Ganga River Basin Management Plan - 2015

Mission 8: Environmental Knowledge-Building and Sensitization

January 2015

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by

Consortium of 7 "Indian Institute of Technology"s (IITs)

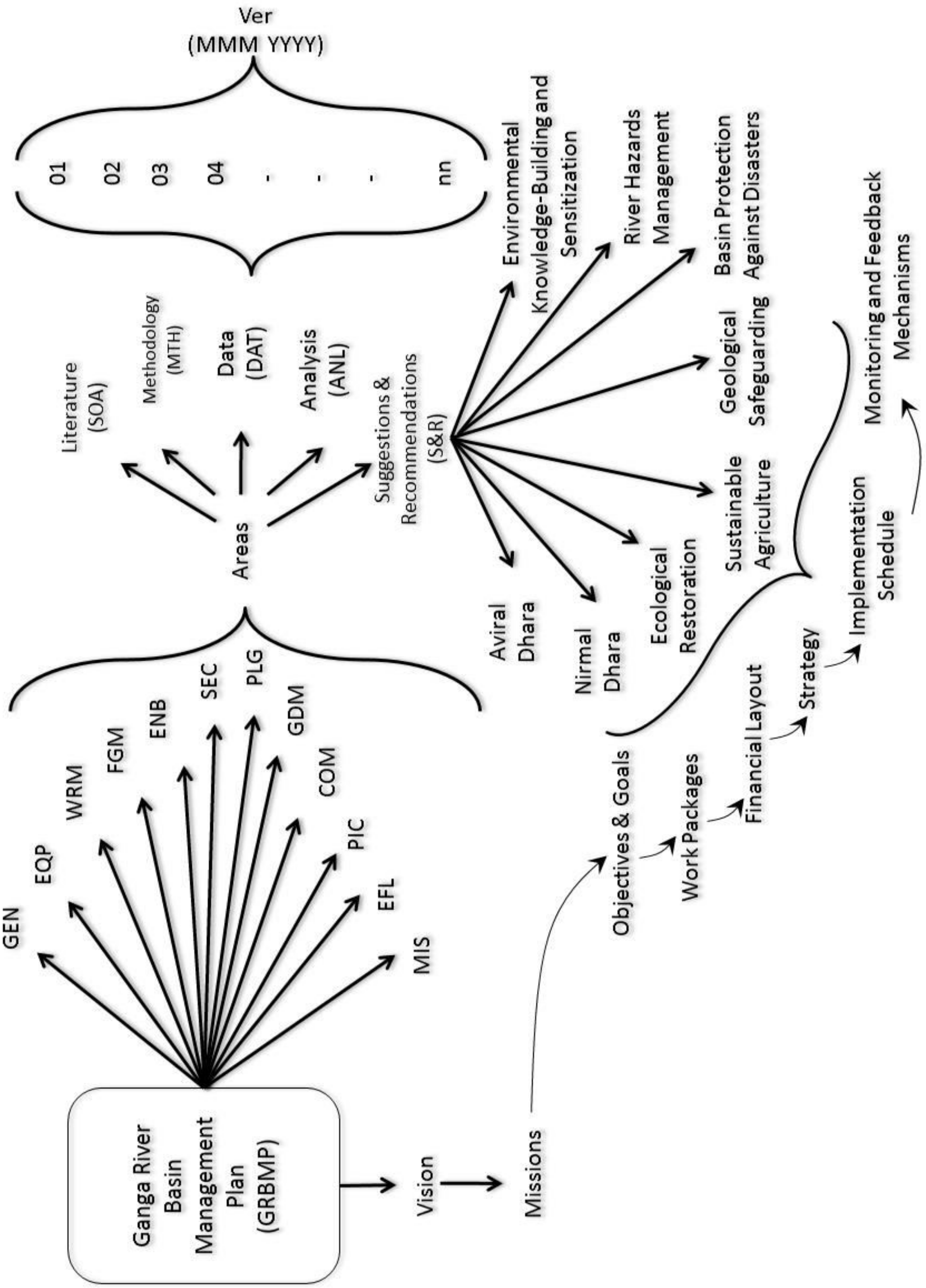
IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

In Collaboration with

IIT BHU | IIT Gandhinagar | CIFRI | NEERI | JNU | PU | NIT-K | DU

NIH Roorkee | ISI Kolkata | Allahabad University | WWF India

GRBMP Work Structure



Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government constituted the National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of River Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP). A Consortium of seven "Indian Institute of Technology"s (IITs) was given the responsibility of preparing the GRBMP by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. A Memorandum of Agreement (MoA) was therefore signed between the 7 IITs (IITs Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

The GRBMP is presented as a 3-tier set of documents. The three tiers comprise of: (i) Thematic Reports (TRs) providing inputs for different Missions, (ii) Mission Reports (MRs) documenting the requirements and actions for specific missions, and (iii) the Main Plan Document (MPD) synthesizing background information with the main conclusions and recommendations emanating from the Thematic and Mission Reports. It is hoped that this modular structure will make the Plan easier to comprehend and implement in a systematic manner.

There are two aspects to the development of GRBMP that deserve special mention. Firstly, the GRBMP is based mostly on secondary information obtained from governmental and other sources rather than on primary data collected by IIT Consortium. Likewise, most ideas and concepts used are not original but based on literature and other sources. Thus, on the whole, the GRBMP and its reports are an attempt to dig into the world's collective wisdom and distil relevant truths about the complex problem of Ganga River Basin Management and solutions thereof.

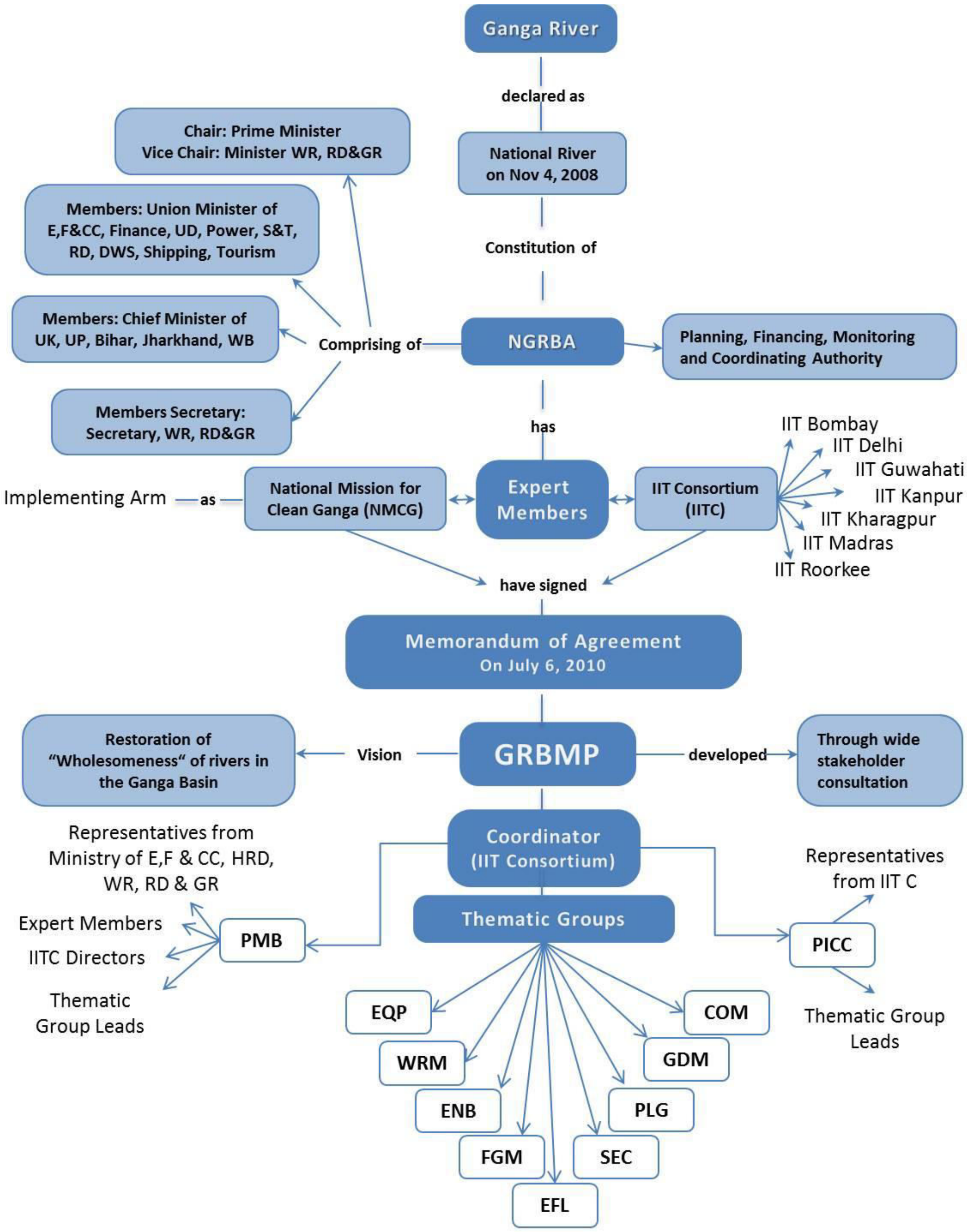
Secondly, many dedicated people spent hours discussing major concerns, issues and solutions to the problems addressed in GRBMP. Their dedication led to the preparation of a comprehensive GRBMP that hopes to articulate the outcome of the dialog in a meaningful way. Thus, directly or indirectly, many people contributed significantly to the preparation of GRBMP. The GRBMP therefore truly is an outcome of collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team and of the associate organizations as well as many government departments and individuals.

Dr Vinod Tare
Professor and Coordinator
Development of GRBMP
IIT Kanpur

Authors

Vinod Tare (vinod@iitk.ac.in) and Gautam Roy (gautamwho@gmail.com)

Organizational Structure for Preparing GRBMP



NGRBA: National Ganga River Basin Authority
NMCG: National Mission for Clean Ganga
MoEF: Ministry of Environment and Forests
MHRD: Ministry of Human Resources Development
MoWR, RD&GR: Ministry of Water Resources, River Development and Ganga Rejuvenation
GRBMP: Ganga River Basin Management Plan
IITC: IIT Consortium
PMB: Project Management Board
PICC: Project Implementation and Coordination Committee

EQP: Environmental Quality and Pollution
WRM: Water Resources Management
ENB: Ecology and Biodiversity
FGM: Fluvial Geomorphology
EFL: Environmental Flows
SEC: Socio Economic and Cultural
PLG: Policy Law and Governance
GDM: Geospatial Database Management
COM: Communication

Project Management Board [PMB]

Expert Members:

- Sri Swami Avimukteshwaranand Saraswati
- Dr Madhav A Chitale
- Dr Bharat Jhunjhunwala

Project Implementation and Coordination Committee [PICC]

Representatives from IIT Consortium:

- Dr Shyam Asolekar, IIT Bombay
- Dr A K Mittal, IIT Delhi
- Dr Mohammad Jawed, IIT Guwahati
- Dr Vinod Tare, IIT Kanpur
- Dr D J Sen, IIT Kharagpur
- Dr Ligy Philip, IIT Madras
- Dr I M Mishra, IIT Roorkee

Thematic Group Leads:

- Dr Purnendu Bose, Environmental Quality and Pollution (EQP)
- Dr A K Gosain, Water Resources Management (WRM)
- Dr R P Mathur, Ecology and Biodiversity (ENB)
- Dr Rajiv Sinha, Fluvial Geomorphology (FGM)
- Dr Vinod Tare, Environmental Flows (EFL)
- Dr S P Singh, Socio Economic and Cultural (SEC)
- Dr N C Narayanan and Dr Indrajit Dube, Policy Law and Governance (PLG)
- Dr Harish Karnick, Geospatial Database Management (GDM)
- Dr T V Prabhakar, Communication (COM)

Composition of Thematic Groups

1. Environmental Quality and Pollution (EQP)

Lead: Purnendu Bose, IIT Kanpur

Members: Shyam R Asolekar, Suparna Mukherjee (IIT Bombay); A K Mittal, A K Nema, Arun Kumar, T R Sreekrishanan (IIT Delhi); Ajay Kalmhad (IIT Guwahati); Saumyen Guha, Vinod Tare (IIT Kanpur); A K Gupta, M M Ghangrekar, Sudha Goel (IIT Kharagpur); Ligy Philip, Mukesh Doble, R Ravi Krishna, S M Shivnagendra (IIT Madras); A AKazmi, B R Gurjar, Himanshu Joshi, Indu Mehrotra, I M Mishra, Vivek Kumar (IIT Roorkee); Anirban Gupta (BESU Shibpur); P K Singh (IIT BHU); Rakesh Kumar (NEERI Nagpur); S K Patidar (NIT Kurukshetra); Sanmit Ahuja (ETI Dynamics, New Delhi)

2. Water Resources Management (WRM)

Lead: A K Gosain, IIT Delhi

Members: Rakesh Khosa, R Maheswaran, B R Chahar, C T Dhanya, D R Kaushal (IIT Delhi); Subashisa Dutta, Suresh Kartha (IIT Guwahati); Shivam Tripathi, Gautam Rai, Vinod Tare (IIT Kanpur); Anirban Dhar, D J Sen (IIT Kharagpur); B S Murty, BalajiNarasimhan (IIT Mdras); C S P Ojha, P Perumal (IIT Roorkee); S K Jain (NIH, Roorkee); Pranab Mohapatra (IIT Gandhi Nagar); Sandhya Rao (INRM, New Delhi)

3. Fluvial Geomorphology (FGM)

Lead: Rajiv Sinha, IIT Kanpur

Members: Vinod Tare (IIT Kanpur); Vikrant Jain (IIT Gandhi Nagar); J K Pati (Allahabad University); Kirteshwar Prasad, Ramesh Shukla (Patna University); Parthasarthi Ghosh, Soumendra Nath Sarkar, Tapan Chakarborty (ISI Kolkata); KalyanRudra (WBPCB); S K Tandon, Shashank Shekhar (University of Delhi); Saumitra Mukherjee (JNU Delhi)

4. Ecology and Biodiversity (ENB)

Lead: R P Mathur, IIT Kanpur

Members: A K Thakur, Vinod Tare (IIT Kanpur); Utpal Bora (IIT Guwahati); M D Behera (IIT Kharagpur); Naveen Navania, Partha Roy, PruthiVikas, R P Singh, Ramasre Prasad, Ranjana Pathania (IIT Roorkee); Sandeep Behera (WWF-India)

5. Socio Economic and Cultural (SEC)

Lead: S P Singh, IIT Roorkee

Members: Pushpa L Trivedi (IIT Bombay); Seema Sharma, V B Upadhyay (IIT Delhi); P M Prasad, Vinod Tare (IIT Kanpur); Bhagirath Behera, N C Nayak, Pulak Mishra, T N Mazumder (IIT Kharagpur); C Kumar, D K Nauriyal, Rajat Agrawal, Vinay Sharma (IIT Roorkee)

6. Policy Law and Governance (PLG)

Lead: N C Narayanan, IIT Bombay and Indrajit Dube, IIT Kharagpur

Members: Shyam Asolekar, Subodh Wagle (IIT Bombay); Mukesh Khare (IIT Delhi); Vinod Tare (IIT Kanpur); Deepa Dube, Uday Shankar (IIT Kharagpur); G N Kathpalia, ParitoshTyagi (IDC, New Delhi)

7. Geo-Spatial Database Management (GDM)

Lead: Harish Karnick, IIT Kanpur

Members: N L Sharda, Smriti Sengupta (IIT Bombay); A K Gosain (IIT Delhi); Arnab Bhattacharya, Kritika Venkatramani, Rajiv Sinha, T V Prabhakar, Vinod Tare (IIT Kanpur)

8. Communication (COM)

Lead: T V Prabhakar, IIT Kanpur

Members: Purnendu Bose, Rajiv Sinha, Vinod Tare (IIT Kanpur)

9. Environmental Flows (EFL)

Lead: Vinod Tare, IIT Kanpur

Members: Shyam Asolekar (IIT Bombay); A K Gosain (IIT Delhi); P M Prasad, R P Mathur, Rajiv Sinha, Shivam Tripathi (IIT Kanpur); M D Behara (IIT Kharagpur); B S Murthy, N Balaji (IIT Madras); Pranab Mohaparta, Vikrant Jain (IIT Gandhinagar); S K Jain (NIH Roorkee); Nitin Kaushal (WWF-India, New Delhi); Sandeep Behera (NMCG, MoWR, RD & GR, New Delhi); A P Sharma K D Joshi (CIFRI, Barrackpore); Ravindra Kumar (SWaRA-UP); Ravi Chopra (PSI, Dehradoon); Paritosh Tyagi, (IDC, New Delhi)

Abbreviations and Acronyms

1.	AK	:	Available Potassium.
2.	AP	:	Available Phosphorous.
3.	C/N	:	Carbon : Nitrogen ratio.
4.	EU	:	European Union.
5.	GDP	:	Gross Domestic product.
6.	GRBMP	:	Ganga River Basin Management Plan.
7.	IITC	:	IIT Consortium.
8.	MoEF	:	Ministry of Environment and Forests.
9.	MoEF&CC	:	Ministry of Environment, Forests & Climate Change
10.	MoWR	:	Ministry of Water Resources.
11.	MoWRRD&GR	:	Ministry of Water Resources, River Development & Ganga Rejuvenation
12.	NFM	:	Natural Flood Management.
13.	NGRBA	:	National Ganga River Basin Authority.
14.	NMCG	:	National Mission for Clean Ganga.
15.	NRGB	:	National River Ganga Basin.
16.	SOM	:	Soil Organic Matter.
17.	SOC	:	Soil Organic Carbon.
18.	WWTP	:	Waste Water Treatment Plant.

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Summary

The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Basin planning and management combine diverse natural resources (water resources, land resources, biological resources, etc.) and processes (river dynamics, geological phenomena, atmospheric processes, etc.) with traditional wisdom and grassroots knowledge. Hence, it is necessary to build a comprehensive data bank to enable meaningful analyses and obtain quantitative indicators of NRGB's status. Moreover, since NRGB's welfare needs the co-operation and help of both formal and informal sectors of society, the data bank should be accessible to citizens to enable people's participation in the overall upkeep of NRGB. To adequately inform and sensitize stakeholders, the data bank also needs to be complemented with community-specific educational material and programmes on NRGB's environment. The main measures recommended are**:** (i) Establishment of a comprehensive Data Bank by continuous collection, processing and storage of information on natural resources, anthropogenic activities, and environmental monitoring data of the basin; (ii) Preparation of secondary results (charts, tables, etc.) based on primary data; (iii) Preparation of documents and materials for easy understanding by non-specialized people; (iv) Keeping all the above information in open domain for easy access by all interested individuals and institutions; and (v) Conducting workshops and educational campaigns with various stakeholders and interested citizens to enable their comprehensive understanding of basin processes and take meaningful action.

1. Introduction

Indian civilization grew up under the care of River Ganga, nourished by her bounties for thousands of years. The Ganga river – along with her many tributaries and distributaries – provided material, spiritual and cultural sustenance to millions of people who lived in her basin or partook of her beneficence from time to time. To the traditional Indian mind, therefore, River Ganga is not only the holiest of rivers and savior of mortal beings, she is also a living Goddess. Very aptly is she personified in Indian consciousness as "MOTHER GANGA". This psychic pre-eminence of River Ganga in the Indian ethos testifies to her centrality in Indian civilization and her supreme importance in Indian life.

The Ganga river basin is the largest river basin of India that covers a diverse landscape, reflecting the cultural and geographical diversity of the India. It is also a fertile and relatively water-rich alluvial basin that hosts about 43% of India's population [MoWR, 2014]. It is fitting, therefore, that the Indian government declared River Ganga as India's **National River** in the year 2008. But the declaration was none too early. River Ganga had been degrading rapidly for a long time, and national concern about her state had already become serious in the twentieth century. It was against this backdrop that the Ministry of Environment and Forests (Govt. of India) assigned the task of preparing a Ganga River Basin Management Plan (GRBMP) to restore and preserve National River Ganga to a "Consortium of Seven IITs". The outcome of this effort – the GRBMP – evolved a seven-pronged action plan, with each prong envisaged to be taken up for execution in mission mode.

A river basin is the area of land from which the river provides the only exit route for surface water flows. For understanding its dynamics, a basin may be viewed as a closely-connected hydrological-ecological system. Hydrological connections include groundwater flow, surface runoff, local evapotranspiration-precipitation cycles and areal flooding, while ecological links are many and varied (such as the food web and transport by biological agents). These linkages provide for extensive material transfer and communication between the river and her basin, which constitute the functional unity of a river basin. Directly and indirectly, therefore, National

River Ganga (along with her tributaries and distributaries), is a definitive indication of the health of the basin as a whole. Hence, GRBMP adopted the Ganga River Network as the primary environmental indicator of the National River Ganga Basin (NRGB).

River basin management needs to ensure that a basin's natural resources (biotic and abiotic) are adequately preserved over time. The main abiotic (or physical) resources of a river basin are *soil* and *water*, along with a multitude of minerals and compounds bound up with them. Now, water is a highly variable resource. Barring variations from year to year, the water in a basin follows an annual cycle of replenishment (primarily through atmospheric precipitation and groundwater inflows) and losses (primarily through river and groundwater outflows, evaporation, transpiration, and biological consumption). In contrast to water, formation of mature soils – from the weathering of parent material (rocks) to chemical decomposition and transformation – is a drawn-out process that may take hundreds or thousands of years [Jenny, 1994; Wikipedia, 2014]; but, once formed, soils can be fairly durable. Thus, changes in a basin's water resource status tend to be relatively faster and easily detected, while those of soils are slow and often go unnoticed for long periods. However, soil and water are affected by each other through many biotic and abiotic processes. Being thus interrelated, degradation of either soil or water has a concurrent effect on the other, hence neither can be considered in isolation.

It is not only soil and water that are mutually interactive, living organisms also interact with them and help shape the basin's environment. The biotic resources of a basin consist of plants, animals and micro-organisms. Since biota evolve over time to achieve a stable balance in a given environmental setting, the biotic resources of a river basin depend on its constituent ecosystems – rivers, wetlands, forests, grasslands, etc. However, with significant human activity in many ecosystems (as, for example, in agro-ecosystems and urban ecosystems), the complexity of human-technology-environment systems has increased manifold [Pahl-Wostl, 2006]. Nonetheless, GRBMP attempts to incorporate interactive natural resource dynamics and human-technology-environment considerations in the Basin Plan. For, with human activities multiplying and diversifying in the basin, the resulting environmental consequences have also been pronounced in recent times. In sum, GRBMP focuses on the basin's overall resource environment and the major factors affecting it (especially diverse anthropogenic activities), and seeks ways and means to protect the basin and its resources against identifiable adverse impacts. For, only thus can we secure the environmental foundation of NRGB for the good of one and all.

2. Objective

The objectives of Mission "Environmental Knowledge-Building and Sensitization" are**:** (i) to synthesize environmental knowledge pertinent to the National Ganga River Basin, the anthropogenic factors affecting NRGB, and the remedial measures available to counter negative (resource-depleting) effects; and (ii) to disseminate such knowledge and sensitize stakeholders to enable their meaningful participation in NRGB's upkeep.

3. Why Environmental Knowledge-Building and Sensitization is important for Ganga River Basin Management

The National Ganga River Basin covers a large and diverse geo-climatic region that is both highly populated and home to a wide range of ecosystems. The consequent diversity of ecosystem services that goes into the making of a healthy NRGB is thus also subject to a variety of human influences, resulting in a complex web of ecosystem-human interactions that has caused significant environmental degeneration of the basin in recent times. Hence it is imperative to synthesize the entire gamut of ecosystem processes and human-environment interactions prevalent in NRGB in order to comprehensively restore and regenerate the basin. Moreover, the entire population of NRGB constitutes stakeholders that are served by the ecosystem goods and services of the basin and whose quality of life depends on the basin health. Thus it is also important to gather relevant information from stakeholders, disseminate available knowledge in the public domain, and enable meaningful participation of stakeholders in sustained upkeep of the basin.

4. Environmental Data Bank and Knowledge-Building for NRGB

Diverse human activities and developmental pressures have affected NRGB's environment in complex ways which need continuous monitoring and in-depth understanding of their linkages. Such understanding is dependent foremost on building a comprehensive bank of environmental data to help arrive at quantitative indicators of the state of the basin and its changing status with some degree of certainty. The importance of such a data bank has been repeatedly stressed by various agencies and experts. For water resources data such recommendations include the World Bank Report titled "India's Water Economy" [Briscoe and Malik, 2006], India's "Comprehensive Mission Document on National Water Mission – 2011" [MoWR, 2011], "National Water Policy – 2012" [MoWR, 2012], WWC's "Better Water Resource Management" [Sadoff and Muller, 2009], SANDRP's "Water Sector Options for India in Changing Climate" [Thakkar, 2012], UNICEF's "Water in India: Situation and Prospects" [UNICEF, FAO and SaciWATER, 2013], United Nations' "Water Security and the Global Agenda, 2013" [UN University, 2013], etc. Similar recommendations for other types of natural resource data pertinent to basin management include DST's "National Resource Data Management System (NRDMS)" brochure [DST, undated], Gundimeda *et al*. [2007], ICAR's "Vision 2030" document [ICAR, 2011], and Lenka, Lenka & Biswas [2015].

The government's "River Basin Plan Guidelines" [CWC, 2007] may be cited here as an example of water-related data needed for water resource planning**:**

"The exact data requirement will vary depending upon the particular study environments and approach chosen. In general, the data normally needed would be of the following category:

1. Topographical data such as topographical maps, aerial photographs etc.
2. Hydrological data such as stream flow, snow data, watershed characteristics, sediment inflow rate, duration of flooding for various reaches of rivers.
3. Meteorological data such as rainfall, evaporation, temperature, etc.
4. Geo-hydrological data such as aquifer characteristics, ground water elevation, etc.

5. Water quality data for both surface and ground water including sources of pollution and related information.
6. Environmental data such as flora, fauna, historical monuments, wildlife sanctuaries, fisheries etc.
7. Land resources data such as land use, soil survey, land classification, etc.
8. Agricultural data such as cropping pattern, crop water requirement, etc.
9. Demographic data including urban and rural distribution, grouping by age, sex, etc.
10. Power demand survey data including alternative sources available, demand centres, etc.
11. Natural disaster data primarily for flood and droughts. These include disaster-prone areas, damage statistics, mitigation measures, etc.
12. Seismic data, especially in the vicinity of probable storages and structures.
13. Industrial data especially for those which are water-intensive. The data include growth trends, water consumption, possible alternate sources etc.
14. Inland water navigation data such as demand, alternate transport system available, etc.
15. Data on recreational prospects related to water resources development.
16. Data on projects in the basin such as completed and on-going projects and their water consumption (planned as well as actually utilized), potential projects identified including reconnaissance reports for major and medium projects. Data on flood control works carried out in the past and their performance.
17. Drainage works executed, evaluation. Data on drainage congestion problems including near the confluence point of tributary/sub-tributaries with main river, behind of the embankment system due to continuous high stage of Main River.
18. Geologic data such as formations, mineral deposits etc.
19. Economic data related to project/plan evaluation.
20. Financial data such as those required for financial feasibility analysis and also data on sectoral allocation of plan outlays, etc.
21. Legal constraints such as inter-state/international agreements and tribunal awards.

22. Social environment such as water-related institutions, interest groups, public awareness.

Apart from these data, the change in the food intake pattern, virtual export of water, in terms of food grain export from surplus to deficit water basin/sub basin, is also the growing concern of the planners."

While the above list is recommended for river basin water resource management, much of the data may not be available at all with government bodies. As noted in IITC's hydrology report [IITC, 2014b], many basic data needed for hydrological analyses, such as precipitation data for higher elevation areas, dam operations (inflows, storages and releases), canal water diversions, and crop irrigation, were unavailable from government agencies. Likewise, data available on sediment concentrations in the Ganga river network are very limited rivers [IITC, 2015a]. It should be also noted here that the above list comprises only broad categories of data, while the actual data needed must meet their specific spatial and temporal resolutions. This is because the specific body of data needed for each type of data will depend on the intended analyses and the parameters of interest to be derived from them. Some redundant data is also often desirable – both to cross-check the data of primary interest and to enable other analyses that may be needed in future. Examples of some basic results covering mostly water quantity and quality aspects in different spatial and time domains are cited below for the Danube River Basin – an international river basin of Europe – in Figures 4.1 to 4.5 and Tables 4.1 to 4.4 [ICPDR, 2005]. These results indicate the wide variety and extent of data requirement even for a broad overview of a river basin.

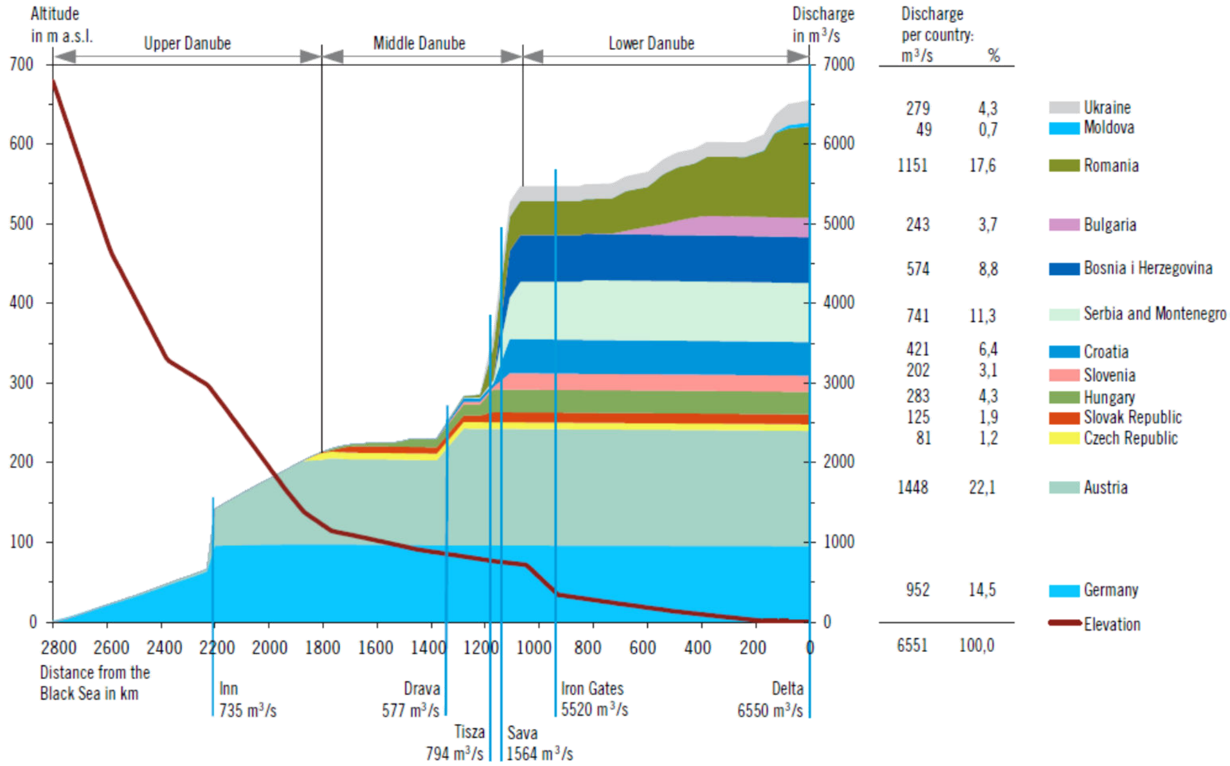


Figure 4.1: Longitudinal Profile of River Danube and Contribution to Danube River Flow from each Country of the Danube Basin during 1994–1997 [ICPDR, 2005]

Table 4.1: Significant Point Sources of Pollution in the Danube River Basin [ICPDR, 2005]

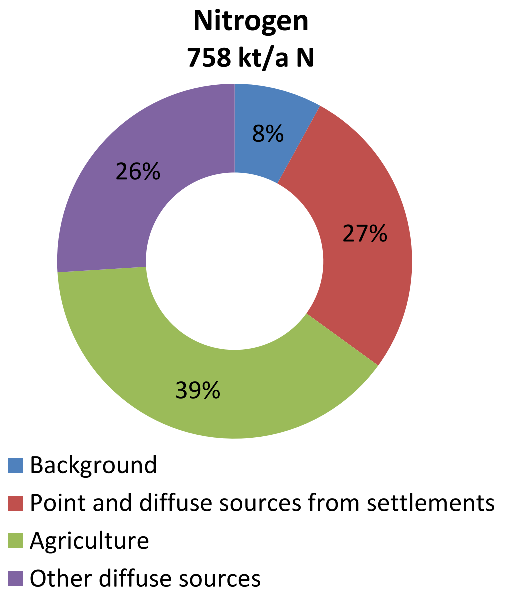
		DE	AT	CZ	SK	HU	SI	HR	BA	CS	BG	RO	MD	UA
Municipal Point Sources:	WWTPs	2	5	1	9	11	3	10	3	4	6	45	0	1
	Untreated Wastewater	0	0	0	2	1	3	16	15	14	31	14	0	0
Industrial point sources		5	10	10	6	24	2	10	5	14	5	49	0	5
Agricultural point sources		0	0	0	0	0	1	0	0	0	0	17	0	0
Total		**7**	**15**	**11**	**17**	**36**	**9**	**36**	**23**	**32**	**41**	**125**	**0**	**6**

***** Two of these water bodies are shared by SK and HU*

Table 4.2: Population (%) Connected To Wastewater Treatment Plants in Different Countries of the Danube River Basin [ICPDR, 2005]

	Total (in%)	Primary treatment (in%)	Secondary treatment (in%)	Tertiary treatment (in%)
Austria	86[a]	1[b]	17[b]	64[b]
Bosina i Herzegovina	na	na	na	na
Bulgaria	38[a]	1[a]	37[a]	0[c]
Croatia	na	na	na	na
Czech Republic	68[a]	na	62[d]	na
Germany	91[b]	1[b]	6[b]	83[b]
Hungary	32[c]	2[c]	24[c]	6[c]
Moldova	na	na	na	na
Romania	na	na	na	na
Serbia and Montenegro	na	na	na	na
Slovak Republic	49[b]	na	na	na
Slovenia	30[d]	15[d]	15[d]	0[d]
Ukraine	na	na	na	na

a: 2001; b: 1998; c: 2000; d: 1999



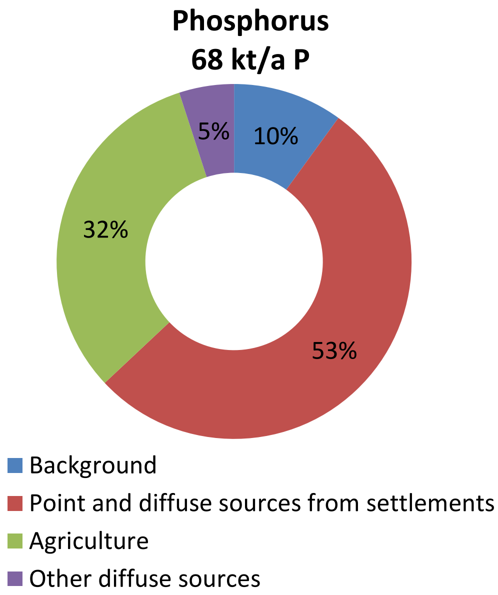


Figure 4.2a: Total N & P Emissions by Human Sources in Danube River Basin during 1998–2000 [ICPDR, 2005]

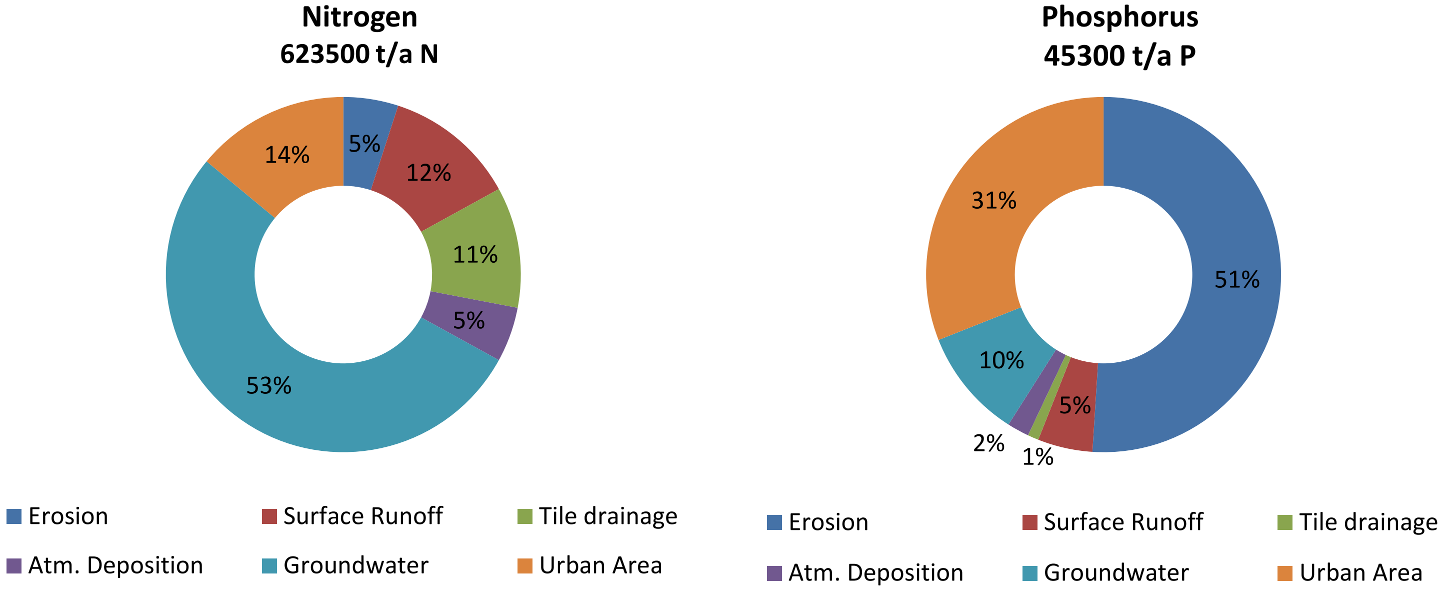
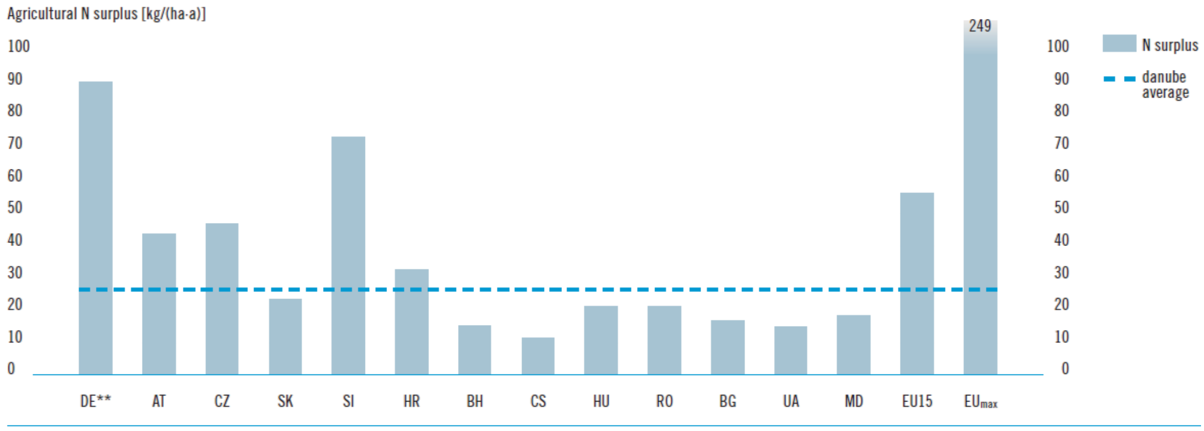


Figure 4.2b: Diffuse N & P Pollution Emissions by Pathways in the Danube Basin during 1998–2000 [ICPDR, 2005]



* *Data sources: SCHREIBER et al. (2003), based on data of FAO and national statistics for the German "Bundesländer"; data source for EU15 and EU_{max}: FAO (2004). The data of these sources are not directly comparable, but give a general indication.*

Figure 4.3: Nitrogen Surplus per Unit Agricultural Area in the Danube Countries during 1998–2000 [ICPDR, 2005]

Table 4.3: Pesticide Consumption in Some Danube Countries in 2001 [ICPDR, 2005]

	DE	AT	CZ	SK	HU	SI	RO
Pesticide category	t/a	t/a	t/a	t/a	t/a	t/a	t/a
Fungicides and bactericides	7,912	1,336	1,050	537	1,637	921	2,802
Herbicides	14,942	1,436	2,590	2,136	3,149	362	3,960
Inorganics	1,959	99	272	0	684	504	0
Insecticides	1,255	0	157	175	298	81	1,110
Rodenticides	80	1	162	34	20	19	0
Total	26,148	2,872	4,231	2,882	5,788	1,887	7,872
Pesticide consumption	kg/ha·a	kg/ha·a	kg/ha·a	kg/ha·a	kg/ha·a	kg/ha·a	kg/ha·a
Specific pesticide consumption per ha agricultural area and year	1.53	0.82	0.99	1.18	0.94	3.77	0.53

* *according to the FAO database on agriculture*

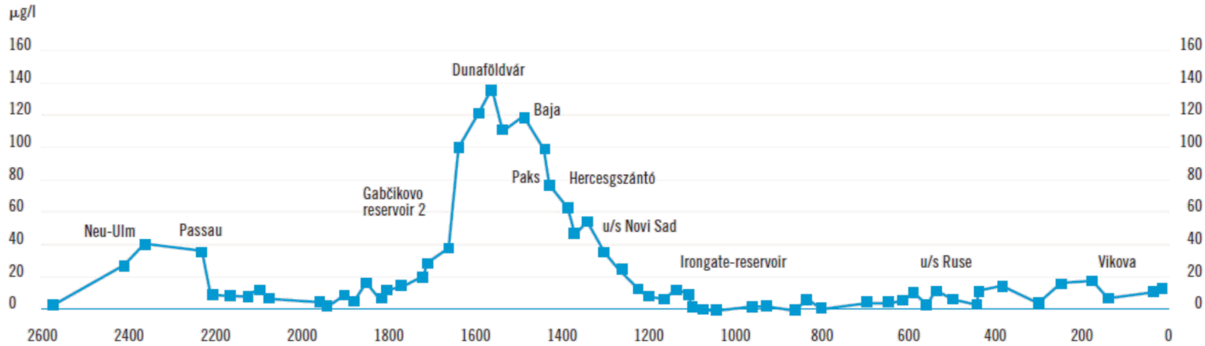
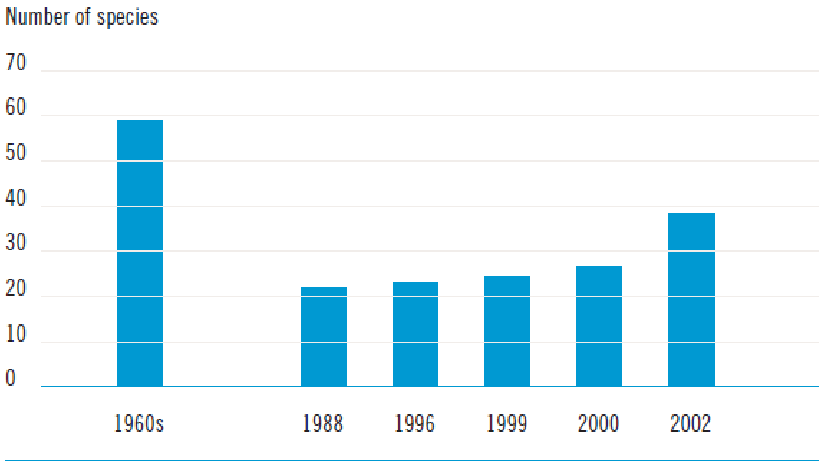


Figure 4.4: Chlorophyll Concentrations in River Danube at Different Locations during 1998–2000 [ICPDR, 2005]

Table 4.4: Annual Mean Saprobic Index Based on Phytoplankton during 1997–2000 [ICPDR, 2005]

D - Danube site (rkm)	Saprobic index (phytoplankton) 1997	1998	1999	2000
RO01-Bazias (1071); D	2,03	1,86	1,83	2,06
RO02-Pristol/Novo Selo ; D Harbour (834)	2,12	1,92	1,88	
RO04-Chiciu/Silistra (375); D	2,07	2,02	2,08	1,96
RO05-Reni-Chilia/Kilia arm; D	2,08	2,11	2,11	2,17
UA01-Reni-Chilia/Kilia arm; D				
RO06-Vilkova-Chiliaarm/Kilia; D arm		2,08	2,06	2,17
RO07-Sulina-Sulina arm ; D			2,05	2,13
RO08-Sf.Gheorghe arm; D Gheorghe arm			2,03	2,32



**10 stations on 3 transects off Constanta, data from C. Dumitrache, IRCM Constanta*

Figure 4.5: Number of Macro-Benthic Species In Front of the Danube Delta [ICPDR, 2005]

For river basin management it should be clearly noted that the data types listed above are required mainly for water resource management in the basin [CWC, 2007; CWC, 2010]. For comprehensive environmental management of NRGB, the data needs are much more – especially those pertaining to other natural resources such as soils, nutrients and biota, as well as those of harmful substances and wastes. Among non-material substances, energy is an important resource for inclusion. Many forms of energy abstracted for anthropogenic needs are also needed by ecosystems – especially renewable energies such as solar energy, wind energy, hydropower and tidal energy, but also other forms of energy that may readily available to ecosystems such as geothermal energy (e.g. by hot springs). However, many other commercial resources (such as fossil fuels) and commercial minerals are often ecosystem-neutral. Naturally, inclusion of environmentally significant biodiversity, soils, nutrients and energy resource data and related anthropogenic activities will increase manifold the data requirement of a basin. In fact, many data needs other than those of water resources have been highlighted by various agencies and experts such as DST [undated], EEA [2011b], Gundimeda *et al*. [2007], ICAR [2011], Lenka, Lenka & Biswas [2015] and SLUSI [undated] for purposes that overlap with basin management needs.

To illustrate the data needs of natural resources other than water, the ICAR Vision Declaration [2011] for sustainable agricultural growth by 2030 in India may be cited. The ICAR document emphasizes the improvement of "knowledge management system to act as an efficient clearing-house of technology, knowledge and information in agriculture and allied sectors." Such a system would obviously need an exhaustive information bank to be effective. Such information may also need spatial analysis and be easily comprehended by spatial representation. For instance, land degradation has significant implications for agriculture as well as for NRGB's overall status. Thus land degradation maps can clearly indicate the considerable degradation in different states of NRGB, vide sample results for two states [ICAR, 2010] shown below.

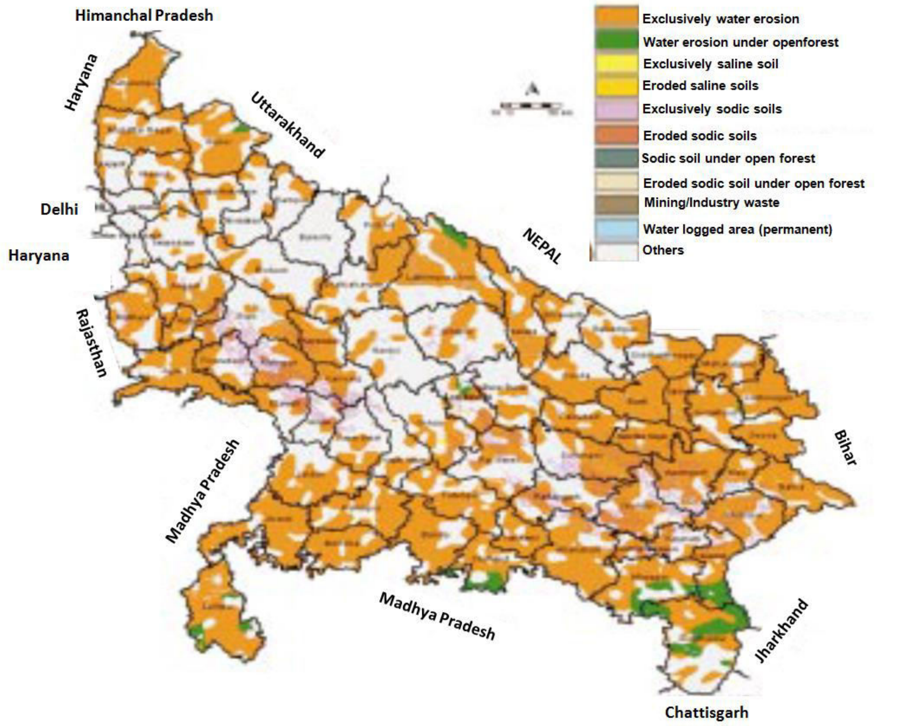


Figure 4.6a: Degraded and Wastelands of Uttar Pradesh [ICAR, 2010]

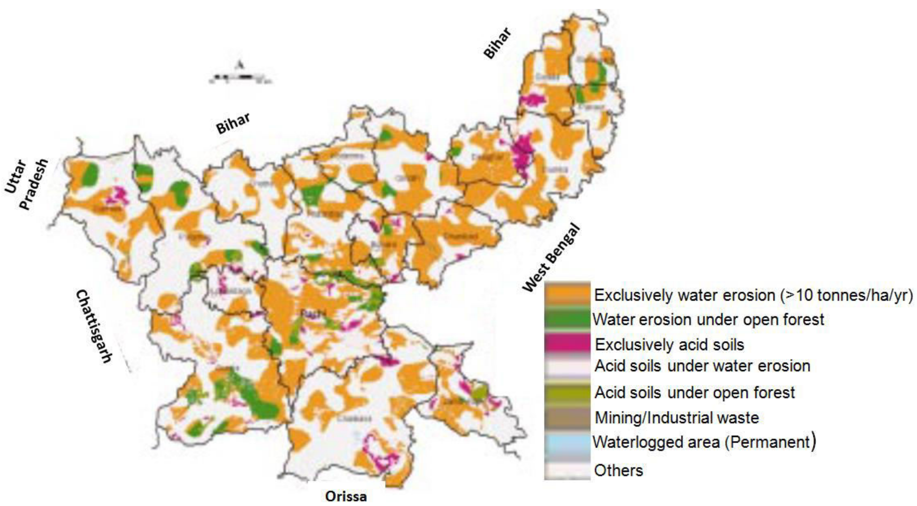


Figure 4.6b: Degraded and Wastelands of Jharkhand [ICAR, 2010]

While the above figures give only a broad overview of state-wise land degradations, a much finer resolution may be needed in field-level planning of land improvements and assessing the impacts on water bodies. SLUSI [undated] proposes to attempt such detailed Land Degradation Maps and Tables. For comprehensive basin data handling the National Spatial Data Infrastructure – 2006 [DST, undated] initiated by the government may provide a useful geo-spatial data management system. But the foremost task would be to systematically collect the data needed.

In sum, while there is considerable data collection by national and state agencies focussing on specific themes such as water resources, forest resources, agriculture, industry, land-use, etc., comprehensive management of NRGB needs the integration of disparate groups of data into a cohesive whole. Planning and management of NRGB must combine diverse fields such as *water resources, land resources* and *biological resources* (plus *energy and other extractable resources*) with *fluvial dynamics, geological phenomena* and *atmospheric processes* as well as *grassroots knowledge* and *traditional wisdom* – the experiential essence of generations of people – to account for NRGB's interactions with human activities. For, until all relevant data are brought together and made easily available, the planning, monitoring and maintenance of NRGB can only be a fickle endeavour. But important data needs – even for natural resources – are presently unavailable. For instance, apart from the paucity of water resources data mentioned earlier, data on biodiversity of River Ganga are available only "in fragments in geospatial terms" and "in different time domain and isolated stretches" of the river [IITC, 2014a]. Likewise, there is limited information on pesticides and heavy metals loading in the Ganga river system and quanta of anthropogenic pollution of rivers through municipal sewage, industrial effluents and solid wastes [IITC, 2015b].

To start with, therefore, the actual data available with various central, state and private agencies should be collected and compiled in a single environmental data bank. The additional data needs should be then identified and a program for such data collection initiated. Over time, the data bank must be developed into a multi-dimensional archive with historical and regularly collected basin information, intermittent monitoring data, as well as specific observations and interpretations covering a wide and eclectic data field to transform it into an open-ended knowledge system. For only such knowledge systems can fulfil NRGB's developing needs as envisioned, for example, in the European Environment Agency's "Forward-Looking Information and Services (FLIS)" whose primary aim is to "introduce forward-looking components and perspectives into existing environmental information systems to expand the knowledge base" [EEA, 2011].

5. Environmental Sensitization for NRGB

The proposed Environmental Knowledge Bank (or Data Bank) combining comprehensive basin data, their significant parametric, tabular and graphical representations, relevant scientific reports, and meaningful individual observations will cater to various users – not only to specialised analysts, researchers and policy-makers, but also to other NRGB residents (ordinary stakeholders) whose well-being depends considerably on the basin status and whose interactions with basin processes may be significant. Thus, there is a need to make the Data Bank accessible to all stakeholders and hence organize it in an easily searchable and retrievable format. While the need to access the Data Bank by professional users – such as government agencies, private industry and research institutions – can be easily anticipated from their institutional functions, the needs of common stakeholders of NRGB are less well defined. The difficulty in pinpointing the needs of common stakeholders is because their interactions with NRGB occur in a great variety of ways depending on their locations, professions, life-styles and cultural traditions. But it is also because of these variations that they can play a significant role in reversing the NRGB degradation processes if equipped with proper understanding and knowledge of pertinent environmental processes. For, just as good road sense depends on knowledge of "traffic rules", knowledge of "environmental rules" (or environmental processes) is essential for meaningful contribution to NRGB. Moreover, since basin-wide monitoring would be needed in NRGB and since environmental concerns are always open to fresh insights, much can be gained from sensitizing people and motivating them to participate in the monitoring and environmental upkeep of NRGB. Such sensitization can be achieved by complementing the environmental data bank with target-specific educational and training material on NRGB's environment for community education and sensitization.

In attempting to inform and sensitize the common stakeholder, a key point to be disseminated is the spatial and temporal linkages between various natural resources in the basin. The EEA monograph on "Sustainable use and management of natural resources" {*EEA, 2005*] may be cited here though it is based on a regional perspective and not from a river basin perspective. The report focuses on only a handful of natural resources of commercial value, namely fisheries, forestry, water, fossil fuels, metals and construction minerals, and land use (and excluding the environmental impacts of agriculture). But it throws meaningful light on the anthropogenic impacts of extraction of these resources. Thus, it reports that with "total material consumption in industrialised countries between 31 and 74 tonnes/person/year largely for housing, food and mobility" there is considerable pressure on natural resource and on sinks for harmful wastes (from domestic and industrial wastes and mining) in the European Union. However, the GDP growth rate significantly exceeds the growth rate in weighted material consumption, vide Figure 5.1. Regarding water resource, the water consumption of the region was found to be gradually decreasing since 1990, except for agricultural water consumption, vide Figure 5.2. The pollutant loads in European rivers also showed essentially decreasing trends (vide Figure 5.3), suggesting effective control on anthropogenic pollution of rivers. For land use, a significantly increasing trend of built-up areas was observed (due to urbanisation and infrastructure development), leading to significant sealing of land surface (vide Figures 5.4 and 5.5 and Table 5.1). But soil erosion (mainly water erosion) and contamination were also caused by certain land uses. While agricultural impacts on natural resources may not have been estimated, some key impacts were identified, vide Table 5.2. The composite effects of various processes on local contamination were also identified as shown in Figure 5.6. Overall these results illustrate some key factors of natural resource management that are likely to have significant implications for river basins.

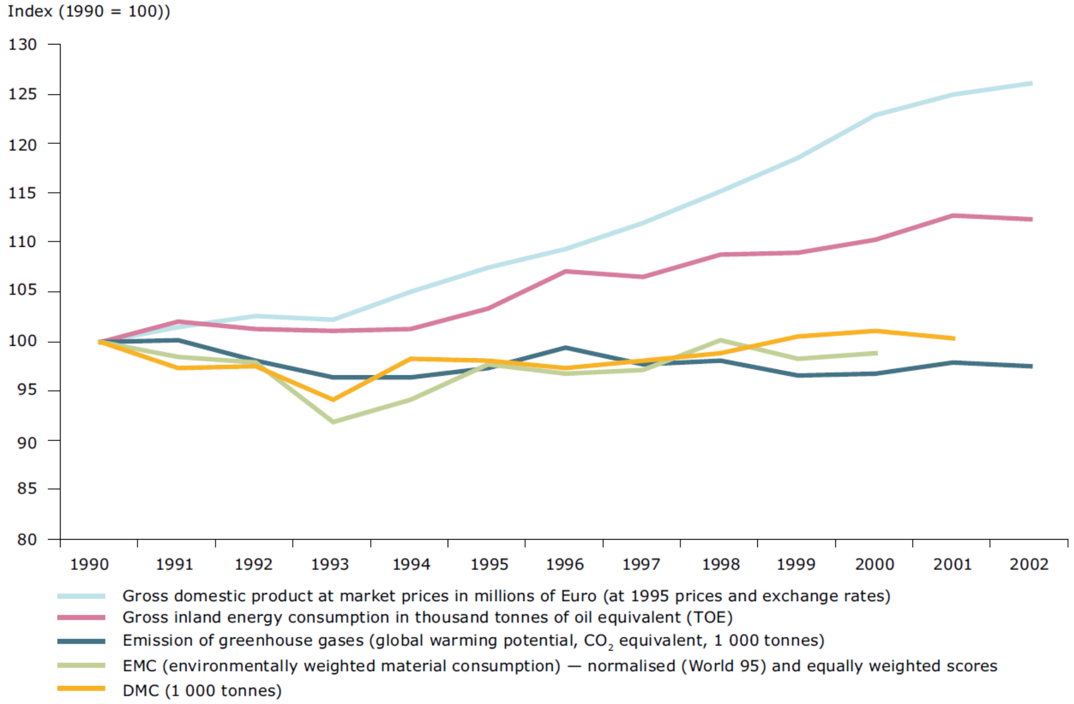


Figure 5.1: Comparison of Growth in GDP and Resource Use in EU-15 Countries [EEA, 2005]

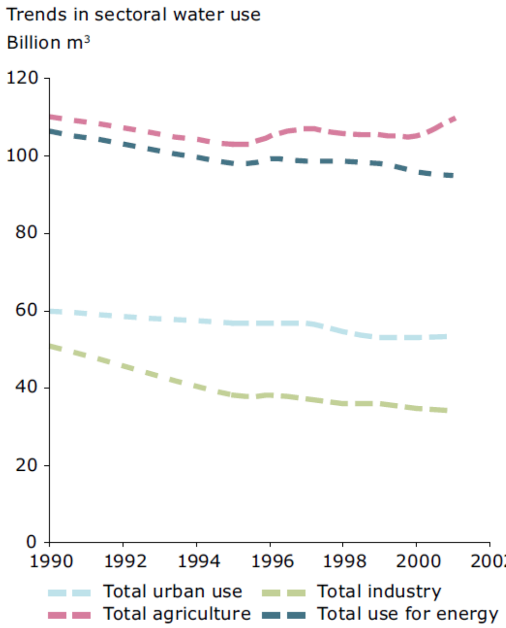


Figure 5.2: Trends in Sectoral Water Use in Europe [EEA, 2005]

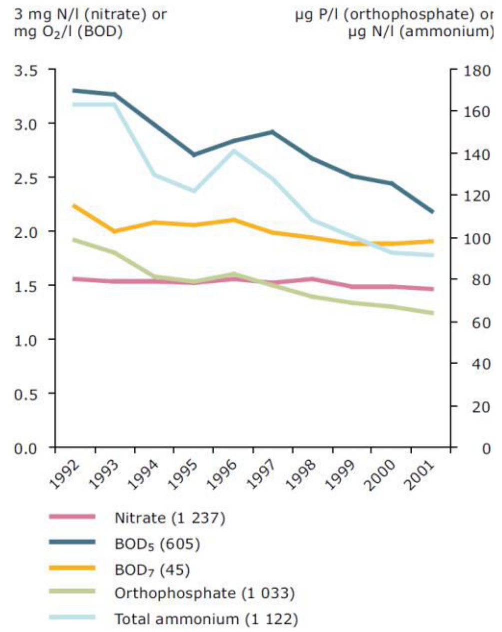


Figure 5.3: Concentrations of Some Pollutants in European Rivers between 1992 and 2001 [EEA, 2005]

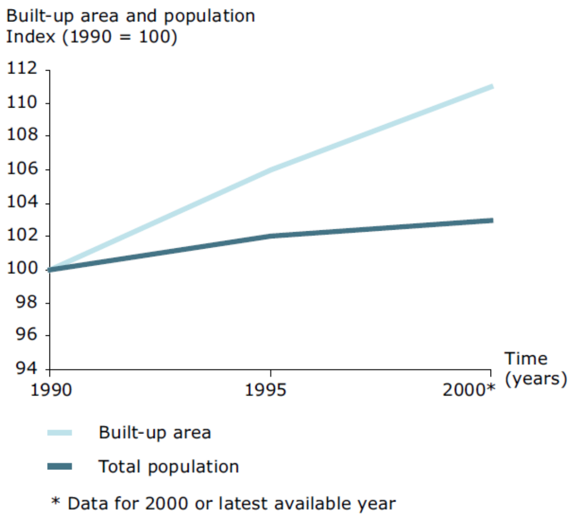


Figure 5.4: Built-Up Land in Relation to Population [EEA, 2005]

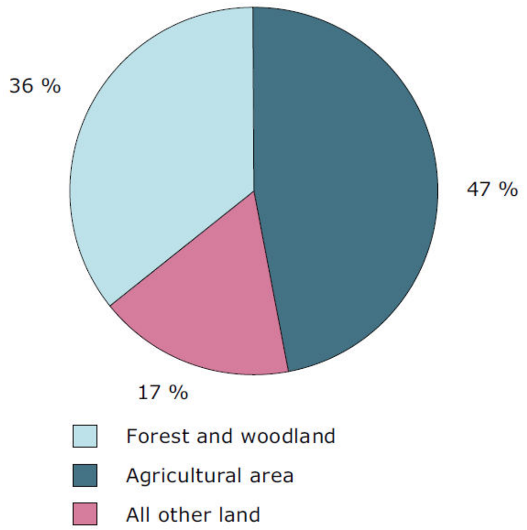


Figure 5.5: Land Use in EU-15 Countries [EEA, 2005]

Table 5.1: Soil sealing and land use [EEA, 2005]

In 2000, the rate of increase in areas for settlements and infrastructure in Germany was a staggering 130 ha per day. This fell to 93 ha per day in 2003 due to economic conditions. Settlements account for about 80 % of this growth and transport infrastructure for the remaining 20 %. About half of this area, equivalent to eighty football fields per day, is effectively sealed. In the 2002 Sustainability Strategy, the German government set the target of reducing the increase of areas for new settlements and infrastructure to a maximum of 30 ha a day by 2020.

Source: Federal Government of Germany, 2003.

Table 5.2: Land use for agriculture [EEA, 2005]

Agriculture uses soils and water as a resource for food production, and at the same time impacts these resources. The impact of agriculture is demonstrated by the fact that more land has been converted to cropland since 1945 than in the eighteenth and nineteenth centuries combined. The extent and causes of the environmental impacts of agriculture, notably by arm and crop type, vary significantly across Europe. Nevertheless, the continuing search for efficiency, lower costs and increased scale of production is resulting in substantial pressures on the environment, landscapes and biodiversity, particularly in the most intensively farmed areas. At the same time, agriculture remains essential to the maintenance of many cultural landscapes.

Agricultural production throughout the continent continues to rely on non-farm resources such as inorganic fertilisers and pesticides. However, there has been a decline in the use of these resources and, particularly in Eastern Europe, a reduction in the pressure on the environment. Recent shifts to environmentally-friendly production systems are apparent, for example to organic production or conservation tillage systems. Organic framing covered about 4 % of the total agricultural area of the EU-15 in 2003. The development of certified organic farming in other European regions still lags significantly behind this figure.

In terms of resource conservation the most important impacts of arable and livestock production are those relating to soil erosion and nutrient leaching, respectively. Soil erosion is particularly severe in the Mediterranean region and parts of eastern Europe, and increases with share of arable land of total land use, mitigated by physical background factors (slope, soil type rainfall patterns) and farming practices. Nutrient leaching is caused where the application of livestock manure and mineral fertilizers exceeds the nutrient demand of crops. The highest nutrient surpluses are found in areas of intensive livestock production, particularly in north-western Europe.

While agriculture can exert significant pressure on the environment, It Is Itself subject to negative environmental Impacts linked to air pollution and urban development. Soil sealing by transport or housing infrastructure eliminated many thousand hectares of agricultural land every year, particularly in western Europe.

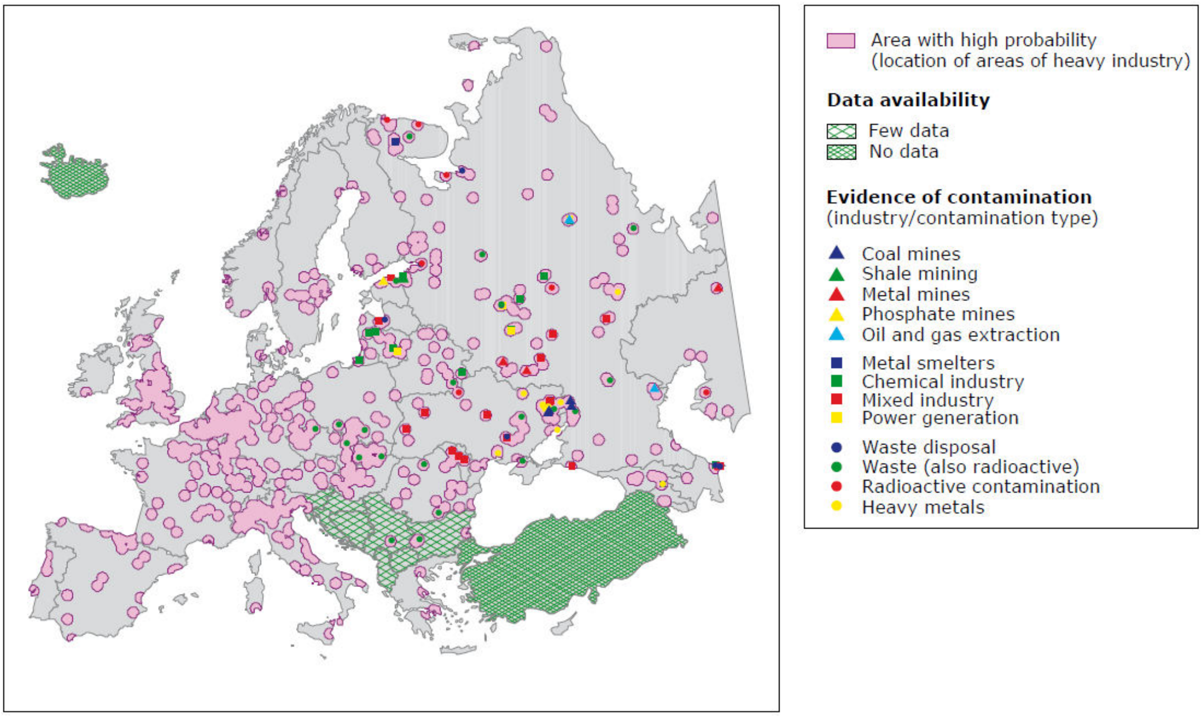


Figure 5.6: Probable Problem Areas of Local Contamination in Europe [EEA, 2005]

While results such as the above presented for NRGB can be useful for advanced users and policy-makers, the common stakeholders' sensitization would depend more upon informing them about ground-level processes and results suitable for their active participation. The first three chapters of Main Plan Document and the Mission Reports of GRBMP can provide useful material to inform and sensitize common stakeholders. For specific community actions to be carried out on the ground such as monitoring of water bodies or rejuvenation of the basin's ecosystems, specific material and information fine-tuned to such tasks need to be created. For example, flood damages to human life and property are a recurring feature in several sub-basins of National River Ganga. While large-scale engineering measures have their drawbacks and potentially negative impacts on ecosystems (as discussed in Mission "River Hazards Management" and Mission "Basin Protection Against Disasters"), they are beyond the control of ordinary citizens. However, Natural Flood Management (NFM) can involve the populace to minimize flood damages without compromising the ecosystem services of sub-basins. Some basic material on NFM in Scotland may be cited in this regard. The NFM approach to increase water infiltration and storage and to decrease soil erosion and flow velocities, identifies the following key techniques [Johnson, Watson & McOuat, 2008]**:**

1. Reforestation of upland hill-slopes.
2. River channel restoration, especially restoration of channel meanders.
3. Restoring wetlands and enhancing floodplain storage.
4. Agricultural modifications, especially to increase soil infiltration rates.
5. Planting dense woodlands in gullies and watercourses.
6. Enhancing riparian vegetation.

The practical application of NFM is briefly explained for ordinary rural stakeholders through a poster with short, boxed texts as cited below [*RSPB, undated*].

Natural flood management presents a shift from our predominantly piecemeal and reactive approach to flooding towards a strategic, catchment-based approach. Natural flood management is achieved by:

- *Adopting a strategic, source to sea (catchment) approach*
- *Protecting and using natural systems and habitats*
- *Promoting soft engineering techniques.*

Catchment-scale planning

- *Consider the whole catchment from source to sea.*
- *Ensure better co-ordination of flood management by local authorities, individual landowners and farmers.*
- *Use river basin management plans to provide a strategic forum to consider natural, sustainable flood management.*
- *Encourage neighbouring farmers to work together for more coherent management.*

Protecting and using natural systems and habitats

- *Restore bogs and keep them healthy so they retain water.*
- *Manage uplands to reduce run-off and erosion.*
- *Protect and restore natural floodplains both inland and at coasts.*
- *Use natural forests to store water and slowly release it back into rivers.*
- *Use wetland habitats such as bogs, fens and saltmarsh to soak up water and release it slowly back into rivers.*

Wetland wildlife benefits

- *A natural approach to sustainable flood management helps to achieve national and local biodiversity action plan targets.*
- *Lochs and rivers provide habitats for threatened species such as the Atlantic salmon, the freshwater pearl mussel the osprey and the water vole.*
- *Ponds and pools support the rare medicinal leech, the northern blue damselfly and the great crested newt.*
- *Blanket bogs support a rich diversity of invertebrates and breeding wading birds such as greenshanks, dunlins and golden plovers.*
- *Floodplain wetlands support farmland wading birds and wildfowl, including lapwings. Snipe, teals and pintails.*

Economic benefits

- *Hard engineered, concrete flood defences are expensive to construct and maintain.*
- *Soft engineered schemes are cost-effective and sustainable, fulfilling many roles as well as flood defence.*
- *Wetlands act as natural cleansers and improve water quality by storing pollutants.*
- *Soft engineered solutions are cheaper in the long-term and provide sustainable adaptation to climate change.*
- *Healthy wetland systems are vital to our economy, supporting industries such as freshwater fisheries, the whisky industry and tourism.*

Promoting and implementing soft engineering techniques

- *Recognise the role that wetlands play in helping to alleviate flooding.*
- *Re-connect rivers with their natural floodplains.*
- *Establish more demonstration sited to test the effectiveness of natural flood management.*
- *Protect and restore wetland habitats through the programme of measures.*

Floodwater storage areas

- *Avoid embankments that divorce the river from the floodplain.*
- *Let water stand on low-lying fields when the rivers overflow, reducing pressures on urban areas downstream.*
- *Store floodwaters in natural habitats to release them back into the river system.*

Urban areas

- *These will require only modest flood embankments to defend them against flooding, thanks to protection by sustainable management of the catchment.*

Social benefits

- *People living and working in urban areas downstream are protected from floods.*
- *Wetland habitats and landscapes are good for ecotourism and education.*
- *Recreation opportunities encourage a healthy lifestyle.*

Uplands

- *Manage uplands to reduce erosion and run-off.*
- *Keep bogs healthy so they retain water.*
- *Restore gullies and natural forests.*
- *Avoid overgrazing by sheep and deer to prevent damage to upland habitats and peatlands.*

Floodplain management

- *Consider grazed grassland rather than intensive arable cropping.*
- *Allow shallow flooding or surface flashes of water in spring for the benefit of breeding wading birds.*
- *Leave wet corners or patches within fields, as these are good for wildlife.*
- *Manage native wet woodlands as an alternative to crop production.*
- *Make sure that agricultural incentives reflect the important flood alleviation role.*

The above information set is worth emulating in NRGB as useful advice to rural communities for Natural Flood Management. Similar issues of specific concern to urban communities can also be brought to their attention. For instance, given the rapidly increasing urbanization in NRGB, the status of urban ecosystems and their impact on the basin as a whole are becoming increasingly important. Thus, urban drainage and urban flooding are issues that are best tackled with the participation of urban communities. To give an example, the Sustainable Urban Drainage brochure of SUDSWP [2002] of Scotland identifies 3 key targets, namely Water Quantity, Water Quality and Amenities as depicted in Figure 5.7. "Water Quantity" targets the reduction of flood peaks due to rapid urban runoff from rainfall events as depicted in Figure 5.8. "Water Quality" targets pollution carried into rivers by urban drainage, which can be a significant source of river pollution as depicted in Figure 5.9. "Amenities" targets several ecological, social and environmental issues. Based on the 3 considerations, four broad methods were identified in the document for Sustainable Urban Drainage, viz. filter strips and swales; filter drains and permeable surfaces; infiltration devices; and basins, ponds & wetlands. The techniques were further explained with illustrations for easy understanding by urban communities.

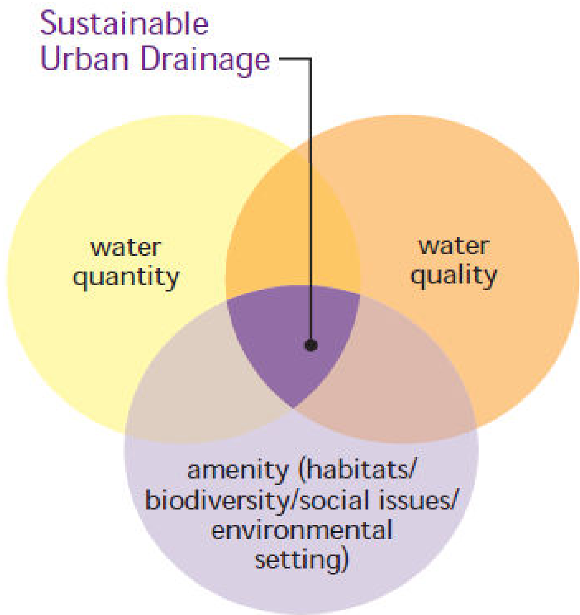


Figure 5.7: Key Targets of Sustainable Urban Management [SUDSWP, 2002]

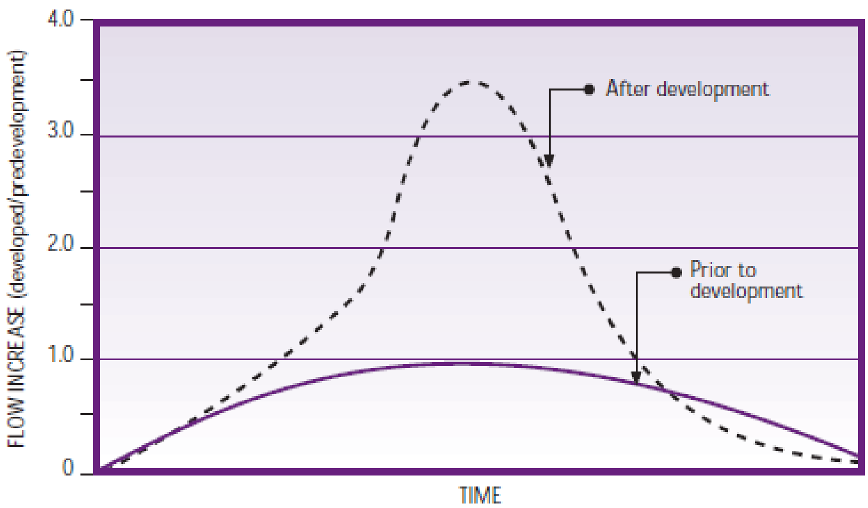


Figure 5.8: Typical River Flood Peaks due to Urban Storm Water Runoff [SUDSWP, 2002]

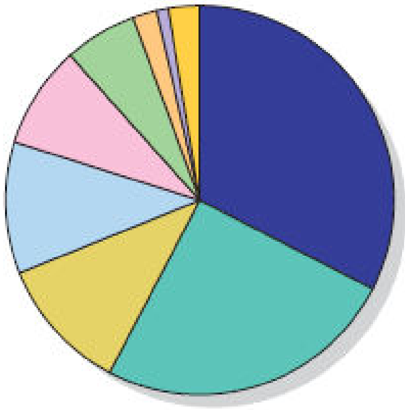


Figure 5.9: Main causes of Pollution of Scottish Rivers in 1996 [SUDSWP, 2002]

Apart from anthropogenic factors in drainage, there are many other urban issues of concern that affect river basins where informed citizens can readily play a corrective role. As in other river basins, urban ecosystems in NRGB may be expected to be highly modified ecosystems whose functioning can be significantly improved by urban residents. A simple example is that of urban soils. As noted by Pavao-Zuckerman [2008], "urban soils represent a distinct taxonomic class that differs with respect to their morphologic structure and function from nonurban soils." The uniqueness of urban soils are related not only to changed soil developmental trajectories but to many direct and indirect impacts on soil properties and processes such as land surface sealing and compaction, urban heat islands and altered hydrological regimes, near-surface atmospheric ozone and carbon oxide levels, and other chemical effects (often with elevated heavy metals, nitrogen and sulphur in soils.) These changes have consequent effects on the activities of soil organisms and biotic compositions, which ultimately shifts the ecosystem functions and processes related to biogeochemical cycling. The effects of urbanization on urban soils also tend to vary with urban size. For example, the effect of urbanization on some soil properties was found to differ greatly among three U.S. cities with different orders of magnitude of population [Pavao-Zuckerman, 2008], as shown in Table 5.3.

Table 5.3: Comparison of Soil Characteristics and Nutrient Cycling Rates in Three US Cities [Pavao-Zuckerman, 2008]

	New York City		*Baltimore*		*Asheville*	
Population	*7,420,166*		*645,593*		*61,607*	
Soil variable	Rural	Urban	Rural	Urban	Rural	Urban
pH	4.7	4.5	4.6	5.2	4.9	4.9
SOM (g/kg)	75	108	110	90	97	79
Mean annual temperature (°C)	8.5	12.5	12.8	14.5	11.9	13.0
N mineralization ($mg \cdot kg \cdot d^{-1}$)	4.02	10.3	2.2	8.0	0.11	0.26
Leaf decay (mg/day)	0.0068	0.0113	n.a.	n.a.	0.0012	0.0009

The populations of the cities range over three orders of magnitude, and although all exhibit impacts of urbanization on soil properties, the nature and degree of these impacts vary from city to city. Such comparisons suggest that urban soil ecological knowledge for restoration will be to a large degree city specific. Some data sets were not available (n.a.) for comparison.

Specific examples pertinent to the above aspects of urban ecosystems is the study of urban soil nutrients in China, China being a rapidly urbanizing country like India with numerous plant nutrient deficiencies observed in cities. In Mao et al's [2014] study of soil in China's capital Beijing, the authors found that "Urban soils in the Beijing metropolitan region are considerably alkaline and compacted. Soil TN, SOC, and AP are in deficit, while AK is abundant and sufficient for supporting plant growing. Heavy metal pollution in Beijing is low. … Soil AP, AK, SOC, C/N, Pb, and Cu increase from suburbs to the urban core, while other elements showed no significant difference. … Roadsides and residential areas are the two land uses characterized by higher soil nutrients and heavy metal pollutants." (Note: The terms AP, AK, SOC and C/N denote Available P, Available K, Soil Organic Carbon and, Carbon:Nitrogen ratio respectively.) Mao et al. recommended further research with the conclusion, "it is critically important to enumerate the different ecosystem services (and disservices) provided by urban soils."

Another significant study was reported for Hubei Province of China by Li et al. [2013]. Li et al. found that "in general, urban soils in Hubei Province had a higher pH than natural soils, were deficient in organic matter, and low in available N, P, and B concentrations." Moreover, "nutrient concentrations were significantly different among land use types, with the roadside and residential areas having greater concentrations of calcium (Ca), sulfur (S), copper (Cu), manganese (Mn), and zinc (Zn) that were not deficient against the recommended ranges. Topographic comparisons showed (that) … concentrations of N, Ca, Mg, S, Cu, and Mn in plain cities were greater than those in mountainous cities and show a negative correlation with city elevation."

The above studies indicate the need for detailed studies, monitoring and amelioration of urban soils in NRGB, since urban soils invariably affect the functioning of these ecosystems with consequent effects on other ecosystems of the basin. To a large extent such activities can be effectively conducted with the involvement of the urban populace through informative discourses, motivation and training. Likewise, a host of data collection, monitoring and corrective measures needed in NRGB will be best carried out by informing, sensitising, training and involving ordinary stakeholders in basin upkeep. At the very least, stakeholder sensitization will lead to automatic self-corrective measures rather than their contributing to basin degradation processes out of ignorance. And a more positive approach to stakeholder sensitization can certainly be expected to pay richer dividends in rejuvenating the National River Ganga Basin.

6. Summary of Recommendations

The main conclusions and recommendations for Environmental Knowledge-Building and Sensitization are summarized below:

i) Establishment of a comprehensive Data Bank by continuous collection, processing and storage of information on natural resources, anthropogenic activities, and environmental monitoring data of the basin.

ii) Preparation of secondary results (charts, tables, etc.) based on primary data and conducting advanced studies and analyses for advancing the knowledge base of NRGB's developing needs.

iii) Preparation of documents and materials for easy understanding by non-specialized ordinary stakeholders of NRGB.

iv) Keeping all the above information in an open-access library for easy access by all interested individuals and institutions.

v) Conducting workshops and educational campaigns with stakeholders, interested citizens, special–interest groups and rural/urban communities to enable their comprehensive understanding of basin processes and participate in basin rejuvenation through meaningful action.

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