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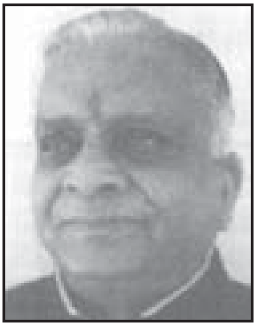
CONTENTS



Chairman's Message

Wetlands form important resources in the State of Rajasthan and as such with this view in mind the Social Policy Research Institute with the support of Ministry of Environment and Forests, Government of India organized a National Seminar on the subject "Wetlands and their Conservation: Strategies and Policy Options with special reference to Rajasthan" on 3rd and 4th October, 2007.

Wetlands in Rajasthan being inland types, geographically enveloped by arid and semi-arid conditions, have developed features to adjust with the shortage of water, brackish water, erratic rainfall and recurring drought conditions.

Two wetlands with the status of international Ramsar sites in Rajasthan viz., Keoladeo National Park and Sambhar Lake, while supporting remarkable habitat for grassland and birds/reptiles, have deteriorated over a period of time leading to problems for their very survival. Several other wetlands eg. Jalmahal, Ramgarh Dam near Jaipur and lakes in the environ of Jodhpur, Ajmer, Udaipur etc. are also facing similar threats. It is observed that these water shed areas are being converted into commercial lands and recharge or smooth flow of water has been blocked.

The seminar was organized in a way that it remained interactive through out. Strategy and policy options for integrated development of the wetlands and its conservation, role of wetlands in hydrological cycle, groundwater recharges, erosion control, maintenance of wetlands for sustenance of genetic diversity, conservation of bio diversity, regulatory mechanisms and integrated watershed management were subjects which were discussed in details.

The views and outcome of the seminar have been brought out in this volume. It is very satisfying that the Seminar fulfilled the aims with which it was planned. I am sure that the knowledge gained during the seminar would provide food for thought to scientists and administrators engaged in solving the problems related to conservation and management of wetlands.

Shiv Charan Mathur

FROM THE CHIEF EDITOR'S DESK

This is the fourth issue of the SPRI VISION. It devotes itself on the problems of Wetlands with particular reference to Rajasthan. The papers included in this issue were presented during a National Seminar on "Wetlands and their Conservation: Strategies and Policy Options with special reference to Rajasthan" held at the Institute on 3rd/4th October, 2007. The issue has been divided into five parts:

a) Strategies and Policy Options

b) Engineered Wetlands

c) Environment and Related Issues

d) Management and Conservation Issues

e) The Outcome of the Seminar

The participants in the Seminar included policy makers, technocrats and activists. A number of recommendations were made during the two days of the Seminar which have been summed up in the last section of this issue. I hope the issue will not only provide useful information to its readers but may also lead to policy changes as well as building up of public awareness on the crucial issues deliberated upon during the seminar.

Dr. Sudhir Varma

A Word of Thanks

The Institute is grateful to the Ministry of Environment and Forests, New Delhi for financially supporting the organization of the seminar. Our special thanks are to the Hon'ble Shri Namo Narain Meena, Minister of State of Environment and Forests for inaugurating the seminar and enriching the knowledge of participants by his address. We are thankful to Shri V L Chopra, Member of Planning Commission for his key note address and thought provoking ideas and his subsequent visit to the Sambhar Lake for a first hand knowledge of the condition of this Ramsar site. The papers presented in the seminar were of high quality and the deliberations have led to concrete recommendations. We thank all our speakers for enriching knowledge of the participants and for being with us by taking time out of their busy schedule.

STATUS PAPER

Wetlands: Status and Management Strategies with Special Reference to Rajasthan

By Dr. B.P.Shreevastava[1] *& Dr. Ashwini Kumar*[2]

INTRODUCTION:

Wetlands are ecotones or transitional zone between permanently aquatic and terrestrial ecosystem defined as "*wetlands are interface between truly terrestrial ecosystems and aquatic systems making them inherently different from each other yet highly dependent on both*". They represent areas of marsh, permanent or temporary water storage which may be brakish or salt including areas of marine water, the depth of which at low tide is six meters.

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica.

For regulatory purposes under the Clean Water Act, the term wetlands means "*those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted*

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for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Wetlands do more than provide habitat for plants and animals in the watershed. When rivers overflow, wetlands help to absorb and slow floodwaters. This ability to control floods can alleviate property damage and loss and can even save lives. Wetlands also absorb excess nutrients, sediment, and other pollutants before they reach rivers, lakes, and other waterbodies. They are great spots for fishing, canoeing, hiking, and bird-watching, and they make wonderful outdoor classrooms for people of all ages.

RESOURCES OF WETLANDS

Globally wetlands are estimated to occupy nearly 6.4% of the earth surface. Of those wetlands, nearly 30% is made up of bogs, 26% fans, 20% swamps and 15% flood plains. Wetland ecosystem constitute an integral resource for cultural and biodiversity landscape measuring 34 million hectares in India. A wide variety of wetlands exist in our country in consequence to its geographic situations in the globe and climatic conditions.

CHARACTERISTICS OF WETLANDS:

Wetlands are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season. Water saturation (hydrology) largely determines how the soil develops and the types of plant and animal communities living in and on the soil. Wetlands may support both aquatic and terrestrial species. The prolonged presence of water creates conditions that favor the growth of specially adapted plants (hydrophytes) and promote the development of characteristic wetland (hydric) soils.

GEOGRAPHICAL AND BIODIVERSITY CHARACTERISTICS

The geographical area determines the characteristics of wetlands, and biodiversity of a particular area is highly specific to the region. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica.

TYPES OF WETLANDS:

Two general categories of wetlands are recognized:

Coastal or tidal wetlands and inland or non-tidal wetlands**.** Rajasthan has mainly Wetlands of the later "inland" category.

WETLANDS IN RAJASTHAN:

The Inland Wetlands of state of Rajasthan have special significance with one third of its geographical area enveloped by arid and semi-arid conditions. It suffers from poor to erratic rainfall, brackish water and recurring drought conditions with its unique sustainable features adjusting with shortages of water. The annual normal rainfall of the state is 575 mm, out of which 75 to 95% of rainfall mostly precipitates in the monsoon period i.e. from 1st June to 30th September. The normal rainfall of the state for monsoon period is 533 mm.

Although Rajasthan has two Ramsar wetland sites of international importance viz Keoladeo National Park, Bharatpur and Sambhar but there are small and big water bodies amounting to thousands in number of the types described below:

a) **Village wells/Personal 'tanka':** Each household in villages enjoyed a personal tank (called 'tanka' in local parlance) which was at a corner of house and developed in a manner that rain water would automatically flow into it to recharge its quantity. If it was short of water, people would fetch water from the village reservoir or a well to replenish it.

b) **Village 'nadi' (reservoir):** Each village had one or more such water body. It was rainwater deposited in depressions around the village. It was for common use by all, people and cattle. The village body ensured that such an open water body was respected.

c) **Tanks or Dams:** They were created by princes who ruled the state in those days, and were for irrigation purposes as well. More such tanks were created by the government after independence.

Further, the aforesaid types in Rajasthan could be classed as:

(a) River system, (b) Playas, and (c) Man-made Reservoirs

(a) **River system:** There are only two perennial rivers in Rajasthan: Chambal, and Mahi though there are numerous seasonal rivers. Both are of far reaching benefits to people. Each one has been adequately dammed and network of canals developed for irrigation benefits at distant places. Their ecological quantification is, however, yet to be attempted

(b) **Playas:** The important playas are confined to western Rajasthan including the Ramsar Site of Sambhar Lake. Other important palayas are: Kuchaman, Deedwana, Rewasa, Kanod, Baramsar, That etc.

(c) Man-made reservoirs

(i) These are generally confined to the eastern part of the State and were necessitated by the ephemeral nature of water system. They vary in size and depth of water in various ways. The prominent ones are:

1. Rana Pratap Sagar Dam, Chittorgarh
2. Raj Samand, Rajsamand
3. Sadarsamand, Jodhpur
4. Guda, Bundi
5. Jawai, Pali
6. Gambhiri, Chittorgarh
7. Meja, Bhilwara
8. Morel, Sawai Madhopur
9. Parvati, Dholpur etc.

(ii) The characteristic feature identified for enumerating such water bodies is based on dynamics of aquatic life, coupled with the vegetation around them that supports the avifauna. The prominent reservoirs are tabulated in Table 1.

RAMSAR SITES OF RAJASTHAN:

1. **Keoladeo National Park, Bharatpur:** This 29 sq km park is a world heritage site and is classified as a national park. It is an important

habitat (aquatic, grassland, woodland and scrub) for birds of migratory and resident types. In addition, belonging to mammals, amphibians and reptiles also form a big number. Lack of administrative control on several factors has made this site face a grave threat to its survival, the main reason being non-availability of water flowing in the wetland. This appears to be due to the construction of Panchana dam stopping flow of Gambhiri river which provided such water to it since ages. Though alternative sources are being proposed by the State Government by Chicksana canal and Goverdhan dam, however these are both at discussion level and as such the fate of the park is uncertain.

2. **Sambhar Lake:** This wetland measuring around 200 sq km of water in the environ of Sambhar is by the dint of monsoon flow through Medha and Roopangarh rivers. Both of these are blocked by innumerable salt works which have mushroomed all around the lake resulting in the extraction of water and scrapping of lake surface. These have caused the lake to remain dry for most of the time in the year and whatever water is received post monsoon season is drained out by the public sector salt manufacturing company located there.

There are contradictory statements by each of these works which the administration has not been able to resolve probably because of the issue of ownership of this important wetlands which once has supported the biodiversity of this region.

BIODIVERSITY RELATED TO WETLANDS SPECIFIC TO RAJASTHAN:

Being a wetland ecosystem which supports the flora and fauna of both the types, the loss of wetlands results in considerable depletion and disappearance of biodiversity. As an example the wetlands of Ramgarh were quite rich in Pteridophytes like *Equisetum, Marsilea* but due to disappearance of streams and the wetlands these two plants are now not common in Ramgarh area. *Utricularia* which was common to the streams, *Azolla* a fern, and *Polygonum* a water plant of shallow waters are all disappearing from the Ramgarh lake and its stream areas. Similarly there is considerable loss of biodiversity as monitored from the satellite pictures in Ajmer region especially in the Pushkar and Budha Pushkar areas. There can be several such examples and even loss of halophytes from the Sambher lake area is glaring. Keoladeo National Park is yet another wetland depleting in fauna and flora exhorbitantly.

Besides the biodiversity loss there is also considerable loss of fauna particularly avifauna:

a) Threatened Breeding Avifauna. Following are the resident bird species which are under severe threat (BirdLife International criterion) and have been observed breeding at some of the wetlands listed in this report:

    1. Blackbellied Tern
    2. Blackheaded Ibis
    3. Blacknecked Stork
    4. Painted Stork
    5. Indian Skimmer
    6. Sarus Crane

b) Threatened Migrants Avifauna. Following are the migrant species under severe threat (BirdLife International criterion) reported at some of the wetlands listed in this report:

    1. Siberian Crane
    2. Marbled Teal
    3. Dalmatian Pelican
    4. Lesser Flamingo
    5. Ferruginous Duck.

c) Waterfowl observed in the State (breeding* and non-breeding). List of this type of Avifauna is given in Table 2.

MANAGEMENT OF WETLANDS:

Management is the manipulation of an ecosystem to ensure maintenance of all functions and characteristics of the specific wetland type. The loss or impairment of a wetland ecosystem is usually accompanied by irreversible loss in both the valuable environmental functions and amenities important to the society. Appropriate management and restoration mechanisms need to be implemented in order to regain and protect the physical, chemical, and biological integrity of wetland ecosystems. In this context, a detailed study of wetland management and socio-economic implications is required from biological and hydrological perspectives. Largely speaking they are related to problems such as:

i. Hydrologic alterations, which include changes in
   - The hydrologic structure
   - Functioning of a wetland by direct surface drainage, de-watering by consumptive use of surface water inflows
   - Unregulated draw down of unconfined aquifer from either groundwater withdrawal or by stream channelization for various human activities.

ii. Increased sedimentation, nutrient, organic matter, metals, pathogen, and other water pollutant loading from
   - storm water runoff (non-point source)
   - wastewater discharges (point source).

iii. Atmospheric deposition of pollutants into these lakes mainly by the vehicular and industrial pollution both from within the cities and from the suburban industrial complexes.

iv. Introduction or change in characteristic wetland flora and fauna (exotic) as a result of change in the adjacent land uses deliberately or naturally changing the water quality, and so forth.

MANAGEMENT/ RESTORATION STRATEGIES OF WETLANDS

Management of wetland ecosystems involving activities to protect, restore, and manipulate require intense monitoring and increased interaction and co-operation among various agencies such as concerned State departments for environment, soil, agriculture, forestry, urban planning and development, natural resource management; NGO's; citizen's groups; research institutions; and policy makers.

Wetland management has to be an integrated approach in terms of planning, execution, and monitoring, requiring effective knowledge on a range of subjects from issues related to ecology, hydrology, economics, watershed management, and local expertise, people, planners and decision makers. All these would help in understanding wetlands better and evolve a more comprehensive and long-term conservation and management strategies. Some of the suggested strategies in this regard are:

1. Involving protection of wetlands by regulating inputs, using water quality standards promulgated for wetlands and such inland surface waters to promote their normal functioning from the ecosystem perspective.
2. Providing multiple values for suburban and city dwellers in urban wetlands.

The important factors to be considered for developing a management strategy are:

I. Necessity of immediate need to create a database on the wetland types, morphological, hydrological, and biodiversity data surrounding land use, hydrogeology, surface water quality, and socio-economic dependence.

II. Conducting regular water quality monitoring of surface water, groundwater, and biological samples. Such programs help in formulating a comprehensive restoration, conservation, and management program.

III. Pollution Prevention Program through environmental awareness programs.

IV. Creating buffer zones for wetland protection, limiting anthropogenic activities around the demarcated corridor of the wetland.

Thus the restoration programme should mandate all aspects of ecosystem and should be based on:

- Wetlands that could recover without any intervention.
- Wetlands that could be restored close to their former condition to serve their earlier functions, considering cost involved, technical

review of the restoration plan, and based on the goals and objectives set.

- Wetlands that are not restorable to any degree viably.

BENEFITS OF WETLANDS

Wetland systems directly and indirectly support millions of people, providing goods and services to them. They contribute to important processes, which include the movement of water through the wetland into streams; decay of organic matter; release of nitrogen, sulfur, and carbon into the atmosphere; removal of nutrients, sediment, and organic matter from water moving into the wetland; and the growth and development of all organisms that require wetlands for living.

The direct benefits of wetlands are the components/products such as fish, timber, recreation, and water supply. The indirect benefits arise from the functions occurring within the ecosystem such as flood control, ground water recharge, and storm protection.

Wetlands have the capacity to retain excess floodwater during heavy rainfall that would otherwise cause flooding. By retaining flood flows, they maintain a constant flow regime downstream, preserving water quality and increasing biological productivity for both aquatic life as well as human communities of the region.

Periodically inundated wetlands are very effective in storing rainwater and are the primary source for recharging ground water supplies. The extent of groundwater recharge depends on the soil and its permeability, vegetation, sediment accumulation in the lakebed, surface area to volume ratio, and water table gradient.

Wetlands retain nutrients by storing eutrophic parameters like nitrogen and phosphorus, flooding waters in vegetation, or accumulating them in the sub-soil, thus decreasing the potential for eutrophication and excess plant growth in receiving waters. They also help in absorbing sewage and in purifying water supplies.

Apart from this, the socio-economic values, through water supply, fisheries, fuel wood, medicinal plants, livestock grazing, agriculture, energy resource, wildlife resource, transport, recreation and tourism, and so forth, are significant. The functional properties of a wetland ecosystem clearly demonstrate its role in maintaining the ecological balance.

Stress is laid world over for safeguarding the remaining peat swamps forests of wetlands specially because the mechanism to prevent release of large quantities of previous CO_2 stock currently stocked in wetlands (especially peatlands) is directly related to tackling climate change.

CONCLUSION

1) Wetland ecosystems are interconnected and interactive within a watershed.

2) Dewatering of wetlands by consumptive use of surface water inflow destroys the existing ecosystem.

3) The exploratory survey and physico-chemical and biological characterization of lakes indicate that lakes are polluted mainly due to sewage from domestic and industrial sectors and unorganized human activities.

4) The restoration program with an ecosystem perspective through Best Management Practices helps in correcting point and non-point sources of pollution wherever and whenever possible. This along with regulations and planning for wildlife habitat and fishes helps in arresting the declining water quality and the rate in loss of wetlands. These restoration goals require intensive planning, leadership, and funding, with active involvement from all levels of organization etc.

TABLE 1: Man made Reservoirs

1. **Ajmer** Ramsar, Ana Sagar, Kamsar, Aheran, Dund, and Phulsagar (Kishangarh), Phulsagar (Beawar)
2. **Alwar** Jaisagar, Mangalsar, Mansarovar, Jaisamand
3. **Baran** Ratai (Shahbad). The Kalisindh and Parvati rivers
4. **Barmer** Kagoda (near Agawada village)
5. **Banswara** Mahi reservoir, Suwania, Haro, Talwara. Mahi river supports breeding.
6. **Bharatpur** Keoladeo National Park, Ajan Bund, Bund Baretha
7. **Bhilwara** Meja
8. **Bikaner** Indira Gandhi Nahar and RDs
9. **Bundi** Guda, Bardha, Kanaksagar, Dhaneshwar, Abhaipura.
10. **Chittorgarh** Rana Pratap Sagar, Jawahar Sagar, Bhopalsagar, Orai, Gambhiri, Menal, Talaia and Mahi
11. **Churu** Tal Chhapar
12. **Dausa** Kalakho, Sainthal
13. **Dholpur** Urmila Sagar, Talab-I-Shahi, Ramsagar, Parvati Bund.
14. **Dungarpur** Lodeshwar and Lakshman Sagar
15. **Hanumangarh** Badopal and IG Nahar
16. **Jaipur** Phulera, Chhaparwada
17. **Jaisalmer** Kanod, Baramsar and That
18. **Jodhpur** Agolai
19. **Karauli** Panchana
20. **Kota** Alnia, Umaid Sagar, Kota Barrage, Udupi and Chambal river.
21. **Nagaur** Deedwana, Kuchaman
22. **Pali** Jawai, Sardar Samand, Hemawas, Kharda
23. **Raj Samand** Raj Samand, Kumbhalgarh, Nand Samand (?)
24. **Sawai Madhopur** Morel, Deel Sagar, Bhagwatgarh, Surwal, Devpura, Mansarovar.
25. **Sikar** Rewasa
26. **Sirohi** Oda, West Banas and Dantiwara
27. **Tonk** Tordi Sagar, Chandsen, Galwania, Galwa, Bisalpur
28. **Udaipur** Mataji ka Khera, Sei, Udaisagar, Fateh Sagar, Pichhola-Sarup Sagar, Badi, Badgaon, Vallasbhnagar, Sad Samand

TABLE 2

Avifauna of Rajasthan

1.	Little Grebe*	63.	Mallard
2.	Great Crested Grebe	64.	Spotbilled Duck*
3.	Blacknecked Grebe	65.	Pintail
4.	White Pelican	66.	Garganey
5.	Spotbilled Pelican	67.	Shoveler
6.	Dalmatian Pelican	68.	Marbled Teal (facing severe threat)
7.	Great Cormorant*	69.	Redcrested Pochard
8.	Indian Shag*	70.	Common Pochard
9.	Oriental Darter* (facing threat)	71.	Baer's Pochard
10.	Yellow Bittern*	72.	Ferruginous Duck (facing severe threat)
11.	Great Bittern	73.	Tufted Duck
12.	Little Bittern	74.	Smew
13.	Cinnamon Bittern*	75.	Common Crane
14.	Black Bittern*	76.	Sarus Crane* (facing severe threat)
15.	Blackcrowned Night Heron*	77.	Siberian Crane (on verge of extinction)
16.	Pond Heron*	78.	Demoiselle Crane
17.	Cattle Egret*	79.	Water Rail
18.	Little Green Heron*	80.	Baillon's Crake
19.	Little Egret*	81.	Whitebreasted Waterhen*
20.	Intermediate Egret*	82.	Water Cock (Kora)
21.	Great Egret*	83.	Moorhen*
22.	Purple Heron* (facing threat)	84.	Purple Moorhen*
23.	Grey Heron*	85.	Coot
24.	Painted Stork* (facing severe threat)	86.	Pheasant-tailed Jacana*
25.	Openbilled Stork* (facing threat)	87.	Bronzewinged Jacana*
26.	Black Stork	88.	Painted Snipe*

27. Woollynecked Stork* (facing threat)
28. White Stork
29. Blacknecked Stork* (facing severe threat)
30. Lesser Adjutant Stork* (facing severe threat)
31. Blackheaded (White) Ibis * (facing threat)
32. Black Ibis*
33. Glossy Ibis*
34. Greater Flamingo
35. Lesser Flamingo (facing threat)
36. Lesser Whistling Teal* (facing threat)
37. Greylag Goose
38. Barheaded Goose
39. Lesser Whitefronted Goose (facing threat)
40. Ruddy Shelduck (Brahminy)
41. Common Shelduck
42. Comb Duck (Nukta)* (facing threat)
43. Cotton Teal*
44. Eurasian Wigeon
45. Falcated Teal
46. Gadwall
47. Common (Greenwinged) Teal
48. Black Bittern*
49. Common Redshank
50. Marsh Sandpiper

89. Blackwinged Stilt*
90. Great Stone Plover*
91. Oriental Pratincole
92. Little Pratincole*
93. Northern Lapwing
94. River Lapwing*
95. Yellow-wattled Lapwing* (declining)
96. Sociable Lapwing (facing severe threat)
97. White-tailed Lapwing
98. Greyheaded Lapwing (declining)
99. Redwattled Lapwing*
100. Pacific Golden Plover
101. Grey Plover
102. Little Ringed Plover*
103. Kentish Plover
104. Mongolian Plover
105. Greater Sand Plover
106. Blacktailed Godwit
107. Bartailed Godwit
108. Curlew
109. Spotted Redshank
110. Common Snipe
111. Jack Snipe
112. Little Stint

51. Greenshank
52. Green Sandpiper
53. Wood Sandpiper
54. Terek Sandpiper
55. Common Sandpiper
56. Ruddy Turnstone
57. Rednecked Phalarope
58. Woodcock
59. Whitewinged Black Tern

61. Gull-billed Tern
62. Indian River Tern*

113. Temminck's Stint
114. Dunlin
115. Curlew Sandpiper
116. Broadbill Sandpiper
117. Ruff
118. Brownheaded Gull
119. Blackheaded Gull
120. Whiskered Tern
121. Blackbellied Tern* (facing severe threat)
122. Little Tern*
123. Indian Skimmer* (facing severe threat)

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WETLANDS MANAGEMENT AND CONSERVATION: POLICY ISSUES & STRATEGY OPTIONS

i. Inaugural speech by Shri Namo Narain Meena, Hon'ble Minister of State, Ministry of Environment & Forests, Government of India.

ii. Keynote Address by Shri V L Chopra, Member, Planning Commission

iii. Presentation by Dr. C L Trisal, Director, Wetland International, South Asia

iv. Presentation by Shri Ashok Jain, Principal Secretary, Ministry of Environment & Forests, Government of Rajasthan

Wetlands and Their Conservation: Strategies and Policy Options with Special Reference to Rajasthan - Inaugural Speech on October 3, 2007 at Jaipur Rajasthan

*By Namo Narain Meena**

1. It is matter of great pleasure for me to be with you on the eve of National Seminar on "Wetlands and their conservation: Strategies and Policy Options with special reference to Rajasthan", being organized by Social Policy Research Institute, Jaipur. During the 20th century while the world's population tripled, freshwater withdrawal increased 6 times, reflecting massive urbanization, growing dependence on irrigated agriculture and rising standards of living. 2.3 billion people live around the rivers where there are frequent water shortages and 1.7 billion of these people live in the areas where water is scarce. In addition, 1.1 billion people do not have access to safe drinking water and as such 3 million people die every year, many of them children, due to various water borne diseases.

2. Wetlands are lands, transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by the shallow water. They are classified into different types based on their origin, vegetation, nutrient status, thermal characteristics, like Glaciatic wetlands (Tso Morari in Jammu and Kashmir, Chandertal in Himachal Pradesh), Tactonic

* Hon'ble Minister of State, Ministry of Environment & Forests, Government of India.

Wetlands (Nilnag in Jammu and Kashmir, Khajjiar in Himachal Pradesh, and Nainital and Bhimtal in Uttaranchal), Oxbow Wetlands (Dal, Wullar in Jammu and Kashmir and Loktak lake in Manipur and Deepar Chilika in Orissa), Crater wetlands (Lonar lake in Maharashtra), Salt water wetlands (Pangong Tso in Jammu and Kashmir and Sambhar in Rajasthan), Urban wetlands (Dal lake in Jammu and Kashmir, Nainital in Uttaranchal and Bhoj in Madhya Pradesh), Ponds/Tanks, man-made wetlands (Harike in Punjab and Pong Dam, Himachal Pradesh), Reservoirs (Idukki, Hirakud dam, Bhakra-Nangal, Govind-Sagar), Mangrove (Bhitarkanika, Orissa), Coral reefs (Lakshadweep), Creeks (Thane Creek, Maharashtra).

3. Most widely used definition is of Ramsar Convention as given below:

   "Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres."

4. Wetlands are seriously threatened from encroachment, reclamation through drainage and landfill, pollution (discharge of domestic and industrial effluents, disposal of solid waster), hydrological alterations (water withdrawal and inflow changes) and over-exploitation of their natural resources. These impacts are causing significant loss of biodiversity and serious disruption in goods and services provided by wetlands.

5. In order to ensure the health of wetlands, we have to find ways to use them wisely. By using wetland resources wisely, we not only help them conserve but also get economic benefits. A shining example is of East Kolkata wetlands which produces 11000 tons of fish and 5500 tons of vegetables per year as well as provide clean water for paddy fields after treating sewage.

6. To protect and conserve wetlands, there are a number of laws in existence like Forest Act, 1927; Forest Conservation Act, 1980; the Wildlife Protection Act, 1972; the (Prevention & Control of Pollution) Act, 1974; the Water (Prevention & Control of Pollution) Cess Act,

1977 and the Umbrella provision of Environment (Protection) Act, 1986. There is no exclusive legal framework for wetland conservation in the country. As such, we need to have some regulatory mechanism to prevent their unacceptable degradation like reclamation & conversion to non-wetland uses, discharge of raw sewage & un-treated effluents, water inflow and withdrawals, non optimal excess resource extraction (e.g. fishing) etc.

7. Realizing the importance of wetlands National Wetland Conservation programme has been launched in my Ministry, where 100% assistance is given to the concerned State Governments for identified wetlands under National Wetland Conservation Programme for activities like data collection and survey, identification of problems, mapping of wetlands, landscape planning, hydrology, eutrophication abatement, aquatic weed control, wildlife conservation, fisheries development, environmental awareness and research on various aspects of wetland processes and functioning. Maintenance and development will be the responsibility of the State Govt. as all conservation efforts need to be sustained even after the completion of the activities for conservation of a wetland in question.

8. Wetlands are threatened due to global warming and climate change. High altitude wetlands, which are considered as fresh water towers of the world, assume more significance as they effect wetlands down stream. Water is becoming a scarce commodity day by day and role of wetlands as re-charging of aquifers assumes great significance. As such, we have to concentrate our efforts in better ways for conserving them through proper institutional mechanism, adequate inventorization, capacity building, collecting appropriate baseline data on research, sharing of information, establishing proper synergy and linkages, and blending traditional knowledge with latest scientific techniques.

9. Some of the significant steps taken by the Ministry include identification of major wetlands for conservation on the basis of their importance, ecological characters, representativeness, biodiversity, cultural & religious importance, supporting indigenous fish, important source of food & fodder, recreation &

eco-tourism.

10. Taking into consideration importance of wetlands, National Environment Policy approved by Cabinet recognizes the numerous ecological services rendered by wetlands. The Environmental Policy identifies the following six-fold Action Plan.

    1) Set up a legally enforceable regulatory mechanism for identified valuable wetlands to prevent their degradation and enhance their conservation. Develop a national inventory of such wetlands.

    2) Formulate conservation and prudent use strategies for each significant catalogued wetland, with participation of local communities, and other relevant stakeholders.

    3) Formulate and implement eco-tourism strategies for identified wetlands through multi-stakeholder partnerships involving public agencies, local communities and investors.

    4) Take explicit amount of impacts on wetlands of significant development projects during the environmental appraisal of such projects; in particular, the reduction in economic value of wetland environmental services should be explicitly factored into cost-benefit analysis.

    5) Consider particular unique wetlands as entities with 'Incomparable Values', in developing strategies for their protection.

    6) Integrate wetland conservation, including conservation of village ponds and tanks, into sectoral development plans for poverty alleviation and livelihood improvement, and the link efforts for conservation and sustainable use of wetlands with the ongoing rural infrastructure development and employment generation programmes. Promote traditional techniques and practices for conserving village ponds.

11. On the basis of criteria recognized by international Ramsar Convention, 1971, some of the major wetlands have been identified for conservation in the country. These were 27 in 2004 which have risen to 94 in 2006 covering 23 States and one UT. So far, total amount of Rs. 58.28 crore has been released for conservation and

management of wetlands overall till date. Projections for Eleventh Five Year Plan for conservation and management of wetlands has been enhanced to Rs. 90 crore. For more integrated approach, the three major schemes, viz., Conservation of wetlands, Mangroves & coral reefs and National Lake Conservation Plan are being integrated under "Conservation of Aquatic Ecosystems" to make it more cohesive and inter-disciplinary in nature.

12. From Rajasthan two wetlands viz Sambhar and Keoladeo National Park have been identified as Ramsar sites of international importance. **Sambhar** wetland has been identified for conservation and management under National Wetland Conservation Programme and is the most important wintering area for Lesser and Greater Flamingoes. Financial assistance of an amount of Rs. 300.45 lakhs has been released by Govt. of India to the State Govt. for its various catchments area treatment activities like survey & demarcation, contour bunding, drainage line treatment, check dams, silt detention structures, gabion structures, vegetative measures, afforestation, etc.

    Keoladeo Ghana National Park is a wetland of international repute and also a World Heritage site. This wetland is wintering area for many resident and migratory birds and has been the only wintering site for the central population of rare and endangered Siberian crane. Ministry provides financial and technical assistance to the State Govt. for strengthening protection, habitat enrichment, improvement of infrastructure and staff, veterinary care, eco-development, etc. An amount of Rs. 158 lakhs has been released during the last five years for establishment of boundary wall around the sanctuary, removal of unwanted vegetation, eco restoration, improving the road network, strengthening protection chokies, augmenting water supply etc.

    Rajasthan being a draught prone area there is an urgent need for more water harvesting structures, protection of all wetlands irrespective of their size as their role for recharging aquifers is important for water storage capacity. I will urge Rajasthan state govt. for identifying more wetlands under national wetland conservation programme for managing their water resources. All these issues need to be deliberated at length at various technical sessions so that some meaningful solutions emerge out of the deliberations for conservation of wetlands in the country in general and wetlands of Rajasthan in particular.

13. At the international level, our role has been well appreciated. India is the only country which has the most heterogeneous mix of 25 wetlands identified as Ramsar sites. These include high-altitude wetlands, mangroves, estuaries, oxbow type of wetlands, urban and rural wetlands and so on. Through designating a Ramsar site, we promote conservation and wise use of wetlands through management action plans, which is implemented with the participation of all stakeholders. If the site is under threat, we can put it under Montreaux Record. Ramsar Conservation Award to India in 2002 for ecological interventions in Chilka wetland has indeed made us proud of our conservation efforts. We not only achieved this feat but also made Chilka wetland to come out of Montreaux Record. India organized Asian wetland symposium in February 2005 at Bhuvneshwar, attended by 34 countries from Asian region. Our country also organized a capacity building workshop on High altitude wetlands in Himalayas at New Delhi during June, 2006 in collaboration with ICIMOD and WWF- India. We also organized a meeting of Board of Directors of Wetland International in India in October 2005 which is a partner organization of Ramsar Convention, which was attended by 23 countries.

14. The Social Policy Research Institute has been engaged in working in the field of health, education and watershed development, particularly to sharpen the effectiveness and impacts of public and social policies, by uncovering bottlenecks for better understanding, cooperation and promotion for ultimate realization of such policies. I am sure that deliberations, in general and Rajasthan in particular will be taken care of. Thematic areas of cultural and ethical aspects, poverty alleviation for communities depending on wetland resources for their livelihood, problems of water harnessing and long term conservation planning are to be addressed in such a manner as to yield tangible results. I wish all success for the workshop.

“Wetlands and their Conservation: Strategies and Policy Options” – Key Note Address

*By Dr V L Chopra**

It gives me great pleasure to address this National Seminar on “Wetlands and its Conservation: Strategies and Policy options”, and share with you some thoughts about the Wetlands and their importance in India.

Wetlands are among the earth’s important freshwater resources. Wetlands provide many services and commodities to humanity. Each wetland is ecologically unique and is recognised for its economic, cultural, scientific and recreational value. Wetlands perform numerous valuable functions such as water storage and conservation; protection from storms and floods; recharge of ground water; purification of water; support to fisheries; agriculture and wildlife resources; transport; recreation, etc. For various reasons, however, wetlands are under severe threat currently.

Wetlands in Asia have traditionally provided people with ecological security and livelihood support through their varied processes and functions. Increasing population pressures and receding awareness about their relevance and importance have led to degradation of wetlands. Their increased vulnerability has caused serious deprivation for local users. There is thus, an urgent need to address the challenges posed by unbalanced sectoral development on the one hand and poverty and

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inadequate capacity for effective restoration and management of wetlands on the other.

The Ramsar Convention had highlighted the pivotal role of wetland ecosystems and identified them as the starting point for all integrated water management strategies. Sustainability of development can be ensured only by maintaining health of the wetlands which are the source of freshwater, besides being the main stay of livelihood of surrounding rural population.

India is richly endowed with wetlands. These range from the high-altitude lakes of the Himalayas to floodplain wetlands of major river systems and their extensive network of tributaries draining from the Indian landmass in all directions. They are fragile ecosystems susceptible to damage even with minor changes in their surroundings. They are threatened due to inadequate water holding capacity, excessive withdrawal, pollution due to raw sewage and sullage, industrial effluents, eutrophication, leached fertilizers and insecticides. The imposed excesses necessitate restoration and formulation of conservation strategies for sustainable management of wetlands.

The degradation of wetlands caused by unsustainable development should be urgently halted and reversed, and knowledge based strategies and techniques adopted for conservation and restoration of wetland ecosystems and livelihood improvement of communities. The cultural values of wetlands which have great relevance to communities around wetlands have to be recognized and integrated into wetland management practices.

Innovative ecosystem based approaches have to be adopted to promote wetland conservation and management to support sustainable livelihoods. There is need to promote biodiversity conservation and sustainable use of wetland resources. Traditional knowledge and wisdom of local people can greatly help this effort. Documentation and respect for cultural heritage and values justifies creation of a platform for conservation and management. Supporting local livelihoods through traditional knowledge base and eco-enterprises, including eco-tourism, and promoting public-private partnerships, can add value to wetland products and help in generating additional income and reducing pressure on wetland resources

Adopting wetland conservation and management policies, plans and strategies into sectoral development planning at all levels is necessary to ensure sustainable development. Identifying, promoting, and replicating successful case studies and pilots of partnerships for wetland management and conservation and disseminating these examples at local, national and regional levels will help in creating awareness and promote change of attitudes and perceptions towards sustainable wetland management. Developing, strengthening and promoting of capacity building programs for wetland managers, policy makers, planners, practitioners, media, decision makers and local communities will restore wetlands and maintain their ecological integrity and productivity to sustain local livelihoods.

This seminar on Wetland Conservation presents a good platform for Government Agencies and citizen groups to create synergies and spread the message of conservation through appropriate means. I wish you all very fruitful deliberations and shall look forward to outputs of these deliberations.

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Integrated Management of Wetland: Policy and Strategies

*By C L Trisal**

WETLAND MANAGEMENT:

Wetlands are at present not integrated into sectoral developmental plans, values and functions of wetlands not recognized and integrated into policy and institutional frameworks. Experience all over points that hydrology is the key factor determining values and functions of wetlands. Hydrology needs to be concentrated on for management of wetlands being a function of socio-economics and biodiversity considerations.

WETLANDS AND RIVER BASIN MANAGEMENT:

Researches have indicated that inland wetlands belong to river basin system which is a natural unit for sustainable wetland conservation and management. This is amply substantiated by an interconnectivity of wetlands within a basin ranging from high attitude to coastal region and so also changes at one level which impact the other being parts of a single unit.

Wetland and Human beings are intimately connected and as such their participation is very important for drawing benefits of a wetland such as products obtained from ecosystems, regulatory and non material benefits, and environmentally clean and safe shelter resulting in ability to be adequately nourished and having energy to keep warm and cool socio-economic systems.

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REGULATORY REGIMES FOR WETLANDS:

Regulatory regimes need be framed taking into account a matrix of its functions, and biotic stresses with weightages being assigned specially for anthropogenic threats, conversion, pollution, water inflow/ withdrawls.

Dependent on the case studies on existing wetlands such as Loktak, Chilka Lake and Rudrasagar, a formulation of Management Action Plan at River Basin level need be undertaken with hydrological intervention for lake restoration, participatory watershed management and environmental flow assessment for maintaining ecological character of lake.

The management process may be through Stakeholder Executive Committee and Project Steering Committee composed of Technical Core Group and Community Consultation Group

INTERGRADED MANAGEMENT OF WETLANDS OF RAJASTHAN:

The key issues of water allocation biased towards human ignoring ecological demands, patch level approaches focused at few sites, absence of linkages of water regimes with biodiversity and socioeconomics, sectoral approaches focused on engineering measures ignoring ecological aspects, ineffective institutional mechanism could be resolved by an integrated Wetland Management planning framework following Multiscalar, hierarchical approach for wetland inventorisation and assessment (Fig. 1)

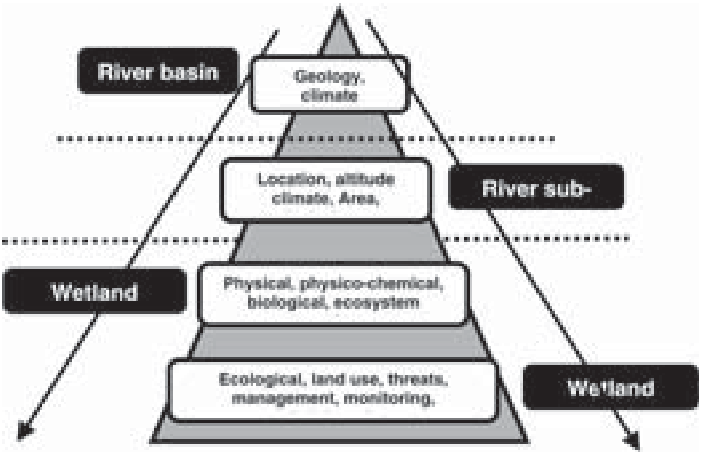

Fig. 1 : Multiscalar, hierarchical approach for wetland inventorisation and assessment

WAY AHEAD

A way ahead could provide through establishment of institutional mechanisms for coordinated actions at river basin level, development of water allocation policy harmonizing human uses with ecological requirements, systematic and hierarchical inventorisation and assessment to support management planning, involvement of stakeholders, particularly local community at all levels of planning and implementation, communication, education and public awareness, being the important parts of management strategies.

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Wetlands and their Conservation: Strategies and Policy Options with Special Reference to Rajasthan

*By Ashok Jain**

INTRODUCTION:

Wetland may be defined as "Areas on which water covers the soil or if water is present either at or near the surface of that soil". Wetlands of India are largely associated with major rivers and coastal areas. Ramsar Convention, an international body dealing with the management and conservation of the Wetlands world over came into force in 1975. India signed the convention in 1981. Chilka Lake (Orissa), Keoladeo Bird Sanctuary (Rajasthan), Sambhar Lake (Rajasthan), Loktak Lake (Manipur), Harike Lake (Punjab), Wullar Lake (J & K) are the sites which fulfilled several of the required qualities of being referred to as Ramsar sites of international importance.

RAMSAR SITE OF RAJASTHAN

As far as Rajasthan is concerned Keoladeo Bird Sanctuary, Bharatpur (Fig. 1) located between latitude 27°13′ and longitude 77°32′ with a total area 2873 hectares is a part of the Indogangetic Great Plains. Natural vegetation of the sanctuary is dry deciduous type having 353 species of birds so far identified. It is known for nesting of its resident birds and visiting migrating birds specially rarest Siberian cranes who arrive in winter.

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Fig. 1 Keoladeo National Park

Sambhar Lake (Fig. 2) is India's largest salt lake with a total area 24000 hectares. The vegetation present in the catchments area is mostly xerophytic type and it is famous for harbouring flamingos in large

Fig. 2 Sambhar Lake Wetland

numbers. Siltation, soil saliniation and discharge of sewage from the town are the major problems.

IMPORTANCE OF WETLANDS

Wetlands provide services of great value to society, control floods and host a great diversity of species. It harbours cultural and economical importance while maintaining ecological balance and provide nesting environment to the birds

THREATS TO WETLANDS

The major threats to wetlands are urbanization, anthropogenic activities, hydrological activities such as canals, diversions etc., pollution likewise dumping of waste water, sewage, solid waste; salinization due to overdrawal of water; climate change such as high temperature, shift in precipitation etc.

POLICY FOR WETLANDS

As of now no policy exists at State level as a result of which in the last 5 decades 70% of wetlands in the Gangetic flood plains have been lost and wetlands are disappearing at the rate of 2-3% every year.

The intrinsic studies would tend to show that essential ingredients of policy should cover all wetlands, should have both preventive and developmental measures (restoration) and should encompass relevant sectors viz ecology, flora & fauna, pollution abatement. Since the management of wetland involve several disciplines all relevant departments, civil society and scientific community need jointly working while following a proper regulatory framework to prevent depletion of wetlands.

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ENGINEERED WETLANDS

i. Sustainable Treatment of Domestic and Industrial Wastewaters significance of Constructed Wetlands by Dr. Shyam Asolekar and K M Chaturvedi

ii. Sustainability of wetlands requires systematic scientific studies of their hydrological balance by Dr. S.M.Seth

Sustainable Treatment of Domestic and Industrial Waste waters: Significance of Constructed Wetlands

*By Dr Shyam R. Asolekar and Manoj K. M. Chaturvedi**

INTRODUCTION

Urbanization, which is proceeding at an accelerated speed around the world, has posed several new problems before urban residents. Inadequate water supply and poor water quality have been provoking serious contemporary concerns for many municipalities, industries, agriculture and the environment. Communities are thirsty for potable as well as process waters. It has not been possible for communities living in the slums to get even 10L of water per person per day. On one hand, there is an escalating demand for water for domestic, agriculture, as well as industrial purposes. On the other hand the available water is getting deteriorated as a result of disposal of domestic and industrial effluents [Asolekar and Gopichandran, 2005].

In the last two decades, several attempts have been made to develop alternative and appropriate systems for wastewater treatment with a major focus on reduction of the use of non-renewable resources (Geber and Björklund, 2002). Although up to certain extent environmental engineering could also be advantageous to a local or regional level through controlled abatement of the pollution besides it also poses some disadvantages to the contiguous ecosystem, either by transference of pollutants produced by it self, such as flushed water and dredged sludge,

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or by some new pollution produced from another industry supplying the energy or equipment to the environmental engineering. It may result, more or less, in disturbance to the whole.

APPROPRIATENESS OF TREATMENT TECHNOLOGIES

Several features can characterize an appropriate wastewater treatment technology:

- The technology should be low-cost and have minimum possible mechanization, which reduces the risk of malfunction,
- The technology should be simple to operate, locally manufactured (at least constructed) as well as labour intensive (rather than power intensive),
- The technology should not rely upon expensive chemical inputs, such as chlorine for tertiary pathogen reductions to meet quality guidelines, and should be able to recover and reuse the resources as far as possible; and
- The technology should be capable of being incrementally upgraded as user demand or quality standards and treatment guidelines increase (Chaturvedi, Langote, and Asolekar, 2002).

Further to this, the good engineering design and performance control of such systems are urgently needed, to ensure the sustainability and productivity of the system. Therefore, "appropriate" wastewater treatment technologies are required to enable communities to own, operate, and maintain the process equipments and the technology for wastewater management and, at the same time, offer ecological, environmental and societal benefits (Chaturvedi and Asolekar, 2001).

CONSTRUCTED WETLANDS (CWS):

Constructed Wetlands are typical natural engineered treatment systems, designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating the wastewater. They have been gaining increasing international interest and now being assumed to be highly applicable in developing countries, due to their characteristic properties like utilization of natural processes, simple construction, simple operation and maintenance (O/M), process stability, and above all its cost effectiveness.

ECOLOGY OF CWS

Wetlands, being defined as representative transitional areas between land and water, encircle a broad range of wet environments, including marshes, bogs, swamps, meadows, tidal wetlands, floodplain, and ribbon (riparian) wetlands along stream channels, behaves like a kidney of the earth ecosystem (see **Figure 1**).

As depicted in Figure 1**,** wetlands are often located at the ecotones between dry terrestrial systems and permanently flooded deepwater aquatic systems such as rivers, lakes, estuaries, or oceans. As such they have an intermediate hydrology, a biogeochemical role as source, sink or transformer of the chemicals and generally high productivity if they are open to hydrologic and chemical fluxes.

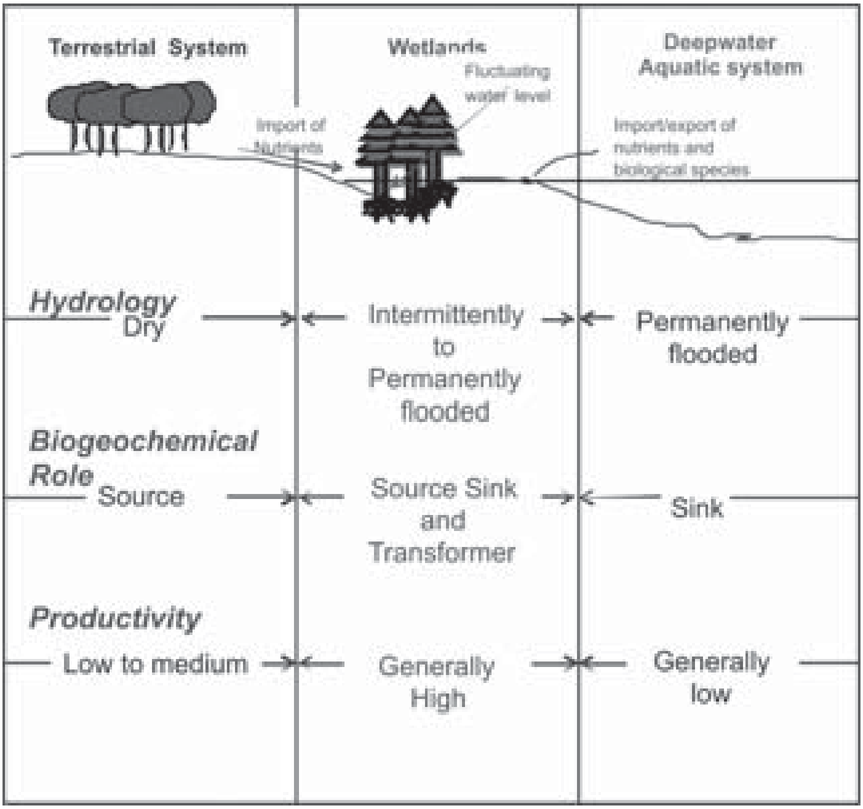

Figure 1 Position of wetland in nature
[Adopted from Mitsch and Gosselink, 1993]

WASTEWATER TREATMENT MECHANISMS

The CWs appears to perform all of the biochemical transformations of wastewater constituents that take place in conventional energy intensive, environmental engineering based systems including activated sludge process, septic tanks, drain fields and other form of land treatments. These systems have also been found to be very effective in removal of BOD, SS, and nitrogen, phosphorous, metals, trace organics, and pathogens more effectively than conventional means. However phosphorous removal capacity varies from system to system and depends largely on site-specific factors. This reduction is accomplished by diverse treatment mechanisms *viz.* sedimentation, filtration, chemical precipitation and adsorption, microbial interactions, and uptake by vegetation. The principal removal and/or transformation mechanism involved in the CW systems has been summarized in **Table 1**. As shown in Table 1, it is difficult to separate constituent removal and transformation processes, as both occur simultaneously in these systems.

Table 1 : Removal mechanisms in CW systems

Constituents	*Free water systems*	*Subsurface flow*
Biodegradable organics	Bioconversion by aerobic, facultative, and anaerobic bacteria on plant and debris surfaces of soluble BOD, adsorption, filtration, and sedimentation of particulate BOD	Bioconversion by facultative and anaerobic bacteria on plant and debris surfaces
Suspended solids	Sedimentation, filtration	Filtration, sedimentation,
Nitrogen	Nitrification/denitrification, plant uptake, volatilization	Nitrification/denitrification, plant uptake, volatilization
Phosphorous	Sedimentation, Plant uptake	Filtration, sedimentation, Plant uptake
Heavy Metals	Adsorption of plant and debris surfaces, sedimentation	Adsorption of plant and debris surfaces, sedimentation
Trace organics	Volatilization, adsorption, biodegradation Adsorption, biodegradation	
Pathogens	Natural decay, perdition, UV irradiation, sedimentation, exertion of antibiotics from roots of plants	Natural decay, perdition, sedimentation, exertion of antibiotics from roots of plants

[Adopted from Crites and Techobanoglous, 1998]

USAGE OF CWS

Constructed wetlands are used extensively to treat domestic [Billore *et al*, 1995; Kadlec and Knight, 1996; Srinivasan et al., 2000] and industrial wastewater [Hammer, 1989; Robinson et al., 1999; Billore *et al.* 2001; Arceivala and Asolekar, 2006]. They have also been applied to passive treatment of diffuse pollution including mine wastewater drainage [Hammer, 1989; Kadlec and Knight, 1996; Mungur et al., 1997; Robinson et al., 1999; Jing et al., 2001], and highway runoff following storm events [McNeill and Olley, 1998]. Besides, wetlands, being a model ecosystem, can serve as wildlife habitats and can be perceived as natural recreational areas for the local community. Some typical Indian experiences is being given in **Table 2**.

Table 2 Performance of some Constructed Wetlands currently working in India

Location and Capacity	Wastewater Type	Performance (% removal)				References
		BOD	TSS	P	N	
Uni. Campus, Ujjain Madhya Pradesh (13 m^3/d) **(CW 1)**	Municipal Sewage	65	78	58	36	Billore *et al.* (1999)
Ravindra Nagar, Ujjain, Madhya Pradesh (40 m^3/d) **(CW 2)**	Municipal Sewage	67	74	-	71	Billore (2006)
Barwah Distillary Madhya Pradesh (10 m^3/d) **(CW 3)**	Industrial Wastewater (Distillery)	85	40	80	65	Billore *et al*. (2001)
Ekant Park, Bhopal Madhya Pradesh (70 m^3/d) **(CW 4)**	Municipal Sewage	71	78	-	80	Billore (2006)
Chennai, Tamilnadu (5 – 100 m^3/d) **(CW 5)**	Industrial Wastewater (Tannery)	50-62	25-52	-	-	Emmanuel (2000)
Pune, Maharashtra (0.2 – 40 m^3/d) **(CW 6)**	Industrial Wastewater (Chemical, Automobile)	83-90	90	-	-	Gokhale (2000)

CASE STUDY: SEWAGE TREATMENT PLANT AT UJJAIN, M. P

With an embodied aim of improving and advocating comprehensive treatment of wastewater utilizing low-cost technologies, about three year ago a constructed wetland system in the Ravindranagar residential neighborhood in urban Ujjain was installed which has now eliminated this source of pollution to the Kshipra River (see **Figure 2**) [Billore, 2006].

It works with the help of a perennial reed (*Phragemitis karka*), which is found in abundance in Indian plains around water streams and swampy areas. The dense root planted in the gravel bed supports thousands of micro-organisms, protozoa, metazoan and a complete food chain system that kill harmful microbes and decontaminate the pollutants in the waste water. The hollow grass acts as an oxygen pump and through its root canal diffuses and oxygenates the wastewater. The gravity-based system has an entrance at one end through which the wastewater flows in and an outlet at the opposite end for collection of the treated water.

Average treatment performance after five months from the installation SF system recorded removal efficiencies of 78% for NH4-N, TSS; 58-65% for P, BOD and TKN. Effluent dissolved oxygen levels increased to 34% indicating existence of aerobic conditions in the rooted-gravel bed. The SF system overall results established: (a) very cost-effective treatment technology, (b) SF removal efficiency above 50% for BOD, NH4-N, TKN, and P. This SF system presents a unique design consideration compared with the land-intensive Kickuth standard system design.

ADVANTAGES, DISADVANTAGES, AND FUTURE PROSPECTS

This emerging technology has enormous potential for application of in our country, as our country's climate is conducive for higher biological activity and productivity, hence can harness better performance of wetland systems. Further to this our regions are known to sustain a rich diversity of biota that may be used in wetlands. Although land may be a limiting factor in dense urban areas (class 1 cities), constructed wetlands are potentially well suited to smaller communities (class-2 & 3) and for our 5 lacks Villages, where municipal land surrounding schools, hospitals, hotels and rural areas is not in short

Figure 2 **Constructed wetlands at Ravindranagar, Ujjain, Madhya Pradesh**

supply. If, for the sake of simplicity, capital investment costs are taken into account, conventional activated sludge process costs Rs. 600-700 per capita; assuming each person contributes average 180 L volume and 50 g of BOD_L every day whereas the cost for stabilisation ponds could be Rs. 150-200 per capita.

As stated earlier, that constructed wetlands are very similar to waste stabilization lagoons from a maintenance and operational perspective, therefore the cost for waste stabilization can be taken as say 200 per capita/day

Thus, the difference in the cost is about Rs.500 per capita which could be applied towards purchase of land. At what price is land "reasonable" to buy? While it is a tricky question to answer, based on the above example; the maximum price one can pay will be 250 Rs/m^2 because the constructed wetlands will be Rs. 500 per capita cheaper. In fact, the break-even price of land could even be higher if the comparison of O&M costs is applied towards land purchase.

Constructed wetlands have been implemented as wastewater treatment facilities in many parts of the world, but to date, the technology has been largely ignored in developing countries in general and our Indian sub-continent in particular, where effective, low cost wastewater treatment strategies are urgently needed. Given the appropriate climatic condition of our country, CWs may be successfully established with plant species acclimated to the tropical environment and able to be harvested for use in secondary functions like fuel production.

ACKNOWLEDGEMENTS

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Sustainability of Wetlands Requires Systematic Scientific Studies of Their Hydrological Balance

*By Dr. S.M.Seth**

1.0 INTRODUCTION

Wetlands are one of the most threatened habitats of the world. Wetlands in India, as elsewhere are increasingly facing several anthropogenic pressures. The rapidly expanding human population, large-scale changes in land use/land covers, burgeoning development projects and improper use of watersheds, all these have caused a substantial decline of wetland resources of the country. Significant losses have resulted from its conversion threats from industrial, agricultural and various urban developments. These have led to hydrological perturbations, pollution and there effects. Unsustainable levels of grazing and fishing activities have also resulted in degradation of wetlands.

There is still much about wetlands that is not known. There is a lot to be learned about the role of these resources in the landscape and how humans and natural systems benefit from their presence. More study is needed before it can be fully understood how these complex ecosystems perform their varied functions.

There is a necessity for research in the formulation of a national strategy to understand the dynamics of these ecosystems. This could be useful for the planners to formulate strategies for the mitigation of

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pollution. The scientific knowledge will help the planners in understanding the economic values and benefits, which in turn will help in setting priorities and, focusing the planning process. For achieving any sustainable success in the protection of these wetlands, awareness among the general public, educational and corporate institutions must be created. The policy makers at various levels, along with site managers, need to be educated. Because the country's wetlands are shared, the bi-lateral cooperation in the resource management needs to be enhanced. Wetlands performs a variety of functions on several levels. These functions are a great benefit to human pursuits and to natural systems. Not all wetlands perform every function nor do they perform them at the same level. The differences in the performance of functions is the result of the variety of wetland types. These differences are further emphasized by variations between individual wetlands within a specific type.

1.1WETLANDS IN INDIA

India, with its annual rainfal1 of over 130 cm, varied topography and climatic regimes, supports and sustains diverse and unique wetland habitats. The current loss rates in India can lead to serious consequences, where 74% of the human population is rural (Anonymous, 1994) and many of these people are resource dependent. Healthy wetlands are essential in India for sustainable food production and potable water availability for, humans and livestock. They are also necessary for the continued existence of India's diverse populations of wildlife and plant species; a large number of endemic species are wetland dependent. Most problems pertaining to India's wetlands are related to human population. India contains 16% of the world's population, and yet constitutes only 2.42% of the earth's surface. The Indian landscape has contained fewer and fewer natural wetlands over time. Restoration of these converted wetlands is quite difficult once these sites are occupied for non-wetland uses. Hence, the demand for wetland products (e.g. water, fish, wood, fiber, medicinal plants, etc.) will increase with the increase in population. National wetland strategy should encompass (i) Conservation and collaborative management, (ii) Prevention of loss and promotion of restoration and (iii) Sustainable management. These include : (1) Protection (2) Planning, Managing and Monitoring (3) Comprehensive

Inventory (4) Legislation (5) Coordinated Approach (6) Research (7) Building Awareness

2.0 ARID AND SEMI ARID AREAS - MANAGEMENT ISSUES:

It is expected that in coming years also much of the population growth will take place in arid lands, particularly in cities that will accelerate the demand for water for domestic, industrial and other uses. Further more, since the developed lands are already exploited, attention is increasingly turned towards semiarid and arid regions to release population pressure. There is need for proper understanding, continuous monitoring and scientific assessment of effect of human activities on land and water resources in these regions for effective and sustainable management of supplies and demands.

The societies in arid zones have generally developed on traditional farming methods, involving rain-fed agriculture and limited withdrawal of groundwater. However, introduction of modern methods, irrigation canals, electrical pumps, and growth of towns and cities have completely changed the environmental balance. The variability of precipitation is the most crucial factor along with high potential evapo-transpiration in these regions.In planning, developing and managing water resources, the quantity of water available is not the only important variable, the quality is also equally important, particularly in arid zones where the natural input to the system from rainfall is small. There is greater risk of salt accumulation in the soil and groundwater from fertilizers and other agricultural inputs, and urban and industrial wastes. The sustainability and environmental degradation require an increased focus in development and management of land and water resources in arid and semi arid areas. Wetlands are one of the most threatened habitats of the world.

3.0 RAJASTHAN STATE

The state of Rajasthan faces severe handicaps in terms of availability of water. It roughly possesses 1 percent of the water resources of the country though it accounts for nearly 8 percent of the country's population. The availability of water is inadequate compared to minimum needs of the population. The spatial and seasonal fluctuations in the availability of water are more pronounced due to generally arid and semi-arid climate over most parts of the state. The traditional ways of conserving water have become extinct to a large extent due to changes in habits, urbanization and rise in standard of living. Furthermore, current practices of conveyance and use of water for all major purposes-domestic, irrigation and industry etc. are wasteful. There is need and ample scope for conjunctive use of surface and groundwater as single entity – water.

Rajasthan's lakes, ponds, marsh lands and grass lands are a haven for bird lovers. One can find around 550 species of birds and most of these are residents. The best colony of birds in the world is Kealodeo National Park situated in Bharatpur.It has more than 400 species of birds and more than 130 of them breed inside the park. Being a unique bird place, the UNESCO has recognized it as a world heritage site. It is truly a paradise of feathered life which provides unlimited opportunities to bird watchers. Various other lakes and ponds, spread over the state offer the enthusiast an opportunity to watch the activities of the birds.

Semi Arid Wetlands of Rajasthan were important water-bodies and require active management and restoration. However, generally management of these systems has tended to concentrate on the provision of flows of appropriate magnitude to sustain wetlands. The role of sediments is however, neglected. Catchment disturbance due to agricultural development increases the sediments in flood plain of wetland areas. Sediment accumulation influences habitat quality, surface topography and the distribution of water across flood plains during times of inundation. It also acts as retention storage for nutrients in particulate form as well as for toxic materials discharged with domestic and industrial wastes. An integrated approach of management of wetlands requires due consideration of land and water issues as well as sediment aspects. The environment management of wetlands has to be considered side by side with water management.

4.0 SUSTAINABILITY

A primary consequence of sustainability is that the sectarian approach, in which the different categories of water problems – water supply, water quality, hydropower etc. – are seen and solved separately sector-wise. It must give way to a more integrated or holistic view, in which water resources problems are intertwined with societal problems at many different levels, and in which scientific problems arise in many different water applications. The sectarian view has an old tradition. The field of water resources even today is divided into many sub-areas, in which different aspects of water resources of a region are treated separately. This separation is reflected in the scientific and engineering methods and design rules, which are, at least in their terminology, field specific.

4.1 SPACE AND TIME SCALES

The translation of sustainability into actions depends on space and time scales. The smallest space scale is that of the village. It is the basic unit of a sustainable interaction of man and his environment. In it, in ancient times, food production, human consumption, and waste disposal are linked in a closed cycle. In theory, such a cycle could be truly sustainable if a stable population would wisely maintain a social structure in which consumption is restricted to the production, in which productivity of the fields is stable, and in which the population did not exceed the carrying capacity of the village land.

4.2 CHANGING THE ENVIRONMENT

In earlier years, disturbances of this cycle through climatic changes or through overexploitation by increasing populations – as with overgrazed fields or over utilized forests – was felt directly by the local people. They were forced to take corrective action by adjustments of local habits, by moving to another location or by expanding the area of habitation. However, now in modern times, people began developing technologies for changing the environment to suit their needs. To meet water demands in regions not blessed with sufficient rainfall, ingenious methods were developed to increase the water supply. Cities and villages and, on a larger scale, whole regions and nations form new ecological systems. Man in modern civilizations no longer recognized large scale ecological impacts of his local societal actions.

Disturbances of this cycle through climatic changes – like that suffered in the Pueblos of the American Southwest, or through overexploitation by increasing populations – as with overgrazed fields or overutilized forests – was felt directly by the local people. They were forced to take corrective action by adjustments of local habits, by moving to another location or by expanding the area of habitation. If such corrections were not made by the people themselves, nature would force them to happen. In later days, people began developing technologies for changing the environment to suit their needs. To meet water demands in regions not blessed with sufficient rainfall, ingenious methods were developed to increase the water supply.

Cities and villages and, on a larger scale, whole regions and nations form new ecological systems. Sustainability of a village depends on the sale of its products for acquiring machinery and the fertilizer needs to produce excess food; and wastes are no longer completely disposed of locally. Instead, they are discharged into rivers or transported to dumps. For such a system, local departures form sustainability are strongly affected by an interdependence with the outside: they can be compensated for, or they can be aggravated by, actions in the outside world – that is, in the world outside the field of vision or experience of the local people. The farther the interactions reach, and the larger the interconnected system becomes, the less possible it is for a person to sense the feedback effects of local actions. The city dweller knows little of what his demands do to the villages, and the citizen of one nation knows even less of how his actions influence citizens of other nations. Apart from economic and sociologic implications, this lack of knowledge gives rise to a critical lack of awareness of ecological consequences. A demonstration of this interaction, which is quite obvious in hindsight, is the use of the Syr Darya and Amu Darya rivers for irrigation, as described in Box 1 (from the World Development Report, 1992). Man in modern civilizations no longer recognized large scale ecological impacts of his local societal actions.

4.3 RESEARCH NEEDS FOR ASSESSING ENVIRONMENTAL EFFECTS

The regional scale of ecological studies is the watershed or its sub-areas. The eco-systems of many watersheds are imperfectly understood in the relationships that exist between different kinds of plants, types of soil, and groundwater levels and fluctuations. Detailed studies of such plant communities are required for many different and typical areas, in which the plants and their locations are mapped. Biological studies of the interaction of the plant communities as they develop with time give valuable indications of their vulnerability and resilience. Acceptable discontinuities in the eco-system should be defined to determine the impact of hydraulic engineering works and the scale of interference. Monitoring networks and related information systems are necessary to assess impacts on aquatic eco-systems and water quality.

5.0 HYDROLOGY

Hydrology is considered the master variable of wetland ecosystems, driving the development of wetland soils and leading to the development of the biotic communities. It can determine plant species composition as well as the distribution of species within a wetland (for example, vegetation zonation with depth in freshwater wetlands), their productivity and capacity for nutrient uptake. Despite this fact, quantitative hydrologic data is not often collected as part of mitigation monitoring. Hydroperiod (the pattern of water levels over time) has been called the most important predictor of future wetland success. Hydrological modifications (at natural or mitigation sites) can drastically alter ecosystem processes such as primary productivity and species composition. Some studies have argued that mitigation wetlands can never achieve parity with natural wetlands if the hydrology is not correct.

Other studies have found that even if hydrologic parity is achieved, restored wetlands may not develop plant communities similar to natural wetlands. In addition, inadequate hydrologic restoration or hydrologic disturbance often leads to colonization by invasive species.

5.1 HYDROLOGY OF ARID AND SEMI ARID AREAS

The hydrology of arid and semi-arid areas is substantially different from that in more humid regions. General environmental features characterizing such areas include:

(i) High levels of incident solar radiation

(ii) High diurnal and seasonal temperature variations

(iii) Evaporation is prominent in the hydrological cycle

(iv) Strong winds with frequent dust and sand storms

(v) Sporadic rainfall of high temporal and spatial variability

(vi) Extreme variability of short duration runoff events in ephemeral drainage systems

(vii) High rates of infiltration loss in channel alluvium

(viii) High sediment transport rates

(ix) Relatively large groundwater and soil moisture storage changes

(x) Distinctive geomorphology, with poorly developed soil profiles.

Although the natural geography of the arid and semi-arid zones is complex and differs from site to site, the characteristics in common are infrequent rainfall, drought, poor vegetation cover, low cover ratio, serious soil loss and erosion and high river sediment concentrations during the flood season.

5.2 HUMAN INFLUENCE ON THE HYDROLOGIC CYCLE

Watersheds are subjected to many types of modifications, major or minor, for various reasons. In each case the effects must be predicted before any modification is undertaken. Watershed changes affect virtually all elements of hydrologic cycle, especially in the context of small watersheds. There has been a growing need to quantify the impact of major land use changes on hydrology for anticipating and minimizing potential environmental detriment and to satisfy water requirements of the society. Most watershed changes can be distinguished as point changes and non-point changes, structural changes such as dam construction, channel improvement, and detention storage, etc. are examples of point changes and have usually been known to affect watershed hydraulics. Forestry, agriculture, mining, and urbanization are non-point land use changes that affect watershed hydrology.

For incorporation of ecological effects, the interaction of water and the biosphere need to be studied at scales ranging from point to local. On the point scale one will have to incorporate aspects of vegetation into the hydrological and hydro-geological processes to extend the understanding of the feedback loops between the atmosphere and the soil. On the point scale one has to determine the plant-sol and water interactions needed for assessing environmental impacts of pollutants, such as storm water or sewage, or of chemicals, such as fertilizers or pesticides, on the plant cover. They can also effect on the micro-fauna existing in the soil, in both the unsaturated and saturated regions.

5.3 HYDROLOGICAL ALTERATION

Alteration in the hydrology can change the character, functions, values and 'the appearance of wetlands. The changes in hydrology include either the removal of water from wetlands or raising the land surface elevation, such that it no longer floods.

To the hydrologist, the three water quantity functions that are quoted can be considered as merely a subset of functions associated with the interactions between wetlands and groundwater/river systems. Thus, it is possible from the hydrological viewpoint to propose a different structure to the Table of functions. In doing so, the hydrologist may well consider ascribing wetland influence to more specific indices of hydrological process, such as:

- Evapotranspiration and total river flow contributions
- Groundwater recharge
- Base flow contributions, including annual base flow, dry season flow duration, dry season flow magnitude, dry season flow recession rates
- Flood characteristics, including flood volume generation, flood peak magnitudes and flood timing

5.4 HYDROLOGICAL FUNCTIONS

Wetlands have many important hydrological functions. They effect both ground and surface water supplies. They recharge aquifers; serve as surface water sources for wildlife, human consumption, recreation, agricultural irrigation, and industrial processes; and act as cleaning filters for the water that passes through them. Of all the hydrological functions wetlands perform, however, the effects they have on the hydrology of the surface waters in their specific watershed are perhaps the most pronounced. Wetlands help reduce the effects of both flood and drought conditions in a watershed. They function like sponges, storing and releasing water relative to the amount of water around them. Some wetlands which have a relatively stable hydrology may routinely retain a specific amount of water. During dry periods they may lose some of this water to surrounding parched areas and through evaporation and transpiration. During wet periods they may also have the capacity to store more water than they usually contain. Wetlands associated with Riverine systems serve as floodways, transporting flood pulses from upstream to downstream locations and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

There are many types of wetlands, including bogs, fresh water and salt water marshes and swamps. Wetlands stay wet for any of several reasons: they are in low areas that stay saturated by rain; they are fed from below by ground water that is at or near the surface; they are near rivers and other bodies of water that flood them periodically; or they are saturated along the coast by the tide. Wetlands are valuable and productive in critical ways. They control floods by slowing down rushing water, thereby, letting it spread out over a broader area and eddy around trees and other vegetation.

Wetlands also help purify water by trapping silt. Wetland soils are classified as hydric soil. This type of soil is saturated and has little or no oxygen. A variety of chemical reactions occur in hydric soil. These reactions affect the nature of the soil over time, changing some of the physical and chemical properties. The initial composition of the soil, degree of wetness and frequency and duration of flooding determine what the soil will look or feel like.

An area with water above the soil surface for 7-21 consecutive days is considered a wetland. Freshwater wetlands are highly productive ecosystems. Wetlands are sedimentary systems. They accumulate carbon, nitrogen, phosphorus and other materials and exchange them among the wetlands, atmosphere and landscape.

Wetlands provide many services and commodities to humanity. Regional wetlands are integral parts of larger landscapes; their functions and values to the people in these landscapes depend on both their extent and their location. Each wetland thus is ecologically unique. Wetlands perform numerous valuable functions such as to recycle nutrients, purify water, attenuate floods, maintain stream flow, recharge ground water, and also serve to provide drinking water, fish, fodder, fuel, wildlife habitat, control rate of runoff in urban areas, buffer shorelines against erosion and offer recreation to the society. The interaction of man with wetlands during the last few decades has been of concern largely due to the rapid population growth- accompanied by intensified industrial, commercial and residential development, that further leads to pollution of wetlands by domestic, industrial sewage, and agricultural run-offs, such as fertilizers, insecticides and feedlot wastes. The fact that wetland values are overlooked has resulted in threats to the source of these benefits.

Wetlands are often described as "kidneys of the landscape" (Mitch and Gosselink, 1986). Hydrological conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties, and pH. These modifications of the physicochemical environment, in turn, have a direct impact on the biotic response in the wetlands (Gosselink and Turner, 1978). When hydrological conditions in wetlands change even slightly, the biota may respond with massive changes in species composition and richness and in ecosystem productivity.

Wetlands are important ecosystems internationally recognised, as exemplified by Ramsar Convention. They are diverse in terms of habitat, biota, distribution, functions and uses. Many of the wetlands have lost their pristine quality and have been transformed to modified ecosystems, but their salient role in the ecosystem function cannot be replaced. Over exploitation due to developmental activities are threatening their existence. The protection and effective management of these wetlands is a herculean task. The key to their protection lies in appreciating their value and functions, considering the difference within and between different wetlands. With fluctuating water levels, varying sources of water, changing biota, they have vital physical, chemical, biological and socio-economic functions. Activities that damage the wetlands and inhibit their functions, has local, regional, national and global impacts. Evolving a correct conservation strategy and a sound management plan is essential in addition to protecting the existing water bodies, and reclaiming and restoring wetlands. Alternatives for human use systems need to be slated before implementing the management agenda.

5.4.1 STREAM FLOW

Wetlands help reduce the effects of both flood and drought conditions in a watershed. They function like sponges, storing and releasing water relative to the amount of water around them. Some wetlands which have a relatively stable hydrology may routinely retain a specific amount of water. During dry periods they may lose some of this water to surrounding parched areas and through evaporation and transpiration. During wet periods they may also have the capacity to store more water than they usually contain.

Wetlands associated with Riverine systems serve as floodways, transporting flood pulses from upstream to downstream locations while lessening flood peaks. As flow rates increase in a given stream and the water level rises, wetlands adjacent to a stream "soak up" some of the overflow. This occurs through the filling of backwater lakes or other low lying depressions in the floodplain and by the saturation of soil in otherwise dry regions in the floodplain. This absorption and storage of excess water lowers the overall amount of flow that would otherwise be carried by a stream.

When the flow of a stream begins to drop below its normal level, adjacent wetlands drain back into the main stream and augment its flow. These floodplain wetlands work cooperatively with wetlands outside of the floodplain which store flood waters at higher elevations and slowly deliver it downstream. Consequently the water that enters the stream through this process is much cleaner than when it entered the wetland due to the settling out of sediments and the biological uptake of certain constituents by the hydrophytic plants and micro-organisms contained in the wetlands.

5.5 SPACE-TIME SCALES IN HYDROLOGY

The scope of hydrology is best defined by the hydrologic cycle. Depending on the hydrologic problem under consideration, the hydrologic cycle or its components can be treated at different scales of time and space. As a consequence, different hydrologic problems may have different space-time scales. The global scale is the largest spatial scale and the watershed, or drainage basin, the smallest spatial scale. A drainage basin, or watershed, is the area that diverts all runoff to the same drainage outlet. In between these two scales lie such scales as continental, regional and other space scales convenient for hydrologic analysis. Clearly, the watershed, or drainage-basin, scale is the most basic of all; and all other scales can be constructed by building on the drainage basin scale. Most hydrologic problems deal with a drainage basin. It should be clearly understood that the watershed scale does not usually or necessarily coincide with territorial or jurisdictional boundaries that might be determined by political or economic considerations. A drainage basin can be of almost any size. It might be as small as a small parking lot or as large as Ganga River basin. Large watersheds are usually broken down into smaller drainage basins to suit the requirements of a particular problem and to assist in orderly quantitative analysis.

Time scales used in hydrologic studies range from a fraction of an hour to a year or perhaps many years. The time scale used in a hydrologic study depends on the purpose of the study and the problem involved. Hourly, daily, weekly, ten daily, monthly, seasonal and annual time scales are common. Sometimes the time interval for the collection of data determines the time scale for hydrologic analysis. Hydrologic time scales often do not coincide with those used in fluid mechanics or in hydraulics and likewise do not coincide with political, environmental or economic time scales.

5.6 HYDROLOGICAL WATER BALANCE

The equation is based on the concept of continuity as follows:

Input to the system - Outflow from the system = Change in storage in the system

The various components of the above continuity equation can be represented in equation form as:

$$P + Input = Q + ET + Export + Sm + Sg + Sd + L$$

$$P + (Ic + Ig) = Q + ET + (Oc + Og) + Sm + Sg + Sd + L$$

where,

P = precipitation

Ic = surface supplies through rivers, canals and drainage from outside the basin

Ig = inflow to the groundwater from other basins

Q = runoff

ET = evaporation and evapotranspiration

Oc = surface supplies going out to other basins

Og = ground water outflow from the basin to other basins

Sm = change in soil moisture

Sg = change in ground water storage

Sd = change in depression storage

L = loss through deep percolation

5.7 GROUND WATER BALANCE

Considering the various sources of recharge and charge to the ground water reservoir and change in storage in the ground water, the basic equation of ground water balance based on the concept of continuity can be written as:

Rr + Rc + RI + Ig + Is = Tp + Og + ET + Es + Sg + L

where,

Rr = natural recharge from precipitation

Rc = recharge due to seepage from rivers, canals, water courses, ponds, reservoirs, etc.

RI = recharge from irrigation and other activities

Is = influent seepage

Tp = withdrawal from groundwater storage

ET = evaporation and evapotranspiration from ground water

Es = effluent seepage

5.8 WATER USE BALANCE

Water use for the growth of crops and other vegetation comes from their root zone. Considering the various sources of supply to and losses from the root zone of crops and vegetation and the change in the soil moisture of the root zone, the water use balance equation can be written for irrigated areas, unirrigated areas and for water bodies as follows:

$$E' = Cc + T'p + IT + PE + Mg - Lc - LI$$

where, E′ = evaporation from irrigated crops Cc = canal supplies T′p = supply from groundwater storage for irrigation IT = irrigation supplies from drains and tanks Mg = contribution from groundwater irrigated fields Lc = losses from canals and water courses LT = losses from irrigation fields

For un-irrigated crops:

$$E'' = P'E + Mg + E'T$$

where E″ = evapotranspiration from vegetation, unirrigated crops and natural land P′E = effective precipitation for vegetation and unirrigated fields Mg = contribution from ground water for forests, trees and unirrigated fields

For water bodies:

$$E = Er + Ec + Ew$$

where, E = evaporation from water surface Er = evaporation from surfaces in rivers, drains, etc.

Ec = evaporation from canals, water courses, etc. Ew = evaporation from other water bodies

It may be noted that in above Eq.,

$$Er = E' + E'' + E$$

6.0 TYPICAL HYDROLOGICAL STUDIES

Walton, Chapman and Davis (1996) carried out a study for development and application of the wetlands dynamic water budget model. A Wetlands Dynamic Water Budget Model was developed and applied to support a large field investigation of processes in the Black Swamp wetlands of the Cache River between Patterson and Cotton Plant, Arkansas. The model is called the Wetlands Dynamic Water Budget Model because it provides magnitudes for the water budget components, as well as water depths, discharges, and flow velocities throughout the modeled system. The development of the computer program is based on concepts and approaches of a number of programs in common use. It includes three dynamically-linked modules that include all the major components of a typical water budget, including precipitation, canopy interception, overland flow, channel flow, infiltration, evapo-transpiration, and horizontal ground-water flow. The surface-water module of the model was applied to the Cache River in Arkansas, and augmented a comprehensive hydrologic field study by filling data gaps that occurred due to gage problems and by providing long-term simulation data for broad areas of the wetland, particularly those far away from any measurement station. The results demonstrated that these wetlands are inundated primarily from the backwater produced at downstream constrictions, rather than from the forward-moving flood wave.

Cole, Brooks, and Wardrop(1997) characterized wetland hydrology as a function of hydro-geomorphic (hgm) subclass as a key to assessing relative function over a range of wetland types.

Koreny , Mitsch , Bair , and Wu(1999) characterized regional and local hydrology of a created riparian wetland system. Three methods, two laboratory and one in situ, were used to calculate the hydraulic conductivity of the wetland substrate. Hydraulic conductivity values and measured vertical gradients were used to estimate seepage loss to ground water. Surface-water inflow and outflow dominated the hydrologic budget for the wetland. Precipitation, seepage loss, and evapo-transpiration were minor components of the hydrologic budget. Water seeping from the wetland into the ground-water-flow system has characteristics of a local ground-water-flow system. Ground-water modeling and particle tracking show that water originating from the wetland seeps into the ground water and flows in the local ground-water system to the southeast portion of the site. Ground-water travel times were estimated to range from 700 to 1,200 days before being discharged to the Olentangy River.

Hunt, Walker, and Krabbenhoft(1999) characterized hydrology - considered the most important component for the establishment and persistence of wetlands, and the importance of ground-water discharge in natural and constructed wetlands. Hydrology has been hard to characterize and linkages between Hydrology and other environmental conditions are often poorly understood. In this work, methods for characterizing a wetland's Hydrology from hydrographs were developed, and the importance of ground water to the physical and geochemical conditions in the root zone was investigated. Detailed sampling of nearly continuous hydrographs showed that sites with greater ground-water discharge had higher water tables and more stable hydrographs. Sub-sampling of the continuous hydrograph failed to characterize the sites correctly, even though the wetland complex is located in a strong regional ground-water-discharge area. By comparing soil-moisture-potential measurements to the water-table hydrograph at one site, we noted that the amount of root-zone saturation was not necessarily driven by the water-table hydrograph but can be a result of other soil parameters (i.e., soil texture and associated capillary fringe). Ground-water discharge was not a significant determinant of maximum or average temperatures in the root zone. High ground-water discharge was associated with earliest date of thaw and shortest period of time that the root zone was frozen, however. Finally, the direction and magnitude of shallow ground-water flow was found to affect the migration and importance of a geochemical species. Areas of higher ground water discharge had less downward penetration of CO_2 generated in the root zone. In contrast, biotically derived CO_2 was able to penetrate the deeper ground-water system in areas of ground water recharge. Although ground-water flows are difficult to characterize, understanding these components is critical to the success of wetland restoration and creation efforts.

Ramberg, Wolski and Krah(2006) studied water balance and infiltration in a seasonal floodplain in the Okavango delta, Botswana. The infiltration values were found to be high compared to other large recharge wetlands (e.g., the Everglades, the Hadejia-Nguru) and result from a combination of lack of a low permeability surface layer in the floodplain and strong drainage of floodplain ground water driven by evaporation from the surrounding drylands. High infiltration and lateral ground-water flows have major implications for the Okavango Delta ecology, as they provide water to riparian vegetation, affect floodplain nutrient balance, and are part of the process responsible for immobilization of dissolved minerals.

7.0 RESOURCE CONSERVATION AND MANAGEMENT OF ENVIRONMENT

Effective management of the ecosystem is not possible and the protection and conservation practices may fail. The management programmes should adopt economically sound measures that act as incentives for conservation and sustainable use of resources and components of biodiversity of these habitats. Promoting scientific, technical and socio-economic co-operation with the stakeholders, and implementing measures that avoid and minimize adverse impacts on biodiversity should be encouraged.

Integrated management with a collaborative approach, which brings together interested parties to incorporate social, cultural, environmental and economic values, needs to be looked into. Socio-economic assessment for conservation, social, cultural, and economic activities is an essential component in the development of integrated management plans. The second avenue for work focuses on the development of adaptive responses to water problems and policy approaches that reflect and respond to uncertainty, change and the absence of real understanding of systems and their interactions.

8.0 REMARKS

Wetlands are important ecosystems internationally recognized. They are diverse in terms of habitat, biota, distribution, functions and uses. Many of the wetlands have lost their pristine quality and have been transformed to modified ecosystems, but their salient role in the ecosystem function cannot be replaced. Over exploitation due to developmental activities are threatening their existence.

The protection and effective management of these wetlands is a Herculean task. The key to their protection lies in appreciating their value and functions, considering the difference within and between different wetlands. With fluctuating water levels, varying sources of water, changing biota, they have vital physical, chemical, biological and socio-economic functions. Activities that damage the wetlands and inhibit their functions, has local, regional, national and global impacts. Evolving a correct conservation strategy and a sound management plan is essential in addition to protecting the existing water bodies, and alternatives for human use systems need to be slated before implementing the management agenda.

There are three key points: First, access to wetlands will continue to allow intensification of agricultural activity in response to changing patterns of demand. Second, the scope for managing various demands is limited, particularly where rural communities are trying to escape from poverty. Third, the overexploitation of wetlands by agriculture and other uses is forcing users into economic and social transitions. The net consequences will be loss of some wetlands and adverse effects on environment, biota and wildlife.

The actual experience of wetland management, or the lack of it, needs to be charted if real responses are to be effective. Target studies could include case studies. For incorporation of ecological effects, the interaction of water and the biosphere need to be studied at scales ranging from point to local. On the point scale one will have to incorporate aspects of vegetation into the hydrological and hydro-geological processes to extend the understanding of the feedback loops between the atmosphere and the soil and to determine the plant-soil and water interactions needed for assessing environmental impacts of pollutants, such as storm water or sewage, or of chemicals, such as fertilizers or pesticides, on the plant cover. They can also have effect on the micro-fauna existing in the soil, in both the unsaturated and saturated regions. The regional scale of ecological studies is the watershed or its sub-areas. The eco-systems of many watersheds are imperfectly understood in the relationships that exist between different kinds of plants, types of soil, and groundwater levels and fluctuations. Monitoring networks and related information systems are necessary to study hydrologic balance for water quantity as well as quality and systematically assess impacts on aquatic eco-systems and water quality.

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WETLANDS: ENVIRONMENT RELATED ISSUES

Wetland Conservation - Abatement of Pollution

*By A S Brar**

Wetlands provide the habitats for a gamut of fauna and flora. For millennia, man has used wetland plants and animals for food. Reads and canes have been harvested for building houses, papyrus swamps provided the first material for manufacture of paper, flood plains used for cattle grazing, aquatic and wetland plants have been harvested for consumption besides fisheries. They carry out a crucial role as breeding grounds for fish and other aquatic life. Wetlands also serve as life support system by helping in water quality improvement, flood control, recharging of ground water, storm protections, shoreline stabilization, regulation of hydrological regime, conservation of biological diversity and reduction of sediment loads to the water bodies.

The convention on wetlands of International importance specially as Waterfowl Habitat, known simply as the Ramsar Convention, is an intergovernmental treaty which provides the frame work for International Co-operation for conservation of Wetland habitats. India acceded to the convention in October, 1981 as contraction party. The 1971 Ramsar convention defines the Wetlands as 'Areas of marshes, fens, peat lands or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters.'

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The U.S. Department of Interior Fish & Wildlife Service Authority adopted the following definition of Cowdrin,1979 :

The wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.”

The Ministry of Environment & Forests, Government of India has estimated that India has about 4.1 million hectares of Wetland (excluding paddy fields and mangroves) of which 1.5 million hectare are natural and 2.6 million hectares manmade. Mangroves are estimated to cover 0.6 million hectare. Under the Ramsar convention, 93 major wetland sites were identified in the country, out of which, two sites namely: Sambhar Lake and Keoladeo National Park are pertaining to the Rajasthan State. In the State, 65 wetland sites are also existing in the down stream of lakes and reservoirs, besides the above, two sites as identified under Ramsar convention.

ENVIRONMENTAL ISSUES:

With gradual increase in human population, pressure on land for agriculture, urbanization, industrialization and developmental activities, the wetlands are severely endangered and decaying day by day. The major problems confronting the wetlands are as follows:-

- Decrease in biological diversity particularly endemic and endangered species.
- Deterioration of water quality.
- Sedimentation & shrinkage in the area.
- Decrease in migratory bird population, fish, and other faunal productivity.
- Prolific growth of obnoxious aquatic weeds.

Factors responsible for degradation/vanishing of wetlands:-

(i) Encroachment

Large number of people living in and around wetlands have been encroaching upon these areas and vast areas have already been drained for agriculture, urban expansion and other purposes.

(ii) Siltation

Siltation is one of the major problem in most of the wetlands in India. Deforestation and other anthropogenic activities have accelerated soil erosion resulting in increased sedimentation rates and resultant shrinkage of wetlands. About 13 million tones of silt is deposited annually in Chilka lake choking its mouth leading to reduced communication with Bay of Bengal. Some other lakes experiencing this problem are Wullar, Dal, Kolleru, Loktak etc.

(iii) Weed infestation

Almost all wetlands in the country, barring a few located in the high altitude Himalayas, are heavily infested with aquatic weeds. *Eichornea crassipes, Ipomea sp., Salvinia natans, S. Molesta and Paspalem* sp., etc. are posing great threat to the wetlands hampering their ecological functions.

(iv) Pollution

- Indiscriminate discharge of industrial/domestic effluent, leachates generated from improperly disposed industrial solids waste, hazardous waste, municipal solid waste and bio-medical waste in the streams/land or the catchment area of the wetlands, not only deteriorate the water quality of the system but the Toxic Pollutants i.e. trace heavy metals and trace organics are absorbed in the biomass in form of aquatic weeds i.e. water hyacinth and algae etc.
- The air pollutants emitted from the industrial activity carried away with precipitation and leachates of the pollutants deposited on land aggravates the problem of pollution of Wetlands.
- The residual pesticides and fertilizer generated due to excessive use of the commodities are carried away with rain water run off to the wetlands from the catchment areas.
- Drainage & flood control programmes have long been a threat to the wetlands in terms of water/soil quality deterioration.
- Tourism activity is also one of the major threat to the wetlands,

wherein improper disposal of packing material, plastics, garbage and other solid waste creates environmental problems.

(v) Aquaculture

Conservation of wetland areas indiscriminately for aquaculture without proper land use planning has also resulted in the destruction of a number of wetlands.

NATIONAL WETLANDS PROGRAMME

The Ministry of Environment & Forests has appointed a National committee on Wetlands, Management & Coral leefs to advise the Government on appropriate policies and programmes for the conservation of these eco systems. State Level Steering Committee headed by the Chief Secretary have been assigned the responsibility to formulate, implement and monitor the programmes. The Management Action Plans under the National Wetland Programmes assist the following:-

(i) Protection

— Bringing the identified wetlands under the country's protected area network of national parks, sanctuaries and biosphere reserves.

— Strengthening the infrastructure facilities of protected wetlands.

(ii) Siltation control

— Soil conservation and erosion control through afforestation, vegetation contour bunding, the construction of water harvesting structures, gully control and stream bank erosion control.

(iii) Pollution control

— Monitoring water quality of major, medium and minor river systems, groundwater and lakes by the Central and State Pollution Control Boards and under the Global Environmental Monitoring Systems(GEMS), Monitoring of Indian national Aquatic Resources(MINARS) and Ganga Action Plan(GAP) programme.

— Carrying out environmental impact assessments of developmental projects affecting the wetlands.

— Issuing administrative Notifications such as the Coastal Regulation Zone (CRZ) Notification imposing graded restrictions on industrial operation and processes in coastal areas and banning construction within 500 m of the high tide line.

(iv) Weed Control

— Both biological control methods(on an experimental basis) and manual removal of aquatic weeds.

— Evolving a comprehensive, integrated, long term approach to combat the weed menace.

(v) Afforestation

— Afforestation activities in the catchment areas of Bhoj(Madhya Pradesh), Wular(Jammu & Kashmir), Harike and Kanjli(Punjab) and Chilka(Orissa).

(vi) Wildlife Conservation

— Captive breeding of some endangered, wetland-dependent wildlife species such as rhinoceros in Assam, Sangai in Manipur and freshwater turtles.

— Improving wetland habitats for waterfowl.

(vii) Fisheries Development

— Emphasising sustainable utilization of fishery resources rather than short term gains through intensive aquaculture at natural wetlands.

(viii) Legal Aspects

— Enacting of legislations such as the Environment (Protection) Act,1986; Water (Prevention & Control of Pollution) Act, 1974; Forest (Conservation) Act, 1980 and Wildlife (Protection) Act, 1972.

(ix) Environmental Education

— Building awareness about the values and the need for conservation of wetlands among all target groups through audio-visuals, posters, nature campus, films etc.

Conducting the National Environmental Awareness Campaign every year.

RESEARCH

A wealth of data has been gathered from several projects funded by the Ministry of Environment and Forests under the Wetlands Programme. Several wetland ecosystems viz. Dal, Wular, Renuka, Rewalbai, Pichola-Fatehsagar, Sukhna, Bhoj, Sagar, Chilka, Kolleru, Loktak, Sasthamkotta, Kodaikanal etc. have been investigated in detail, especially the physico-chemical characteristics of water, sediment composition, flora, fauna, weed infestation, pollution, hydrology and other limnological parameters.

Keeping in view, the problems confronting the wetlands in India and the research studies carried out so far, the following priority areas have been identified under the Wetlands Programme:-

— Survey and mapping of wetland resources in the country using remote sensing technology.

— Application of Geographical Information System(GIS) and mathematical modeling in some selected wetlands.

— Evolving wetland evaluation techniques to facilitate a quick appraisal of the health of specific wetland ecosystems and also environmental impacts of developmental projects and other human activities on the ecosystem.

— Control of prolific growth of some exotic species and weed management.

— Siltation control.

— Fisheries development.

ABATEMENT OF POLLUTION

For abatement of pollution in the country, the following environmental regulations have been enforced, wherein, the responsibilities for enforcement has been assigned to the State Board:-

- Water(Prevention & Control of Pollution)Act,1974.
- Water(Prevention & Control of Pollution)Cess Act,1975.
- Air(Prevention & Control of Pollution)Act,1981.
- Environment(Protection)Act,1986.
- Hazardous Waste(Management & Handling)Rules,1989.
- Municipal Solid Waste(Management & Handling)Rules,2000.
- Bio-Medical Waste(Management & Handling)Rules,1998.
- The Batteries(Management & Handling)Rules,2001.
- Environment Impact Assessment Notification – 14.9.2006.

ROLE & RESPONSIBILITIES OF RSPCB

- The Water & Air polluting industries are being regulated under the consent mechanism, wherein the industries are to take Consent to Establish and Consent to Operate before establishment and operation from the State Board. There are 2211 Red Category, 9131 Orange Category and 2447 Others Category industries and around 25363 mining units(3557 Red Category), in the State which are being regulated under consent mechanism.
- The industries are required to install proper and adequate pollution control measures to achieve the discharge/emission standards and to comply with the conditions imposed under consent and such industries are being inspected and monitored by the State Board regularly at scheduled frequency.
- The duration of the consent issued to industries are 1,3,5 and 15 years depending on the type and category of the industry.
- The water polluting industries are required to install Effluent Treatment Plants (ETP) comprising of physico-chemical, biological(activated sludge, floating aeration/diffused aeration, trickling filter, up flow biological filters, biological rotating/fix disc filters, chemical adsorption system, anaerobic digester, bio-math ration and polishing treatment(sand filteration, activated charcoal filter) ozonisation and Reserves Osmosis/and the treated effluent may be reused/ recycled.

- For treatment of the domestic effluent generated from urban centers is being treated through Sewage Treatment Plant(STP) having physico-chemical, activated sludge, floating aeration/diffused aeration, oxidation pond, up flow biological filter, trickling filter, oxidation ditch, facultative ponds, filteration through sand/ activated charcoal filter media, chlorination/ozenization etc.
- In the air polluting industries pollution control measures such as cyclones, multi cyclones, Electro Static Precipitators(ESP), Ventuary Scrubbers, Pulse Jet Filters, Bag Filters etc. are being installed & operated.
- The State Board has identified 415 hazardous waste generating units in various sectors which are being regulated under the provisions of the Hazardous Waste(Management & Handling)Rules,1989. For proper treatment, storage and disposal of hazardous waste, one Common Treatment, Storage & Disposal Facility(CTSDF) has been developed at Udaipur having 296 member units and 12 Secured Land Fill Facilities(SLF) and 3 incinerators have been developed by individual industrial units.
- The State Board has identified 1828 Health Care Facilities(HCF) i.e. hospitals, dispensaries, clinics, blood banks and pathological laboratories which are being regulated under the Bio-Medical Waste(Management & Handling)Rules,1998 for segregation, collection, storage, transport and disposal of bio-medical waste. The HCF's are required to take authorization from the State Board for the activities for proper management of such waste.

  In the State, 7 Common Bio-Medical Waste Treatment, Storage, Treatment & Disposal Facilities(CBMW, TSDF) have been developed at Ajmer, Alwar, Bikaner, Jaipur, Jodhpur, Hanumangarh & Udaipur catering the requirement of the HCFs in various neighbouring districts and 6 such facilities are under development at Kota, Udaipur(Additional), Jaipur(Additional), Jhalawad, Sikar and Swaimadhopur.
- The Department of Local Self Government has identified the municipal solid waste disposal sites for 153 municipal bodies out of 183 in the State in compliance of the Municipal Solid

Waste(Management & Handling)Rules,2000. The Jaipur Municipal Corporation has prepared an action plan for proper management of MSW.

- It has been estimated that in six major cities of the State namely : Ajmer, Bikaner, Jaipur, Jodhpur, Kota & Udaipur around 262 MLD of sewage is generated. Presently, most of the areas of the cities have not been provided with the sewerage system and treatment facilities except Jaipur. In Jaipur, two Sewage Treatments Plants(STPs) near Jal Mahal and Dehlawas are working. Under Rajasthan Urban Infrastructure Development Project Sewerage System and STPs are under construction in the above major cities. Such facilities to be developed in other cities and towns also.
- The State Board is monitoring the water quality of import surface water resources i.e. river Chambal, Kaslisindh, Kansuah Nallah, Parvati, Mahi and Lake Pichhola, Fateshsagar, Udaisagar, Pushkar, Ramgarh, Kadoradam, Nakki and well water in various parts of the State at 66 monitoring stations under National Water Quality Monitoring Programme(NWMP) and State Water Quality Monitoring Programme.

POLICIES – PRIORITIES OF THE STATE BOARD :

- Classification of industries based on pollution load i.e. 17 category (Aluminium, Cement, Chlor-Alkali, Copper, Distillery, Dyes & Dye Intermediates, Fertilizers, Integrated Iron & Steel, Oil Refineries, Pesticides, Petrochemicals, Pharmaceuticals, Pulp & Paper, Sugar, Tannery, Thermal Power Plants & Zinc, Red, Orange & Others category.
  - — 153 categories of non-polluting industries have been exempted from consent mechanism.
- Strict compliance of environmental regulations is envisaged from highly polluting industries and close vigilance is ensured through frequent inspection and monitoring.
- Installation of adequate pollution control measures in all categories of polluting industries is ensured to avoid adverse impact on recipient system.

- Regular environmental surveillance is being ensured through monitoring of ambient air quality and water quality of water resources of the State and wherever required actions for abatement of pollution are being taken.
- Encouragement to combined treatment and disposal facilities in case of small sector cluster of industries keeping in view the techno-economic capabilities of small entrepreneurs.
  - 8 CETPs for textile industries at Pali, Balotra, Bithuja, Jodhpur and Jasol.
  - 1 CETP for small tanneries at Manpura Machedi.
  - 1 CETP at Bhiwadi.
- Zoning Atlas for siting of industries to avoid adverse impact of pollution on environment and financial burden of E.I.A. on entrepreneur while submitting the project proposals for establishment of industries and it also facilitates industrial estate planning.
- Promotion to waste minimization practices i.e. improvement in production efficiency, modification in processes, segregation of waste, use of better quality of raw material, internal auditing of processes and waste generation etc.
- Encouragement to reuse and recycle of treated waste water by providing polishing treatment the waste water may be used in process or for toilets, gardening, washing and dust suppression purposes.
- Promotion to pollution prevention technologies over control measures for environmental sustainability.
- Encouragement to introduction of cleaner technologies – switching over from silicating process to steam ageing in textile units for colour fixation, replacement of mercury cell to diaphram cell in chlor-alkali industries etc.
- Promotion to water harvesting/recharging systems in industrial premises.
- Ensuring preparation and implementation of Environmental

Management Plan for sustainability of environment and ecology.

- Encouragement to conservation of natural resources including water and energy in production processes through environmental auditing and environmental statements.
- Promotion to eco-friendly products to avoid unnecessary burden on environment through mass awareness.
- Public Participation through public hearing for the new project proposals and expansion in production during clearance.
- Fiscal incentives for environmental protection activities inform of rebate in water cess, exception in Custom/Excise Duty, Octroi and Sales Tax for procurement of pollution control equipments.
- The State Board takes action against the polluter and emphasis on rehabilitation of contaminated sites following the polluter pays principles.
- Social Positive & Negative Incentives – Award/Reward and Punitive Actions. The State Board has planned to introduce awards for the industrial units for their outstanding performance for environmental protection and punitive actions are being taken against chronical defaulters.
- The State Board is taking all measures for prevention, control and abatement of water and air pollution and for maintaining the wholesomeness of lakes, rivers, well and air. Thereby acting and protecting the natural resources in consonance with the Doctrine of Public Trust.
- The State Board create mass awareness through Seminars, Workshops, Electronic and Print Media, Akashwani & Doordarshan for environmental protection and preservation.
- For abatement of pollution in the polluted stretches of perennial river due to indiscriminate discharge of domestic sewage, municipal waste and disposal of dead bodies under National River Conservation Plan. The State Government has taken up a project for Chambal River from Kota to Keshoraipatan for diversion of the sewage outfalls from the river and to treat the domestic sewage through STP.

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WETLAND MANAGEMENT VIS-À-VIS ANTHROPOGENIC PROCESSES FROM EXPANDING HUMAN POPULATION

*By Dr Rashmi Sisodia and Chaturbhuj Mounditya**

INTRODUCTION

Wetlands are vital water bodies, as crucial in a natural ecosystem as kidney in a human body. Their role is complex and varied. Apart from being highly productive as the habitat of birds, fishes and a variety of other aquatic life forms, including microorganisms, wetlands provide other ecosystem services from maintaining the natural balance and for sustaining human livelihoods.

Unfortunately, there has been much neglect of wetlands in recent times due to an overall lack of appreciation of their role and on account of the pressures of growing human needs, agriculture, urbanization (due to expanding human population) and sheer mismanagement of land resources. There is also a very unfortunate misconception that wetlands are like wastelands. As a result, many precious wetlands have been sacrificed and converted to other uses all over the country and elsewhere in the world. This trend has to be checked and reversed for the larger good of all concerned. This assumes added significance especially in a water stressed region, such as Rajasthan, where it is vitally important to conserve every drop of rainwater and to preserve every bit of water body. Rajasthan state is endowed with rich wetland resources that are

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also facing degradation by the aforementioned threats. The degradation in the water quality affects the floral and faunal population along with the people dependent on these ecosystems. Hence, the conservation of wetlands deserves the utmost attention of all concerned.

In the present paper we have tried to look into the factors responsible for the loss and degradation of the wetlands viz Jal Mahal Lake (urban location) and Jamwa Ramgarh wetlands of Jaipur and Kalakho Lake of Dausa district Rajasthan (Rural location) the aims being:

- To find out the pollution load and level of dependency on these lakes.
- To identify and analyze the qualitative and quantitative impact of urbanization on wetlands.
- To analyze various physico-chemical and biological parameters
- To carry out socio-economic survey
- To compare the results with Indian Standard Specifications

SIGNIFICANCE OF WETLANDS

Wetlands are among the most productive ecosystems. They directly or indirectly support millions of people and provide goods and services to them. They support important processes like the movement of water into streams and oceans, decay of organic matter, release of nitrogen, sulfur, and carbon into the atmosphere, removal of nutrients, sediment and organic matter from water moving into the wetland; and the growth and development of all organisms dependent on them. The direct benefits of wetlands are in the form of fish, agriculture, fuel wood, recreation and water supply etc. and their indirect benefits arise from functions occurring within the ecosystem such as flood control, ground water recharge and storm protection. Wetlands retain nutrients by storing eutrophicational parameters like nitrogen and phosphorus flooding waters in vegetation or accumulating them in the sub-soil, decreasing the potential for eutrophication and excess plant growth in water. They also help in absorbing sewage and in purifying water supplies.

The mere existence of wetlands may have great significance to some people, as they are a part of their cultural heritage. Water is required for various purposes like drinking and personal hygiene, fisheries, agriculture, navigation, industrial production, hydropower generation and recreation. Apart from these, some socio-economic values - fuel wood, medicinal plants, livestock grazing, agriculture, energy resource, wildlife resource, transport, recreation and tourism etc. are significant through water supply.

In recent years, there has been increasing concern over the continuing degradation of wetlands and in particular, rivers and lakes. Wetland sustains all life and perform some useful functions in the maintenance of overall balance of nature. The functional properties of wetland ecosystem demonstrate clearly its role in maintaining the ecological balance.

WETLANDS LOSS AND DEGRADATION

The impact of wetland may be grouped into 5 main categories: loss of wetland area, changes to water regime, changes in water quality, overexploitation of wetland products and introduction of exotic or alien species.

The primary factors causing degradation are sedimentation, eutrophication, pesticide pollution, salinity, heavy metal pollution, weed infestation, low dissolved oxygen and pH (UNEP, 1994).

The major activities responsible for the wetland loss are urbanization (due to expanding human population), drainage for agriculture and water system regulation (IUCN, 1999). Development activities like excavation; filling, draining etc. are the major destructive methods resulting in a significant loss of the biological diversity of flora and fauna, migratory birds and also the productivity of the system. Wetlands throughout India are experiencing varying degrees of environmental degradation, related mainly to encroachments, eutrophication (from domestic and industrial effluents) and siltation.

JAL MAHAL LAKE (JAIPUR)

The Jal Mahal (Man Sagar Lake) in Jaipur, was aimed at developing a reservoir- water harvesting –to dam the rainwater which flowed down the hills of Nahargarh and Jaigarh hills. It was developed by 1727 when the city of Jaipur was founded by Maharaja Sawai Jai Singh II of Amber as a sustainable water body.

As population spread, Jaipur busted over its walled boundaries. With haphazard housing mushrooming around the lake, Man Sagar has had most negative impact on its aquatic character; the lake got polluted with continuous discharge of sewage from northern areas of the city.

The problem of water pollution due to discharge of domestic, agricultural and industrial wastes into aquatic system has become a serious problem in the country. Jaipur city drainage system has been divided into North and South Zone. The North Zone, which includes most of the walled city, covers population under the sewage scheme. Though South Zone covers a portion of the walled city area and most of the new Jaipur. The city has got only one sewage treatment plant that was commissioned in 1995 near Jal Mahal Lake (Man Sagar Lake), where the effluent from the North Zone is treated but the treatment plant are not working since last five years. It has changed the very character of this lake. Not only the lake water is polluted beyond the tolerable limit but also it is causing adverse effect on the health of people who reside in its close proximity. In the South Zone of the city, the sewage is discharged, without any treatment, into Amani Shah's drainage.

Today it appears that people of Jaipur have stopped caring for their own reservoir Jal Mahal. The race for development has kept the city's Municipal Corporation, Councilors, Legislators, Ministers, and the Government busy in exploring new alternatives. Consequently, Jal Mahal is receiving -

- Effluents of lakhs of people of Jaipur.
- Silt which is deposited into its bed, generated from the nearby

  Catchment's hill slopes which are totally denuded, and
- Encroachments, which have altered the original shape and total area of Jal Mahal.

KALAKHO LAKE (DAUSA)

Kalakho Lake is situated in eastern part of Rajasthan nearby Kalakho village in Dausa district. This greatest wetland of Dausa is about 74 km away from Jaipur and 14 km away from main city of Dausa. Lake is situated on the National highway No. 11. It was constructed in 1952 having spread over an area of 52.25 Sq. miles receiving water from Khardi River and natural streams and canals. The anthropogenic activities in its catchment area may be considered as source of pollutants.

The site comprises fresh water swamps, which are part of the Indogangetic Great Plains. Both the lakes (Jal Mahal Lake & Kalakho Lake) have microbiogeographical location and oriental zoogeographical location. Climatic condition in this region is semi-arid and Indus-Ganges monsoon forest region. Both Jaipur and Dausa area are in eastern plains within the catchments of Banas river which is major tributary of the river Chambal which ultimately joins the river Yamuna. Eastern plains have rich alluvial soils drained by seasonal rivers.

JAMWA RAMGARH LAKE

The wetland of Jamwa Ramgarh Lake, located at Jaipur, Rajasthan, India, covers an area of 297 square miles. The Jamwa Ramgarh reservoir receives water from the Banganga River and attracts a large number of migratory and domestic birds. In Jaipur city 60 million gallons of water used to be supplied from Jamwa Ramgarh Lake but presently the lake is completely dried up. The water from this wetland, besides being a source of potable water for inhabitants of Jaipur, had economic value such as fish breeding.

Presently (2007) the lake received no water even after heavy rainfalls due to construction of eight anicuts (one of them is Bishenpura Bandha), which is an obstruction for water. It stops water from flowing into it until it overflows. If these were not constructed water would have directly reached the Ramgarh Lake (12th July, 2007, Ref. Patrika). Many plots and farmhouses have been sold in the area. Illegal construction in the area of river Banganga (Ref. 6th June 2007, Patrika) is also responsible.

There is no proper storage facility for rain water as a result 29% rainwater flows and is wasted which could fulfil the needs of 13 crore 59 lakh people for 1 year

Water Quality Index (WQI):

The WQI was calculated from the point of view of the suitability of lake water for human consumption. The indices are among the most effective ways to communicate the information on water quality trends to the general public or to the policy makers and in water quality management.

(i) WQI Calculation:

For calculation of WQI, selection of parameters has great importance. Since selection of too many parameters might widen the water quality index and importance of various parameter depends on the intended use of water. Eight physico - chemical parameters namely pH, TDS, total alkalinity, total hardness, chloride, DO and BOD are used to calculate WQI.

Calculation of WQI

WQI is calculated from the following equation

$$WQI = \sum_{n=1}^{n} q_n W_n / \sum_{n=1}^{n} W_n$$

Where,

W_n = unit weight for n^{th} parameters

q_n = quality rating for the n^{th} water quality parameter.

(ii) Assessment of water quality based on WQI

Table : Water quality index (WQI) Kalakho Lake

	(Jan. 02 to Dec. 02)			(Jan. 03 to Dec. 03)		
Sampling Station	Summer	Mansoon	Winter	Summer	Monsoon	Winter
Station I	460.4742	599.3328	408.336	455.737	606.55303	418.736
Station II	472.6972	600.386	413.562	464.2	614.48472	424.182
Station III	465.9755	564.0349	414.484	456.471	569.63876	423.327
Station IV	479.7297	527.9066	414.69	480.424	520.09648	432.615

Kalakho Lake $S_2 > S_1 > S_3 > S_4$

S-1: Near the agriculture field

S-2: Near the village area

S-3: Along the National Highway road

S-4: End point of lake (outlet)

Table : Water quality index (WQI) of Jal Mahal Lake

	(Jan. 02 to Dec. 02)			(Jan. 03 to Dec. 03)		
Sampling Station	Summer	Mansoon	Winter	Summer	Monsoon	Winter
Station I	1142.28	1484.0248	1476.427	1127.4	1624.2233	1480.12
Station II	4183.25	3653.0542	3676.466	4156.25	3654.5526	3654.203
Station III	1787.08	1738.5853	1477.795	1768.26	1732.447	1473.298
Station IV	1789.31	1753.1076	1472.93	1777.31	1753.0146	1476.091

Jal Mahal Lake $S_2 > S_4 > S_3 > S_1$

S-1: Along the road side (Amber road)

S-2: Mixing point of domestic and sewage waste

S-3: Near the hilly side (Kanak Vrindavan side, North East side)

S-4: Outlet of water (near the bird watching fair area)

- Index value was always above 100 at all the sampling station of both lakes.
- In the both wetlands, WQI values in 2003 were higher than the 2002 at all the sampling stations indicating better picture in year 2002.
- WQI values of Jal Mahal Lake indicate that it is under stress of severe pollution due to discharge of wastewater from various sources into the lake.

In Jamwa Ramgarh the pH of Ramgarh lake water ranged from 6.8 to 8.5, which may be due to high buffering capacity of the system. The electrical conductivity values ranged from 500 to 700 micromhos/cm, with a maximum in summer and minimum in monsoon season. The total alkalinity values fluctuated from 102.6 to 215 mg/l, indicating that the water is hard.

Avifaunal Studies

The study was undertaken for:

a. To monitor cost-effective way of the overall health of the ecosystem.

b. Correlating the presence of avifauna and flora with the physiochemical characteristics of wetlands,

c. in relation to the water body in rural (Kalakho Lake) and urban areas (Jal Mahal Lake).

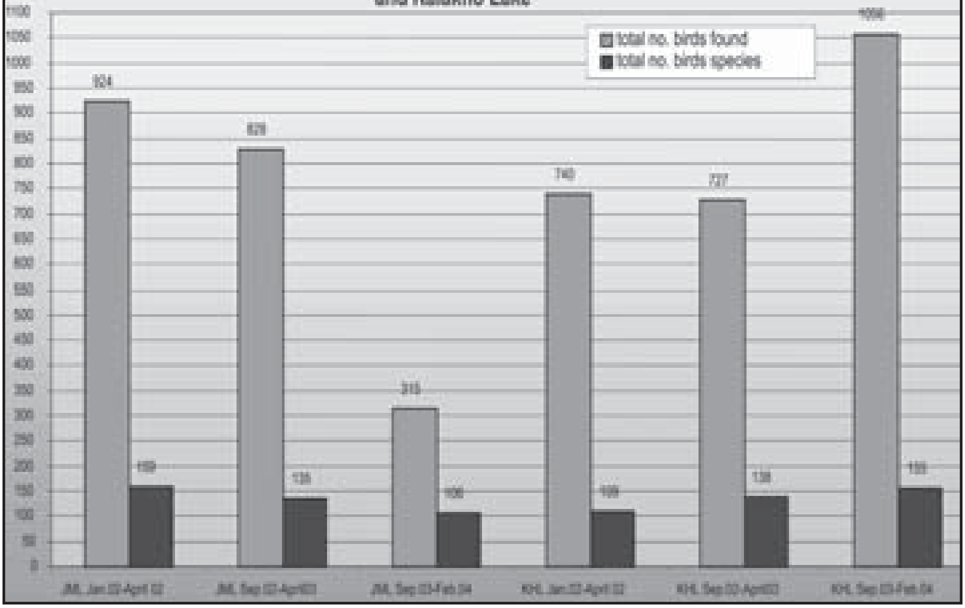
STATUS OF AVIFAUNA

- Species such as egrets, paddy birds and waders were widespread in cultivated areas of both wetlands.
- Both lakes offer habitats for a variety of migratory and resident birds.
- More than 180 species of birds belonging to 49 families were recorded during the study (January 2002 to February 2004) - Fig 1.
- These included some rare, endangered, uncommon, vulnerable, threatened and near threatened species as the most common sightings.

In terms of numbers of bird species and the total number of bird, Kalakho Lake was much better than the Jal Mahal Lake. The rural location of the Kalakho Lake seems to be responsible. It appears to be less polluted than Jal Mahal Lake. In Jamwa Ramgarh more than 100 species of birds belonging to 38 families were recorded at Lake during the winter season of year 2002. As the lake was affected by scanty rainfall and had only one-fourth water of its total capacity the number of waterfowls visiting was reduced to only four to five thousand, now the number is further reduced due to constructional activities and lake of water. In drought year 2002 in Rajasthan scanty rainfall affected the diversity and number of birds species. The year 2003 witnessed heavy monsoon but still the number of birds species decline upto 15.95 continuously through the year which further declined to 33.34% by the end of 2003 to beginning of year 2004.

- In Kalakho Lake heavy rainfall in year 2003 resulted in increased availability of food items and vegetation, number of birds species increase significantly by 26%. The end of 2003 to beginning of 2004 saw further increase in number of bird's species 42.2%.

Fig. 1: Species composition and number of birds of Jal Mahal Lake and Kalakho Lake



Reason of decline of biodiversity (birds): Our study show that the decline of biodiversity may be due to:

1. Changes in the natural habitat such as uprooting of vegetation (food items for birds).
2. Desilting operations conducted by the Jaipur Development Authority.
3. Motor exhaust pollution, noise pollution, litter etc.
4. Some birds during their migration stop at Joardh, man-made ponds and anicuts, which become filled with water after the rainy season. Teeming of small life in these water bodies attracts a few migratory birds, which fail to reach the lake.

5. Gradual loss of vegetation in the adjacent reserved forest area through deforestation (by local residents). (Ministry of environment and forest 2005,forest and tree cover in India- report submitted to the Central government). The total forest cover area adjacent to these lakes and all over Rajasthan has decreased by 0.5%.
6. Scanty rainfall in 2002 resulted in the reduction of overall water capacity of the lakes to one fourth, which affected the numbers of migratory birds.
7. Changes in water quality of lake water.
8. Waste disposal and malpractices around the lake
9. Inflow of sewage and industrial effluents are responsible for decline of the biodiversity.

SOCIO-ECONOMY SURVEY

Earlier the human interference was restricted to bathing and washing of clothes though not permitted officially. Both wetlands have now become a recreation place for tourists. The constant disturbances all around the lake by anthropogenic activities and agricultural practices in the dried up area of wetland has resulted in the shrinkages of wetland. Socio-economic values of wetlands for prioritization of biological conservation sites are a very important aspect because of the number of species that depend on them.

The government has leased the lake to contractors for catching fish, which resulted in considerable depletion of fish fauna of the lake. Since fish forms a very important chain of food in a wetland ecology. The adjacent reserved forest area is scantily vegetated and thus does not offer much by way of food or habitat.

In our study of the lakes – reed gathering, grazing, clay gathering, solid waste disposal, agricultural waste, drinking/wallowing by cattle, domestic uses, fishing and peta-kashth in the dried up area were recorded. Jal Mahal Lake has also used for sewage disposal and as a recreation place for tourists. At downstream of the Jal Mahal Lake, more than a thousand acres are irrigated by outflow of mixed lake water and raw sewage.

ECONOMIC DEPENDENCY

(a) Dependency for irrigation and its products were high per day, during cropping season in the dried up areas of Jal Mahal Lake, whereas Kalakho Lake has low agriculture value on account of low water level during summer.

(b) Dependency for fuel and fish in Jal Mahal Lake was low per day, at Kalakho high per day.

Dependency for livestock in the Kalakho Lake was higher when compared with Jal Mahal Lake.

The eutrophic status of Jal Mahal Lake has made the wetland resource unusable. Water spread area has also declined due to encroachment of peripheral areas for agricultural purposes, settlements and construction of roads, etc.

ANTHROPOGENIC DISTURBANCES IN AND AROUND THE WETLANDS

In our study of both lakes many anti-conservation activities like

- Reed gathering
- Grazing and drinking/wallowing by cattle
- Clay gathering
- Agricultural waste
- Domestic uses (bathing and washing of clothes into the lake)
- Fishing and peta-kashth
- Encroachment on peripheral areas for human settlements

Eutrophication of these lakes through human activities has also proved to be one of the most widespread and serious problems. Eutrophic status of the lake has affected the avifauna of the wetland.

These activities are a constant source of disturbance for birds.

CONCLUSION

From the above findings the following conclusions can be drawn:

1. At Jal Mahal Lake high values of BOD, COD, pH, and EC, noted seen to be responsible for given rise to algal blooms indicating heavy

environmental pollution. Lake has attained eutrophic condition evident from high levels of TDS, alkalinity, hardness, weed infestation and low DO.

2. Socio-economic survey showed that, the economic dependency in the case of Kalakho Lake is more than that of Jal Mahal Lake due to better water quality and ecosystem.

3. WQI values indicate that water quality of Jal Mahal Lake is not suitable for any purpose.

4. Water spread areas of both the lakes have been considerably reduced during last two decades, due to sedimentation and encroachments for developmental activities.

5. The degradation of the water quality affects the floral and faunal population and also the people dependent on these ecosystems.

6. The present study highlights the magnitude of wetland conservation, need for restoration and formulation of conservation strategies for sustainable development.

    - It provides sound data and policy advice on which the government can base more effective conservation actions.
    - In water-stressed region Rajasthan, some highly adaptable thinking must be found to permit development activities, including tourism, subsistence agriculture, and conservation of wildlife to be each given "a fair share" of the one biome – the wetland.

RECOMMENDATION FOR MANAGEMENT STRATEGIES

For the conservation of these wetlands and their biodiversity and to improve the water quality certain recommendations have been proposed which are as follows:

1. Wetlands in Rajasthan are threatened owing to the pressures of unplanned urbanization and land use pattern. Industrial and residential layout near the wetland should not be permitted.

2. Many anti-conservation activities observed during our study must be strictly prohibited, since the activity is a disturbing factor for birds.

3. Fishing should be strictly monitored according to the rules and regulation of Rajasthan Fisheries Act 1953.
4. Peta-kashth in the dried up area of wetlands leads to shrinkage of the wetland, which should not be permitted.
5. The open drains, which bring enormous quantity of effluents into the lake, which is hazardous for people residing near by, should not be permitted.
6. An action-programme should be drawn to lay down cement pipelines to carry the city's effluents away from the present flow.
7. Effluent Treatment Plant (ETP) should be installed which will result in improvement of water quality.
8. Steps should be taken to prevent further silt deposition leading to erosion of the lake by planting vegetation.
9. Planting trees in adjacent forest area to increase the density of existing forest cover.
10. Mound Plantation - The tree species like: Acacia nilotica (desi babool), Ficus bengalensis (bar), Ficus religiosa (peepal) etc need to be planted to facilitate breeding by migratory and resident birds.
11. Creation of Nesting Island is recommended in lakes, which at present have none.
12. Restricted boating activity within 60 m of the nesting sites.
13. De- weeding: Prolific growth of weed like water hyacinth etc, it should be harvested so as to remove this biomass from the lake system.
14. Anthropogenic stress should be controlled by strict implementation of laws by government, with suitable support from NGO's.
15. Increasing awareness among the people. This means engaging local people in a way, which makes them concerned to conserve their resources.
16. The most important is coordination between different organizations and authorities, otherwise whatever money will be senctioned for restoration will be a waste as noted previously. One agency planted

trees but since no tree guards were put around them, the animals grazed them.

Lastly strong political will is needed.

- This study strongly recommends the need to save these wetlands of Rajasthan, because of their great ecological importance. The government of Rajasthan should declare these areas as bird sanctuaries in view of their tremendous potential.

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Water Quality Monitoring in Lakes/ Reservoirs using Remote Sensing: A Case Study

*By Dr V. K. Choubey**

1. INTRODUCTION

Water quality is an important environment variable, because it affects human health and economic activity (Alfoldi and Munday, 1978). Suspended sediment is an important environmental parameter used in determining water quality.

Sediment deposition in reservoir reduces its storage capacity and, hence, its ability to control flooding. Suspended matter reduces the penetration of light into water, this further reducing the production of food for fish. The poor visibility in turbid water also makes it difficult for fish to find what food is available (McCauley, 1977).

Water quality in the form of the water transparency in the visual region is very important for hydro-optical application (Lindell *et al.,* 1985). Absorption and scattering processes determine the water transparency. Light penetration depth is primarily controlled by sediment loads (Yarger *et al.,* 1973). During the past 10 there has been a renewed interest in the methodology and procedure used to monitor water quality in reservoirs. Several investigators successfully used Landsat MSS/TM imagery in determining and monitoring water quality in reservoirs and estuarine systems.

Recent studies include Bukata *et al.* (1983), Khorram and Cheshire

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(1985), Ritchie and Cooper (1988), Lindell (1985), and Ramsay and Jensen (1990). These investigators used multispectral digital data and concurrently acquired field measurements to develop a predictive equation for water quality parameters. Such methods are specific by their very nature, site, and even season (Nanu and Robertson, 1990). However, there still exists a need to study physical and optical properties of suspended sediments to enhance the utility of remote sensing for water quality monitoring.

There is no government/private agency to monitor the water quality of the Tawa reservoir (Central India) covering large areas. It is apparent that a timely low cost method of providing information on water quality to various users of the reservoir water is important. Conventional methods involved tedious and expensive in-situ and laboratory studies. Satellite-borne sensors have capabilities off providing repetitive, low cost, multi-spectral, timely, reliable information over areas. There is a need to investigate the usefulness of IRS-IA-LISS-I (Indian Remote Sensing Satellite-lA-Linear _Imaging Self-Scanning System-I) data for monitoring water quality in this geographical area.

Considerable research in the various aspects of remote sensing for monitoring water quality in riverine and estuarine environments has been undertaken abroad using various satellite/airborne data except IRS-IA. In India, no such type of work has been reported so far. In view of the potential application of IRS-IA data to Indian tropical waters, a study was undertaken to calibrate the IRS-IA-LISS-I spectral data to water clarity.

The purpose of this study was to quantify the relationship between remotely sensed data and water clarity. The effect of clay and non-clay minerals on water transparency with particular emphasis being given to the spectral complexities of the reservoir water were subject of this study. The IRS-IA-LISS-I multi-spectral digital data have been used in this study.

2. STUDY AREA

Tawa reservoir is a large impoundment located in Central India on the Tawa River of the Narmada basin (Figure 1). The water spread area is about 225 km^2 and filling of reservoir is mainly from two major rivers, the Tawa and Denwa, during the monsoon period. These rivers join the reservoir from the South and east and flow through different environments. The Tawa river flows through semi-forested and cultivated land, whereas the Denwa flows through dense forest. A very small portion of the area is a meandering plain formed due to the meandering of the Tawa River. Mostly rivers are structurally controlled and, hence, very deep bank sides occur. The principal tributaries of the Tawa River are the Machua, Malni, Suktawa, Koti, and Sonbhadra of Denwa river. The basin is characterised by a tropical climate with an average annual rainfall of 156 cm.

The soils are derived from sandstone and basalt under a subtropical monsoon climate. Folding and faulting have given rise to different features and physiography has modified the soil formation at different physiographic situations. About 83.8% of the area belongs to red and yellow soils of the catchment; out of this 57.3% is shared by coarse loamy and 26.5% by fine loamy soils. The dark grayish brown (black) clayey cracking soil occupies 14.1 % of the catchment area. The alluvial soils have a minor extent of 1.5%. The soil taxonomy is classified as orthents, ochrepts, ustalfs, and usterts, etc.

The Tawa and Denwa rivers drain an area of 2310 km^2 and the catchment area is 5982.90 km^2. The reservoir is designed to have a storage capacity of 0.231 million ha m^{-1} at full reservoir level of 355.397 m.

3. METHODOLOGY

The optical properties of water are related to light penetration and visibility of submerged objects in the visual range of the spectrum (Davies-Colley and Vant, 1988). The secchi disc is a suitable instrument for measuring the water clarity.

An alluminum disc of 20 cm diameter was used with additional iron pallets attached to make it heavy and steady in the water during measurements. The disc was painted black and white on alternate quadrants. The reflectance, as measured in the laboratory, was about 85% for white and 2.5% for black paint. The secchi disc was used to measure the extinction depth (the depth at which the disc just becomes invisible in the water). The average of two readings for the depth at which the disc disappears during descending and reappears during lifting is adopted. The concentration of suspended material is compared with the depth of penetration. Secchi depth observations were made from the shaded side of the boat to avoid sun glare (Davies, Colley and Vant, 1988) in all 47 sampling locations (Figure 1). At extinction depth, water samples were collected with the help of a depth sampler for all the sampling locations. At every sampling point the depth of the bed was measured for identifying a point with negligible bottom effect and to ensure the extinction depth is less than the bottom depth to avoid bottom noise effect.

To reduce the time lag between IRS-1A overpass and sampling, the collection of water samples and measurements of pH, conductivity and secchi depth were carried out between 7 a.m. and 6 p.m. for all the sampling locations on the days of two successive overpasses. (28 September and 20 October 1988).

Water samples were filtered through an ultra cellulose membrane filter paper (millipore 0.45 ì*m)* using a Buchner funnel and a vacuum pump to estimate the total suspended matter. Suspended sediments of eight water samples representing various reaches of the reservoir were selected for bulk mineralogy and particle size analysis. Initially, the suspended matter was treated with hydrogen peroxide to remove organic matter coatings on mineral grains. The sediments were mounted by the drop on slide technique (Gibbs, 1967) and were uniformly spread on the glass slide to avoid differential settling of the particles and glycolation. The mineral composition was determined using a Philips x-ray difractometer with Cu-Ká radiation and Ni filter. Mineral identification and estimation of abundance was done following the methods of Biscaye (1965) and Carrol(1970).Particle-size distribution in suspended solids were determined by a Fritsch analysette-22 laser particle size analyser.

IRS-IA-LISS-I computer compatible tapes (CCT's) were acquired for the scene (path-row 27-52) of Tawa reservoir on 28 September and 20 October 1988. The image data on the CCT's were radiometrically and geometrically corrected. In order to seperate land and water components, a binary mask was made by determining an interactive threshold for LISS-I band 4, which was then used to mask out land areas in other bands 1, 2 and 3 (Lindell *et ai.*, 1985; Khorram and Cheshire, 1985). Masked (water) pixel values for each spectral band were extracted for 3 x 3 arrays encompassing each of the 21 and 47 sampling locations for 28 September and 20 October 1988, respectively. The LISS-I pixel values measured in DNs were converted into radiance in mW/cm^2/ìm for bands 1,2 and 3 before the regression analysis. Water is a strong absorber of band 4 (0.77-{).86µ*m)* near infrared radiation and, hence, is not included in the analysis.

4. RESULTS AND DISCUSSIONS

The absorption and scattering process determine water transparency (Lindell *et at.,* 1985). Clear water being blue in color absorbs light in all the other spectral regions to a large extent and reflects blue light. Suspended particles scatter light and the amount of light scattered is related to the degree of turbidity, particle surface area, and the physical and ʻoptical properties of the material (Jerlov, 1976).

It has been observed that uniform atmospheric conditions existed over the entire reservoir because air masses and the sky in the region were dry and clear. No wave action was observed on the calm water surface. No urban/industrial units existed in the region which could produce aerosol nonhomogenity (Topliss *et al.,* 1990). Hence, it is assumed that an atmospheric contribution to the signal is relatively unimportant in the Tawa reservoir, which is enclosed by hilly terrain. Yarger *et al.(1973)* suggested that sun elevation=45 degrees exhibit a weak dependence on the sun angle and that the angle of incidence of reflected light are not important factors for a reservoir (concrete target).

The Tawa reservoir is devided into three hydrodynamic zones, inflow, transition, and main body of the reservoir (Figure 1). The inflow zones are turbid and the transition zones are relatively less turbid. The mixing of water and sediment discharge from the Tawa and Denwa rivers is observed in the main body of the reservoir, where turbidity is less than in the other two zones.

The reservoir water is alkaline in nature (pH 7.8). The conductivity reflects the chemical characteristics of the water discharged by the river into the reservoir. A significant difference in conductivity values was observed in both flanks (Tawa and Denwa) and a combined effect of both rivers water in the main body of the reservoir water. The average conductivity values are 291.9 µs cm^{-1}, 142.3 µs cm^{-1} and 225.4 µs cm^{-1} in the waters of the Tawa and Denwa rivers and in the main body of the reservoir. This suggests that the Tawa River discharges more chemicals than the Denwa into the reservoir.

Water transparency is primarily controlled by suspended load (Choubey, 1990), Figure 2 shows that the secchi depth (SD) measurements of light extinction decreases when the concentration of suspended solid increases, which indicates that SD is inversely related with suspended solids concentration.

The seechi depth (SD) measurements varied considerably for various reaches of the Tawa reservoir (Table I). On the Tawa inflow zone of the reservoir, the SD varies between 21 and 30 cm. The low water transparency is due to the heavy suspended solids loading from the river outlet. In the transition zone, water transparency gradually increases and the water becomes more homogeneous with a SD of 30-35 cm. The abrupt change in a few locations (example s1. No. 16) indicate influx of supended load from small tributaries joining the transition zone. In the Denwa inflow area, the SD values are comparatively low, in range 13-25 cm, which indicates the presence of a high concentration of suspended solids discharged by the river. On the other hand, in the main body, due to intense mixing of river sediment laden with water, the SD is between 22-27 cm. The maximum suspended solids loading appears to be from the Denwa region.

A plot of SD against radiance values for each LISS-I band (Figure 3) indicates that as the SD values increase, there is a decrease in the radiance value. It was noticed that bands 1 and 2 exhibit hyperbolic curves and a flat response beyond 25 cm. This indicated that bands 1 and 2 (0.45 to 0.59ì*m)* approach saturation above a SD of 25 cm. However, band 3 *(0.62-O.68*ì*m)* shows a consistently decreasing linear trend and a high correlation (r = 0.89). The relationship between SD and radiance suggests that the water clarity depends on the concentration of suspended solids and on the physical and optical properties of suspended matter (primarily inorganic particulates).

The mineralogy characterises the nature of the suspended sediments in the reservoir water; as such they may not exactly represent the final suspended material in the reservoir after mixing (Subramanian, 1980). The reservoir's main body exhibits mineralogical characteristics between those of the Tawa and Denwa sediment discharges. The Denwa suspended sediments are coarse grained, whereas those of the Tawa are finer. Grain size-controlled mineralogy due to differential settling mechanism (Gibbs, 1967) can cause differences in the mineralogy of reservoir-suspended sediments.

The mineral composition of the suspended sediments at eight locations are shown in Figure 4. The mineral composition of the suspended sediments is an important parameter affecting the relationship between water clarity and reflected radiance (Choubey, 1990). The Tawa River contributes an equal amount of kaolinite and montmorillonite expandable clays in the inflow-transition zone and a significant amount of feldspar observed in the inflow zone. A very high percentage (70%) of kaolinite and a substantial amount of montmorillonite, illite, quartz, and feldspar are present in the Denwa inflow zone.

The different mineralogy of the Tawa and Denwa discharge indicates that the dominance of fine clay minerals in the Denwa inflow may be the reason for the low water transparency at a more or less equal concentration in the Tawa inflow where the presence of silicates (feldspar) with clay minerals permits deep light penetration. This also suggests that water clarity depth varies with the presence of clay and non clay minerals in water.

In the Denwa region, the suspended solids concentration is comparatively higher than those of Tawa. However, the secchi depth values do not show appreciable change with change in the suspended solids concentration. Hence, it can be stated that water transparency is expected to be affected mainly by the layer of expandable kaolinite and montmorillonite clay. In this case, there is a drastic change in the conductivity of water in Tawa (291.9 μm cm^{-1}) and Denwa (142.3 μm cm^{-1}).

Therefore, its influence on the relationship between suspended matter and water transparency cannot be ignored and needs to be studied. The conductivity is inversely related to dissolved organic material and the optimum wavelengh band 3 for monitoring water clarity is not influenced by dissolved organic matters (Topliss, 1990).

TABLE I. Field measured value of secchi depth and LISS-I radiance values in bands 1,2, and 3 for 20 October 1988

Sample No.	*Secchi depth*	*Band 1*	*Band 2*	*Band 3*
1	22	4.68	3.89	2.23
2	21	4.58	3.85	2.07
3	27	4.47	3.87	2.20
4	26	4.53	3.91	2.20
5	27	4.53	3.87	2.20
6	27	4.53	3.87	2.20
7	26	4.61	4.05	2.24
8	27	4.58	3.91	2.31
9	28	4.52	3.85	2.14
10	28	4.44	3.67	2.13
11	27	4.47	3.66	2.13
12	27	4.45	3.66	2.13
13	27	4.45	3.66	2.13
13	26	4.47	3.68	2.04
14	30	4.44	3.56	1.99
15	32	4.43	3.66	2.04
16	27	4.56	3.72	2.05
17	31	4.45	2.68	1.95
Tawa transition zone				
18	4	4.43	3.55	1.95
19	31	4.45	3.49	1.97
20	34	4.42	3.53	1.93
21	35	4.42	3.51	1.81
22	34	4.43	3.56	1.81
23	35	4.36	3.56	1.81
24	30	4.48	3.72	1.93
Main body				
25	27	4.77	4.05	2.10
26	27	4.84	4.10	2.20

Sample No.	*Secchi depth*	*Band 1*	*Band 2*	*Band 3*
27	27	4.89	4.12	2.19
28	26	5.08	4.68	2.60
29	24	5.21	4.68	2.60
30	25	5.10	4.62	2.41
31	27	5.08	4.60	2.42
32	23	5.28	4.82	2.52
33	27	5.07	4.62	2.41
Denwa inflow zone				
34	22	5.32	4.95	2.93
35	18	5.34	5.12	2.93
36	22	5.07	4.78	2.86
37	19	5.35	5.09	3.00
38	26	4.90	4.11	2.52
39	20	5.20	5.00	2.90
40	21	5.30	5.01	2.92
41	21	5.23	5.01	2.94
42	20	2.26	5.01	2.94
43	15	5.43	5.24	3.30
44	25	4.93	4.70	2.93
45	13	5.38	5.20	3.31
46	16	5.38	5.20	3.31
47	15	5.33	5.20	3.20

Sample locations are shown in figure 1.

The particle size is the major component influencing light scattering (Merry, 1977). The percentages by surface area of sand and coarse silt <0.30 ì*m)*, silt (5-30 ì*m)* and clay <5 ì*m)* are shown in Figure 5 for eight samples representing various reaches of the reservoir. The percentage of organic matters in suspension in water was around 10% (determined by removing organic matters from suspended sediment). The suspended solids of the reservoir water contain a high percentage of fine clay size particles (0.5-0.10 ì*m)*, in Tawa (77%), Denwa (82%), and 56% in main body. The inflow zones carry coarser grains than the transition zone. The particle size distribution in the reservoir water shows no great variation in the particle size of suspended matter, hence a uniform effect of particle size on reflected radiance can be assumed (Munday *et al.*, 1979).

The optical properties of suspended sediments are an important parameter affecting the relationship between remotely sensed data and water clarity. The scattering of light is the result of diffraction, refraction, and reflection. Diffraction will occur independent of the particle composition, whereas refraction and reflection are determined by the refractive index of the particles (Jerlov, 1976). The suspended particles in the reservoir water are non absorbing spherical/foliated particles, characterised by a refractive index (Nanu and Robertson, 1990). The index of refraction for the violet of the spectrum is greater than for the red and, on refraction, red is deviated less than violet (Kerr, 1959).

TABLE II. Optical properties of major minerals present in the suspended of reservoir water

Mineral	*Refractive index*	*Crystal system*	*Bifringence*	
Kaolonite	Least	1.561	Triclinic	0.005
	Greatest	1.566		
Montmorillonite	least	1.492	Monoclinic	0.021
	Greatest	1.513		
Illite	least	1.535-1.570	Monoclinic	0.030
	Gretest	1.565-1.605		
Feldspar	least	1.518	Monoclinic	0.008
(alkali)	greatest	1.526		
Quartz	least	1.544	Haxagonal	0.009
	Greatest	1.533		
Pure water		1.333		

Montmorillonite and illite; their average indices of refraction are 1.563, 1.503, and 1.569, respectively.

In general, it is reasonable to expect that the refraction from the mixture of clays and non clay minerals of varying reflective indices in the Tawa region may blur the light and bring out the same effect on reflected radiance. On the other hand, kaolinite (70%) with a higher refractive index than montmorillonite (20%), may produce more refraction in the visible region of the spectrum.

Further study on the effect of the optical properties of individual minerals and combinations of various minerals on the relationship between suspended matter concentration (relating to water transparency) and reflected radiance in laboratory controlled conditions may provide better results.

To develop the estimator equation, LISS-I multispectral digital data and field measurements of 20 October 1988 were used. A least-squares regression procedure was used to produce the estimator equation for secchi transparency in terms of LISS-I radiance values. The dependable variable was SD and LISS-I bands 1, 2, and 3 radiance values were independent variables. Forty-seven data points of 20 October 1988 from the Tawa reservoir surface water were used to obtain the estimator equation for SD.

In order to increase the analytical range, a multiple band approach was adopted. All the possible combinations of the independent variables were tested so as to find the most efficient equation. An optimum estimator equation (Table III(a) is obtained on the basis of the highest correlation coefficient approaching unity; the minimum standard error aproaching zero and the F value four times greater than a critical value for F (Fer) (Whitlock *et al.,* 1982). The relationship between observed and estimated values for the 20 October 1988 data set are shown in Figure 6(a), and the statistical parameter in Table III(b). The estimator equation has given good agreement with field data of the SD, where suspended sediments are dominant.

TABLE III. Multiple regression equation used to estimate value of secchi depth from 20 October 1988, LISS-I mean radiance values. For verification 28 September 1988 Liss-I mean radiance values were used

$Y_{SD} = a\text{-}bx_1\text{+}cx_2$

Where Y_{SD} = Secchi depth expressed in centimeters

x_1 = (band 1+ band 2+band 3).

x_2 = (band 1+ band 3).

a = 72.97, b = 0.85, c = -1.99.

TABLE III b. Statistical summary for the multiple regression equation based on 20 October 1988, LISS-I mean radiance values

	Secchi depth
Coefficient of Determination	0.887
Coefficient of Correlation	0.942
F value	161.62
R.M.S.E.	1.83
F/Fcr	
(0.01 level)	31.13
Residual range	-7.99 to 4.54

The distribution of points around the 1: 1 line is suggesting little or no bias in the data. Some of the scatter reflects an error in the field measurements of SD, which is around 10% (Davies-Colley and Vant, 1988). The time lag between IRSIA overpass and SD measurements (6 to 7 hours) may introduce an error. The SD values are underestimated at high SD, which may be due to the presence of 10% organic matter (pigment) in suspension. The probable reason for overestimation at low SD may be the increasing inhomogenity in the suspended solid distribution in the sampling locations.

The verification of the estimator equation was tested by applying it to the 21 data sets of 28 September 1988 bands 1, 2 and 3 radiance values for the Tawa reservoir. The relationship between field-measured values and values estimated by the equation are shown in Figure 6(b), which shows the validity of the estimater equation as data points are scattered around the 1: 1 line. The effect of unequal illumination caused by changing sun elevation angles from one IRS-IA pass to the next appears to be at its minimum (2: 45 deg). The coefficient of correlation and standard error was r=0.92 and 1.36 cm respectively. This indicates that the estimator equation appears to be satisfactory for prediction water clarity in the Tawa reservoir.

5. CONCLUSIONS

The result from this study may help to determine the water quality of the Tawa reservoir. On the basis of the results obtained, it can be concluded that:

(1) a functional inverse relationship exists between SD and LISS- I radiance values in the wavelength range 0.45-0.68ìm. The Tawa reservoir water calibration of SD and band 3 of LISS-I shows a good correlation (r = 0.89, n = 47) in the range of 13-35 cm;

(2) the coefficient of correlation between observed and estimated SD data for the 28 September 1988 data set was r= 0.92, indicating that the equation could accurately predict the water quality for this reservoir on new occasions from IRS-IA-LISS-I spectral data;

(3) IRS-IA-LISS-I multispectral data are well suited for water quality mapping, since the LISS-I spectral bands 1, 2 and 3 (0.45-0.68ìm) are located in the visible region, having penetration capability in water;

(4) the errors are caused probably by the field measurements of Sd 10%) and the presence of organic matters in the suspension in water;

(5) A generalised estimator equation can be developed considering varying conditions of sun illumination angle, algal pigment and hydrodynamic conditions during different seasons of the year;

(6) the water quality is primarily controlled by the concentration, and physical and optical properties of the suspended sediments.

(7) further study on the effect of optical properties of water constituents (suspended matters) on the reflectance may be useful to enhance the utility of remotely sensed data for water quality monitoring.

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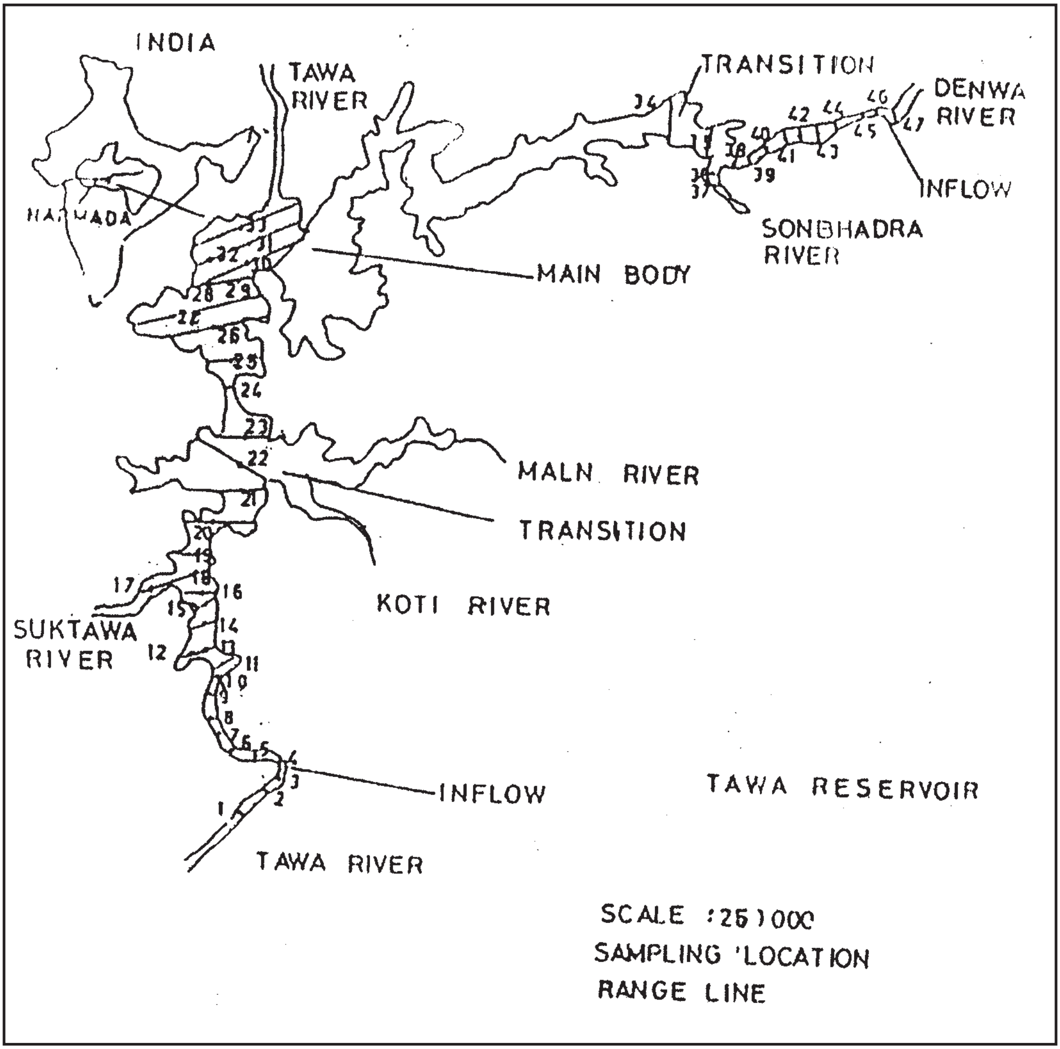

Fig 1. Location map of water sample sites on the Tawa reservoir

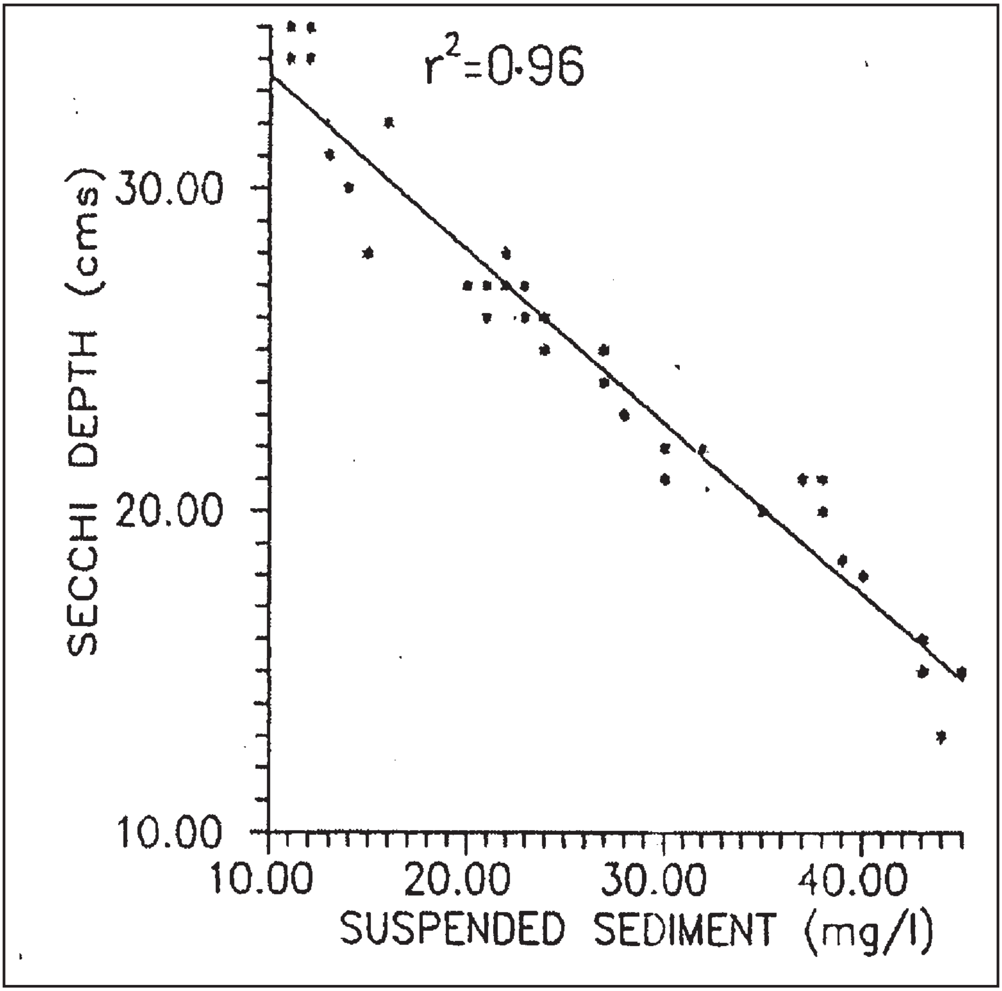

Fig 2. Relationship between suspended solids and secchi depth

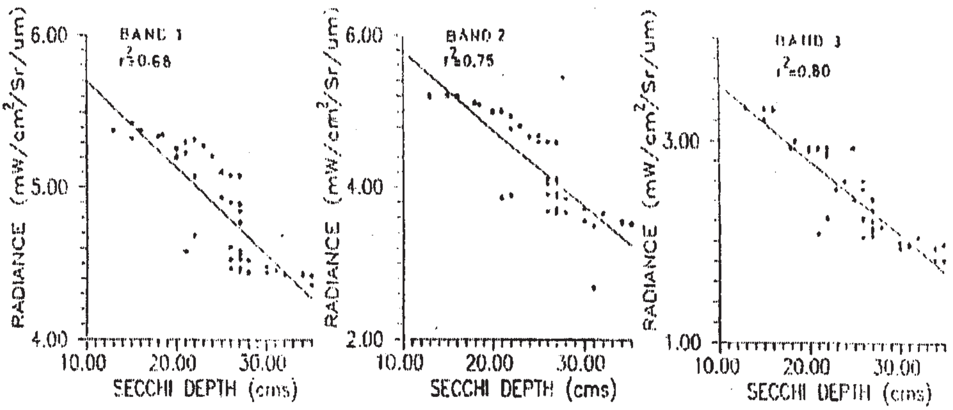

Fig 3. Relationship between secchi depth and LISS-I radiance value in band 1,2 and 3

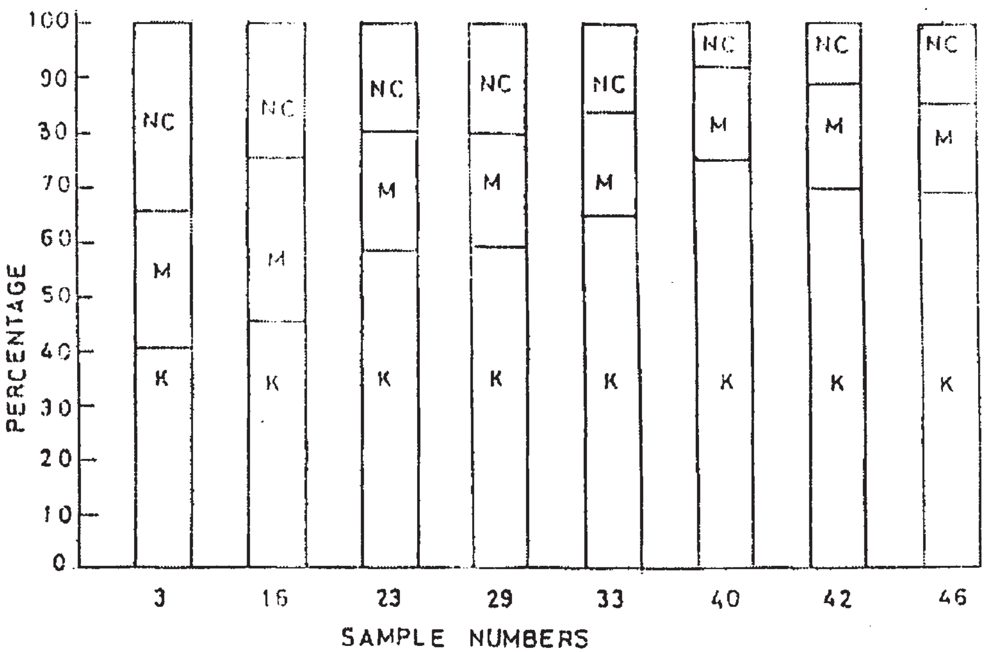

Fig 4. Histogram of the mineral composition of suspended solids. K=Kaolinite, M=montmorillonite, NC=feldspar + quartz

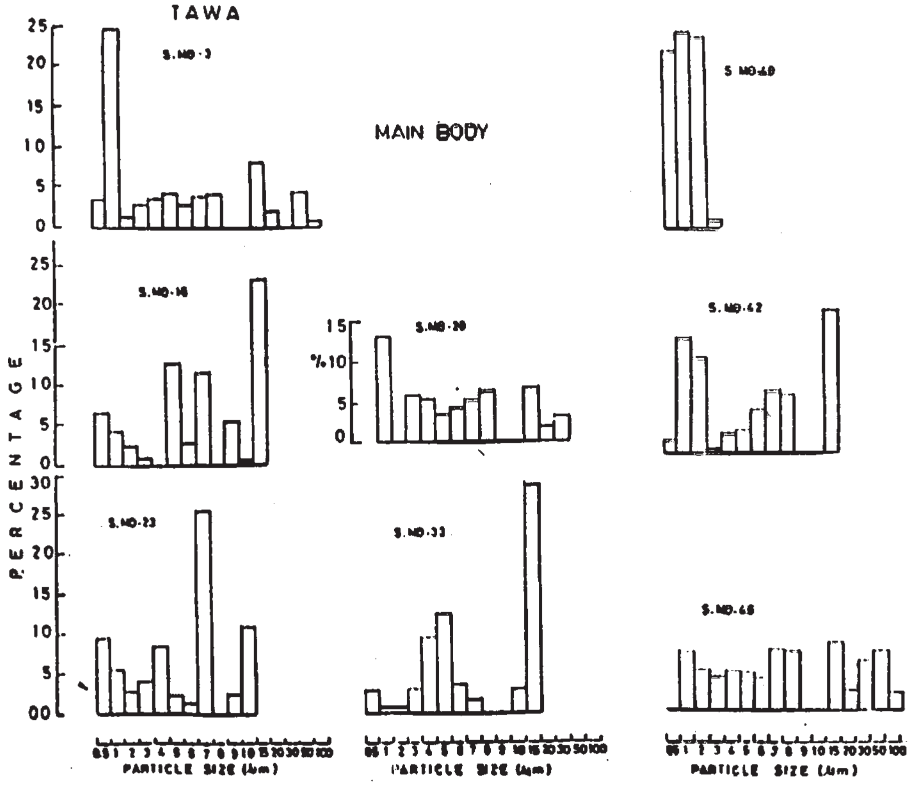

Fig 5. Histogram of the particle size distribution of suspended

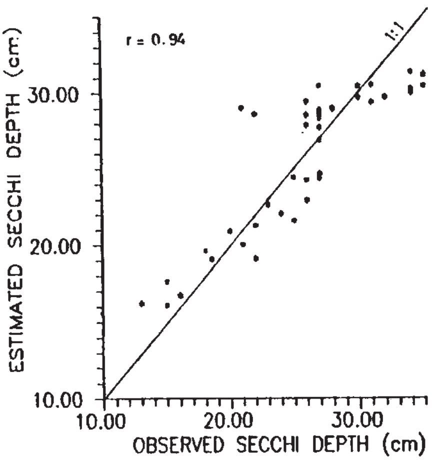

Fig. 6(a)

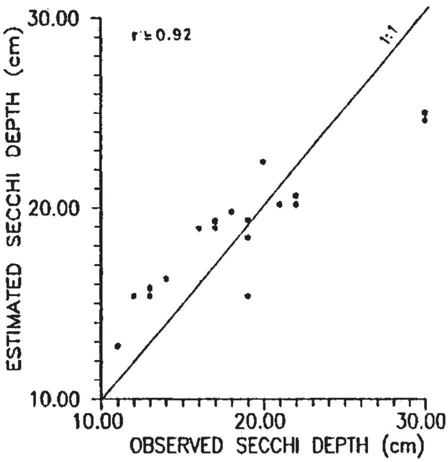

Fig. 6(b)

Fig 6. (a) Relationship between field-measured and estimated values of secchi depth from multiple regression equation using 20 October 1988 LISS-I radiance data. (b) Relationship between field-measured and estimated value of secchi depth from developed multiple regression equation using 28 September 1988 LISS-I radiance data for equation verification.

MANAGEMENT AND CONSERVATION ISSUES

A. Ramsar site of Keoladeo National Park

i. Wetlands: A Background Note by Harshvardhan

ii. Community participation in management of Keoladeo national park by Sunayan Sharma

B. Ramsar site of Sambhar Lake

i. Conservation of Sambhar wetland in Rajasthan by R P Mathur and L N Mathur

ii. Sambhar Lake – wetland an assessment by A. Abdul Rahman

iii. Present and Palaeo wetlands of northwest Thar desert, Rajasthan, India – implications for geo-environmental conservation by P C Shrivastava and S K Wadhawan

Strategy/Management & Conservation of Ramsar Sites : Keoladeo National Park - A Presentation

*By Harsh Vardhan**

INTRODUCTION:

Keoladeo National Park (KNP), a Ramsar Site, a UNESCO Heritage is one of the best Aquatic habitat for Birds-Mammals, renowned for bio diversity. It occupies 29 sq.km area having 11.6 sq.km, of aquatic area with 350 sp. of birds (120 migratory), mammals and reptiles.

There is an amazing diversity in number of birds of prey at KN Park. Harriers presently and almost all others types of birds visiting the park during winter, Owls at mid day etc., at hand shaking distance are most visitor friendly character of the park. This park is the smallest wetland supporting such a big fauna and flora of its kind not only in this country but in the entire globe.

HISTORICAL BACKGROUND:

The maharaja of Bharatpur 200 years ago constructed the dyke of Ajan Bund and created this reservoir where in water flowed by Gambhiri and Banganga rivers forming a wetland, a heaven for avian activity. Keoladeo National Park due to its site on way of migrating birds (Fig 1) from extreme North thus became for at least two centuries a research ground for global expert to study these 350 species of birds cooing in this reserve.

* Hon. Gen. Secretary, Tourism & Wildlife Society of India, Tilak Nagar, Jaipur.

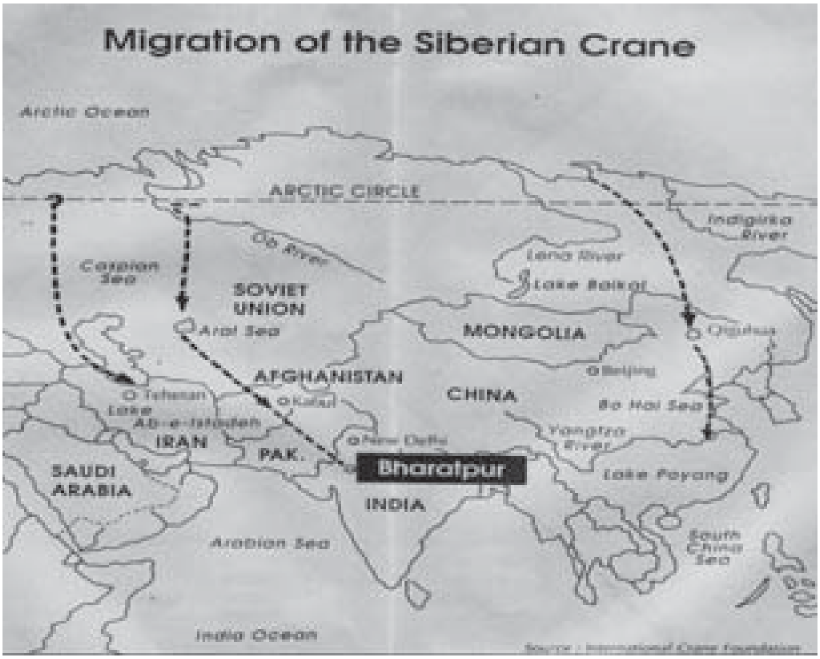

Fig 1: Migration of the Siberian Crane

KNP acquired status of a Ramsar site providing a pleasing site for visit of large number of bird watcher from all over the world for observing and viewing during day and night the birds, mammals and reptiles from closest distance one could imagine from places around the park by short promenade or by even a hand pulled riksha ride.

DEVASTATION OF THE WETLANDS:

Once prolific site sheltering the fauna specially avifauna got invaded due to continued drought (no flowing water) leading to extinction of several fauna from the park rarest of them being otter (oot bilav). *Prosopis juliflora* has taken over aquatic regime of Park leading to extinction of several species specially python. Also several flora species faced extinction. Eradication of acquatic vegetation was responsible for the decline of visit of water fowl due feed loss for their survival. Important of them are:

- Siberian Crane extinct (Fig 2)
- Heronries decline
- Ducks reduce

- Habitat loss
- Water crisis in villages.

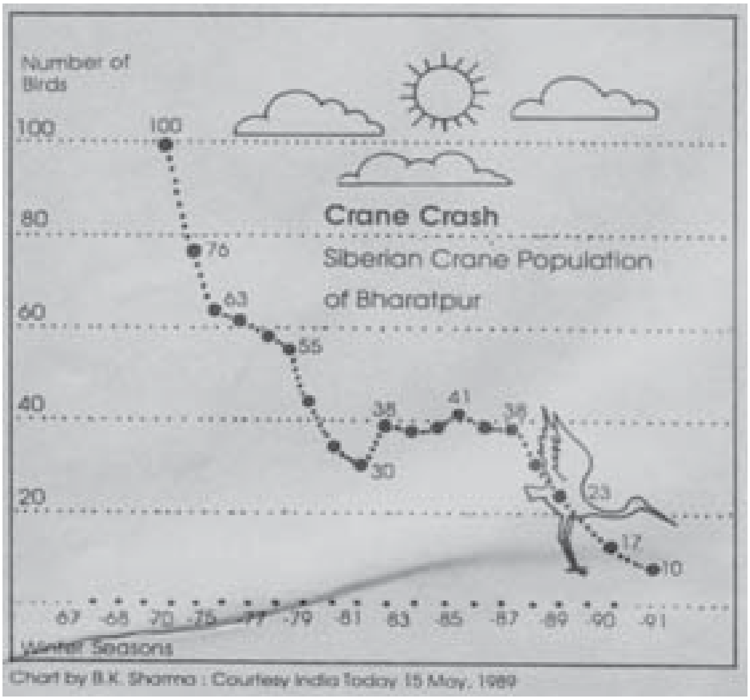

Fig 2. Crane Crash

In addition the causes of the decline were:

- Erratic rainfall, intermittent drought and no concern for ecological decline…
- Pachana Dam under way since mid 80s, and forest officials keeping a Nelson's Eye over future of Park
- By 2002-03, Pachana ready and Park is shorn of flowing water

KEOLADEO ON DEATH BED:

Repeated reminders by Indian and overseas experts to Govt. about lack of flowing water to Park failed and even issues of reports were not accepted by Supreme Court. The result was writing an "Obituary of Park". It is sad situation that State or Central Bodies found the devastation as a natural calamity with very few or no options.

MANMADE EFFORTS:

Rain have failed to provide water to this park. However, continuous man made efforts from concerned stake holders have led to installation of Chiksana canal (funds from government) and also Goverdhan Drain which are expected to provide water to the park in coming future. If these efforts are successful we could revive the ecosystem and God willing KNP may again recoup rarest of the rare bird like Siberian Cranes and other species of avifauna. The efforts of the forest department in removing exotic species with collaboration from the community would be one of the most important man made effort for recuperation of the park to the past glory.

STRATEGY:

One may think of following considerations as strategic points for conservation and management of KNP:

- Involve stake holders
- This Seminar to resolve for drafting the strategy to goad Govts. & honour their Constitutional Conservation Commitment; a Working Group be set up
- Seek Court's intervention
- Involve Research Institutions

❑❑❑

Community Participation in Management of Keoladeo National Park

*By Sunayan Sharma**

Keoladeo National Park, popularly known as "Bird Paradise" is one of the world's most renowned wetland. Presence of three major ecosystems namely the Wetland, Grassland and Woodland offers a diverse habitat for many animals and bird species. The wildlife values for which the park is being managed are:

- Around 370 species of birds and 375 species of flowering plants have been recorded in this man-made wonder of 29 Sq.Km.
- The Park has one of the world's most spectacular heronries, which hosts a large number of migratory and resident birds (15 Species).
- The park serves as a major wintering ground for migratory waterfowl from the Palaearctic region. A large congregation of migratory waterfowl cover the water surface during midwinter. Of the 25 known duck species, eight are common.
- Keoladeo National Park is the only wintering site in India for the central population of the rare and endangered species of Siberian Cranes. The Siberian cranes come to the park between the middle of October and middle of November and leave for Siberia between the end of February and the middle of March.
- The park has the last remnant patch of the Yamuna flood-plains.
- The herpeto-fauna of Keoladeo National Park is very rich. The whole

* Director, Keoladeo National Park, Bharatpur

of Rajasthan state has only ten species of turtles while this small park alone has seven species. Besides this, there are five lizards, thirteen snake species and seven species of amphibians.

- Mammal fauna of the park is equally rich with 27 identified species.

Invasion of *P. juliflora h*as posed a serious threat to the fragile eco system of this world heritage site. Chief reasons responsible for this critical situations are:

1 Acute water shortage in the park

Keoladeo National Park (K.N.P.) receives water from Ajan dam which is situated adjacent to the park. This dam receives water from two rivers namely Gambhiri and Banganga. In last 10 years due to lot of constructions of various water harvesting & other structures the later has virtually seized to contribute to the dam.

After construction of Panchana dam over Gambhiri in Karauli district of Rajasthan, supply of water from Gambhiri also got adversely effected. The main problem arose in 2003 when the dam height of Panchana was raised to increase its water holding capacity from 450 to 2100 Mcft. As a result 2004 was a drought year for this park when the park received only 18 Mcft. water from Ajan. Fortunately heavy rains in the catchment of Ajan brought sufficient water in 2005, but 2006 was again a total drought year.

Shortage of water spread in the park provides great opportunity to P.juliflora seedlings to germinate and vigorous growth in its bigger plants.

It is mentionable that the optimum water requirement of this park is about 550 M.cft. Up to 70s with so much of water for some period of time the entire park including its wood land area, spread over 11Sq.km, used to get inundated under water, during rainy season for quite a period of time. This technique was extremely fruitful in keeping a check over undesirable growth of weeds like P. juliflora, as the seed of this weed used to get perished under such conditions.

In 80s, water supply to the park started reducing due to reasons mentioned above. Now taking advantage of the dry conditions in the park, *P.juliflora* started spreading & establishing fast in various areas of the park. Within a span of few years it succeeded in not only taking over the entire wood land but also invaded wetlands of this park.

2. Enormous coppicing power of *P.juliflora*

P.juliflora has vigorous coppicing power. The park management has been trying to kill the mother trees since long but could not succeed because of its enormous coppicing power. Even the burnt stumps of its trees sprout back with great vigor. Therefore, this weed can not be eradicated by adopting any technique other than uprooting every individual plant, big or small.

3. Easy seed dispersal.

A. Winds are common in K.N.P during summer when *P.juliflora* mother trees are seen laden with ripe seeds.

B. High number of mammal population in K.N.P.

The wild animals like Blue Bull , Chital ,Wild Bore & the feral and domestic cows eat the ripe seed and throw it in the entire park. The seed so treated in the animal stomach when falls on the moist floor of the park's soil along with the pellet dung, sprouts quickly.

Due to the above reasons *P. juliflora* has succeeded in posing a real threat to the survival of the unique eco system of this park.

HOW TO COUNTER THIS THREAT?

Uprooting of every individual plant of *P.juliflora* is the only solution to this problem .Several crore plants are standing in the park. Therefore uprooting especially of the mother trees require crores of rupees,which is very difficult to be procured from the Government.

Of course the trees with fuel wood value could attract some wood merchants/contractors, who could agree to uproot the trees free of cost and even pay some price for the wood so obtained from the uprooted trees.

This could be a good solution to the problem but could not be practiced because of the strict prohibition imposed by the Wildlife Protection of India. As per the provisions of this act no profit can be earned through removal of any kind of produce (including weeds) from the National Parks.

Under such a situation the only remedy left was to get the trees uprooted free of cost through the neighboring villages. But it was almost an impossible task because of the peculiar temperament of the Bharatpur (rural) people. This was the chief reason responsible for failure of the efforts done by the park management in the past.

Of course manual uprooting of big size trees was a herculean task.

In a situation when *P. juliflora* had brought the park to the height of degradation of its bio diversity, it was imperative upon the park management to take up this issue on top priority alike the water issue.

THE PARK MANAGEMENT TOOK UP THE CHALLENGE OF MOTIVATING THE VILLAGERS.

- K.N.P. is surrounded by 16 villages. Strategically RamNagar village was selected as the first village to start this new experiment.
- The best Forest Guard was posted at Ram Nagar chowki, under which this village lies.
- One Range Officer was deputed for this purpose alone under the supervision of another senior range officer.
- This team along with the personnel of the concerned Naka held number of meetings with the villagers of RamNagar.
- They ultimately succeeded in motivating people to agree to uproot the *P.juliflora* trees in lieu of the wood so obtained from these trees.
- An Eco Development Committee (EDC) was formed on 15.2.07 by registering almost all the villagers belonging to various caste, creed, financial & social positions.
- The work was started in front the RamNagar chowki & under strict supervision of the above forest personnel but with the instructions to guide the villagers instead of rebuking them.
- The (EDC) members were grouped family wise and each family was allotted a 10x100mt area. These plots were numbered serially. They were asked to remove all the *P. juliflora* trees including new seedlings & saplings, by root.

- They were allowed to take away the wood so procured from these trees &plants free of cost ,to their home for their bonafiade use.
- Complete record of the wood so transported out of the park by every individual and their families was maintained by the park management.
- In spite the initial problems, the uprooting work kept on going at a reasonable pace.
- Good message was passed on to other villages and we availed this opportunity in persuading them to take up this work on the pattern of Ram Nagar village.
- By the end of June 07 EDC were formed in all the 14 villages surrounding the park.1378 people belonging to 338 families had joined hands with the park management in removing this menace of *P.juliflora* from the park.
- On 25.7.07 one more village named Nagla Abhay Ram joined this operation
- 36 more families belonging to first 14 villages joined the work
- The villagers worked hard throughout the summer when temperature rose even to 47 degree C.
- In return of the hard labour the villagers belonging to these 15 villages received about 61195 quintal of wood up to 15th Aug, 07
- Thus by people's participation we could succeed in freeing about 4.5 Sq.Km.of area, from the *P.juliflora* mother trees along with several thousand seedlings & saplings.

This is not the end . The work is continuing. More & more villagers are joining with great enthusiasm.

The park management is hopeful of accomplishing this impossible task of freeing the park completely from the *P.juliflora's* mother trees, in just another one year

Perhaps it is the lone example in the country where such a successful managerial intervention of this magnitude has been done by the park management with people's(villagers) participation.

Conservation of Sambhar Wetland in Rajasthan

BY R.P.Mathur & L. N. Mathur**

1. INTRODUCTION

Sambhar literally means salt. Sambhar Salt Lake in Rajasthan is well known for salt manufacturing since long including periods of Scindhias, Rajputs, Marathas, Moghuls, rulers of Jaipur and Jodhpur (joint owners) leased it to British in 1870. Independent India has witnessed its possession by Government and presently managed by Sambhar Salt Limited and Hindustan Salt Limited. Sambhar wetland is of tourist interest also. The saline lake has been designated as Ramsar site (wetland of international importance) because of wintering area for tens of thousands of flamingos and other birds migrated from northern Asia. The lake is referred in epic Mahabharta. Raja Yayati (Emperor of Bharatvarsh) and a descendant of Lord Brahma married Devyani (daughter of Sukracharya) who lived near the lake. A temple of Devyani still exists near lake city. According to other legend the Goddess Shakambhari whose temple also exists under a rocky outcrop near the lake gifted the lake some 2500 years ago. Archaeological findings near Nalisar (4 Km from lake city) give evidence of planned settlement of Kushan and Gupta periods. The lake is good place to enjoy sunset.

The elliptical shaped India's largest Sambhar salt lake is situated in the vicinity of Aravalli hills (26^0 58′N 75^0 05′ E) at an altitude of about 350 metres above mean sea level (mamsl) covering an area of about 233 Sq.Km. It is about 60 Kilometres away from Jaipur and comes partly in

* Central Ground Water Board, Jhalana Institutional Area, Jaipur.

Jaipur and Nagaur district of Rajasthan State. 5 Km long stone dam has divided the lake. Brine from vast western side of dam is pumped via sluice gates after a particular density (considered optimal for crystallization) to eastern side of dam, which serves as reservoir for salt extraction. Britishers laid down rail trolly system (presently replaced by mini diesel locomotives) across the dam to various far flung locations of lake. Maximum length of lake is 22.5 Km (ENE-WSW) whereas its width widely ranges from 3.2 to 11.2m. Depth of lake ranges from few centimetres to maximum depth of about 3m. Average depth of lake during monsoon period is about 0.6m. The area experiences semi-arid to arid climatic conditions with annual average rainfall of 550mm, average annual temperature of 23^0C and maximum temperature of 45^oC. Geomorphologically, the lake playa is surrounded by aeolian deposits except in the west and northwest where hillocks comprising of gneisses and schist are found. The salt lake is fed by present drainage systems of Mendha, Roopnagar, Kharian and Khandel. Mendha river, the largest feeder stream (catchment area 3600 Sq. Km) originated in the north east of the lake (Sikar district), flows southwestward and enters the lake towards north. Rupangarh river originating in the south near Ajmer city has northeasterly flow and join the lake from south after draining about 625 Sq. Km hilly areas. Total catchment area of the lake is about 7500 Sq. Km. The drainage system carries about 0.15 tones of salts annually to the lake mainly by river Mendha followed by Rupangarh. Despite large catchment area, the lake presently receives very little surface rainwater run off due to construction of numerous check dams and also because of diversion of lake water in to the reservoir (eastern side of dam) for large scale salt manufacturing.

The wetland of Ramsar status is under threat of shortage of water, desertification, disappearing biodiversity, decreasing salt production, deteriorating quality of salt and overall ecosystem. There is urgent need for developing effective management strategy based on scientific studies for conservation of the wetland of international importance.

2. GEOLOGY AND MINERALOGY

The Sambhar salt lake area is occupied by Delhi Super Group of rocks (early to middle Proterozoic age) comprising mainly of quartzite, schist and gneisses at places. Outcrops of Aravalli Range (500mamsl) are found in northern parts (north of Nawa), northwestern parts (around Palri, Gudha etc.). Quaternary unconsolidated lacustrine sediments along with aeolian sand deposits overlie these hard rocks. The clastic sediments consist of quartz, alkali feldspar, mica chlorite, amphibolite and weathered product including kaolinite and goethite whereas the non-clastic evaporates are mainly halite and calcite. Thenardite, Kieserite and Polyhalites are the dominated minerals above 5.5m depth while gypsum is the major mineral below this depth (R. Sinha et al, 2003).

3. HYDROGEOLOGY

Depth to water level in the lake area ranges from 18m to 20m. Most of the wells and tube wells in the area are tapping alluvial aquifers and weathered/fractured portion of underlying Delhi Super Group of rocks. Sambhar Salt Limited has constructed 83 tube wells for groundwater withdrawal for salt manufacturing by simply evaporation process. Out of these 50 wells are abandoned because of mechanical failure or declining groundwater levels. Salt production is also being done by the private industries. Groundwater level is declining at the rate of 0.70m per year.

4. GENESIS OF SAMBHAR SALT LAKE

Various hypotheses prevails for hyper-salinity in parts of Thar desert which include:

- **Humes (1867-68)** : Humes suggested submergence of an extensive area of Rajasthan and Gujarat due to eustatic rise in sea level during Quaternary period (Arabian sea).
- **Holland and Christie (1909):** They suggested transportation of salt from Rann of Kutch through strong windy storms.
- **Godbole (1952):** Godbole suggested inland extension of Tethys Sea in parts of Rajasthan.
- **Saksena and Seshadri (1966):** Salinity in ground water is due to subsurface flow of water from khewra etc. of salt range in Pakistan.
- **Khandelwal (1975)**: Reported halite bed in the Didwana Lake and suggested the salinity of all the salt lakes of Rajasthan due to presence of such salt beds.

- **Paliwal,B.L:** Explained origin of salt by existence of subsurface salt domes.
- **Singh et al (1974):** Singh suggested that present aridity might have caused choking up of the earlier drainage system forming closed basins leading to accumulation of salts because of higher rate of evaporation.
- **Inland drainage system:** The lower reaches of river Kantli, Banganga, Luni etc. die off inland where spread and stagnation of water in arid climates (more evaporation rates) as well as fine texture of soil and aquifers gives salinity.

Isotopic studies however suggest that lake brine is replenished by meteoric surface run off (Ramesh et al.,1993; Yadav, 1997). Sambhar depression was developed due to neo-tectonic activities during Quaternary period causing disorganization of earlier drainage (developing inland drainage) and forming local base level. The closed basin lake is situated at the confluence of present and palaeo-channels. Palaeobotanical studies by Singh et al. (1974) assigns an age of 10,000 B.P. to lacustrine deposits of Sambhar from freshwater pollen evidence and with the onset of aridity during Quaternary times (high evaporation and less rainfall), the stagnant freshwater started to develop salinity and transformed in to a salt lake with passage of time. However, carbon dating suggests that the geochemical evolution of the lake is phenomenon of more than 30 ka and salinity is associated with clastic sediments along with thin non – clastic evaporites (R Sinha & B.C Raymahashay, 2003). Thus, salinity in the area is geo-genic. Gneisses and schists formations in the area contribute to salinity during weathering through various present & palaeo-channels under arid and semi-arid climatic conditions.

5. GROUND WATER QUALITY

It has been witnessed that surface of lake undergo desiccation during summers forming efflorescent crust mainly consisting of halite & calcite with minor amount of dolomite, which gets dissolved in rainwater run off during monsoon increasing solute load of brine. Salt crystallization takes place between 5^o to 25^o Be (density 1.036 to 1.208 g/cm^3). There is change in deposition environ and brine chemistry at depth of 5.5m during Quaternary period from K- Na- Ca- Mg-SO_4-Cl at shallow depth to K-Na-CO_3-SO_4-Cl type at deeper levels. At deeper levels evaporation has taken place under the conditions of Ca> alkalinity whereas reverse is true for shallow deposits (R. Sinha et al, 2003). Analysis of groundwater brine collected by Central Ground Water Board in the lake reveal specific conductance (EC) over 1,00,000 micro-mhos/cm at 25° C and chloride ion is dominated with concentration from 1,17,860 ppm to 1,32,770 ppm. Salient features of chemical quality are as follows:

- Specific conductance of all the brine samples is more than 1,00,000 micro-mhos/cm at 25° C in all the samples.
- Chloride concentration is dominated with concentration from 1,17,860 ppm to 1,32,770 ppm.
- Sulphate concentration varies from 11,100 ppm to 28,300 ppm.
- Brine samples have pH values up to 8.6.
- Nitrate concentration ranges from 74 ppm to 210 ppm.
- Total hardness expressed as calcium carbonate is found between 1200ppm and 2800 ppm.
- Sodium values in brine lies between 84,500 ppm and 97,300 ppm. Potassium values ranges from 254 ppm to 432 ppm.
- Sodium Absorption Ratio (SAR) varies from 761 to 1232.
- Degree/density of brine varies from 17° to 20°. Brine with higher degree is considered as more productive.
- Turbidity of water ranges from 243 to 266 turbidity unit.
- Dissolved oxygen in brine varies from 0.10mg/l to 0.70mg/l.
- Type and Class of water – Sodium is dominated cation (98.42% to 99.29%) while chloride is dominating anion (83.86% to 92.07%). Thus water quality is of Na-Cl type and falls under C4-S4 class so far as the irrigation is concern.

6. ISSUES AND PROBLEMS

Calcite and high Mg–Calcite gets precipitated during early stage of salinity increase followed by precipitation of mineral sequence of sulphate, silicates and chlorides, which is controlled by relative concentration of Ca, Mg, HCO_3, SO_4 and Cl. Carbonate precipitation may occur at higher salinity within the field of gypsum and halite (Schreiber,1998). This may be due to influx of Calcium rich groundwater (Rouchy et al. 2001).

Annual rainfall, average lake water level and salt production

S.N	*Year*	*Annual rainfall (mm)*	*Average lake water level (cm)*	*Salt production (Tones)*
1	1995-96	907.80	76	157412
2	1996-97	1098.00	89	120148
3	1997-98	798.40	33	128125
4	1998-99	669.70	18	157597
5	1999-2000	331.91	00	125171
6	2000-01	288.30	23	106327

Surface water input in to the lake from various drainage systems has been lessened due to construction of several surface embankments in the name of rainwater harvesting. Groundwater exploitation in and around lake has significantly increased causing decline in groundwater levels and thereby diminishing natural recharge to groundwater. Despite the fact that this has increased concentration of groundwater, the overall production and quality of salt has deteriorated. It is reported that a off white colour precipitate in powder form and dark brown chips are the impurities on the wall of the wells impacting quantity and quality on salt and damage to pump assembly.

The impurities in the form of powder or chips are in dissolved form in groundwater in the aquifer (Calcium rich at deeper levels) due to relatively higher pressure and temperature. During pumping of groundwater through wells the pressure gets released to some extent and temperature is marginally lowered causing deposition of least soluble calcium and magnesium in presence of NaCl. NaCl rich groundwater having $CaSO_4$ and $MgSO_4$ as the impurities will tend to lower the temperature of crystallization and will get precipitated first in comparison to NaCl. The impurities of calcium-magnesium sulphate, carbonate or bicarbonate get crystallized around any particle or object in the path of way i.e. wall of the well or soil particle in drain act as nuclei of crystallization. Early precipitation of impurities is also due to disturbance in equilibrium in lacustrine deposits. There is increase in concentration of groundwater owing to decreasing input of surface water and lowering of natural recharge to groundwater due to declining water groundwater levels. The non-equilibrium state is thus causing reverse order of precipitation and in turn deteriorating quality of manufactured salt and damage to wells and pumps.

7. MANAGEMENT STRATEGY

Maximizing input of surface water, base flow or groundwater inflow in the lake is the solution of the issues of reducing quantity and deteriorating quality of salt & overall ecosystem of the Sambhar wetland. Construction of rainwater harvesting structures like anicuts and other surface embankments has caused significant evaporation losses of water, thereby without visible benefits in the catchment areas. The existing policies require reviewing and reorienting. There is urgent need for rainwater harvesting for recharge to groundwater especially in the major feeder catchment areas of Mendha and Rupangarh rivers along with other stream beds and palaeochannels so as to minimize evaporation losses. The rainwater is to be harvested and recharged where it falls i.e. roof top & storm water in urban/sub-urban areas, village water run off using dug wells/dug cum bore wells/percolation tanks, gabian structures with shafts etc. This will not only enhance freshwater resources for local use but will also increase groundwater inflow in to the Sambhar wetland. This in turn will raise groundwater levels in and around the lake causing improvement in quality & quantity of salt production, protecting biodiversity and resulting in conservation of Wetland of Sambhar Salt.

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Sambhar Lake - Wetland an Assessment

*By A.Abdul Rahman**

INTRODUCTION :

Sambhar Lake, one of the largest inland saline depressions in western desert of India was declared a Ramsar site in 1990 due to its biological and biotic importance. It is situated west of Jaipur, in latitude 26°58″N and longitude 75°5′′ E on the east of the Aravalli hills. The lake bed varies from 1181 feet to 1196.76 feet above the sea level. There are two types of brine in this wetland viz.,lake brine and subterranean brine.

The lake along with Phulera and Didwana salt lake forms a vast saline wetland, which constitutes the most important area for the flamingos outside Rann of Kutch. In 1982 –83, over 5 Lakh flamingos were counted in addition a large number of pelicans. Despite its importance as a water fowl habitiat, Sambhar lake is also known as source of salt producing area marketing where 2.5 lakh T of salt annually by government enterprize and over 15 lakh to 20 lakh T by groups in private sector. This production is procured using sub-soil brine from borewells.

OBSERVATION :

The lake in the desert of Rajasthan is something like a bowl depression in which rain water is stored. Due to depression in the middle, the water collected is used for salt production. In 1985, a flood situation occurred in Sambhar, which resulted in increase of fishery resources. This invited winged avian visitors to this lake.

The following migratory avian fauna have been recorded.

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1. Greater flamingo
2. Common shelduck
3. Red shank
4. Common sand piper
5. Black wing stilt
6. Kentish plover
7. White cheeked Bulbul
8. Ruff
9. Ringed plover
10. Sociable lapwing from Siberia.

This situation continued for a year resulting increase of fishery population and hence a blooming business.

In 1992, again the lake experienced a very heavy rain. The fishery resources were again increased. However with increase of salinity to 1-1.2° Be, the fisheries got threatened and ultimately died.

With the lapse of time, the salt content increased and diversity of the organisms decreased. The green algae which were dominating initially in the fresh water have completely disappeared. As a result of this the flamingos which were visiting lake during the season migrated to the other feeding ground.

When the river water flows in the lake, because of the existing saline condition in the lake, the rain water gained salinity. The density of the saline water increased and the leading salt manufacturers started tapping the brine for salt production. Some low and marginal salt producers were also drawing the brine at the periphery of the salt lake from sub-soil for salt production.

Though the salt herein is extracted from brime but the effluent in the form of bittern instead of draining outside or its use for another activity either biological or chemical, the bittern got recycled in the resource itself resulting in the quality of salt deteriorating gradually. The biological characteristic of bittern normally support development of chlorophyll bearing green algae, such as *Dunaliella salina.* Additionally the bittern produce fertilizer such as potassium ammonium phosphate, which is chloride free. However in unfavourable drought condition the lake got contaminated with the other organic compounds such as dead algae which when got entangled with the fine silt of the lake deteriorated the quality of salt

The original status of Sambhar Lake once receiving good rainfall because of the perpetual drought condition has changed. Also most of the rivers got filled with sand due to wind action.

To sum up the following factors could be attributed for the threatening of wetland eco-system of Sambhar Lake.

1. The path of the fresh water has been restricted
2. Because of the drought, the Government made a policy to stop the water flow by making check dams and anicuts for agricultural purpose or to improve water table by water harvesting. Because of this, the water flow to the lake was completely stopped from the catchment area.
3. Now for the water, the lake has to depend on the local rainfall. This resulted in the very low water availability in the lake. Because of less available water in the lake, it is presumed that the percolation got reduced. The result was sub-soil contained concentrated brine of 18-24^0 Be.
4. This higher concentration of brine diffused in the lower concentration making the fresh water get converted into brine.
5. These three processes of percolation, evaporation and diffusion are the processes which seem to be responsible in converting the rain water into high density brine.

REVIVAL OF THE ECO SYSTEM:

It is possible if rain water reach to the lake from the catchment area, which is now restricted because the rainwater is being harvested for the other economical activity such as drinking water supply and agricultural. Thus the only hope for conservation of Sambhar Lake is to depend on the localized heavy rain. However, unfortunately Rajasthan state experiences heavy rain once in 10 years.

The Sambhar wetland is thus faced with grave situation. Serious consideration are necessary for measures in saving Sambhar Lake from its deterioration through a concerted balance of ecosystem vis-a-vis natural processes.

RECOMMENDATIONS :

There are possibilities to balance the ecosystem of Sambhar Salt Lake with development of wetland ecosystem combined with salt production.

The paper thus recommends to make a study on the geochemistry of the soil and suggests to practice biological management of salt work

It is recommended to practice biological management of salt work by introducing the right kind of brine shrimp ***Artemia*** strain that will feed on the micro algae and thus quality of salt could be enhanced. The brine shrimp introduction will in turn help to renew the wetland ecosystem, which forms the feeding ground for flamingoes. The bittern from salt lake could be isolated to produce magnesium ammonium phosphate as chloride free fertilizer. However, the presence of brine algae in Sambhar salt lake is considered as goldmine for extracting beta-carotene for future course of action on techno-commercial basis.. The key areas suggested would in turn support to conserve the delicate wet land ecosystem of Sambhar salt lake in a balanced way.

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Present and Palaeo Wetlands of Northwest Thar Desert, Rajasthan, India - Implications for Geoenvironmental Conservation

*By P C Srivastava and S K Wadhawan**

INTRODUCTION

Arid zones cover about 33% of the earth's land surface in the world and are characterized by low annual rainfall (0-500 mm), usually hot temperatures up to 47 degree centigrade and high evaporation index up to 4000 mm per year. The naturally occurring ephemeral shallow inland basins and depressions of varying size and origin within these regions are known as arid wetlands represented by the fluvio – lacustrine environment and geologically termed as "Playas". The Playas / wetlands are generally devoid of hydrophitic plants due to accumulation of salts which do not favour their establishment and generally occur above the groundwater table, often fed by the seasonal surface water runoff. Important natural wetlands in the northwestern parts of the Thar Desert are: - Jamsar – Khichiyan, Lunkaransar, Dhirera, Dholera, Kaoni, Akasar, Karnisar Dhar in Bikaner district and near Rawatsar, Suratgarh, and Hanumangarh, etc.

The wetlands in the arid regions can be classified into the following types owing to their geologic origin and geomorphic development:-

1) Those which have been formed in the tectonic/ structural depressions

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2) Those which have been formed within the deflated interdunal basins

3) Abandoned and deranged inland drainages

4) Depressions / basins fed by ephemeral rivers / drainages.

Further on the basis of age, they have been classified into palaeo - wetlands and present wetlands. The present wetlands are both naturally occurring as well as man - made. The palaeo wetland represents a palaeo-lake or an abandoned playa in which the process of its formation and growth have ceased. The present day wetlands which include ephemeral saline lakes, the process of formation is still operative. The water - logged areas along the canal (Indira Gandhi Nahar Pariyojna) are also categorised as the present day man - made wetland. The present day wetlands and palaeo – wetlands in Thar Desert are resource potential of evaporite mineral deposits such as gypsum, selenite, salts, halites, etc. They have become sites for quarry of these mineral deposits in the arid land.

STUDY AREA

Jamsar – Khichiyan wetland, Lunkaransar wetland in the Bikaner district and water - logged areas along the IGNP canal command between Suratgarh and Hanumangarh areas in Hanumangarh and Bikaner district represent three different types of wetlands selected for detailed geoscientific study (Figure 1, 2 &3). They fall in Survey of India degree sheets 44H, 44K and 44G.They are located near Bikaner – Suratgarh – Hanumangarh highway and can be approached by fair – weather roads.

QUATERNARY GEOLOGY, GEOMORPHOLOGY OF JAMSAR – KHICHIYAN PALAEO WETLAND: -

Jamsar – Khichiyan wetland is approximately 4km. long and 2 km. wide with orientation in N.E. – S.W. direction (Figure 1). It is classified as older interdunal playa on the basis of origin and geomorphological set up. As the genetic growth process has ceased, it is occurring as presently as abandoned palaeo – lake with rich reserves of gypsite and selenite evaporites.

It occurs as a deflated depression within the interdunal sandy flat. The interdunal areas are surrounded by linear, transverse and coalesced parabolic and comb - shaped dunes. The dunes are highly stabilized and are composed of brown, highly oxidized, pedogenic, well sorted and consolidated sand. They are capped by loose, yellow well sorted sand cover and supported by xerophytic vegetation. The linear dunes are 20 to 30 m high having NE-SW orientation.

The composite Quaternary strata log (Figure 4) prepared on the basis of study of ten geological sections indicate nine Quaternary geological units. The maximum thickness of the sections is approx. 9 m. The youngest unit - A (30 cm to 2.75 m) in the log is composed of well sorted, semi consolidated, non - cohesive brownish sand deposited by past aeolian activity. Its sub unit B comprises of gravelly gypcretes, calcretes and at places desert rose deposited by aeolian action and groundwater capillary rise. The unit - C (5cm to 1.5m thick) comprises of fine pedogenised gypsum in the powdery form. Next younger deposits were laid due to aeolian activity, the sand rich in $CaSO_4$ deposited over the playa. The unit D (40 cm to 1m) which is impersistent in the other sections comprises of medium grained crystalline granular gypsum with silt partings and massive coarse crystalline granular gypsum respectively. Both of these interlayered units represent lacustrine environment. The unit - E (15 cm to 2m thick) comprises of pale - greenish non –cohesive, well sorted fine sand. This unit indicates dry climate and on going aeolian activity at the time of evolution of the playa. The unit - F (1m to 2m thick) comprises of alternate layers of warped laminations of gypsum with silt partings. The unit E represents deposition under lacustrine conditions. The unit - G which is impersistent layer and comprises of alternate layers of pale greenish white laminations of clay and silt layers and represents localized ponding conditions. The unit H - (50 cm to 1..5m) comprises of warped layers of coarse crystalline aggregate of gypsum showing deposition under lacustrine environment and probably the base of the playa below which the aeolian unit E is repeated.

Gypsum deposits are generally associated with areas having less than 300 mm mean annual rainfall. Field stratigraphy of these gypsum bearing playas (palaeo wetlands) suggest multiple precipitation events (evaporite formation) separated by sand and silty clay horizons implying lacustrine (wetter) conditions. Absolute dating of these playa sediments indicated: 1) over all more humid conditions (enhanced monsoon) during

13ka to 4 ka period. 2) aridity in the region with highly reduced rainfall and excessive evaporation in this part of Thar Desert has been experienced since 4ka. Most near surface gypsum occurrences in the region belong to this period (Wadhawan, et al. 2005)

QUATERNARY GEOLOGY AND GEOMORPHOLOGY OF PRESENT DAY WETLAND AT LUNKARANSAR AND MAN - MADE WETLANDS OF HANUMANGARH AREA: -

Lunkaransar wetland is linear shaped wetland approximately 2 km. long and 1 km wide oriented in NE-SW direction (Figure 2). It is classified as younger interdunal saline lake. It is a recent playa in which the process of evaporite formation is still in progress. It occurs within the vast interdunal sandy flat between the older parabolic dunes that are 20 to 30 m high and are stabilized. Their arms are aligned in NE-SW direction and comprise of yellowish brown colored, well sorted, semi consolidated sand. The interdunal sandy flats are the most extensively developed geomorphic landforms. They comprises of brownish silty loam with formation of calcretes and gypcreates near surface.

The composite Quaternary strata log (Figure 5) prepared on the basis of seven sections within the playa indicate six Quaternary geological units. The maximum thickness of the section is 1.6m. The youngest geological unit A (30 - 40 cm thick) is yellowish well sorted aeolian sand in the form of dunes and sandsheets. This is followed by unit B (2-3 cm) grayish silty clay with salt crusts occurring as salt capping over the playa. The unit - C (20 -25 cm thick) is buff brown colour, non cohesive, semi consolidated aeolian sand. This is followed by unit D - (30 to 40 cm) dark brown, highly cohesive sandy silt representing lacustrine environment. The unit E - (30 -40 cm thick) comprises of dark grey coloured, highly cohesive laminations of silty clay with salt capping deposited under lacustrine conditions. The unit - F (20 -30 cm thick) comprises of black silty clay with coarse selenite crystals. This unit also represents lacustrine and evaporative arid environment. Ground water rich in brine and dissolved salts occurs below this unit at shallow depths.

Permanently water - logged areas have been formed along the IGNP owing to seepage and leakages form the main canal and its distributaries. Interdunal depressions have stored the excessive surface water due to poor drainage and absence of out flow in this dunes and hard calcrete pans infested terrain of northern Thar Desert. The area between Suratgarh and Hanumangarh comprises of stabilized dunes and interdunal depressions. The occurrence of calcrete pans at a shallow depth within the interdunal areas and lack of surface drainage are the main causes of water logging and formation of man made wetlands. The calcrete pans occur within the sandy silt within the interdunal areas.

EVOLUTION OF THE WETLANDS:-

Deflated basins were created within the interdunal areas due to high speed winds. Shallow pools were formed by the rainwater, surface runoff during humid conditions and rise of groundwater table enriched in CaSO4. With increase in aridity and rate of evaporation, the CaSO4 enriched water got converted into brine. The geochemistry of the water samples of Lunkaransar wetland have indicated TDS varying from 61050 to 80118 mg/l. The SO4 varies from 1000 mg/l to 14820 mg/l. Ca varies from 1040 mg/l to 1290 mg/l. The CaSO4 precipitated out as gypsum from the brine water. The intermittent sandy layers represent contemporaneous aeolian activity.

GEOENVIRONMENTAL ASPECTS, SUSTAINABILITY AND CONSERVATION ISSUES, ECOTOURISM VALUES OF WETLANDS:-

Palaeowetlands and present day wetlands are resource potential of evaporate minerals such as gypsum, salts, etc. Crystalline gypsum and gypsite have been quarried from Jamsar – Khichiyan and Lunkaransar wetland. Salt and gypsum are being produced in the Lunkaransar wetland. Interference through excavation and extraction of these resources have scarred the landscape and interrupted the geochemical evolution of evaporate formation. Abandoned quarry pits and overburden dumps besides these quarries have degraded the land and are a source of dust generation during the hot and dry summer months. The man - induced recent wetlands near Suratgarh and Hanumangarh areas have affected vast stretch of land by soil salinity due to high evaporation index.

The arid zones are characterized by low and highly variable rainfall. Rainwater is spatially and temporally unpredictable, rarely falling in large amounts thus causing the flash floods. Occurrence of gypseferous and calcrete pans, impervious sediments create impeded drainage and water logging. In some palaeo wetlands, e.g. in Jamsar – Khichiyan, Kawas etc. there is an increased human settlements over the wetlands. Desertification and loss of productivity are an important problem in the wetland area. The groundwater and the soil in the wetland is highly saline both in the naturally occurring and man - made wetlands with continued seepage and collection of surface irrigation surplus water in the local depressions. The problem of salinity can further spread in the adjoining areas of the wetland.

Ecological sustainability and conservation of wetlands are key issues which should be given due attention. The overburden around the abandoned pits/quarries should be stabilized by heavy afforrestation of the xerophytic vegetation over it. This will also prevent sand mobilization and dust generation. Reclaimation / conservation of abandoned pits and wetlands in arid landscape of Thar Desert should be done by leveling and sand filling of these pits. The Jamsar – Khichiyan and Lunkaransar wetlands are situated near the canals. The water in the wetlands can be augmented by diverting the fresh water of canal into it. This will also minimize the salinity of the wetland area. Aquatic plants and animals which depends on wetlands and can adapt to live in these inhospitable environments should be rehabilitated. Fish farming and water birds should be encouraged as sanctuaries. Trees plantation around the wetlands should be increased. The excess water in the water - logged areas near Hanumangarh, Suratgarh can be pumped out and transmitted into different wetlands such as Sambhar salt lake and other wetlands in the adjoining areas. This will also prevent flash- floods and help sustained conservation of wetlands.

Bikaner city is an important tourist place in Rajasthan attracting number of tourists from India and other countries. Jamsar and Lunkaransar wetlands are in the close vicinity of Bikaner city. It can be developed into Desert ecotourism sites such as “Desert eco-santurary”. The wetlands occurring near the Jamsar and Lunkaransar wetlands such as in Dhirera, Karnisar, etc can also be developed into significant Desert tourism sites as well as helpful in combating desertification problems and conservation of wetlands.

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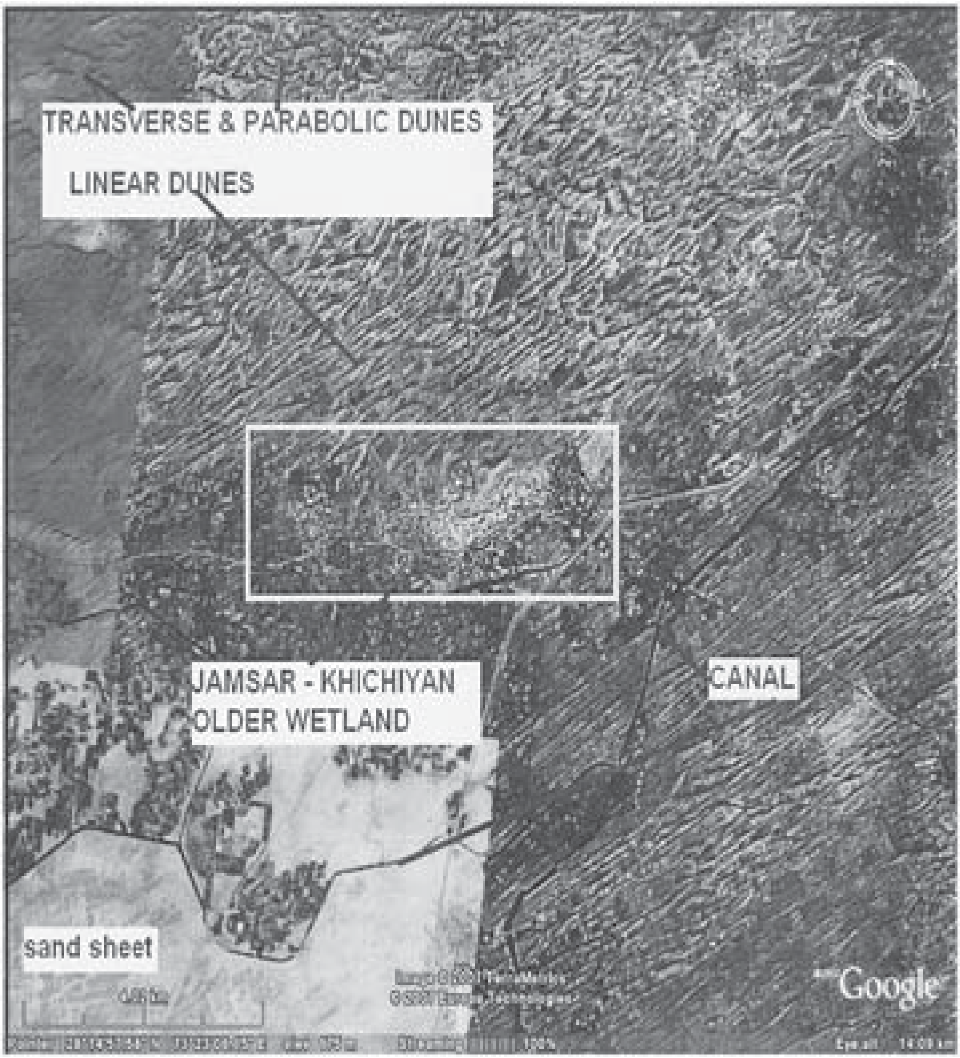

Fig. 1. Location Map of Jamsar - Khichiyan Older Wetland

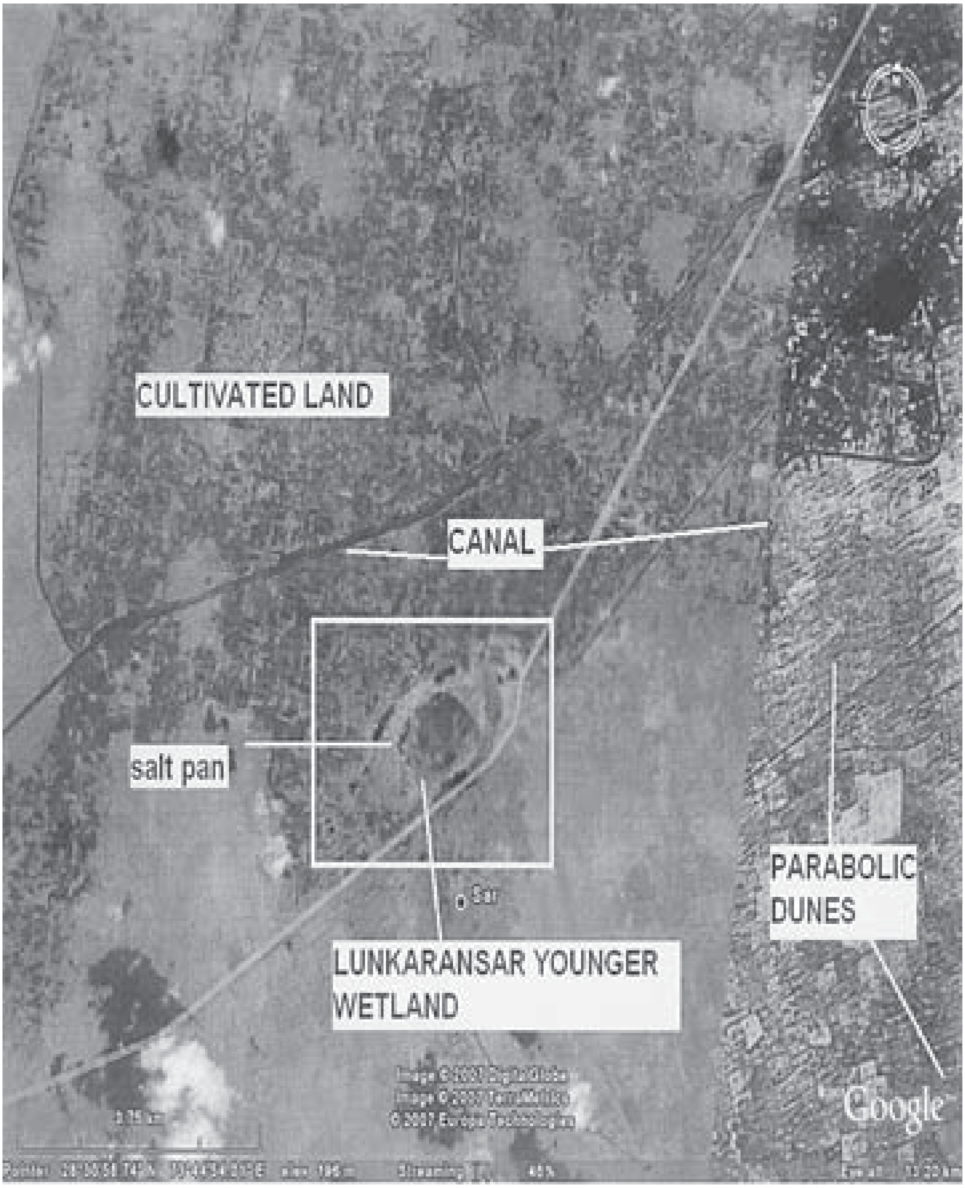

Fig. 2. Location Map of Lunkaransar Younger Wetland

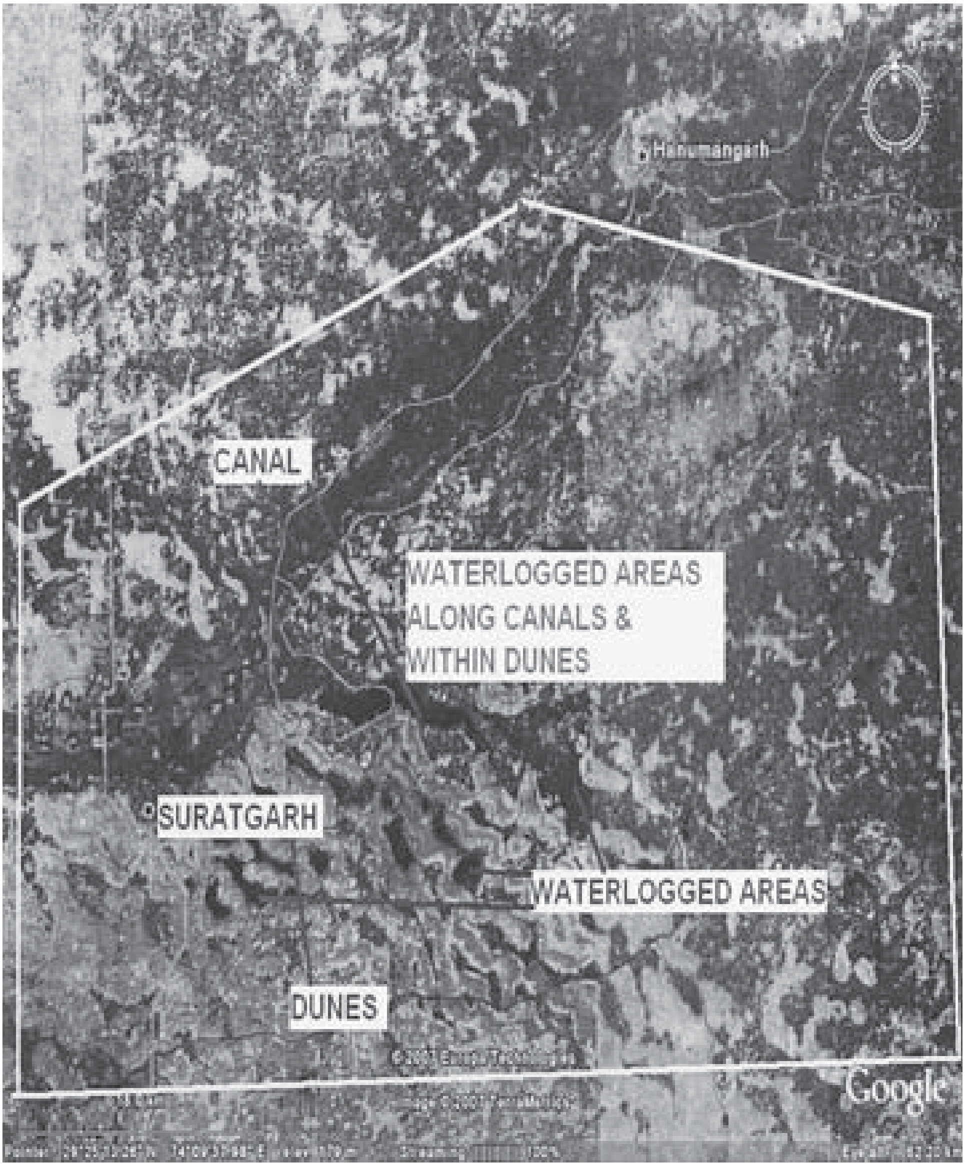

Fig. 3. Waterlogged areas along IGNP, Hanumangarh district

Type of Playa : Older Interdunal Flat

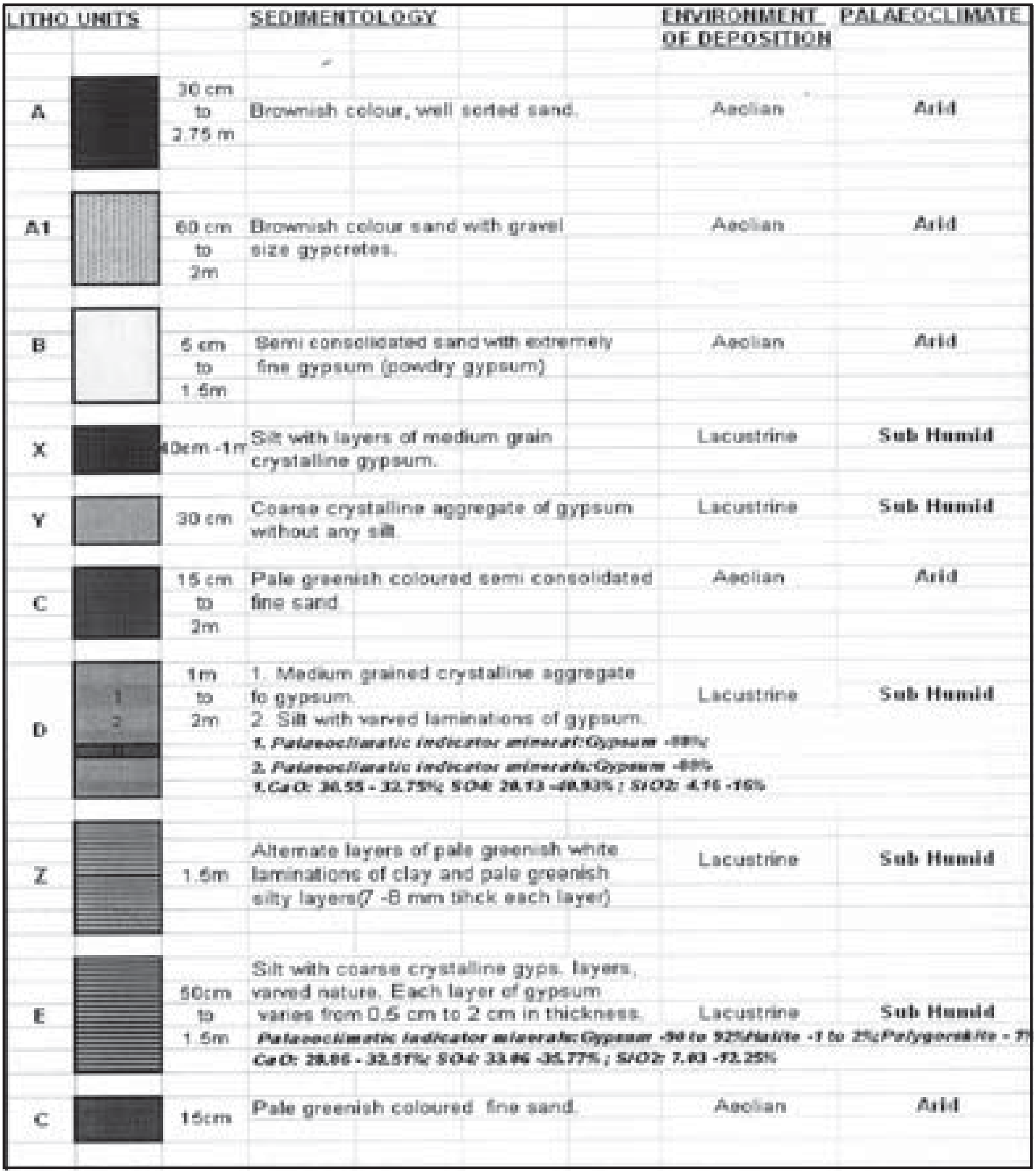

Fig. 4. Composite Quaternary Stratalog of Jamsar - Khichiyan Playa

Type of Playa : Youngar Salt lake

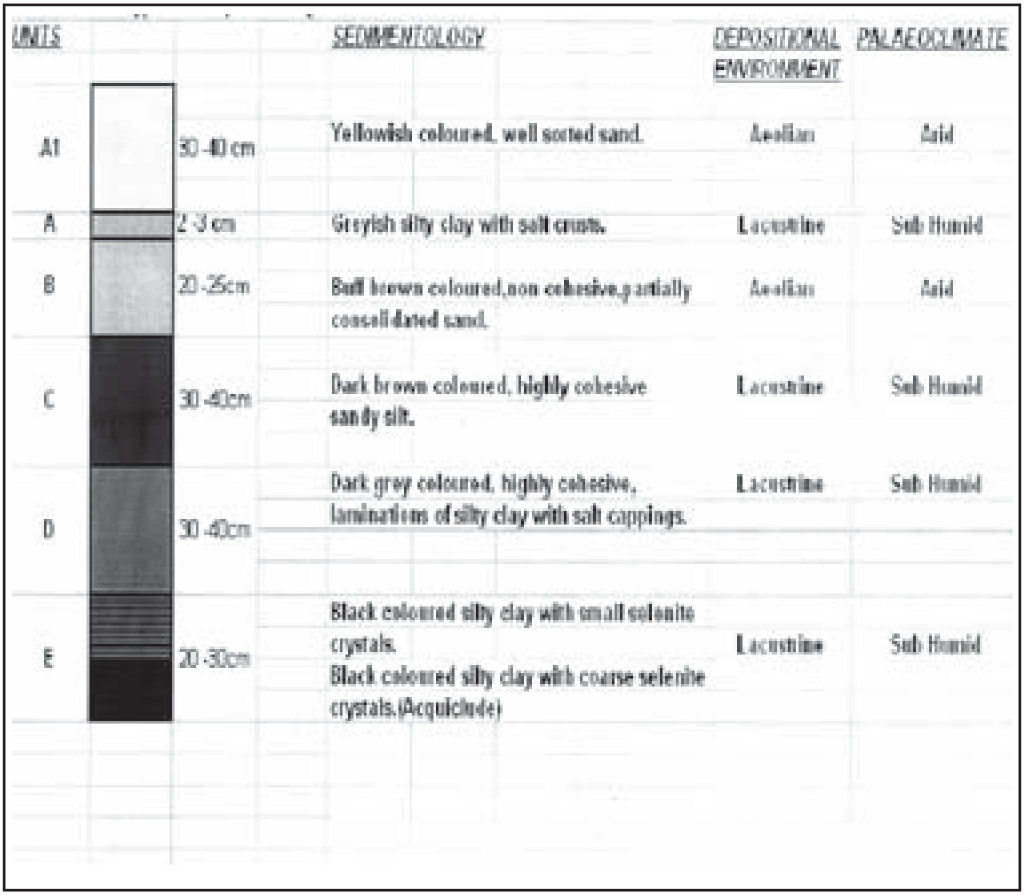

Fig. 5. Quaternary Stratalog of the Lunkaransar Playa

OUTCOME OF THE SEMINAR SUGGESTIONS AND RECOMMENDATIONS

Wetlands and their Conservation: Strategies and Policy Options with special reference to Rajasthan by Dr. Sudhir Varma

WETLANDS AND THEIR CONSERVATION: STRATEGIES AND POLICY OPTIONS WITH SPECIAL REFERENCE TO RAJASTHAN - RECOMMENDATIONS OF THE SEMINAR

*By Dr. Sudhir Varma **

INTRODUCTION :

The Social Policy Research Institute organized a national seminar on "Wetlands and their Conservation: Strategies and Policy options with special reference to Rajasthan" on 3rd and 4th October, 2007. Deliberations during the seminar pointed out that strategies and policies exist in part but there is a need for an integrated policy on the specific subject of Wetlands. Measures were suggested for the conservation of wetlands especially in the area of bio-diversity and the need of decreasing pollution. Hydrology plays a key role in controlling the structure and functioning of wetlands which affect biotic community structure and nutrient cycle. Large-scale irrigation and river diversion, agricultural expansion, over-harvesting of available resources, forest denudation, urban and industrial pollution are major threats to wetland conservation which have to be a part of any policy for conservation.

STRATEGY AND POLICY OPTIONS :

The outcome of the deliberation on policy and strategy options

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revealed that strategies need to be based on the following considerations.

- Water allocation policy should harmonize human uses with biodiversity requirements.
- Should have both preventive and developmental measures (restoration) through hydrological intervention and participatory watershed management involving local community at all levels of planning and implementation.
- Should involve all relevant departments, civil society and scientific community for developing effective institutional mechanisms for integrated management and capacity building. A far more active stakeholder participation which should be totally a political could bear fruits in conservation and restoration efforts of the site.
- Should lay down a proper regulatory framework to prevent depletion of wetlands in which a Technical Core Group should work in close coordination with a Community Consulting Group and the frame work should be closely linked with livelihoods.
- There is a need of analyses of various alternatives for eco-restoration strategies for different wetlands, with larger interest from both State and Central Governments.

ROUND TABLE DISCUSSIONS:

The seminar organized two Round Tables for the Ramsar sites of Keoladeo National Park and Sambhar Lake.

a) Round Table Discussions on the Keoladeo National Park:

The speakers while giving the historical background of this National Park originally used for water fowl hunting during the princely states times, said that this wetland was raised to a Ramsar site level in 1981. It has supported amazing diversity and 350 species of birds. However, now, erratic rainfall, intermittent drought and no concern for ecological decline and most of all the construction of Panchna Dam has played havoc in the devastation of this park.

The deliberations urged on the need for measures to replenish the wetland with sufficient water for supporting the biodiversity and its related benefits. Hopes are still there about chances of getting the Siberian Cranes back to this bird watching paradise if steps are taken for conservation.

A paper by Shri Sunayan Sharma on "Community Participation" revealed that working with the people of the region has helped in uprooting the *Prosopis juliflora* which has been spreading through the entire park and such public awareness could help in conservation becoming very effective.

Important suggestions by the contributors are:

1. Planning Commission may be requested to undertake mission mode projects for eco-restoration.
2. Possibility exists for attracting Siberian cranes to Keoladeo National Park if the water bodies in the wetlands are brought to the earlier level as this wetland is on the route from Siberia to other wetlands in India. This would ensure it to continue as a Ramsar site of international status.

b) Round Table on Sambhar Lake:

Revealing the origin of this inland saline depression of 233 sq km aerial extent, this wetland was geologically defined as a neotectonic subsidence of Quaternary times by the scientists participating in the session. Stratigraphically speaking it is composed of sand-silt-clay lacustrine deposits interbedded with grit formation and overlying a pre-Cambrian micaceous schist. Made up of evaporates (calcite, halite, thenardite) and gypsum, this wetland had supported growth of salt resistant algae providing rich food for flamingoes, the migratory bird abounding this wetland. Recent rapid land use changes in catchment area and check-dams has an adverse environmental impact turning it into a dryland pan which is responsible for generating dust storms from this wetland converting it into a great dust bowl.

Important conservation and management measures for this wetland are:

1. There is a necessity of a water allocation policy amongst Sambhar lake and anicuts etc being used as a recharge structures or irrigation etc.

2. The rain water is to be harvested and recharged where it falls. This would increase ground water inflow into the Sambhar Lake which would improve quality and quantity of salt thus protecting biodiversity and resulting in conservation of Sambhar Lake Wetland.

3. Work should be done on the suggestion of a balance between salt extraction and biodiversity activation. Salt extraction would stop any salt laden dust formation which may make fresh water more saline in areas far and wide even upto Delhi and beyond.

4. Biological management through salt extraction and maintainence of biodiversity is needed.

5. An integrated study programme for the desertic and evaporitic wetland of Sambhar Lake for microbial diversity and productivity is required.

6. No more conversion in the salt area for salt extraction should be taken up by the administrative authorities, so that the enhancement of drying wetland is further checked.

7. There is necessity of study of the biochemical products from Sambhar Lake and the bittern for commercialization of the by-products from this important resource.

8. Depositional cycle in Sambhar Lake indicates the possibility of a dry spell approaching. Detailed geological studies need to be undertaken so that action plan is made for the conservation of this dessicating saline lake.

ENGINEERED WETLANDS :

An ingredient of the policy in the field of pollution control would be a much bigger emphasis on Engineered Wetlands. Such wetlands could resolve the problems of biodiversity as well act as a source of removing the pollution which has polluted vast rural areas through anthropogenic pressures, unsustainable levels of grazing, sediment accumulation, toxic material discharge etc.

Such natural treatment systems are effective, low cost and utilize plants and associated rhizospheric microorganisms and the natural synergetic relationship of plants, microbes, soil and water. Such methodologies, apart from having benefits of ground water recharge and use in agriculture and agro-forestry, encourage resource recovery and income generation through multifunctional mechanisms.

SUGGESTIONS AND RECOMMENDATIONS:

The seminar recommended the following strategies to be a part of a policy.

a) Related to Management

1. There should be a strong law against land use changes in catchment area and check-dams which have an adverse environmental impact. Although many Acts exist for tackling pollution problems but Wetlands involve several authorities such as industries, irrigation, forest, pollution control etc. However, there is no Act exclusively for wetlands which requires composite management. Thus a separate authority for management of wetlands is needed involving all sections of the government.
2. Recognition of traditional system in deciding technology for optimum results similar to their methodologies of obtaining quality and quantity of water is needed.
3. Villagers involvement in Eco-restoration through village level committees is a must.
4. Development of awareness programmes and raising of the rural conscience for the issues related to the importance of wetlands and their benefits through participation in conservation efforts should be taken up.

b) Related to Conservation

1. Ecological shift has to be prevented
2. Hydrology is considered important for irrigation but not for conservation of wetlands which is wrong.
3. A balance between water for agriculture from anicut as well provision of water supply to the wetlands for maintaining

diversity is necessary.

4. Importance of past experience through event studies should be taken into consideration for devising management and conservation policies.

c) Related to Data Collection

1. Impact assessment studies and data collection on socio-economic impact of wetland loss and how peoples initiative could be used to restore them.
2. Geoscientific studies of the past data for interpreting the present and envisaged future behaviour for working of the strategies and policy options for the conservation of wetlands are needed.
3. Knowledge on data exists but a continued effort is needed for collecting data for their analysis regularly for type of water, existing biodiversity and status of management efforts.
4. Use of satellite imageries combined with aero magnetic/gravity and electric sensitivities for studies of quality of water and monitoring for eco-system as well as biodiversity conservation requirement of larger areas for proper and better control is required.

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