning and management rules and regulations should be able to integrate and facilitate the operationalization of urban riverfront development guidelines.

Only in collaboration with the local governments and planning and development authorities, can a city or town move towards active management of riverfronts - be it mitigating flood risks or harnessing the ecosystem services and river resources.

This would mean in the long run, towns/cities located on the banks of rivers like Ganga will have to evolve models and guidelines for development. URMP can be seen as a preliminary step towards empowering municipalities and local governments in preparing, planning and managing their towns/cities located along the river.

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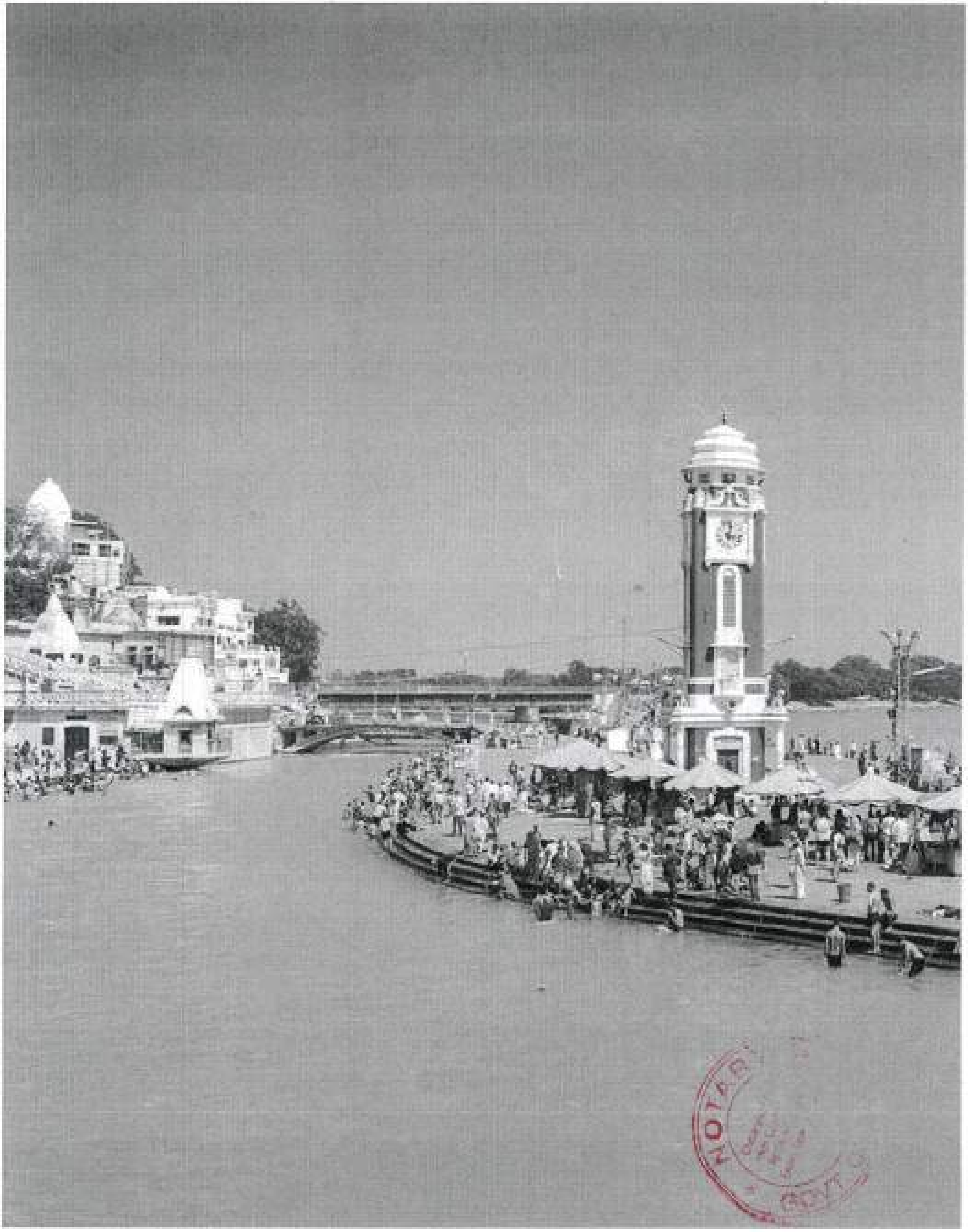
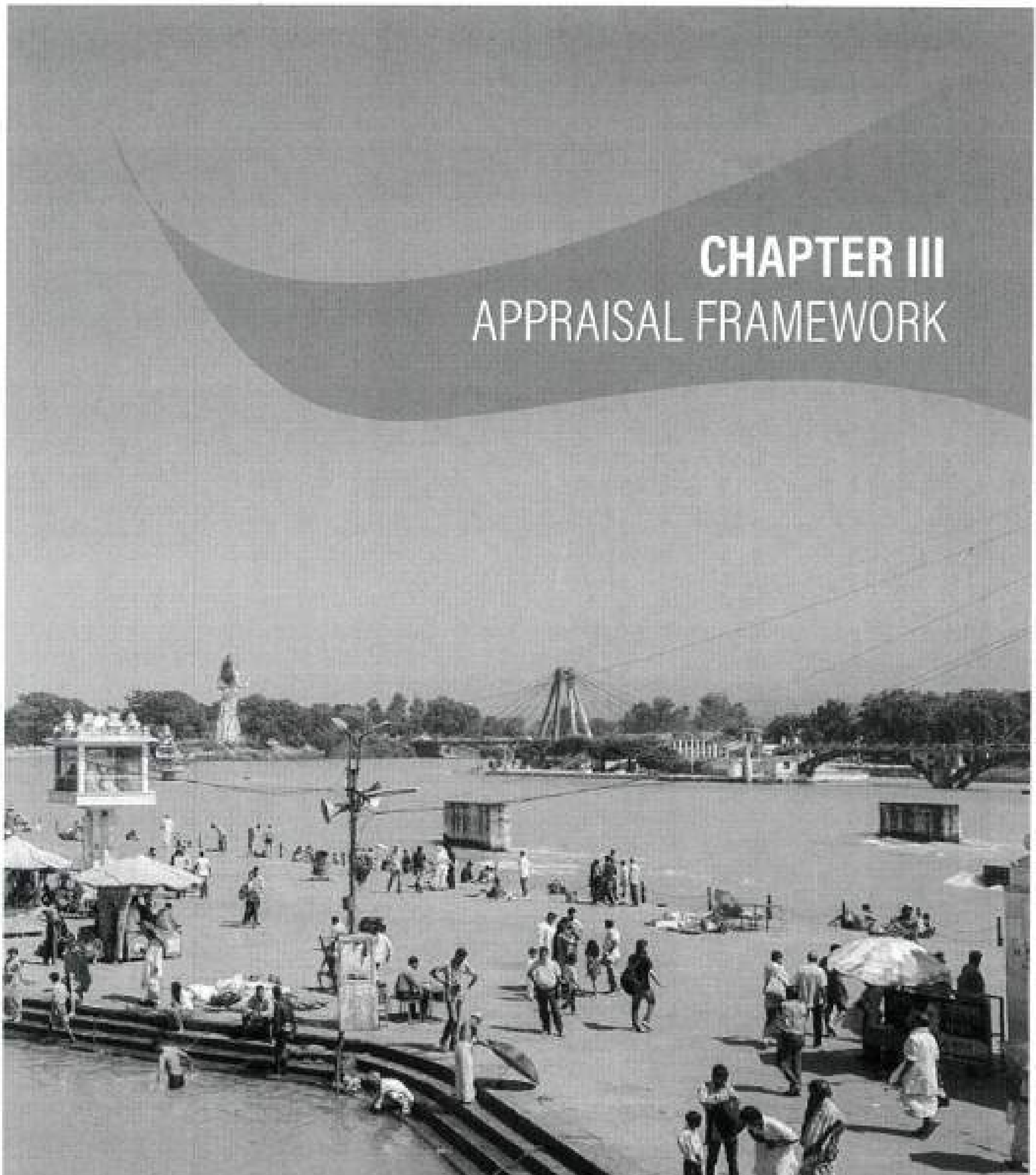


CHAPTER III

APPRAISAL FRAMEWORK

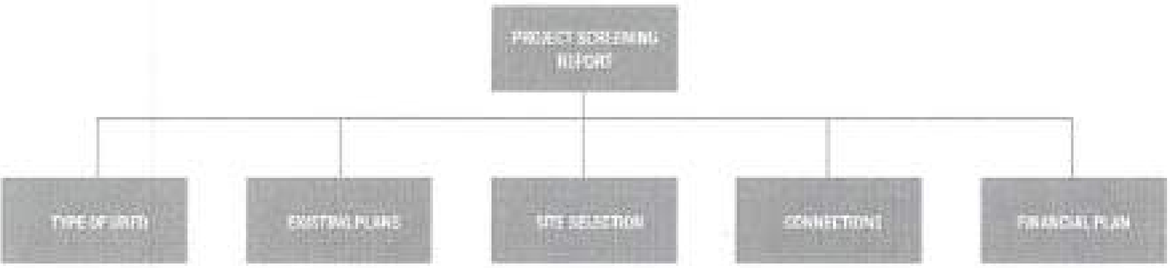


CHAPTER III: APPRAISAL FRAMEWORK

A new urban riverfront planning and development appraisal framework is being proposed for appraisal of urban riverfront development (URFD) proposal and to make sure the proposed project and associated investment is environmentally sensitive, climate adaptive and socially inclusive. A set of project reports should be the basis of phased evaluation, approval or rejection of a URFD proposal. The guidelines for preparation of the project reports are discussed in the subsequent section. The project proponent should prepare a Project Screening Report (PSR) first followed by a Detailed Project Report (DPR) if the project proponent receives an (conditional/ unconditional) approval on the PSR.

[A] Project Screening Report (PSR)

A Project Screening Report (PSR) is the initial high-level project report that a project proponent should prepare for preliminary approval prior to the development of a detailed project report. No expensive primary data collection and consulting services is required for the development of the PSR report. A PSR should contain the following information:



A.1 Type of Proposed URFD Project

Every urban riverfront development (URFD) project is different and requires planning solutions appropriate to its unique conditions. Accurately classifying these unique conditions is an essential first step. Factors to consider are:

- Energy environment of the floodplain; and
- Development intensity

Energy Environment of the Floodplain

Energy environment of the floodplain (Knighton 1984) reflects the interrelation between a river stream's ability to do work (as estimated using specific stream-power) and the erosional resistance of the floodplain (as estimated from sediment size). There is an inverse relationship between the erodibility of a river and sediment size. The classification is as follows:

- High and Medium Energy Floodplain - those floodplains are comprised largely of non-cohesive alluvium (gravel to find sand)

Figure 5 | Ganga flowing in upper Himalayan range

Image Credit: Asdelhi95, Wikimedia Commons

- Low Energy Floodplain – those floodplains are comprised largely of cohesive alluvium (silt and clay).

Figure 6 | Slow flowing river/ streams in Sunderbans

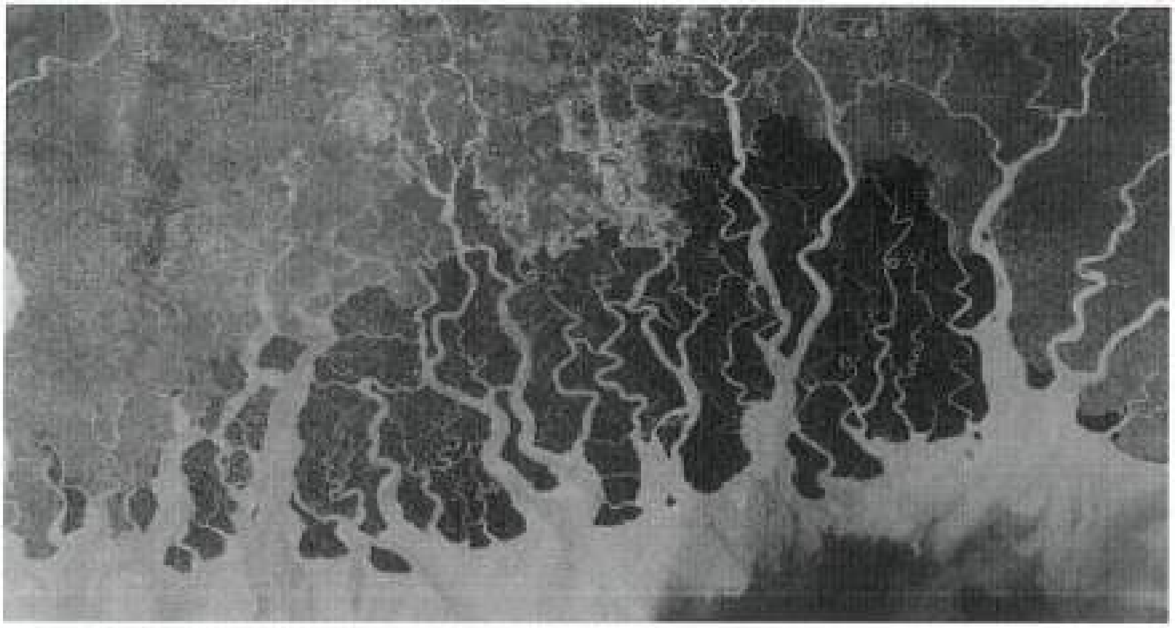


Image Credit: Jitendra Katha

Development Intensity of the URFD

The devtelopment intensity of a riverfront corridor can be classified according to the degree or percentage of impervious cover—hard surfaces such as buildings, streets, parking lots, and sidewalks—found within the corridor. A basic classification system might be:

- ultra-urban (80 to 100 percent impervious cover)
- urban (40 to 79 percent impervious cover), and
- suburban (10 to 39 percent impervious cover) (Center for Watershed Protection 2003).

An URFD may fall under a straightforward classification or have a mix of classifications (for e.g., densely developed downtown-commercial riverbanks to stretches of more naturalized riverbanks in suburban-residential areas).

A.2 Interrelation between Existing Plan(s) and URFD Proposal

Existing city level master plans and land use plans should be examined to identify opportunities for spatial integration of open green spaces with the riverfront and riparian zones. Any proposed URFD spatial plans should be informed by the city level master plan and land use plans. Local area spatial development plans should be developed to include the spatial and visual re-linking of riverfront areas with the city public spaces and to create a network of green landscape infrastructure that is sensitive and incremental to the existing baseline of socio-economic and environmental values.

Additionally, the basin level management plan (if it exists) provides a comprehensive background on the environmental, ecological, hydro-geological, morphological, socio-economic and socio-cultural conditions and context of the river basin[ii]. It is important for the URFD project proponent to review and incorporate the suggestions and directions as mentioned in the respective basin level management plan within URFD plan.

A.3 Site Selection

In case of large rivers (such as the Ganga) which are managed through multi-layered institutional mechanisms, it is critical to examine the choice of a site for URFD. Where URFD proposals are developed on sites which are ecologically sensitive, vulnerable or the proposal is not socio-economically or socio-culturally viable, then the return on investment on the RFD project will be limited. To ascertain that a site is suited for an URFD project it is suggested that the following general guidelines be followed during site selection:

- **Preserve natural geomorphology of riverbanks:** URFD proposals (master plan or design) should not extensively affect or damage existing geomorphic features of the riverbanks. Geomorphic features and the active floodplain can be mapped using high-level remote sensing technology. Morphological features may include; river islands, floodplains, estuarine wetlands, etc.
- River features are not only evidence of how a river behaves, it is also a self-regulating mechanism of the river to manage its course. Destruction of these natural and dynamic formations of the river within its floodplain will make the riverbanks and settlements alongside much more vulnerable to inundation/flood risks and erosion. Urban riverfronts have to be sensitive to the river features, both geomorphic and ecological.

Figure 7 | Use of remote sensing to map river morphological features and change over time - Patna, India

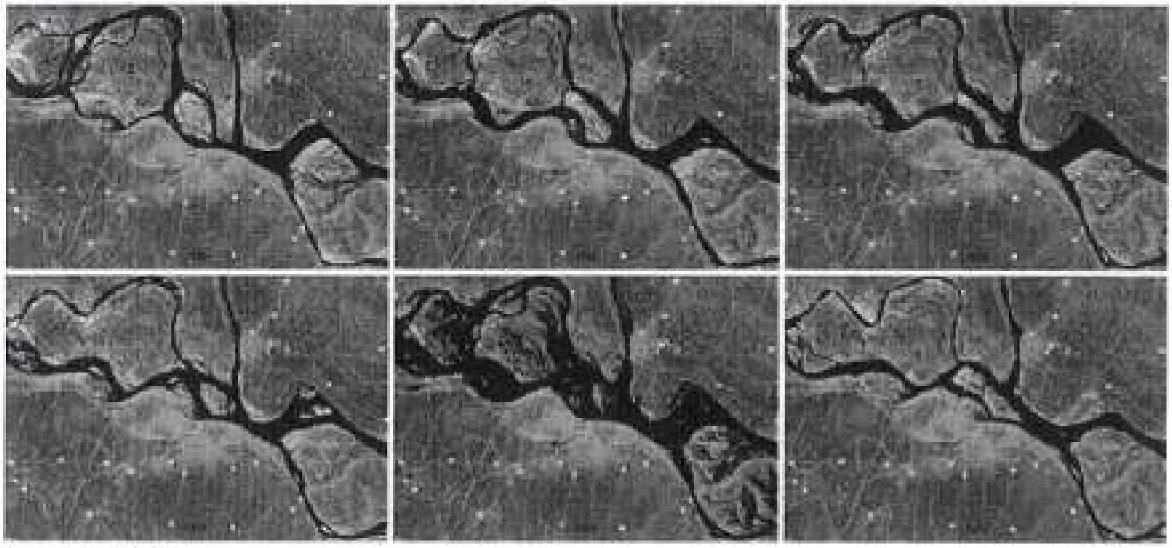


Image Credit: WRI India

Box 3 | Altering river geomorphology: issues with concretization of natural waterways - Los Angeles River

Channelization of the 51-mile Los Angeles River and its tributary streams was carried out by the U.S. Army Corps of Engineers in 1938 to quickly remove stormwaters from urban areas and direct them to the ocean (Otto, McCormick and Leccese 2004). Since then the city of Los Angeles has continued to reduce its natural and cultural connections and dependence on the river. Industrial development grew along the channelized river but from the 1980s industrial decline has left large expanses of brownfield sites along the river.

Figure 8 | Concretisation of the Los Angeles River in 1938 (Masters 2017)

Image Credit: Nathan Masters

Today, studies indicate that the excessive hardscape and concrete-lined riverbanks have resulted in poor water quality caused by urban runoff and the destruction of native habitat. The original rational for the concrete channel system was to move stormwater out to the ocean as quickly as possible after rainfall events. This objective is being re-evaluated now given the region's dependence on imported water, depletion of groundwater and the impacts of stormwater pollution on state beaches. The series of plans to renew the Los Angeles River centre around naturalizing the river course by removing the concrete channel and approximating a natural river channel.

- **Preservation of floodplain:** The floodplain is the space of the river which allows for the accommodation of variabilities in river dynamics; such as increased volume of water, debris load, etc. The floodplain is also a critical belt and hosts riparian biodiversity which is fundamental to ecological functions such as nutrient assimilation, water quality regulations, inundation regulation, etc. Urban riverfront master plans should be planned and designed to include the floodplain extents such that no new permanent-built constructions are allowed within the floodplain; and all new permanent-built constructions should be allowed only beyond the floodplain. Where space is limited (as is often the scenario in urban areas), the permanent structures constructed may be elevated above the high flood level to minimize the impact on floodplain ecology and environment. Where floodplains have been altered, these should be revived to natural conditions (if not consumed by the city) through landscaping and bio-engineering interventions. Any spatial interventions to provide access to the river in the floodplain should be limited to temporary structures on stilts, or floating members using natural materials like coir, wood, rubble/boulders.

Figure 9 | Characteristics of a river floodplain

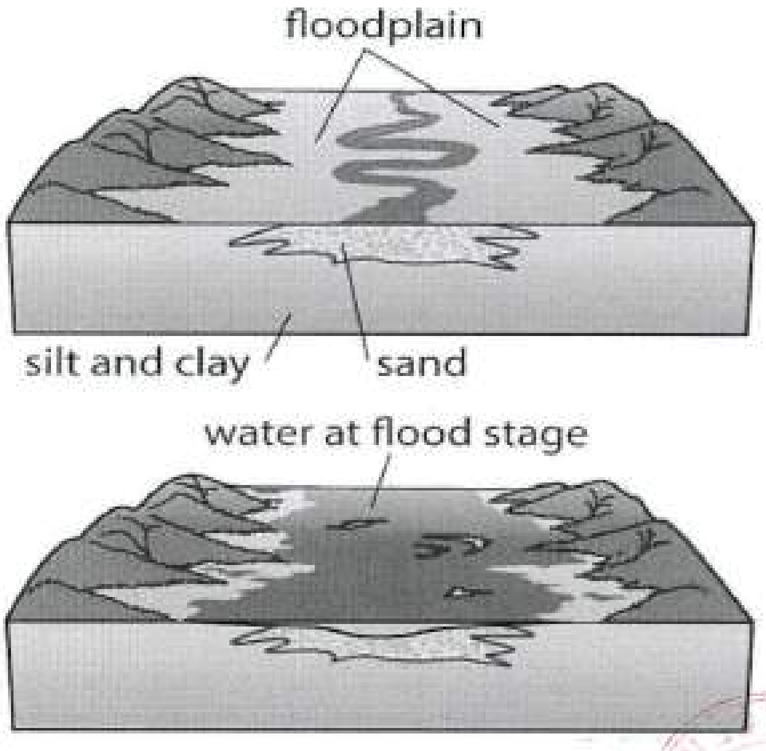


Image Credit: Elizabeth Morales

URFD proposals should necessarily include blue green infrastructure (ecological design elements and nature-based solutions) integrated with minimal grey infrastructure (built-up development). Areas which are highly vulnerable to erosion with unstable landform and edge conditions are also locations along the river which require special attention.

Spatial analysis tools such as remote sensing and GIS mapping are robust planning tools that can help categorize floodplains depending on return period (for example: delineation of 50 year floodplain or 100 year floodplain). This detailed definition can empower policy makers to take informed decisions regarding safe permanent and temporary uses along urban rivers. The Delhi Development Authority (DDA) in collaboration with School of Planning and Architecture, Delhi and CSIR-National Environmental Engineering Research Institute (CSIR-NEERI) has mapped the floodplains of River Yamuna. A biodiversity park has been approved and is being implemented in Zone O which is identified as protected riverine ecology (NGT 2020).

Box 4 | Bioengineering as an ecological river restoration tool - Sammamish River Trail

The Sammamish River in Redmond, Washington State, USA is considered a critical component for flood management for the urban and rural communities along the river. In the 1960s the natural river course was converted into a concrete channel for quick diversion of stormwaters away from inhabited areas. Increased urbanization in this watershed has increased the risk of flooding as development has occurred closer to the water course and pressures on grey stormwater infrastructure has also increased. The river was also an important migratory path and breeding ground for various fauna such as salmon and trout (Knutson and Wood 2009) whose numbers had reduced following the channelization of the river.

Rather than rely upon the Army Corps' traditional approach to controlling the river, in the 1990s project planners sought to let the river be a river as part of river restoration. The river restoration master plan had two major objectives - to create a more natural waterway that is accommodating to people and wildlife and continues to provide flood control and protection to the neighbouring communities. The project combined bioengineering, in-stream habitat construction, and weed removal. The floodplain was enlarged by 50 feet through sculpted riverbank "benches" planted with native vegetation. The river's meanders and curves have been revived by adding boulders, root wads, and gravel bars to the once-uniform channel. The bank was graded into a series of earth benches. The top of the bank was moved back from the river about 50 feet at its maximum point. These benches were planted with native vegetation and provide the potential for different habitat zones. They also are helping to maintain the river's flood-flow capacity.

The restored riverfront has become the centrepiece of a new 16-mile trail that connects to a regional greenway system. Salmon, steelhead, native trout, and upland riparian species have returned to the river and its banks (Holt 2002).

- **Managing grey (built up) infrastructure in and around the URFD:** Dams, embankments, bridges and culverts are structures that alter the characteristic of a river including ecological/ environmental flows, ecology, inundation extents and morphology of the river. Apart from the health of the river, the immediate precincts upstream and downstream of dams are also vulnerable to natural disasters. It is important to identify, map and describe (including potential risks and qualitative impacts of such structures) such existing and proposed structures (up-stream 20 km and downstream 10 km) as part of the PSR.

  In cases where development (settlements, or roads) has already taken over in downstream reaches rehabilitation measures for older/ original floodplains must be prioritized. The rehabilitation efforts must be supported with bio-engineered measures and water diversion mechanisms which can operate or carry water that inundates beyond the floodplain.

- **Locations with polluting land uses:** It is important to identify, map and describe (including photo-documentation) treated and untreated wastewater (domestic and industrial) discharge points and solid waste dumping locations. In cases where such points exist within the river precincts/riverfront, additional measures to mitigate pollution risks have to be taken. Suggested measures include: placement of bio-retention ponds, reed-beds, bio-engineered swales, gross pollutant traps, filter strips, etc., at the edge of such land uses. The suggested measures can reduce the intensity of pollution in such cases.

Box 5 | Pollution mitigation for river restoration - Sligo Creek, Maryland, Washington DC

In Montgomery County, Maryland, near Washington, D.C, the 13.3-square-mile Sligo Creek watershed, in poor condition before 1990, has benefitted from a reconstruction effort. More than 60 percent of the watershed had paved or impervious surfaces. The creek was polluted by combined sewer overflows (CSOs) during storms. As a result, only a few fish species— none of them native—survived in Sligo Creek.

From 1991 to 1994, Sligo Creek received one of the nation's most extensive watershed wide restoration efforts—one that combined grey and green infrastructure interventions.

The water quality in the creek and its tributaries were improved by separating storm and sanitary sewers to eliminate CSOs and through revegetation, bank stabilization, and reconfiguration of in-stream flows.

Upstream, three connected ponds were built to detain runoff for up to 36 hours after rainfall events, which allowed pollutants and sediments to settle and not be carried downstream in runoff.

The downstream channel was completely rebuilt with 19 native shrub species reintroduced to the riparian zone. Volunteers then reintroduced native fish to the streams.

By 1996, fish species had increased from three to 16, including native and pollution-sensitive fish. Fish deformities, lesions, and tumours dropped 75 percent. New greenway trails provide access to this revitalized resource (Thompson 1996).

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Box 6 | Pollution mitigation for river restoration - Dravyavati Riverfront Development, Rajasthan, India

The Dravyavati River originates in the Aravalli Hills in India, flows through the city of Jaipur for about 47 kilometres collecting stormwater and wastewater and connects with the Dhund River further downstream. The river faced typical urban stresses, such as encroachments, water pollution and solid waste dumping as the city urbanized and in 2012 there was a significant flood event leading to high loss of life and property. The flood event caused a major rethink of the river's presence and importance in the city and plans to rejuvenate the river and resume the waterfront were undertaken by the TATA Project Limited on behalf of the government.

To maintain a pristine riverfront and continuous flow of water, a significant challenge was to intercept and treat the sewage and industrial effluents that were entering the river. To achieve this outcome 5 sewage treatment plants have been constructed along the length of the river to treat up to 170 million litres of wastewater per day (TATA Projects 2018).

Figure 10 | Before and after pictures of Dravyavati River, Jaipur

Image Credit: Tata Projects

A.4 Connections

Rivers are complex networks with physical and functional connections to subsidiary streams and tributaries that flow into as well as distribute its water. The relation between rivers and settlements primarily develop due to access to natural resources, cultural drivers, and to increase the value of neighbouring properties. To leverage benefits of an urban river through an URFD the natural and spatial connections and links have to be strengthened.

- **Connection of river with tributaries, distributaries, lower order streams and immediate micro-watershed:** Physical disconnection or disruption of the functional links between the main river and any streams (tributaries flowing into it or distributaries flowing out of it) or any lower order natural streams should be avoided. The immediate micro watershed along the river is also an extremely important connection of the river with its larger system and hence the URFD should necessarily avoid (impermeable) hardscapes to ensure that the surface and sub-surface flows are self-regulated.
- **Connection of city's green open spaces with the riverfront:** Riverfront development is an opportunity for creating well connected, universally accessible public spaces for citizens. Derelict river edges can be rejuvenated under such projects thereby ensuring that these spaces are converted into vibrant and thriving urban districts. Spatially and physically connecting to a city's popular and important public spaces and parklands increases accessibility to and footfall in riverfront districts. Connecting open green spaces with the riverfront also provide safe corridors for biodiversity movement which can help restore fragmented and degenerated natural habitats (parks/ sacred groves, etc.) existing within a development/city.

Figure 11 | Stream order

Stream order classifies streams according to their size and position in the watershed. When two first-order streams intersect, the downslope stream is assigned an order of two. When two second-order streams intersect, the downslope stream is assigned an order of three, and so on. This most common method of ordering is known as the Strahler Method.

Image Credit: K. Ferraro

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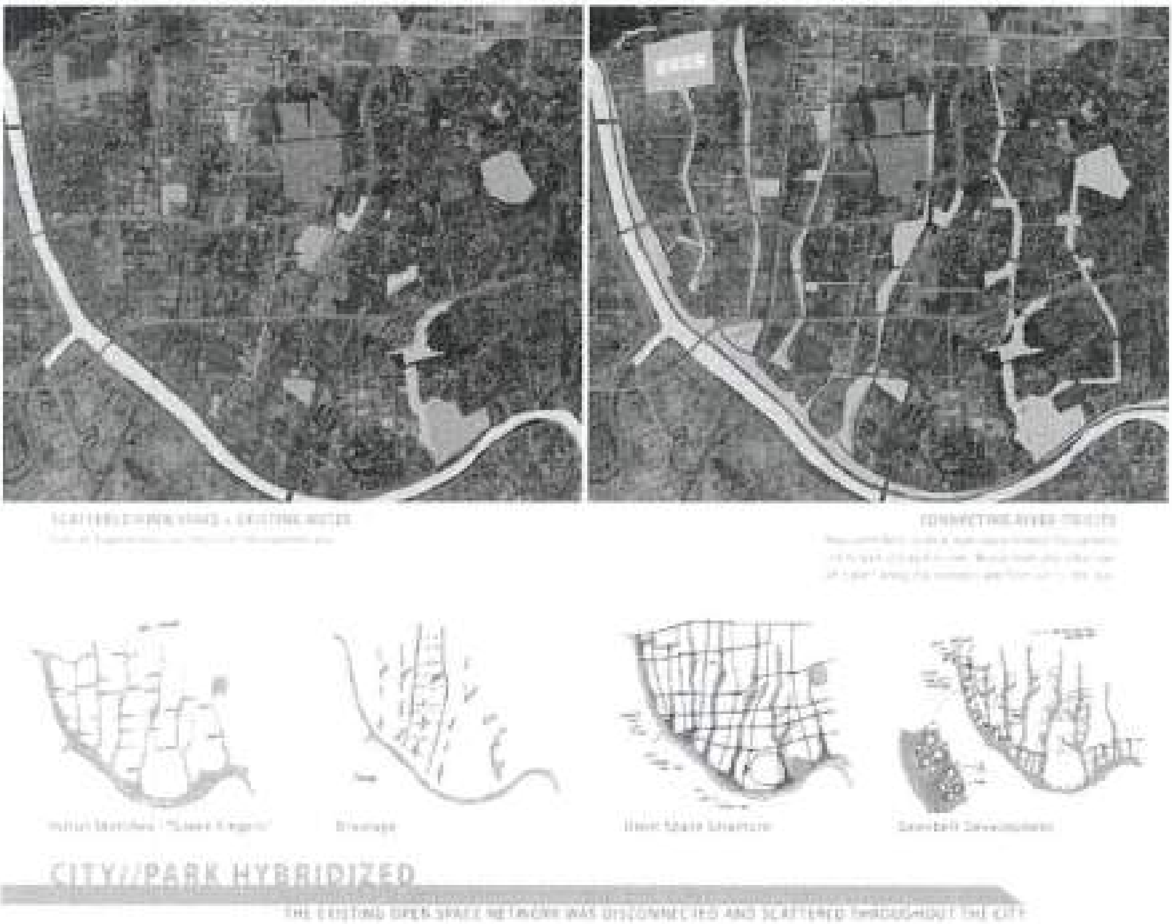
Figure 12 | Connecting city to river



Source/Image Credit: SWA Group, Laguna Beach, CA (ASLA Professional Awards 2013)
https://www.asla.org/2013awards/212.html

- **Connection of city's pedestrian and cycling paths with the riverfront:** Creating cycling and pedestrian connectivity to riverfronts, is the most direct way to make riverfronts accessible. Additionally, river-front cycling paths and walkways that are shaded will attract more people to the riverfront. While providing such increased accessibility, it is also important to provide ancillary infrastructure. It is also commonly observed in many cases of riverfront development that cycle-traffic can cause disturbance to the public space and therefore cycling access will have to be regulated. It is also important to ensure that cycle paths do not dominate or obstruct the view to the riverfront or affect the riparian habitat. Pedestrian and cycle paths should not be constructed on the floodplain unless the floodplain is already lost to development.

Box 7 | Connecting green and pedestrian corridors with riverfront – Sammamish River, Redmond, Washington

The Sammamish River in Redmond, Washington, is typical of many urban and suburban streams. The river lost much of its riparian area and native vegetation when the U.S. Army Corps of Engineers straightened and reconstructed the river into a deep trapezoidal channel in the 1960s. Straitjacketing the river destroyed habitat and dealt a blow to its once-abundant salmon. In the 1990s, a stretch of river was refurbished.

Using a multidisciplinary approach, community groups and other stakeholders came together to revitalize Redmond's waterfront. Among the groups involved were project designers, Parametrix, the City of Redmond, King County, public agencies, and the citizens of Redmond.

Behind City Hall engineers recreated the river's meanders and curves, and added boulders, root wads, and gravel bars to the once-uniform channel. Tying these restoration projects together is Redmond's new riverwalk, a thoroughfare for joggers, bikers, and shoppers.

The Sammamish River Trail links the communities of the Sammamish Valley with the King County trail system. The county hired JGM-Landscape Architects to develop a master plan that includes trails, fishing opportunities, planting buffers, and wildlife habitat enhancement. Currently underway is a water conservation demonstration garden where residents can learn low-water use and environmentally friendly gardening techniques as part of public stewardship of the river's ecology.

Figure 13 | Pedestrian access to spaces within a 5-minute walk of the riverfront

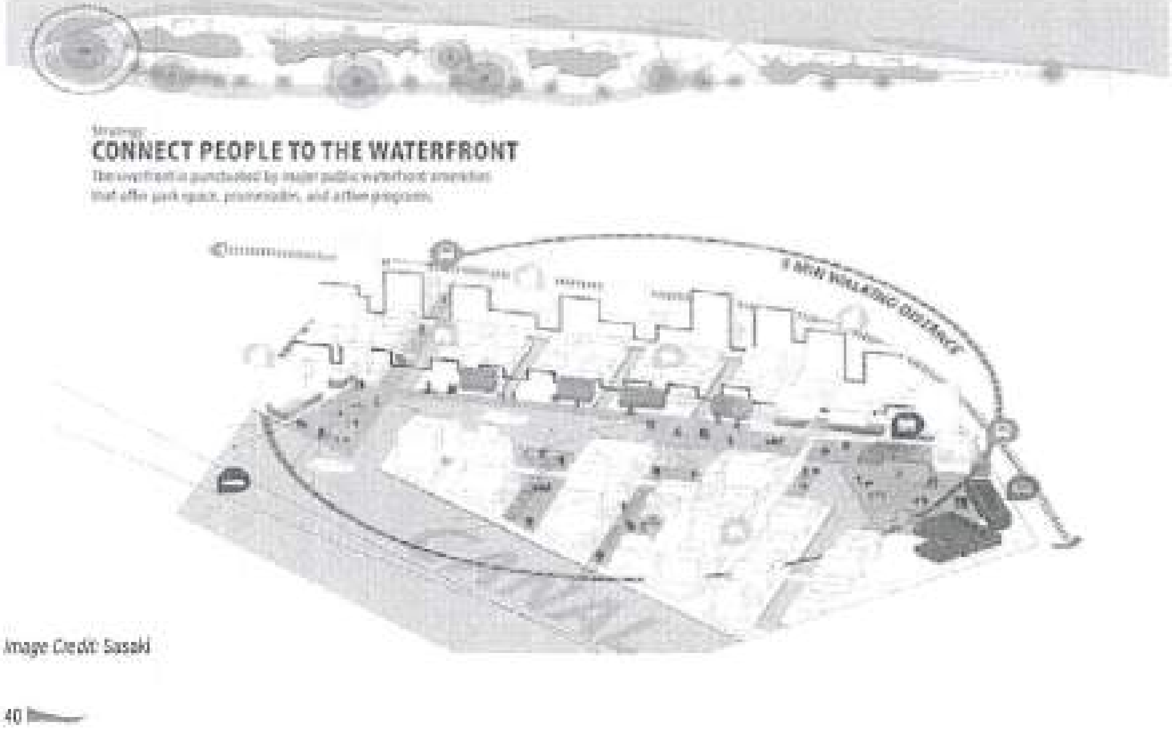
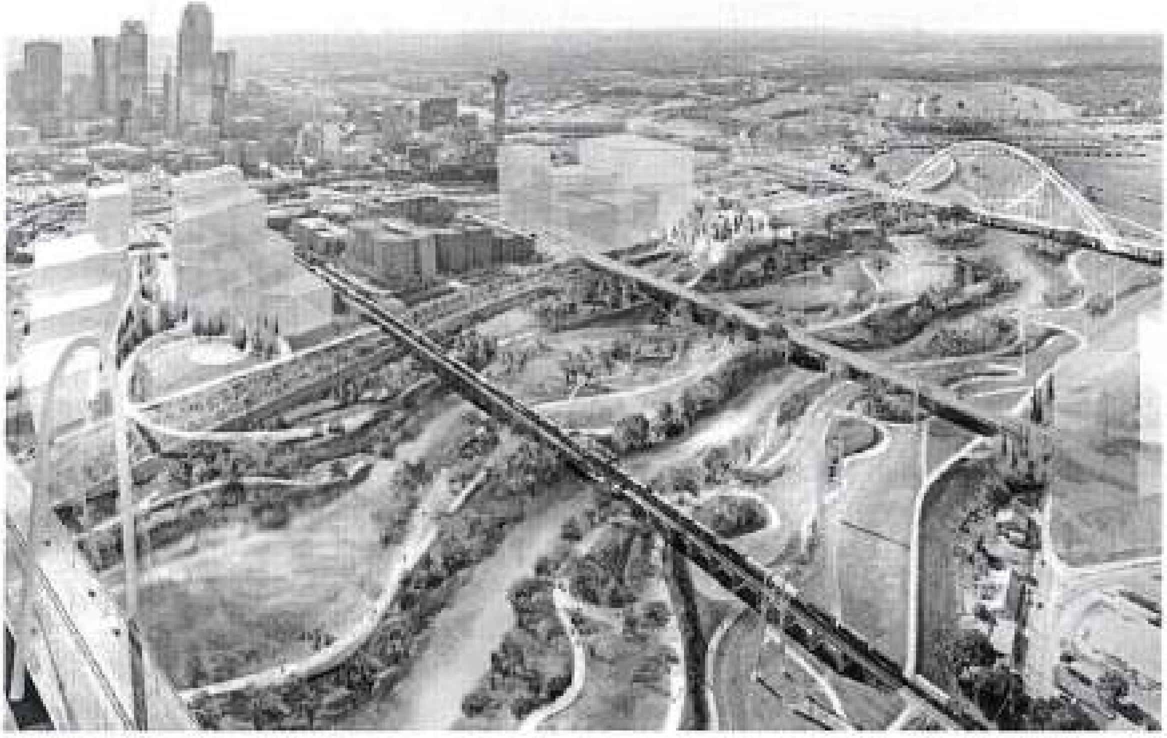


Image Credit: Sasaki

Figure 14 | Trinity River Park in Dallas, Texas



Source/Image Credit: Michael Van Valkenburgh Associates Inc.

A.5 Financial Plan

In addition to multi-stakeholder collaboration, a financial plan must be part of the planning strategy for URFDs. The financial plan must include an outlay for pre-design studies, design and implementation phases and for operations and maintenance, and monitoring and evaluation works that will have to be undertaken post-implementation. The financial plan can propose drawing upon national and state level funds from river rejuvenation programs.

A.6 Development of Key Performance Indicators

As part of the PSR it is recommended to develop a series of Key Performance Indicators (KPI) which can be used to evaluate whether certain required outputs and outcomes have been achieved through the subject URFD project. Below is an indicative list of possible KPIs that can be considered. This is not an exhaustive list and project proponents are urged to create KPIs to address the unique context of their location and community. Once relevant KPIs are considered for a project, the project proponent must establish benchmarks for the same, so that change over time (pre and post-project impacts) can be monitored.

- Safety, security and access indicators:
  a. Projected increase in public access to river
  b. Degree of equitable and inclusive connectivity – pedestrian and non-motorized transport network to connect urban areas with the proposed riverfront

c. Degree of access to differently abled and vulnerable groups (children, elderly, etc. Inventory of elements enhancing accessibility (ramps, directional pavers, etc.)

    i. Inventory of elements enhancing accessibility (ramps, directional pavers, etc.)

    ii. Inventory of safety elements (lighting, lifeguard booth, etc.)

- Enhancement of the public realm indicators:

    a. Measure increase in area of enhanced public space from pre-project state. (enhanced public space can refer to new plaza space, park space, river walk, etc., that has been created)

    b. Type and number of amenities and services to enhance public space (drinking water, toilets, etc. Ideally number of amenities should be as per global standards of services stated; such as minimum of 1 toilet cubicle per 550 women or female children; minimum of 1 toilet cubicle per 1100 men (ASEAN 2016))

- Ecological functions indicators:

    a. Number of natural infrastructure interventions included which provides

        i. Treatment capacity of X million litre per day

        ii. Storage capacity of Y million litres for certain range of rainfall event

    b. Pollution abatement numbers

        i. Pollution reduced by X% from pre-project stage

        ii. Water quality of output from nature-based systems meets Pollution Control Board standards for discharge into water body

    c. Increased biodiversity

        i. Increase in number of species in comparison to pre-project stage

        ii. Increase in total number of individuals per species in comparison to pre-project stage

    d. Micro-climate changes

        i. Reduction in daytime/night-time temperature in comparison to surrounding areas

- Economic benefit indicators:

    a. Projected increase in tourist footfalls to the site and associated revenue generation

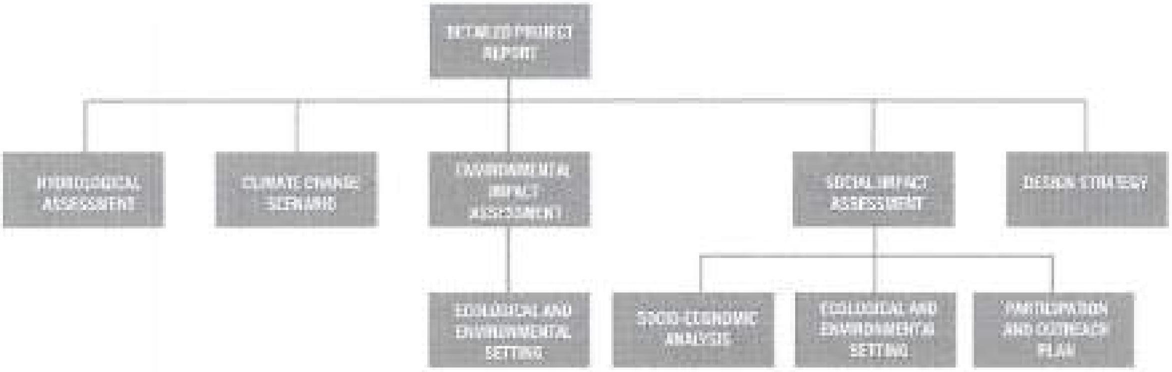
    b. Projected revenue generation from site amenities

    c. Projected increase in informal (vendors, artisans, fisherfolk) livelihood generation

    d. Projected increase in surrounding (beyond designated floodplain) land value generation and tax revenue collection

[B] Detailed Project Report (DPR)

A Detailed Project Report (DPR) should be undertaken if the PSR is approved by the appropriate stakeholders and decision-makers. This is a follow-on detailed study which should be carried out by collecting primary data, modelling, stakeholder consultation, etc. A DPR report should contain the following information:



B.1 Hydrological Assessment

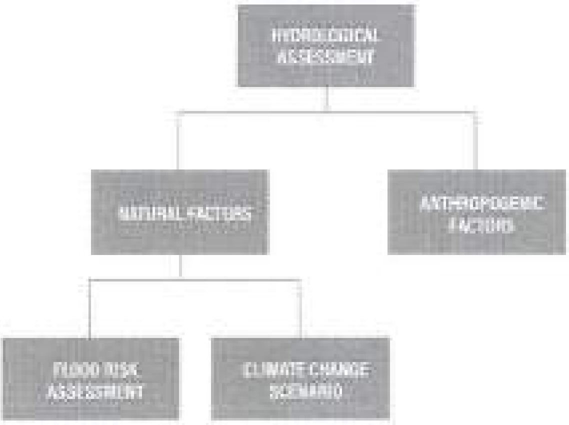
The hydrological setting of every river system is anchored on intrinsic or extrinsic (anthropogenic) aspects. While rivers in pristine conditions and away from any human interventions would have only intrinsic aspects governing their hydrological settings, most rivers round the world are considerably influenced by extrinsic anthropogenic aspects.

The key intrinsic factors that determine the hydrological setting of any stretch or part of the river is: origin and source of water, the terrain and landform through which the river flows, the geographic region that it is located in. Within the river, the hydrological setting changes when the river moves from upstream reaches to midstream reaches and it is considerably different downstream and near its sinks (usually deltas/estuaries before flowing into the sea/ ocean).

Therefore, to determine and understand the hydrological setting of a river or a segment of a river, following aspects and related parameters and indicators can be examined and studied:

- Water quantity: incident rainfall in the basin and runoff generated, time of concentration together determine the rate of flow and volume of water in the river at any given time (river hydrograph analysis)
- Hydrodynamics: river features created by the flow of river and the geomorphology of the valley
- Source of water: glacial, rain-fed, lake, sub-surface streams (groundwater)
- Variability of inundation during peak and lean flows
- Saline water intrusion extent in the estuary (in lower reaches of river segment), the inundation extents during high tide and low tide events of the sea

In addition, the following generic list of natural and man-made problems which are normally encountered in river hydrology should be evaluated as per the guideline mentioned by Central Water Commission, Government of India (CWC 2009).



Natural Problems

- Frequent changes in river course.
- Avulsion of one river into another (beheading).
- Heavy shoal formation causing diversion of the main current towards the banks.
- Development of natural cut-off in meandering rivers. This, sometimes, changes the meandering pattern.
- Heavy landslides in the catchment causing sudden and steep rise in silt load.
- Heavy aggradation of the riverbed. This causes high flood levels resulting in overtopping of banks/embankments even during floods of relatively moderate intensity.
- Heavy erosion of banks by hill streams due to flash floods.
- River instability due to changes in bed slopes as a result of seismic activity.
- Changes in river channels due to changes in rainfall pattern.
- Erratic behaviour of rivers in deltaic areas where they have numerous spill channels.
- Erratic behaviour of braided rivers.
- Morphological changes in a river due to changes in its base flow (too little or too much water).

Anthropogenic Problems (primarily forward-looking risk identification study)

- Degradation of riverbed downstream due to any future dam or barrage construction.
- Effects of constriction of river width due to any future barrage/bridge construction.
- Effects of any future flood embankment project on the regime of rivers.
- Effects of extraction of sand and boulders from the riverbeds and banks.
- Effects of spurs and bed bars of different types on river behaviour.
- Effects of inter-basin transfers of water on the regime of river.
- Effects of riverbed cultivation and construction by farmers in a river reach.
- Effects of dredging/channelization of riverbed.
- Effects of any current and future RFD and ghat development on the regime of river.
- Effects of growing urbanization on the regime of river.

Flood Risk Assessment

Also, it is extremely critical to undertake a flood risk assessment study to determine the following:

- High Flood Level (HFL) for a return period of 100, 50 and 30 years, Danger Level (DL), Warning Level (WL) and annual normal flood level
- 100-year-old floodplain extent
- 50-year-old floodplain extent
- 30-year-old floodplain extent

Large permanent structures should not be built within the 100-year floodplain because they increase the amount of impervious surface, exacerbate runoff problems, and increase the risk of costly flood damage (Otto, McCormick and Leccese 2004).

Box 8 | Flood protection - Patna Riverfront, Bihar, India

The riverfront in the city of Patna, India has a dense urban edge, in that habitation (formal and informal), education institutions and government offices are placed along the river edge with nominal elevation from the river level. The river too has annual flooding events and the high flood level is significantly higher than the surrounding inhabited areas, making all these human activity zones vulnerable to flooding. To mitigate this risk the riverfront development project has constructed an embankment wall along the project to reduce the risk of flood events which can damage habitation and official spaces (VOYANTS 2014).

Figure 15 | Embankment walls along riverfront to protect built spaces in the city

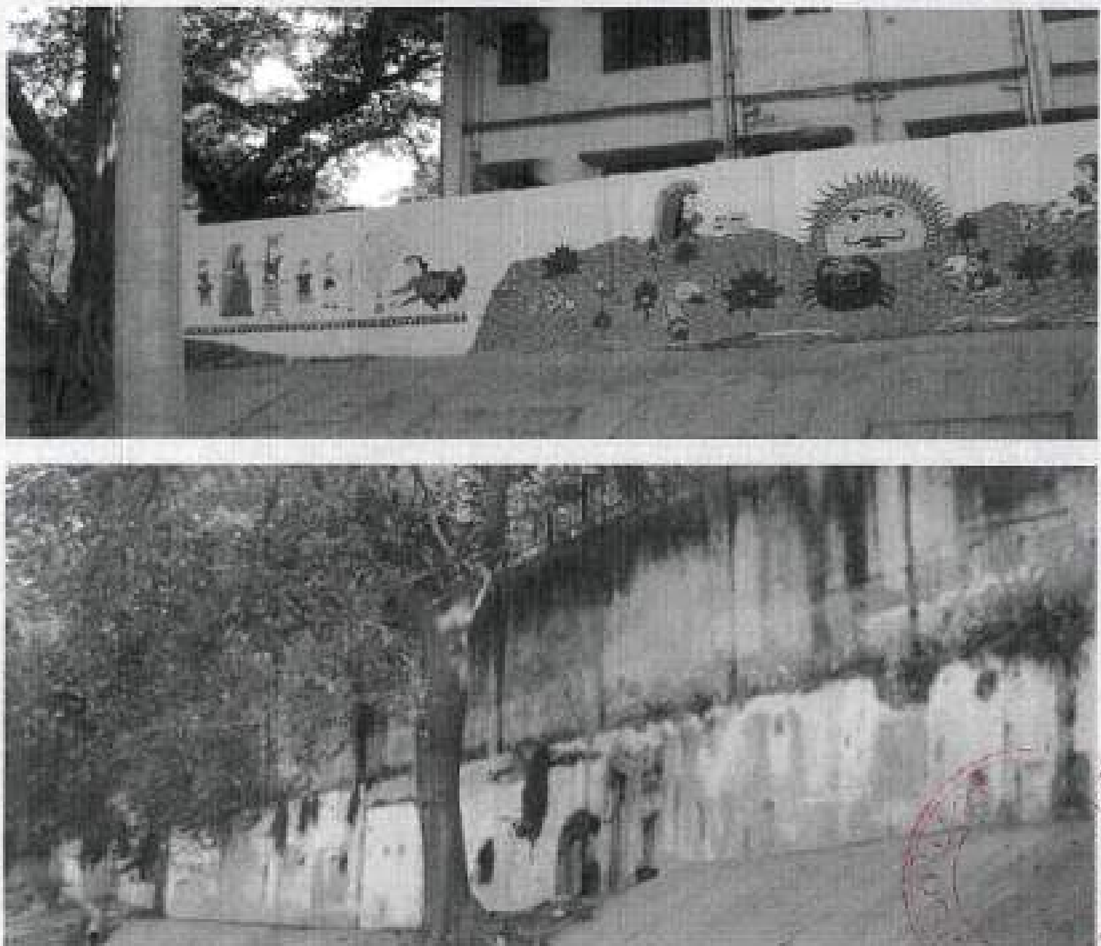


Image Credit: WRI India

B.2 Climate Change Scenario

Climate change poses a high risk to urban infrastructure and services as extreme weather events (particularly floods) can potentially overwhelm engineered systems. Furthermore, capacity of urban local bodies has to be strengthened to comprehend and plan for climate uncertainty and adapt/ adjust planning and construction codes so that new build and retrofit of existing systems can be done so as to mitigate forecasted climate extremes (GCA 2019).

Box 9 | Sponge City Program in China

Urban areas are vulnerable to extreme weather events; hydrological assessments of urban water bodies (lakes, streams and rivers) can help in the mapping of at-risk areas by understanding the flow quality of urban waters. Cities can no longer depend exclusively on grey infrastructure solutions to mitigate against climate change driven extreme events. Rather, climate proofing using flexible tools and mechanisms (such as blue-green or natural infrastructure) and capacity and resilience building is critical for cities to adapt and maintain their economic prominence.

The Sponge City Concept (SPC) developed in China is a resilience building measure and water management tool for cities to mitigate effects of environmental changes and natural disasters. The objective of the SPC is that stormwater generated from rainfall events is absorbed, stored, infiltrated and cleaned using natural and/or manmade facilities and the rainfall and stormwater is transformed into a water resource that may be utilized during times of drought (MHURD 2014).

The SPC aims to shift the traditional thinking and approach around stormwater management which focuses on the quick discharge of runoff to avoid flooding and inundation. Instead SPC looks to capture and utilize stormwater to the maximum extent possible as a critical water management practice. Under the SPC sustainable urban design and low-impact development is required so that a city builds resilience (and blue-green infrastructure) to adapt to climate change driven extreme events and provides ecological function (Chan, et al. 2018). The SPC concept is similar to some stormwater management concepts in developed countries such as low-impact development (LID), green infrastructure (GI), and water-sensitive urban design (WSUD) (Li, et al. 2016).

Figure 16 | Sponge city concept

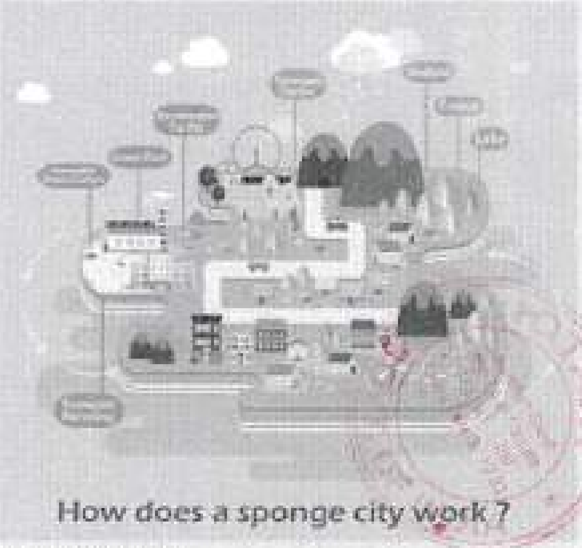


Image Credit: Scoopnest

Climate change is already bringing about distinct changes to river hydrology across India (Singh and Kumar 2018); (Sharannya, Mudbhatkal and Mahesha 2018). Shifting rainfall patterns, hotter and drier summers and shorter and wetter monsoons are dumping more water in a shorter duration of time onto Indian rivers. In addition, research in the Himalayan regions indicate a significant increase in glacial melt rates which are likely to increase Indo-Gangetic river levels for a short period before dwindling down.

In this scenario the development of riverfront areas into key urban locations is fraught with uncertainty whether the riverfront will have viable water available throughout the year. It is, therefore, recommended that 100-year return period scenario of the flood risk assessment study as mentioned under hydrology section should be adopted in the feasibility study. Also, to have usable riverfront developments year-round, these developments must include flexible spaces which can accommodate a varied range of activities and functions.

Figure 17 | Sponge city in China

Image Credit: Business Insider

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Box 10 | Restoring and creating floodplains to allow river flooding during extreme wet period - Room for the River Program, Netherlands

The Netherlands is a country at high flood risk due to its location at the delta of three river systems - the Rhine, Meuse and Scheldt which flow into the ocean through this country. Furthermore, much of the country lies below sea level and is protected from flooding by the presence of levees, sea walls and coastal dunes. (Dutch Water Sector 2019). Over the past century, rivers in the Netherlands have been increasingly constrained and confined with higher dykes, and former floodplain zones have also decreased as new land uses have taken over these spaces. Higher volumes of water are expected in these rivers as a consequence of increased precipitation and frequent flood events due to climate change (Mott MacDonald 2019).

Since 2007, the Dutch government has implemented a programme to improve flood protection to vulnerable, low-lying areas by allowing rivers space to expand naturally (flood) when carrying high water volumes. A range of measures are implemented as part of this programme, including restoring/ reclaiming natural floodplains, deepening river channels, removing barriers to the flow of flood waters (such as dykes and bridge bases), areas to slow, retain and absorb flood waters and restoration of riparian wetlands to act as natural sponges (CEDA n.d.); (ruimtevoorderivier 2016). A mix of 9 different solutions have been implemented at 34 locations on the Rivers Ijssel, Rhine, Lek and Waal, with a budget of 2.3 billion euros.

The project necessitated collaborative working between national and local levels of government, various utilities, local businesses and communities. About 150 homes and 40 businesses had to be relocated in this project to make room for the rivers (UN-IHE 2013).

Examples of such floodplain restoration works and making room for rivers are also present in various other countries, with some notable emerging examples in the US, which has been facing a cascade of flood events. Typically having faced successive flood events where flood protection infrastructure such as levees have failed or been damaged, there is a shift towards reconnecting the floodplains with rivers and removal of levees and other flood barriers (Shader 2019).

The Army Corps in the US are widely responsible for construction, maintenance and repairs to flood protection Infrastructure. Following recurring flooding on the Maquoketa River in Iowa which damaged a levee, the Army Corps in collaboration with the Iowa Department of Natural Resources secured 300 acres of floodplain land. This land was transferred to the Green Island Wildlife Management for restoration and protection of the floodplain to reduce the impacts of floods. Similarly, following the 2011 floods in the Missouri River, a flooded landowner chose to setback a levee instead of rebuilding it in its original location (Shader 2019).

Figure 18 | Menu of flood mitigation measures as described in the 'Room for the River' program

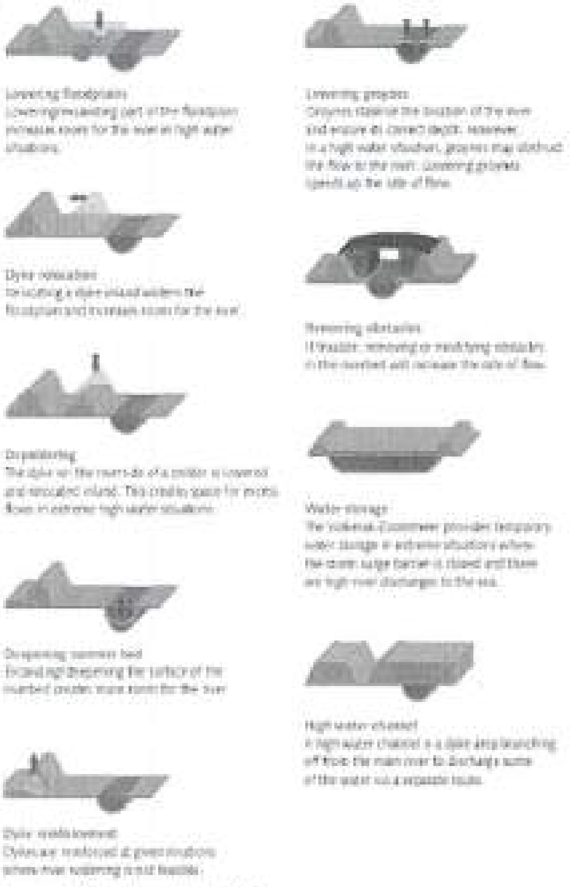


Image Credit: ruimtevoorderivier 2016

B.3 Environmental Impact Assessment (EIA)

Environmental Impact Assessment is a process that evaluates a project's:

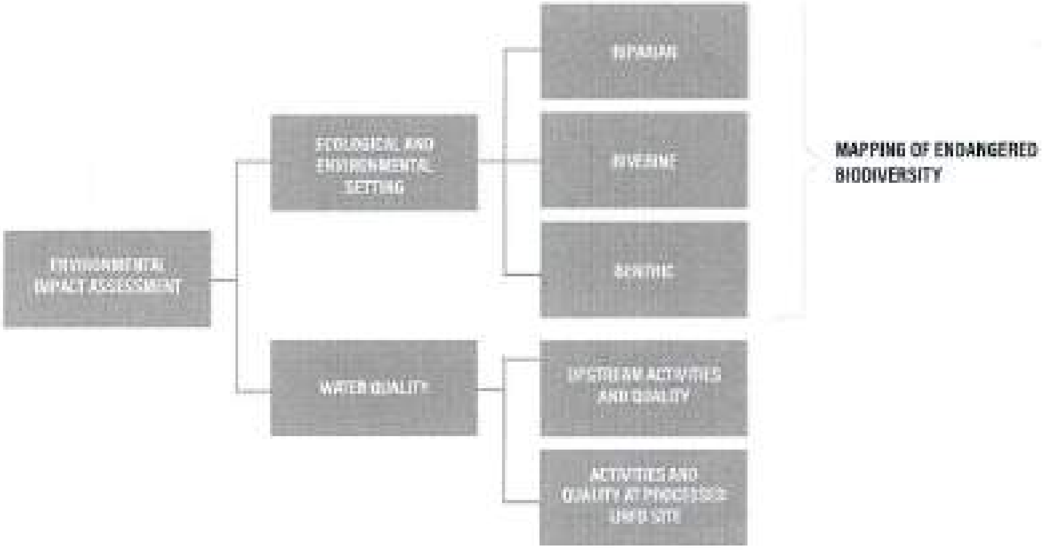
- potential environmental risks and impacts in its area of influence; examines project alternatives;
- identifies ways of improving project selection, siting, planning, design, and implementation by preventing, minimizing, mitigating, or compensating for adverse environmental impacts; and
- enhancing positive impacts; and includes the process of mitigating and managing adverse environmental impacts throughout project implementation.

URFD project proponent should apply a precautionary approach to natural resource management to ensure opportunities for environmentally sustainable development.

Based on the findings of the EIA, an **Environment Management Action Plan (EMP)** should be developed to ensure environmentally sustainable development of the proposed URFD both during the construction as well as during operational phases. The EMP is site and time specific including necessary responsibility matrix.

Figure 19 | Secondary channel and island developed as part of the Room for the River program near Nijmegen

Image Credit: ruimtevoordewaal.nl



Ecological and Environmental Setting

The ecological and environmental setting of a river across its width and length varies considerably. Across the width of the river, three broad ecosystem zones exist:

- **Riparian:** This is the belt that forms the interface between the water line and the land. Wetlands and most of the river features can be found here. The biodiversity here is typically diverse, while at the same time sensitive to the conditions and activities in the floodplain and lands adjoining it. Amphibian and aquatic life flourish here. Floral diversity includes wetland species. This is also an important edge for terrestrial biodiversity which access the river for water, fishing, etc.
- **Riverine:** This is the water flowing belt, which is dominated by aquatic biodiversity. Floral biodiversity here is much lower than the riparian zone. Most of these species form the higher order in the food web/chain. This makes them highly dependent on the species in the lower order of the food web.
- **Benthic:** Benthic species are the small invertebrate species which occupy the floor of a stream/river. The microorganisms in this layer are critical to the health of the water body as their biological and chemical actions directly prevent the build-up of carbon in bottom sediments and deoxygenation of bottom waters. These species also act to sequester and move contaminants and excess nutrients from groundwater and sediments as well as controlling emissions of greenhouse gases (such as carbon dioxide and methane). The integrity of the freshwater supply depends on how various benthic species make their living and contribute to complex food webs (Covich, Palmer and Crowl 1999).

In all these ecosystem types, the biodiversity within these habitats are critical in keeping the food cycle and thereby nutrient and energy cycle intact and healthy. And the biodiversity

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in each of these ecosystem types thrive in its unique ecological settings as elaborated above. Biodiversity and habitat conditions or ecological and environmental settings are therefore co-dependent on each other and together determine the health and functional capacity of the river. Studies have shown that "habitat diversity and water quality become severely compromised when as little as 10 percent of a floodplain is paved or covered with an impervious surface. A floodplain that is more than 50 percent paved will result in a waterway with little wildlife habitat and few natural features" (MacBroom 1998).

The DPR for proposed URFDs should include information on the biodiversity and its status (current and baseline). It should also ensure that the design proposal does not affect/impact the floral and faunal diversity. The objective of this activity is to protect natural habitats including the forest areas and wildlife which in turn protects and enhances the environment enabling long-term sustainable development. URFD project should support the protection, maintenance, and rehabilitation of natural habitats and biodiversity.

Figure 20 | Bird species map along river Ganga

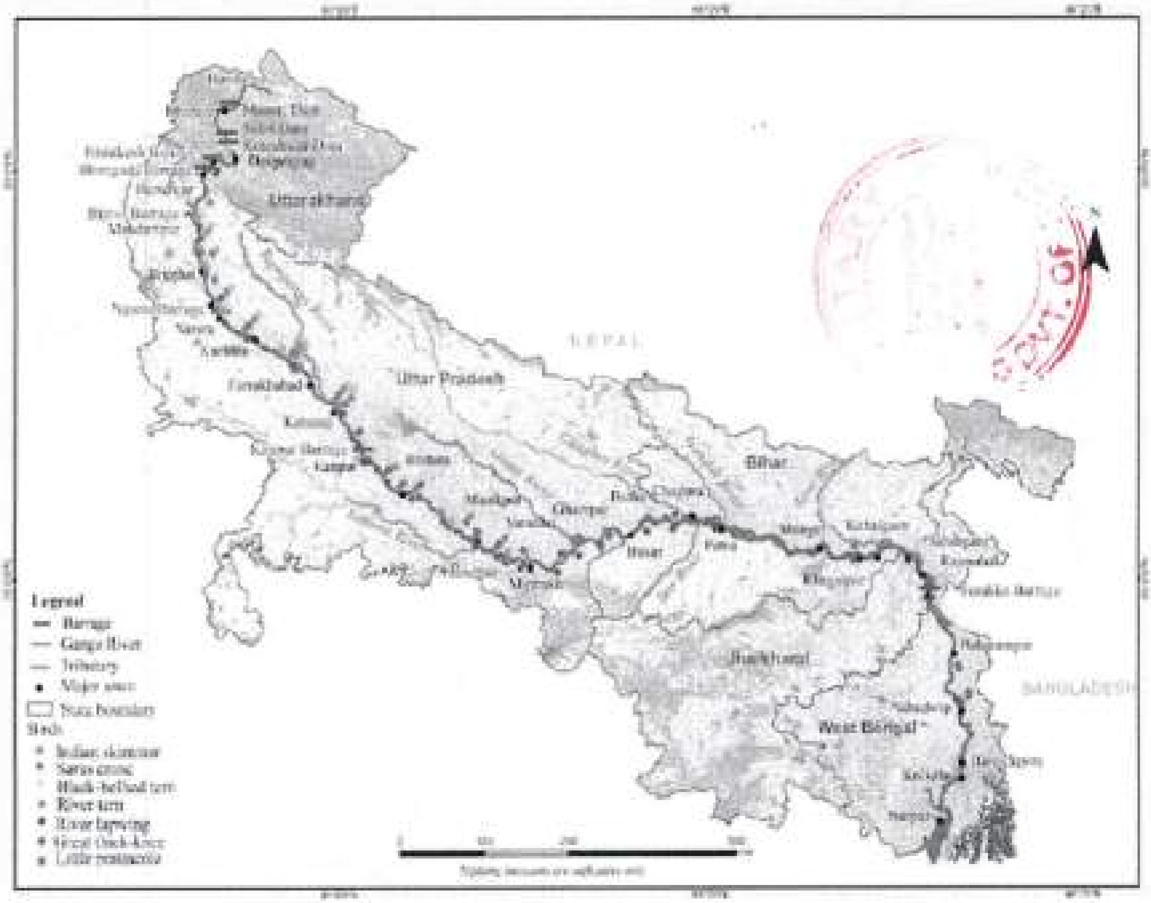

Image Credit: NMCG

Locations with endangered biodiversity: While the river and riparian habitat host aquatic and wetland biodiversity, some segments of a river may be habitat to certain species which are endangered/ threatened/rare.

Therefore, URFDs in such stretches should pay greater attention in spatially and physically controlling access to the river[illegible]. These stretches should be visually accessible and viewable from land for ease of monitoring. Such riverfronts will require provisioning of noise buffers such as through placement of vegetated buffer strips along the river edge. Community stewardship and awareness plays an important role in managing locations with endangered biodiversity. URFD areas can have information and display kiosks, viewing decks above ground (non-permanent structures within the vegetation buffers) to provide an opportunity for people to (re)connect with nature without disturbing any endangered species.

Box 11 | Design elements for the protection of Gangetic river dolphins - Patna Riverfront, Bihar, India

The Patna riverfront development on the Ganga river is a critical example of an urban river project incorporating design details for preservation of key fauna in the river. The Gangetic river dolphin is an iconic species in the river and is present across the river stretch near the city of Patna. No wildlife sanctuary is in the vicinity and an environmental impact assessment was not mandatory, but the project recognizing the presence and importance of the river dolphins introduced design elements considering these species. There are 3 specific interventions that were considered –

1. Gabion wall being constructed to preserve the river edge would use fine wire mesh (of 4 inches size) to prevent incidents of dolphins being stranded in these spaces.
2. Space between ghats would be retained in their natural form and no exotic plant species would be introduced, allowing aquatic and amphibious flora to grow in this riparian zone.
3. During project implementation, care was taken to minimize sound pollution in the river due to heavy equipment. Boats used in the river for project construction and implementation used propeller guards to prevent injury to river dolphins (VOYANTS 2014).

Figure 21 | Gabion wall and riparian flora

Image Credit: WRI India

Quality of Water in the stretch of the river where URFD is proposed: Water quality of a river varies across its course depending on uses and activities in its catchment areas. It is important to map discharge of (treated, partially treated and untreated) municipal and industrial effluents and disposal of solid waste. Further water quality (physical and chemical) in and around (especially up to 5 km upstream of) the proposed URFD project must be evaluated. In conditions where the quality of water is not up to bathing quality , physical access to the river should be controlled and necessary information about the quality of water should be provided at the riverfront. Also, a deteriorated riverfront environment from contaminated/ polluted water and floodplain will attract lower footfall at any URFD development project. It is important to remediate contaminated/ polluted river water and floodplain (i.e., improve visuals and odour) prior to opening of an URFD project to public.

Similarly, any activities (like washing, cattle bathing, open burning of dead bodies) that could further deteriorate the quality of the water should be suspended. In case any such activities are intrinsic to some communities and is not feasible to ban them completely, a stakeholder consultation process should be initiated to achieve a balance between the needs of communities and the quality of water.

Box 12 | Ecological restoration - Taewha River, South Korea

The Taehwa River flows through the metropolitan city of Ulsan, located in the southeast of the Korean Peninsula. Originally a farming and fishing community, in 1962 it was designated as a special industrial zone. Its status changed again in 1997 when it was designated a metropolitan city. As the area developed over the years, low levels of environmental awareness and insufficient flows resulted in high levels of river contamination from poorly treated industrial wastewater and domestic sewage. The river water quality deteriorated significantly, resulting in a large fish kill in 1992 and again in 2000. Exacerbating the dire situation, unplanned riverbank developments added to the environmental deterioration of the river and its surroundings. The Taehwa River recorded its worst biological oxygen demand (BOD) level in 1996 at 11.3 ppm. Awareness of the severe river pollution was raised to national levels in 2000 when massive fish kills were televised across the country (Lee 2015).

Through implementation of Phase I and II of the Taehwa River Master Plan, 2005-2014, water quality in the river improved significantly. The basic concept of the Taehwa Master Plan was 4-fold: "Safe and clean river", "Ecologically healthy river", "Familiar and close river", and "Historical and future river", each with its own focus activities, and undertaken through the organization and participation of local stakeholders (UNESCAP & KOICA 2011).

Water quality improvement activities included:

1. The removal of debris, contaminated sediment and sludge.
2. Concrete structures along the riverfront were replaced with natural revetments for flood protection, and green lawns and walking paths were introduced in formerly deserted areas along the riverbanks.
3. To further encourage people to engage with the river, observatory towers and a tourist pavilion were constructed.

Improved water quality due to the riverbank redevelopment efforts paid off when, in 2012, the river was selected as one of South Korea's twelve eco-tourism sites.

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B.4 Social Impact Assessment

Social Impact Assessment (SIA) should be carried out to make URFD project responsive to social development concerns. SIA can also help enhance project benefits towards poor and vulnerable communities while minimizing or mitigating concerns, risks and adverse impacts. Furthermore, during the project other social issues may emerge such as influx of labour during construction, a systematic assessment provides the basis to prepare a Social Management Plan for the implementation phase.

The main objectives of SIA are:

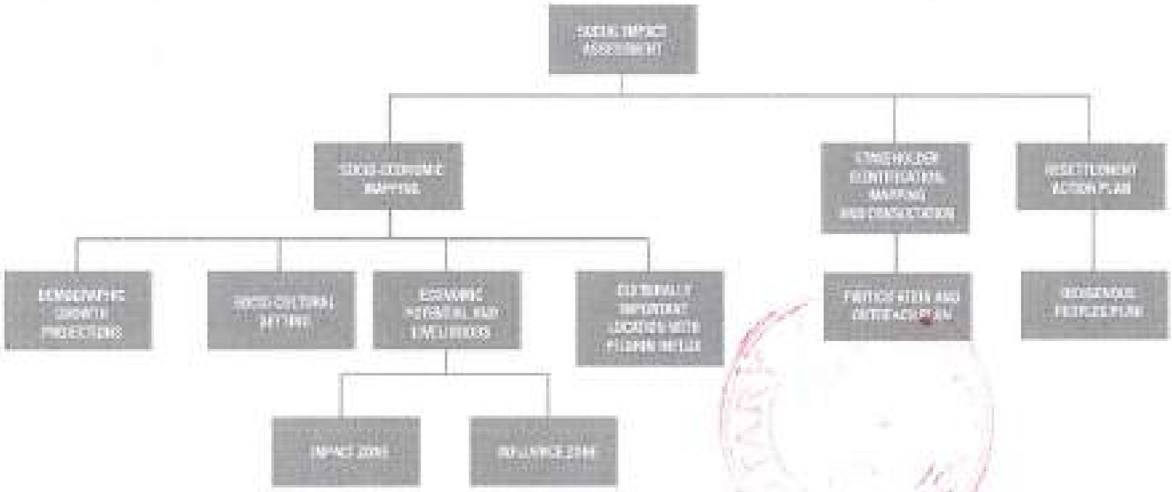
- to carry out a socio-economic, cultural and political/institutional analysis to identify the project stakeholders and social issues associated with the project;
- to assess the extent of asset loss and undertake the census of potential project affected people;
- to develop a Resettlement Action Plan (RAP) in consultation with the affected people and project authorities;

Socio-Economic Mapping

Demographic Growth Projections

A riverfront project must consider the number of local residents, daily and annual visitors that are expected to enter and use the URFD, as well as account for any variations on festivals, holidays and other culturally significant days. To estimate daily footfall into the URFD, the demography of the urban area, and specifically of the impact and influence zones must be surveyed. In addition, the growth projections for the impact and influence zones and tourist footfall must also be estimated to be able to develop the URFD appropriately which can accommodate the estimated influx of people.

Demography and growth projections for the entire urban area can be considered as per census data or any other estimates developed as part of other master plans or regional plans. For the impact and influence zones as well as tourist footfalls, surveys must be conducted to understand the various user groups in the URFD. The demographic survey should include socio-economic data, gender, age, time spent on the riverfront, activity on the riverfront,



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amenities used, etc. Such data can reveal insights into the users accessing the riverfront and indicate amenities and services they might need. Further such studies can indicate if there are any communities living within at-risk areas such as floodplains and their vulnerability to extreme weather events. This data can be useful to support relocation/ rehabilitation plans as part of the URFD.

Socio-cultural Setting

The socio-cultural setting is a key element to understand the existing and projected usage that a riverfront development will have. As part of the feasibility study, a survey of time periods (specific days or months) of cultural significance on the riverfront must be developed. The socio-cultural setting will also include the estimated footfall onto the riverfront during these times – divided into local citizens and tourists accessing the site on these special event days.

Economic Potential and Livelihoods

Riverfronts have historically been sources of revenue generation for riverside dwellers due to the abundance of natural resources available in these locations. But with growing pollution levels and decreased dependence on rivers for basic needs such as drinking water and food these livelihood options have dwindled. Now riverfront areas are usually disconnected from the city due to the presence of industrial enclaves or dump yards (which add to river pollution loads). In addition, low income communities inhabit these areas as these are the open spaces available to such communities to set up informal habitations.

Rejuvenated riverfronts, though, have the potential to support new livelihood options including traditional practices such as fishing and new ones like river-based tourism (boating, etc.). In addition, clean and vibrant riverfront districts are prime locations for businesses such as restaurants and cafes which can generate revenues for the city. The impacts of a riverfront development when done well can extend beyond the actual site and is likely to influence a wider region in proximity to the riverfront.

To establish the extent of economic and livelihood generation potential a study of the of the riverfront site must be conducted. This assessment must provide an overview of 2 areas, the impact zone or the actual riverfront development site and the influence zone the area in proximity to the riverfront development where changes might happen due to increased foot traffic to the riverfront development site.

Impact Zone

- Existing traditional water-based activities (types of activities and number of people employed in this) which can be rejuvenated to add to the cultural value of the site as well as enable people to reengage with their crafts
- Potential of seasonal fishing markets based on the biodiversity that can be safely harvested from the river.
- Extent of river-based tourism activities such as boating and water sports which can be deployed with minimal impact on natural flora and fauna
- Map other urban amenities such as walking tracks, bike paths which can be extended to the riverfront development to connect the site to the city and increase footfall to the site.

Influence Zone

- Identify service industry activities such as restaurants and cafes, hotels, etc., which can provide additional amenities to the users of the riverfront development. Such existing uses must be mapped to integrate them appropriately with the riverfront development plan. Also, recommendations to city codes to support the development of additional mixed uses in the influence zone of the riverfront development must be included.

Culturally Important Location with Pilgrim Influx

River and river precincts are culturally significant landscapes in India, with many important and high footprint religious and cultural nodes located along riverbanks. For example, the River Ganga hosts major cultural and religiously significant nodes, especially in the upper and middle segment of the river. Such nodes have temples, ghats, gathering grounds and other semi-public spaces with very high footfall, especially during festivals and special occasions. Seasonal influxes are managed by the municipality and city administration (e.g., Kumbh mela) with specific management plans. The day to day influx of pilgrims, cultural activities and access to the river also have to be managed effectively to protect the river and its habitat and at the same time provide a safe and enriching experience to visitors (pilgrims and tourists). A well designed URFD that integrates architectural, aesthetic and spatial markers/features can enrich the experience while protecting the ecology of the river. Therefore, such URFD proposals should consider:

- Control of access with respect to footprint
- Ghats that are designed for ease of access with spatial micro-zoning for activities on the ghats so that movement of people towards the ghats is not obstructed
- Well-designed gathering spaces in the landward side with capacity to hold people waiting to access the river or river ghats.

Stakeholder Identification, Mapping and Consultation

A stakeholder is "a person, group, or organization that has a direct or indirect stake in a project/organization because it can affect or be affected by the Project/organization's actions, objectives, and policies". Stakeholders thus vary in terms of degree of interest, influence and control they have over the project.

"Stakeholder Analysis" is the process of identifying the individuals or groups that are likely to affect, or be affected by, a proposed project and categorizing them on the degree of impact they may face. This information is then used to formulate interventions so that the interests of stakeholders are addressed in the project plan, policy, program, or other action.

The importance of such an analysis is to strengthen the understanding of the socio-political environment surrounding the project. It allows for the:

- Identification of the interests, concerns and potential risks surrounding the stakeholders, as well as conflicts of interests (if any).
- Identification of relations between stakeholders that may enable "coalitions" for project sponsorship, ownership and

co-operation as well as the mechanisms which may have a role in influencing other stakeholders.

- Key groups/ individuals to be pinpointed who need to be informed about the project during the execution phase.
- Identifying stakeholders (those who are likely to have an adverse impact on the project) and employing effective strategy to mitigate their concerns.
- Generation of information essential to the planning, implementation and monitoring of the project.
- Development of a framework for participatory planning and implementation of various project activities.

The identification of stakeholders and their inclusion in the decision-making process is thus essential to the process of prioritising, analysing and addressing issues. The project proponent can develop management systems and strategies to address the concerns/ expectations of various stakeholders. Finally, such an analysis can also reveal stakeholders who can be potential allies, collaborators and champions for the URFD project, and these capacities can be leveraged during the design, implementation and Operations & Maintenance (O&M) phases.

"Stakeholder mapping" is a process of examining the relative influence that different individuals and groups have over a project as well as the influence of the project over them. The purpose of a stakeholder mapping is to:

- Identify each stakeholder group;
- Study their profile and the nature of the stakes;
- Understand each group's specific issues, concerns as well as expectations from the project that each group retains.
- Gauge their influence on the Project.

On the basis of such an understanding, the stakeholders are categorised into High Influence/ Priority, Medium Influence/ Priority and Low Influence/Priority. The stakeholders who are categorized as high influence are those who have a high influence on the project or are likely to be heavily impacted by the project activities and are thus high up on the priority list for engagement and consultation. Similarly, the stakeholders categorized as medium influence are those who have a moderate influence on the project or even though they are to be impacted by the project, it is unlikely to be substantial and is thus neither high nor low in the list for engagement. On the other hand, the stakeholders with low influences are those who have a minimal influence on the decision-making process or are to be minimally impacted by the project and are thus low in the engagement list.

	High	Medium	Low
Influence			
Priority			

Suggested method to estimate stakeholder engagement profile

Stakeholder mapping is a critical component to develop an URFD so that a wide range of users and impacted groups can be identified, and their inputs can be taken during the planning stage. Mapping of a stakeholders of the development (including, but not limited to) must look at:

- Official stakeholders such as government agencies, implementation groups.

- Stakeholder groups such as business associations, NGOs, community groups, educational institutions.
- Residents in the impact and influence zones (particularly any groups which may have to be relocated).
- Other stakeholders such as students, design and landscape specialists, environmentalists, etc.

Participation and Outreach Plan

A riverfront development will be a key addition to a city and has the potential to be a vibrant space generating high levels of direct and indirect economic opportunities for citizens and businesses. A key component to develop a successful riverfront is to engage deeply and meaningfully with the local community and stakeholders to understand their requirements and integrate their feedback into final riverfront development proposals. URFD planning and design must include the participation of all identified stakeholders. While a complex process to bring in multiple views and perspectives, particularly of non-subject experts, integrating the voice of actual users and implementers of the project will ensure the long-term success of such developments.

The stakeholder participation process must have 2 essential components:

- Development of a participation plan using various participatory mechanisms to ensure that a diverse set of people and stakeholders can express their views during the planning process and of the proposal.
    i. Public engagement through series of public meetings, design charettes, feedback forms and surveys.
    ii. Ensure diverse attendance of participants by hosting such sessions in public community spaces (such as schools or colleges), at varying times and days.
- Engaging various stakeholders to be partners in the participatory process to ensure a sense of ownership for the riverfront development project.

i. Partnering with educational institutions to have them support participatory meetings (both by use of their premises and use of their resources in terms of teachers and students).

ii. On-boarding local business and resident welfare associations to maintain their long-term support for riverfront developments.

Efforts should be extended beyond identifying traditional stakeholder groups and reach out to neighbourhoods that historically may not have used the riverfront. URFD will be more vibrant, inclusive, and successful when local officials and developers, as well as planning staff participate in stakeholder meetings to ensure that everyone works toward the same vision and that all important considerations are made known.

The URFD project proponent will be required to formulate a stakeholder engagement plan (SEP) and Grievance Redressal Mechanism (GRM) for the project. The plans will be aimed at:

- Identifying and engaging with stakeholders through the life cycle of the project.
- Identifying and addressing key social concerns and requirements.

- Building relations and support with the stakeholders, especially the local community and Panchayat members.
- Receiving, recording and addressing any grievance/complaints received from the stakeholders in a timely manner.

Box 13 | Community outreach and participation in river restoration in Seoul, South Korea

The Han River is the lifeline of the city of Seoul and it is over 1 km wide along the section traversing the centre core of the city, dividing the older (north) section of the city from the new (south) CBD. The city of Seoul is one of the most densely occupied cities in Asia, and the need for corresponding infrastructure had given rise to the ubiquitous highways along both sides of the Han River and 18 bridges for motor vehicles and trains. As the city encroaches ever nearer to both banks of the Han River, public accessibility and the condition along these banks become more compromised. The city has embarked on a series of recovery programs to return much of the banks and islets on the river to a more natural state for public use and recreation, though the existing highways and traffic congestion will also remain (Hee and Low 2009).

With the latest 2008 draft master plan and Hangang (River) Renaissance Project, Seoul municipality aims to regain the friendly relationship between humans and nature and to recover the uninterrupted linkage between all sections of the city. It also seeks to create a new brand for the city by continually rediscovering the hidden value of Han River.

Among the more prominent projects initiated by the government are the redevelopment of Seoul Forest, Seongyudo Island and designating Bamseom Island as a nature conservation area. These projects are implemented in partnership with private companies and only after in-depth consultations with Seoul citizens (Hee and Low 2009).

As a positive result of this consultative approach, urban transformations along Han River have avoided the earlier pitfalls and citizen protests and engaged her citizens through family-oriented and meaningful public spaces along the waterfront.

Due to these consultations, the projects were well rated by the public and were in direct response to the needs of Seoul citizens. Being public in nature, these spaces also serve to bridge the inland developments with Han River through appropriate developments along the riverbanks. The programmatic functions were also influenced by the feedback from the public hence securing the critical mass of users to enliven the place and ensure the sustainability of the development (Hee and Low 2009).

Resettlement Action Plan (RAP)

A URFD project may result in land acquisition and/ or relocation or loss of shelter for non-titleholders and/ or loss of assets or access to assets and/ or loss of income sources or means of livelihood. A study should be undertaken to avoid or minimize involuntary resettlement where feasible, exploring all viable alternative project designs. It also intends to assist displaced person by improving their former living standards, community participation in planning and implementing resettlement and to provide assistance to affected people, regardless of the legality of title of land. An understanding of the issues related to social, economic and cultural factors of the affected people is critical in the formulation of an appropriate rehabilitation plan. A Resettlement Action Plan (RAP) should be prepared in consultation with the Project Affected People (PAP) to ensure that no one is worse off than before the project. Restoration of (at least) pre-project levels of income is an important part of rehabilitating socio-economic and cultural systems in affected communities.

Indigenous Peoples Plan (IPP)

This plan aims to protect the dignity, right and cultural uniqueness of indigenous people impacted by URFD projects and to ensure that they do not suffer due to development and they receive social and economic benefits. This plan will be prepared in consultation with the community and project authorities.

B.5 Design Strategy

Riverfront developments must be imagined as key public space additions to a city and must be open and accessible to all citizens. Furthermore, as a public space in a city riverfront spaces should also include elements and features that enhance the public realm by creating a space that is attractive to a wide range of users.

Equitable Access

Equitable access should be ensured for persons across all income categories, age ranges and for differently abled persons.

- To ensure that all people are welcome to such a public space it must be ensured that access is free for all persons.
- To ensure that persons across various age ranges and different abilities can access riverfront spaces, the public space should be universally accessible and include design features such as ramps and slopes to allow for ease of movement.
- Signage should include multiple languages and iconography to provide information for users with varied linguistic abilities.
- At a city scale, URFD projects must be accessible from other locations via multiple public transit and para-transit connections. Thus, access points to URFDs must be included in the transit network of the city

Addressing and Managing the Built Environment

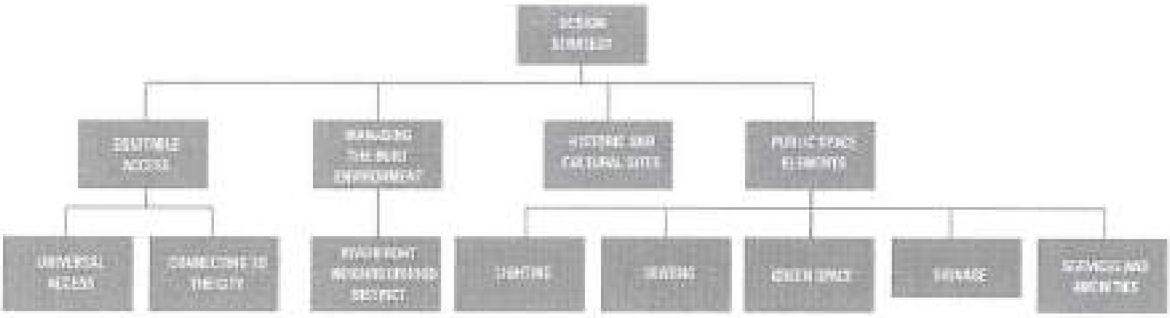
The built environment in a riverfront development must integrate with and respond to the existing natural landscape and built form on site. In addition, the built elements on site must also enhance the experience for users by providing visual/ aesthetic appeal and/or comfort.

Riverfront Neighbourhood and District

In addition to the riverfront development site, the design plans and proposals must also include interventions (at least minor) in the adjoining neighbourhoods and riverfront district. The interventions can be limited to improving pedestrian thoroughfare access in these localities to access the riverfront easily and provide signage towards the river. Vehicular access to the riverfront can be limited to specific locations only to reduce congestion in riverfront districts.

Historic/ Cultural Aspects

Most existing riverfronts in India have historic or cultural significance and are the sites for various cultural practices which require access to the river. In such cases the URFD must integrate these existing uses and enhance these sites by providing a greater level of comfort for uses (such as shaded areas, benches, etc.) and increased services and amenities (toilets, changing rooms, drinking water, etc.).



Public Space Elements

Public space elements are crucial to develop usable and accessible public spaces such as URFDs. These elements must include lighting design and fixtures, seating elements, green space, signage and services and amenities at the very least. These elements must be designed as per existing safety norms and also to meet the forecasted use on site. Furthermore, public space elements must be designed and located taking into account possible flooding and high-water levels so that there is no or minimal damage to these elements. URFD authorities can opt for low-impact design for public space elements and choose locally available or manufactured products for public space elements.

Above and beyond this URFD authorities can choose to implement additional elements such as public sculptures, artwork, etc., which can enhance the public space and improve the experience of users in the space.

Lighting

Lighting design on a riverfront is critical as appropriate lighting will improve safety and enhance the environment of the site for evening and night-time use. Lighting must include measures for ambient light, safety light and work light. Use of lighting fixtures must be considered in tandem with trees and other high features which might cause obstructions. It would be useful to include multiple types of lighting fixtures which can provide lighting at various heights. Provision of solar lights might be considered to reduce dependence on the grid and reduce variable supply issues. Lighting design must also account for varying water levels (high flood level, etc.) and place fixtures in such locations to minimize chances of damage from rising water levels. .

Seating

The riverfront is both a usable and leisure space and can attract users carrying out either or both functions. Providing appropriate seating can enhance the time spent by users on the riverfront. Seating should be designed and located to provide unobstructed views of the river. Seating at varying heights and different configurations would accommodate a wide range of user groups across various ages. Care must be taken that seating elements themselves do not obstruct movement paths and views for users.

Green spaces

Including green spaces in URFDs will improve visual aesthetics and comfort (shade). Using

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a range of local and native tree/ plant species can improve the micro-climate by helping to regulate temperature, humidity on a micro scale. URFDs should integrate existing trees into the design. Furthermore, green spaces can also be developed to provide ecological services such as erosion control, water quality improvement, bio-diversity refuge, etc.

Box 14 | Public space - Dravyavati Riverfront, Rajasthan, India

The Dravyavati Riverfront project was undertaken in the city of Jaipur, India after a significant flooding event in 2012 which led to high loss of life and property. The river suffered from typical issues which ail many urban streams in India, such as encroachments and habitation built onto the river's floodplains, sewage and industrial outflows into the river and dumping of solid waste. The 2012 flood was a wake-up call to the local government and citizenry to review and revive their relationship with the river. The project undertaken since 2015 on behalf of the government by TATA Project Limited rejuvenated the river and created an extensive and high-quality public space for the city of Jaipur.

The public space added to the city is a total of 100,000 sq. m area distributed along the river in multiple sections. A wetland zone in the river rejuvenation stretch was developed as a bird park, creating a habitat for local and migratory birds. This site was formerly the Ram Sagar Dam which had been damaged in a flood event (TATA Projects 2018).

A landscape park has been developed which hosts a range of public space elements, such as walking tracks, cycle paths, pavilions, viewing areas and a marketplace. In addition, public space amenities such as food kiosks and drinking water points are also present. Finally, a botanical garden has also been created housing over 40,000 plants of around 1000 species (TATA Projects 2018).

Figure 22 | Scenes from along the Dravyavati Riverfront project in Jaipur

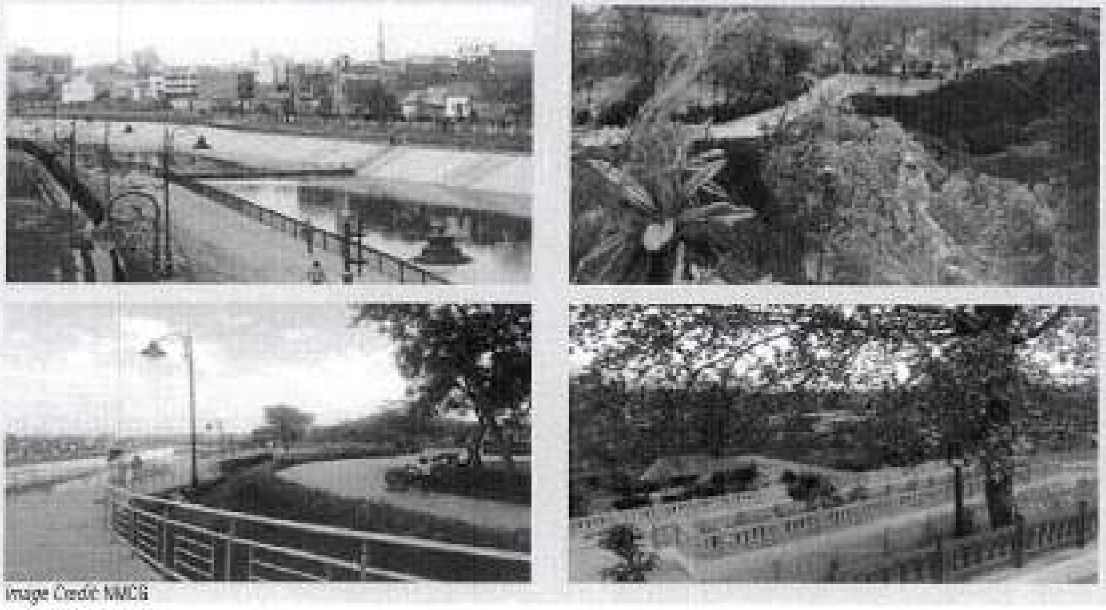

Image Credit: NMCG

Signage

Signage is a key component of successful public space design as it helps users identify services and amenities on site and provides any historic/ cultural/ ecological information on the riverfront as well. Signage should be developed in multiple languages and in simple iconography to allow a range of users (of varying linguistic ability) to be able to access information.

Services and Amenities

URFDs are developed with the aim to increase riverfront footfalls. These sites should also improve services to the increased number of users to the location. Service and amenities in URFDs should include (but are not limited to):

- Drinking water.
- Toilets, washrooms and changing rooms.
- Waste bins (segregated).
- Cycle stands.
- Lifeguard booth.
- Food kiosks.

[C] Planning and Institutional Strategy

Many URFDs are driven by national river conservation plans which see riverfront development as a critical part of river rejuvenation. But eventually the maintenance and upkeep of URFDs falls to the urban local bodies where the development is located. The URFD planning strategy should include a mechanism for collaboration across agencies and a financial plan to ensure ease of implementation and O&M. For continued O&M works, the O&M agency and a revenue generation stream must be identified. Some of the services and amenities provided at URFDs (such as convention centres, auditoriums etc.) can be paid services.

Institutional collaboration must be ensured so that design, planning and implementation of the URFD can happen in a seamless manner.

Box 15 | New institutions to finance and implement urban riverfront developments - Copenhagen City and Port Development Corporation, Denmark

Copenhagen, like many global cities faces challenges of upgrading older and stressed urban infrastructure and yet has to deal with contestation against tax increases and cesses. The city developed a new type of institution (a public asset corporation) as an alternative to existing public authorities, which could function independently, yet be publicly accountable, cost efficient and revenue maximizing, while maintaining a long-term, holistic view of projects undertaken. The Copenhagen City and Port Development Corporation (CCPDC) was set up by national law (Noring 2019) to manage port and other harbourfront (re)developments (Noring 2019).

The CCPDC is a publicly owned, privately managed organization which brings together the lean business efficiency of a corporation with the public accountability of a government agency. The CCPDC is designed to be able to bypass public sector regulations such as tendering and is able to create subsidiaries, joint-ventures and use other corporate mechanisms to increase revenues. This allows the agency flexibility to choose or discard project options and opportunities, financing mechanisms (PPP, TIF, etc.) with only maximum revenue generation as a goal and are not hindered by other socio-political concerns (Noring 2019).

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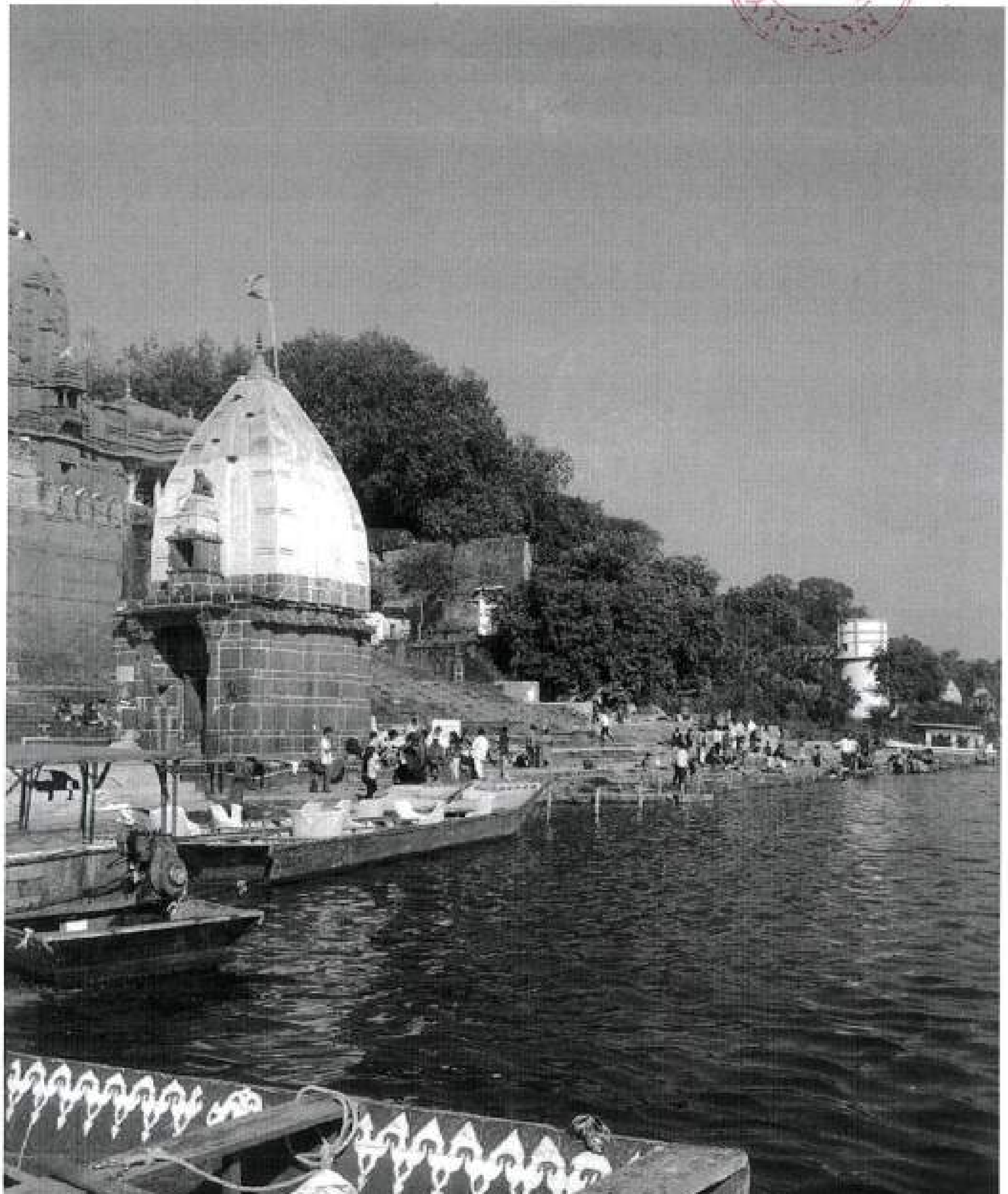
Further URFDs are by their location often cut off from the rest of the city. Working in partnership across agencies can help build connections and access to the URFD, for example local transport agencies can support the URFD with dedicated bus, auto services to some of the riverfront locations. Similarly working in partnership with water resources departments can ensure that water flows in URFDs are maintained.

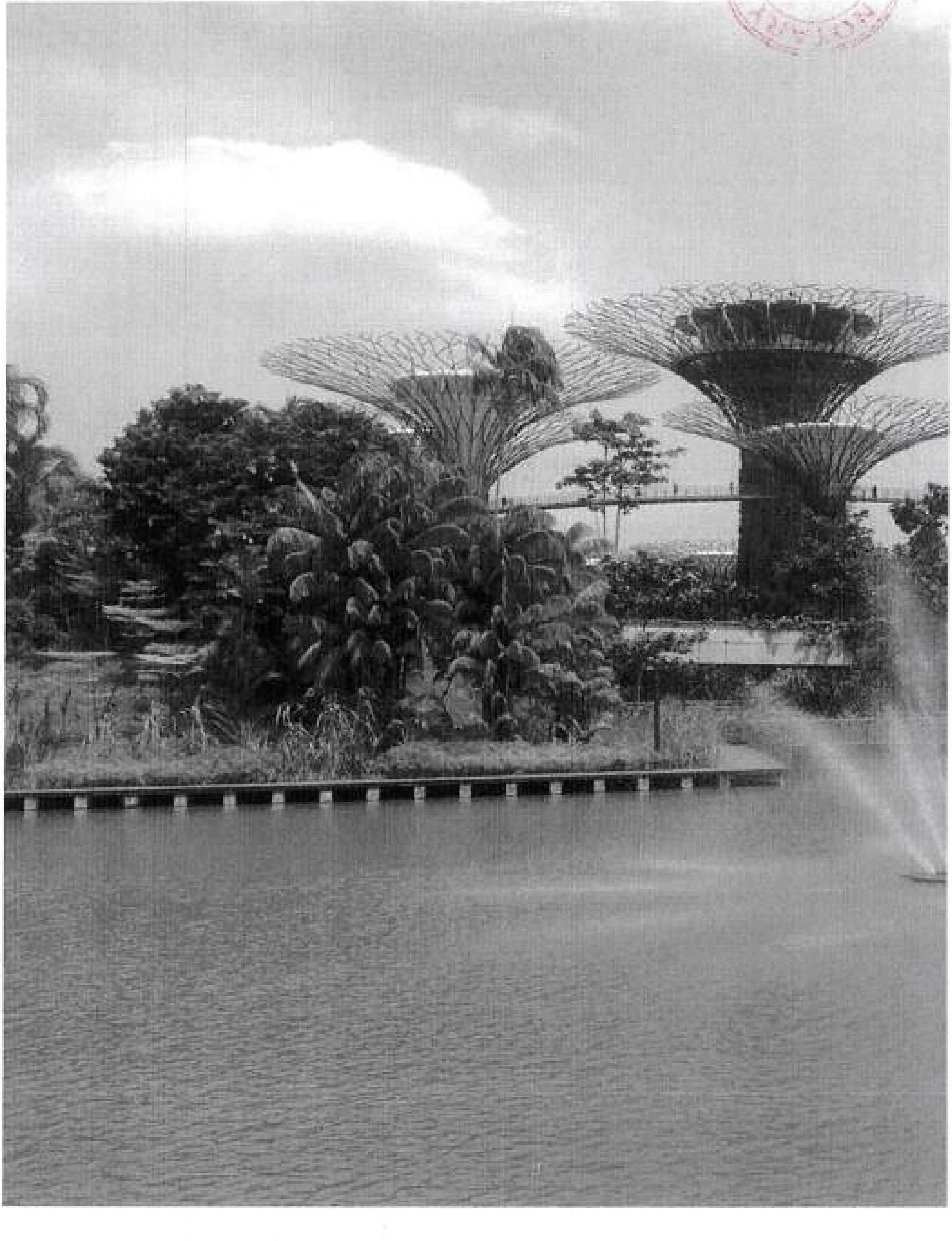
Box 16 | Constitution of the National Mission for Clean Ganga to implement river improvement projects, India

The Ganga river is one of the most iconic rivers in the world and in India is revered as a holy river with various legends, myths and cultural narratives associated with it. In addition, the river basin accounts for approximately 26% of the country's land mass (NMCG 2019) and houses about 600 million inhabitants (The World Bank 2015). Decades of development, urban and industrial growth and the associated changes in land use in the river basin brought about significant pollution and changes to water flows in the Ganga River.

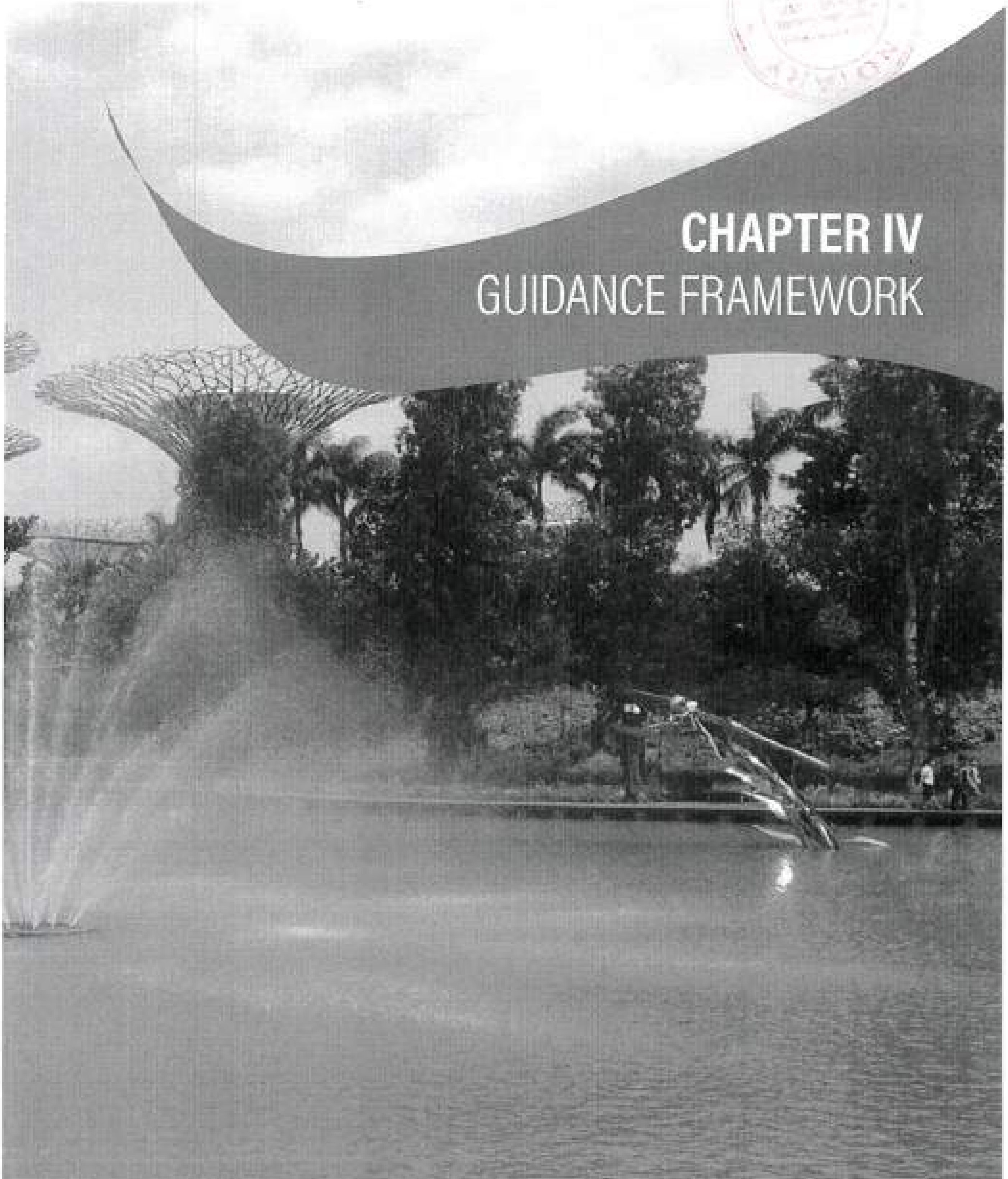
To enable pollution abatement and conservation of the river, under the powers of the Environment (Protection) Act, 1986, the Central Government constituted the National Ganga River Basin Authority (NGRBA) in 2009. The NGRBA in 2011 set up the National Mission for Clean Ganga[a] (NMCG) as the implementation agency to undertake on-ground project work in conjunction with relevant local bodies (MoEF 2009) to achieve the mandate of NGRBA.

NMCG maintains a basin-level perspective (through live data monitoring) and oversight of on-going and proposed projects and is able to assess the impacts of interventions in a local and river basin scale. This is a single agency with the charge of pollution abatement and maintaining river health by managing environmental flows. It is able to undertake a range of interventions to support development and deployment of technologies, processes and community engagement to achieve these outcomes. Projects approved by the NMCG are eligible to access a range of funding such as from the World Bank project or the Clean Ganga Fund. Furthermore, NMCG itself has discretionary powers to undertake disbursement of funds for Ganga rejuvenation projects through management of an endowment or trust (NMCG 2019).





CHAPTER IV
GUIDANCE FRAMEWORK

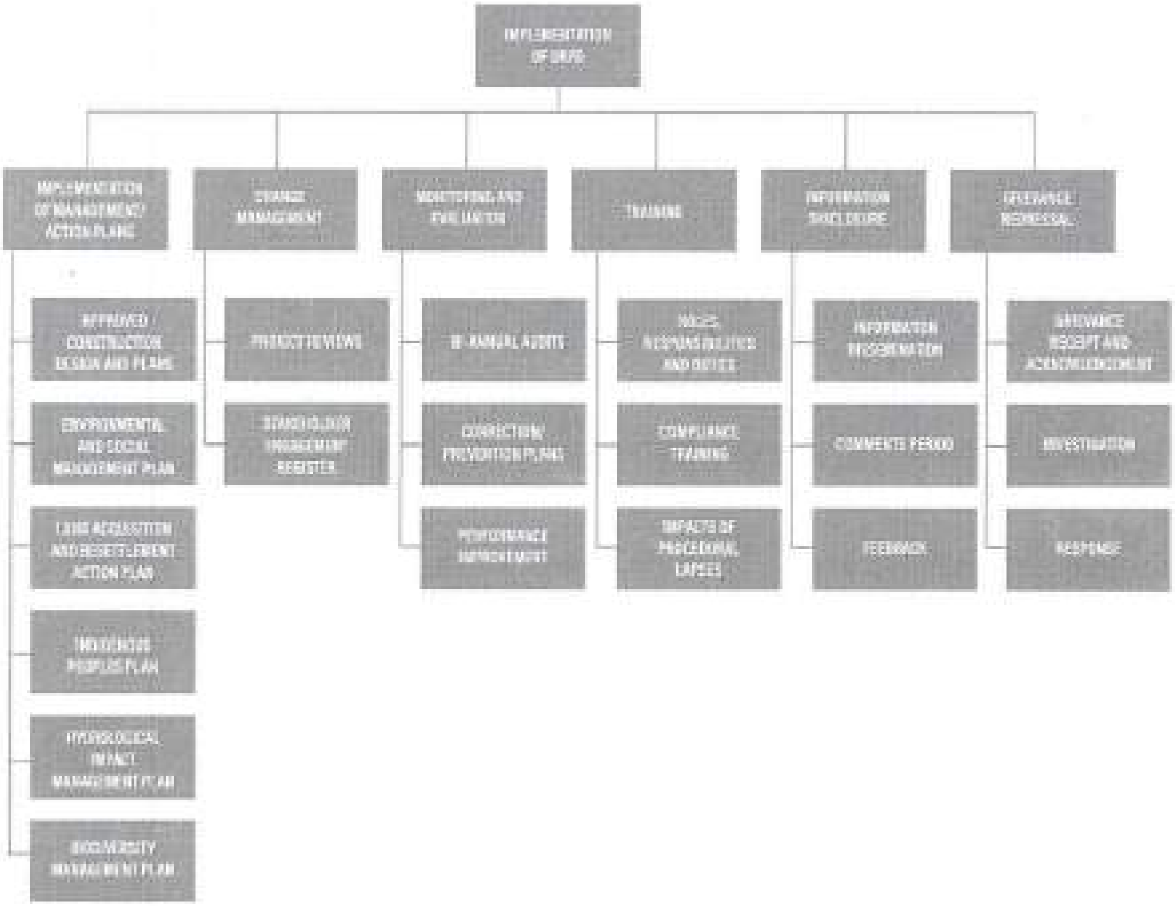


CHAPTER IV: GUIDANCE FRAMEWORK

This section provides a guidance overview that should be adopted during implementation and operational phases of URFD project. This guidance is intended to provide a generic overview to ensure the effective implementation and adaptation of the following plans for URFDs:

- Management/ Action Plans
- Change Management
- Monitoring and Evaluation
- Training
- Information Disclosure
- Grievance Redressal

This guidance overview is currently generic in nature and is not inclusive of all the state and national compliance requirements as well as requirements obligated by financial institutions that are supporting the Project. A project specific plan shall provide a transparent translation into action of the Project's approved design plans, impact management plans, applicable federal and state legislations and permitting conditions, project lenders' requirements and other environmental and social commitments and obligations.



[A] Implementation of Management/ Action Plans

These are core documents and supporting processes which allow the identification and understanding of requirements, commitments, risks and impacts, set out the various controls and measures needed to manage risks and objectives, and drive continual improvement. Following is a minimum list of plans that need to be consulted during implementation of URFD.

- Approved Construction Design and Plans
- Environmental and Social Management Plan
- Land Acquisition and Resettlement Action Plan
- Indigenous Peoples Plan (if any)
- Hydrological Impact Management Plan
- Biodiversity Management Plan

These documents should be accompanied with procedures and/ or flowcharts that define implementation processes and controls (including standard procedures or flowcharts, detailed work instructions, manufacturers' operating / maintenance instruction manuals, etc.) to ensure effective implementation.

Wherever feasible, these documents will be retained in electronic format to facilitate efficient control and distribution. All these documents should be clearly identifiable. Each update or revision should be authorised by the appropriate authority prior to distribution. Documents are to be organised in a disciplined manner, clearly identified with respect to type of record and range/period covered.

[B] Change Management

Management Plans are intended to be 'live' documents as the site-specific conditions can change with time. In case of any change of site-specific conditions, the project implementation team should initiate a review of management plans. The project lead should seek for external third-party consulting help for any change in approved management plan. In addition, the project lead should voluntarily initiate a review of all management plans on an annual basis to update the plans, if needed (note: some plans may specify a different minimum frequency of updating). In case of any such change in management plans, the revised plans/ the proposed changes should be approved by project lead, project lender as well as regulators and stakeholders as deemed appropriate.

Additionally, the on-going process of stakeholder engagement may generate additional commitments (often 'promises' or 'undertakings' to individuals or stakeholder groups) that may not be reflected or identified in the approved management plans. These commitments should be recorded throughout the implementation phase in a live document like Stakeholder Engagement Register, which facilitates tracking across all the various commitments made to stakeholder groups (affected communities, local government, lenders, NGOs, or other organisations) over the life of the Project. The Register should set out timeframes for action and assign responsibility for fulfilling such commitments to the appropriate individuals, business units or, in some cases, the implementing third party (e.g. the contractor, an NGO or local government agency).

Box 17 | Community engagement

Community Engagement and Participatory initiatives often loose traction in the long term, due to lack of ownership and stewardship among users and direct beneficiaries (communities). This is attributed to the gaps in the modus operandi of community participation and engagement employed in most of the current community engagement practices.

The model for Community Engagement by TREE Craze Foundation (TCF)[44] under its program CERRE (Community Engagement for River Rejuvenation and Environment) suggests an institutional framework for the non-formal, non-government entities, namely CBOs, NGOs, academic organizations as well as citizens to work together. The key components are anchored around a River Trust Model which can be initiated and operationalized through a pilot. Some of the components of this River Trust Model are:

- River Trust which includes a hierarchy of local chapters and regional chapters which are based on hydrological boundaries.
- Public Participation and Stakeholder Strategy Plan.
- Working groups which includes focus groups.
- Action Plans for sub-programs.
- Knowledge materials: Toolkits, guidelines and a Charter for the River Trusts. The model is designed to achieve the following objectives:
    1. Two directional flow of information between government and communities
    2. Awareness
    3. Empowered citizens
    4. Transparency
    5. Ownership
    6. Collaboration and partnerships to work together
    7. Bridging gaps between participating stakeholders and decision makers

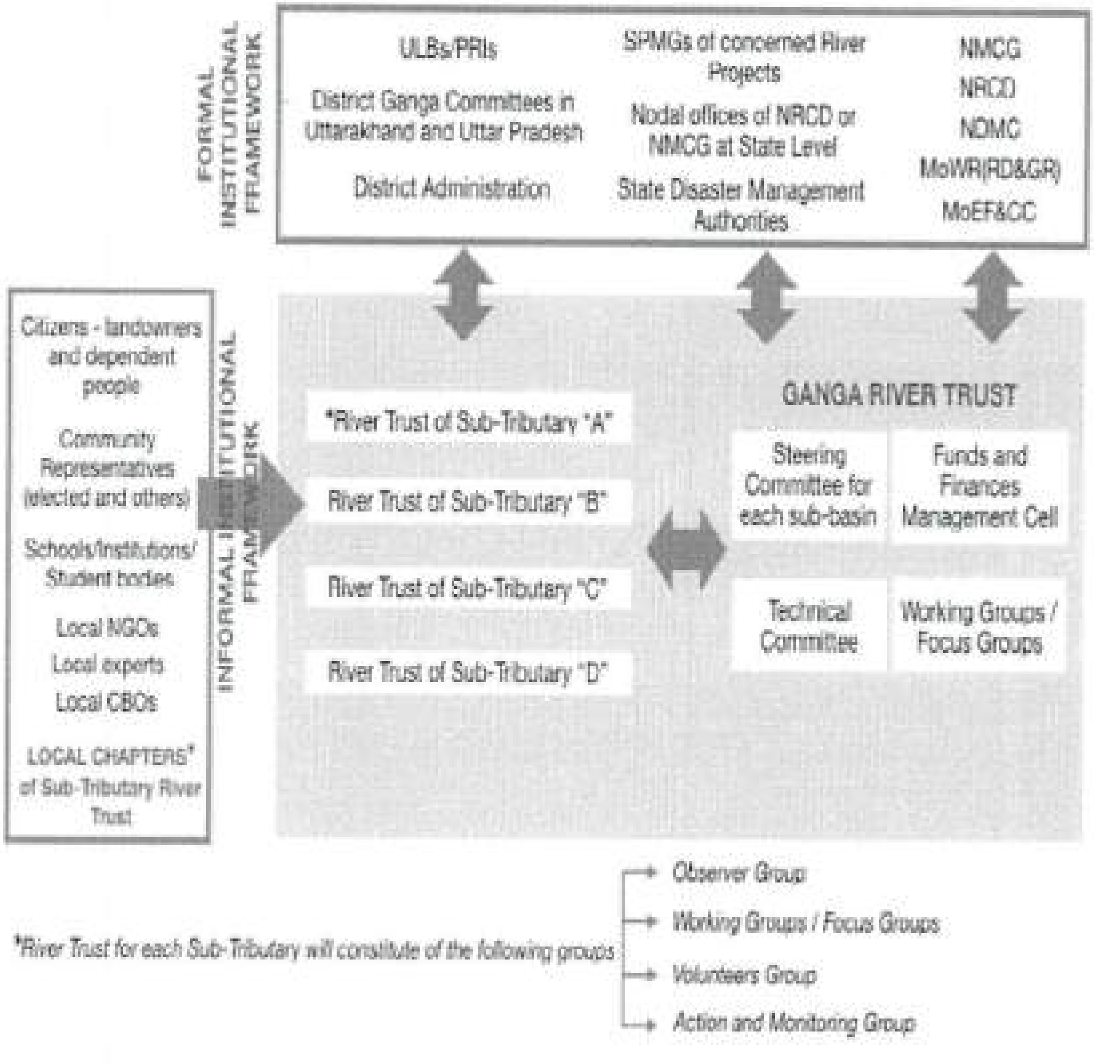
This model by TCF for community engagement enables an institutional arrangement which can anchor, host, manage, initiate and hand-hold community members and other stakeholder and decision makers. River Management Trusts or River Trust at local and sub-basin level supported by a Steering Committee and Working Groups for each local river trust is the most successful institutional model worldwide. Given the scale of rivers, types, and the population impacted in a country like India, it is preferred to have local river trusts for each sub-tributary or tributary of the river, each of which is represented at the larger body which would be the River Trust for a given River.

The ultimate objective of CERRE program is to empower the citizens to own, run and manage their local river trusts and together build the network of local and regional river trusts to enable local and basin level goals for river rejuvenation.

The model for non-formal institutional framework under CERRE programme of TCF is illustrated below:

The box to the bottom left of the above illustration shows the composition of local chapters. No formal, governmental institutions are part of the river trusts. This distinction is absent in almost all entities formed for implementing projects and programmes, but this distinction is important to ensure that citizen and community voice is truly and independently represented. This is an important and unique feature of the model for community engagement proposed by TCF.

Figure 23 | TREE Craze Foundation (Information Brochure on CERRE Programme)



*Local Chapters will be created for each of the major ULB or Gram Panchayat within the area of the Sub-Tributary River Trust

Image credit: TREE Craze Foundation

[C] Monitoring and Evaluation

Monitoring and Evaluation (M&E) are critical for effective implementation of management/ action plans. M&E records consists of documents, reports, photos, forms / templates, recordings, data, etc., that demonstrate the implementation of management plans stating results achieved or providing evidence of activities performed.

The project proponent should set up a M&E team which should report to the project lead. The M&E team should have an overarching responsibility for the management, monitoring, inspection, and reporting of management plans. The team should ensure that the project implementation team should have the right knowledge, skills and experience necessary to perform their work as per the approved management plans. The M&E team should:

- Conduct bi-annual audits on effective implementation of management plans.
- Report corrective and/or preventive actions in coordination with the project execution team.
- Drive the continuous performance improvement in relation to implementation of management plans.
- Reporting of KPIs on regular basis as detailed in PSR (Chapter III: Section A6).

[D] Training

All Project personnel, whether internal or external (with specific assigned tasks), are required to be professional and competent. As appropriate, individual competencies will be demonstrated through professional qualifications and/or on the basis of adequate personal experience, training and/or instruction.

It is imperative that all project execution staff and contractor personnel know and understand:

- Their respective roles, responsibilities and specific duties in relation to implementation of management plans.
- The importance of compliance to project management plans, to the requirements of the various regulations and to the project lender's requirements.
- The potential consequences of procedural failures or deviations from planned arrangements, especially with regard to potential environmental degradation or stakeholder disappointment.

Training should occur at all levels throughout the implementation phase of the project. Project specific training program should be developed by incorporating various requirements under management/ action plans, regulatory and permit requirements as well as any specific requirements from the project lead. The training materials should be reviewed and updated on an annual basis to accommodate any change in circumstances. It is important to maintain up-to-date training records as well as to ensure sufficient qualified capacity to deliver these training programs.

[E] Information Disclosure

Implementation of URFD projects are expected to have social and environmental impacts on the community. Therefore, inquiries, concerns and complaints are expected to arise during the implementation phase. The project proponent's response and its approach to manage such issues can have significant implications on the success of such projects. The project proponent should ensure that all stakeholders are well informed about the project throughout its implementation lifecycle. Stakeholders will have the opportunity to express their opinion about the project including complaints.

The project proponent should use all effective communication tools with all stakeholders such as face to face meetings, informational meetings, visits in the communities, presentations and focus group meetings. The project proponent should ensure effective and timely communication with all stakeholders, including the media and provide information on progress of operation phase as well as to respond to concerns related to the Project. Stakeholder engagement program shall define the communication with key interest groups and the frequency of such meetings.

[F] Grievance Redressal

A grievance can be defined as an actual or perceived problem that might give grounds for complaint. As a general policy, the project proponent should work proactively towards preventing grievances through the implementation of impact mitigation measures and community liaison. These activities should be designed to anticipate and address potential issues before they become grievances.

Anyone should be able to submit a grievance to the Project if they believe the project is having a detrimental impact on the community, the environment, or on their quality of life during the implementation phase. They may also submit comments and suggestions to the project team.

Any comments or concerns can be brought to the attention of the project team verbally or in writing (by post or e-mail) or by filling in a grievance form. Grievance forms can then be submitted to the relevant project personnel whose contact details should be provided clearly.

All grievances should be acknowledged within 10 days. The response to a comment should be provided within 21 working days, unless there are exceptional circumstances. Grievances should be categorized based on validity and risk level. Where further investigations are required, project team and qualified external authorities, as appropriate, should assist with the process. The grievance redressal mechanism should record the manner in which any review has been carried out, the results of the review, any changes to activities that will be undertaken to address the grievance and how the issue will be managed to meet appropriate environmental and social outcomes. Grievance information should record the following in the form of a grievance log:

- Stakeholder name and contact details
- Details of the nature of the grievance
- Date received, responded to and closed out
- How it was submitted, acknowledged, responded to and closed out.

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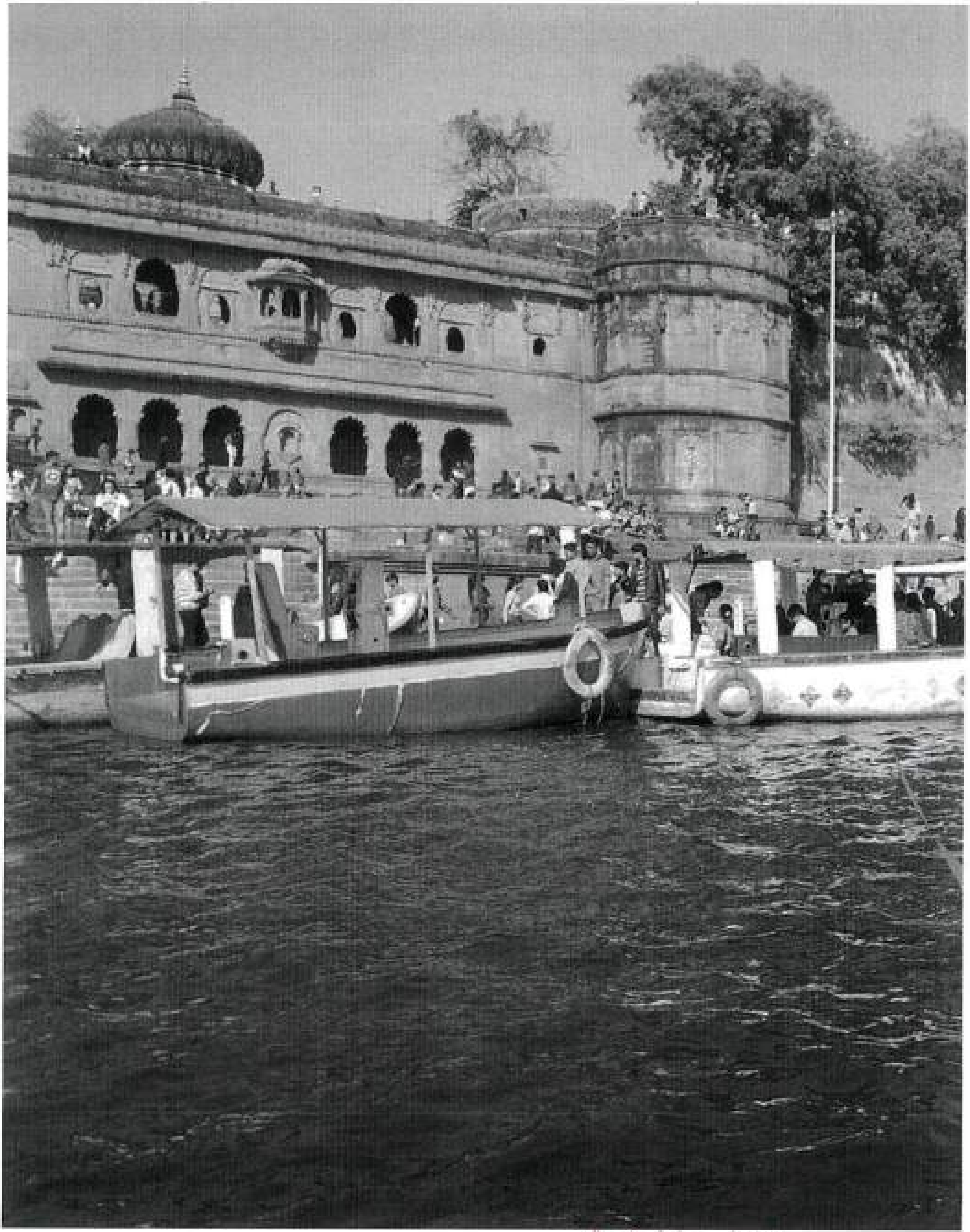

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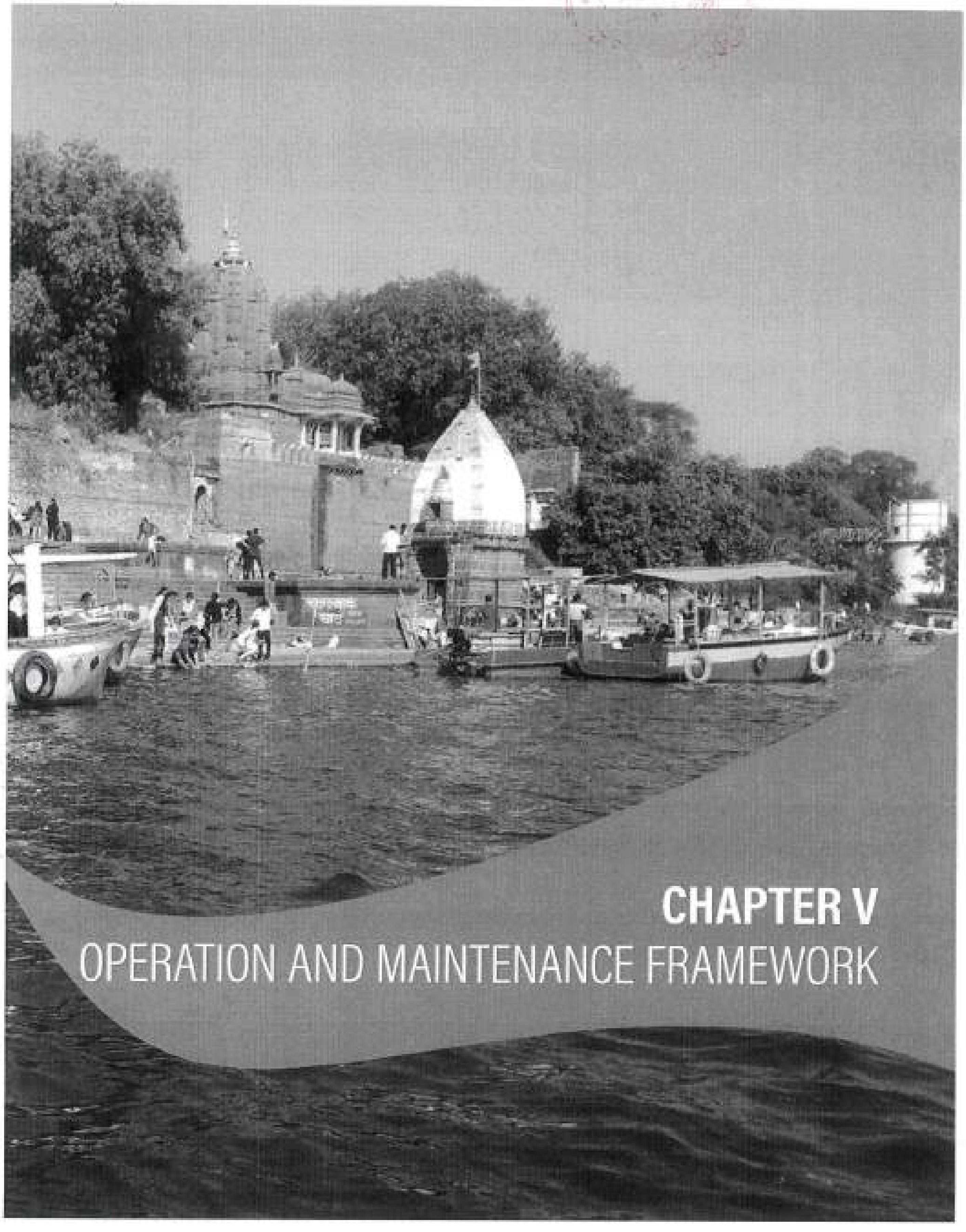


CHAPTER V

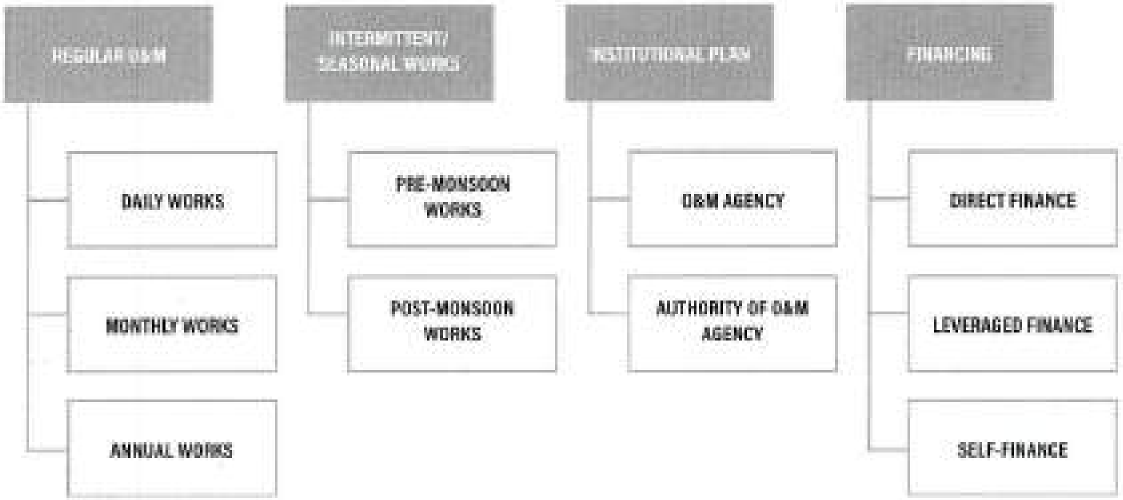
OPERATION AND MAINTENANCE FRAMEWORK

CHAPTER V: OPERATION AND MAINTENANCE FRAMEWORK

Urban riverfronts have the potential to bring in tourists and new users which can help revitalize riverfronts and adjacent neighbourhoods and improve revenues in these areas. The presence of more people along the riverfront, though, will require adequate services and amenities and measures to mitigate the environmental impacts of increased foot traffic in these districts.

Operations and Maintenance (O&M) will be a critical component of a successful urban riverfront project. Ideally an O&M plan must be developed during the design and planning stages so that design and construction support ease of O&M works at a later stage and protocols are established early on in the project.

The O&M plan must clearly designate the authority which will be in charge and establish protocols of regular (daily, monthly and annual) works. In addition, there must be a clear set of guidelines on pre and post flooding works that must be undertaken to ensure the longevity of the riverfront development.



[A] Financing Operations & Maintenance in URFDs

Alongside a pre-defined O&M plan, adequate and long-term funding must be allocated for O&M efforts in URFD project. These funds must be allocated/ disbursed to the agency in charge of project management. There are multiple avenues from which funding can be ascertained and these can be divided into 3 categories:

- Direct Finance
- Leveraged Finance
- Self-financing

A.1 DIRECT FINANCE

Direct finance will include all such funds which are granted directly to urban local bodies (ULBs) by state or national governments or are leveraged by ULBs through grants or loans to build urban infrastructure. For projects such as URFDs urban local bodies can add the capital and O&M expenses as another item in their budget estimates along with water and sanitation, roads and public health. The URFD would be considered as another work undertaken by the ULB for the public good. Funds for these works could be secured from:

- ULB budget: money allocated by the local government for the URFD in their annual budget and the URFD is taken up as a public amenity similar to public roads or water supply and sewerage systems.
- Grant or seed money: provided by initiatives such as Namami Gange/ SMART Cities/ AMRUT/ NRCD.
- Loans: from infrastructure banks or development agencies.

A significant challenge associated with direct finance is that while beneficial to support capital expenses it is difficult to ensure on-going funding for O&M works. Particularly as ULB budgets are already constrained with on-going activities which might have priority and O&M costs typically increase with increasing age of infrastructure. Grant or seed money also does not provide for robust funding streams for long-term O&M works. And finally, with loans there is an additional expense of repayment that must be borne.

Box 18 | **Funding river rehabilitation works - Qinhuai River, Nanjing, People's Republic of China**

Nanjing is a historically important city in China, having also been a former capital city and 34 kilometres of the Qinhuai River flows through the city. In the 2000s the city faced major water related stresses brought about by rapid urbanization and increased rural to urban migration. The region went from 50% rural population in 1990 to a mere 27% rural by 2003. Increased domestic and industrial demand in a region of inconsistent rainfall led to cycles of urban flooding and stagnation and water scarcity. In addition, the region's water sources (rivers and lakes) including the Qinhuai River were severely polluted, with areas within the river wetland diverted for garbage dumps and squatter settlements (Vollmer 2009).

Eventually, the focus of urban development arrived at river improvement and rejuvenation with about USD 90 million (from 1985 to 2009) spent on grey infrastructure (upgrade drainage and sewage treatment), which led to significantly improved water quality by 2002. Moving beyond pure infrastructure improvements, the city also looked to mitigate floods and improve urban health and approached the ADB for financing to achieve these objectives. The ADB agreed to fund USD 100 million in the proposed USD 236 million project. The ADB funds were targeted towards various outcomes and 3 components are of particular interest. The primary objective was for wetland rehabilitation of 33 hectares of degraded and occupied wetland zone to create a wetland park. The project also included a component for the resettlement of the occupiers within the wetland area. Also included was a component on strengthening local institutions, particularly to improve environmental management and monitoring. Preliminary assessment of the proposed plan suggests net benefits of about USD 112 million can be accrued from the wetland park alone. (Vollmer 2009)

Box 19 | Riverfront development on River Ganga – Patna, India

The World Bank has been a long-time supporter of the Ganga rejuvenation project and is providing financial support of about USD 1 billion (2011-2021) for improvements, interventions and capacity building for authorities in areas across the Ganga Basin (The World Bank 2011). As part of the overall project, the World Bank also provided funding for the Ganga Riverfront Development project at Patna in 2013. The project management and funds disbursal for this project was undertaken by Bihar Urban Infrastructure Development Corporation Ltd. (BUIDCo), which is the nodal agency in Bihar under the NGRBA (Tripathi 2013).

This project had a 26-month timeline to develop 20 ghats in 4 distinct urban districts and a continuous promenade along the riverfront as well as implement landscaping, electrical works and public amenities in the space. With the World Bank's presence in this project the bidding procedure was conducted through the Bank's guidelines (BUIDCo 2013). The cost sharing of the proposed USD 43 million project (Malhotra 2016) was worked out as 70% from NGRBA (Central agency) and 30% from the state. Of the Centre's share 90% of the amount was provided by the World Bank, which was 63% of the total project amount (Tripathi 2013).

Box 20 | Financing using funds from Corporate Social Responsibility

Alongside usual funding sources of loans or budget line items, another potential source of funds in India can be from the Corporate Social Responsibility (CSR) funds as provided by corporations in India. As per the Corporate Social Responsibility Policy (2014) to improve corporate citizenship, companies are required by law to channel at least 2% of net profits of 3 previous fiscal years towards works of social or environmental benefits, institute a CSR Committee which will oversee the disbursal of funds and maintain oversight of and report project status (Finance Department 2019).

In 2014 the CSR Policy was modified which now allows corporations to directly provide funds towards the Clean Ganga Fund instead of towards specific projects where the corporation would have to maintain oversight. Instead, by contributing to the Clean Ganga Fund, corporations are still able to meet their obligations under the CSR Policy, yet do not need to maintain records of how the funds were used within the project itself (Government of India 2014).

A.2 LEVERAGED FINANCE

Given the growing challenges that ULBs face to secure financing for projects and for O&M, a range of innovative financial mechanisms have been attempted across cities. While most of these mechanisms are new to India, a few of them have been used to support infrastructure works such as city road improvements and water supply and sewerage projects. URFDs could look to these innovative mechanisms to leverage funds for O&M works. The financial tools are as follows:

- Municipal Bonds/ Green Infrastructure Bonds: wherein financially viable ULBs are able to tap into market capital by issuing

Box 21 | Pioneering green bond to fund green infrastructure project - DC Water Environmental Impact Bond, Washington

In September 2016, DC Water and Sewer Authority (DC Water) issued the US's first Environmental Impact Bond (EIB) of USD 25 million to fund the initial project (construction of green infrastructure for Rock Creek Project A). This was part of the total USD 2.6 billion program to control stormwater runoff and improve water quality of the rivers and streams in the district (Goldman Sachs, 2016). The amount raised through this 30 year tax exempt bond (with a mandatory tender[*] period of 5 years) will be used specifically to construct green infrastructure which uses nature based technologies to reduce storm surges and decrease combined sewer outflows in the current context of frequent and extreme rainfall events (US EPA 2017) (North and Gong 2017).

This innovative bond uses a Pay for Success model and allows for performance based risk/ reward sharing between DC Water (see table below) and the investors and helps raise the investment needed for capital costs in the project.

There are 2 principal benefits to the use of green bonds such as DC Water's EIB:

The risks associated with the performance of the project are shared between DC Water and the investors; thus, when there is low performance the investors will provide additional payments allowing DC Waters to recover some of its costs.

By connecting performance with outcome (runoff reduction) as well as infrastructure built or deployed, the focus to build and maintain higher outcomes is incentivized.

The risk sharing mechanism in this EIB is set up as a special (potential) pay-out to investors at the end of the mandatory tender period but is contingent on performance outcomes. If the new infrastructure (nature-based technologies) functions efficiently (reduces stormwater runoff by more than 41.3% of existing flows) then the utility pays to the investors. But when the system function is low (stormwater reduction less than 18.6%) then investors pay the utility[x].

Performance Tier	Outcome Ranges	Contingent Payment
1	Runoff Reduction >41.3%	DC Water will make an Outcome Payment to Investors of $3.3 million.
2	18.6%>= Runoff Reduction <= 41.3%	No Contingent payment due.
3	18.6%>= Runoff Reduction <= 41.3%	Investors will make Risk Share Payment to DC Water of $3.3 million.

Basically, the risk sharing mechanism denotes that the utility, DC Water's, payment obligation to investors is contingent on the functioning of the systems installed. Other than the risk sharing payment, the EIB functions like any other investment bond and offers a 3.43% return, payable semi-annually for the first five years[xi] (US EPA 2017).

bonds (Vaidya and Vaidya 2010).

- Tax Credit Programs: allows ULBs to raise capital by accepting contributions from private entities, usually businesses, and providing tax credits/ tax breaks to these entities in return[xii].

Business Improvement Districts/ Community Benefit Districts: are demarcated regions where businesses agree to a higher tax rate from which infrastructure improvements or community projects can be undertaken (Shah, et al. 2015). When local residents also agree to such a revised

Box 22 | Masala bonds and the potential for infrastructure funding in India

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Financing needs for emerging economies such as India are wide and varied but regulatory and institutional barriers impact the flow of funds in these markets. In addition, while there may be global interest in participating in these economies, the markets function on local currency only which limits the participation of global players. To overcome the challenges of currency exchange risks and yet allow local/ national companies the opportunity to tap into global investment mechanisms the International Finance Corporation (IFC) worked closely with Indian agencies to develop a debt instrument in local currency[xiii]. This was termed as Masala Bonds and are essentially off-shore Rupee Denominated Bonds which can be traded on global markets and the monies raised can be invested in projects in India (Shi 2017).

The first Masala Bonds were offered by IFC on the London Stock Exchange in 2014 for a total amount of USD 1 billion (INR 62 billion). As of 2016 Masala Bonds of about USD 95 billion had been issued by various Indian and foreign entities[xiv] at the London Stock Exchange (Challa and Kanakadurga 2016). An Indian entity incorporated under the Companies Act is eligible to issue Masala Bonds in global markets. Monies raised through Masala Bonds can be used for a wide range of purposes except for certain limiting activities as delineated by the Reserve Bank of India (RBI). The following activities are prohibited for Masala Bonds (MEA 2016):

- Purchase of land or real estate activities (except for affordable housing and integrated township projects.
- Investment in capital markets.
- Lending to other entities.
- Any activity prohibited by the foreign direct investment guidelines.

Masala bonds protect bond issuers from global currency fluctuations as the bonds are issued and returns are offered on the local currency[xv]. For investors, Masala Bonds are attractive as they offer a higher rate of return of about 5% to 7% as compared to about 2% to 3% returns in the US (MEA 2016).

While corporate, banking and public sector units can easily access overseas bond markets using Masala Bonds, there is still some question on the mechanism through which government entities (though incorporated) can access this market. These were raised on the issuance of Masala Bonds on the London Stock Exchange by the Kerala Infrastructure Investment Fund Board in April 2019. Though this issuance was approved by the RBI as the first state level body to issue such bonds there remains the question of how sovereign guarantee would be applied (Shikha and Gulati 2019).

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tax rate these districts are called CBDs. Such tools might be particularly relevant to URFDs to ensure community participation and a sense of stewardship as the money from the community/ local businesses will be used to manage the project and O&M.

A.3 SELF-FINANCING

In addition, ULBs implementing URFDs can look to self-financing mechanisms for such projects to remove dependence from the fluctuations of ULB budgets and/ or external funding sources. Assets on the project site can be used to generate revenues under self-financing mechanisms. Some possible self-financing mechanisms include rents on spaces such as convention centres, auditoriums, etc., and advertising charges.

Box 23 | Municipal bonds and SMART Cities

Urban infrastructure needs in India are enormous, with a projected need of USD 4.5 trillion until 2040 (PTI 2018) as both older and emerging cities require either new systems or substantial infrastructure upgrades. Budgetary allocations will not meet this huge requirement if Indian cities are to provide equitable, high-quality infrastructure for all citizens. To meet this financing gap, urban local bodies and financing agencies have explored a variety of alternate mechanisms to raise funds to meet capex and opex costs for urban infrastructure. Municipal bonds might be a crucial tool to support urban local bodies to raise investments.

A municipal bond is a debt instrument which urban local bodies, special purpose vehicles, parastatals can use to raise financing for infrastructure projects such as road construction, water supply and sanitation, schools, health centres, etc. Through this mechanism the issuer (urban local body) is obligated to pay to the investors the principle and interest amount after a fixed tenure. This instrument also benefits investors as municipal bonds typically have higher rates of returns, are low-risk and have attractive tax savings associated with them (ICAI 2018).

Though this mechanism was first used in 1997 by the Bangalore Municipal Corporation, the municipal bond market has remained sluggish in India (Kapoor and Pati 2017). The recent initiatives around SMART Cities and AMRUT have led to more interest among urban local bodies and utilities to explore the municipal bond market to raise funds. In addition, relaxation of various regulations by the Securities and Exchange Board of India in 2019 may also spur the municipal bond market in India (PTI 2019).

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Box 24 | Value creation through river rejuvenation and redevelopment - Dravyavati Riverfront, Rajasthan

The Dravyavati River (Amainshah Nallah) flows about 48 kilometres through the city of Jaipur, is a rain-fed stream, which until the river rejuvenation project had become a wastewater stream. The deteriorating water quality, diminished biodiversity and ecosystem, resultant health hazards and a disastrous flood event (in 2012) were key triggers for the city authorities to plan a river rejuvenation scheme. The project was awarded by Jaipur Development Authority (JDA) to Tata Projects Limited (TPL-SUCG Consortium) to develop a rejuvenation plan, implementation of the area development plan on a turn-key basis and manage operation and maintenance for a 10-year period (Anand 2018). The project is estimated to be about Rs 1676 crore including construction cost of Rs 1470 crore and 10 years' maintenance of Rs. 206 crore (Kumar 2018).

The TPL-SUCG Consortium also proposed a Business Plan for value creation and monetization of the improved and reclaimed lands post-redevelopment. This was to showcase to the JDA the added benefits (monetary and other tangible benefits) the city could accrue from the river rejuvenation project (Anand 2018). The plan estimated that up to 85 hectares of reclaimed land could come into the ownership of government authorities. In addition, the value of existing government land (about 53 hectares) would also be enhanced. In total, these added lands and enhanced areas could potentially add a value of approximately INR 1,900 crore (~USD 275 million considering an exchange rate of INR 70 against 1 USD) to government coffers (Jaipur Development Authority n.d.).

This study does not include adjoining private lands which would also see increments in their property values which could flow to government authorities in the form of property tax.

Box 25 | Trust Fund mechanism for river rejuvenation - Clean Ganga Fund, India

The Clean Ganga Fund (CGF) was established in 2014 in India, as approved by the Union Cabinet, under the direction of the Prime Minister. The fund is designed to be managed by a Trust led by the Finance Minister. This trust and fund mechanism allows for the creation of a large corpus of money which can be used at the direction and discretion of the Trustees. The eligible actions that can be undertaken from this fund includes a range of pollution abatement projects (including mitigation of point and non-point sources of pollution, setting of sewage treatment plants in urban areas along the river, etc.). Further, the fund allows actions on conservation of biodiversity, community engagement and awareness, research and development, monitoring and reporting of water quality (Press Information Bureau 2014).

This type of fund gives project proponents the flexibility to tap into unencumbered finances to undertake a range of projects for river rejuvenation and redevelopment. Further, the fund structure provides for on-going donations from both private individuals and corporations (national and foreign), thus maintaining a robust and growing funds pool that project proponents can tap into. Finally, funds as part of corporate social responsibility can be placed in this fund directly to add to the fund pool (NMCG 2017).

Corporates can also choose to use their CSR funds for specific projects instead of contributing to the CGF, such as piloting of new technology, ghat adoption, tree plantations, awareness drives, research, etc.

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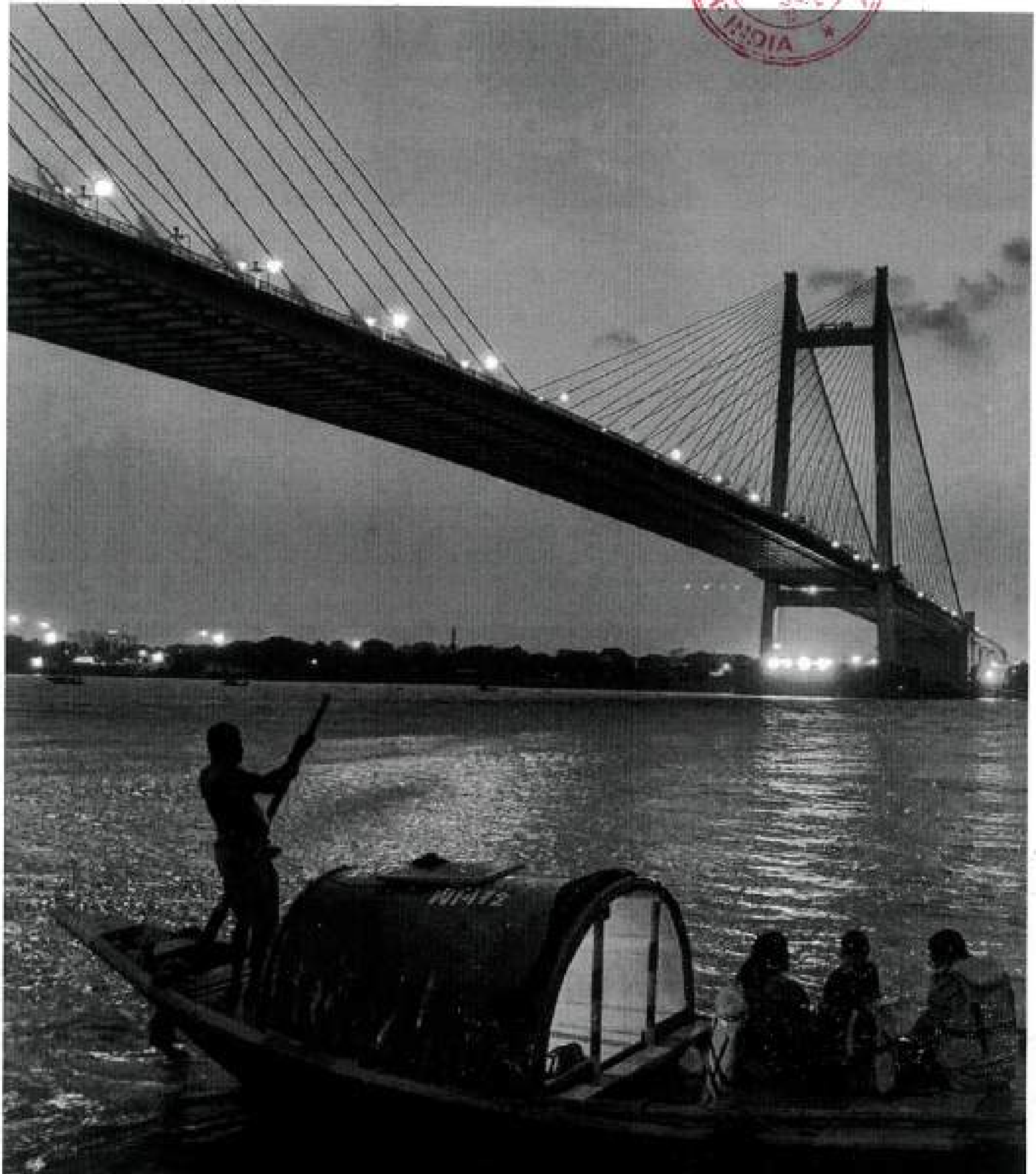

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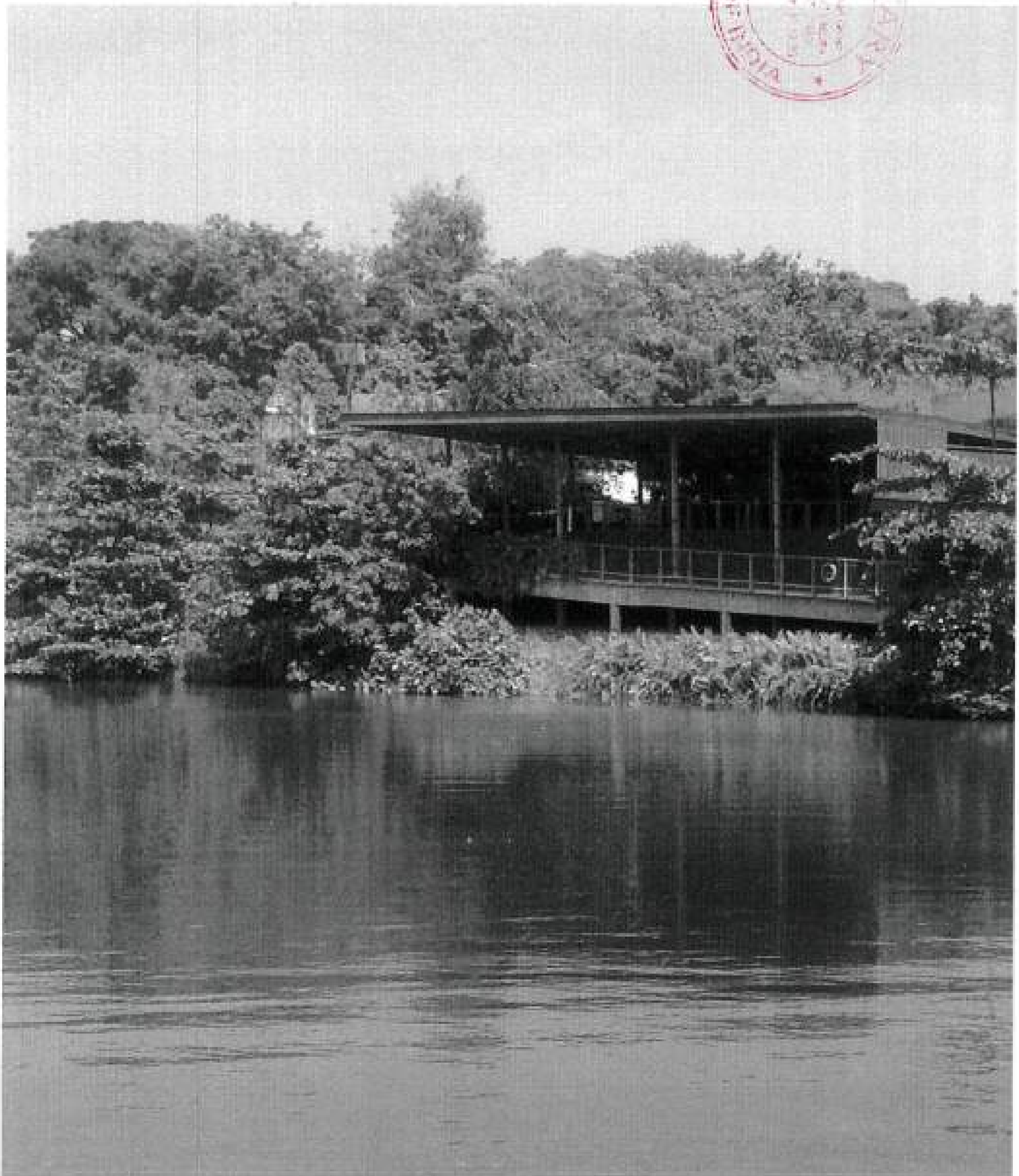

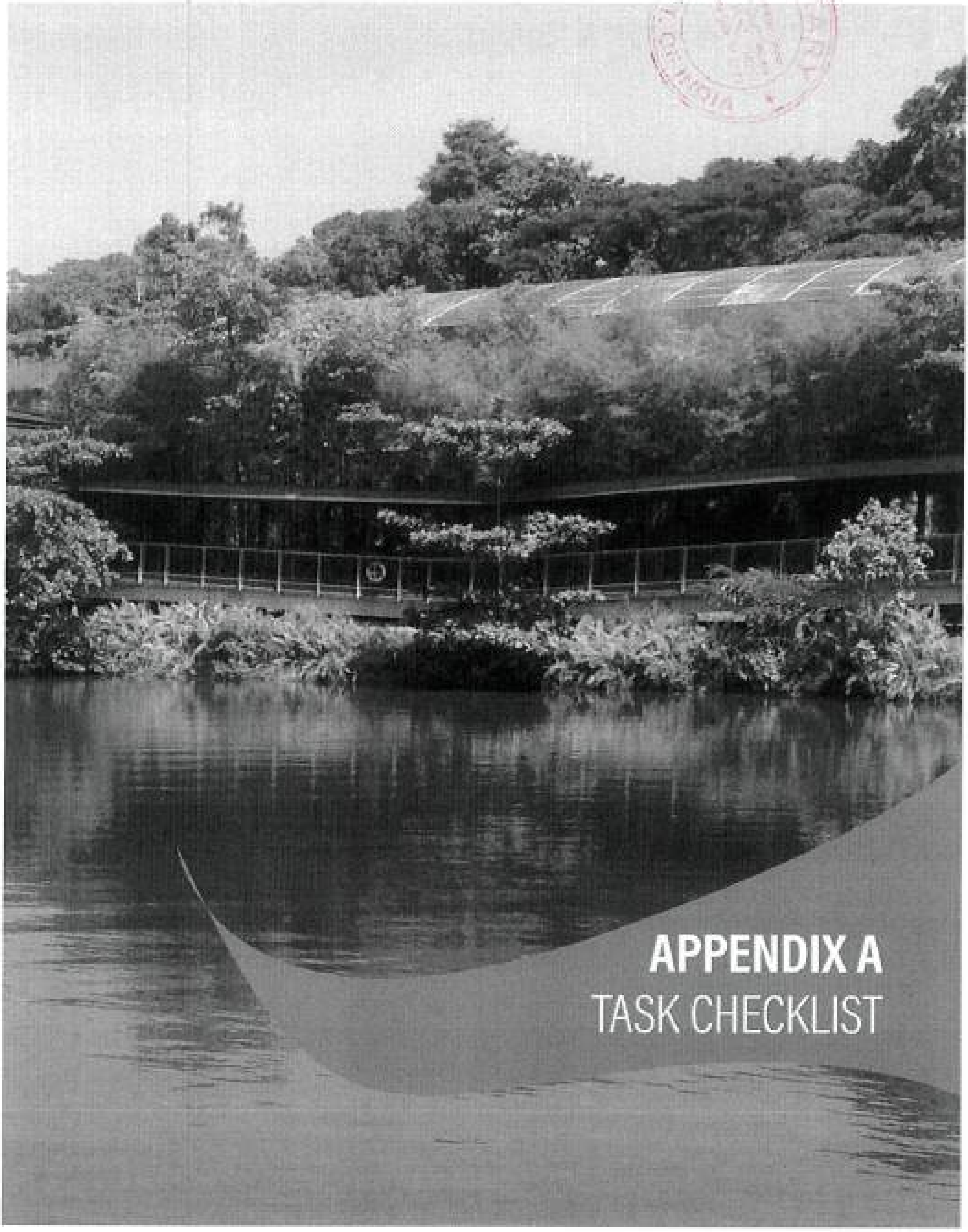

APPENDIX A

TASK CHECKLIST

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APPENDIX A: TASK CHECKLIST

The tasks to be undertaken (and their order) are described as a questionnaire below which can be used as a checklist for approvals, implementation, management and evaluation of the environmentally sensitive, climate adaptive and socially inclusive urban riverfront planning and development.

Table - Questionnaire

S.No.	Task	Yes	No	Comment
1	Has a Project Screening Report (PSR) been prepared which includes:			
a	Urban riverfront development (URFD) typology, based on			
i	Energy environment of river			
ii	Energy environment of river			
b	Study of existing plans and proposed URFD			
c	Site selection analysis based on			
i	Natural geomorphology of riverbanks			
ii	Floodplains extent			
iii	Grey (built up) infrastructure in and around the URFD			
iv	Locations with polluting land uses			
d	Urban and riverine connections			
i	Connections to upper and lower order streams, tributaries and distributaries			
ii	Connections to urban green spaces			
iii	Connections to pedestrian and NMT pathways for accessing the URFD			
e	Financial plan			
f	Review of URMP, other projects/ programmes, Development Controls and other zoning regulations applicable in the project area			

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S.No.	Task	Yes	No	Comment
2	Has a Detailed Project Report (DPR) been developed which includes			
a	Hydrological Assessment			
b	Environmental Impact Assessment			
c	Social Impact Assessment			
d	Design Strategy			
3	Has a Planning and Institutional Strategy been developed for the URFD?			
IMPLEMENTATION ACTIVITIES				
4	Have the following management/ action plans been developed?			
a	Approved Construction Design and Plans			
b	Environmental and Social Management Plan			
c	Land Acquisition and Resettlement Action Plan			
d	Indigenous Peoples Plan, if any			
e	Hydrological Impact Management Plan			
f	Biodiversity Management Plan			
5	How are changes and feedback being managed?			
a	External consultant approves changes to existing plan			
b	Has an annual review of all management plans been undertaken?			
c	Is there a stakeholder register allowing input of feedback from various stakeholders?			
d	Have stakeholder inputs resulted in changes to the plan or project commitments and have these been used to update the management plans?			

S.No.	Task	Yes	No	Comment
6	Has a monitoring and evaluation team been set up as part of the URFD project?			
a	Has a bi-annual M&E report been generated with corrective actions indicated?			
b	Have the corrective actions been implemented on the URFD project site?			
c	Has the M&E report been used to update the management plans?			
7	Have all URFD personnel undergone an orientation training session with focus on roles and responsibilities; compliance requirements; and consequences of procedural lapses?			
8	Is there a portal/ platform for regular information dissemination and disclosure for the URFD? Does the platform support user/ stakeholder feedback?			
9	Is there a dedicated team and a platform/ mechanism for grievances to be submitted with regards to the URFD?			
a	What is the rate at which grievances are addressed and resolved?			
b	What are the steps undertaken to ensure transparency to address the issue shared with the complainant?			

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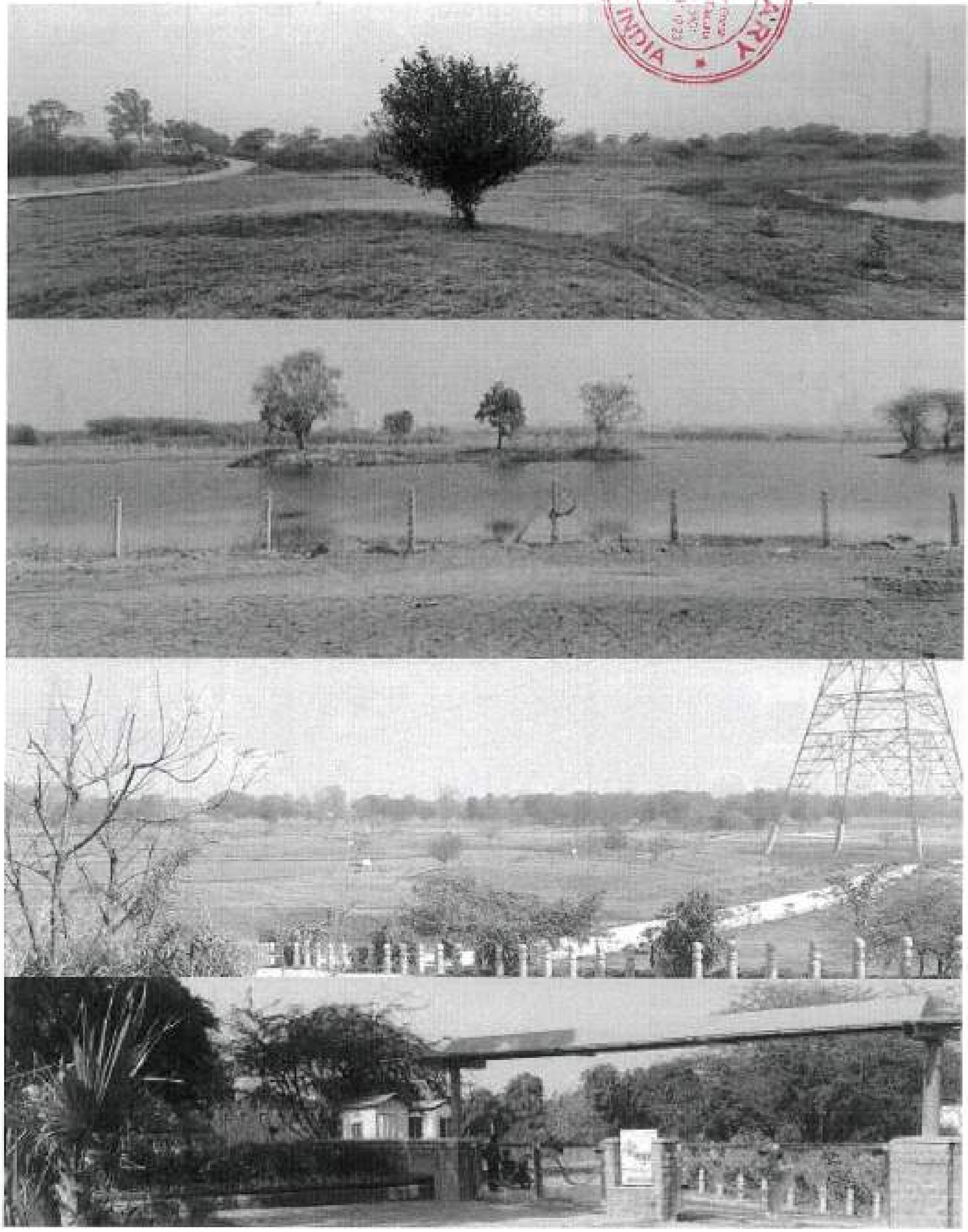

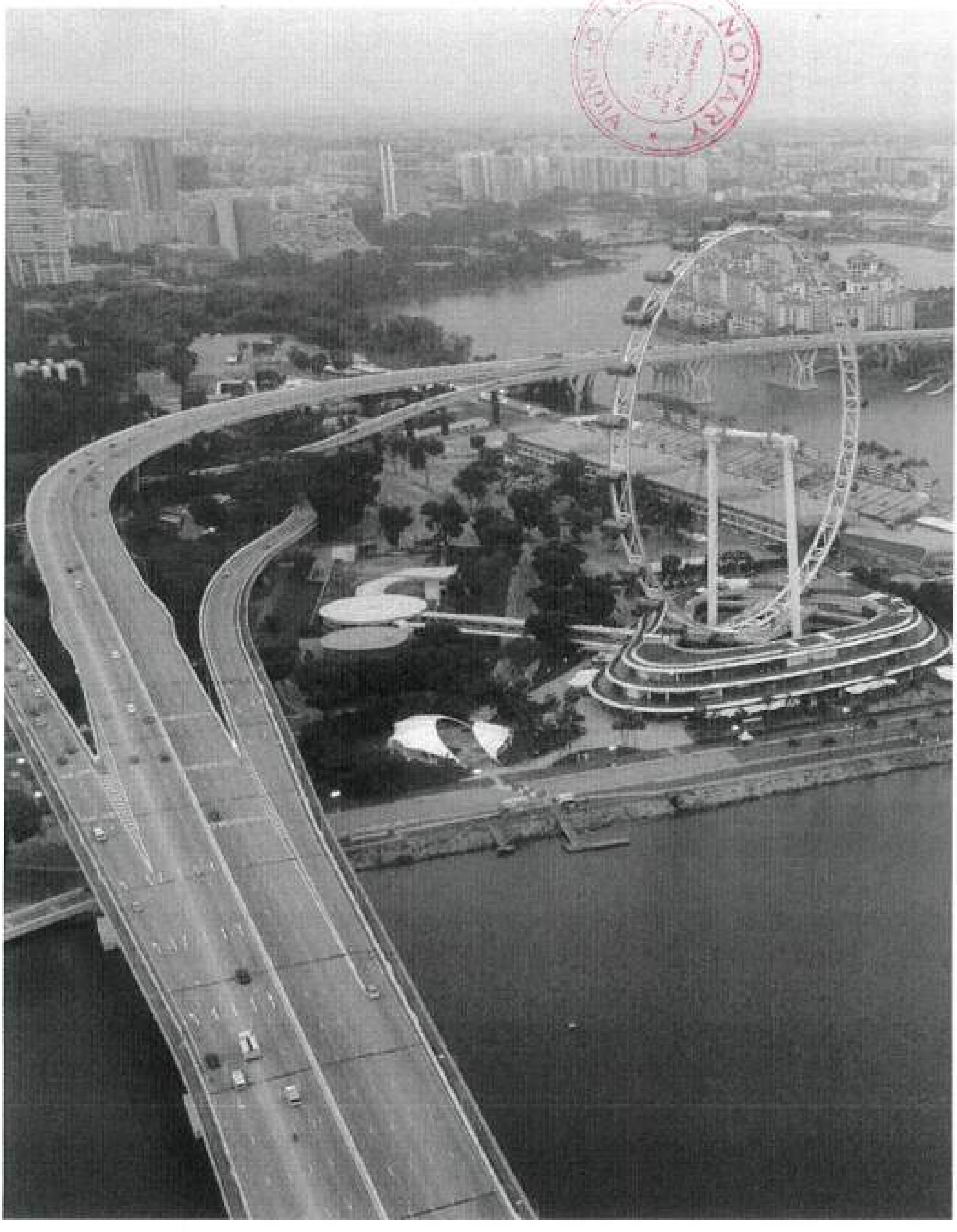

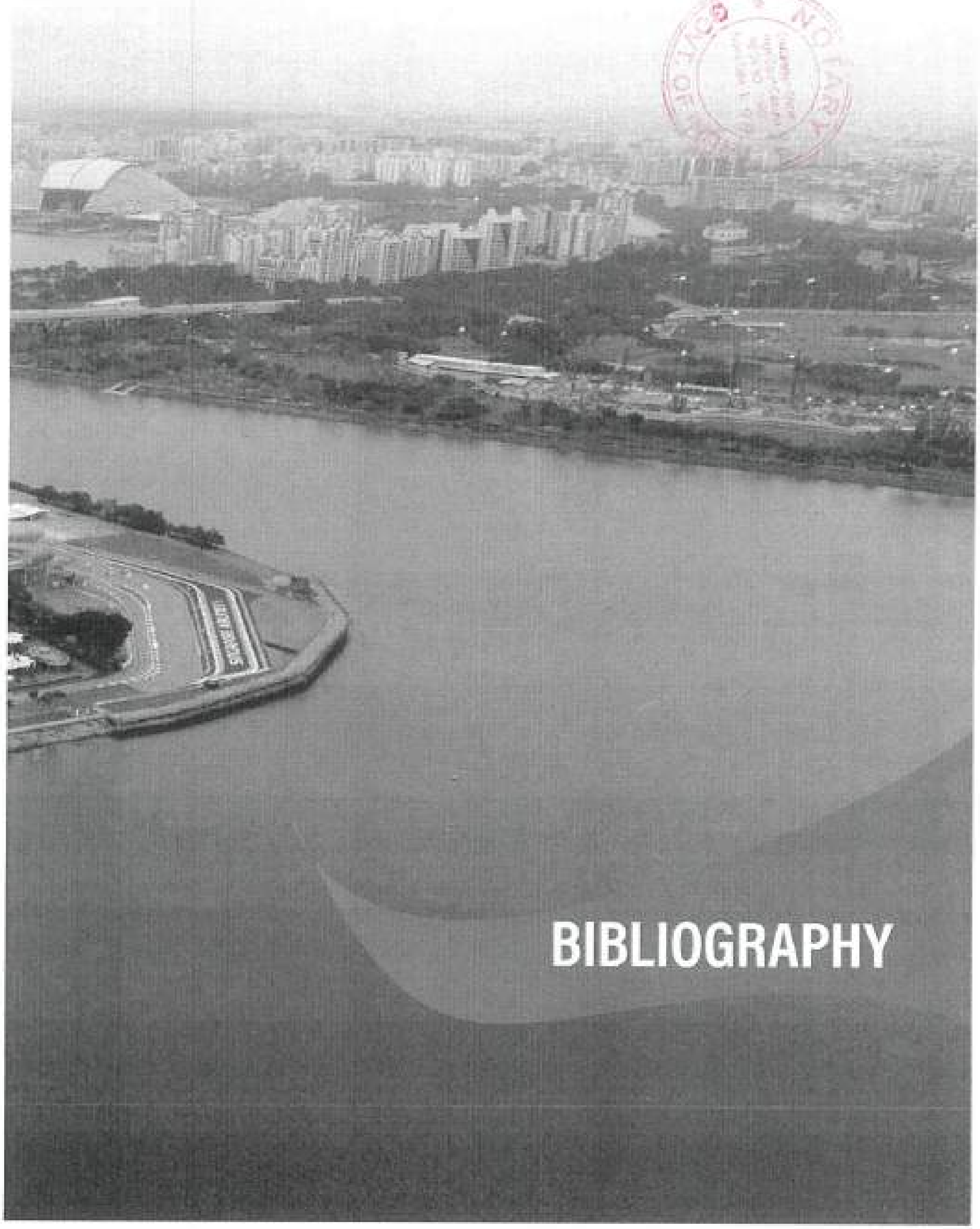

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ENDNOTES

[i] Ecological Riverfront Design: Restoring Rivers, Connecting Communities. (Planning Advisory Service Report Number 518-519. 2004 https://www.csu.edu/cerc/documents/EcologicalRiverfrontDesign.pdf) by Betsy Otto, Kathleen McCormick, and Michael Leccese; Publisher: American Planning Association.

[ii] Such a management plan exists for the River Ganga basin and this plan also provides directions for developing, managing and reviving the river through the guiding objectives.

[iii] Geomorphic features for River Ganga are mapped along its entire stretch and this mapping data is available with IIT consortium and can be made available by the National nodal agency (NMCG). Similar mapping of geomorphic features along with active floodplain and valley margin mapping/delineation are available for most of the major rivers in the country.

[iv] Access control to the river will include interventions such as limiting ghats or paths leading to the river, boating activities, shipping, etc.

[v] CPCB prescribes bathing water quality (CPCB n.d.) in ghat areas where people will access the water for cultural and recreational purposes. Another notification from US EPA also prescribes minimum measures of water quality parameters for various uses including recreational use (US-EPA 2012) which the project proponent can choose to follow.

[vi] The NGRBA was dissolved in 2016 and replaced with the National Council for Rejuvenation, Protection and Management of River Ganga (referred as National Ganga Council) (NMCG 2019).

[vii] TREE Craze Foundation TREE Craze Foundation (TREE stands for Tree, Rivers, Ecology, and Environment), a section-8 not-for-profit company, committed to the cause of Trees, Rivers, Ecosystems & Environment. It acknowledges the power of communities and is striving to charge up the communities to own up their rivers and act for them leveraging international best practices.

[viii] Pennsylvania Department of Community and Economic Development. Waterfront development tax credit program. https://dced.pa.gov/programs/waterfront-development-tax-credit-program-wdtc/

[ix] Mandatory tender period refers to the minimum period of time that the bond has to be held or amount locked in before the investor can seek to recover their investment.

[x] The utility recovers the risk share payment by holding back the requisite amount (USD 3.3 million) from investors final payout (North and Gong 2017).

[xi] At the end of the mandatory tender period the rate of return can be revised based on existing market dynamics for the rest of the bond tenure.

[xii] Samurai bonds in Japan and dim-sum bonds in China were developed on similar lines to the Masala bonds on India (Shi 2017).

[xiii] Masala bond issuers include Housing Development Finance Corporation, National Thermal Power Corporation, province of British Columbia, Canada and European Bank for Reconstruction and Development (EBRD) in 2016 (Challa and Kanakadurga 2016).

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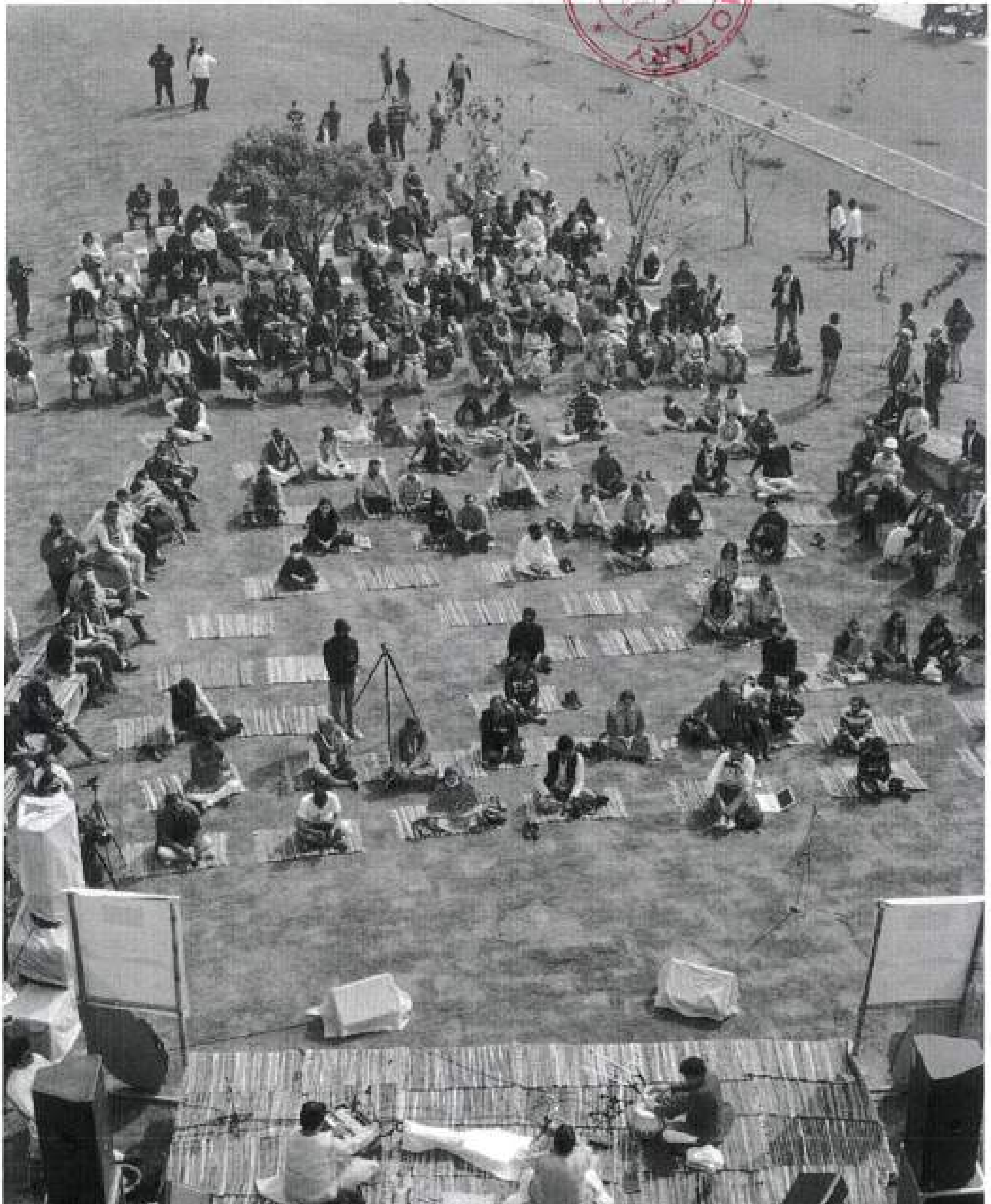

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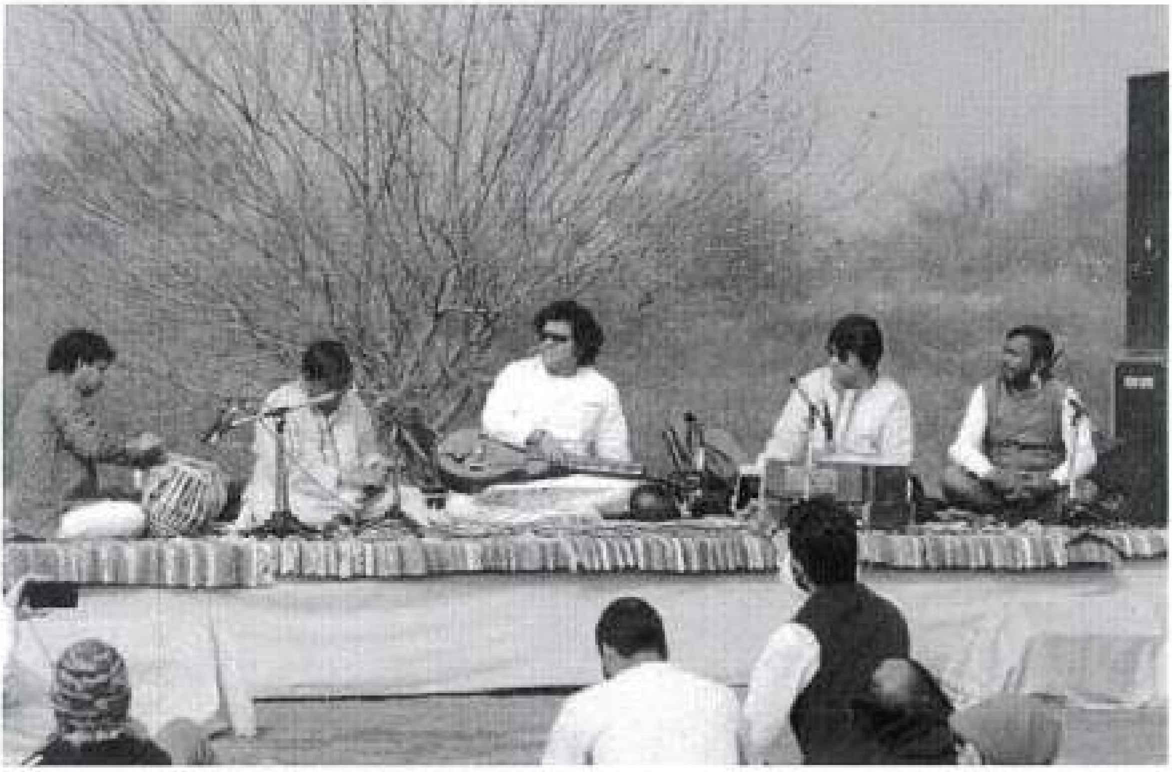

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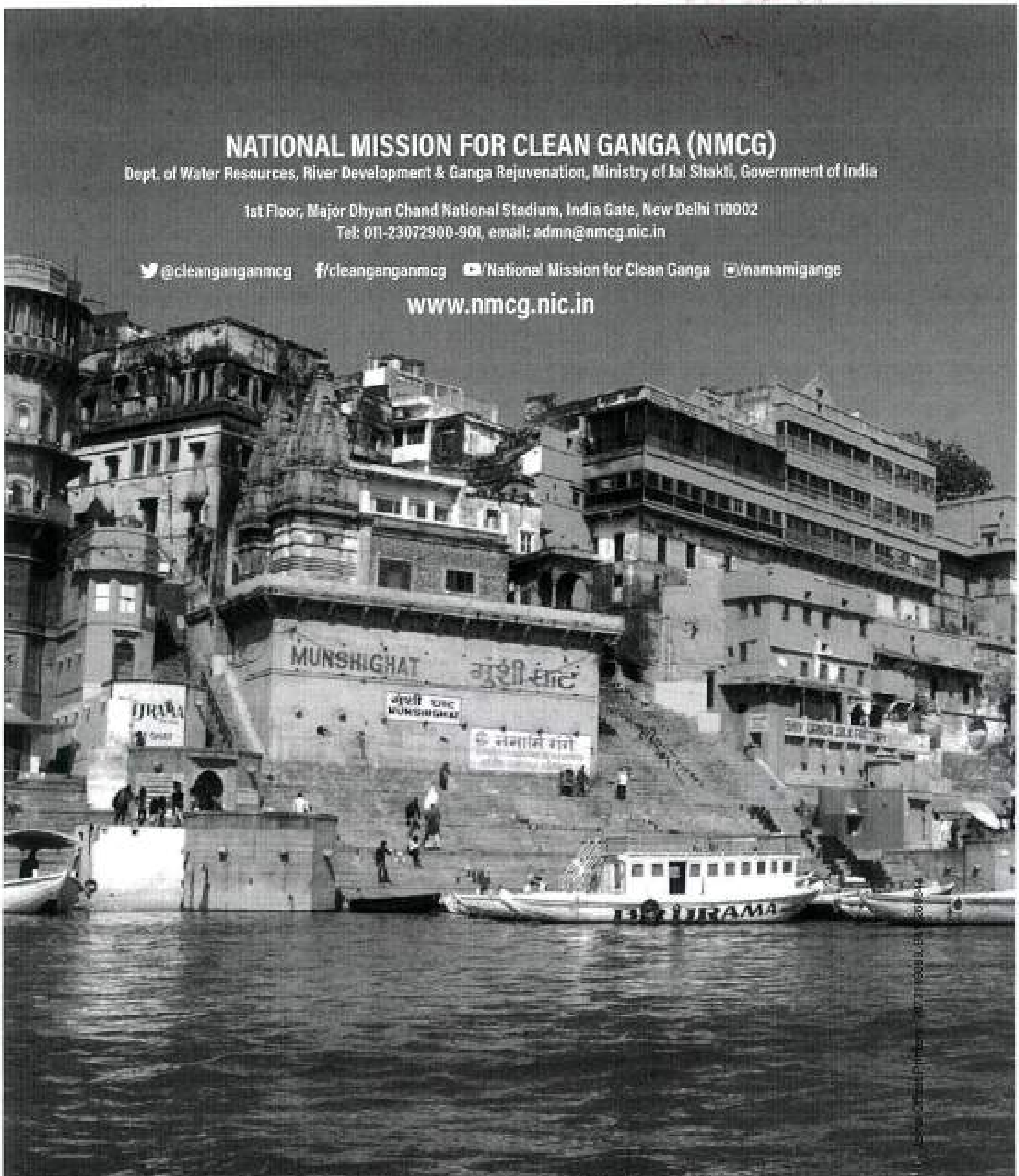

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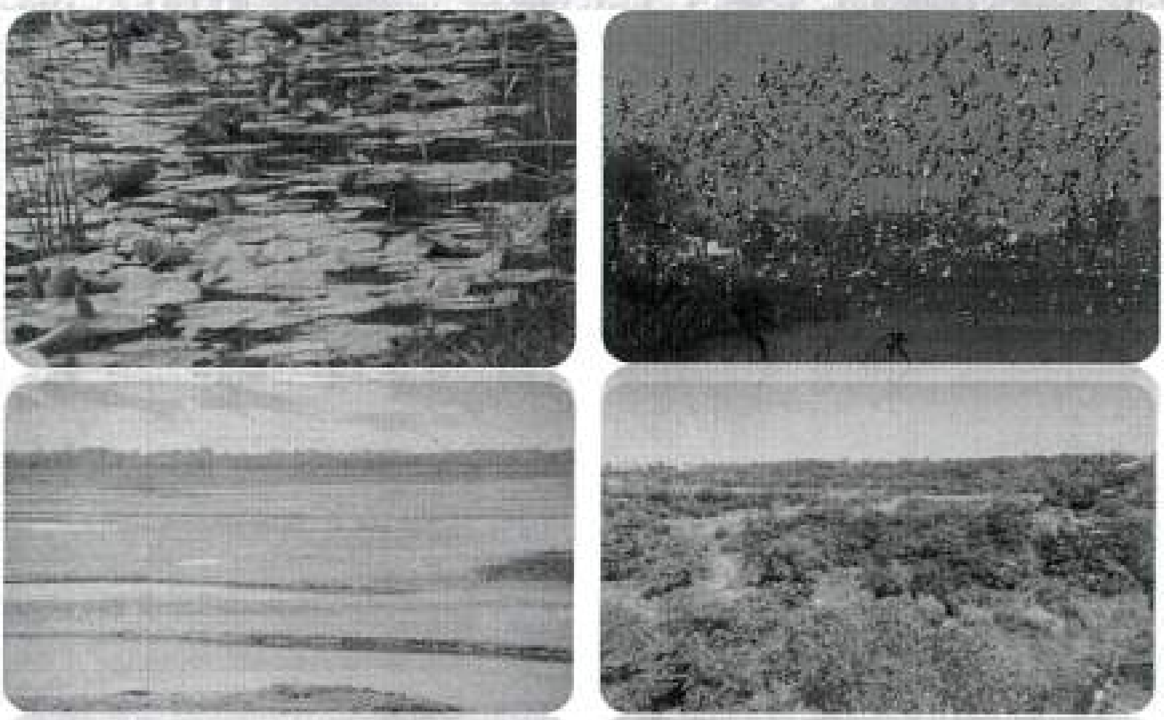
Annexure-IV.

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

NOTARY
GOVT. OF

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

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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.

Delhi Development Authority and the Staff (Scientists, Technical and supporting Staff) of Yamuna Biodiversity Park are duly acknowledged for providing the photographs of Yamuna Biodiversity Park. Acknowledgement is also due to Professor Brij Gopal of National Institute of Ecology for giving the permission for inclusion of information on the river system from his published articles/books.

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.

C. R. Babu
C. R. Babu

GOVT. OF INDIA
NOTARY

शिव दास मीना, भा.प्र.से.
अध्यक्ष
Shiv Das Meena, I. A. S.
Chairman

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार
CENTRAL POLLUTION CONTROL BOARD
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE, GOVT. OF INDIA

NOTARY

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.

NOTARY

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.

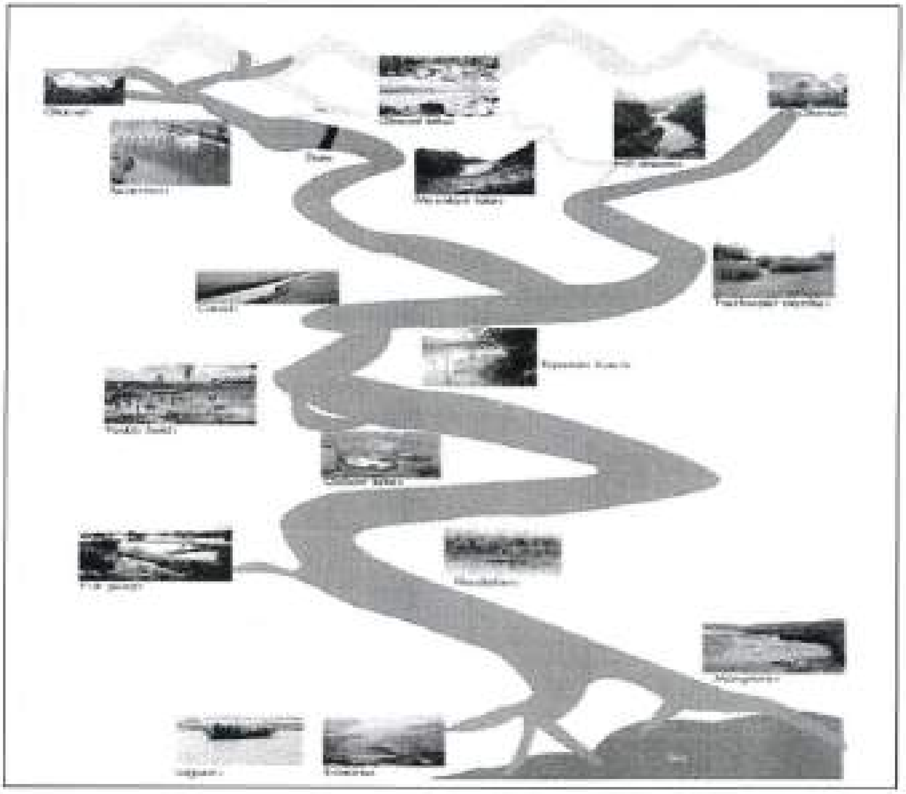

Figure 1: Different river ecosystems in the riverscape starting from the source of the river to its mouth at sea. *(Source: Gopal, 2013)*

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.

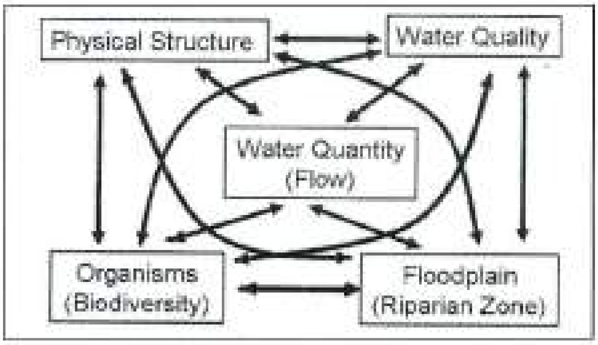

Figure 2: Five elements of the riverscape (river system) and interactions among them. *(Source: Gopal, 2007)*

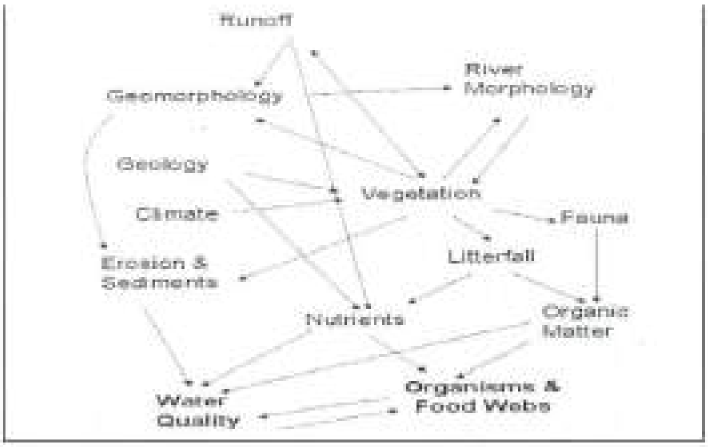

Figure 3: Illustration showing how the interactions among five elements of riverscape together with the geology, geomorphology and climate influence the water quality.

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.

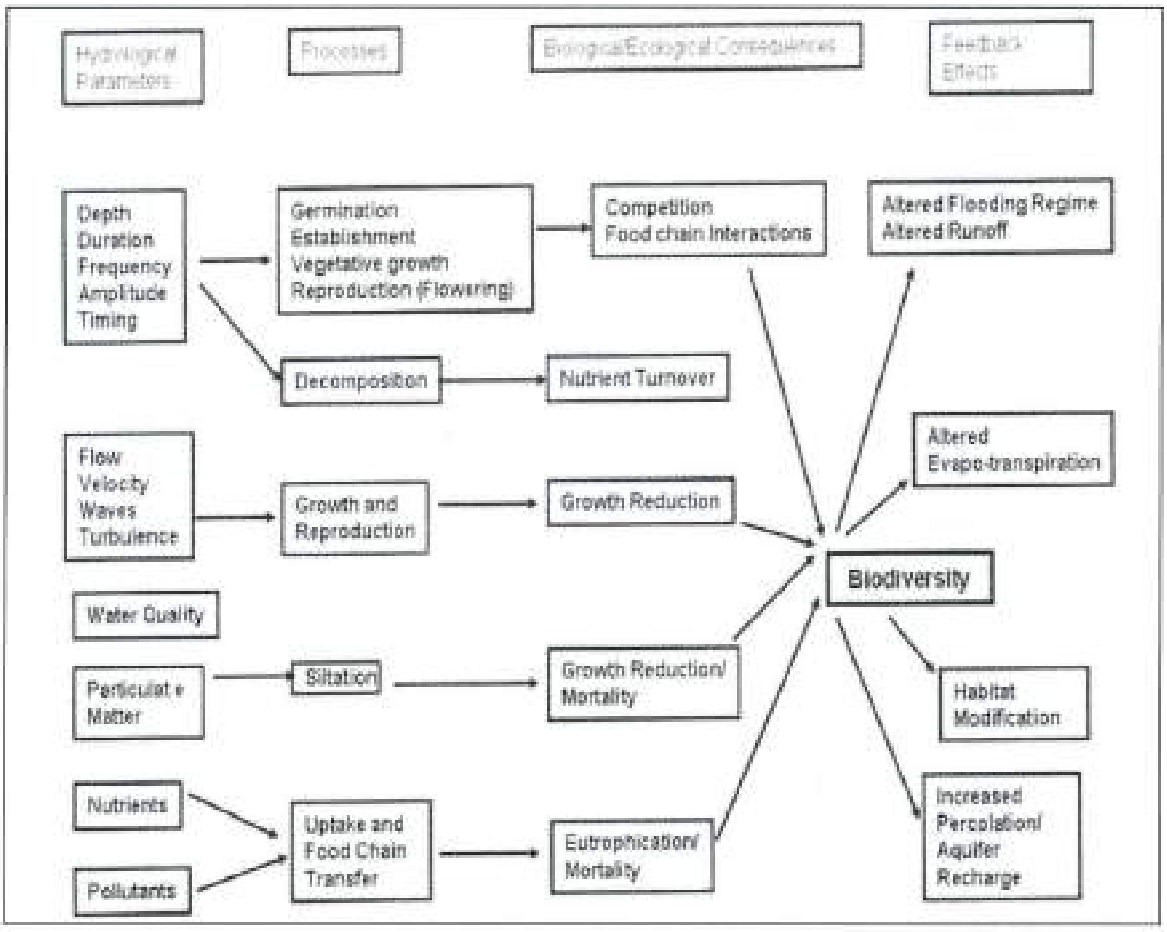

Figure 4: Different hydrogeological parameters (including water quality) of the river system and their impacts on biotic communities through ecological processes and the resulting feedback effects. *(Source: Gopal, 2007)*

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.

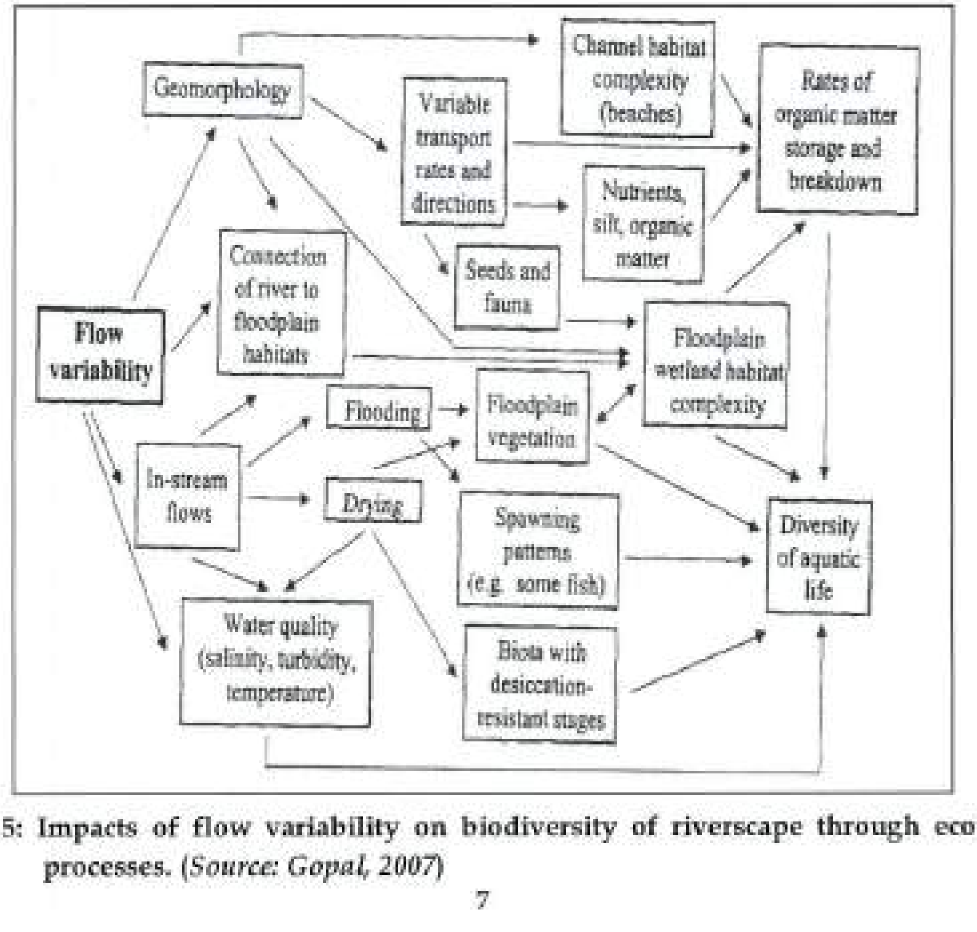

Figure 5: Impacts of flow variability on biodiversity of riverscape through ecological processes. (*Source: Gopal, 2007*)

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):

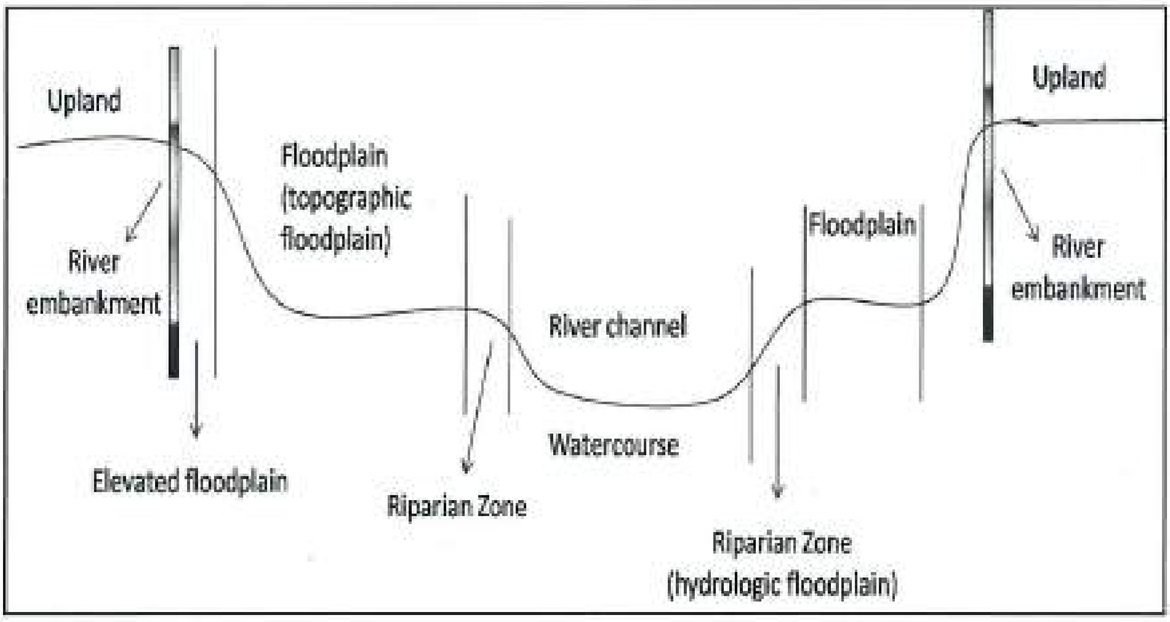

Figure 6: Diffenet zones of a typical riverscape of the rivers in plains.

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.

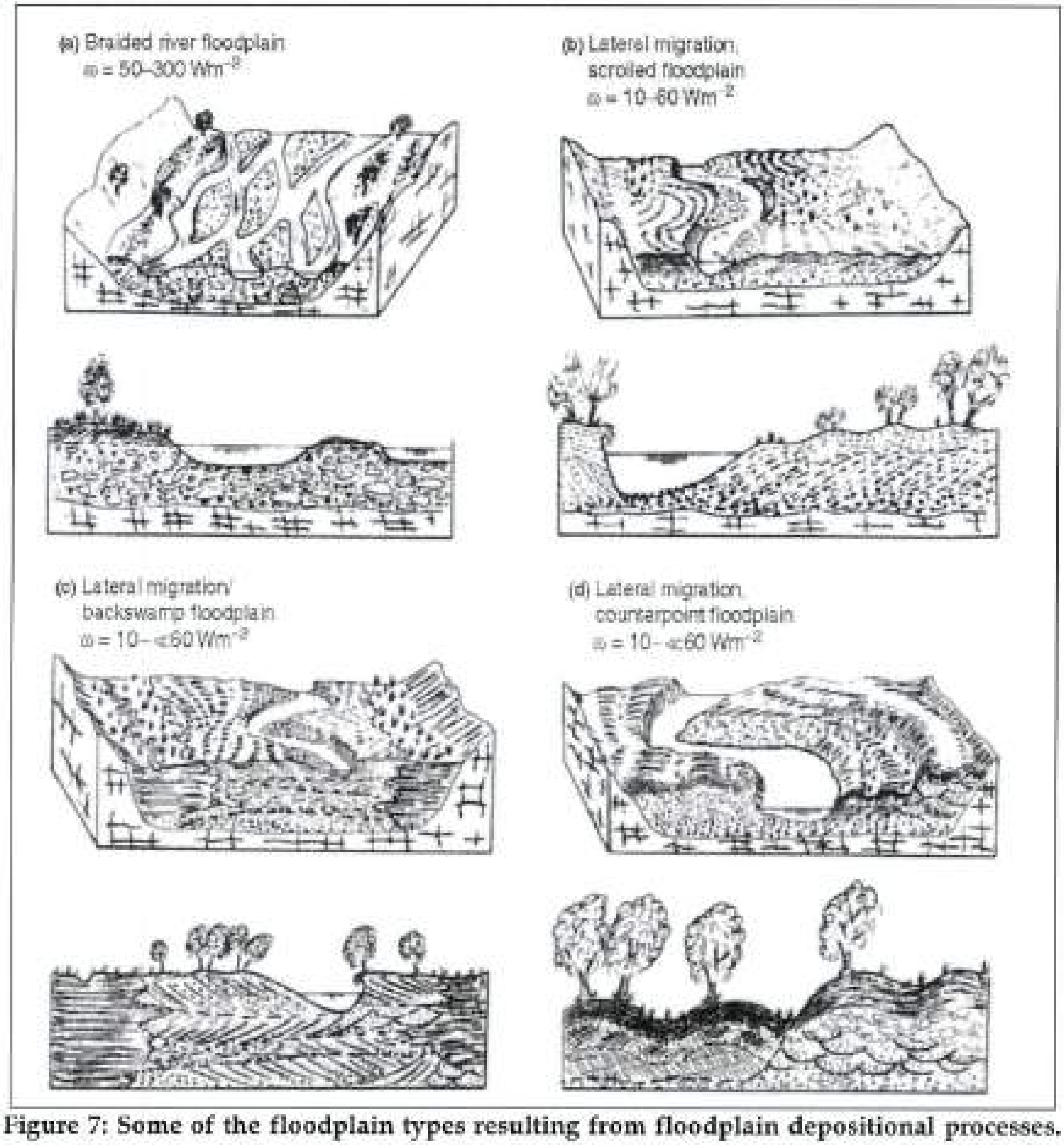

Figure 7: Some of the floodplain types resulting from floodplain depositional processes. **(*Source: Nanson & Croke, 1992*)**

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).

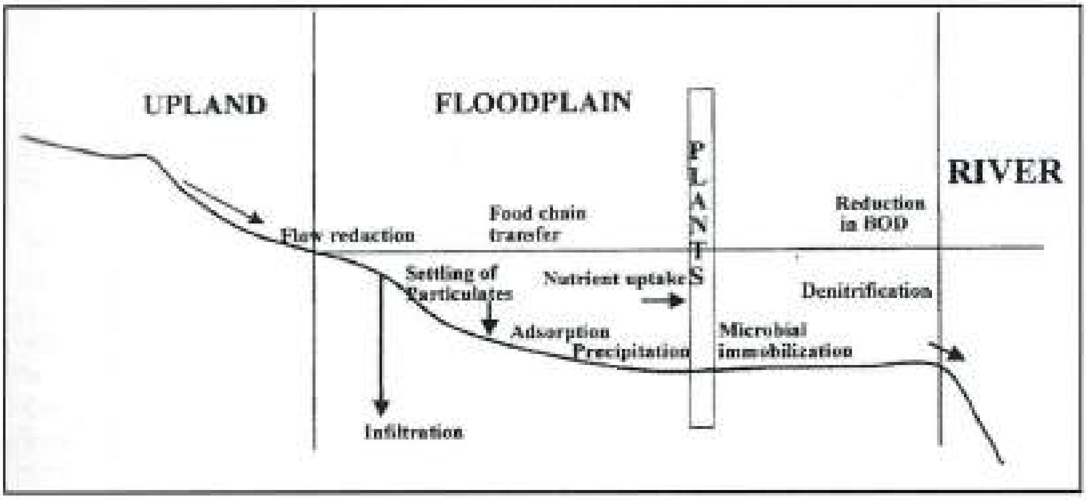

Figure 8: **Interaction between uplands and river through ecological processes of the floodplains.** (*Source: Gopal, 2007*)

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.

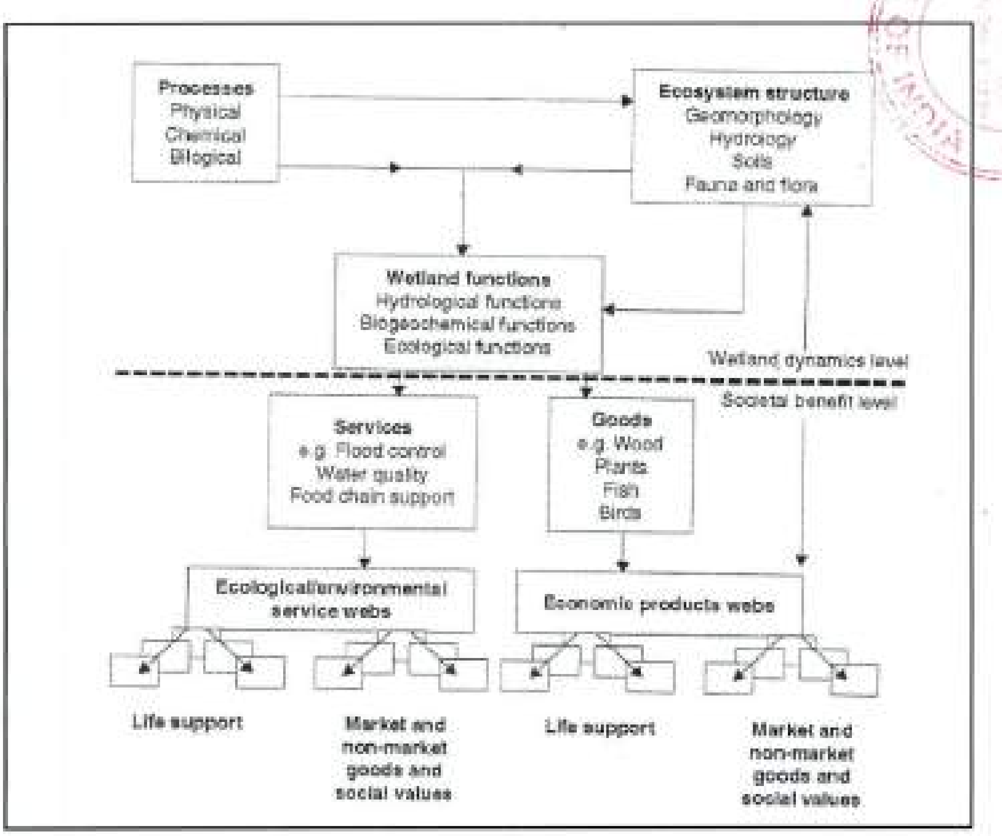

Figure 9: Structure and function of wetlands and the ecological processes that generate goods and services. (*Source: Gopal, 2007*)

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.

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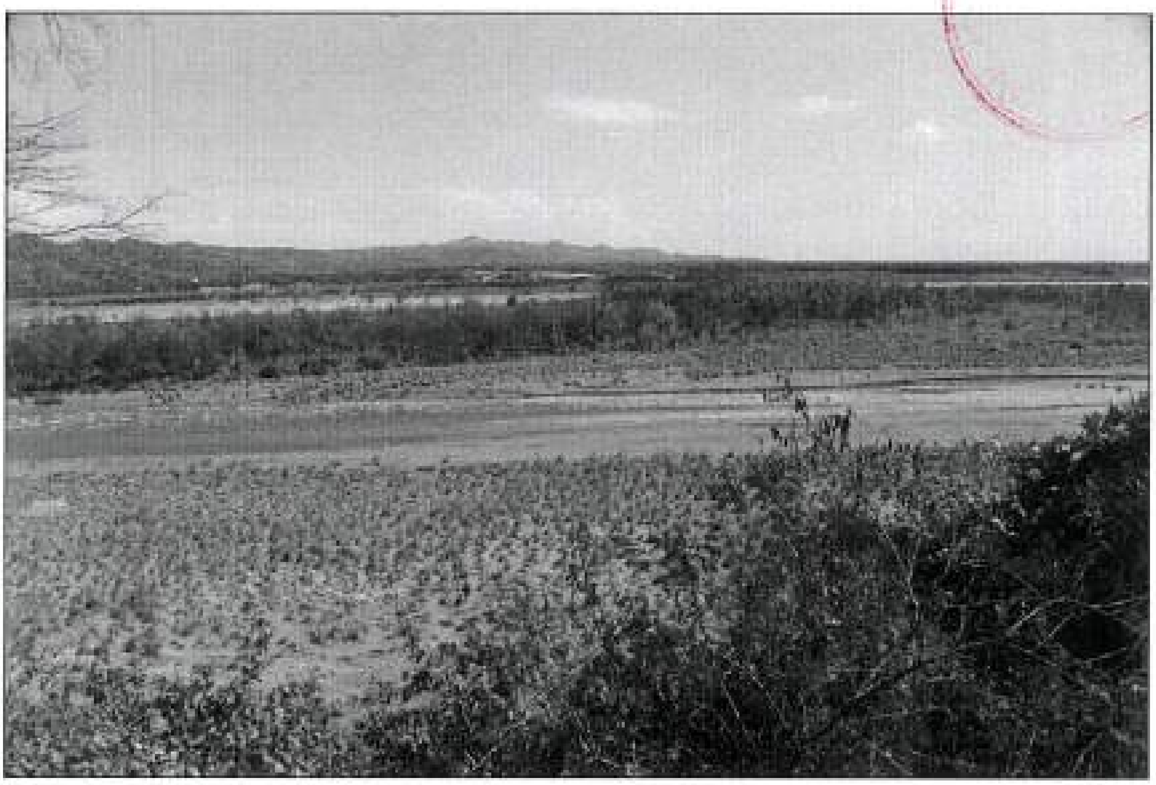

Figure 10: Overview of the riverscape of Yamuna river in the upstream of Hathni Kund reservoir at Kalesar National Park showing watercourses (channels), the riparian zone, the floodplain, and the islands.

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.

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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.

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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.

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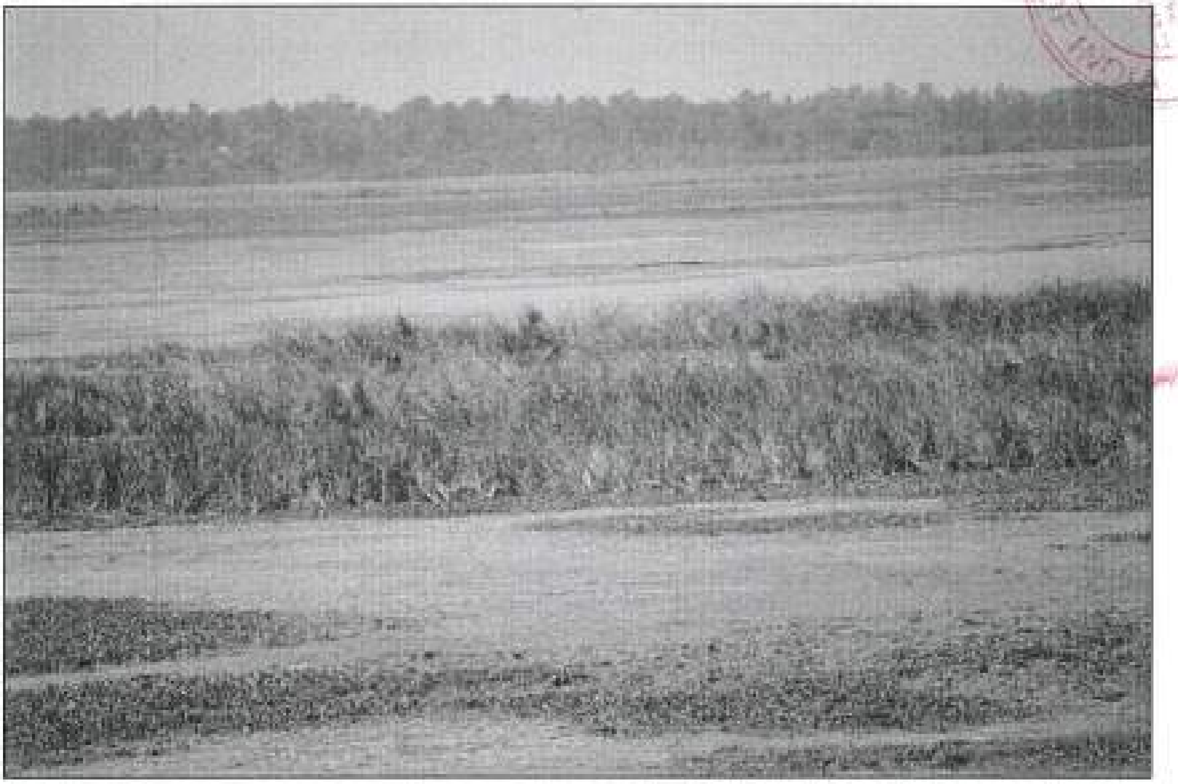

Figure 18: Floodplains of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetalnds) showing luxuriant marshy vegetation, grasslands and floodplain forest.

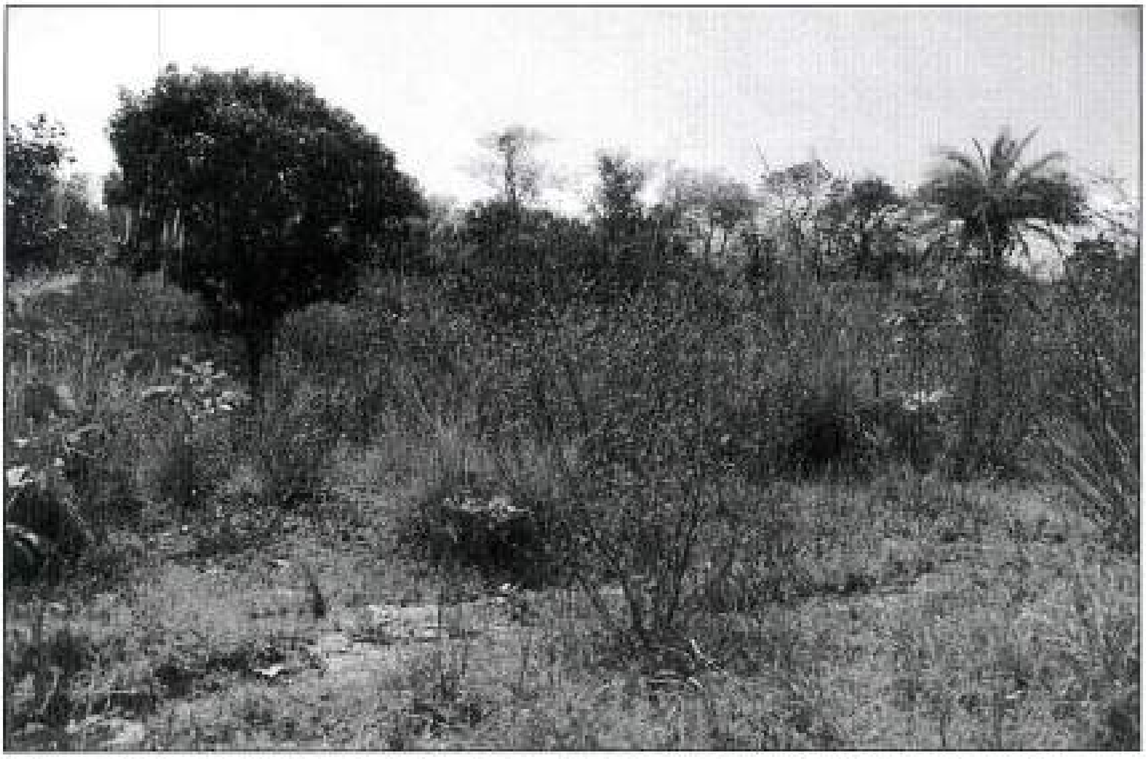

Figure 19: Floodplain forest of river Ganga in the upstream of Madhya Ganga Barrage at Bijnor (Haiderpur Wetland).

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.

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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.

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

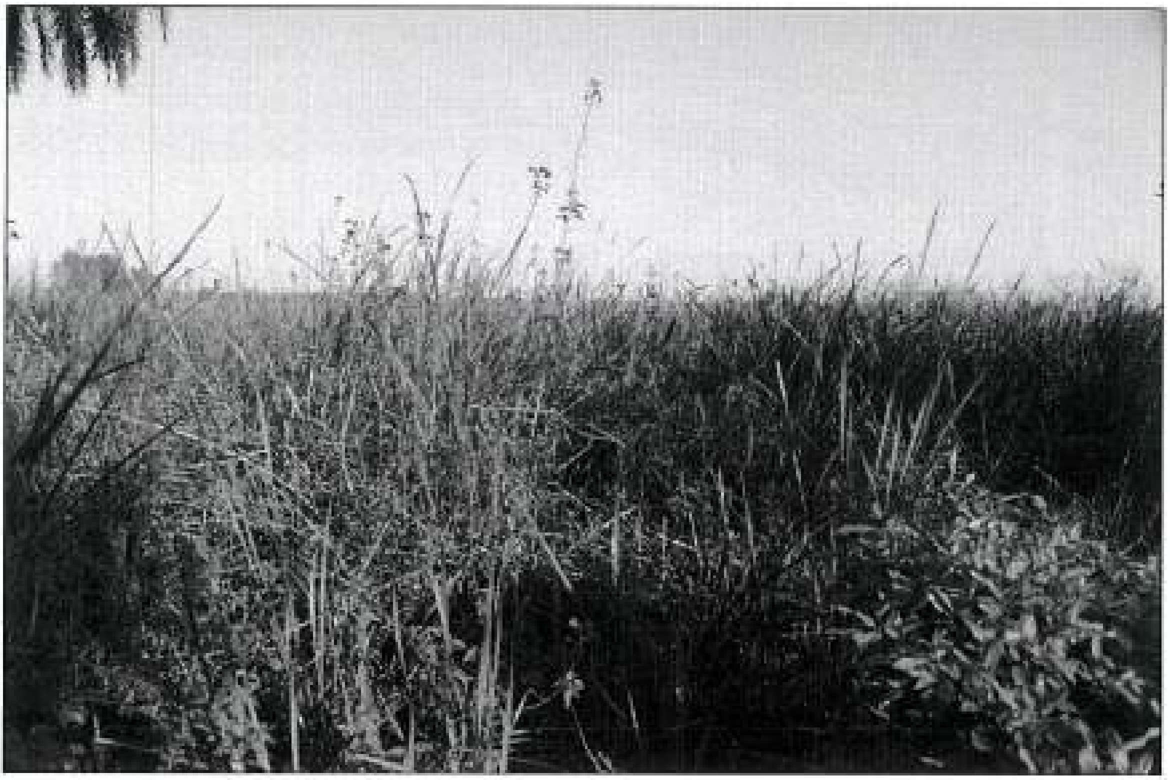

Figure 27: Riverscape of river Ganga at Hastinapur Wildlife Sanctuary showing floodplain swamp with reeds, cattails and woody vegetation.

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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.

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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.

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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).

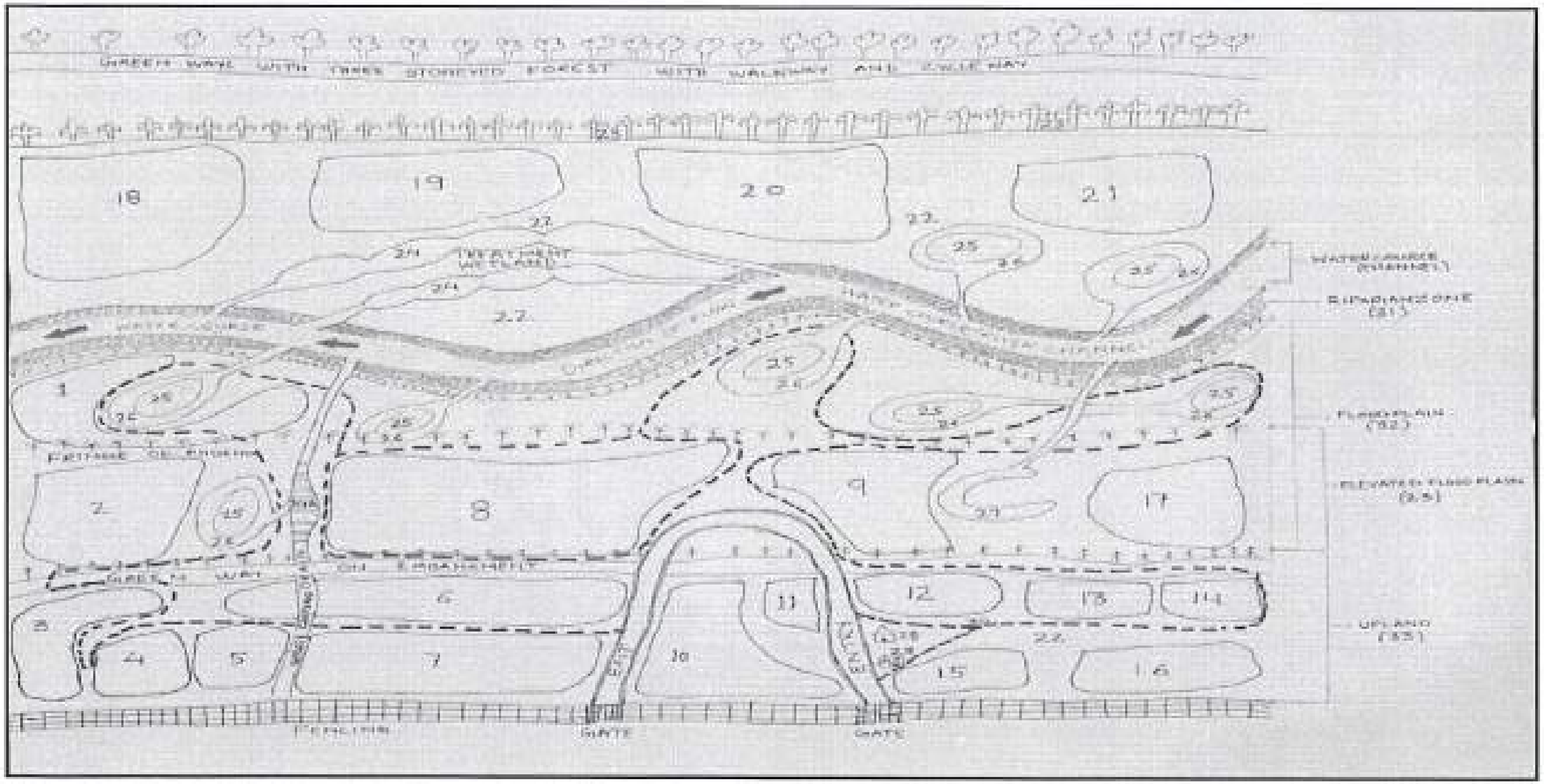

Figure 28: Schematic layout of a typical Biodiversity Park of the riverscape showing different structural components.

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

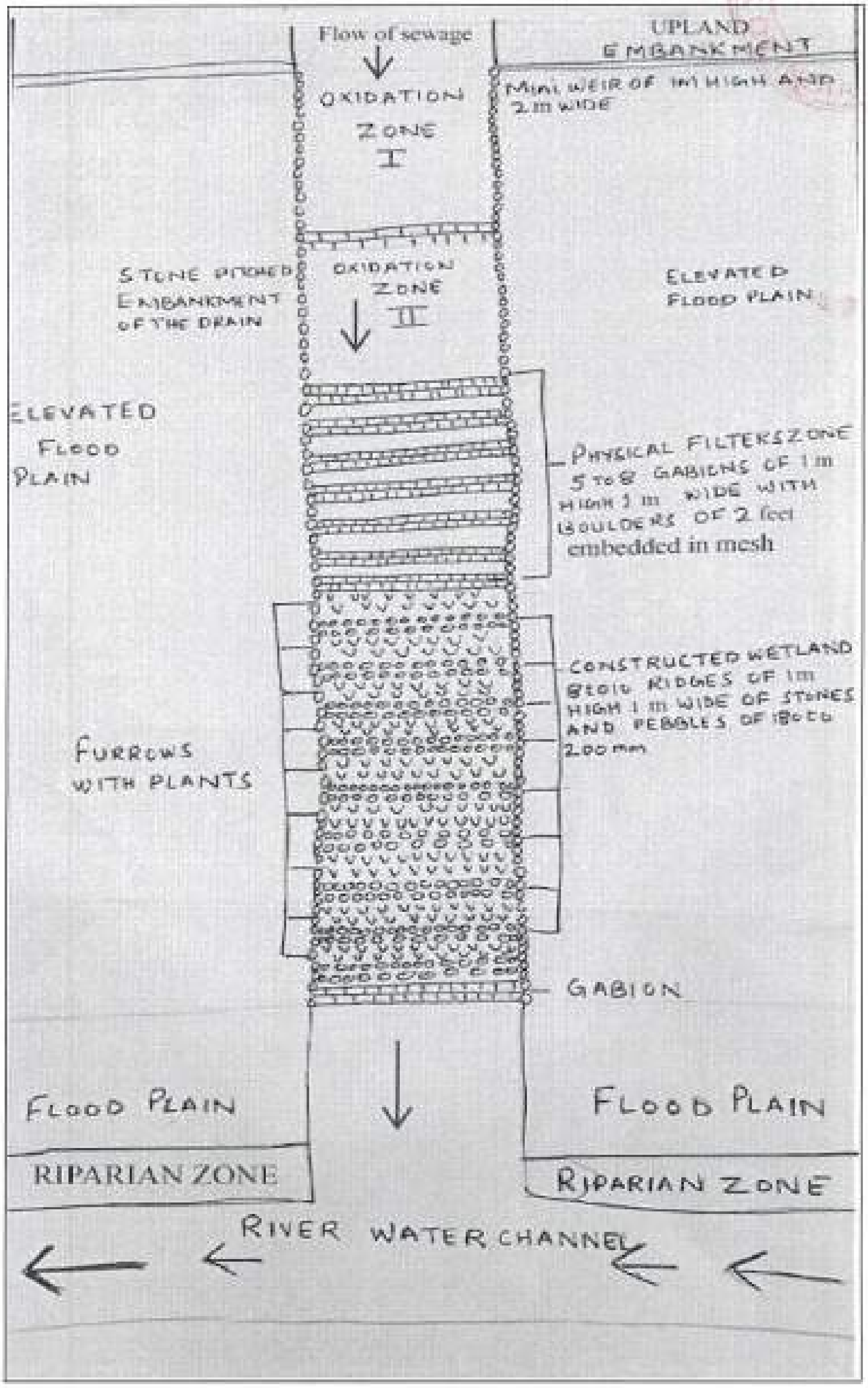

Figure 29: Schematic layout of a typical Constructed Wetland System for in-situ remediation of sewage/ industrial effluent of the drain that pass through Upland Elevated Floodplain of the riverscape.

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.

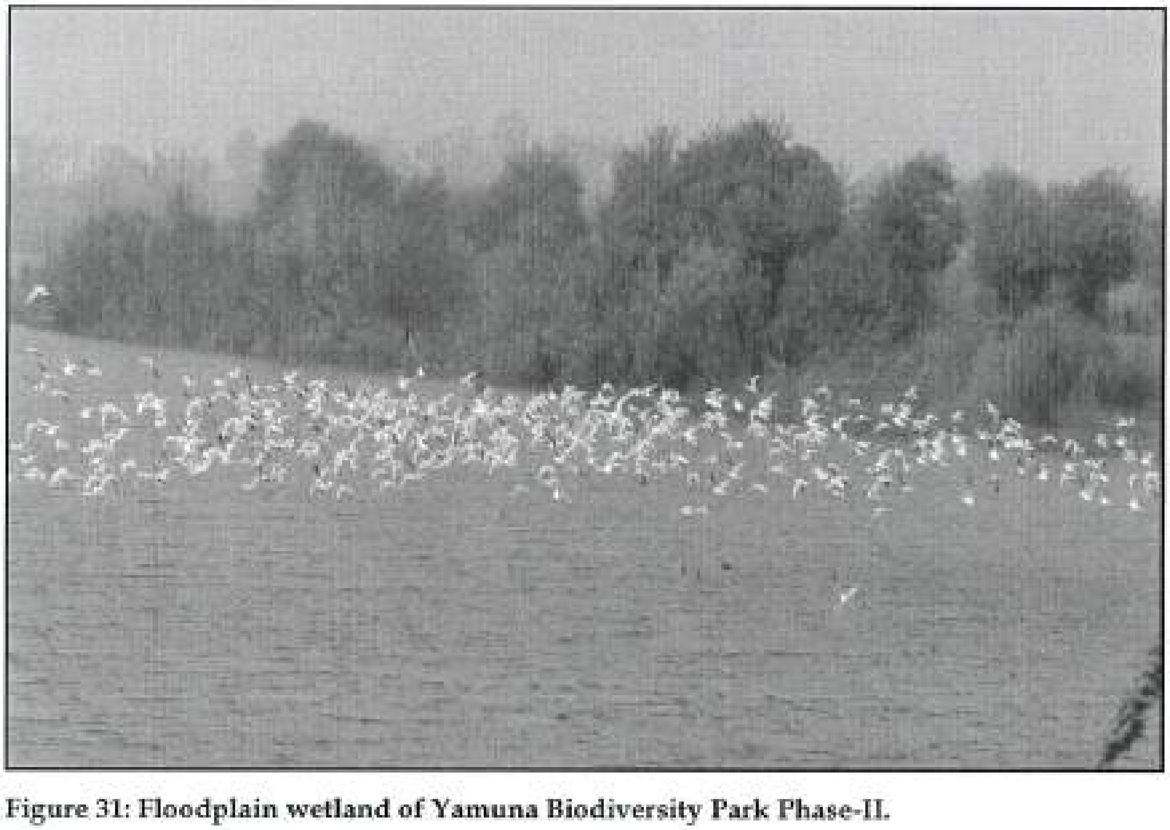

Figure 31: Floodplain wetland of Yamuna Biodiversity Park Phase-II.

Figure 32: Floodplain wetland showing impounded flood water.

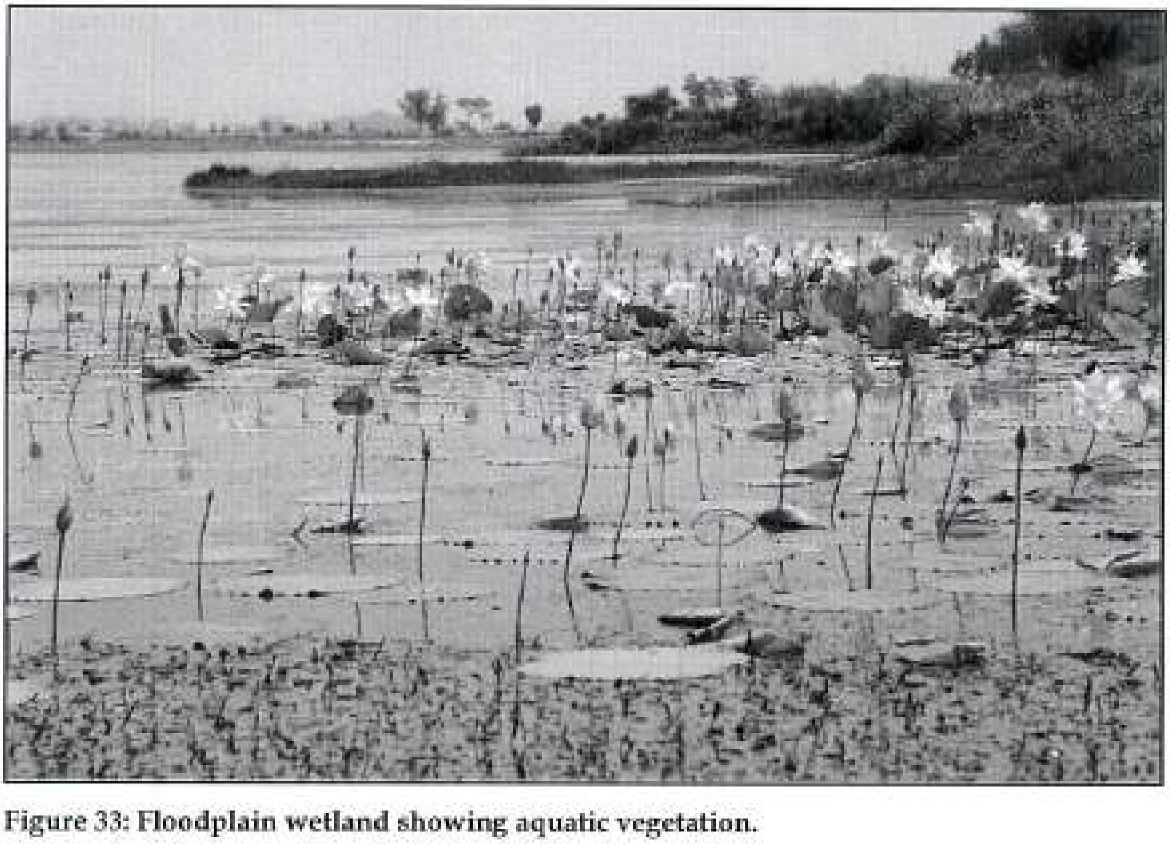

Figure 33: Floodplain wetland showing aquatic vegetation.

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.

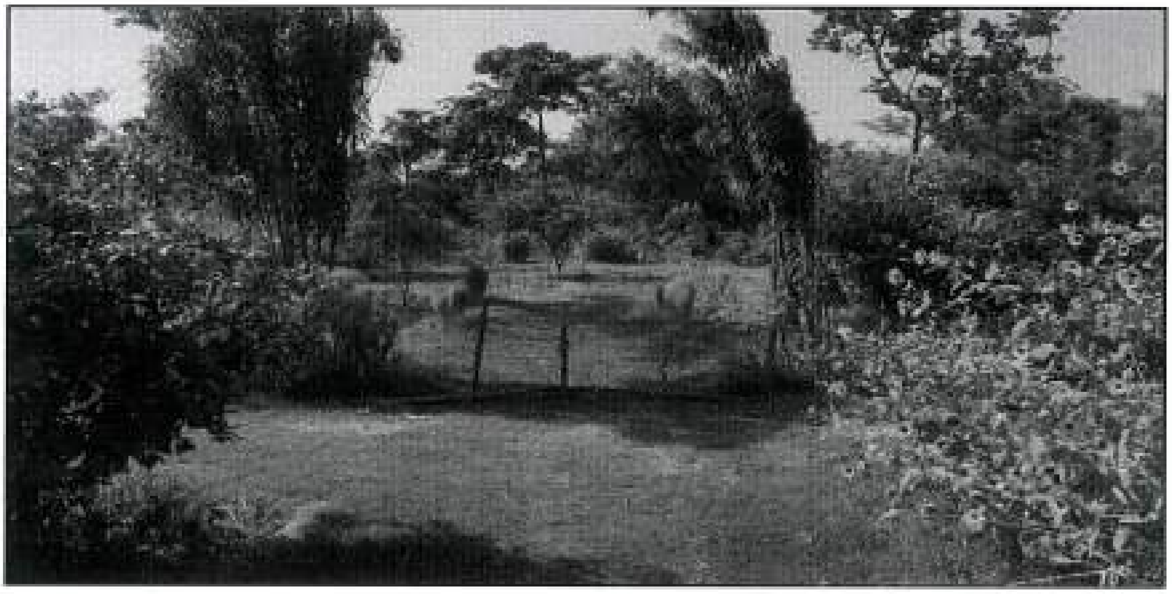

Figure 34: Butterfly Garden at Yamuna Biodiversity Park.

Figure 35: Herbal Garden at Yamuna Biodiversity Park.

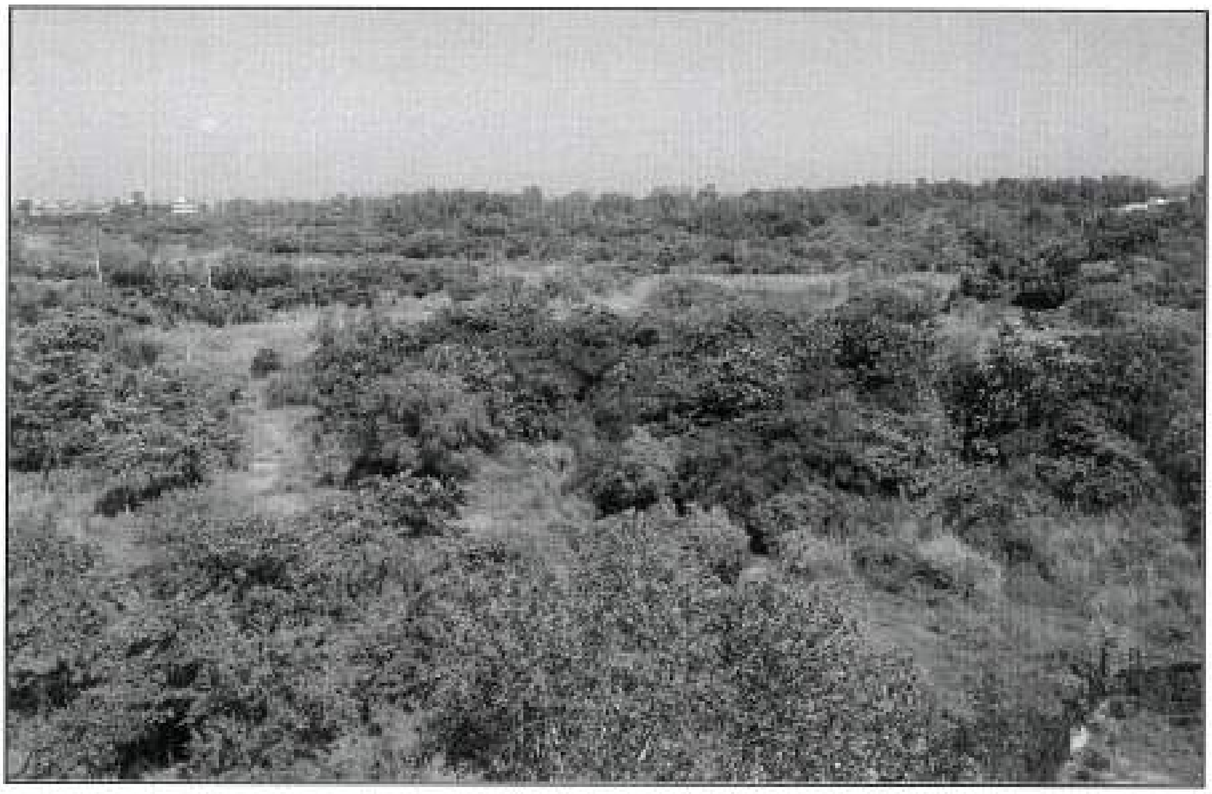

Figure 36: Overview of river ecosystems at Yamuna Biodiversity Park.

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

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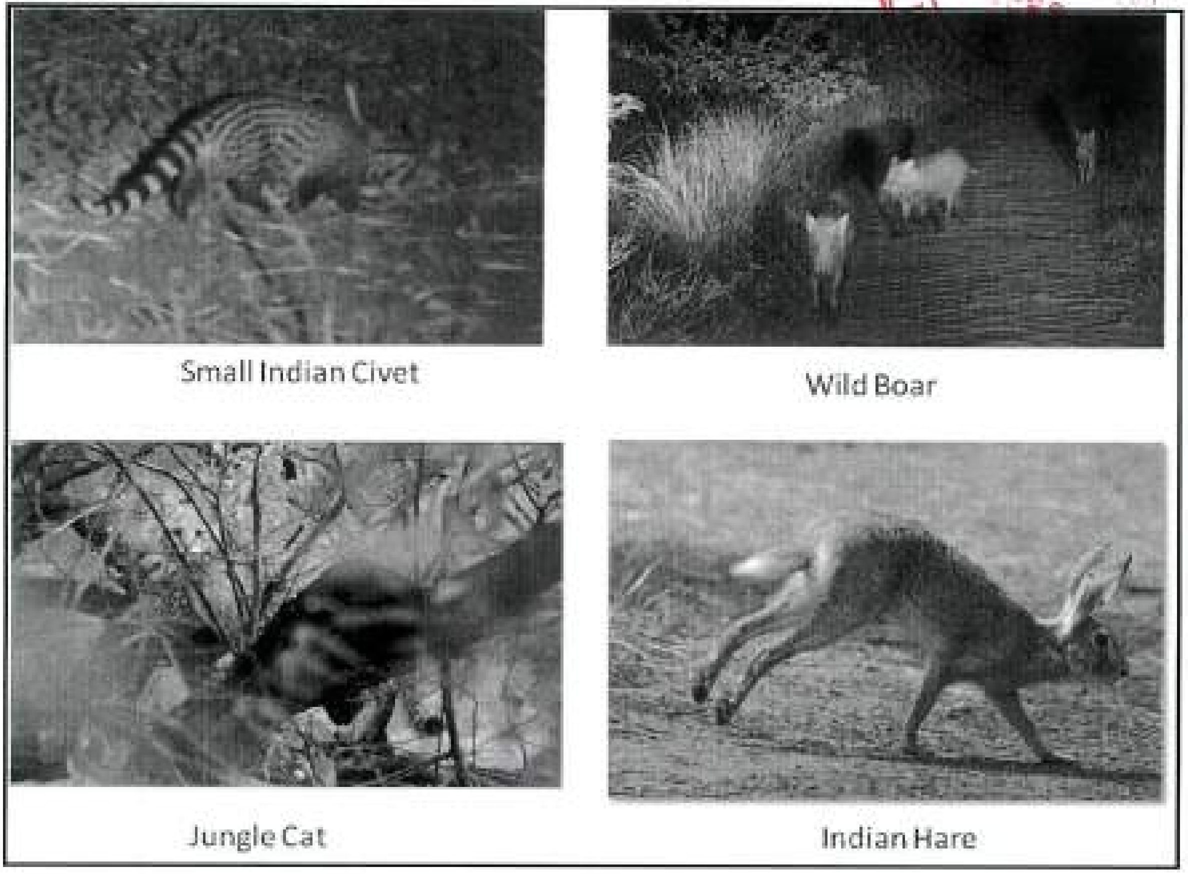
Small Indian Civet

Wild Boar

Jungle Cat

Indian Hare

Figure 38: Mammals of Yamuna Biodiversity Park.

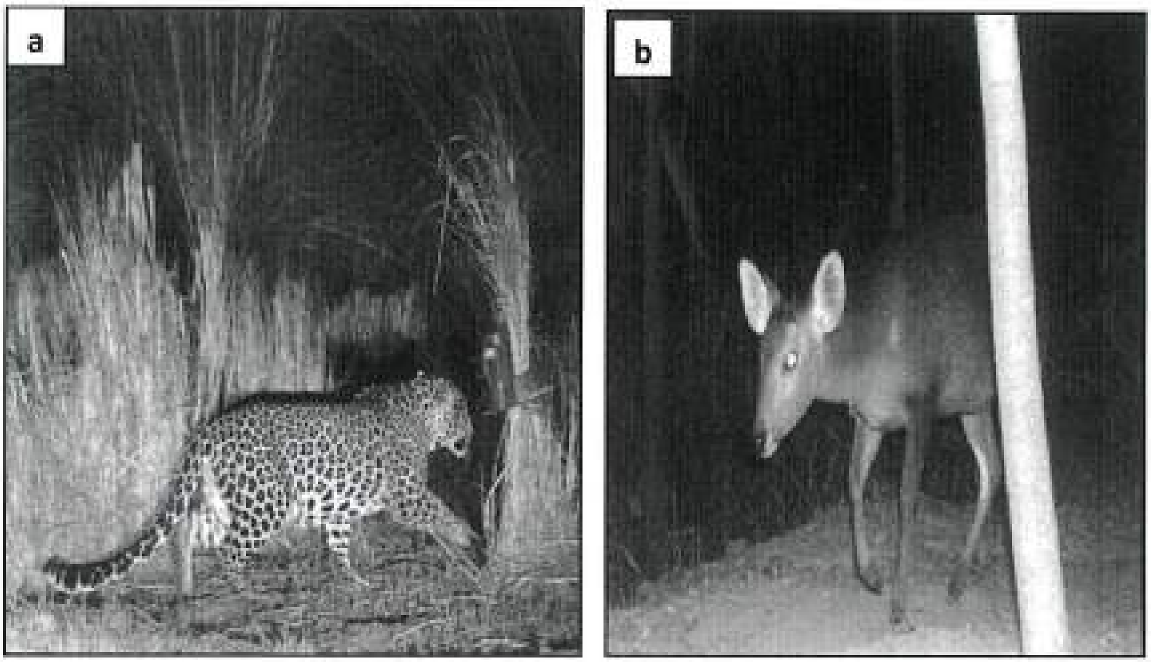

Figure 39: Carnivores (a) and Herbivores (b) in Yamuna Biodiversity Park.

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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