ENVIRONMENTAL PARAMETERS FOR CANALS AND ESTUARIES
Case Study: Aqueous Bengal Delta

Prof. Santosh Ghosh* and Unmesh Kirtikar**

*President, Centre for Built Environment, 2/5, Sarat Bose Road, Kolkata – 700020, India
(Email: sghoshcbe@hotmail.com)
**Jt. Secretary, Centre for Built Environment, 2/5, Sarat Bose Road, Kolkata – 700020, India
(Email: calkirtikars@vsnl.net)

Abstract
There are many cities that have been built on riverbank, seashore and on marshy land in deltaic region. Many of these are on water basins with rivers, streams, canals and sometimes with lakes and wetlands of varying sizes. Bengal delta on the coast of Bay of Bengal in India and Bangladesh has world's largest mangrove forest with wide variety of flora and fauna. On Indian side, canals, streams, swamps and estuaries within forests have been silted and water has become saline at many places. There are 3 million people who live here and there are conflicts between man and nature. Unesco has declared this as biosphere area. But as urbanization spreads upstream, there are adverse environmental effects on canals and waterways which are filled up with silt, some are encroached, effluents are discharged into the water, navigability is lost and reducing beds due to sedimentation cause flooding especially in tidal rivers and connecting canals. Constructions of upstream dams cause flood and drought. The cleaning, channelizing etc. have limited success unless ecology of the system is understood. Conservation and environmental management within a holistic regional plan is necessary. There are several coastal zone parameters – physical, biological, human activity, natural and environment.

Keywords
Aqueous, biodiversity, biosphere, deltaic, ecology, environment, geochemistry, geo-hydrology, geomorphology, hydrogeology, hydrography, mangrove, parameters, pedology, salinity, siltation, urbanization,

Introduction
The vast Bengal deltaic region of about 1,000,000 ha of land and water, also known as Sundarbans, facing the Bay of Bengal, of which 38% is in India has been declared by the Unesco as one of the Biosphere regions for wide range of bio-diversity of plants and animal life, including Royal Bengal Tigers. It is the largest delta in the world which has a megacity Kolkata, a large number of smaller towns and villages, flora and fauna, industry, agriculture, fishery, forestry and a large number of people are placed along or in between rivers, canals, creeks, estuaries etc. The tidal swamps at one time extended towards north and there were geographical and resultant hydrological changes. There were strong weather changes with cyclone, storm, earthquake, flood etc. and there was intrusion of saline seawater and gradually composition of plants changed (Choudhuri and Choudhury, 1994). There is frequent subsidence causing complete disappearance of part of forestland. From very ancient time these estuaries were known. But according to some geologists the whole of lower Bengal was an estuary. The lower Gangetic delta was formed by the deposition of the debris and silt carried down by rivers – mainly Ganges and Brahmaputra. Parts of the area were reclaimed for human habitation. About 3 million people live in the Sundarbans region. The people living here have adjusted themselves to natural disasters and also with the environment and wild life. People have built embankments and small dunes and as a result upstream water at many places cannot go out. Tidal water has the problem and swamps were created (Mondal & Ghosh, 1989). On the other hand at the mouth of the Bay of Bengal new land mass out of deposition of silt appears and flooding occurs occasionally affecting flora and fauna.

Degradation of the habitat by poor villager, conversion of mangrove areas for intensive aquaculture, freak weather patterns and increasing salinity are among the caused factors. Reclamations in the flood plains has created problems as large volume of sediments carried by tidal water are being deposited on the river beds and as such larger areas are liable to flooding. Salinity varies according to the distance. There are certain infrastructure development projects that are often uncoordinated. There is absence of risk management and vulnerability analysis. Also there is no holistic integrated land use planning of upstream urbanization in tandem with downstream activities.

Environmental Problems

This aqueous delta is also part of coastal zone on the Bay of Bengal. Rivers, canals and streams take water, waste and sediments from upstream but during the tide saline water enters into the area. Pollution is wide spread, caused by discharge of burnt oil from speedboats, ships and oil tankers. In addition, it is estimated that 397 tons of sewage per day from Calcutta Metropolitan area are discharged while 22.9 tons are released into the Hooghly river from other areas. Estuaries are highly polluted. Industrial pollution is rampant; wastewater and sewage from Digha resort town on the west are dumped into the Bay of Bengal (DOE, 1999). It is not known how much pollution is caused by Haldia Industrial town where a large petrochemical complex has been set up recently. Apart from coastal erosion due to wave actions and storm there is deforestation for building construction and fuel wood, Sand and clay are also used. Recently brick making activities are rampant, Embankment, levees and small dams have been built over the decades to control tidal flood in order to protect agriculture and people living in the Sundarbans region. Due to siltation and rising of beds of canals and streams, upstream flood during rainy season cannot go to the bay and vast areas are waterlogged. On the other hand reduction and control of downstream annual flooding affects the natural productivity of riparian areas, flood plain and deltas. Dynamic interaction of flooding and sedimentation has helped agriaqua culture. The direct loss of annual silt and nutrient replenishment as of consequence of upstream activities is one of the causes of loss fertility. Channelization projects, which continue to be widely advocated, designed, and constructed through federal, state, and local programs, represent one of the most unnecessary threats to the quality of watersheds because restoration alternatives can successfully address the flood-risk and erosion-reduction objectives the Channelization and riprap projects purport to address, while bringing more effective long-term stability to the watershed (Riley, 1998). The functions of the physical components of streams and their relationships to the biological components are important in evaluating the impacts of stream channelization. Often there are connections between the loss of biological functions and the loss of physical functions of streams resulting from channel straightening and vegetation removal. However, a broader discussion on restoration and environment management is necessary.

Restoration Problems

Gracie and Clar mention in issues in restoration and protection that in urban setting it is almost never possible to restore streams to their original condition. If the disturbance, which created the need for restoration, was an altered hydrologic regime, then the original dimensions are no longer appropriate nor would they allow for stability. (Gracie and Clar, 2004).

Often infrastructure installed creates problems and assessment tools are usually targeted at chemical, biological or physical parameters, chemical monitoring and assessment using water quality criteria is the most commonly used assessment tool to identify stream impairment according to Gracie and Clar who emphasize restoration of habitat functioning.

In this connection German experiences in restoration of river corridors can be referred (Larsen, 1996). It includes a planned schedule – Pre-investigation, pilot project, survey and evaluation model image and water planning. Survey and evaluation include river morphology, landscape ecology and limnology and special investigations. As an example, an old Danube project investigations included - analysis of historical river morphology, mapping of riparian vegetation and of ecology of river banks, physical and chemical parameters, insect larvae and fish species, weirs and drop structures in respect of migration, geo-hydrological survey, vegetation and land use of the former floodplain, selected groups of insects and birds, and hydrological and hydraulic studies for flood protection.

Restoration is a complex issue with complex problems. On the whole site investigation and background studies include a wide range of subjects i.e. (1) General site conditions (2) External hydraulic parameters (3) Bank composition (Hemphill and Bramley, 1989).

Management Aspects

The environmental objectives include purification of water quality, increasing manageability where necessary, preventing soil erosion, preservation of historic or cultural resource, providing greenery, and pedestrian and bicycle trails, bringing birds, fishes and providing employment in fishing and other activities, enhancing aesthetic environment etc. Modern remote sensing and geographical information system will provide mapping of all waterways, which will help to prepare a regional environment plan. There are sectoral components of such plan, study of parameters, physical, biological, human and environmental aspects, assessment of impacts, development control regulation, presentation of natural resources, biodiversity, cultural aspects, pollution control, methods of disaster mitigation, loweconomic development, techniques of environmental structure of local governance, public awareness, citizen participation etc. are also important. This covers a large number of studies such as geomorphology, hydrogeology, hydrography, pedology, and geochemistry, natural and human interaction. However environmental sustainability depends on interactions and integration and a river, canal or an estuary falls within areas of different local governments. The purification of river Hooghly going through Kolkata, a tributary of the river Ganges has been taken up. A millennium park has been established on the riverbank. There are other projects but such piecemeal projects will have problems of coordination and an integrated holistic regional environment plan is required. Environment is directly related to conservation and development of canals, estuaries, river etc. in the event of problems generated by direct effects of anthropogenic activities, by the effects of natural phenomenon and interaction of multiple activities. There are four basic approaches for resource management: ecological, economic, technological, ethnological approach.

McCully emphasized that land management is important to manage the water - a healthy river and healthy watershed – unpolluted, supportive of a wide diversity of life forms, and able to flood according to their natural pattern, He says: (McCully 1996). “Managing or restoring watersheds with forests, wetlands and healthy soils minimizes damaging flush floods and the risk of drought, cuts down soil erosion and so the amount of sediments washed into the riverbed, increases the ability of the river system to break down and filter pollutants, and provides diverse wildlife habitats”.

During the last 300 years, most river basins were dramatically modified due to human disturbances such as agriculture, grazing, deforestation, and urbanization. These disturbances also have been changing the Earth’s albedo and, consequently, its surface energy budget,

affecting local and regional climate, and, ultimately, the amount and quality or water in the river basins of the world (UNEP 2002).

One of the fundamental tenets of the concept of sustainable development is the maintenance of a homeostatic equilibrium within the ecosystem. Over – exploitation, or biotic structure degradation, alters the ecosystem processes to the point where the ecosystem's ability to produce desired resources is seriously diminished. A decline in water quality and biodiversity, observed at the global scale in both developed and developing countries, has provided sobering evidence that a purely "mechanistic" and fragmented approach to water resources management, based largely on hydrotechnical solutions such as application of sewage treatment technologies and regulation of hydrological processes through flood control and drought mitigation measures, has been less than successful. While elements of this approach remain valid and viable, a technical solution alone is clearly insufficient for the sustainable use of the world's water resources.

The optimistic aspect of this story is that if, during periods of sharply increased population growth, the carrying capacity of the environment is increased, the population possesses additional time during which homeostatic regulatory mechanisms may be established to achieve a state of dynamic equilibrium between the density of the population and the carrying capacity of ecosystem. Thus, the question becomes one of providing an answer to the question of how to achieve and sustain this equilibrium, or, better yet, of how to expand the carrying capacity of global ecosystem to sustain an increasing population?

The answer is through developing an understanding of ecological processes at different spatial and temporal scales. Such an understanding can be achieved by integrating the different sectors or branches of the environment sciences.

Ecohydrology (Zalewski et al. 1997; Zalewski 2000) is a new concept in environmental problem solving, which is based upon the suggestion that sustainable development of water resources is dependent on the ability to maintain evolutionarily established processes of water and nutrient circulation and energy flows at the basin scale. This depends on a profound understanding of the whole range processes involved that have a two-dimensional character. The first dimension is temporal: spanning a time frame from the past, paleohydrological condition to the present, with due consideration of future, global change scenarios. The second dimension is spatial:
understanding the dynamic role of aquatic and terrestrial biota over a range of scales from the molecular – to the basin-scale.

The wetlands within the river valley and along the river course form the buffer zone: they reduce inputs of mineral sediments, organic matter, and nutrient loads that would otherwise be transported by the river during floods through sedimentation and biological activity. In some artificial wetlands, nitrogen loads can be reduced significantly by regulating the water levels to stimulate denitrification through anaerobic processes. In shaded rivers with high nutrients loads, it is possible to amplify the self-purification capacity of the stream by creating more complex, intermediate ecotones. If despite all the above measures, combined with sewage treatment, the nutrients concentrations in reservoir remain high and the potential for toxic algal blooms exists, other methods can be applied to reduce the recirculation of nutrient within the reservoir. These measures include locking the nutrients within the biomass of macrophytes or translocating the nutrients to other trophic levels (e.g., by manipulation of the lake's biological communities, or "biomanipulation:). Since the properties of large-scale systems cannot be

accurately predicted from the properties of its component elements, such a complex strategy for restoring and controlling nutrients within the catchment's landscape and freshwater ecosystem should be assessed continuously at each stage of implementation and adjusted to maximize potential synergistic effects.

The Sundarbans in Bengal delta

In 1989, the entire inter-tidal zone of Sundarbans (India) i.e. over 9630 sq.km. (bounded on the south by Dampier-Hodges line) was declared Sundarbans Biosphere Reserve by the UNESCO. Sundarbans Biosphere Tiger Reserve with its 1700 k.m. core are (including 1330 sq.km. National park) and Sajne Khali Wildlife sanctuary of an area of 362 sq.km. Included. It also includes Beid Lothian Island Wild Life sanctuary 15.95 sq.km. total forest area is 4264 sq.km. and non-forest area 5366 sq.km.

Besides Sundarbans protected area including National Park as mentioned above, there are forest area and agriculture area. There are also areas for supporting activities to serve people. There is Restoration zone of 450 sq.km. Below Sagar island a Sagar Marine Park with 800 sq.km. has been set up – wilderness zone – 250 sq.km. estuary zone 200 sq.km. and buffer zone 350 sq.km.

The UNESCO's man and biosphere programme outlines three functions – (a) conservation function – preserving flora, fauna, landscape, species etc. (b) development function – to benefit local people and developing social, cultural, economic and ecological aspects within sustainable development and (c) support or logistics function – education and training monitoring and research.

There are three territorial components (a) core area – protectual and conservation / reserve area (b) buffer zone-surrounding core area, some compatible activities for human benefits and (c) transition zone-an outer flexible zone where tourism, recreation and other activities are permitted (Batisse. 1997). The Forest Dept. Govt. of West Bengal in charge of the Sundarbans has demarcated these zones also.

The Sundarbans is also a great wetland area and it has complex interactions between soils, topography, microorganisms, plants, animals, birds etc. and the area become a productive ecosystem.

A study of the economic valuation of wetlands discusses the following aspects (Barbier. 1997)

(a) Components – fish, timber, fuel wood and tree products wildlife, fertile land for agriculture, water supply, water transport, pest etc.

(b) Functions – flood control, storm protection, ground water recharge, sediment and nutrient retention, etc.

(c) Attributes – biological issued by Ramsar Convention Bureau (Ramser, 1999) on the wetland conservation and wise uses.

There are guidelines issued by Ramsar Convention Bureau (Ramser, 1999) on the wetland conservation and wise uses.

Sundarbans is also a coastal zone and its management should be in the framework of regional environment plan. The Integrated Coastal Zone Management (ICZM) should include all of the coastal resources of interest and areas of the activities that are capable of affecting the resources and water of the coastal zone (Post, 1996). The urgency is due to increasing conflict between man and nature, damage to productive ecosystem, increasing pollution, depletion of resources and loss of life and property.

Integrated Coastal Zone Management (ICZM) plan is in fact a long-range comprehensive regional environmental plan. The coastal zone is a complex environment, : It is a zone of interested dynamic relationship amongst the natural environment and its ecosystems, it is subject to societal demands for space and natural resources, and to external natural and human influences. (IOC, 1994).

Integration of the eco-socio system human activities and the anthropogenic components is required. Human activities in the exploitation and development of the area have profound impact on the areas including tidal swamps and water bodies. The problems are classified into three: (IOC, 1997).

Category I: Problems generated by the direct effects of anthropogenic activities on the total environment.

Category II: Problems generated by the effects of natural phenomena in human settlements.

Category III: Problems generated by the interaction of the multiple activities developed in coastal Zone.

There are certain criterions – with parameters (IOC, 1997)

Physical Criterion: Geomorphology, Coastal oceanography, Coastal climatologiy, Hydrography, Surface hydrology, Pedology, Hydrogeology, Geochemistry.

Biological Criterion : Biological wealth, Sites of reproduction, Living resources, Biodiversity.

Human Activity Criterion: Population, Developments and Uses, Management.

Environmental Status Criterion: Natural environment – Inputs, Monitoring, Event, Developments Human environment – Heritage, Conflicts, Activities.

The criteria are intended to quality the eco-socio system in each coherent management unit. Four stages have been identified (1) analysis of the problem (2) Definition of the coherent management units (3) Qualification of the coastal space (4) Indicator and indices and (5) Information systems (6) Orientations and proposals for objectives.

The World Bank and other international organizations have emphasized Regional Environmental Assessment within which restoration of canals, streams, estuaries and rivers can be taken up.

Case Studies in River Restoration

Several countries have now adopted restoration projects. Israel has initiated awards for best river restoration projects. London Rivers Association has done good works. Many urban rivers in USA have been restored and many nonprofit organizations have come forward. In Japan nature oriented river works have been executed – allowing natural process in river flow, restoring diversified shapes of river banks, restoring and old river course, recycling and preserving riparian zone etc. (TRCRD, 1999).

Conclusion

Worldwide campaign for cleaning and vitalization of rivers is giving results. The Ramsar Convention is trying to protect the wetlands and international organizations are also active. There are critical research needs and summary points are (Schwartz et al, 2004) are:

1. Improved understanding of fundamental geomorphic, hydraulic and ecological process.
2. Improved classification and assessment – watershed and streams.
3. Improved watershed management and assessment of vulnerability.
4. Development of regional hydraulic geometry.
5. Improved Engineering Design criteria.
6. Advancement of restoration design methods.
7. Development of restoration design framework.
8. Improved pre and post construction monitoring.

Following are some suggestions:

a) A comprehensive study with inventory on urban rivers, canals, wetlands etc. from physical, ecological, social and economical aspects.
b) A long-range regional environment plan for water basin, coastal zone etc with the urban water system.
c) Restoration of rivers, lakes, canals including dead rivers and dried up water bodies.
d) Development of water transport system and water front development linking the river with the city.
e) Preservation of natural and historic areas along the water bodies.
f) Measures to mitigate water logging and flooding of urban areas.
g) Abatement of pollution of surface water and underground water resources.
h) Removal of unauthorized encroachments and squatters from the river and canal front with alternative accommodation.
i) Productive use of rivers and wetlands by developing fisheries and aquatic species.
j) Impact analysis of construction of dams and bridges at upstream and downstream and highways flyovers and high-rise structures in the city.

Because of complexity of environmental issues, variety of project and involvement of different Governmental Departments, private companies, people and other stakeholders an annual environmental audit is necessary within a framework of a regional environmental management plan. A public participatory process is also essential.

References

Barbier, Edward B. et al. (1997): Economic Valuation of Wetlands. Ramsar Convention Bureau, Gland, Switzerland.

Batisse, Michel (1997): 'Biosphere Reserves' in Environment Vol. 39, No.5, June, 1997.

Choudhuri, AB and Choudhury A (1994): Mangroves of the Sundarbans, Vol. One, India. IUCN The World Conservation Union, Bangkok.

Champion HG and Seth SK (1968): A revised survey of forest types of India. Govt. of India publication, New Delhi.

Curtis SJ (1993): Working plans for forests of Sundarbans Division. Bengal Government Press, Vol. 1 & 2, Calcutta.
Department of Environment (1999): Report on the Status of Environment in West Bengal, Dept. of Environment, Govt. of West Bengal, Calcutta. Chapter 22. Current Efforts.

Gracie, James and Clar, Michael (2004): Issues in streams in restoration and protection in Michael Clar et al, edited "Protection and Restoration of urban and rural streams " , American Society of Civil Engineers (ASCE), Va.
Hemphill, R.W. and Bramley, M.E. (1989): Protection of River and Canal Banks, Butterworths, Kent, U.K.
Intergovernmental Oceanographic Commission (1994): International Workshop on Integrated Coastal Zone Management. Report No. 114, Unesco, Paris.
Intergovernmental Oceanographic Commission (1997): Methodological guide to integrated coastal zone management, Unesco, Paris.
Larsen, P (1996): Restoration of River Corridors. German experiences in Geoffrey Petts and Peter Calow, edited " River Restoration " , Blackwell, Oxford.
McCully, Patrick (1996): Silenced Rivers (The ecology and politics of large dams). Zed Books. London.
Mandal, AK and Ghosh RK (1989): Sundarban, (A Socio bio-ecological study), Book land Pvt. Ltd. Calcutta.
Omara-Ojunga PH (1992): Resource Management in Developing Countries, Harlow, Longman. Referred in UNCHS (1995).
Post, Jan C and Carl G Lundin, ed (1996), Guidelines for Integrated Coastal Zone Management. ESD studies and monographs no. 9. The World Bank, Washington D.C.
Ramsar (1999): Resolutions and Recommendations 7th meeting, Convention on Wetlands, San Jose, May 1999.
Riley, Ann L. (1998): Restoring Streams in Cities, a Guide for Planners, Policymakers, and Citizens, Island Press, Washington D.C.
Schwartz, John S. et al. (2004): "Research needs for improvement of principles and practices in urban stream restoration" in Michael Clar, et. al. edited " Protection and restoration of urban and rural streams", American Society of Civil Engineers (ASCE), Va.
TRCRD, Technology and Research Center for Riverfront Development (1999): Nature oriented River works – brochure.
UNCHS (1999): Issues in the intergraded Planning and management of River / Lake basins and coastal areas, UNCHS, Nairobi.
UNEP (2002): Guidelines for the Integrated Management of the Watershed, Phytotechnology and Ecohydrology, Division of Technology, Industry and Economics, Osaka and Shiga, Japan.
Zalewski, M. (2000): Ecohydrology the scientific background to use ecosystem properties as management tool toward sustainability of freshwater resources. Guest editorial Ecological Engineering 16: 1- 8.