Regulation of Human Activities Along Rivers and Lakes

A Background Document
for the Proposed Notification on
RIVER REGULATION ZONE

Prepared for the

National River Conservation Directorate
Ministry of Environment and Forests
Government of India

रक्षये प्रकृतिं पांतु लोकाः

National Institute of Ecology
New Delhi

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National Institute of Ecology
NEW DELHI

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has been prepared by

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EXECUTIVE SUMMARY

1. All large, medium and small rivers are polluted to varying extent. Considerably large stretches of several rivers are highly degraded as exemplified by the Delhi stretch of River Yamuna.

2. Despite huge efforts to set up sewage treatment plants and the enforcement of the Water Pollution Control laws, often with the intervention of judiciary at the highest level, the water quality deterioration has often extended to the upper reaches of the rivers.

3. Most of the rivers, especially in the Ganga basin, are highly regulated with dams and barrages to store and divert water for irrigation, hydropower and other uses. This has resulted in reduction in flows downstream, often to the extent that river stretches are completely dry during the dry season.

4. Most rivers are also heavily regulated with the construction of embankments that have eliminated most of the natural floodplains.

5. Reduced flows coupled with embankments have promoted extensive utilization of the remaining floodplains (riparian fringes) for residential, commercial, recreational purposes, thereby directly interfering with the ecological functions of wetlands. These lands are readily encroached upon by various means, and are often used as landfill sites. Floodplain vegetation has been seriously affected by felling, burning, forage removal and intensive grazing.

6. In the absence of adequate flow and rejuvenation by floods, agriculture on floodplains has become dependent upon heavy doses of agrochemicals including pesticides. Groundwater is exploited heavily for irrigation. Even river beds have been brought under intensive cultivation of vegetables (especially cucurbits).

7. Religious offerings of flowers etc., immersion of ashes and idols, and also disposal of dead bodies and caracasses, besides enormous amounts of non-degradable waste (such as plastic and polythene), as well as dhobi ghats (washing clothes) at various places have

increased manifold with the increasing human population. However, the impact of these activities in aggravated seriously due to lack of flow in the rivers.

8. Mass bathing of auspicious days is an age-old custom. However, these congregations during dry season when the river flows are minimal, not only result in excessive pollution of rivers but are a direct health hazard to the bathers.

9. Indian rivers, especially those of Indus, Ganga and Brahmaputra basins, are well known for their high sediment load. Alluvial deposits of sand have traditionally been mined for construction, and such mining has saved rivers from silting up. River regulation by dams, barrages and embankments has enhanced the rate of siltation. At the same time, **sand and gravel mining has become either exploitative due to greater demand or negligible due to increasing pollution load.**

10. Various problems have arisen because of lack of an approach towards rivers as natural ecosystems. Rivers are not mere channels that transport water; they are dynamic ecosystems that change over time in response to hydrological and biological processes, and human interventions. They are three-dimensional systems dependent upon longitudinal, lateral and vertical transfers of material, energy and biota. All rivers interact laterally with adjacent lands (floodplains) that are periodically flooded by the river with varying frequency and amplitude. Floodplains are an integral part of river ecosystems and play an important role in sustaining the functions of a river and its biological diversity. The most important functions include:

- ensuring flow in streams for most of the year
- recharge of groundwater and improvement of its quality;
- production of valuable natural resources (timber, fuel, fodder, fish);
- breeding and feeding grounds for fish, reptiles and amphibia, etc.);
- improvement of water quality through retention and transformation of nutrients and other chemical substances.

11. In view of the great ecological significance of floodplains and their interactions with river channels, and in view of the impact of various human activities that are growing in magnitude everyday and impinge on both the river water quality and the river ecosystem functioning,

and hence riverine biodiversity (especially fish), it is necessary to regulate all kinds of human activities to different extent in different stretches of the rivers (as well as around lakes).

12. It is proposed to identify four different categories (zones) of river stretches on the basis of climatic and geomorphic features, state of degradation, urban & rural settlements along rivers, and various activities.

13. It is proposed that the MOEF may consider, in consultation with other concerned ministries and state governments, regulation of various activities in different Zones recognized for the purpose.

14. Several other suggestions are made with respect to institutional arrangements and for creating education and awareness among people for supporting the regulations. It is further suggested that the lakes and reservoirs should also be brought within the purview of this notification because various human activities around the lakes and reservoirs impact upon them in the same manner, and that these aquatic ecosystems need similar protection.

ACKNOWLEDGEMENTS

This Report has been prepared at the request of the National River Conservation Directorate of the Ministry of Environment and Forests, Government of India, New Delhi. The National Institute of Ecology gratefully acknowledges the financial support from the NRCD.

The undersigned was a Member of the SubCommittee of the NRCD which decided on the need for this background document to form the basis for further discussion on the proposed River Regulation Zone Notification. I am indeed grateful to the chairman (Mr R.P. Sharma, then Adviser, NRCD) and other members for assigning this work to the National Institute of Ecology (of which I am the Secretary General). I am also highly grateful to Mr A.M. Gokhale, then Additional Secretary, MOEF, and Project Director, NRCD, for his keen interest in river conservation in general and the proposed notification in particular, and for his valuable discussion on the subject. An earlier draft of the Report was presented and discussed at another meeting of the Sub-Committee in September 2002, under the chairmanship of Mr Subodh Sharma, Adviser, NRCD. I am highly grateful to Mr Gokhale, Mr Sharma and all other members of the SubCommittee for their useful suggestions for finalizing this Report. Later also, I had several discussions with Mr Subodh Sharma and this has helped the Report greatly. Finally, I wish to thank especially Dr (Mrs) R. Dalwani, Director, NRCD, for her help, cooperation and support during the preparation of this report.

I am conscious of the shortcoming of this Report and I am alone responsible for any errors, omissions or discrepancies.

New Delhi BRIJ GOPAL

December 2002

1. BACKGROUND

RIVER CONSERVATION IN INDIA

Rivers in India occupy a special place in the history of humankind. Not only some of the world's oldest civilizations developed on the banks of Rivers Indus and Ganga, and some of the oldest settlements continue to flourish today, the extensive canal irrigation system, requiring diversion of river flows, also originated in the Indus river basin. Rivers have been held in reverence and worshipped as Goddesses. Scriptures recognized the self-purification potential of flowing rivers and exhorted people against disposal of several kinds of wastes and forbade numerous activities in or near the rivers.

However, rapid increase in human population and the consequent intensive agriculture, urbanization and industrialization, have not only increased the demand for water but also impacted directly upon the rivers. Rivers have been tamed, amputated, abused and treated with utmost contempt. First, the river flows were diverted or held behind dams, leaving the downstream reaches dry. Riparian vegetation was totally removed, and human settlements and agriculture encroached upon the floodplain. Soon, the river courses were channelised by creating embankments in name of flood control. All kinds of domestic and industrial wastes were discharged, mostly without any treatment, into the rivers. Lately, the riverbanks have become landfill sites for dumping all kinds of solid wastes. Even the dry riverbeds are cultivated with indiscriminate use of organic wastes and agrochemicals.

The consequences of such human abuse of rivers were felt long ago in the form of declining fisheries and other wildlife, frequent floods, and degradation of water quality. Efforts were initiated in 1981 to improve water quality of rivers, and an early focus on River Ganga led to the formulation of the Ganga Action Plan. The original resolution of the Ministry of Environment & Forests, Government of India, published in the Gazette of India - Extraordinary dated 16 February 1985, setting up the Central Ganga Authority, noted that:

*"Deforestation in the catchment areas leading to **high silt loads, floods** and reduced navigational possibilities, **drainage of pesticides and fertilizers** and industrial and municipal waste are among other major areas of concern. It is necessary to take measures for preventing irreversible damage and restoring the water quality of this unique riverine system. While **a holistic long-term programme covering all the aspects needs to be planned and implemented in phases**, the pollution problem call for immediate action …. .."*.

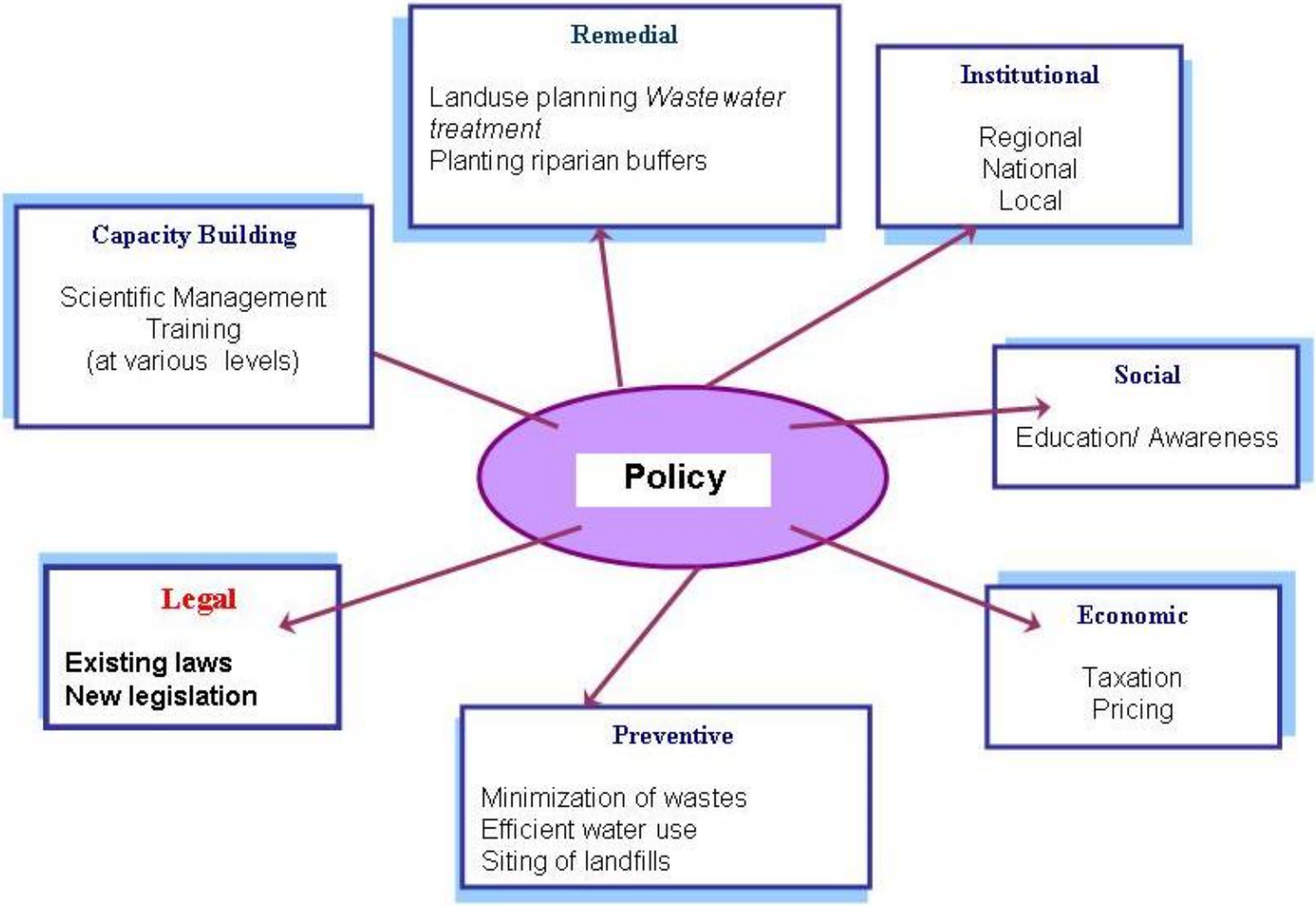
Though the MOEF clearly recognized the multitude of problems, and the need for a holistic approach, the Action plan focused upon the improvement of water quality through interception, diversion and treatment of domestic sewage. After completion of Phase I of the Ganga Action Plan and approval of the National River Conservation Plan (NRCP) in July 1995, the Central Ganga Authority was redesignated as the National River Conservation Directorate (NRCD). The NRCP, covering 18 major rivers, focuses on pollution abatement works in 46 towns in the states of A.P., Bihar, Gujarat, Karnataka, Maharashtra, M.P., Orissa, Punjab, Rajasthan and Tamil Nadu.

It is noteworthy that the Ganga Action Plan did not achieve the desired results and many questions have been raised about the program and its implementation. While the problems related to the operation and maintenance of the infrastructural facilities have been recognized, the complex of ecological factors, including the non-point sources of pollution, that regulate the river water quality have been overlooked.

POLICY FRAMEWORK

The success of a policy for conservation of any kind, and more so for river conservation, depends upon a variety of measures to be taken in tandem with each other (Figure 1). These measures for action are categorized into (a) Preventive measures, (b) Remedial measures, (c) Institutional arrangements, (d) Measures for capacity building, (e) Social measures, (f) Economic instruments, and (g) Legal measures. Even a cursory appraisal of the measures initiated so far for river conservation in India readily reveals that while some action has been taken in respect of several measures, many other measures have remained totally neglected. Neither there are strong multidisciplinary institutions which can handle the issues related to complex river ecosystems nor there is adequate and appropriate scientific and technical manpower in the country trained or experienced in river ecology. Remedial measures have been limited to wastewater treatment which cannot bring results without proper landuse planning and protection of floodplain/riparian areas. Even the preventive measures are grossly inadequate because there has never been an effort made to minimize wasteful use of water. On the legal front, despite numerous legislations at state and central level, civic bodies seem to be helpless to check numerous problems affecting the rivers and their immediate environment, and existing laws seem to be inadequate. This report had its origin in the recognition of this lacuna.

Fig. 1. Policy and Related measures Required for River Conservation



RECENT DEVELOPMENTS

Discussions on the Tenth 5-year Plan Proposals

During formulation of the Tenth 5-year plan proposals of the MOEF, Dr Brij Gopal, a Member of the Working Group of Environment, submitted that,

"River conservation means much more than improving water quality by inerception, diversion and treatment of sewage. It requires that rivers are treated as ecosystems in their own right, and their physical, hydrological, chemical, and biological integrity is taken into consideration. River conservation should aim at sustainable utilization of their water resources along with the protection of natural habitats and the native flora and fauna of the riverine environment. It is impossible to protect riverine fisheries, for example, without protecting the natural floodplain and natural flooding regimes that are essential for their breeding and development."

MOEF-JNU Workshop and Recommendations

Following discussions in the Working Group on Environment, and on the proposal of Dr Brij Gopal, the NRCD-MOEF, jointly with the Jawaharlal Nehru University, organized a two day National Workshop on Conservation of Rivers and Floodplains in India, in New Delhi, during 23-24 November 2001. The Workshop, opened by Dr D.N. Tiwari, Member (Environment & Forests), Planning Commission, Govt of India, had full and active participation of the officers of the NRCD including Mr A.M. Gokhale, Additional Secretary, MOEF, & Project Director, NRCD. Among other recommendations (Annexure I), the Workshop unanimously called upon the Ministry of Environment and Forests, Government of India,

*"To take necessary steps towards issuing a notification under the Environment Protection Act, to protect river floodplains, and areas surrounding all inland water bodies, from uncontrolled anthropogenic activities (tentatively called as **River Regulation Zone** notification)"*

and.that

"The MOEF should set up a Committee to draft the notification which must take into consideration all scientific, technical, socio-economic, cultural and administrative aspects. The Draft should be discussed in another Workshop with representatives of different stakeholders, government agencies and administration, before circulation to the States for comments."

Follow-Up Action

It is heartening and very significant to note that the Report of the Steering Committee on Environment, Forest and Wildlife for the Tenth Five-Year plan (2002-2007), issued by the Planning Commission in February 2002, includes the following item under the "Strategy for Tenth Plan" (page 34):

> ***Legislation would be attempted for a River Regulation Zone on the lines of Coastal Regulation Zone".***

Committee set up for RRZ

Taking cognizance of the recommendations of the National workshop, the NRCD set up a Sub-Commiittee under the chairmanship of the Adviser, NRCD, to discuss the issues related to the River Regulation Zone and to formulate requirements for the purpose (Annexure II).

The Sub-Committee at its first meeting held on 3 January 2002, decided to get prepared, with the help of Dr Brij Gopal, a Draft Document which will form the basis for further action on the subject.

Accordingly, the NRCD entrusted the National Institute of Ecology with the task of preparing the present document (vide letter no. J-15011/16/2001-NRCD dated 18 February 2002).

SCOPE OF THE DOCUMENT

As discussed at the meeting of the Sub-Committee, and consequently noted in the proposal of the National Institute of Ecology, the scope of the Draft document was:

"The Draft document should consider all available information on rivers and various activities affecting the rivers.

The document will summarise the context justifying the need for RRZ, and include criteria for zoning of rivers on the basis of climatic and geomorphic features, state of degradation, urban rural settlements along rivers and various activities.

It will identify the activities to be regulated for each zone.

It will provide more detailed framework for the Yamuna river basin.

All scientific, technical, socio-economic, cultural and administrative aspects of the RRZ will be covered.

It will cover the legal framework (existing laws etc.) and suggestions for institutional mechanisms and inter-ministerial coordination."

2. STATE OF INDIAN RIVERS

The river systems in India can be grouped, according to their origin, into Himalayan and Peninsular rivers. R. Indus, R. Ganga and R. Brahmaputra are the major rivers originating in the Himalaya. However several tributaries of R. Ganga arise from the northern flanks of the peninsular plateau and flow northwards. Remaining rivers arise in different parts of the peninsula and flow eastwards or westwards.

Himalayan Rivers

R. Indus (2880 km) arises from the Mansarovar Lake in Tibet at an altitude of about 5180 m and flows westward through India before turning south-southwest into Pakistan and finally discharges into the Arabian Sea forming a delta near Karachi. R. Brahmaputra (2900 km) arises from Lake Kanggyu Tsho in Kailash ranges (east of Mansarovar Lake) at 5150 m above m.s.l., and flows eastward through Tibet and China for 1600 km before taking a U-turn and then moving south to enter into India. It flows southwest and west through Arunachal Pradesh and Assam for about 800 km, and then bends southwards near Dhubri to enter Bangladesh where it joins the R. Ganga at Golaundo. It is known as R. Tsangpo in Tibet, Dihang or Siang along its southward bend while entering into India, and R. Jamuna in Bangladesh. During its course through the Assam valley, the river often increases its lateral spread up to 10 km on either side. Interestingly, R. Brahmaputra descends steeply from about 3600 m in Tibet to 150 m at Sadiya in India within a short distance after entering the Indian territory. R. Ganga (2525 km) arises from the Gangotri glacier (7010 m* above m.s.l.) in the Himalaya within India, flows southwest before descending in the plains at Rishikesh. It then flows south and turn eastward meandering its way through the plain upto Farakka where it turns south and divides into two main channels one of which (now called R. Padma) flows through Bangladesh and meets R. Jamuna before forming an extensive delta. R. Padma finally joins R. Meghna in Bangladesh in its last stretch just before forming the delta.

All the three rivers have many major perennial tributaries most of which arise in the Himalaya. River Yamuna, the largest tributary of R. Ganga (1376 km long), also arises in the Himalaya from the Yamunotri glacier (6320 m above m.s.l.) and flows almost parallel to R. Ganga until its confluence with latter at Allahabad. R. Yamuna itself is joined by another major tributary R. Chambal which however drains a large area lying on the south and west of R.

Yamuna. R. Chambal arises from the Vindhyan ranges and brings more water than the R. Yamuna at their confluence. The total discharge of R. Yamuna at Allahabad also exceeds that of R. Ganga. Among other tributaries are the many rivers which originate in Nepal (Sharma 1997). Rivers Mahakali, Karnali, Sapt Gandaki and Sapta Kosi in Nepal are called Sarda, Ghagara, Gandak and Kosi respectively, in India. These rivers contribute over 40% of the annual flow of R. Ganga at Farakka (Khan 1994). Rivers Ramganga, Gomti, and Buri Gandak also arise in Nepal. R. Mahananda rises from Darjeeling hills, flows south and meets R. Ganga inside Bangladesh. Several tributaries such as Rivers Tons, Son and Punpun which flow northward from the hills east of Vindhyan ranges, join R. Ganga on its right.

Five major rivers, the Chenab, Sutluj, Ravi, Beas and Jhelum, originating in the Indian Himalaya join R. Indus from the eastern side. R. Brahmaputra is joined by several tributaries in its mid-reaches. Of these, several rivers originate in Bhutan, Sikkim and even in Tibet. The more important tributaries are Subansiri, Jia Bhareli, Manas, Sankosh (=Mo in Bhutan), Raidak, Torsa, Jaldhaka and Tista (all joining from the right), Lohit, Dibang, Buri Dihing and Dhansiri (joining from the left).

Among other rivers originating in the Himalayan belt, mention must be made of R. Meghna and R. Imphal. R. Meghna arising from the hills in Assam, flows southwards into Bangladesh. It is joined by several tributaries which drain parts of northeastern India. R. Imphal, one of the medium rivers, and known as R. Manipur in its southern reach) originates from Manipur hills, flows south through the valley into Myanmar where it joins R. Chindwin, a tributary of R. Irrawady.

Peninsular Rivers

Eleven major rivers, besides some tributaries of R. Ganga, originate in and drain the Peninsular India. These rivers meander through incised valleys in the plateau where narrow deep gorges result in many waterfalls. R. Tons, a tributary of R. Ganga, passes through a 113 m deep gorge in the Kaimur Hills in central India. The Jog Falls on R. Sharavati, a tributary of R. Krishna, has a drop of 253 m, R. Cauvery falls by 101 m at Sivasamundram, R. Subarnarekha has a 74 m deep fall near Ranchi in the Chotonagpur Plateau, and R. Narmada drops by 15 m at Marble falls near Jabalpur.

R. Narmada originates in the Amarkantak hills (1057 m altitude) and flows westwards through a narrow basin lying between the Vindhyan and Satpura ranges. It is joined by 18 main tributaries and after flowing through several gorgesand for 1312 km, it meets the Arabian Sea near Broach (Bharuch). R. Tapi (also called R. Tapti) also flows westwards and almost parallel

to R. Narmada, from its source at the eastern end of Satpura ranges (at 730 m altitude) to the Arabian Sea.

R. Mahanadi arises in the Chhattisgarh region of southeast Madhya Pradesh and flows eastwards into the Bay of Bengal where it forms a large delta (7000 sq. km) north of Lake Chilka. R. Godavari, the largest peninsular river, rises in the northern part of W. Ghats (near Nasik), flows east-southeast and forms a delta (2500 sq. km) near Rajamundhry in Andhra Pradesh. Among its several tributaries, the major one are rivers Manjira, Waingunga and Indrawati. R. Krishna and its major tributaries namely Rivers Bhima and Tungabhadra arise from the middle part of the W. Ghats. R. Tungabhadra carries more water than R. Krishna at their confluence whereas R. Bhima becomes nearly dry during the summer season. R. Krishna also flows eastwards and forms another delta (about 2500 sq. km) just south of the Godavari delta, before discharging into the Bay of Bengal.

R. Cauvery, originating in the lower part of the W. Ghats, is relatively small (800 km) and is joined by many tributaries. In its lower reaches, the river bifurcates first into R. Coleroon and R. Cauvery which join together about 18 km downstream only to bifurcate again into R. Vennar and R. Cauvery. Finally, it forms a larger delta (about 5000 sq. km).

Among other major rivers, R. Subarnarekha and R. Brahmani drain most of the eastern area between the drainage basins of R. Ganga and R. Mahanadi. They flow eastwards into the Bay of Bengal. R. Pennar, another east flowing river, drains an area of 55200 sq. km between R. Krishna and R. Cauvery. Two west-southwest flowing Rivers, Mahi and Sabarmati are much smaller (34800 and 21700 sq. km respectively) and drain the semi-arid parts of Rajasthan and Gujarat west of Yamuna River drainage basin.

Almost all medium and minor rivers have their drainage basin within peninsular India. Majority of them are small, flow westwards from the W. Ghats into the Arabian Sea or from the Eastern Ghats into the Bay of Bengal. A few of them are seasonal or ephemeral streams in the western arid and semi-arid region of the subcontinent.

River Discharge, Sediment load and Channel dynamics

The rivers in India, like many other rivers, are characterised by large seasonal variation in river discharge. This results directly from the seasonal and interannual variations of precipitation. The Himalayan rivers are fed during the dry summer months by the snow-melt which however provides for only a small flow. More than 70% of the total discharge occurs during a short rainy season which varies from east to the west with the onset and advancement of the southwest monsoon. Rains start in May in the east but occur only after the end of June in the west. The

spatial and temporal variations in the intensity of rains at different places in the catchments of the tributaries also result in the time and magnitude of peak discharge at different places. The peninsular rivers and those of Sri Lanka derive their flow from both the southwest and the northeast monsoon and exhibit far lesser seasonal variation in their discharge. The rivers in the western arid region exhibit extremes of discharge from total absence of flow to very high flow in some years.

The relative importance of the rivers may be assessed from their respective drainage area and the annual discharge. Of the total gross annual discharge from all major rivers in India, Indus, Ganga and Brahmaputra together account for about two-thirds of the total flow from approximately the same proportion of the land area.

The drainage basins of the Himalayan rivers constitute the most densely populated area of not only the subcontinent but the entire world. Further, these rivers originate from the mountain ranges which, being geologically young, are composed of unconsolidated sedimentary rocks and hence, are highly prone to erosion. Therefore, it is not surprising that these rivers also carry a high silt load -highest among the world's rivers, as well as a high solute load (Subramanian 1979, Subramanian et al. 1987). The total amount of silt carried by these rives accounts for more than 50% of the world's total. The Ganga- Brahmaputra- Meghna river systems form the world's largest delta (about 6 Mha) which is well known for its mangroves. The peninsular rivers carry a relatively smaller sediment and solute load (Vaithiyanathan et al. 1988).

Closely related to the high sediment load of these rivers and their tributaries) is their channel dynamics (meandering and braiding) which is also influenced by the tectonics of the region. Extensive sediment deposits and an abrupt break in the slope cause shifting of the river channels to long distances. In some cases the shifting has occurred over centuries whereas some rivers shift more frequently. For example, R. Son has shifted back and forth during the past few centuries. R. Brahmaputra has shifted in its lower reaches by 80 to 100 km westwards since 1830. R. Tista, a Himalayan tributary of R.Brahmaputra, has also shifted its course to a similar extent. R. Kosi, a tributary of R. Ganga is notorious for changing its course in the plains of north Bihar. It has moved about 120 km westwards during the past 220 years (Gole & Chitale 1966, Wells and Dorr 1987, Agarwal & Chak 1991). Tectonic activity and morphogenetic uplift of the western part have been shown to be causing an eastward shift of the River Ganga in its lower reaches (Gupta 1957, Chowdhury 1966).

Ecology and Water Quality

Though riverine fisheries of India were extensively investigated during early half of the 20th century (Hora 1921, 1923, 1934, 1935, 1937, 1944) and later continued vigorously at the Central Inland Fisheries Research Institute (Jhingran 1991), ecological studies on the rivers or their biota as well as on the water quality were initiated only in early 1950s in India. The early Indian studies focused mostly on certain sections of River Ganga and Yamuna where universities or other research institutes were located close to these rivers (Roy 1949, 1955, Dutta et al. 1954, Chakrabarty et al. 1959, Lakshminarayana 1965, Ray et al. 1966, and Rai 1962, 1974). A beginning was also made in south India with some minor rivers (Chacko and Ganapati 1949, Iyengar and Venkataraman 1951, Chacko et al. 1953). During the 1960s and 1970s, physico-chemical characteristics of water, and phyto- and zooplankton communities of several smaller rivers were also studied (e.g. Venkateswarlu 1969, 1970, 1986, Venkateswarlu and Jayanti 1968) but river systems in general remained ignored by the biologists and limnologists.

Soon after the Stockholm Conference, the Government took a lead by enacting a Water (Prevention and Control of Pollution) Act in 1974. Steps were initiated to reduce pollution of surface waters. River Ganga was studied for various parameters at different stations along its entire course with the support under Ganga Action Plan. These studies stimulated investigations of water quality and biological communities of rivers throughout India. At the same time, a national programme of monitoring water quality in major and medium rivers was started by the Central Pollution Control Board (CPCB 1996). This program focuses on several physico-chemical parameters and coliforms. Thus, during the past 20 years or so, considerable information has been obtained on a few limnological components of several, mostly smaller, Indian rivers (see Trivedy 1988, 1990). Among the larger rivers, only R. Cauvery (Sivaramakrishnan et al. 1996) and R. Narmada (Unni 1996) have been investigated to some extent.

Studies on River Ganga and River Yamuna

R. Ganga has a very steep gradient in the Himalayan region as it descends from 3129 m at its source to 350 km at Rishikesh within a distance of about 250 km. Thereafter, the gradient is very small - less than 10 cm per km in the lower reaches. Similarly, its tributaries arising in Nepal also descend steeply just before entering the plains in Indian territory. The low gradient and huge sediment load result is a vast floodplain - stretching to over 100 km on either side in some stretches. Less than 10% of the alluvial plain is under natural forests, and the forest cover in the hills is fast disappearing. The most important land use in the basin, and even on the hills, is

agriculture which is sustained by an extensive irrigation system. The upper Ganga Canal built in 1853 diverts more than 60% of the flow (and almost 100% of the dry season flow) at Hardwar only 30 km downstream of Rishikesh. The Lower Ganga canal further diverts the water 240 km downstream. The small gradient of 36 m between Hardwar to Aligarh (about 200 km) has been exploited for 13 small hydroelectric projects. Now a dam is being constructed in the hills at Tehri on its major tributary, R. Bhagirathi, to exploit its hydroelectric potential despite the fact that the area lies in the seismic belt. There are more than 100 important urban settlements along the banks of R. Ganga alone. Numerous industries are also located along the river, particularly in its middle and lower reaches.

Geographers and geomorphologists have studied the fluvial geomorphology of the river basin extensively for landuse planning and flood control. In the upper reaches where the river flows southwards, the floodplain (locally known as Khadar) is characterised by a combination of extensive braiding and meandering. The river course oscillates laterally from northwest to southeast, resulting in formation of terraces, alluvial fans, marshes, pointbar deposits and shallow waterbodies. Six micro-geomorphological belts in accordance with a depositional succession from west to east have been identified (Dasgupta 1975). Braiding is relatively less common in the lower reaches but several tributaries from Nepal develop extensive braiding, and change their course very frequently, mainly by avulsion. Recently, Sinha and Friend (1994) have discussed in detail the sediment flux of these tributaries. They have observed that the mountain-fed rivers are characterised by very high discharge and low suspended sediment load, the river originating in foothills have moderate discharge and sediment load and the plain-fed rivers have low discharge and high sediment load. More than 90% of the sediments are retained in the basin and the remainder carried to the delta. Floods are a regular feature every year. Hence, Large stretches of the river have already been regulated by embankments. However, the embankments and dams have failed to reduce the flood hazard.

R. Ganga is among the most polluted rivers in the subcontinent. Studies conducted during 1983-1989 included analysis of river water quality, inventory of biota, identification of bioindicators of pollution, assessment of heavy metal pollution and microbiology (Krishnamurthy 1991). However, these studies suffered from lack of coordination, clearly defined objectives and a standard methodology. No effort was made to identify trends of changes along the entire length of the river, and to relate the observations to influences of various tributaries. These studies revealed increasing levels of pollution in the plains. The Himalayan stretch of R. Ganga (represented by R. Bhagirathi and R. Alaknanda, the two major tributaries) had relatively unpolluted water. The middle stretch at Kanpur is heavily polluted

with heavy metals from industrial effluents. Biological studies provide an inventory of the biota at difference places and its seasonal changes. However, neither a clear upstream to downstream trend nor a clear correlation with the pollution levels has been established. Studies on the food webs, nutrient dynamics or spiralling, and ecosystem functioning or the riparian (floodplain) interactions are totally lacking. Studies on the impacts of dams and barrages on the water quality and biology are rare. Chakraborty and Chattopadhyay (1989) have reported a shift in the species composition and an increase in abundance of the planktonic community in the estuarine section of R. Ganga (known as R. Hoogly) after the construction of Farakka barrage, due to greater availability of freshwater and lowering of salinity.

Long-term studies on the fisheries resources of the river show clearly a sharp decline in the fish catch and also a significant change in the species composition. Dams have long been considered to impact upon the fishes (Jhingran 1991). In the Himalayan stretch, habitat alterations including dams have drastically impacted upon the fish communities. The characteristic coldwater schizothoraciine fishes such as mahseer (*Tor putitora, Tor tor*) and snowtrout (*Schizothorax richardsonii, S. plagiostomus*) have declined because of the blockage of their migration routes (Sehgal 1994, Dhanze and Dhanze 1996). In the lower reaches, the Farakka Barrage (which was constructed to ensure flow to the Diamond Harbor seaport) has frequently been discussed for causing the decline in hilsa (*Hilsa* (=*Tenualosa) ilisha*) and other fisheries. Hilsa is a typical long-distance anadromous species which used to migrate beyond the middle reaches of R. Ganga. Its catch declined from 19.3 tons to 1.04 tons at Allahabad and from 32 tons to 0.6 tons at Buxar after the construction of the Farakka barrage (Chandra 1989). In the plains, carps (*Cirrhinus mrigala, Catla catla, Labeo* species) and catfishes (*Mystus* sp., *Wallago attu, Ompok* sp., *Pangasius pangasius*) constitute the major fisheries. Freshwater prawns (*Macrobrachium* species) are also abundant. Fish landings have declined during recent years, from 961 kg per km in 1956-60 to 630 kg per km in 1981-87 (Chandra 1989, De et al. 1989). The loss of feeding and breeding habitats in the floodplain lakes due to embankments, and the increased silt load and macrophytic growth which have reduced the deep perennial pools in the river channel have been identified as major causes for declining fish catches (Jhingran 1991). Other river valley projects on the tributaries such as R. Kosi and R. Gandak have also adversely affected the fisheries in north Bihar.

Among other fauna which have been serious affected by changes in the river habitat and water quality, the Ganges River dolphin (*Platanista gangetica*) is the most important. This dolphin was once abundant and widely distributed in the Ganga-Brahmaputra river system, with its distribution limited upstream by the lack of water and rocky shores, and downstream by the

salinity. In recent years, its population has declined rapidly from about 2000 in 1988-89 to only 152 (Sinha 1997). Much concern has been raised about the threats to River Dolphins in the subcontinent due to pollution, water withdrawal and dams (Perrin et al. 1989, Reeves et al. 1991, Ahmed 1992, Smith et al. 1994, Biswas et al. 1997). Similar concerns have also been expressed about the threat to otters (Lutra species) - another widely distributed aquatic mammal in the subcontinent (De Silva 1993).

River Yamuna, the largest tributary of R. Ganga, is relatively better investigated because three important cities, Delhi, Mathura and Agra, are located on its banks. Several smaller rivers of the Yamuna river system, such as R. Khan and R. Kshipra have also been investigated. These studies have been reviewed in some detail by Gopal and Sah (1993). The extraction of water through a series of barrages, extensive channelisation, and heavy discharge of untreated domestic and industrial effluents, have turned the river into a sewer at least between Delhi and Agra. It regains its riverine characteristics partly only after its confluence with R. Chambal which has a larger flow than that of Yamuna. The water quality and the biota have changed greatly during the past four decades (Gopal and Sah 1993). The turtles and crocodiles, once abundant in the river have almost diasppeared. Even in River Chambal, the crocodiles have declined very much, necessitating the establishment of a National Chambal sanctuary for the Gharial.

3. HUMAN ACTIVITIES IMPACTING UPON RIVERS

Since independence rapid urbanization, industrialization, and intensification of agriculture have brought numerous benefits to the growing human population, However, the natural environment has been the victim: reduction in the forest cover, land degradation and soil erosion, pollution of both air and water have often undone the benefits of development. The rivers and lakes which have been over-exploited and even abused, are among the most threatened features of the Indian landscape

RIVER (FLOW) REGULATION AND WASTEWATER DISCHARGE

Two major categories of human impacts on rivers (and also lakes) are readily recognized. First, the rivers are regulated by storage, abstraction, diversion and channelisation of flows for different reasons. Second, all kinds of domestic and industrial wastes are discharged into the rivers (and lakes as well) often with no or only partial treatment.

Agriculture is the major consumer of water. It requires an assured supply in the wake of unpredictable precipitation. The construction of reservoirs (irrigation tanks) for storing surface runoff, and diversion of river water through canals for irrigation has been practiced throughout the subcontinent since pre-historic times. The Grand Anicut on R. Coleroon (a branch of R. Cauvery) was built in first century AD. In Rajasthan, two dams - Rajasamand and Jaisamand (=Dhebar lake) were constructed 1671 and 1730, respectively.

The water of R. Ganga and R. Yamuna were diverted in late 18th and 19th century though the Upper Yamuna Canal (1789), Western and Eastern Yamuna Canals (1810), Upper Ganga Canal (1854), Lower Ganga Canal (1868), Sone Canal (1879). Water from the eastern tributaries of R. Indus was diverted between 1872 and 1922. Construction of large dams had been started in the beginning of this century with Krishnarajasagar (1932), Chamrajasagar (1934) and Mettur Dam (1934) on the R. Cauvery. Many rivers were also dammed to create reservoirs for drinking water supply. The Upper Lake in Bhopal was created on the R. Kolans as early as the 11th century.

During the past fifty years, river regulation has proceeded at a faster rate. Besides barrages for diverting water, thousands of multipurpose reservoirs have been created by building high dams for water supply, irrigation, hydropower and fisheries. Large stretches of rivers,

particularly those passing through the urban areas, have been channelised by constructing levees and filling up the floodplain for both flood control and urban development on reclaimed land.

In India alone, there are now more than 1550 large and medium dams (by 1980s), over 100 barrages on all the major rivers (except R. Brahmaputra) and their tributaries. They are required to meet the increasing demands of hydroelectric power, irrigation and flood control. Today all major rivers in India are dammed or in the process of being damned. Large dams are ecologically unsound and economically unjustified, if environmental and health costs are fully accounted for. These costs include the loss of forests and wild life, water logging, loss of arable land and increases in waterborne disease. Impounded reservoirs cause fundamental changes in community structure and ecosystem function as a naturally free flowing and continuous river course is transformed in to river segments interrupted by impoundment. Water clarity increases because of the reduced sediment in transport. Primary habitat of benthos is destroyed. Dams have proven to be primary destroyers of aquatic habitats as they break the upstream-downstream connection connectivity- a natural feature of rivers. The impact of dams and barrages on fish faunas in tropical areas are poorly known but reservoirs certainly impede the downstream passage of young migratory fishes.

Inland river transport has been historically very important for communication, trade and commerce. River Ganga was used for regular ferry service Calcutta to Allahabad since 1842. River Yamuna was also used for navigation from Allahabad to Agra until 1940. Similarly, Brahmaputra and Meghna were also regularly used until 1950s. However, water extraction, dams and siltation has made them unfit for navigation except in some lower stretches or by country boats. R. Hooghly, the estuarine section of R. Ganga requires regular dredging for navigation, and the cargo ships have to be guided from the sea to the port.

Impacts of wastewater discharges on water quality are well known and extensively documented by the Central Pollution Control Board in its various reports. The degradation of water quality due to domestic wastes in already recognized by the NRCD as a major problem and the NRCP aims at abating it. However, the linkages between river regulation and wastewater discharges are not recognized. Withdrawal of water to the extent of complete cessation of natural river flow takes away all the self-purification potential of the rivers. The uncontrolled discharge of untreated (or at best partly treated) municipal sewage and industrial effluents has therefore rendered many stretches of the rivers into virtual wastewater drains where they have been categorised into class E (MOEF 1994). Among the best known examples are River Yamuna between Delhi and Agra, R. Sabarmati from Ahmedabad to Ventha, R. Gomti near Lucknow, R. Khan near Indore and downstream, R. Kshipra near Ujjain. Similarly, the

estuarine section of R. Narmada is endangered by the Sardar Sarovar dam. Proposals for interbasin water transfers, now under active consideration for implementation within the next 10 years, may cause serious damage to the ecology of the rivers and their catchments.

OTHER HUMAN IMPACTS ON RIVERS

The human impacts on the rivers (and lakes) extend beyond the direct use of water to all anthropogenic activities in their entire catchment (watershed or river basin). A large plethora of other human activities both in and near water as well as in the catchment causes severe problems for rivers and lakes, but has not been given due attention. Many of these activities are as old as the human civilisation and have therefore been ignored as a part of socio-cultural milieu of the human society. However, during the past few decades, these activities have increasingly become both intensive and extensive, resulting in serious impacts on rivers. The nature of these activities has also changed. Agriculture on the floodplains right up to the river banks, human settlements, deforestation, grazing and forage removal, mining and quarrying, mass bathing and washing, immersion of idols, religious offerings and disposal of various kinds of wastes are among such activities that extend now right up to the headwaters of all rivers and have increased in magnitudes. These are briefly discussed under two groups: (a) those in the riparian areas and (b) those in the river channel.

Human Activities in Riparian Areas

Intensive Agriculture and Grazing

Floodplains have been traditional grazing grounds and have been under cultivation for millennia, but during the past few decades, intensive agriculture and grazing up to the riparian fringes has almost completely emilinated all natural riparian vegetation. Tree species such as *Tamarix dioica, Anthocephalus kadamba* and *Mitragyna parviflora*, and reeds (*Phragmites* and *Arundo*) which once dominated the banks of River Yamuna have disappeared or occur only rarely. The riparian forests, dominated by species of *Barringtonia, Syzygium*, and *Calamus*, which were common in many parts of India (Champion and Seth 1969) occur now rarely and in small patches.

The floodplain cultivation now makes extensive use of agrochemicals. Cultivation has been extended beyond the riparian fringes to the riverbed itself. After the floods recede, the river bed is ploughed, terraced or transformed into furrows and ridges right up to the water margin,

and vegetables or early ripening winter season crops are grown. Thousands of tons of organic wastes including raw cattle dung are dumped into the sandy bed; huge quantities of pesticides are applied at 1 to 1.5 m depth as protection against root borers, and chemicals are sprayed on crops as well. Large amounts of grass are also laid on sandy surface to protect the creeping plants against heat. These practices have intensified the erosional forces as well as pollution in the main channels whereas the natural breeding and feeding habitats of aquatic biota have almost disappeared.

Intensive agriculture depends also upon liberal use of water for irrigation. Now that the river flows have been diverted to other areas, farmers in the downstream floodplains extensively exploit groundwater. Diesel generating sets are freely used to pump out groundwater. Whereas the absence of flooding for prolonged periods and lack of river flow have reduced groundwater recharge, excessive exploitation is rapidly lowering the groundwater table. At the same time, the groundwater is contaminated with agrochemicals that find their way into it due to irrigation of sandy areas.

Also in the hills where industrial development is relatively slow, deforestation and agricultural activities on the steep hill slopes causes heavy erosion and silt and nutrient load in the rivers, and consequently impacts of the riverine biota. Here also cultivation is generally practiced right up to the water margin.

Throughout the catchment, and especially on the riparian fringes of floodplains, biotic pressure from the huge population of grazing animals is very intense and growing with time. More than 45 million heads of cattle, goat, sheep and camels decimate the vegetation in the catchment of River Yamuna alone. Intensive grazing far beyond the carrying capacity of the land is intensifying erosion, and pollution.

Sand Mining

Activities such as building construction and road laying create demand for sand. The rivers and shorelines are natural targets for sand mining. Himalayan rivers, especially Ganga and Brahmaputra, carry a very high sediment load from natural erosional processes in the young Himalaya. The erosion has only increased due to human activities in the hills. These sediments have sustained the natural fertility of the Indo-Gangetic falluvial plain for millennia. Sediments play a major role in the morphology and dynamics of river channels. In general, sand mining has been practiced from the rivers for many centuries and will be necessary to maintain the present river channels. However, unrestricted and excessive sand collection has grave consequences. Sand mining threatens the life of fisheries and other

fauna. Local nesting habitats of many species like turtles are destroyed irreversibly. This affects the biodiversity of the region.

Similarly, quarrying and gravel mining, particularly in the upper reaches, have considerable influence on the runoff, quality of water and riverine habitats.

Landfill and Solid Waste Disposal

Riparian areas have fast become the most sought after landfill sites for disposal of solid wastes. Domestic, industrial and construction wastes are disposed off in low-lying areas on river banks or even in the river channels. Solid waste disposal occurs at all scales – from domestic wastes from individual households to organized landfills by municipal administrative bodies. In Delhi, most of the Yamuna floodplain has already been reclaimed by landfills. Official sanitary landfill site at Bhalaswa in northwest Delhi is very close to the river-bed but at several other places, landfill continues unofficially. This has occurred extensively during the past few years along the river at Okhla and Nizamuddin.

Landfill is the major method of encroachment upon riparian land. Such encroachments have occurred practically everywhere in the country along all rivers and lakes. It is practically impossible to document all such encroachments as most of them become gradually legalized for political reasons. Landfills reduce the water carrying capacity of the river channels during floods, eliminate groundwater recharge, eliminate important habitats for biota (such as fish and amphibia), and pollute groundwater through seepage.

Human Activities in River Channels

Immersion of Idols and Religious Offerings

Among many religious activities performed in and near water, the immersion of idols by Hindus and tazias by Muslims is an age-old tradition throughout the country. Besides idols immersion, placing religious offerings such as flowers, coconuts, sweets, lamps, ashes etc. in water is also common and widespread activity. Earlier, idol immersion was confined to lotic (running) waters (rivers, streams) but now people have started using lakes and reservoirs nearest to the rural and urban settlements. The urban settlements have limited water resources, which are accessible to the people for the purpose, and hence, people have started using even small lakes and ponds for the immersion of idols and disposal of religious offerings according to their convenience, and totally unconcerned of water pollution and damage to aquatic life. People have not spare even their potable water sources. Upper lake of

Bhopal, Buda Talaab of Raipur, and Hanuman Taal of Jabalpur, Husainsagar of Hyderabad, and Pichhola lake of Udaipur are major examples of important water bodies being used for idols immersion and other rituals.

These days, idols of Lord Ganesha and Goddess Durga are immersed during September and October every year in hundreds of thousands. Similarly, during Moharrum, tazias are immersed, generally during summer every year. The idols are made up of clay, hay, cloth, paper, wood, thermocol, jute, adhesives, and synthetic paints, etc Even plaster of Paris (gypsum) is now being used lavishly. As people are vying with each other, idols are growing larger and larger in size and more non-biodegradable material and toxic paints (with heavy metals such as chromium, lead, nickel, cadmium and zinc) are being increasingly used.

Immersion of idols after the rainy season allows the solid wastes to accumulate and help in gradual filling in of the water bodies. Nutrients released from various materials contribute to eutrophication whereas the biodegradable matter increases the BOD levels. In Calcutta alone, about 15,000 Durga idols are immersed every year in Hugli River, besides plantain leaves, coconuts and other religious offerings. Further, during Laxmipuja and Kalipuja thousands of coloured and painted images of deities are immersed every year. In a study of the impacts of immersion on the Hugli River during Dussehra and Puja festivals in 1993-95. CPCB recorded that 16.8 tons of varnish and Garjan oil along with other accessories like clothing, and 32 tons of various colours are dumped every year in the river. High tidal amplitude in Hugli river, however, caused rapid mixing and dilution of pollutants in the estuary. Heavy metal concentration increased by 0.104 mg/l due to idol immersion alone.

The situation is worse in many stretches of most rivers where the flow is negligible and there are no other major sources of water for domestic uses.

Mass Bathing

Rivers were once revered as Goddesses; hence, disposal of wastes and similar polluting activities were prohibited but mass bathing, particularly on certain auspicious days, was allowed. Several such days are observed throughout the year when hundreds of thousands of people congregate over a small stretch of riverbank where bathing is facilitated by constructing several permanent ghats. The practice continues even today irrespective of water flow and quality. Even lakes and reservoirs with muddy and stagnant water are not spared from ritual bathing. On auspicious occasions such as Kumbh Mela or Solar eclipse, millions of devotees congregate at Allahabad to take a dip in the holy confluence of three holy rivers (Ganga, Yamuna and Saraswati). Washing of clothes and placement of religious offerings

(flowers, milk, ghee, curd and sweets) are invariably accompanying activities. Polythene bags and other garbage is another unsightly addition to the water.

It is but natural that the water quality deteriorates further. The most important effect due to mass bathing on water quality was a change in coliform density. According to a survey made by CPCB, the fecal coliform density was observed to increase 12 to 200 times during the Kumbh mela in 1980, 1982, and 1986 at Haridwar and Allahabad. Amongst the physico-chemical parameters BOD changed significantly during the mass bathing. The total coliform to fecal ratio was very high in Allahabad in 1982 and Haridwar in 1980.

Washing Clothes

Washing of clothes in bulk in rivers and other water bodies is common in both rural and urban areas. Sometimes separate areas (dhobi ghats) are designated for the purpose. This activity has also increased in river stretches along urban centers. The washing substances have changed from simple alkaline soils (reh) to highly polluting detergents and organic dyes. Soaps and detergents contain large quantities of phosphates resulting in eutrophication and various other substances used in them cause toxicity to a variety of aquatic organisms. Large wood stoves are often used along riverbanks for boiling clothes soaked in detergents. These stoves not only use wood from within the area but also spoil the aesthetics of the landscape. The ashes and unburned charcoal is washed into the rivers.

Cattle Wading

Wading of cattle is very common in most rivers, particularly in rural areas. The main occupation of rural people is agriculture and cattle farming. The cattle, particularly buffaloes, which are left for grazing during the day, frequently wade and wallow in the shallow rivers. The animal activities cause turbidity, disturbance to the benthic fauna and fish, damage to spawns, increase in BOD and pathogenic microorganisms, and overall deterioration of water quality.

Cremation and Disposal of carcasses

Cremation of dead human beings along river banks and then the dispersal of ashes in rivers, especially Ganga, is an age-old last religious rite for all Hindus. Cremation ghats along the river Ganga have their own special significance. It has been estimated that thirty thousand dead bodies are cremated annually at the burning ghats using about 15 thousand tons of wood. Ganga is a receptacle for the ashes of burnt bodies, partially cremated or unburnt

bodies. All this also leads to acute pollution load of the river. Having recognized the large requirement of wood for the purpose, electric crematoria have been promoted in many places but the ashes have yet to be disperse only in the rivers. The problem is aggravated mainly due to the absence of flow in many parts of the rivers.

4. NEED FOR REGULATION OF HUMAN ACTIVITIES

The foregoing account highlights that there are many human activities in the rivers, in their riparian areas and in their catchments that have a direct or indirect impact on the water quality. The point sources of wastewater discharge are a major cause of water quality degradation and that their impact is increased manifold due to the lack of adequate flow – or even complete absence of flow in the rivers. Similarly, the degradation of water quality in lakes is also mainly due to the anthropogenic activities in their catchments.

It is necessary to understand the ecological nature of rivers as complex ecosystems in order to appreciate the role of human activities in their catchments and floodplains in affecting their water quality.

SCIENTIFIC BACKGROUND: RIVERS AS ECOSYSTEMS

Rivers not merely channels that transport water; they are dynamic ecosystems that change over time in response to hydrological and biological processes, and human interventions. They are three-dimensional systems dependent upon longitudinal, lateral and vertical transfers of material, energy and biota (Boon et al. 1992, Calow and Petts 1992, 1994, Petts and Amoros 1996). Rivers are complex ecological systems which interact with their drainage basins collecting from them water, nutrients and organic matter, and support large biological diversity besides supporting the human and their activities. These systems are (i) driven by their hydrology and fluvial geomorphology, (ii) structured by food webs, (iii) characterised by spiralling processes, and (iv) are dependent upon changes such as the change in their flows, movement of sediments and shifting of channels (Calow and Petts 1992, 1994).

There are five interacting elements that determine the structure and function of river ecosystems (Fig. 2) - physical character, water quantity and quality, condition of the riparian zone and floodplain and the diversity and population of plants and animals living in the stream (Rutherford et al. 2000). Any change in one of these elements can have significant impacts upon other parts of the system. When addressing a river management problem, it is necessary to ensure that the management interventions do not cause changes in other elements.

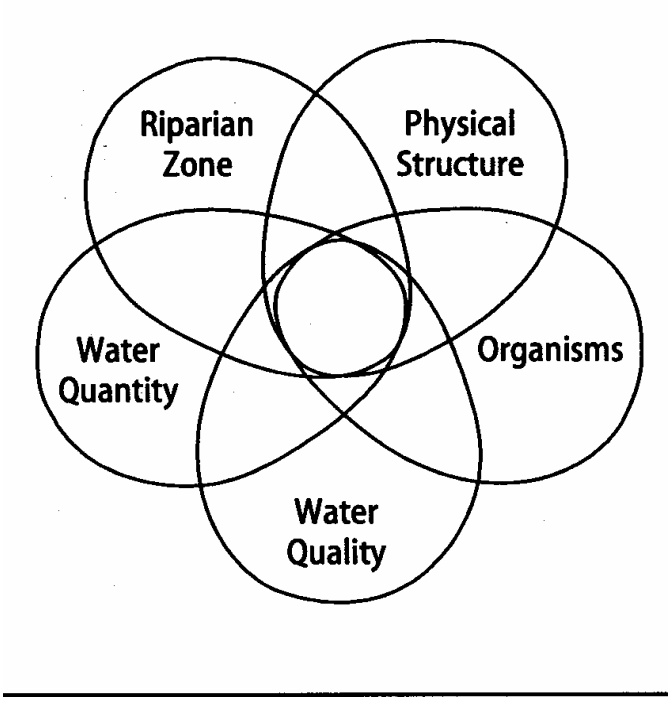


Figure 2: Five elements that determine a river's structure and function

Physical character and habitat

The physical character of a river is primarily determined by geomorphic processes such as sediment transport, flow volume and velocity. The channel of a river or stream evolves to form the most efficient shape for the transport of the water and sediments supplied to it from the drainage basin (= catchment). It is the material transported and deposited by rivers in the channel and in the riparian zone and floodplain that forms the basis of river habitat (Brierley et al. 1996). Some of the common physical features of a watercourse are shown in Figure 3.

In-stream habitat refers to the physical features of a river, such as the substrate (eg,, rock, sand, silt), the geomorphic features (e.g., channel bars, pools, riffles), the depth and velocity of water, the in-stream vegetation and structures such as woody debris and large rocks. Riparian vegetation and the floodplain are other important areas of riverine habitat. Different habitats will support different animals and plants. For example, the animals present in a stream with a variety of riffle and pool habitats will differ from those present in a less complex channel. Some plants such as reeds and cattails prefer areas of still or slow moving water while other aquatic plants thrive in shallow running water (Gooderham and Jerie 1999). A river can be divided into different geomorphic zones based on the supply, storage and deposition of materials. Each zone will have a unique physical character and hence the structure of in-stream habitat and associated biological communities also varies. As several

tributaries join together downstream along the river course, rivers change in size, volume and velocity of flow, nature of sediments and flora and fauna as well as their water quality and various ecological functions (e.g., self-purification).

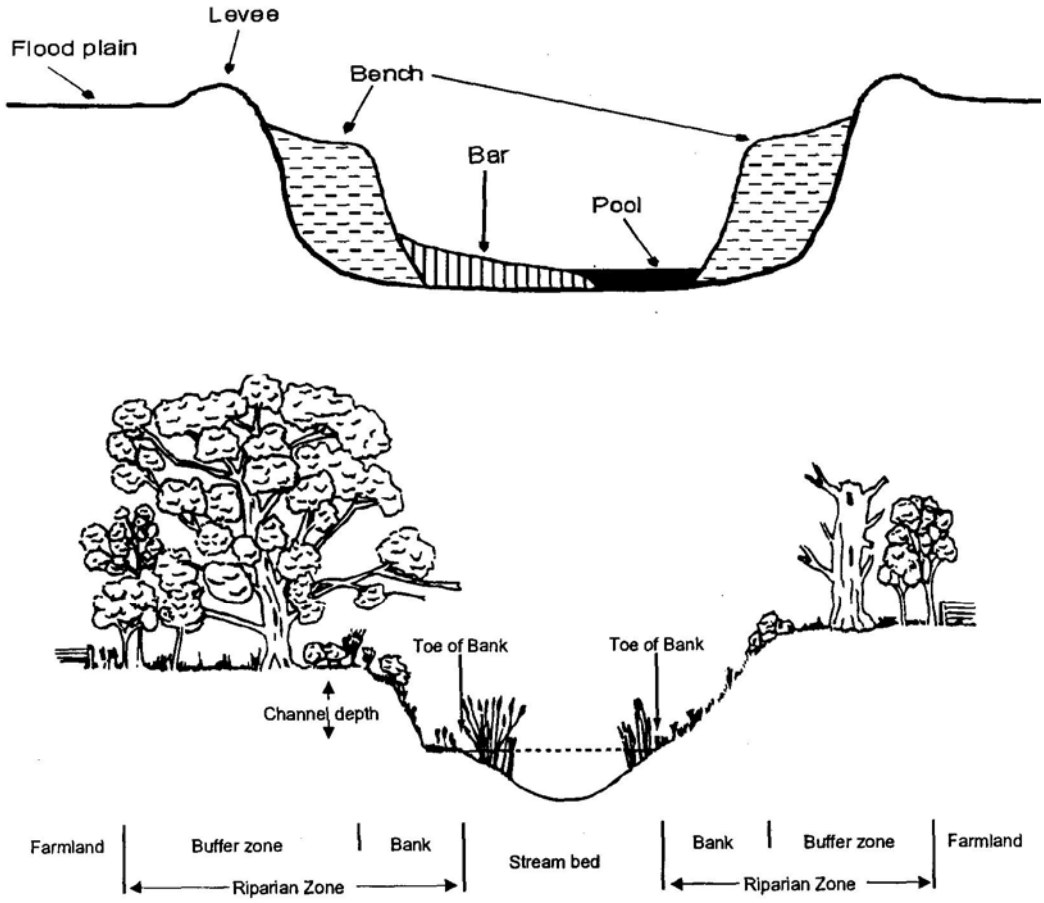


Fig. 3. Physical features of a river

Many animals require a variety of different habitats for day to day life or for different stages of their life cycle (Fig. 4). The ability to freely move between different habitats is important. For example species of freshwater fish use the estuary to breed and then migrate upstream for adult growth. On a daily basis, fish often need areas for feeding, areas to shelter from predators and refuges from flood or drought. Aquatic insects also use different habitats during their lifecycles. For example some mayfly species live amongst cobbles in fast flowing water as nymphs, spend their adult stage amongst riparian vegetation and then return to the stream to lay their eggs. Many macro-invertebrates drift downstream as part of their larval stage (Gooderham and Jerie 1999). A reach with a range of habitats supports a greater diversity of organisms than the same length of reach with a simple pool. Human impacts,

particularly urbanization and other land use changes, have simplified riverine habitats e.g., clearance of riparian vegetation, loss of in-stream complexity by channelisation, incision and deposition of sediment, and loss of flow variability due to dams and barrages (Gooderham and Jerie 1999).

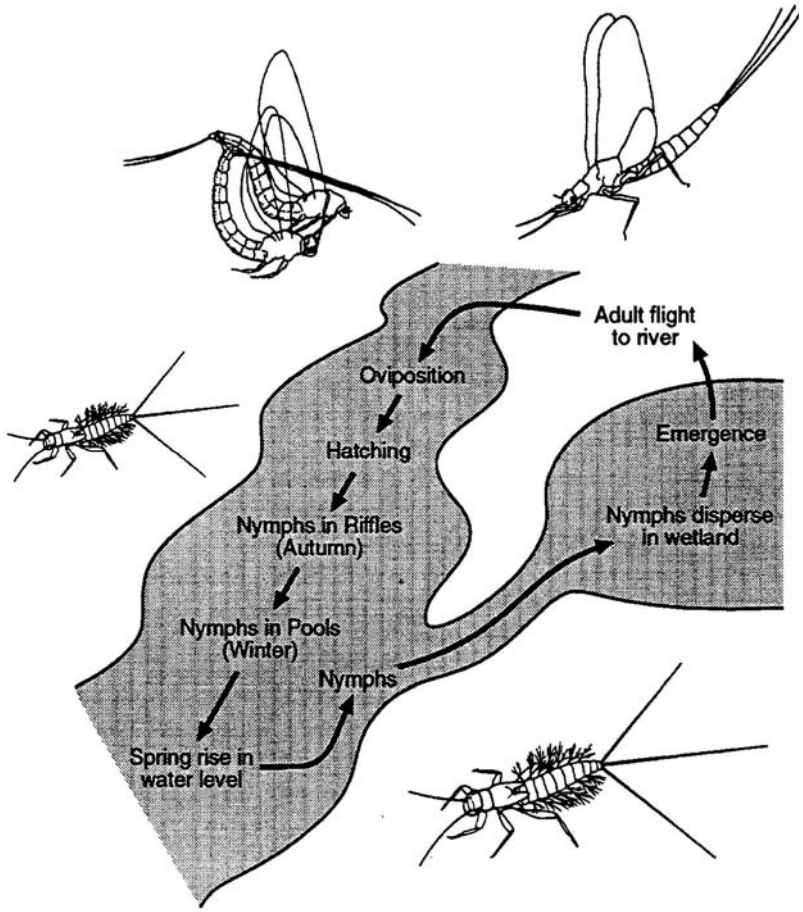


Figure 4: Many organisms pass a part of their life cycles in floodplains which get periodically connected with the rivers.

Water quality

Water quality is important for river condition. Various organisms greatly differ in their ranges of tolerance to different water quality parameters. As water quality deteriorates, most organisms decline in their population and activity. As water quality declines, sensitive organisms are lost while more tolerant organisms, such as bluegreen algae and mosquito fish (*Gambusia*) tend to dominate. Water quality can be affected by: the adjacent landuse, the presence of livestock, the kind and characteristics of the riparian zone, sewage effluent, urban stormwater pollution and industrial wastewater. Water temperature is an important factor

controlling the life cycle of aquatic and terrestrial invertebrates that use the stream for all or part of their life cycle. Changes in water temperature serve as environmental cues that can trigger different parts of an animal's lifecycle. Large changes in water temperature, such as those caused by the removal of riparian vegetation, cause significant changes in biotic communities.

Water quantity and flow regime

Flow volume and velocity directly affect plants and animals through the cycle of flood and drought, as a cue for migration and lifecycle changes and by providing connections with floodplain habitats. For example, reeds and rushes may rely on a period of low flow to establish on the bank of a stream. Several tree species (e.g. tamarix) require periods of flooding for regeneration. Flow is also an important factor determining the physical structure of a river and thus maintaining in-stream habitats. Rivers in semi-arid zones and those depending entirely on monsoon rainfall are characterised by extreme variability in their flows and the native vegetation and wildlife are adapted to cycles of drought and flood. It is this variability which maintains the biodiversity of riverine ecosystems (see Poff et al. 1998).

Various linkages and pathways through which variability in river flows affect biodiversity of a river are shown in Figures 5 and 6. The range and variability of flows are therefore just as important as the volume of water within a system. Other important flow characteristics include seasonal flow patterns, the size and frequency of flows, flow duration and the rate of rise and fall of a flow event. Changes in the natural flow regime, i.e., a change in one or more of the flow characteristics, are generally marked by a reduction in habitat complexity and the diversity of plants and animals. Stream flow may have a component of baseflow that is provided by groundwater discharge. In river systems in low rainfall areas, this baseflow is likely to be vital to the composition and maintenance of in-stream and riparian ecosystems by supporting in-stream and riparian vegetation during dry seasons (Hatton and Evans 1998). Groundwater inflows can play an important role in maintaining water quality and quantity. Shallow groundwater can also play an important role in supporting riverine ecosystems. In-stream, riparian and wetland vegetation may depend to varying degrees on shallow groundwater to sustain growth during dry periods. Many tree and shrub species that were once abundant on river banks in India have disappeared largely due to changes in flow patterns and water quality, besides over-exploitation. Many animals which have the ability to spend part of their lifecycle below the river bed (hyporheic fauna) require subsurface flows.

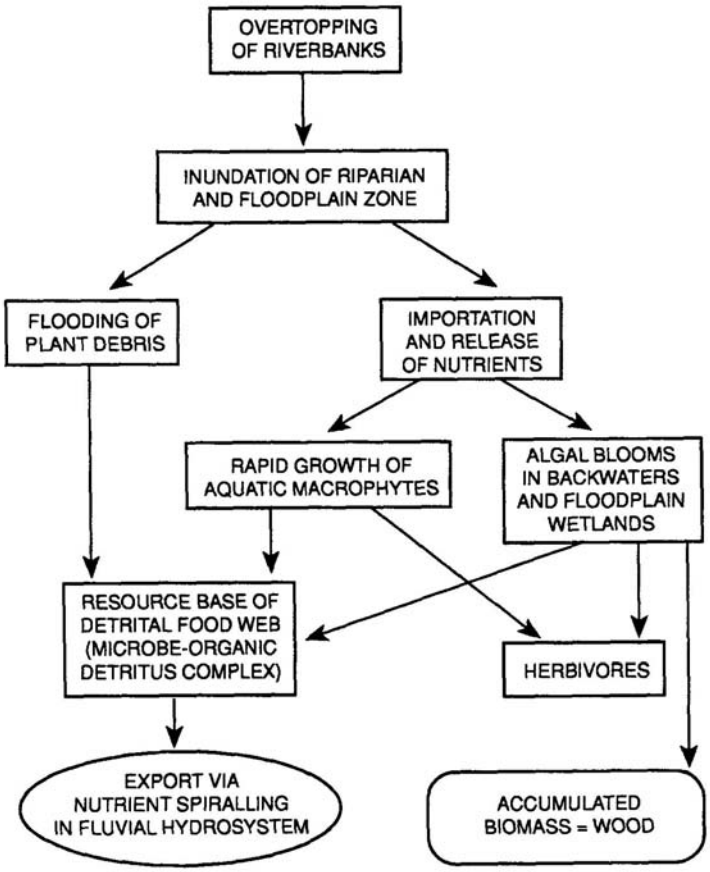


Figure 5: Effect of flooding on plant production and nutrient dynamics in floodplains

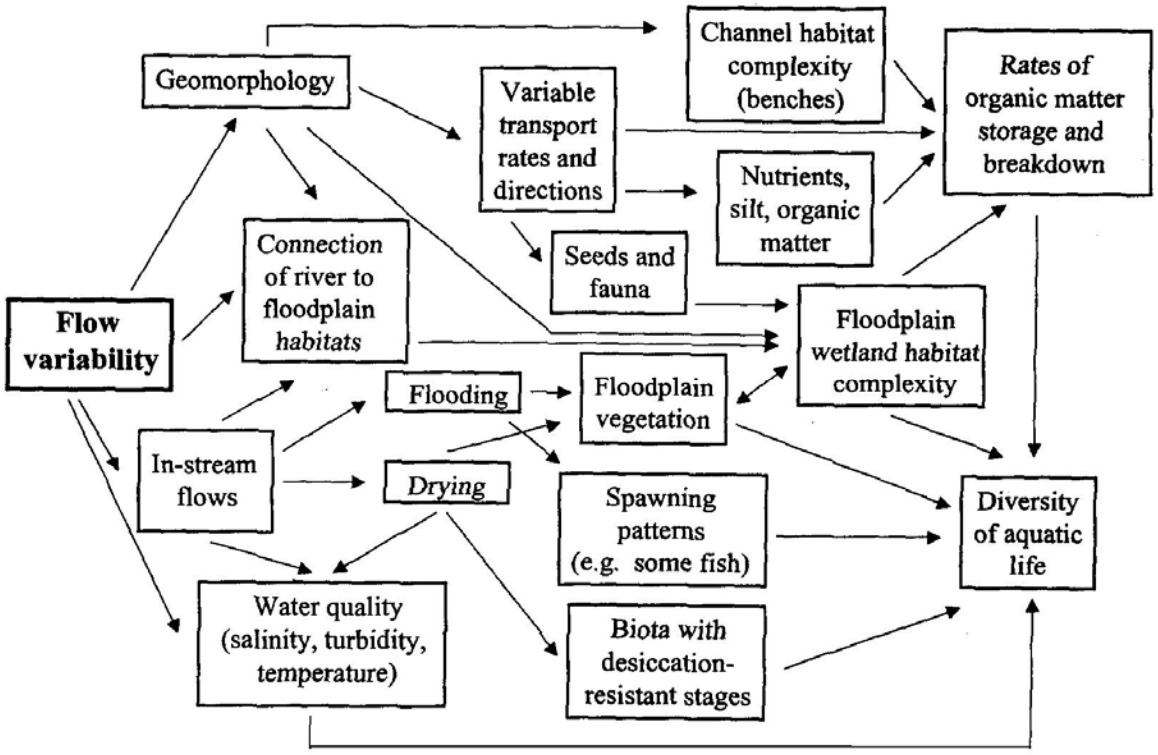


Figure 6: Variability in flow governs biodiversity through a variety of ecological processes

Riparian zone and Floodplain

All rivers interact laterally with adjacent lands (floodplains) that are periodically flooded by the river with varying frequency and amplitude. The riparian zone and the floodplain play significant roles in the ecology of the river environment. The riparian zone is generally defined as the ribbon of land adjacent to, and influenced by, a watercourse. It is widely recognised that this zone is a critical link between terrestrial and aquatic ecosystems. Riparian vegetation includes the 'terrestrial' vegetation adjacent to the stream as well as aquatic and semi-aquatic plants on the edge of the stream bank. The riparian zone has many important functions. It

- helps maintain good stream habitat for fish

· helps maintain cool water temperatures through provision of shade and creation of a cool and humid microclimate over the stream

· provides food resources for the aquatic ecosystem in the form of leaves, branches, and terrestrial insects

· stabilizes banks through provision of root cohesion on banks and floodplains

· filters sediment from upslope sources

· filters chemicals and nutrients from upslope sources

· supplies large wood to the channel which maintains channel form and improves in-stream habitat complexity

· helps maintain channel form and in-stream habitat through the restriction of sediment input or slowing of sediment moving through the system

· moderates downstream flood peaks through temporary upstream storage of water

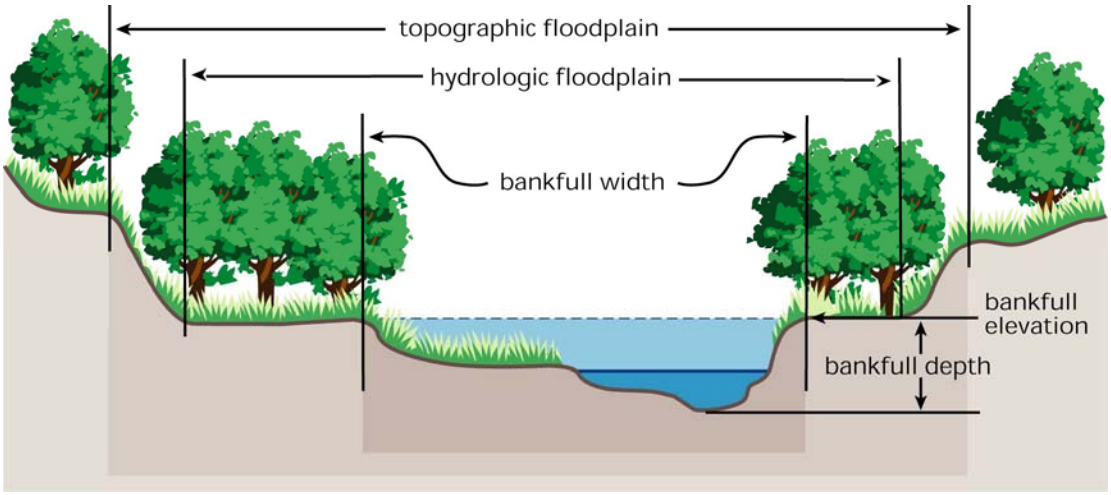


Figure 7: The extent of floodplain

The floodplain is land that lies adjacent to the river (Fig. 7) and is regularly flooded at least once in 100 years. In most cases, greater part of the floodplain has already been brought under settlements and only a smaller portion nearer the river channels is now left in some places, mostly under agriculture or rural settlements. These areas are flooded every year or at least once in 20-30 years. Floodplains play an important role in sustaining the functions of a river and its biological diversity. The most important functions include:

(a) ***modulation of the hydrograph of river discharge*** -by storing huge amounts of water derived from peak flow and storm runoff during the rainy season and later releasing it gradually, and thereby ensuring flow in streams for most of the year;

(b) ***recharge of groundwater*** and improvement of its quality;

(c) ***production of valuable natural resources*** (timber, fuelwood, fodder, and fish)

(d) ***providing breeding and feeding grounds for fish*** and many aquatic animals (turtles, crocodiles, amphibia, etc.); When the floodplain is inundated it provides habitat for macro-invertebrates and for fish spawning. As the flood recedes, leaf litter and other detritus is transported into the river. Some riparian and floodplain plants require periodic flooding for survival and regeneration. Many studies have shown that the fish diversity is directly related to habitat diversity (which includes substrate diversity, diversity of food organisms, flow regimes, and riparian vegetation), disturbance and pollution (Welcomme 1979, 2000, Lowe-McConnell 1987, Arunachalam et al. 1997).

(e) ***improvement of water quality*** through retention and transformation of nutrients and other chemical substances. Natural floodplains generally have a high capacity to recycle nutrients, usually accumulate nitrogen, phosphorus and other nutrients, and also sequester heavy metals and toxic compounds in anaerobic organic sediments. Thus, the floodplains have the capacity to process the wastewaters flowing through them and regulate the input of nutrients and organic matter to the river (Lowrance et al. 1984, Godfrey et al. 1985, Richardson 1990).

The floodplain vegetation also helps reduce the velocity of runoff and traps sediments, thereby reducing the siltation in rivers (Boto & Patrick 1979). Another important role of floodplain and riparian vegetation is in checking soil erosion (Prajapati 1989). The interactions between the river channel and its floodplain have been discussed extensively in several publications; e.g.. Naiman and Decamps (1990), and are shown in Fig. 8.

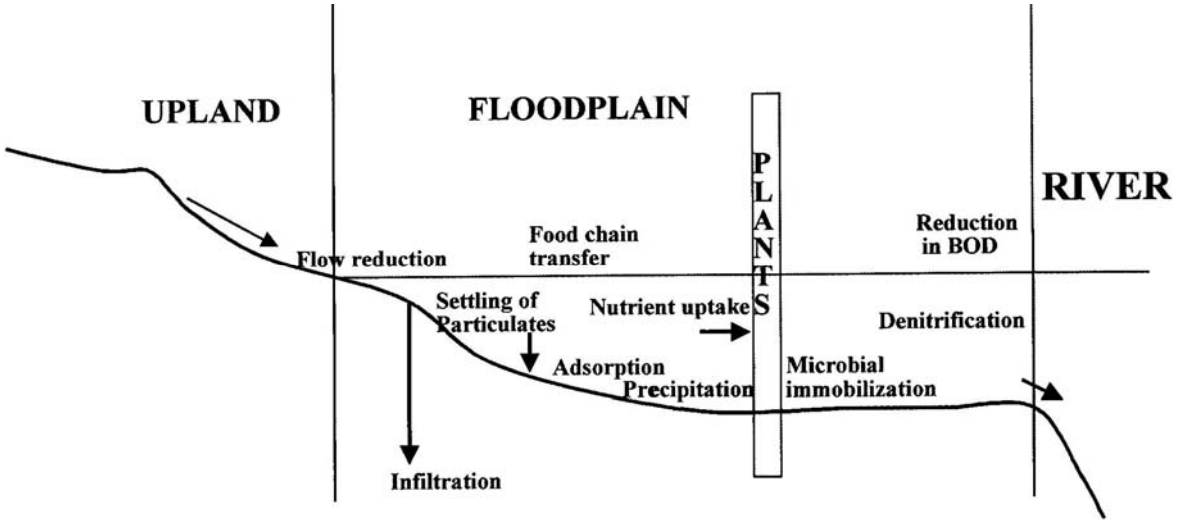


Figure 8: Ecosystem processes in floodplains through which the uplands and rivers interact

Any change in the flow (volume, velocity, quality, etc.) of rivers affects floodplains, and consequently, the water quality and biodiversity. Drastic changes in the flooding regime alter riparian and floodplain vegetation communities and also the animals that rely on that vegetation.

In-stream plant and animal communities

Aquatic organisms living in stream channel are an essential component of the river ecosystem. The plants provide food and habitat for fish, birds and invertebrates, stabilise sediments against erosion, improve water quality and reduce flow velocities. The animals in a river are usually very diverse: they include invertebrates such as snails, worms, shrimps, and insects, and vertebrates such as fish, amphibians, reptiles, birds and even mammals (e.g., dolphins). Within the river ecosystem, animals and plants use each other for food, shelter and recycling of wastes, resulting in complex food webs. Algae and aquatic plants form the basis of the food web. They are an important source of food for herbivores. Plants along the banks or riparian zone of the river also provide large amounts of organic matter (leaf litter and woody debris) to the river ecosystem.. Herbivores are two basic kinds: `Scrapers' graze on algae and decomposers such as fungi and bacteria. `Shredders' consume plant leaves and stems and old or dead plant material or detritus. They include invertebrates such as aquatic snails, freshwater crayfish and a variety of insect larvae. Predators which feed upon herbivores are the larger invertebrates and animals such as fish, frogs, lizards and birds. All

organisms constituting the food web contribute to the maintenance of water quality through decomposition/removal of organic matter and nutrients from the system. These organisms are also a good indicator of the health of the river ecosystem. Fish and invertebrates as well as variety of algae and macrophytes are commonly used by scientists to monitor the water quality in rivers worldwide.

Rivers also interact vertically with the area under their bed. They may owe part of their flow to subsurface water discharge into the main channel and the interstitial spaces in the riverbed support many life forms (hyporheic fauna).

WHY REGULATE HUMAN ACTIVITIES

It will be clear from the foregoing brief account of rivers as ecosystems that
(a) floodplains (including riparian fringes) are an integral component of the river ecosystems,
(b) the structure and functioning of rivers are governed by the flow regimes (depth, velocity and volume), and
(c) lateral exchanges between the rivers and their floodplain are critical to the ecological integrity of the river ecosystems.

It is thus obvious that all natural and anthropogenic disturbances in the floodplain or the river affect the entire river system.

- Wastewater discharges directly affect the water quality and hence the biotic diversity.
- Flow regulation by dams and barrages reduces the availability of water and its periodic variability which in turn affect the river morphology (channel characteristics, interaction of the river channel with its riparian/floodplain areas, and hence the biodiversity.
- Reduced flows attenuate the impacts of wastewaters through lack of dilution and river-floodplain interaction.
- Absence of river-floodplain interaction also directly reduces groundwater recharge.

With increasing demand for land, floodplains have been directly utilized for all purposes from agriculture to settlements and industry. This has necessitated construction of embankments to prevent flooding of the areas converted to other land use. The reduction in the capacity of the river channels to carry floodwaters has gradually increased the intensity of floods and the damage caused by them. The human response has so far been to further regulate flows, store floodwater in areas away from settlements, and increasingly channelise

the rivers. (The issue of floods has been discussed at length by the Center for science and Environment in its report (Agrawal and Chak 1991). A brief note is appended to this report.) A further consequence of all this is the variety of activities directly in the riparian areas and in the river channel, as discussed in earlier section. Disposal of solid wastes and landfills to encroach upon the reclaimed land, intensive agriculture on the riparian fringes and on riverbeds, excessive grazing, and groundwater extraction are all consequences of river regulation and urban sprawl towards rivers.

These various activities directly affect the river ecosystem through modification of riverine habitats (channel morphology) directly or indirectly, depleting (even eliminating) the natural biota, and increasing erosion and the pollution load (Figure).

Economic Considerations

The regulation of certain human activities along rivers (and similarly lakes) can also be considered by applying the principles and methods of Ecological and Environmentalk Economics. The costs and benefits of various human activities must be weighed together in a long-term and river basin wide scale. It will be readily perceived that the costs of human impacts are far greater than the benefits accruing to the society. For example, the cultivation of cereals and vegetables in riparian areas and the riverbed, provides direct benefits to a few farmers from the agricultural produce after meeting expenses on seeds, fertilizers, electricity (or diesel) and labour. The costs, however, include groundwater depletion, pollution of both groundwater and surface water, loss of habitat for fish, increased erosion and instability of river channels, and loss of biodiversity (particularly fuel and fodder resources).

While it may be considered necessary to revive the rivers fully by restoring their natural flow regimes which will require removing dams, barrages and embankments, this is not possible in most places in India in view of the large human population and its various needs. However, we can and must prevent further impacts of human activities in our own interests. Two major actions are required to improve the state of our rivers and conserve (and where possible enhance) their remaining biodiversity. These are:

A. Provision of Adequate Flow (Environmental Flow) in the rivers. There is an urgent need to restore certain amount of flow in all stretches of the rivers for maintaining their ecological integrity (physical, chemical and biological characteristics) and for improvement in their self-purification potential (or assimilative capacity for wastewaters). It

will require detailed studies to estimate the flow requirements in different reaches for different functions of the rivers.

B. Immediate Regulation of all Human Activities that affect Riparian Areas and River Channels. All kinds of activities that affect water quantity and quality (such as disposal of solid wastes, encroachments, agriculture, grazing, sand and gravel mining) must be regulated immediately.

This report addresses only the latter kind of action required for river conservation.

5. ACTIVITIES THAT NEED TO BE REGULATED

A large variety of human activities in and around the rivers either directly modify the riverine habitats and deplete natural resources or degrade water quality (cause pollution). Disposal of sewage and industrial effluents, which is already regulated under the Water (Control and Prevention of Pollution) Act, 1974, is not considered here. Other activities can be grouped accordingly into two categories:

a. Activities directly affecting the habitats

- various forms of encroachment on river beds and floodplains
  - construction of embankments or similar flow regulating/diverting structures;
  - buildings, temples, ghats, slums, jetties,
- disposal of solid wastes, and landfills; including
  - immersion of idols, and
  - religious offerings (flowers, ashes, etc)
- intensive agriculture using agrochemicals and organic manures
- extraction of sand/gravel
- intensive grazing and harvesting of vegetation

b. Activities causing degradation of water quality

- mass bathing
- river transport (steamers, boats)
- wallowing of cattle
- washing of clothes

The impact of all kinds of natural or anthropogenic disturbances on an ecosystem depends upon their scale and frequency. Whereas each individual may cause an insignificant impact, the collective impact of a large population at one site is often highly detrimental. Human activities around rivers also vary in their magnitude and intensity from isolated small-scale events to organized large-scale long-term operations. For example grazing by a few cattle on a well-development floodplain may not be detrimental to the riverine system, intensive grazing by hundred or thousands of cattle on a floodplain with very little vegetal cover

directly threatens the habitat. Similar distinction can be readily made between the bathing by a few people and mass bathing by millions congregating over a small reach.

Regulation implies that various activities may be allowed to different extent at different places and at different times depending upon various ecological and socio-cultural conditions. It may also include a complete prohibition (ban) of certain activities in certain areas. For example, bathing by people in polluted water such as that of River Yamuna at Delhi, notwithstanding their religious sentiments, can certainly be prohibited in view of the health hazard. Religious offerings can similarly be restricted to certain areas of flowing water.

Regulation requires a detailed analysis of the ecological and socio-cultural status for each site or specific area/reach of the river. Only the criteria for such an analysis, together with a broad typology of river reaches, is provided here.

6. ZONING OF RIVERS AND THEIR FLOODPLAIN

Rivers differ among themselves and along their length in a large number of geomorphic, hydrological, chemical and biological parameters. Therefore, many researchers from diverse fields, including ecologists and geomorphologists, have attempted for many decades to classify rivers (Mosley 1987). Most classifications recognise a number of zones along the river length from its headwater to its mouth. These classification schemes are highly diverse depending upon the objectives that range from an understanding of the river behaviour and morphology to river management for engineering and fisheries. Accordingly, the classification schemes have used different variables at different spatial scales. A brief account of these classification schemes is given in Hawkes (1975), and a summary of recent approaches in different countries in given in the appendix.

One of the simplest classification schemes categorises rivers and streams according to their distance from source into first, second, third and nth order. All headwater streams terminating at their first confluence are designated as first order streams; two first order streams join to form a second order stream, two second order streams join to form the third order stream, and so on. Rivers are also classified according to the gradient into mountain or hill streams and lowland streams. According to channel morphology, various reaches of a river are recognised as meandering, braided or anastomosing. Many classification schemes categorise rivers or their zones according to water quality which in turn is often based on the distribution of a variety of organisms. Other schemes recognise zones according to their fish fauna and fishery potential. In India, the most widely used system recognises five categories of river zones, A, B, C, D and E, according to the “best designated use”.

Classification of rivers into zones depends upon the objectives. Hence, it will be necessary to develop a scheme of zonation specifically for the purpose of regulating different human activities in different zones. It must be recognized that Indian rivers have a very long history of interaction with humans and that there is far more geomorphic and climatic diversity than in many other parts of the world. The regulation of human activity will have to consider the present state of disturbance, the state of the river and desirability as well as feasibility for restoration, and the practicality of implementation. For example, the stretch of river Yamuna at Delhi is extremely degraded. There is an immediate need for its restoration which can only be done by restraining all human activities forthwith and by taking remedial

measures for habitat improvement. Specific areas or stretches of rivers have also to be identified for religious activities which can only be restricted but not prohibited. A detailed zonation scheme requires extensive information on geomorphology, hydrology and channel morphology, besides the level of current human activity in every reach/stretch of the rivers. Therefore, only the criteria can be elaborated here for developing the required zonation scheme or identifying specific zones.

CRITERIA FOR ZONATION

Following criteria are proposed for recognizing different zones of various rivers.

Climatic, Geomorphic and Hydrological Criteria

The hydrology of a river depends upon the climate and geomorphology, besides vegetation and human activities. Precipitation (snow and rainfall) - its amount, timing, frequency, intensity, etc., vary greatly in the headwater region of rivers and their tributaries. Many rivers of the Ganga basin often have more flow after they are joined by their tributaries that carry more water. Geomorphology influences runoff and flow characteristics. Based on these criteria, following distinctions can be made:

A. Himalayan rivers (Rivers originating in the Himalayan ranges)

a. Mountain stretches (mostly 1st and 2nd order rivers, steep gradients, usually >500 m altitude, high flow velocity)

b. High gradient reaches (>100 cm per km) – 300-500 m altitude, mostly gravel beds

c. Low gradient stretches (<100 cm per km) – generally sandy or loamy beds, wide floodplain; rivers meandering or braided;

B. Peninsular rivers (All rivers other than Himalayan rivers)

Most rivers arise at relatively low elevation (average <1000 m) and are solely rainfed.

a. Steep slopes (hills of central India and Western Ghats)

b. Low gradient stretch (<100 cm per km)

c. Alluvial plain (mostly formed by tributaries of Ganga basin; also parts of Mahanadi & Godavari river basins)

Urbanisation/Human use

Most intense human activities occur in river stretches along urban and suburban settlements, and is generally related to their population. Activities such as encroachments and landfills/ solid waste disposal are most serious near human settlements along rivers. Areas with high population have multiple demands on land and water, and generate more wastewater. Naturally, the need for regulation is greater in areas with higher population density.

It is proposed to consider at least three levels of population density:

1 Large Cities >1 million human population
2 Medium Cities >100,000 human population
3 Small towns/ village settlements: Less than 100,000 population

Potential for Restoration

Areas where restoration measures are required and can be readily undertaken (i.e. habitat changes are not irreversible) should be given high priority for regulation of further damage. Similarly areas which have not yet been impacted should be accorded protection. Certain activities can be prohibited right now so that habitat degradation does not occur.

A. Embankments
  a. Heavily channelised reached with pucca bunds (embankments)
     and metalled roads and large settlements
  b. Earthen embankments to protect agricultural fields
  c. No embankment

B. Agriculture and Other Human activity
  a. Areas under intensive agriculture and high level of activity
  b. Areas with subsistence agriculture/ moderate activity
  c. Areas with natural vegetation and habitats; no or little human activity

State of Degradation

The state of degradation of river habitat can be assessed in terms of water quality and biodiversity (particularly fish). Though several classification schemes and criteria are used in different countries, the current state of knowledge in India does not permit the use of such

parameters. Therefore, it is proposed to follow the Best Designated Use system to classify river classes A, B, C, D and E.

Ecological Criteria

The zoning of river stretches should also consider characteristics of ecological significance, especially in terms of areas of special interest for biodiversity (areas with rare and endangered species), and areas with potential for fisheries. River reaches where riparian habitats are used for breeding/nesting or feeding by birds, amphibia, reptiles or other such fauna should receive special protection. Habitats with peculiar/rare ecological features should also be considered.

a. Habitats of importance for biodiversity

b. Habitats of special ecological interest

Socio-Cultural Criteria

Some rivers and particularly some of their reaches are of greater socio-cultural significance and therefore need special emphasis for protection again human impacts. For example, mass bathing during Kumbh, Ardh-Kumbh and similar auspicious days occurs at particular places along different rivers. Any regulation measure will have to consider this fact. While mass bathing cannot be disallowed, encroachments, landfills and solid waste dumping must be prohibited. The socio-cultural significance of an area need to be considered.

RIVER REGULATION ZONES

The criteria described above will lead to an elaborate system of zones for the numerous large, medium and small rivers in India. It may not be practical to establish a system of regulation for every zone separately. It will be more difficult to implement any such legal measure of regulation especially because of the dynamic nature of the rivers and changing demographic, socio-cultural and economic requirements. The various kinds of zones derived from the interplay of the criteria listed earlier will have to be grouped into a fewer ZONES for the specific purpose of regulation of different human activities.

We propose to recognize FOUR ZONES with following major features:

RRZ I –

River channels and their floodplains in ecologically sensitive and fragile watershed areas, Areas mostly in foothills (medium elevations), areas of pristine/outstanding beauty, heritage sites, areas rich in genetic diversity or important for biodiversity, particularly rare/endangered species.

RRZ II -

River channels and their floodplains in the hills (>300 m altitude); generally low human population density; high flow velocity; river regulation relatively low

RRZIII –

River channels and their floodplains at lower elevation (<300 m); within municipal limits (high population densities) where floodplain has already been heavily reduced and infrastructure facilities are well developed (e.g., temples, ghats, road, various residential, commercial or recreational buildings, boat jetties, fish landing facility, etc.); River stretches generally heavily regulated or channelised; water quality much degraded and restoration most difficult (low potential)

RRZ IV-

River channels and their floodplains at lower elevation (<300 m) in suburban and rural areas where infrastructure development has not occurred or is only moderate, and where land is primarily under agriculture and grazing; Areas with low degradation but high potential for restoration.

7. LEGAL FRAMEWORK FOR REGULATION OF HUMAN ACTIVITIES IN AND AROUND RIVERS

The need for appropriate legal instruments for the conservation of rivers had been mentioned briefly while providing the background of this document. The purpose of this chapter is to examine two questions: (a) Are the existing environmental laws adequate to address the issues related to the conservation of rivers (and other aquatic ecosystems)? If not, what kind of specific legal instrument is required for the purpose? And (b) Can the MOEF take necessary steps without infringing upon the rights of the State governments? Thus, first we assess the present status of various laws related to environment in general and the river environment in particular in India, and examine their relevance, strength and weakness in relation to the needs of river conservation. During the past few years, various environmental laws of the country have been analysed and interpreted in depth by various courts, including the Supreme Court of India, in numerous cases related to rivers, lakes and other environmental matters. Therefore, we rely upon the judicial pronouncements of the Supreme Court and High Courts of several states, instead of analyzing the laws as such. Further, a comprehensive and in-depth discussion of environmental laws and various cases is provided recently by Divan and Rosencranz (2001). Hence, our treatment here is necessarily brief. We also report briefly on the situation in several other countries in relation to their environmental laws concerning rivers and other water bodies.

CONSTITUTIONAL PROVISIONS

Environment occupies a very prominent position in the Constitution of India and the Constitution itself is rare in the world in containing specific provisions on the protection of environment. Specific articles enjoin upon both the people and the Executive (the Government) a duty to protect and improve the environment. These are:

Constitution: Article 48A

Article 48A of the Constitution reads,

> *"State shall endeavour to protect and improve the environment and to safeguard the forest and wildlife of the country."*

The Government of India has certainly taken many steps "to protect and improve the environment" but it is well known that the environment continues to be degraded by many developmental activities promoted by the Government and also that the government often overlooks or ignores the environmental problems.

` In this context, it is noteworthy that the Supreme Court has held in many cases (Satish vs State of UP 1992; Tarun Bharat Sangh vs Union of India 1992) that this duty of the State can be enforced through Public Interest Litigation (PIL).

Constitution: Article 51A

Article 51A provides for several fundamental duties of the citizens of India. Among them, Article 51A(g) calls upon the citizens

> *(g) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;*

Interestingly, 'lakes and rivers' find a place in Article 51A(g) but not in Article 48A, putting the onus primarily on the citizens.

` The Article has been used by the Supreme Court in several of its judgements to enforce prevention and control of environmental degradation in all forms caused by public and especially business and industry.

Constitution: Article 21

The Constitution of India provides for several Fundamental Rights to the citizens. All Fundamental Rights are enforceable, within specified limitations, through courts. Among these Fundamental Rights, of great significance is the Right to Life and Property, provided by Article 21 which reads:

> ***Protection of life and personal liberty.- No person shall be deprived of his life or personal liberty except according to procedure established by law.***

` It is interesting that the Supreme Court has interpreted this article very broadly and has held in several cases that ***the fundamental rights under Article 21 include the right to wholesome environment***. In the case MC Mehta vs Union of India 1987, it held that *"life, public health and ecology have priority over unemployment and loss of revenue"* and again, in the case Subhash vs State of Bihar 1991, it declared that *"the right to pollution free air falls within Article 21"*.

There is nothing more important than water to the life and survival of humans, as also all other organisms. Both non-availability of water and water of a poor quality threaten the very survival of people. Thus, access to clean water becomes a fundamental right of all citizens of India.

The three Articles of India's Constitution, read and interpreted together, make it abundantly clear that ***in order to uphold the most important fundamental right of every individual, the very source of all water – the rivers – must be protected by the people and that the State must take all necessary action to ensure this protection***. The proposal to regulate all human activities that affect directly or indirectly the river ecosystems is abundantly rooted in these Constitutional provisions.

Precautionary Principle

In matters concerning action required to prevent environmental degradation, the Supreme Court has placed great responsibility upon the Governments and Statutory Authorities. The Supreme Court has repeatedly declared in its various judgements that the ***Precautionary Principle and the Polluter Pays Principle are the law of the land.*** The Court has defined Precautionary Principle as

> ***"Environmental measures - by the State Government and the statutory authorities - must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious and irreversible damage, lack of scientific certainty should not be used as reason for postponing measures to prevent environmental degradation".***

In the context of rivers and other aquatic ecosystems, the Precautionary Principle, declared as the law, makes it abundantly clear in unambiguous terms that the MOEF **must** anticipate the consequences of various human activities on the river ecosystems and take necessary action to prevent such activities without waiting for absolute scientific understanding based on research in this country. There is more than enough scientific knowledge of the ecology and functioning of river ecosystems and also evidence of the impacts of human activities.

Public Trust Doctrine

Another important declaration by the Supreme Court holds that the state (Government) is the trustee of all natural resources. In the well-known Span Motels case (MC Mehta vs Kamal Nath & others, 1997), the Supreme Court applied the Public Trust doctrine which it expanded ***"to include all ecosystems operating in our natural resources"***. The Court observed that,

1. "The State is the trustee of all natural resources which are by nature meant for public use and enjoyment. Public at large is the beneficiary of the seashore, **running waters,** air, forests and ecologically fragile lands. The State as a trustee is under a legal duty to protect the natural resources."
2. "In the absence of any legislation, the executive acting under the doctrine of public trust **cannot abdicate the natural resources** and convert them into private ownership or for commercial use,"

Reference to Rivers

Indian Constitution (Article 246 and Seventh Schedule) has made a distinction between the legislative powers of the Central and State Governments. Several subjects directly related to water such as irrigation, drainage, fisheries and water supply are listed to lie within the exclusive powers of the state to legislate. However, inter-state rivers are listed under the subjects with exclusive legislative powers of the Parliament. Entry 56 of List I of the Seventh Schedule of the Constitution reads:

> *"Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest."*

In India, most of the rivers are inter-state rivers, and therefore, any regulatory measure can be taken by the Central Government. However, there is certainly a need to impress upon the States that irrigation, drainage, fisheries and water supplies are inter-related and inter-dependent subjects and cannot be managed in isolation. The connections between different water resources through the hydrological cycle needs to be emphasized and understood.

Thus, whereas the Central Government is obliged under the Constitution to take regulatory measures for prevention from degradation and improvement of river ecosystems, it should take the States into confidence and seek their cooperation and support for effective implementation of the proposed regulatory measures.

PRESENT LAWS DIRECTLY RELATED TO RIVERS, LAKES, INLAND WATERS

Currently, several Acts are concerned with one or the other aspect of water resources and their use. These include:

` Water (Prevention and Control of Pollution) Act, 1974

` Environment (Protection) Act, 1986

` Coastal Regulation Zone Notification, 1991

` Wildlife (Protection) Act, 1972

` Land Acquisition Act, 1894

Land (incl. water) can be acquired by the state for public purposes.

` The Easement Act, 1882

Surface water belongs to the State and is a state property.

` Indian Fisheries Act, 1897

Regulates fishing

` W.B. Town & Country (Planning & Develpoment) Act 1979

No permission for filling of tanks, ponds, marshy lands used for pisciculture of for ecological/environmental reasons

` National Water Policy

` Ramsar Convention- Contracting Party obligation

Several provisions in these acts are related to the protection of environment and biota of rivers and lakes. However, none examines them in a holistic manner from a river basin wide approach. The Water Pollution Act focuses primarily on water quality and does no consider habitat changes (cf. section 24 (2)) to cause water pollution. The Act concentrates only on point sources of pollution and ignores non-point sources or indirect impacts on water quality.

RECENT JUDICIAL PRONOUNCEMENTS

The issue concerning regulation of human activities in an around the rivers, lakes and other waterbodies involves questions concerning:

(a) the minimum area of the riparian zone or floodplain (or around other water bodies) within which various activities need to be regulated, and

(b) the implications of such regulation in terms of land ownership, religious freedom, etc.

These questions have already been addressed by the Supreme Court in several PILs related to the problems involving rivers and lakes. Invariably, the Supreme Court has held the environment to be inviolate and has ordered against the activities that harm the ecology and environment of water bodies.

` In the case of A.P. Pollution Control Board vs Prof MV Nayudu & others (Civil Appeals 1999), the Supreme Court quoted the following:

> "The basic insight of ecology is that all living things exist in interrelated systems; nothing exists in isolation. The world system is weblike; to pluck one strand is to cause all to vibrate; whatever happens to one part has ramifications for all the rest. Our actions are not individual but social; they reverberate throughout the whole ecosystem." [*Science Action Coalition by A. Fritsch, Environmental Ethics: Choices for Concerned Citizens, 3-4 (1980)] (1988, Vol. 12, Harv. Env. L. Rev. at p. 313*)

ENCROACHMENT, FLOW REGULATION AND HABITAT MODIFICATION

The well-known Span Motels case (MC Mehta vs Kamal Nath & others, 1997; 1997-(001)-SCC –0386 –SC) is directly concerned with encroachment onto riverine land, flow regulation (or diversion) and modification of river habitat. A thorough perusal of the Supreme Court's 1996 judgement in Span Motels case shows that the motel was constructed too close to the river and that the heavy floods in 1995 had caused damage to some property then leased to the motel. In response to this damage, the motel management took steps *that caused diversion of flow and other changes in the river habitat*. Similar cases of damage to property constructed on floodplains close to the river channel are common throughout the country.

The Supreme Court has dealt with the subject in great detail in its several orders in the case. The Court applied the Public Trust doctrine (referred to earlier) and declared that,

> *"In the absence of any legislation, the executive acting under the doctrine of public trust cannot abdicate the natural resources and convert them into private ownership or for commercial use,"*

Therefore, in our view, the government has the responsibility to enact laws/take legal measures to protect natural flows of rivers, protect riparian areas and shorelines and river beds against all kinds of encroachments.

RELIGIOUS FREEDOM vs POLLUTION

Is often argued that any restriction on immersion of idols or on religious offerings such as lamops, flowers, incense, ashes, etc. or on performing certain religious rituals infringes upon the religious freedom enshrined in the Constitution under Fundamental Rights of the citizens. However, in the case Birangana Religious Society vs The State (1996), concerning noise pollution and the constitutional right to religion, the Calcutta High Court observed that

> "*one can practice, profess and propagate religion as granted under Article 25(1) of the Constitution, but that it is not an absolute right, it cannot be said that a citizen should be coerced to hear anything which he does not like or which he does not require*."

The argument is readily extendable to cover other forms of pollution that are caused by religious rituals and are of far more serious nature than nois pollution and are of direct concern to every individual and the society. As interpreted in the aforesaid case, religious freedom is not absolute and cannot be allowed when the freedom to life and "wholesome environment" is at stake.

RIGHT TO PROFESSION, LIVELIHOOD, LAND PROPERTY, ETC.

The cultivation of various crops in the floodplain, particularly the riparian areas close to the river bank, and also on the riverbed poses a major problem for riverine habitat, biodiversity and water quality. The regulation of agricultural activity is opposed on many grounds (such as loss of food production) of which the ownership of land and the loss of livelihood are considered most important and both socially and politically impractical. There are several existing laws and judicial pronouncement which support regulation of such human activities without difficulty.

` In several judgements, the Supreme Court has held that environment shall be given precedence over the hardships caused to a few people due to enforcement of environmental protection measures.

` While the Supreme Court has held repeatedly the right to livelihood, and has directed the Government to provide adequate compensation and rehabilitation when people are to be displaced for any reason, it has clearly held that

"the right to carry on trade or business is subject to statutory regulation that may be necessary in public interest, to prevent pollution and to protect environment".

` In the Dehradun Limestone Quarries case [(Rural Litigation and Entitlement Kendra v. State of U.P. 1986 Supp SCC 517 (1987)], the court held that, "The consequence of this order made by us would be that the lessee of limestone quarries would be thrown out of business. This would undoubtedly cause hardship to them, **but it is a price that has to be paid for protecting and safeguarding the right of the people to live in a healthy environment with minimal disturbance of ecological balance and without avoidable hazard to them, to their cattle, homes and agriculture and undue affectation of air, water and environment.**"

` In the case of Jai Narain and others v. Union of India (1995) under Land Acquisition Act, the Supreme Court has observed that the acquisition of land, shown in Master Plan and Zonal Development Plan as agricultural green, for public purpose of setting up Sewage Treatment Plants to protect the environment, control pollution and in the process maintain and develop the agricultural green, cannot be said to be contrary to Master Plan and Zonal Development Plan. Thus, i**n effect, the government can acquire land for purposes of protecting the environment and controlling pollution.**

` In the case, Kamal Nagar Welfare Association and others vs Govt. of Andhra Pradesh and others (petn. Nos. 29501 and 18782 of 1997, D/6-8-1999; AIR 2000 Andhra Pradesh 132), writ petitions were filed by the residents on the river bed of Moosi in Andhra Pradesh. The inhabitants had been residing there for several decades in permanent and semi-permanent dwellings on the Moosi river bed. The Government had also provided necessary amenities to them. When the Government took a decision to develop the area, the petitioners were being threatened with dispossession from the riverbed. Protection was sought against deprivation of the livelihood of number of people and it was claimed to violate the rights of life under Article 21 of the Constitution of India.

The Supreme Court ruled that the residents have no material to show that they are the property owners except they had been staying there for several decades; that the Moosi river-bed area vests with the government under section 24 of AP Land Revenue Act and all the

affected persons are encroachers on the Moosi river bed. The Court observed that eviction of the residents would amount to neither denying injustice nor causing violence to Fundamental Right of the Citizens enshrined under Article 21of the constitution of India.

` Acts related to land tenure in several states provide that the land under water (river channel, lakes, etc.) belongs to the State and cannot be owned privately. Probably there is no uniform law in this respect because land is a State subject and different states have made different provisions. This gives rise to another problem discussed below.

SHIFTING OF RIVER COURSE AND ACCRETION OF LAND

Most rivers meander and keep shifting every year as a part of their dynamics governed by flow, sediment load and other geomorphic features. This creates some difficulty in defining the boundaries of the river channel and the right over land in legal terms. There is no common law for the purpose.

` Under Punjab Tenancy Act, any land in the bed of a river is considered as a "waste land" that includes other cultivable and uncultivable waste area of the village.

` In Orissa, “all public roads, lanes and paths, the bridges, ditches, dikes and fences, on, or beside, the same, ***the bed of the sea and of harbours and creeks below the high watermark, and of rivers, streams, nallas, lakes and tanks and all canals and water-courses, and all standing and flowing-water,*** and all lands wherever situated, which are not the property of persons, … … are declared to be, with all rights in or over the same, or appertaining thereto, the property of the State Government.”

In a Civil Appeal, under the Orissa Irrigation Act (14 of 1959), the Supreme Court (1998) held the reservoir to be State property and defined the boundaries of the reservoir by the FRL (full reservoir level).

` In another judgement involving the Assam Land and Revenue Regulation (1 of 1886), Regn.3(b), it was declared that "The law in force" governing rights between parties on principles of alluvion and diluvion has not been defined anywhere in the regulation.

The Court observed, “It is an universal law, recognised by all that a land which has gradually and imperceptibly come out of the river bed and added to the land of a riparian owner becomes part of the land belonging to him and is to be considered as his property. This, in some cases, is based on the specific provisions of the Bengal Regulation or other

enactments, in some on custom, and in some cases on the principles of justice, equity and good conscience.

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EXTENT OF REGULATION ZONE

The Costal Regulation Zone nitification under the Environment Protection Act (1986) clearly defined the extent of area beyond the high tide level where various activities were regulated. However, in case of several lakes in different parts of the country, restriction has been sought or imposed on certain activities, particularly certain kind of constructions and industries, in order to prevent pollution of the waterbodies. Several such cases have been brought up before the Supreme Court for discussion and judgement.

` In the case pertaining to regulation of construction and other activities around Badkhal and Surajkund Lakes (MC Mehta vs Union of India 1996), the Supreme Court has observed that:

> *The functioning of ecosystems and the status of environment cannot be the same in the country. Preventive measures have to be taken keeping in view the carrying capacity of the ecosystems operating in the environment surroundings under consideration.*

The Court held that the 200-500 m provision of the CRZ cannot be applied in case of all other places and such restrictions are not violative of the Article 14 of Constitution even if not extended to other lakes in the country. The Court further observed that, "*We have no hesitation in holding that in order to protect the two lakes from environment degradation it is necessary to limit the construction activity in the close vicinity of the lakes*".

The Court decided on one km wide green belt around the two lakes.

` In case of Lake Nainital (Dr A.S. Rawat vs. Union of India; Writ Petition No. 694 of 1993, decided on March 9, 1995), the Court directed shifting of horse stand, ban of construction of multi-storey group housing and commercial complexes, and reduction of vehicular traffic along the lake shore.

` Recent (April 2001), Gujarat High Court restricted new constuction within a radius of 500-1,000 metres around Ahmedabad lakes. The Court ordered that the Precautionary Principle makes it mandatory for the state Government to anticipate, prevent and attack the causes of

environmental degradation. In order to protect the lakes from environmental degradation, therefore, it is necessary to limit the construction activity in the close vicinity of the lakes.

` In exercise of the powers conferred by Section 23 of the Environment (Protection) Act, 1986, the Central Government delegated the powers vested in it under Section 5 of the Act to the State Governments of Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Mizoram, Orissa, Rajasthan, Sikkim and Tamil Nadu subject to the condition that the Central Government may revoke such delegation of powers in respect of all or any one or more of the State Government or may itself invoke the provisions of Section 5 of the Act, if in the opinion of the Central Government such a course of action is necessary in public interest."

Accordingly, the State of Andhra Pradesh (orders of 1994 & 1996) totally prohibited the location of polluting industries within 10 km of the two reservoirs – Himayatsagar and Osmansagar..It prohibited any polluting industries, major hotels, residential colonies or other establishments that generate pollution in the catchment areas of these two lakes within 10 km radius from the full tank level.

`The Supreme Court (in A.P. Pollution Control Board vs Prof MV Nayudu & others (Civil appeals 368-373 of 1999) upheld the notification.

These judicial pronouncements of the Supreme Court clearly show that

a. various human activities around water bodies can be prohibited or regulated, and

b. the extent of regulation and distance from the shoreline of the water body can be decided in each case separately, according the needs and circumstances.

POLICIES AND LEGAL PROVISIONS IN OTHER COUNTRIES

Most of the rivers throughout the world have been subjected to flow regulation, channelization and pollution from urban and industrial wastes in the past. After the rivers had been degraded and its impacts felt, most countries in Europe, North America, Australia and Japan have accorded high priority to their restoration and conservation in recent years. Most of these countries have taken advantage of the advances in ecological research on rivers and their floodplains, and developed their policies accordingly. Though rivers are extensively used for recreation, there are no examples of encroachments, landfills, disposal of solid wastes, etc. Agriculture in riverbeds is totally unknown. There is considerable emphasis in most countries on protecting river floodplains, and the management of riparian areas and in-stream habitats. The Freshwater Directive of the European Union currently governs the plans and policies of European countries. It takes care of restricting human activities along the rivers and in floodplains, and promotes restoration. Given below are a few examples:

Spain:

All types of land uses are allowed in the floodplain only if the area will NOT be inundated by the 500-year flood, and no kind of urban use is allowed if the area is within the 500-year flood zone.

Great Britain (U.K.):

Regulations under House and Town Planning do not permit any settlement in floodplains and minimum limits are set adjacent to river channels. Flood insurance schemes provide that the people must bear the damages caused due to floods; the premiums are quite high in high-risk flood-prone areas. Higher taxes are imposed for those wanting to develop their infrastructure in floodway fringes.

Romania:

The country is currently restoring floodplains and delta areas that had been unsuccessfully reclaimed earlier for agricultural use. The reclamation efforts had failed because of changes to the water regime and consequent salinization. Rehabilitation would restore the natural balance and the water purification capacity of the floodplains.

Maldova:

Efforts are being made currently to minimize agricultural pollution on the Prut River, a large tributary to the Danube River. According to WWF freshwater division, floodplain restoration will increase number of fish, boost local economies and help develop infrastructure for eco-tourists. Floodplains restoration is considered vital for drinking water and health of the people.

Australia:

There is a strong national effort on restoration of rivers in the Murray-Darling basin. The plans emphasise the role of floodplains, especially the riparian vegetation to enhance quality and quantity of water.

U.S.A.

In U.S.A., rivers and all other water bodies receive protection under the Clean Water Act which provides for restriction on all activities that can affect water quality. Floodplains and wetlands receive special protection under the Act through regulatory measures or a system of Permits. In the floodplains, minimum land use is allowed in the form of recreation as parks, boating or swimming or short period agriculture with minimum fertilizers. High taxes are imposed on people wanting to settle in floodplains and they are required to take flood insurance polices. Waterproofing of the houses near floodplains is also required. The US position on Protection and Management of Floodplains is contained in the Executive Order (no. 11988 of 24 May 1977) issued by President Jimmy Carter.

Section 1 of the Order states:

> Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and **to restore and preserve the natural and beneficial values served by floodplains** in carrying out its responsibilities for …. "

Section 6 (c) of the Order defines floodplain as:

> "The term "floodplain" shall mean the lowland and relatively flat areas adjoining inland and coastal waters including floodprone areas of offshore islands, including at a minimum, that area subject to one percent or greater chance of flooding in any given year."

President Clinton's Environmental Policy document on 'Protecting America's Wetlands' issued 24 August 1993, concluded with an important, relevant postscript on floods. It reads,

> *".. Many scientists have concluded that past manipulation of rivers in the Midwest has contributed to the current level of devastation by separating the river channels from their natural floodplains, eliminating millions of acres of additional floods storage capacity. Wetlands within the floodplain and higher in the watershed reduce floods by absorbing rain, snow melt and floodwaters and releasing it slowly, thereby reducing the severity of downstream flooding.*
>
> *We must be cautious not to repeat policies and practices which may have added to the destruction caused by these floods. One way to assist landowners while* ***alleviating some flood risks is through funding wetlands restoration*** *and acquisition programs targeted to help those in flood-ravaged areas."*

DO WE NEED ANOTHER LAW?

There are already too many laws for different components of the environment. The multiplicity of laws creates confusion and often different clauses are interpreted variously to suit the objectives of flouting the law then enforcing it. The multiplicity of laws is accompanied by the multiplicity of agencies and authorities that make the issue still more complicated. Enforcement of laws is often complex and it is easy to get the issue buried by taking matters to the Court. Legal process is exceedingly time consuming. These facts can be readily presented as arguments against another law or legal measure.

However, there are other arguments that need to be considered. The foregoing overview of a few cases related to rivers and other water bodies decided by the Supreme Court clearly highlights the fact that none of the existing environmental laws is adequate or competent to address the complex issues comprehensively. The Water (Prevention and Control of Pollution) Act does not address the problem of pollution by individuals by disposal of small amounts of solid wastes or immersion of idols. It is totally silent on the issue of change in river habitat caused by human action. The Indian Wildlife Act or the Indian Fishery Act does not take into account the problems of numerous organisms in the rivers and lakes.

It must be noted that the Supreme Court had to rely time and again on the Constitutional provision of Article 21, or the Precautionary Principle or the Public Trust

Doctrine to provide relief to the litigants and protect our rivers and waterbodies from the onslaught of human activities.

In this context, the Environment Protection Act (1986) is a comprehensive act of the Parliament. It has the potential and authority of dealing with almost every situation that may arise. However, such necessary actions require an elaborate procedure of Notification under the EPA. One such notification is the Coastal Regulation Zone notification of 1991 which regulates various human activities along India's coastline to protect both the seashore habitats and coastal waters and their biodiversity.

We are of the opinion that the human activities in and along the rivers and their floodplains can be regulated best through an appropriate notification under the Environment Protection Act, 1986.

RELEVANCE TO CRZ

There is great similarity between the CRZ and the proposed regulation of various human activities along different zones of rivers and their floodplains. In both cases, protection is sought to the habitats, water quality and biodiversity against human impacts. Floodplains are same to the rivers as the beaches are to seas. In case of coastal areas, flooding occurs by tides in diurnal and monthly cycles whereas in floodplains flooding occurs from the rivers in unimodal to polymodal annual cycles. In both cases, the organisms living in the water utilize the landward habitats periodically for feeding, nesting and breeding. Again in both cases, the human activities on land influence the water body in many different ways. Coastal areas can in fact be called "floodplains' of the oceans.

It is also noteworthy that the CRZ notification already applies to estuarine areas of the rivers which are directly influenced by high tides.

GENERAL CONCLUSIONS

River conservation throughout the world recognizes the importance of floodplains in mainitaining the ecological integrity (physical structure, water quality and biodiversity) of the rivers. In most of the developed countries, floodplains have been provided protection against almost all kinds of human activities, and are now being restored. In India, not only

floodplains but even the riparian fringes and the riverbeds are most severely affected from encroachments, agriculture and solid waste disposal.

The right to wholesome environment is a Fundamental Right of the citizens in India, and numerous judicial pronouncements of the Supreme Court have made it mandatory for the state to “anticipate, prevent and attach the causes of environmental degradation”. Various Supreme Court judgements have held the right to wholesome environment above all other fundamental rights.

Therefore, there is nothing in the Constitution or any existing law of the country that prevents the Ministry of Environment and Forests from issuing a Notification under the Environment Protection Act to regulate and restrict various human activities in and along the rivers throughout India, in order the protect their ecological integrity that sustains the Indian people.

8. SPECIFIC PROPOSALS FOR REGULATION

As said earlier, the proposed River Regulation Zone notification can be prepared along the lines of the CRZ notification. We propose only a basic framework at this stage as details can be worked out only after discussion among all concerned ministries, organizations and agencies, besides the representatives of the states.

1. ACTIVITIES TO BE REGULATED

All kinds of activities that alter or have the potential for altering the habitat features or adversely affect water quality should be totally prohibited within the river channel and its floodplain to an extent depending upon its classification, unless otherwise exempted.

Various kinds of activities that impact the river ecosystems have been discussed earlier. Specifically they are:

a. All kinds of encroachments (temporary or permanent structures)
b. Any kind of embankment within the prescribed area (if not already existing)
c. Any kind of cultivation. If it is necessary to allow cultivation, use of agrochemicals and organic manures shall be prohibited.
d. Disposal of any kind of solid waste including religious offerings
e. Immersion of idols
f. Washing of clothes, cattle, or discharge of any other polluting substances
g. Overgrazing
h. Cremation and related activities

2. AREAL EXTENT OF REGULATION

Various activities must be regulated within a distance of 500 m from the boundary of the floodplain.

Floodplain of rivers and streams may be defined as "*the low-lying or relatively flat areas adjoining river channels, including at a minimum that area which may be flooded once in fifty years (two percent or greater chance of flooding in any given year)*".

Peak flood of the river is equivalent of the high tide in the coastal areas. Maximum height of tides is relatively fixed for a place and is reached once a month. On the other hand, flood peaks vary year to year and hence, the maximum peak during a period of 100 years is generally considered to define the floodplain boundary.

The standard definition has been modified to reduce the area of flooding from that flooded once in 100 years to the area flooded once in 50 years. In India, the floodplains of most rivers of the Ganga basin have been already restricted by embankments, and it will be impossible to apply the measure to the area covered by the standard definition.

It is also suggested that in case embankments have already been laid with all-season roads, the area of regulation may be restricted to that between the river channel and the embankment on that side of the river.

In cases where river flows have been regulated by barrages, the natural peak floods during the past 50 years must be considered. However, in case of river stretches whose flow has been regulated by a storage reservoir (masonary dam), maximum flood peaks obtained by release of water from the reservoirs may be considered.

REGULATIONS

GENERAL:

There shall be no further channelization of any river/stream.

If embankments have to be constructed along any stretch of the river for any reason, these embankments shall not lie within the floodplain boundary defined by 25 year peak flood.

There shall be no cultivation of any kind on the bed of any river/stream (main channel, spill channel or side arm).

Clear felling of any tree or shrub in the floodplain (including river bank) shall be totally prohibited.

Unless Exempted (as listed below), following activities shall be regulated to the extent indicated in each of the four Zones identified earlier for the purpose.

RRZ I –

Total prohibition of all polluting activities including permanent or temporary construction (Residential, Commercial, Religious, Recreational),

Total prohibition of agrochemical based cultivation,

Total prohibition of disposal of all kinds of solid wastes (including religious offerings and idol immersion)

RRZ II -

Total prohibition on permanent or temporary construction on floodplain and on hill slopes facing the river

Total prohibition on mining/quarrying on hills

Total prohibition on use of fertilizers and pesticides for agriculture

Total prohibition on solid waste disposal

Regulation of forage removal/grazing on hill slopes

Regulation of gravel/sand mining

RRZ III -

No further extension of any infrastructure that may necessitate reduction in the remaining floodplain or affect the course of the river channel

Total prohibition of disposal of all kinds of solid wastes

Total prohibition of groundwater extraction within 500m of the river channel and limited (regulated) extraction beyond that area.

RRZ IV –

Total prohibition of all polluting activities including permanent or temporary construction (Residential, Commercial, Religious, Recreational)

Total prohibition of agrochemical based cultivation

Total prohibition of disposal of all kinds of solid wastes

Total prohibition of groundwater extraction within 500m of the river channel

Total ban on drainage and reclamation of existing wetlands

Regulation of gravel and sand mining – stretches and amounts to be identified and notified

Regulation of grazing and forage removal

EXCEPTIONS

Several kinds of Exceptions to the proposed regulations will be necessary due to the already existing structures and projects of essential services. Further, certain minimum development activity may be necessary and provision will have to be made to accommodate these needs. Therefore, following activities may be allowed when necessary, after assigning clear reasons and exhausting possible options:

1. Activities associated with the construction of rail/road bridges, pontoon bridges
2. Activities associated with power stations, irrigation, water supply, and multipurpose reservoirs
3. Activities associated with specifically approved projects for the restoration of rivers/ floodplains, and for scientific purposes (research, monitoring), will also be excluded from the purview of regulation.

ADDITIONAL PROPOSALS

It is suggested that the MOEF should consider bringing all lakes and reservoirs (other than those covered by the River Regulation Zones) also within the purview of this notification. The impacts of human activities in the catchments and particularly in areas adjacent to lake shores, as well as in the lakes are similar in nature and have similar impacts on water resources and the ecosystem integrity of the lakes. During the past few years, there have been several PILs filed before the High Courts in different states and also before the Supreme Court. These examples are listed in the Appendix. The Supreme Court has already ruled in several cases (as discussed earlier) to uphold or require regulation of various activities in an area of 500m to 10 km beyond the shoreline. It is therefore necessary that these water bodies are also considered at this stage for an uniform, scientifically sound regulation instead of allowing the legal disputes to proliferate and a chaos to be created by the variety of judgements.

It is proposed that

1. All lakes and other inland water bodies (including wetlands)- natural or man-made – should be classified according to suitable criteria.

2. A minimum belt of 500 m to 1 km around the lakes from their highest shoreline (bank full level) may be designated as buffer zone for regulating certain activities. Wherever necessary, this buffer zone can be extended to 10 km for specific industrial activity.

3. A variety of activities should be regulated in around the lakes.

Lakes may also be grouped into four categories:

1. High altitude lakes (>3000 m) and those in near pristine condition, with relatively little human disturbance, no infrastructure developed

2. Mountain lakes, surrounded by steep slopes, rural/semi-urban surroundings

3. Urban Lakes-1: All lakes with urban surroundings; well developed infrastructure; but used for drinking water, recreation and fisheries.

4. Urban and Rural Lakes: used primarily for irrigation

These proposals can be elaborated further if the MOEF decides to include the lakes with the proposed RRZ notification.

INSTITUTIONAL MECHANISMS AND INTER-MINISTERIAL COORDINATION

The implementation of the proposed regulation of various activities in and along the rivers will require a coordination between all concerned ministries and developing appropriate institutional mechanisms for the purpose. We comment upon these requirements only briefly.

INTER-MINISTERIAL COORDINATION

Rivers are multiple use systems. They are major source of water for drinking water supplies, irrigation and hydropower generation. Numerous reservoir built across rivers by damming them are also used for fisheries. The floodplains are extensively used for urban settlements, industry and agriculture. Rivers themselves are also used also for transport between places along their length or across their channels. Thus, several ministries of the Central and State Governments are major 'stakeholders'. They include the Ministries for Water resources, Power, Agriculture, Transport, Urban Development, and Rural Development, besides the Ministry of Environment and Forests which has the responsibility of protecting the rivers and their environment. Some other Ministries also have an indirect interest in the rivers; for example, the Ministry of Tourism and Culture and the Ministry for Youth Affairs and Sports. Therefore, it is important that the MOEF holds discussions with representatives of all concerned Ministries to convince them of the need of such regulatory measures and to seek their cooperation and support.

INSTITUTIONAL MECHANISMS

Two major categories of institutions will be required for implementation of the regulations: (a) those for actual enforcement and monitoring, and (b) those for providing technical support.

Enforcement and Monitoring

Time and again proposals have been made for the constitution of River Basin Authorities who will be entrusted with the task of integrated management of all resources (particularly

water resources) in respective river basins. Such river basin authorities should be responsible for enforcing and monitoring of the RRZ provisions as well. In case of the CRZ, Coastal Regulation Zone Authorities have been constituted for each state separately, besides a National Authority. Since most of the rivers are inter-state rivers – not only flowing from one state to another but also forming the boundary between two states, a coordination between the states is of paramount importance and absolutely necessary. In cases where the river channels shift their course, already there are disputes between states and their people. The regulation of human activities will require greater understanding the river dynamics and speedy resolution of the conflicts, if any.

Thus, it is suggested that the MOEF may constitute a National River Authority, and a River Basin Authority for each of the major and Medium river basins.

However, it must be pointed out that the enforcement and monitoring of the regulations will be required at local level along each zone of a river. This will require involvement of administrative bodies at district, municipal and panchayat levels.

Technical Support Institutions

Enforcement and monitoring of various regulations will require support from technical information about geomorphology, hydrology, and ecology of all rivers, with details in each sector/reach of the river. This information will have to be collected and processed regularly due to the dynamic nature of the river systems and many other human activities that will still continue in the entire river basin. This will require scientific and technical expertise which should be developed at different levels: national, state and local. Existing expertise in the Universities and research organizations can be utilized for the purpose but there is a need for coordination and integration between different disciplines. It will be most appropriate to establish National and Regional Institutes for research and training in river ecology. These institutes only will be able to provide the long-term guidance and support required for real conservation of rivers in the country.

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11. APPENDICES

Appendix 1

National Workshop on
Conservation of Rivers and Floodplains in India
New Delhi, 23-24 November 2001

RESOLUTION

Being aware of the rapid deterioration of the water quality of our rivers and lakes to the extent that in most cases it does not even meet standards for bathing, let alone those for human consumption;

Being concerned at the high levels of abstraction of water from rivers and lakes for agriculture, industries and domestic supplies, to the extent that many downstream reaches of rivers and many other water bodies have no water during the dry season;

Recognising the need for maintaining adequate flow in rivers during the dry season for improving water quality and sustaining the biodiversity,

Further recognising the need for a holistic approach by treating rivers as living ecosystems which harbour and sustain a significant proportion of the country's biodiversity;

Reaffirming that rivers, lakes, wetlands and other water bodies cannot be considered in isolation of their watersheds, and that all inland surface water systems need to be treated together as part of a river basin;

Asserting the need for a river basin approach and for treating each river basin, with its specific geological, climatic, hydrological, biological and socio-cultural features, separately;

Stressing the importance of maintaining the ecological integrity (physical, hydrological, chemical, and biological characteristics, and natural functions) of rivers, lakes and all inland aquatic ecosystems;

Further stressing that floodplains are an integral part of river ecosystems, and that any change in the river flow (volume, velocity, quality, etc.) affects its floodplain;

Emphasizing the functions and values of floodplains for moderating floods, recharging groundwater, production of valuable natural resources, improving water quality, sustaining high biodiversity (especially fisheries), and providing aesthetic beauty to the landscape;

Noting the paucity of information on various aspects of river ecosystems and the absence of appropriate mechanism for retrieving, compiling and disseminating the available information on rivers, lakes and other surface waters, and

Acknowledging and appreciating the legacy of traditional knowledge and practices concerning use and conservation of water resources;

Conscious of the need for giving highest priority to protecting the upper watersheds of rivers (near origins) for checking erosion and improving flow;

Having noted the efforts of the National River Conservation Directorate (NRCD) in the Ministry of Environment & Forests (MOEF) towards improving the water quality of rivers through interception, diversion and treatment of sewage, and enforcing measures for industrial pollution control; and

Recognising the urgent need for coordination between different ministries of the Central and State Governments and various agencies concerned with water resources and their use and management;

We, the participants of the National Workshop on the Conservation of Rivers and Floodplains in India (held in New Delhi during 23-24 November 2001), call upon the Ministry of Environment and Forests, Government of India,

1. To treat all rivers, lakes, reservoirs, wetlands, etc. as integrated components of a river basin, and to develop a mechanism for coordination between all programmes for their conservation and management;

2. To take necessary actions to ensure adequate flow in rivers for maintaining their ecological integrity, water quality and biodiversity;

3. To regulate the abstraction of river/surface water for various uses (including agriculture, industry and domestic supplies) in consonance with the hydrological conditions of the river basin and in a manner that under no circumstances the abstraction exceeds a maximum prescribed proportion of the total flow;

4. To ensure return flow of adequate quality by promoting sustainable land use, and recycling and reuse of wastewater;

5. To take necessary steps towards issuing a notification under the Environment Protection Act, to protect river floodplains, and areas surrounding all inland water bodies, from uncontrolled anthropogenic activities (tentatively called as **River Regulation Zone** notification)**.

6. To declare certain rivers and/or their reaches as "National Heritage Rivers" and restore them;

7. To initiate measures, on highest priority, for the **conservation and restoration of floodplains, and protection of upper watersheds** of rivers throughout the country;

8. To establish a network of **Protected Areas of River Systems** for the conservation of riverine biodiversity;

9. To establish a **National Institute for Inland Waters** for research on inland surface waters, focusing especially on rivers and lakes;

10. To set up a **National Authority for the Conservation and Restoration of Inland Waters** which should coordinate between various ministries and departments, and function under the NRCA.

11. To coordinate with the Ministry for Urban Development and other concerned ministries and Departments to take measures on priority to **decentralise treatment of domestic sewage** by requiring the housing boards, housing societies, builders, etc. to treat domestic sewage at their end and to recycle treated water;

12. To promote **alternate energy-efficient technologies for wastewater treatment** (e.g., root zone./ constructed wetlands) that will help reduce costs of both capital and O&M.

13. To promote and support **research on river-floodplain systems** in the following areas of priority for achieving the goals of river conservation:

A.adequate flow in various rivers/ stretches of rivers
B. hydrology of rivers in relation to their ecological functioning
C. river-floodplain interactions, emphasising nutrient dynamics
D. biological diversity of freshwater ecosystems
E. relationships between groundwater and river flows
F. biological/ecological integrity of rivers, monitoring and assessment0

14. To establish an **ENVIS Center** exclusively for inland surface waters;

15. To promote and support **socio-economic studies** of communities dependent upon rivers (including floodplains) and lakes;

16. To promote and support detailed studies on **Ecological Economics,** particularly of river-floodplain systems emphasizing water quality, biodiversity and natural resources, and

17. To promote **Education and Awareness** about river-floodplain systems. Year 2002 is the Year of Mountains. India must focus on mountain rivers. Similarly, Year 2003, the International Year for Water, should be observed in India by the MOEF as the **Year of Flowing Waters**.

18. To adopt a **Vision Statement (motto)** of the National River Conservation Directorate to reflect a holistic integrated approach to the conservation of rivers and other inland surface waters;

(suggestion:
Ensuring ecological integrity of inland waters for sustainable development)

We urge the MOEF to initiate immediate action towards implementation of these recommendations at the earliest.

****Elaboration of the Recommendation concerning River Regulation Zone Notification*:

a. The notification could be similar to the CRZ notification, and should restrict, regulate or prohibit various activities in specified stretches of rivers to a specified distance on both sides from the natural levee. The distance will vary from a minimum of 500 m to the point reached by the 10- year peak flood in the plains.

b. River courses need to be divided into various "ecozones" or 'reaches' depending upon their climatic and geomorphic features, state of degradation, human use and potential for restoration. The activities to be regulated may be site-specific for each zone. The activities to be regulated include: various forms of encroachment on river beds and floodplains, particularly all permanent constructions; further channelization by levees; disposal of solid wastes, and landfills in floodplains; intensive agriculture using agrochemicals and manure; uncontrolled extraction of sand; intensive grazing and excessive harvesting of vegetation; immersion of idols (especially those using non-degradable and toxic substances); disposal of dead bodies, and religious offerings in indiscriminate manner, etc. Even mass bathing, wallowing of cattle and washing of clothes should be regulated.

c. The MOEF should set up a Committee to draft the notification which must take into consideration all scientific, technical, socio-economic, cultural and administrative aspects. The Draft should be discussed in another Workshop with representatives of different stakeholders, government agencies and administration, before circulation to the States for comments.

New Delhi, 23 December 2001

Signed by participants

Appendix 2

A NOTE ON RIVER FLOODS

Floods are a regular feature in Indo-Gangetic plains. They are caused due to heavy monsoon rains in the Himalayas mainly concentrated in three months of the year. The mountains are soft and very fragile and have sparse vegetation. Poor agricultural practices, deforestation and construction of roads and other infrastructure destruct the fragile ecosystem leading to landslides, which dam the rivers causing massive lakes, which burst and cause flash floods downstream. Many rivers and streams flowing off its slopes carry huge amounts of silt and deposit in the flatter terrain. Silt raises the level of the riverbed, so that its contents spill over on to its banks causing floods. National flood control program was launched in 1953. By 1979, 9.75 billion rupees had been spent on embankments and other structural controls. Annual flood damage have increased nearly 40 times from an average of Rs.60 crores a year during 1950's to an incredible Rupees 2,307 crore a year during 1980's.The flood affected area shot up from an average of 6.4 million hectares a year in the 1950's to 9-17.53 million hectares in the 1980's. Mr. B.B. Vohra warns: The building of spurs and embankments, which have to be rebuilt or raised every year is no answer at all to the problem of floods. Over 400 km of embankments have been built annually since 1954.

Construction of embankments worsens the problem of flooding. By building up the embankment, the river becomes confined to its channel with its sediment load, which keeps on increasing year after year. Earlier it could have been deposited in wider flood plain area. With rise in riverbed, higher flood levels become inevitable, which may lead to a breach in the embankment. This also deprives the flood plain of the rich silt deposits left behind by receding floodwaters. Building up of embankments gives a false security to people, who try to encroach the floodplains near to river channel and suffer more losses. Drainage problem also gets aggravated in the flood protected area. Without the embankments the floodwater either recharges aquifers or goes back slowly in to the rivers. In case of embankment, spilled off water has no place to go back, it only causes the water logging and drainage congestion, because huge quantities of water can collect in case of tributaries joining the main rivers as in case of Kosi joining Ganga in Bihar. Embankments or levees constructed to control floods, especially in towns and cities, do reduce overbank flows but channel restriction causes down cutting. Deposition of sediments is prevented. Cutting from the floodplain also destroys the natural habitat of the river.

. In north Bihar, annual floods cause extensive damage to the crops and the human settlements. Flood is a natural calamity but the land use activities and social settlements of human populations in flood plains increase the damages caused by floods. Himalayan River Ganga brings huge quantities of silt and deposits in a wide riverbed, usually adjacent or as islands in the river, known as Diara in Bihar and eastern UP. River has a meandering and braided channel. It keeps eroding and shifting its course. These annually inundated floodplains are occupied by Diara people, but they need to shift with shifting of the channel. Diara land is fertile and the main occupation of the people living in Diaras is agriculture, rearing of cattle and subsistence on fisheries. During monsoon months, they migrate to nearby towns and take shelters in tents on all the available empty spaces on roads, railway stations. They are unwelcome in towns because of overcrowding and they are also involved in criminal activities. These people fight and even murder each to gain control of shifting lands. Their displacement has led to several social problems. **Embankments constructed to**

avoid floods have resulted in waterlogging and drainage congestion problems. The intensity and fury of floods has increased with construction of structural controls.

Kosi drains the mountains of Nepal into the plains of North Bihar and contributes to vast volumes of Ganga water. It erodes the soil in mountains, carries excessive silt load and causes landslides. It carries along with it rocks and boulders. The river is unpredictable and keeps shifting its course. It has shifted 160 km westwards in the last two hundred years. The people living along its banks in the hot and moist plains of Bihar welcome these muddy silt laden floodwaters every year. In 1954, the government of Bihar decided to build embankments along the Kosi as a flood control measure. This was done to protect the people living on the banks. For some years the embankments provided protection till a bad flood caused breaches and floodwater entered the village and washed away everything. The embankments have affected the natural drainage. Before the embankments, the flood water drain away soon, but now these act as a dam preventing floodwaters from draining. The vast stretches of lands along the embankments have become permanently waterlogged now. The excellent fertile land for agriculture is now converted to stagnant pool of water, an ideal breeding ground for disease causing mosquitoes. Young people have migrated to other areas. Obviously the people are angry. They feel that the embankments being the main reason for their misery. Villagers are demanding that the river be liberated.

Earlier the native people of Ganga-Brahmputra-Meghna basin had devised ingenuous ways of adapting with this riverine ecology. There used to be an intricate system of disused channels called Kani nadis or blind rivers. During flooding these channels actually functioned as canals to divert excess flows. The villagers built low embankments to hold the flood waters, only to deliberately breach them as the level of rivers rose, so that the top layer of flood waters would spread as a shallow sheet all over their paddy fields depositing fine silt and algae, increasing the fertility of the soil and replenishing ground water. These waters also contained fish eggs, which would settle in wetlands. Food webs in water kept mosquito larvae in check. Later on engineering controls caused more problems than they solved.

It has been repeatedly recommended that the government should control human occupation of the floodplains through strong laws. People in floodplains should learn to live with floods, which bring with them several ecological advantages. As flooded waters recede, large areas making up fertile land become available for cultivation for 5 to 6 months. This soil retains moisture for some time helpful for sowing of seeds. Governments should take the responsibility of resettling people living in floodplains, if we want to avoid damages caused by floods.

Over three quarters of the plain area in Assam is flood prone. Since 1986, the ferocity of the floods seems to have increased considerably. The 1988 floods were devastating. They affected 4.22 mh out of the state's total area of 7.54mha. By 1988, 4000 km of embankments had been built in the state but over 90% of the protected area was affected by breaches in that area. Probably embankments worsened the situation by cutting rivers from their floodplains and by causing drainage congestion. Reclamation of swamps or low- lying areas called bils in floodplain has taken away an important natural cushion for floods. The floodplains of India occupy some 20% of the total area but are home to 30-40% of its population. Floodplains improve the quality and quality of water. These improve the habitat and recharge the aquifers. In Delhi, floodplains have been cut off from the main channel. Consequently, the water table has depleted and the poor quality of ground water has also resulted in epidemics like cholera and Jaundice. Depressions in floodplains are useful for nutrient recovery and cycling, releasing excess nitrogen, inactivation of phosphates removing toxins, chemicals, heavy metals through absorption by plants and also in treating waste water.

Floodplain zoning is one of the most practical and effective non-structural means of reducing flood damage. The basic concept of floodplain zoning is to regulate the land use in

floodplains in order to restrict the damage by floods. The purpose of regulation does not mean that no inundation will occur but the human activities should be based on its probability of being flooded and the level of expected damage. It aims at determining the locations and demarcation of the areas likely to be affected by floods. Areas should be demarcated liable to flooding of different frequencies like once in 2 years, five years, ten, twenty, fifty and hundred years. There should be prohibition of obstruction to rivers and drains. River channels need space to spill over depending on the width of the channel. With the onset of monsoon rains, rivers swell inundating the adjoining areas. Low lying areas or wetlands adjacent to channels must be preserved as a cushion for floods. These wetlands act as sponge to absorb water and lessen the intensity of floods.

The major extreme flood affected tract lies between Gandak and the Teesta rivers. Brahmputra is also flood prone. In non-monsoon months, the river channel occupies an average width of 8 km., but when in spate, it spreads from 10-16 km, in width. River has tendency to meander and create flood problems. The Gangetic plain with its low gradient of 10cm./km, at times gets flooded up to a distance of 200 km. on either side of the river. Agricultural fields could be flooded quite frequently and should be located in areas where expected damage is not too high,

- Human dwellings or local infrastructure could be located in areas of very occasional floods (once in 100 years) with a likelihood of very minor damage.
- Dense human settlements and major infrastructure or Industries should be located in areas without any flood risk for very long periods and with very low expected damage.
- River authorities should define limitations on private land adjacent to river channel. They need to control and grant permits for building and landform changes in the riparian land. They should ensure land use planning to be compatible with river dynamics. River dynamics includes the gradient of the river (Very steep, straight slope meandering type, braided channel). Depending on the dynamics, the rivers can be predictable or unpredictable).

Stream Classification

by R Wadeson (South Africa)

Introduction

Classification[1], in the strictest sense, means ordering or arranging objects into groups or sets on the basis of their similarities or differences (Platts, 1980; Gauch, 1982). It is a tool which has been used in virtually all sciences, particularly in their early stages of development.

Rivers have been a frequent subject for classification by practitioners from a wide range of disciplines including both ecologists and geomorphologists (Mosley, 1987). Motivations for identifying different types or classes of river have varied widely, from the desire of the scientist to enhance his understanding of river behaviour and morphology by highlighting common characteristics of a given river type, to the need of an engineer or freshwater fishery manager to extrapolate experience and knowledge of a given river to rivers which behave in a similar fashion (Mosley, 1987). The classification of fluvial systems remains in a formative stage because of the dynamic changes that occur over broad spatial and temporal scales (Salo, 1990), and because classification systems only reflect the current state of knowledge on river function (Frissell *et al*., 1986).

Implicit in the endeavour to classify any natural feature or ecological system is the assumption that relatively distinct boundaries exist and that the boundaries may be identified by a set of discrete variables. However, the classification of streams is complicated by both longitudinal and lateral linkages, by changes that occur in the physical features over time, and because boundaries between apparent patches in fluvial systems are often indistinct (Naiman *et.al.*., 1988; Pringle *et.al.*., 1988; Decamps and Naiman, 1989). Connectivity and variability are fundamental for the long-term maintenance and vitality of stream systems, and become essential but complicating factors in developing an enduring classification scheme (Naiman *et al.*, 1992).

Theoretical background

Stream classification has been attempted by many researchers from different disciplines who have used a number of variables at different spatial scales.

Brussock *et.al.*. (1985) proposed a system to classify running water habitats into longitudinal classes based on their channel form which can be considered in three different sedimentological settings: a cobble and boulder bed channel, a gravel bed channel, or a sand bed channel. Three physical factors (relief, lithology and runoff) were selected as state factors that control all other interacting parameters associated with channel form such as temperature, depth, velocity and substrate. This work confirmed much of the earlier work of

[1] Editor's note: Author to explain that stream classification on geomorphology should not be confused with the water resource management classification system.

Leopold *et.al.*. (1964) that stream channel-form can be predicted along the length of the river within geographic regions.

Schumm (1979) envisaged an idealised fluvial system as consisting of three channel zones: an upper zone of sediment production (source), where the major controls were climate, diastrophism and land use; a middle zone (transfer) essentially in equilibrium; a lower zone (sink or depositional area), where controls were base level and diastrophism. This idealised and simplistic description has been adopted by numerous researchers for the classification of river systems.

The simple model of Schumm (1979) was further extended by another geomorphologist, Pickup (1984), and used to explain variation in bedload characteristics and movement in the Fly and Purari Rivers of Papua New Guinea.

The result of this study was the identification of five separate zones, each with its own characteristic particle size distribution. Pickup stresses that these zones reflected variations in the controls of gradient, bed material, stream power potential along the channel, and the ability to move different sized materials at different frequencies. The resultant zones had a distinctive set of slope, sinuosity and width depth ratio values.

A pervasive theme in recently developed stream classification systems in North America has been a hierarchical perspective that links large regional scales (ecoregions) with small microhabitat scales (Naiman *et.al.*., 1992). A number of such schemes, which incorporate geomorphological concepts, have been developed as tools for effective water management, the most common ones in use include Lotspeich (1980), Bailey (1978), Cupp (1989), Brussock *et.al.*. (1985), Rosgen (1985 and 1994) and Kellerhals and Church (1989). Many of these classifications incorporate the ideas of Frissell *et.al.*. (1986), who extended an earlier approach of Warren (1979) by incorporating spatially nested levels of resolution, and produced a framework which addresses form or pattern within a number of hierarchical levels, as well as origins and processes of development.

Naiman *et.al.*. (1992) provide a useful summary of three working hierarchical systems which have gained a fairly wide usage in North America. Brussock *et.al.'s*. (1985) and Rosgen's (1985) stream classifications provide detailed descriptions of the reach within the context of the stream network. Unfortunately the systems are not linked to hillslope processes and the boundaries are relatively indistinct. On the other hand Cupp's (1989) classification is specific to a portion of a stream (or reach) and has relatively distinct boundaries. Unfortunately, although it places the reach within the local valley topography, it does not relate the reach to the catchment. These systems fall short of the view held by many researchers (Van Deusen, 1954; Slack, 1955; Hynes, 1970; Platts, 1974 and 1979; Morisawa and Vemuri, 1975; Lotspeich and Platts, 1982 and Frissell *et.al*, 1986), that the structure and dynamics of the stream are determined by the surrounding catchment as illustrated in Figure 1.

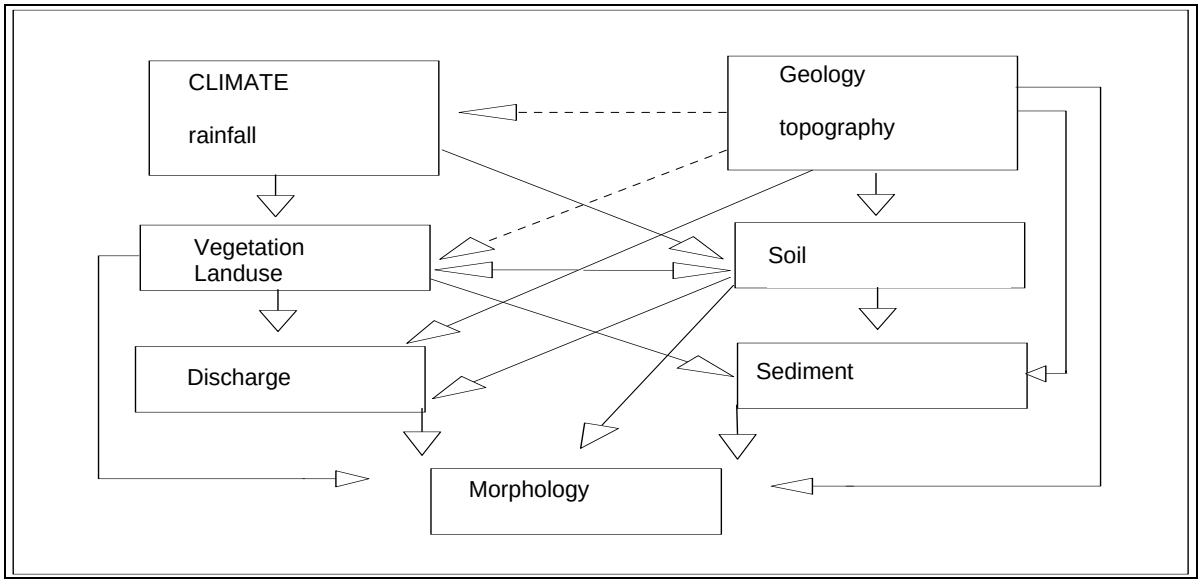

Figure 1. Variables in a catchment influencing the dynamics and morphology of the fluvial system. From Morisawa and Vemuri (1975)

A modification of Frissel's model has been proposed as a procedure for the classification of the geomorphological components of lotic ecosystems within selected South African river systems. This model is comprised of six nested levels: the catchment, the stream segment, the zone, the channel reach, the morphological unit and the hydraulic biotope. The hydraulic biotope scale component within this hierarchy provides the essential link between geomorphology and ecology. The morphological unit and associated hydraulic biotopes provide the basic building blocks of the system whilst the catchment and its sub zones control the driving forces. The channel network, composed of segments and reaches, provides the link between the two. This system not only allows a structured description of spatial variation in stream habitat but also provides a scale based link between the channel and the catchment so as to account for catchment dynamics. The hierarchical model provides the spatial framework of physical features upon which process models of catchment hydrology, flow hydraulics and sediment transport can be based.

R2.3 A hierarchical geomorphological model for South African river systems.

The brief historical review of the literature relating to river classification given above forms the basis of a management tool for South African rivers. Of particular significance is the realisation that in the traditional or conventional sense of the word, there are very few "true" classifications of rivers because this implies the identification and grouping of objects at the same spatial scale. When one links the longitudinal and lateral variables within the catchment, which interact somewhat inconsistently through space and time to produce a hierarchical network making up a river system, any attempt at river classification is made extremely difficult. A geomorphological model proposed here is the first stage of a classification, whereby it provides the framework for the description of the various components of the fluvial system, at any scale. The following discussion introduces the various components of the hierarchical model.

Table 1. The hierarchical structure with definition of terms.

THE HIERARCHY	DEFINITION OF TERMS USED.
Catchment	The land surface which contributes water and sediment to the specified stream network.
Segment	A length of channel along which there is no significant change in the imposed flow discharge or sediment load.
Geomorphological Zones	Zonation concepts are based on downstream changes in the river long profile.
Reach	A length of channel within which the constraints on channel form are uniform so that a characteristic assemblage of channel forms occur.
Morphological unit	The basic structures comprising the channel morphology for example pools, riffles, runs, rapids, waterfalls etc.
Hydraulic biotope	The habitat assemblages with a characteristic range of temporarily variable hydraulic and substrate characteristics which can be equated to the morphological units.

The catchment

The catchment is defined by the topographic divide except where groundwater is a major component of streamflow. The development and physical characteristics of a stream system are dependent upon the geological history and climate of its drainage basin (Hack 1957, Schumm and Lichty 1965, Douglas 1977). Thus, stream systems might be classified on the basis of the biogeoclimatic region in which they reside (Warren 1979, Bailey 1983), the slope and shape of the longitudinal profiles (Hack 1957), and some index of drainage network structure (Strahler 1964).

The segment

The catchment is the source area for runoff and sediment whereas the channels provide the network through which flows of water and sediment are routed. The channel network can be subdivided into segments, where a segment is a length of channel along which there is no significant change in the imposed flow discharge or sediment load.

The Geomorphological Zone

In South Africa, longitudinal rivers long profiles reflect regional geological events and long term fluvial action. Uplift and tectonic warping provide the template upon which the profile develops over geological time the profile becomes adjusted (or graded) to transport the sediment that becomes available to the river channel. A typical graded profile developed on homogenous bedrock is concave in shape. The steep headwaters are in equilibrium with coarse materials being transported by relatively low flows in low order streams, whereas the lower gradient lowland areas are in equilibrium with the transport of finer materials by increasing flows in high order streams.

This classic long profile may be disrupted by a number of features including local outcrops of more resistant rock and rejuvenation due to tectonic uplift or a fall in sea level. In South Africa widespread rejuvenation occurred due to uplift and tilting during both the Pliocene and Miocene. The axis of uplift runs more or less parallel to the east and south coast and reached a maximum of 800m in the Natal midlands in the middle Pliocene, about 4 million years ago.

Rowntree and Wadeson (1998) have developed a zonal classification system for South African rivers modified from Noble and Hemens (1978).

Table 2: Zonal classification system for South African rivers (Rowntree & Wadeson 1998)

1. Source zone	not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
2. Mountain headwater stream	0.1 - 0.7	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
3. Mountain stream	0.01 - 0.1	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool, plane bed, pool-rapid or pool riffle. Approximate equal distribution of >vertical= and >horizontal= flow components.
4. Foothills (cobble bed)	0.005 - 0.01	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel, or cobble often present.
5. Foothills (gravel bed)	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
6. Lowland sand bed or Lowland fllodplain	0.0001- 0.001	Low gradient alluvial sand bed channel, typically regime reach type. Often confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.
Additional zones associated with a rejuvenated profile		
7. Rejuvenated bedrock fall / cascades	0.01 - 0.5	Moderate to steep gradient, often confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades, and pool-rapid.
8. Rejuvenated foothills	0.001 - 0.01	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro-channel activated only during infrequent flood events. A flood plain may be present between the active and macro-channel.
9. Upland flood plain (UFP)	0.0001- 0.001	An upland low gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.

The reach

Variations in channel morphology may occur within a segment due to changes in perimeter conditions which determine the next level of the hierarchy, the reach. For the purpose of this model, a reach is defined as a length of channel within which the constraints on channel form are uniform so that a characteristic assemblage of channel forms occur within identifiable channel patterns. Reach characteristics determine the possible direction of the response to

changes in flow and/or sediment load, in particular whether it acts as a source, transfer zone or sink for sediment. These include valley gradient, geology, local side slopes, valley floor width, riparian vegetation and bank material.

The morphological unit

This level of the hierarchy involves the identification of individual morphological units and related "hydraulic biotopes" within the reach. The morphological units are the basic structures recognised by fluvial geomorphologists as comprising the channel morphology, and are formed from the erosion of bedrock (rapids, waterfalls, plunge pools etc.) or from the deposition of alluvium (sand or gravel bars, riffles, pools etc.). The characteristics and range of morphological units in a reach moderates the ecological impact of a change in flow/sediment regime as they determine the available habitat at any given discharge. The relationship of a given sedimentary feature to its larger-scale (pool/riffle or reach) environment is also important in understanding its dynamics (Laronne and Carson 1976, Jackson and Beschta 1982), so that a description of the different morphological features in a reach is an important input into sediment models.

Ecological habitat or "hydraulic biotope"

The hydraulic biotope may be defined as a spatially distinct in-stream flow environment characterised by specific hydraulic attributes (Wadeson, 1994). This level of the hierarchy is the key to the successful conservation of rivers to maintain ecological integrity within South African fluvial environments because it provides the crucial link between catchment geomorphology and lotic ecology.

Methods for categorising river geomorphology

For a classification system to be successful it must be based on valid process-form relationships, objectively defined units, clear identification procedures and readily accessible data. These features of the hierarchical model are described in Chapter 7 of Rowntree and Wadeson (1998). The chapter describes the methods or techniques used to derive and analyse data and classify features at each level of the hierarchy.

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Appendix 4

LEGAL CASES RELATED TO LAKES AND RESERVOIRS

1. The West Bengal Town and Country (Planning and Development) Act, 1979 has empowered appropriate authorities to call for return under Section 46(1) with respect to any development work which can bring about a change of wetland area. It has emphasized that ***no permission for filling of tanks, ponds, waterbody, marshy land, etc., will be given*** if it is considered necessary for being used as public waterbody, maintaining drainage facility, fire fighting purposes, environmental and ecological reasons and piscicultural purposes. This provision offers a directive against wanton conversion of wetland areas.

2. In Howarh area of Kolkata , in response to the PIL filed in 1980 in Calcutta high court by Howarh Samiti Gantantrik Nagrik Samiti, in its final judgement in September 2001, the court banned completely the filling of urban water bodies. The concerned police officers were given the responsibility to protect the water bodies in their respective region.

3. In the case of destruction of wetlands in the Adyar estuary (Consumer Action Group v Union of India), the Madras High Court prevented the destruction of wetlands, which were being reclaimed to erect a memorial. The petitioners objected to the wetlands being converted in to an auditorium and car park. Allowing the petition, the High Court restricted construction on the 5-acre plot. The Madras Development Authority was told to preserve about 45 acres of low-lying wetlands and not permit any construction in the area.

4. The Public Works Department in Delhi filled the water body in an area to construct the road. The Court was critical about the working of the department. The Court wanted them to build a bridge to protect the water body. In reply PWD argued that the bridge would have costed 10 times as the road. The Court ruled that cost should not come in the way of ensuring environment friendly development.

5. The case People United for Better living in Calcutta-Public and another v. State of West Bengal and others. AIR 1993 Calcutta 215: The State Government submitted a proposal for setting up World Trade Centre and permanent exhibition centre with the object of promoting trade and industries in an area covered by Chinta Singh Bhery (Wetland). In view of the importance of wetlands, the Court ruled that the state respondents are restrained from reclaiming any further wetland. No permission could be granted to any person for the purpose of changing the use of the land from agricultural to residential or commercial. The state was further directed to maintain the nature and character of the wetlands in their present form and to stop all encroachment of the wetland area as indicated in the map.

6. In the case of a 20-year-old property dispute on land of a pond in Ugapur village in U.P., the Supreme Court (August 3, 2001) observed that material sources of the community like forests, tanks, ponds, hillocks and mountains are nature's bounties that maintain delicate ecological balance. They need to be protected for a proper and a healthy environment, which enable people to enjoy a quality life guaranteed under Article 21 of the constitution.

7. The Society of Appeal for Vanishing Environments (SAVE), an NGO in Bhimtal, moved the High Court of Uttaranchal in Nainital on December 20, 2001. It sought an end to the felling of trees by builders, removal of garbage and clearing of the deltas that have formed in places where earth has been removed. It sought the same level of protection for Bhimtal that is extended to Nainital under the National Lakes Conservation Plan.

8. The Andhra Pradesh High Court is hearing a public Interest Petition to protect the Hussainsagar lake from construction on and around the lake or its catchment area. Another petition in the Andhra Pradesh High Court, seeks a ban on annual immersion of idols in the lake during religious occasions, in order to prevent heavy siltation. Yet another petition has asked the Court to prevent the state government from encroaching the lake for the implementation of the cyber city development project.

9. A PIL in A.P. High Court seeks protection of Saroornagar lake in Southwestern Hyderabad against encroachments around the lake which have reduced its size from 74 ha to 25 ha.