Hydromorphic Characteristics and Land Use Zonation of Kolleru Lake – Andhra Pradesh

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CERTIFICATE

This is to certify that the dissertation entitled "**Hydromorphic Characteristics and Land Use Zonation of Kolleru Lake – Andhra Pradesh**" submitted by **B.L. Prasanna** in partial fulfillment of six credits out of the total twenty-four credits for the award of the degree of **Master of Philosophy** of the University is a bonafide work to the best of our knowledge and may be placed before examiners for evaluation.

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(B.L.PRASANNA)

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Chapter I

INTRODUCTION

Conservation of natural regions and preserving the natural balance in an ecosystem has attained special significance in the present times. The reasons are multifold, the foremost being the escalating population pressure on land and water and the resources.

Over exploitation and inappropriate use of natural resources leads to increased stress on natural regious. Natural regions are mainly exposed to 'natural stress' and 'developmental stress'. Natural stress includes disturbance to ecological stability due to natural events such as earthquakes, floods, landslides etc. 'Developmental stress' is an outcome of cultural factors. Technological advances, higher degree of human intervention in the natural processes within ecosystems are the causal factors. Large scale developmental activities, economic activities tend to be detrimental to natural regions.

In view of this stress to natural habitats, conservation of resources demand a multilevel planning initiative. The planning approach should focus on management of natural environments to ensure preservation of ecosystem and integrate main requirements. This involves a thorough understanding of the man environment interaction.

' Wetland ecosystems ' are exemplary in this complex interface of natural and cultural elements. Wetlands are transitional between terrestrial and aquatic ecosystems. They include a diverse and heterogeneous range of habitats from flood plains, salt marshes, mangrove swamps to estuaries. (India's wetlands, mangroves and coral reefs. 1992) The factor characterizing all wetlands is the presence of water for atleast part of the year. These habitats share characteristics of both wet and dry environments.

Wetlands have been variously defined as; **The U.S fish and Wildlife service** defines them as " Wetlands are lands transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface, or the land is covered by shallow water. Accordingly, three attributes are taken as characteristic of wetlands.

1. At least periodically the land supports predominantly hydrophytes.
2. The substrate is predominantly undrained hydric soil.
3. The substrate is non-soil and is saturated with water or covered by shallow water for some time during the year.

The International Union for Conservation of nature and Natural resources (IUCN) defines wetlands as "submerged or water saturated lands, both natural and man made, 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 6 m"

The **Ramsar convention** was initiated by **IUCN** and **IBP** (International Biological program) the 'convention on wetlands of International importance', espacially as waterfowl Habitat" was held in 1971 in Ramsar(Iran) to encourage international co-operation for the conservation of wetland habitats. The Ramsar Convention defines wetlands as " 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 meters"

The definitions by some premier organisations, point to the fact that wetlands are complex, unique ecosystems. These ecosystems are now being recognized for the significant role they play environmentally and culturally. This awareness regarding wetland values is in direct contrast to the traditional viewpoint about wetlands being wastelands fit only as breeding grounds for mosquitoes.

The notable wetland values include recharging of aquifers, flood control, shore stabilization, sources of a variety of nutrient rich food including prawns, shrimps, fish etc. More over, wetlands are some of the most productive ecosystems. Many food chains are dependent on wetland production of nutrient. They act as natural sinks for nutrient recycling. Wetlands are also extremely valuable as wildlife and bird habitats and gene pools. (India's wetlands mangroves and coral reefs, 1992)

However, wetlands are fast diminishing or getting transformed due to misuse and large scale human intervention. Activities such as draining, reclamation for agriculture or other uses are preventing restoration and couservation efforts. The other major problems faced by wetlands include siltation, eutrophication, destruction of the flora, fauna due to toxic wastes and harmful effluents.

One aspect that should be closely monitored and maintained for ensuring the stability of a wetland is the hydrological regime. The water budget is the regulatory factor by which the structure of the wetland maintains its balance as an ecotone, Activities which cause changes in the water budget nutrient levels would inevitably alter the structure and consequently the function of the wetland.

This gives an insight on the need for planning and managing the diverse elements, cultural and physico-chemical within wetland ecosystem. The utilisation of wetland resources has to be within such limits so as not to impinge on the structure of the wetland components. This is important for maintaining the delicate balance typical of wetland ecosystems.

'**Zoning**' is one of the possible methods by which wetland management and conservation can be achieved. It is an integrated approach through which land and water resource uses are regulated spatially. Zones are created for various uses and activities, keeping in view the ecological and cultural parameters.

Zoning of an ecosystem is a means of reducing the developmental stress over a continuous space. Therefore demarcation of zones is guided by the degree of human impact on the ecosystem. The objective is to gradually reduce stress on the natural environment of an ecosystem in a series of zones.

The activities permissible in each zone would be clearly worked out keeping in mind the human population depending on the natural resource, their needs and also the threshold upto which the ecosystem balance is not disrupted.

The series of zones as designated by UNESCO'S 'Man and Biosphere programme (MAB)' are modelled to serve these objectives.

The MAB programme, which was established in 1974, aims at achieving sustainable balance between goals of conserving biological diversity, promoting economic development and maintaining cultural values. The programme requires biosphere reserves to contain following zones.

1. Core Zone : This zone is the protected area where the ecosystem is preserved in its natural state. The disruption by stress factors is minimised.
2. Buffer zone : This zone adjoins the core areas. The buffer zone is characterised by low-impact ecologically permissible activities. It is suitable for research oriented activities, recreation, tourism and environment education awareness programmes.
3. Transition zone : This is the zone of a higher degree of cultural and economic activities such as fishing, farming.

This form of zonation of land use is effective when complemented by regulations regarding all aspects of the natural resource, specific assigning of functions for each zone and thoroughly researched data base regarding biotic and abiotic components of the ecosystem.

The zoning parameters may vary according to the diverse natural regions. The zoning format for each ecosystem may vary depending on intrinsic factors such as species diversity, human- induced stress. Therefore, zonation should take into account the local condition,

communities and their needs in addition to ensuring ecological stability and preserving the ecosystem dynamics.

The most significant functions of zonation of ecosystems are

1. Maintaining ecological integrity.
2. Resource management for optimimum use sustainably.
3. Provides direction to development of policies, regulations and activities within an ecosystem.

Objectives

This study follows the concept of zonation as a management approach for conservation of the Kolleru Lake. The objectives of the study are-

1. Demarcation of lake use zones- aquaculture and agriculture. To delineate a core area within the lake for preserving the natural ecosystem.
2. Measures and recommendations for ensuring balanced interaction of all aspects of the lake and preservation of the ecosystem.

Database

The data consulted in this study are rainfall and population data. The rainfall data for Eluru and Chintalapudi was obtained from Indian Meteorological Department (IMD), Pune for the period 1951-91. The parameters include monthly rainfall and annual rainfall in millimetres. The rainfall data for the period 1901-50 for the four stations Eluru, Chintalapudi, Nuzuid and Gudivada has been obtained from "Monthly Rainfall and number of rainy days" an IMD Publication.

The peak levels of the lake from 1916-80 have been obtained from the department of fisheries, Eluru.

The population data regarding density and area has been taken from the "village and town directory" District Census Handbooks of Krishna and Godavari districts Andhra Pradesh.

The maps have been taken from various sources. The contour map of the lake (upto +7 feet contour) was procured from the Collectorate Office, Eluru. The catchment map was taken from the Irrigation Atlas of India, Volume II. The village map was obtained from the Census Handbooks, Publications of the Census of India. The topographical maps consulted area 65 H/5, 65 H/6, 65 H/7 and 65 H/2.

Methodology

The hydrological characteristics of the lake particularly rainfall are analyzed to infer the pattern of rainfall. The spatial analysis is with the use of mean and standard deviation.

$$\text{Mean} = \frac{1}{n}\sum_{i-1}^{n} x_i \qquad \text{S.D.} = \sqrt{\frac{1}{n}\sum_{i-1}^{n}\left(x_i - x^{-2}\right)}$$

The variability of data is assessed by using the coefficient of variation.

$$\text{Coefficient of variation} = \frac{\text{S.D.}}{\text{Mean}} \times 100$$

The variation at different stations within the catchment emerges. The relationship between the rainfall and peak levels of the lake is brought out by a scatter diagram.

The zonation is based on contours and broad landuse. The various parameters are briefly studied, the zones are demarcated with the help of contour map. The functions of each zone take into consideration the landuse activity most prevalent.

A preview of the study

The study 'Hydromorphic characteristics and land use zonation' focuses on the need for planning and management of natural resources. The case study is Kolleru lake, an important bird habitat which has developed into a micro region with considerable interaction between the natural components and the human. The study deals with the hydrological aspects and the planning of zones. The lake is an important site of aquaculture, paddy cultivation and waterbird habitat.

As a result of the multitudinous use of the lake, the ecological balance has been disturbed as reflected in the levels of siltation, need infestation, pollution of lake waters.

The basic objective of the present study is to demarcate a series of zones in the lake to ensure the lake environment does not deteriorate. To achieve this objective each predominant activity for which the people depend on the lake is assigned a zone.

In order to demarcate effective zones a thorough investigation has to be made regarding-

- The hydrological parameters the rainfall in the catchment and water level fluctuation.
- The suitable conditions for each activity i.e.. cultivation, aquaculture.
- The necessary conditions for the sustenance of a waterbird habitat in harmony with other activities.

The various sections of the study deal with each of these objectives-

The concept of natural resource conservation and its significance in the development of the region is dealt with in the first chapter. The **wetland** as a natural resource, the parameters which are considered in defining a waterbody as a wetland is also brought up in this chapter.

The second chapter deals with the wetlands of India, the scenario regarding the conservation plans and an introduction to the lake environment. The chapter discusses the evolution of the lake, physical characteristics and human settlements. The review of literature and maps is also presented in this section. The review is in chronological order to assess the changes in hydrology, landuse and development of fisheries. This helps in bringing out the broad patterns of change spatially and temporally in the interrelated parameters hydrology, landuse and fisheries. The patterns that emerge would be useful in analyzing and proposing a zonal pattern for overall

development of the region alongwith the conservation of the lake.

The next chapter is an analysis of the rainfall patterns in the catchment and the consequent water level fluctuation in the lake. The chapter gives an overview of general rainfall patterns- spatial and seasonal.

The zonation of the lake would be discused in the forth chapter. The zones would be delimited with a view to conserve the lake ecosystem and regulate human activities in such a way that there is no adverse impact on the lake environment and at the same time lake waters are judiciously used. In other words, the lake should continue to be a suitable habitat not just for the human population, but also the avifauna and other aquatic life forms.

The principal zones would be delimited along contours with different functions. The zones are:

1. Core area
2. Fishing zone
3. Mixed zone
4. Cultivation (in Rabi & Kharif seasons)

The core area is an area of the lake which should have the least interference thereby allowing the natural ecosystem to flourish and sustain. This chapter would also bring out the necessity and constraints of preserving the core area. The next chapter is a summary of the study, it gives an overall view of the study. The recommendations and measures for ensuring the preservation of the ecosystem are putforth. These measures have a special significance for the zonation approach to be successful.

Chapter II

WETLANDS

Wetlands of India

India has a diverse variety of wetlands in varied terrain and climate. These are essentially tropical wetlands which can be categorised into inland and coastal habitats.

The himalayan ranges have palaearctic lakes including Tso Morari, Tso kar etc.They are considerably deep and are of tectonic origin The valley of Kashmir has the well known lakes Wular and Dal lake . These lakes are known for their scenic beauty and their significance in the life of the people . These lakes are freshwater lakes. Besides these, there are man-made lakes and reservoirs notable among them are Pong dam lake in
Himachal Pradesh and Harike lake in Punjab.

Western India has numerous shallow saline wetlands such as Sambhar and Didwana . This arid region has small artifical lakes scattered all over particularly in the fort cities of Jodhpur, Udaipur etc.

Marshes are areas of shallow water where herbaceous vegetation dominates . The vegetation consists of emergents such as reeds, grasses and sedges. Swamps are similarly exposed to flooding but they are characterised by woody shrubs and trees . These trees share an ability to grow in extremely saline and inundated conditions. Mangroves are good examples of vegeta tion adapted to these conditons . Their adaptations include pneumatophores and viviparous seedlings i.e, seeds germinate on the parent tree. Marshes in India are spread along the tarai region of the Himalayas.These are the freshwater marshes . Keola deo ghana National park is a freshwater marsh, although, it is artifically created. The other category of marshes are tidal salt marshes. The Rann of Kutch and the khijadia in the southern coast of Gujarat.

Mangrove swamps are located along the deltaic regions of India the Ganges, Mahanadi, Godavari,Krishna and Cauvery. The Sunderbans along the Bengal coast is one of the largest mangrove areas in India constituting 4200sq.kms. The Andaman and Nicobar islands account

for 1200 sq.kms. of mangrove swamps (India's wetlands, mangroves and coral reefs,1992).

The Vedaranyam and salt lake swamp are other examples of coastal swamps. India has riverine swamp forests along the Brahmaputra valley in northeastern India and Dudhwa National park in Uttar Pradesh .

Floodplain wetlands in India are characterised by both swamps and marshes of the freshwater type and oxbow lakes which are left behind when meanders get cut off from the main channel. These floodplain wetlands have local nanaes 'diara and chaur' (Bihar), 'Khadar and tal' (Uttar Pradesh) , 'char' (Bengal) and ' beel '(Assam).

Estuaries and lagoons also constitute the wetland wealth of India.Estuaries have developed on the west coast of India between the open sea and the river mouths. Lagoons are partially closed outlets to the sea the development of a 'spit' or 'bar' may partially cut off a creek from the open sea and lead to the enclosed lagoon . Lagoons have brackishwater, the notable examples are Chilka (Orissa) and Pulicat (Tamil Nadu and Andhra Pradesh) the backwaters of Kerala are an extensive network of lagoons which fall in the same category.

Wetlands created by man are tanks, reservoirs, canals and paddy fields. These wetland forms are included by virtue of their hydrological charcteristics i.e. inundation for atleast a part of the year and development of hydrophytes. Paddy fields are extensive wetlands typical of not just India , but large parts of south and south-East Asia. They do not possess the biological diversity associatedwith wetlands but they support considerable populations of waterbirds particularly egrets,herons, ducks,storks and cranes. (India's wetlands,mangroves and coral reefs,1992).

Wetland conservations in India

Wetland conservations in India is a comparatively recent concept . Hence, the efforts at conserving wetlands is at its infancy.

A National wetlands programme has been constituted by the Ministry of Enviornment and forests. The Ministry provides full financial assistance to State Government for the

programme, it has two major components, preparation of management action plans and research activites.

The National Wetland Mangement committee has been Constituted for this purpose . The committee is entrusted with the task of preparing action plans under the following heads-

1. To lay down broad policy guidelines for implementing programmes of conservation, Management and research of wetlands.
2. To decide priority of wetlands to be taken up for intensive conservation measures.
3. To monitor the implementation of the programmes of conservation, management and research.
4. To advise on the preparation of an inventory on Indian wetlands (Balakrishnan Nair, 1989)

The committe has identified 16 wetlands in various states Action plans have been sanctioned for Pichola Fateh sagar (Rajasthan), Kanjli and Harike (Punjab), Wular (Jammu and Kashmir), Bhoj (Madhya Pradesh),Loktak (Manipur), Chilka (Orissa), Kolleru (Andhra Pradesh), Sukhna (Chandigarh), Renuka(Himachal Pradesh), Sambhar (Rajasthan), Ashtamudi and Sasthamkotta (Kerala), Ujni (Maharashtra) Kabar (Bihar) and Nalsarover (Gujarat).

The action plans take into consideration the legal and environmental aspect. The problems identified within all wetlands are dealt with. These aspects include-

1. Protection and development of infrastructure development.
2. Siltation control
3. Pollution control
4. Environmental impact assessment studies
5. Weed control
6. Afforestation of the catchment
7. Wildlife conservation
8. Fisheries development
9. Environmental education and awareness programmes.

The research activities include-

1. Survey and mapping of wetland resoures in the country using remote sensing technology.

2. Application of Geographical information systems and mathematical modelling in selected wetlands.

3. Evolving wetland evaluation and monitoring facilities. (India's wetlands, Mangroves and Reefs,1992)

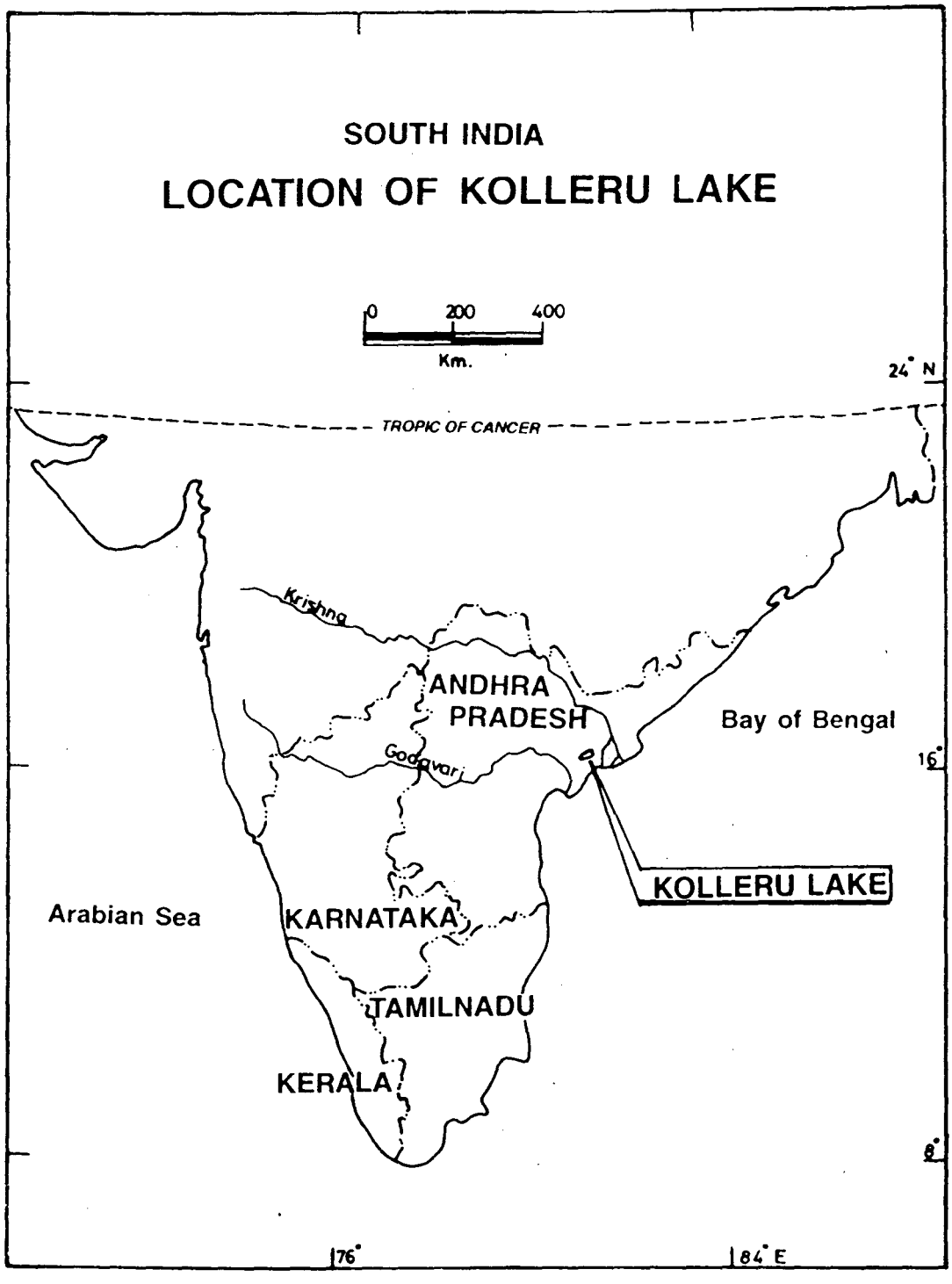
KOLLERU LAKE

The Kolleru lake is a large freshwater lake occupying 900 sq kms. in the plains of eastern India. The lake is a shallow depression between the deltas of the two large rivers Krishna & Godavari.

The lake lies on the boundary between Krishna and west Godavari districts of Andhra Pradesh. It extends between 16 32' N to 16 47' N latitude and 81 5' E to 81 21'E longitude. It is bounded by the Bay of Bengal on the east, the Eluru canal towards the west, the Godawari delta and the Krishna delta to the north and south respectively. The lake is 27 kms away from the coast. (Map 2)

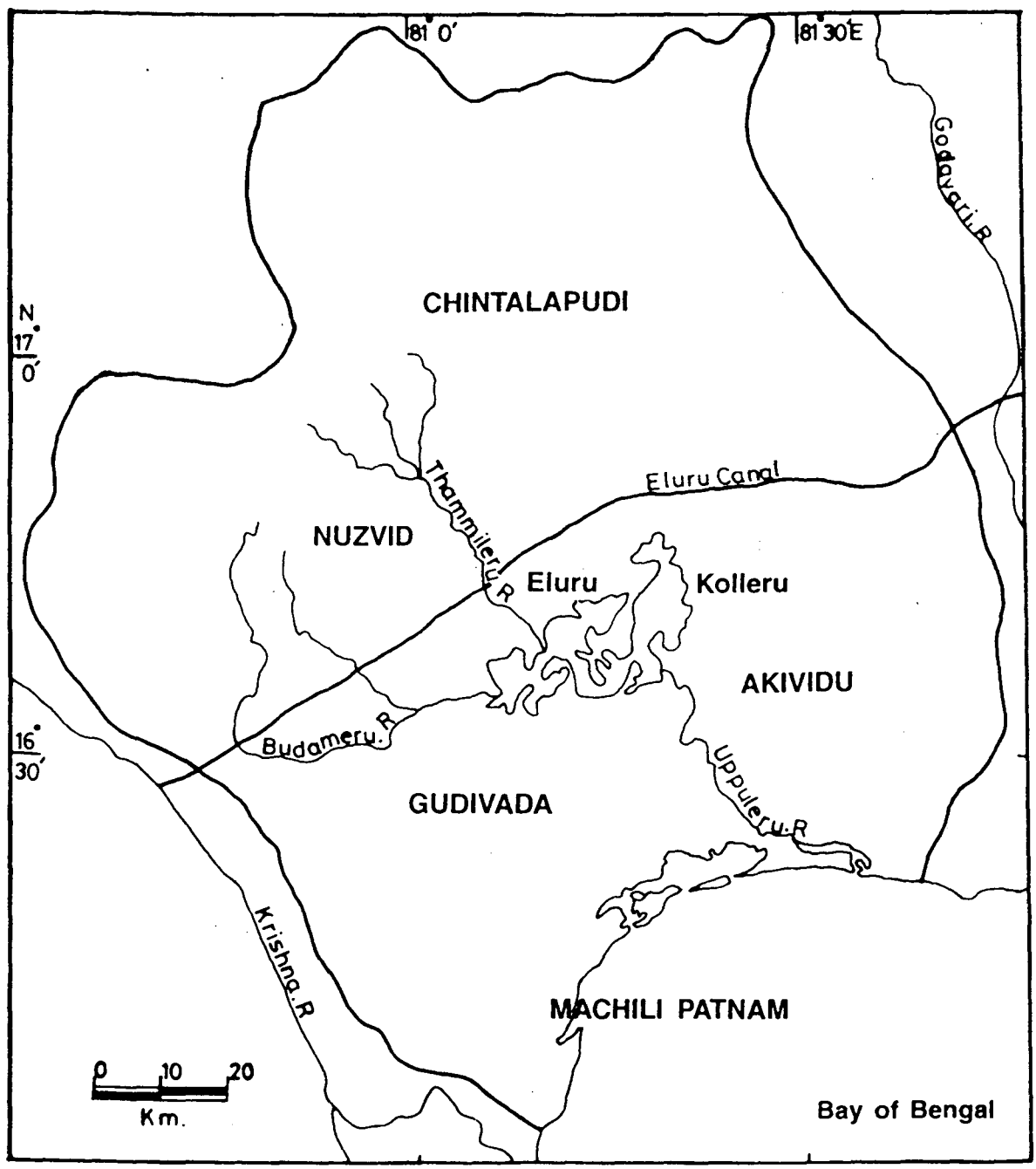
The Kolleru lake is a large freshwater lake. It can be categorieed as an inland wetland. It is one of the large lakes in India, in terms of area. At the maximum flood level the lake extent is about 900 sq km.(Map 1). Chilka lake has an extent of 1100 sq kms. The freshwater lakes Wular and Keoladeo Ghana are 270 sq kms and 29 sq kms in extent respectively. Although these lakes have shrunk in recent times, Kolleru still continues to be one of the larger wetlands in India.

However, the importance of Kolleru among Indian wetlands is not just in terms of areal extent. It is an extremely important fishery centre. It is also a waterfowl habitat with numerous waterbirds residing in the lake region or visiting the lake seasonally.


SOUTH INDIA
LOCATION OF KOLLERU LAKE
0
200
400
Km.
24° N
TROPIC OF CANCER
Krishna
ANDHRA
PRADESH
Bay of Bengal
Godavari
16°
KOLLERU LAKE
Arabian Sea
KARNATAKA
TAMILNADU
KERALA
8°
76°
84° E

Map 1

KOLLERU LAKE CATCHMENT AREA



Map 2

ORIGIN OF THE LAKE

This shallow lake was originally a part of the Bay of Bengal. It developed in the Pleistocene-Holocene period ie. Quartenary epoch. In the middle pleistocene period the NE-SW Kaikaluru barrier spit was deposited. The interdeltaic salt water bay was separated from the sea to form a lagoon. This was possible due to the lowering of the sea level at end of pleistocene and also the progradation of deltas of Krishna & Godavari further into the sea. (Pascoe, E.H. , 1973)

Geomorphic studies and sediment analysis of the lake area provide evidence regarding the marine origins of the lake. Progradation of deltas involves deposition in fluvial and marine environments. The field studies and photogeological interpretations have identified distinct fluvial and marine geomorphic domains. The presence of palaeo channels, delta lobes, beach ridges, the palaeo strandlines in the interdeltaic area give an indication of the advancement of the two deltas further into the sea. In addition the marine fossils towards the west of the lake, salinity in the section of the lake bed indicate the presence of an ancient shoreline closer to the lake.

Some important units identified in this regard are-

1. The Mupparru sea bed exposed between Kesarapalli and Bommuluru is the oldest marine unit identified. The Kolleru sea bed another marine unit is exposed in the lake and in a strip towards the south of Gudivada and towards E-NE of Kaikaluru beach ridge Kaikaluru surface has evidences of barrier ridges indicating a marine environment.
2. Strandlines i.e. palaeochannels are identified at the surface where palecochannels terminate. In case of the Godavari delta, sea water extended upto Tadepalligudem. Errakalva is one of the earliest abandoned channels of the Godavari which terminates at the kaikaluru, Maha devapatnam-velangi strandline. Similarly in the Krishna delta, west of kolleru, the Kaikaluru-Bapatla Strandline is considered the major shoreline having ground evidence. Although there is the possibility of an earlier strandline towards the west of gudivada.

Marine fauna and saline groundwater below one meter indicate marine conditions of sedimentation.

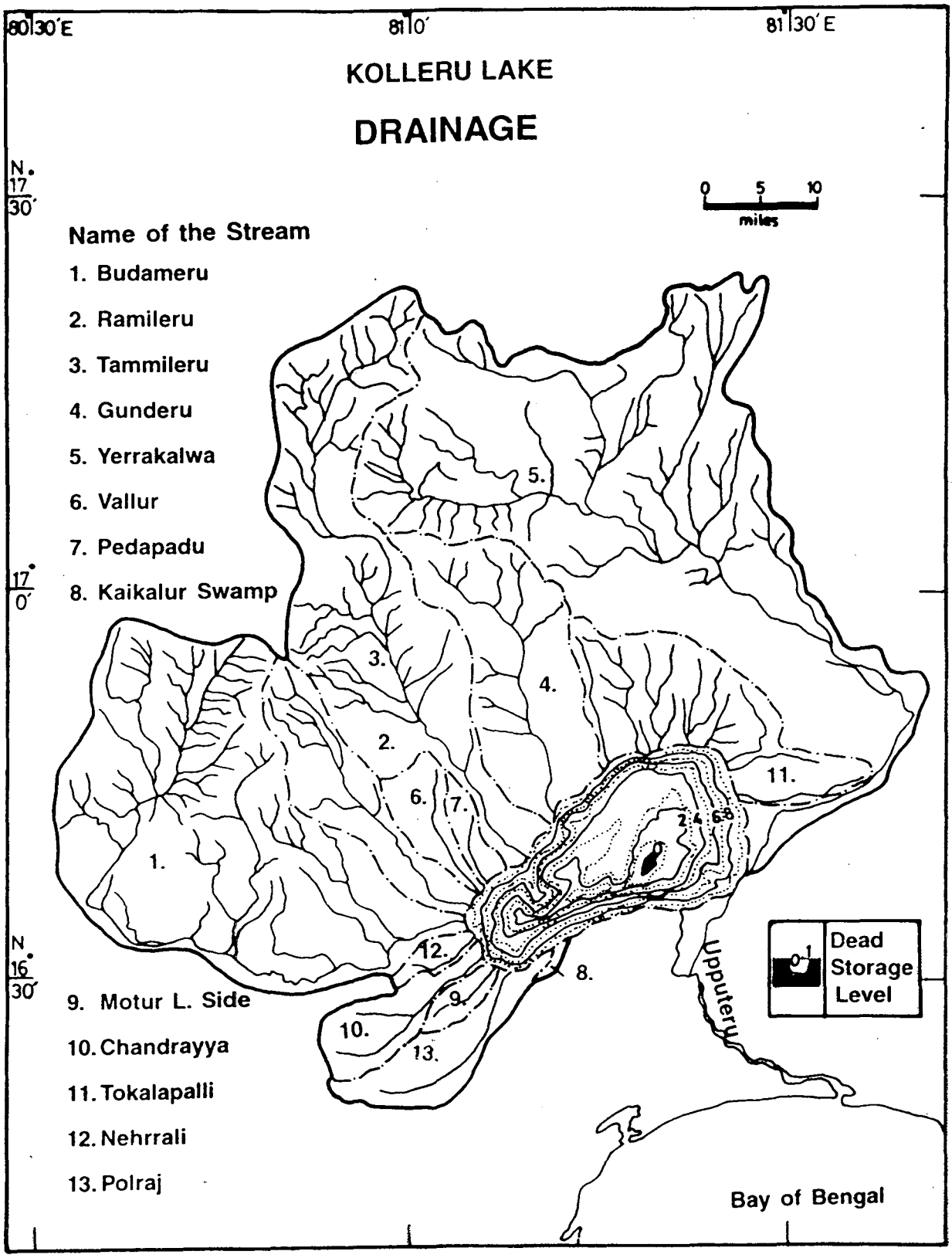
In the humid conditions and heavy rainfall associated with the holocene transgression, the depression got flooded by inflows from thammileru, Budimeru and other streams. These fresh water inflow changed the salt water swamp to a fresh water lake.

Catchment Area of the Lake

The lake has a catchment area of around 4700 sq kms, of which 3400 sq kms is from the upland area and 1300 sq kms is from the deltaic area. The lake is fed by a number of inlets and delta drains Tammileru, Budimeru, Ramileru, Gunderu are the significant inlets. Erra kalva also partly drains into the lake. The Delta drains include Kaikaluru, Moturu, Vatluru, Chandrayya, Mondi codu, Peddapadu and Siddapuram. (Sesavataram ,V. ,1992)

Tammileru & Budimeru are the chief inlets contributing maximum inflow to the lake. Both these rivers are remnants of earlier krishna river channels. Similarly, Erra Kalva, which partly flows into the lake and partly joins the upputeru is an abandoned channel of Godavari. (Map 3). The outlet from the lake is through two channels Perantala Kanuma and Juvvi Kanuma which form the upputeru. The upputeru i.e. salt river, is the outlet from the lake which flows in a winding course of 60 kms to join the bay of Bengal near Pedda Gollapalem. The upputeru discharge capacity is considerably less compared to the various riverlets and drains. At the 3 m level, a water spread area of about 900 sq kms, the discharge is 12000 cusecs, whereas the peak inflow is about 1,10,000 cusecs.

The lake has a waterspread area of 900sq kms at the +3m coutour level and 338 sq kms. at 0.9m contour level . The lake is essetially shallow having a depth ranging between 0.91 to 1.52 m in most seasons . It reaches its highest water spread in the floods following the monsoon.


80 30' E
81 0'
81 30' E
KOLLERU LAKE
DRAINAGE
N. 17 30'
17 0'
N. 16 30'
0 5 10
miles
Name of the Stream
1. Budameru
2. Ramileru
3. Tammileru
4. Gunderu
5. Yerrakalwa
6. Vallur
7. Pedapadu
8. Kaikalur Swamp
9. Motur L. Side
10. Chandrayya
11. Tokalapalli
12. Nehrrali
13. Polraj
Uppuleru
Dead Storage Level
Bay of Bengal

Map 3

The highest water level reached is +10ft. contour (MSL) and the lowest +0.2ft contour (MSL). This is the dead storage level. The deepest level of the lake is -2 ft (MSL). With fluctuations in water level, the water spead area changes.

The catchment and the lake has good seasonal rainfall ranging between 75-100 cms. Most of the rainfall in the region occurs in the south-west monsoon season from june to September. A little rainfall also occurs in the north-east monsoon season i.e. from October - November. The storms and depressions that originate in the Bay of Bengal mostly in the post monsoon season are assocated with heavy rainfall and strong winds in the region. The region has high humidities almost all the year round, summer being extremely hot and oppressive.

The Lake as a Habitat

The area around the lake has alluvial soil. The lake bed has heavy silt, clay and rich organic matter. The lake bed has thick vegetation of common wetland species including water hyacinth, phragmites, typha. (Seshavataram,V., 1992)

The lake is an important habitat for fish and water birds. Among the fish speices there are atleast 40 varieties of fresh water fish. The important commercial fish are Rohu, Catla and Mrigal.

The waterbirds abundant in this area include Teals, Pintails, Pochards numerous species of herons, storks, ibises, cormorants,terns etc. These birds frequent certain areas in and around the lake. The influx of birds is noticeable during September- October. The lake was a well-known pelican colony. But now the breeding sites have been more or less abandoned due to changes in habitat, the pelican members have dwindled to almost negligible levels.

The human settlements in the area are of two types, the bed village and the belt village. Those villages whose geographical area is liable to complete submergence are called 'bed villages'. Belt villages are liable to partial submergence. The kolleru tract has been delimited upto the 10ft.contour level as it is the area liable to submergence at the highest flood peak. Abouts 80 hamlets fall within this area.

The region is populated by backward and scheduled caste people. This micro region is sparsely populated as compared to the otherwise densely populated Krishna- Godavari delta region . The people are economically backward, literacy is very low, civic amenities such as drinking water, proper roads and transport are lacking. The main occupations of the people are agriculure and fishing . Duck rearing forms the occupation of a smaller segment.

Problems of Kolleru lake

The lake is facing problems mainly due to human interference. There has been large scale deforestation in the catchment which has led to sediment load in the inlets and heavy siltation.

A number of industries discharge their effluents into the lake. In addition the pesticides and fertilisers used for agriculture drain into the lake leading to pollution and also eutrophication.

The large scale encroachment of the lake bed and the fragmentation of the lake by crossbunding and building of roads has made it difficult to control weeds. Overall ecological balance has been disturbed.

The pelicanry in the area which had the distinction of being one of the largest in Asia has been more or less wiped out due to deforestation, changes in the lake's fishing activities and also people's negative attitude towards the birds as pests.

These problems are manifestations of the deterioration of the lake environment due to over exploitation of resources without foresight towards long term development. These problems need to be addressed with a view to sustainably develop the lake as a resource. There is need to take steps for conservation to -

1. Maintain ecological balance between physical and environmental attributes i.e..lake characteristics, flora and fauna.

2. Develop the fishery resources for utilisation of the human population depending on the lake.

Review of literature on Kolleru lake

Literature regarding Indian wetland systems is scanty. There is a paucity of studies on wetland hydrology, structure and values. The few wetlands in India with extensive and thorough studies include Ramsar sites Chilka, Keoladeo Ghana bird sanctuary and the Dal lake. Most other wetland systems are inadequately documented.

Studies on Kolleru lake particulary hydrology and landuse are equally insufficient. The most important source of information on the lake is available in reports brought out by various organisations and government departments. The literature is mainly on hydrological aspects, the development of pisciculture and paddy cultivation and the overall development of the lake environment.

The aim of this review is to chronicle these aspects of the lake.

The study of Vidyanath.V (1968) deals with hydrological regime of the lake. The catchment area consists of a number of streams and delta drains. The largest catchment is that of the errakalva the total annual rainfall for the catchment ranges between 90 to 110 cms. The hilly regions of the catchment have a highter incidence of rainfall as compared to the deltaic area. The waterspread area fluctuates with rainfall amount between 900 sq km at 10 ft (3.04 m) to 4 sq km at 2 ft (0.7m) MSL.

The peak levels of the lake are discussed in the study for 50 years from 1916-65. The average peak level for 50 years is 6.6 ft (M.S.L). The month of September has had the highest frequency of peak levels (22 years in September between the period 1916-65). Moreover the month of peak level seldom concides with the months of high rainfall.

The monthly regime of the lake is influenced by monthly inflows and outflows. Vidyanath brings out seasonal regime which show rise in level of lake in June, this contimes till September after which the level starts receeding. The fall in levels after the fall in rainfall amount is very gradual due to low discharge capacity of Upputeru, its meandering course and also due to weed infestation and cross bunding which has fragmented the lake. This study provides a good account of the hydrological regime of the lake before the 1970s. It is one of the more detailed studies of hydrological aspects.

Malla Reddy, P.T and Satyananayana Murthy.M. in their study 'Flood and drainage problems in Krishna-Godavari delta' assess the damage due to the frequent flooding and consequent submergence of the crop.

The Flood problems are mainly the submergence of agricultural area, widespread damage to the standing crop. Drainage congestion is another problem on which their study has focussed. The various inlets and outlets swell up along with the lake. The delta drains are unable to dischage their waters into the lake. Moreover, the outflow is reduced due to lower discharge capacity of Upputeru. This problem is further compounded by theYenamadurru drain flowing into the Upputeru channel south of the lake. This impedes the outflow of lake waters through Upputeru.

The study also discusses the various flood control measures that are being recommended after the 1964 flood by the Mitra Committe. The remedial measures include,

- diverting the flow of upland streams into neighbouring valleys.
- Construction of detention reservoirs on the various upland streams at suitable points.
- Improvement of upputeru outlet for increasing its discharge capacity.

Ecological survey of Kolleru lake (1977) A report of the subcommitte set up by the Andhra Pradesh state board for prevention of and conrol of water pollution, is a detailed account of the lake environment the impact of various activities within the lake and the ecological implications of certain steps being taken for controlling floods and developing fisheries and agriculture. The report points out that the proposed remedial measures by the Mitra committe will bring about the desired results i.e.. limit submergence of Kolleru lake area to a period of not more than 7 days and also reduce the risk to the 1st crop upto +7.00 feet. M.S.L.

However, these measures will result in new problems. The lake would be depleted to a very low level in summers. The agricultural and fishing activities will face a scarcity of water and hence a fall in yield. The flora and fauna will also be affected badly, certain species might ever be wiped out. In addition, the reduction in water levels will further encourage the encroachment of exposed lake bed.

This report discusses in detail the status of aquaculture, the impact of human habitation, lake pollution, tourism, problems faced by the Kolleru ecosystem. It also focusses on the existence of one of the biggest pelicanries in Asia as a bird habitat which has diminished considerably.

The paper by Pradhan P.K. (1988) traces the evolution of the lake with evidences from sediments and the geomorphology of the region. The study also focusses on the state of the lake, in terms of water level and change in conditions. According to the paper, the activities of man have lowered the lake level. It has become shallower and there is development of swamps and widespread weed infestation. The lake has been distorted by the building of bunds for fish tanks and reclamation of lake bed for agriculture.

Seshavataram.V (1990) provides a review of the ecological status of Kolleru. The various aspects- physical features, soil and vegetation, the people are briefly discussed. The physico-chemical characteristics are put forth in detail. The problems of the lake are outlined along with some measures to counter them.

The literature on development of fisheries is mainly unpublished reports. Kumaraswamy. R.G. (1975) discusses the salient features of Kolleru bed villages in terms of settlements agriculture and co-operatives, irrigation. The report further traces the development of Kolleru area particulary the fisheries and other related activities. The report brings to light the need for a comprehensive planning so that the lake is developed for fishing. There is scope for fishing for the best varieties in the freshwater environs of the lake. The infrastructure such as purchasing agency, storage facilities and transport network are recommended for the overall development of this activity.

Report on integral development (1977) prepared by P.W.D., Note on development of fisheries (1978) : District authoritees of West Godavari district, report on development of fisheries in Kolleru (1996) : Department of fisheries Eluru Taluk W.G. district present the development of agriculture in the lake and certain parameters like fishing methods, fish seed dominant species in the lake and the species that are nurtured.

The production schemes for fisheries, the setting up of co-operatives, infrastructure required for development of fishries are delineated in these reports. They bring to light the first plans for development of fisheries by the Andhra Pradesh govt. in 1974. The fish tanks were proposed to be set up in suitable locations between the levels 3ft to 5 ft contour. A scheme was formulated for the construction of fish tanks, 35 each in Krishna and W.Godavari district. Work began by 1976 and work on construction of 35 tanks was completed by 1982.

The tanks were given over to fishermen co-operative societies with 100 members. In Krishna district 38 fishermen cooperatives were registered. 50 acres were given for each co-operative society which consisted of 40 acres of water spread area and 10 acres for bunds.

The reports discuss further allotment of 20 tanks in Krishna and 24 tanks in west Godavari district in a supplementary scheme. By 1995 West Godavari had 88 fishermen co-operatives and Krishna district had 58 fishermen co-operatives.

Recommendations are made for facilities to serve these increased aqua-culture activities and problems faced by the fishermen are set forth.

Vidyanath (1980) takes up Kolleru lake as a case study for environmental determinism. The basis is the dependence of the people on the lake products and the predominance of activities that are guided by the lake hydrology. These include paddy cultivation, fishing and duck rearing. Vidyanath delineates zones keeping in view the land use patterns. Changing landscape of the lake also gives rise to problems. Measures for dealing with the disturbance to ecological balance are taken up by the author.

The literature reviewed brings out the changes in the landscape, The most prominent theme is the man-environment interaction which manifests itself in the resource use of the lake and development of the human settlements. Also man's constant attempt at striking a balance with the course taken by nature.

The Gradual change in hydrology change in land use and development of fishing as a significant economic activity due to commercialisation are essentially disturbing the lake environment.

CHAPTER III

HYDROLOGY OF THE KOLLERU LAKE AND ITS CATCHMENT AREA

Physical Attributes

The Kolleru lake is spread over the coastal districts of Krishna and West Godavari, at 3.05 m contour level it extends over 900 sq. kms. It is a freshwater lake with numerous species of fish. The lake bed harbours thick vegetation, particularly water hyacinth forms thick mats occupying vast areas. The lake bed is represented by heavy silt and clay. It is rich in organic matter. The temperature of the lake water ranges between 24.2°C to 11.6°C in an year.

The lake collects its drainage through a number of rivulets, canals and streams, the important ones among them are Budameru, Thammileru, Ramileru, Gunderu etc. The delta drains that flow into it are Kaikaluru, Moturu, Pedapadu, Vatluru, Mondicodu, Siddapuram, Chandrayya, Pandikoduru and Venkayya drains. The Upputeru is the only outlet connecting the lake to the sea.

The catchment area of the lake is 4700 sq. kms. of which 3400 sq. kms. is from the upland area and 1300 sq. kms. is from the deltaic area. The catchment area is mainly alluvial plains. The uplands extend towards the north and north east of the catchment.

This region is a paddy cultivation area. The lake region has aquaculture. This region does not have any notable forest cover most of the region has been occupied for agricultural purposes.

Rainfall Characteristics of the Kolleru Catchment Area

The region gets most of its rainfall from the south west monsoon which begins at the end of May and ends in September. A little amount of rainfall also occurs in the north east monsoon period during October to November. The average annual rainfall is around 969 mm.

Storms and depressions originating in the Bay of Bengal, during the post-monsoon season cause widespread rain. Rainfall of upto 600 mm has been recorded in some stations during these cyclonic depressions (Seshavataram, V., 1992).

The number of cyclones affecting the Andhra coast from the period 1877-1995 was 80, out of which 33 were severe cyclonic storms. On an average 1 to 2 severe cyclonic storms affect this area. The number of severe cyclonic storms that have crossed the coast near Kolleru are 8 (1891-1995).

These severe cyclonic storms bring torrential rains, high velocity winds and storm surges. The Kolleru lake with proper zoning and protective cover line of trees can to a great extent reduce the severity of the cyclone in this area. The recent severe cyclone over Kandla, Kutch area would have caused less damage had the ecosystem of the region not been disturbed. If the ecosystem of the Kolleru lake is disturbed further, its ameliorating touch will be eliminated to the disastrous consequences of the ecosystem.

Data Sources

The rainfall data has been collected for four stations Eluru, Chintalapudi, Nuzuid, Gudivada.

The parameters taken are monthly rainfall, annual rainfall, heaviest rainfall that occurred in 24 hours. The rainfall for the monsoon season (June to September) has been

calculated for the four stations.

The data for Eluru and Chintalapudi is available from 1901-91 in terms of monthly rainfall and annual rainfall. The data for heaviest rainfall in 24 hours is available from 1951-91 for these two stations. Data for Gudivada station is available from 1901-50 and Nuzuid station's monthly and annual rainfall is available from 1916-50. The data for heaviest rainfall in 24 hours is not available for Nuzuid and Gudivada stations.

The data from 1950 onwards for Eluru and Chintalapudi in West Godavari district has been obtained from Indian Meteorological Department - Pune. The data regarding the earlier period has been obtained from monthly rainfall and number of rainy days published by IMD.

Spatial Variation of Rainfall

The average rainfall for Chintalapudi and Nuzuid which are in the upland area of the catchment is more than 1000 mms. Eluru and Gudivada have average rainfall between 970-990 mm for the period 1901-50. (Table 1)

For the period 1951-91 and 1901-91, the average rainfall is higher in Chintalapudi than Eluru. The upland areas of the catchment receive more rainfall than the deltaic areas.

The co-efficient of variation expresses the consistency of the data. A higher value of C.V. shows higher inconsistency in the data, whereas a lower value of C.V. shows consistency i.e. the data is not highly variable.

In this case, higher variability is seen in Eluru and Gudivada. Chintalapudi and Nuzuid show lower variability for the period 1901-1950. The rainfall is very high in both stations Eluru and Chintalapudi for the period 1951-91. The C.V. is almost twice, the co-efficient of variability for the period 1901-50. For the overall period from 1901-91, both the stations Eluru and Chintalapudi have almost similar values 31.41 and 31.05 respectively.

Table 1 : Spatio-Temporal Variations in Rainfall.

Station	Average Annual Rainfall (mm)	Standard Deviation	Co-efficient Variation	Monsoon Rainfall (mm)
Eluru				
1901-50	990.5	225.27	22.74	
1951-91	882.1	354.65	40.21	
1901-91	941.4	295.74	31.41	691.41
Chintalapudi				
1901-50	1073.1	223.51	20.83	
1951-91	965.5	392.99	40.70	
1901-91	1024.5	318.11	31.05	791.41
Nuzuid				
1901-50	1004.2	195.59	19.48	691.76
Gudivada				
1901-91	970.1	238.38	24.51	611.72

Seasonal Distribution of Rainfall

The maximum rainfall is in the month of July. It continues to be high upto October after which the monsoon begins to weaken. The monsoon rainfall June to September forms almost 70% of the annual rainfall. (Table 2)

Table 2 : Monsoonal Rainfall.

Stations	Monsoon Rainfall (mm)	Annual Rainfall (mm)
Eluru	690.6	1088.1
Chintalapudi	794.5	1073.6
Nuzuid	692.4	1005.9
Gudivada	612.0	970.6

After the monsoons the rainfall gradually decreases. By November the rainfall is below 60 mm. The months of December and January have rainfall of less than 10 mm. There is a gradual increase in rainfall by April and May. The Kolleru region essentially gets its rainfall from the monsoons. The gradual increase in rainfall has a bearing on the Kolleru lake (Appendix II).

The Lake Regime

The water regime in the lake is more or less guided by the inflow and outflow. The level of the lake begins to rise in June. By September normally the peak level is reached. This is the month of maximum inflows and outflows (Vidyanath, V., 1968).

There is a considerable increase in inflow and outflow from June to July and the lake rises to 2.7 feet. In October when there is a fall in inflow to the lake, the outflow does not get reduced.

The reason behind this is the single outlet from the lake Upputeru and its low discharge capacity. The meandering course is one of the reasons for this low discharge. This is further compounded by the draining of a part of Yerrakalwa into the Upputeru. In this season, the Upputeru itself is liable to flooding, which retards the outflow from the lake.

In November the lake level is at 5 feet. The lake water continues to recede. In January at the onset of the *Rabi* crop the lake level is at 3 feet. The lake level reaches a level of 0.5 feet in May. At this time the lake area is considerably reduced and large tracts are open to encroachment.

The activities of the lake are linked to the water level changes that take place seasonally. However, the lake is sometimes completely dried up because of drawing too much water for the fish tanks and agriculture in the lower regions particularly during *Rabi* seasons. This is detrimental to the lake ecosystem. It has to be considered while preparing a plan for conservation.

Relation between rainfall and water level of the lake

The Kolleru lake has constant fluctuations in the water levels. This is in response to the variations in rainfall. As observed in the 'seasonal variations in rainfall', the water level fluctuates seasonally.

In fact, the activities of the lake are influenced by the lake levels. There are seasonal changes in lake use. This relationship between the lake level and rainfall is assessed with the use of a scatter diagram.

The scatter diagram (Figure 1) brings the relationship between the two elements rainfall (in mms) and Peak levels (in metres) Appendix III. The rainfall is taken for the monsoon months i.e. June to September.

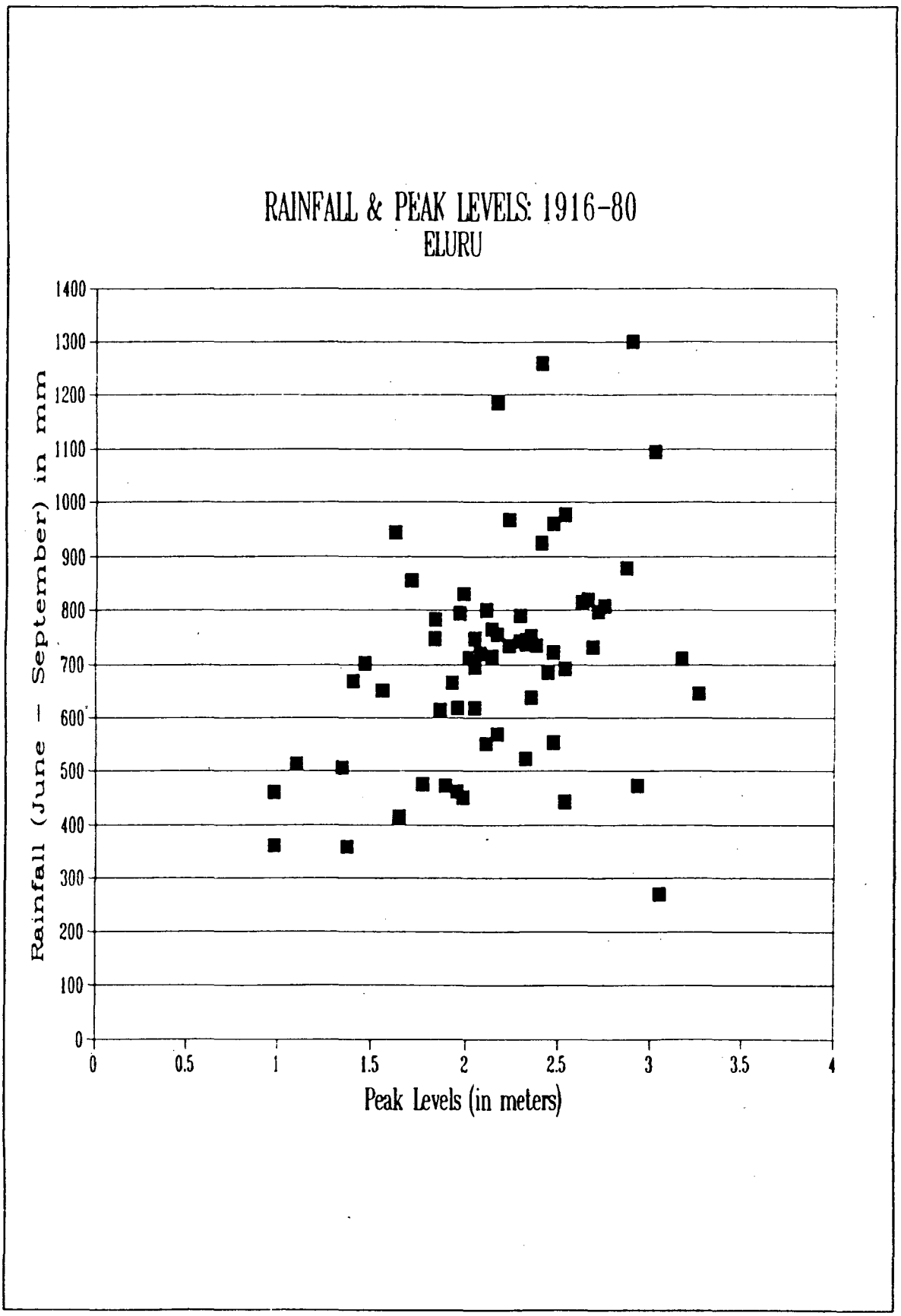

RAINFALL & PEAK LEVELS: 1916-80
ELURU
Rainfall (June - September) in mm
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Peak Levels (in meters)

Fig. 1

There is a clustering of the rainfall and peak level parameters between 60-80 mm, the corresponding peak level range for this amount of rainfall being 2-2.5 m, further away from this range the observations are scattered.

There is a correlation between rainfall and peak levels. There are other factors influencing the peak level of the lake. The other factors could be natural factors such as:

1. Intensity of rainfall: The higher the intensity of rainfall, more runoff and higher lake levels. Similarly less intensity of rainfall results in more infiltration and less runoff into the lake.
2. Discharge capacity of outlet as a result of flooding and drainage congestion.
3. The causes could also be man-related i.e. excessive withdrawal of water for agriculture or aquaculture activities.

CHAPTER IV

ZONATION OF THE KOLLERU LAKE

Zonation is a management strategy for the protection and co-existence of ecosystem and cultural resources of values. Application of this strategy in the real world requires a keen understanding of the various components that constitute the ecosystem. The spatial and temporal patterns of interaction need to be taken into account. The zonation process will be guided by the necessity for ecological balance.

Zonation provides a framework for monitoring various changes in the ecosystem. Moreover, the guidelines for maintenance of ecological equilibrium would complement the zoning system.

The Kolleru lake ecosystem is an example of the juxtaposition of environmental and cultural components. The lake has been deteriorating in recent times which is evident from the disappearance of certain species of birds, fish and flora. The increase in eutrophication and pollution levels of the lake also point to this deterioration. The conservation of the lake through 'zoning' is the appropriate strategy for preventing further deterioration. Specific guidelines have to be laid down within each zone, keeping in view the character and the function of the zones.

The first step in zoning is to identify the most important parameters interacting within the ecosystem. The parameters taken into account in relation to Kolleru lake are the population and occupational structure of the lake region:

- Population and settlement characteristics
- Cultivation of paddy
- Aquaculture

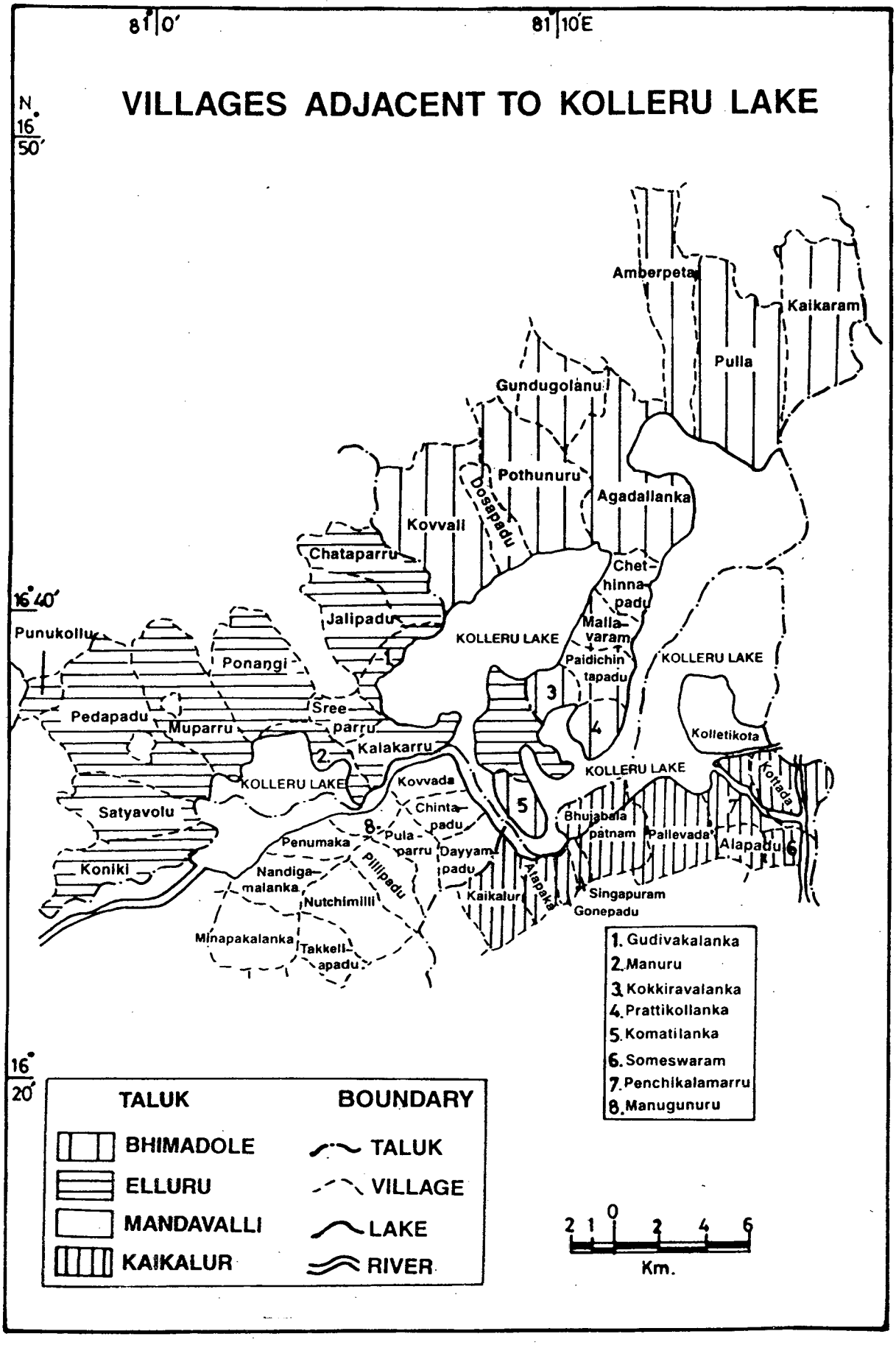
- Waterfowl habitat, particularly the pelicanry.

Demographic and Settlement Characteristics

The lake area is less densely populated as compared to the rest of the deltaic area. The peripheral villages being located on higher contours show higher densities. The villages along transport routes also have higher densities compared to villages at lower contour levels. The reason being the possibility of periodic flooding and consequent losses. The average density of villages in the Kolleru (68 bed and belt villages as given in Appendix I) was 156 persons/sq. km. in 1971.

The average size of the households is lower than the national and state averages. In most of the villages the proportion of agricultural labourers to total workers is higher than workers in fishing activities or cultivators. The bed villages have a small proportion of workers in fishing activities. However, they do not dominate the occupational structure in any of the regions. In most villages the proportion of females to males is well-balanced. The predominantly rice cultivating villages located on the periphery have greater proportion of females because of the large component of female labour in paddy cultivation. The fishing villages however, have a smaller proportion of females in the workforce, (Vidyanath, V., 1970).

The distribution pattern and spacing of settlement is also guided by environmental factors. The size of the settlement shrinks towards the interior. Medium and large sized settlements are concentrated in the peripheral regions. The settlements are compact and far apart closer to the lake (Map No. 4). In the belt villages and peripheral villages, the settlements are along the shore. (Vidyanath, V., 1985).


81°0'
81°10'E
N.
16°
50'
VILLAGES ADJACENT TO KOLLERU LAKE
16°40'
16°
20'
Amberpeta
Kaikaram
Pulla
Gundugolanu
Pothunuru
Agadallanka
Kovvali
Dosapadu
Chataparru
Chet-
hinna-
padu
Jalipadu
KOLLERU LAKE
Malla-
varam
Paidichin
tapadu
KOLLERU LAKE
Punukollu
Ponangi
Sree
parru
Pedapadu
Muparru
Kalakarru
Kolletikota
KOLLERU LAKE
Kovvada
Kottada
KOLLERU LAKE
Satyavolu
Chinta-
padu
Bhujabala
patnam
Pallevada
Alapadu
Penumaka
Pula-
parru
Dayyam-
padu
Koniki
Nandiga-
malanka
Pillipadu
Alapaka
Kaikalur
Singapuram
Gonepadu
Nutchimilli
Minapakalanka
Takkeli-
apadu
1. Gudivakalanka
2. Manuru
3. Kokkiravalanka
4. Prattikollanka
5. Komatilanka
6. Someswaram
7. Penchikalamarru
8. Manugunuru
TALUK
BHIMADOLE
ELLURU
MANDAVALLI
KAIKALUR
BOUNDARY
TALUK
VILLAGE
LAKE
RIVER
2 1 0 2 4 6
Km.

Map 4

The literacy rate is comparatively lower in this region than in the delta and coastal Andhra. The literacy rate is 27% (Vidyanath, V., 1970). The low literacy rate the high proportion of agricultural labours and the predominant dependence of the population on primary activities such as agriculture and fishing are indicators to low development status of the area.

The development infrastructure in terms of roads, medical facilities, educational facilities and drinking water also need to be addressed in the development plans.

The settlement patterns and location may be taken into account while preparing guidelines for each zone. The development infrastructure also needs to be complementary to the zoning objective of ecosystem presentation. In other words the location of these facilities has to be carefully planned so as not to have further repercussions on the ecosystem.

Agriculture

Rice is the principal crop grown in this region. *Rabi* and *Kharif* crops are cultivated, although *Rabi* is more important. The *Kharif* crop (June-December) is liable to submersion. In this season the cultivation mainly takes place above the 7 feet contour. The *Rabi* crop which is grown from January-May is grown from 3 feet contour onwards, as the water level recedes in the lake. *Rabi* crop is sown in 88 villages whereas *Kharif* crop is sown in 68 villages.

The *Kharif* season commences in June, sowing takes place in the third week of June and harvesting takes place in the first week of November, Since, the highest mean monthly level is upto 6 feet contour. *Kharif* crop is cultivated in villages above 7 feet contour. Weeding is done in May before sowing. Transplantation of paddy is done at the end of June.

The cultivators often harvest the crop prematurely in October. This is because in November the water level in the lake goes down.

The fields have 1 foot water which makes harvesting difficult. In October since the water level is higher the crop is harvested using boats. Although the harvest is easier but, the yield gets affected. The threshing operation is immediately after harvesting since *Rabi* sowing starts in January.

The *Rabi* season begins in January. The cultivation takes places mainly between 2 feet and 3 feet contours. The average water level is 3 feet. As the season progresses the water level recedes. The land between 7-3 feet is given out on lease by the Government.

The lake waters in the lower level (below 3 feet) are stored in high water tanks and used for cultivation. Above 3 feet canal irrigation is used where needed.

Harvesting takes place in April and May, threshing is carried out in the fields. In the *Rabi* season, 6 feet high bands are formed around huge plots and water is baled out. It is stored in tanks from which it is pumped back into the fields whenever required. The fields are irrigated by Kolleru water in these villages and by canal water in belt villages and peripheral villages (Vidyanath, V., 1970).

The land between 5 feet to 7 feet is generally fertile and gives higher yields. The farmers are introducing certain varieties of rice for ensured higher yields and minimisation of losses due to inundation. These varieties have thick stalks which are erect even in flood conditions. Moreover, in floods the stalk grows fast. The crop is always above the highest water level. Unlike, the delta area, there is no crop rotation system in this region.

Aquaculture

Fishing is an important occupation in the lake area. It can be developed as it is

suitable for cultivating some good varieties of freshwater fish. About 70 fish tanks have been constructed in the lake bed, with a waterspread area of 1000 hectares (Seshanataram, V., 1994). These fish tanks are under fishermen co-operatives. However, in recent times a few private enterprises have also started constructing fish ponds further into the lake, the lake bed is being encroached.

The fish tanks have to be ensured water all the time to prevent losses. The water level is maintained at 5 to 6 feet. But, in summer due to shortage of water it is reduced to 3 feet level, the trench region gives a good cover to the fish (Note on fisheries in Kolleru area, 1996).

Catla, Rohu and Mrigal are usually stocked in the ratio of 3:7:2. Manuring is done regularly at intervals of 10 to 15. However, manuring is stopped during summer to prevent pollution. The application of pesticides has drawn attention due to its adverse impact on the fish tank ecology. The fish catch is marketed to the Howrah market. Eluru, Akividu etc. are local fish centres from where the catch is sent to various markets.

The rather unregulated development of fisheries in the lake is a cause for concern. The problem areas in Pisciculture development are:

1. Lack of water for fish culture tanks above +4 feet contour.
2. The private pisciculturists are excavating ponds indiscriminately, obstructing free flow of water.
3. Indiscriminate release of water from pisciculture tanks rich in unused feeds, faecal decomposed matter, resulting in pollution of adjacent water area.
4. The large inputs which have already gone into existing tanks, growth of stocked fish and the actual production must be closely monitored, before planning further expansion.

In fact, it was believed that if the fish tanks do not occupy more than 10 percent of the lake area and if they are located 2 kms. apart, they are not going to disrupt the natural flow of water in the lake.

While preparing a plan for the lake there are certain necessary measures which have to be taken to deal with these problems.

Waterfowl Habitat

The Kolleru lake is also important as a habitat for a variety of waterbirds, passerines (songbirds and perchers) and a number of raptures (birds of prey). The lake has conditions and factors highly conducive for bird species both resident and seasonal migrants. (Ecological survey of Kolleru lake, 1977).

The lake was a well known Pelicanry. The region had been declared a protected area in 1963 and a bird sanctuary in 1973 by the Andhra Pradesh Government. A study of the bird species recorded 188 species out of which 88 were waterbirds (Note on fisheries in Kolleru lake area, 1996).

This gives an indication towards the significance of the lake as a waterbird habitat. The Kolleru lake also had the distinction of being the largest pelicanry in the subcontinent attracting large numbers of Grey pelicans which nested in this area. It is the only major breeding place of the Grey pelican.

These pelicans started deserting the area after 1973 due to various causes such as human disturbance or less of habitat values. This itself is an indication of changes in the environment and loss of viability of the lake as a habitat.

A brief description of the various aspects of the pelicanry would throw light on its significance. The pelicanry was situated between the towns of Ganapavaram and Undi in the

West Godavari district. It lies between latitudes 16°35′ and 16°45′ and longitudes 81°25′ and 81°30′. It is 11-12 kms. east of Kolleru lake (Neelakantan, K.K., 1961).

The Pelicans have shifted atleast three sites since the early 1900s. The first site favoured by the pelicans was Aredu village. In the 1940's they moved to Sarepalli due to harassment by the villagers of Aredu. By the 1960's the birds had to shift to Kolleru village, which is presently depopulated. The nesting area was extended upto Sarepalli.

Breeding Habits of the Pelican

The Grey Pelican spends about 9 months every year at the pelicanry. Some proportion also remained throughout the year in the vicinity of the Kolleru lake.

The birds arrive in September or October and left in May or June. They build their nests on the Palmyra, Raintree, Babool, Coconut or Mango trees. They lay their eggs in December which are hatched by January. The birds live in compact colonies. They mainly feed on fish from the lake.

The pelican guano has inestimable value as fertilizers as it is rich in phosphates and other chemicals. This is of much economic value.

Problems faced by the birds:

- Pollution of the lake by heavy discharge of pesticides and insecticides affecting fish life.
- Human activity on an increasing scale.
- Disappearance of suitable trees for nesting due to deforestation.

The problems faced by the pelican and causes due to which they abandoned the area would apply for other waterbirds too. So, to restore the lake as a waterfowl habitat these aspects should be dealt with. Maybe the pelicanry can be re-established through efficient

planning.

Zones for Lakeuse

The delineation of zones in the lake is broadly guided by the contours. Since each activity is dependent on the availability of water this is the most appropriate basis. The lake is divided into 4 zones for sustainable, ecologically sound use of the lake. There are various measures to be taken to ensure the efficient use of each zone. The measures should be complementary to the function of each zone.

Core Zone :

The core zone of the lake is delineated to the east of Agadallanka village in Bhimadole Taluk of West Godavari district. This village was chosen as a site for a bird sanctuary in the earlier plans. This zone encloses the 3 feet contour along Agadallanka, Mallavaram, Chettunnapadu, Kolletikota and Villages of Tadepalligudem Taluk including Kolleru, Timmaraogudem which are depopulated villages. The depopulated villages can be enclosed completely, irrespective of the contour level.

This zone contributes to the conservation function of the lake. The objective of this zone is to preserve the ecosystem in a natural state as far as possible. This includes the development of avifauna, typical to the lake area. The zone could be conditioned to reintroduce the now negligible population of the grey pelicans. The depopulated villages may be demarcated for planting suitable trees for resting. The birds, particularly pelicans live in colonies. The density of birds per tree is high. Hence, fewer trees over small areas may suffice initially.

A research and monitoring centre should be established in the Kolletikota island to study the interactions of the ecosystem. Education and research are fairly low impact

activities which are non-destinctive if well-regulated against unnecessary expansion. This would also ensure a permanent centre for monitoring all changes in the lake-core and periphery areas and also building a well researched database with reference to all aspects of the lake. The biological diversity of the region is one such significant aspect. The others include the hydrology and the socio-economic structure of the population. This database is essential in view of the scanty data available.

Zone II :

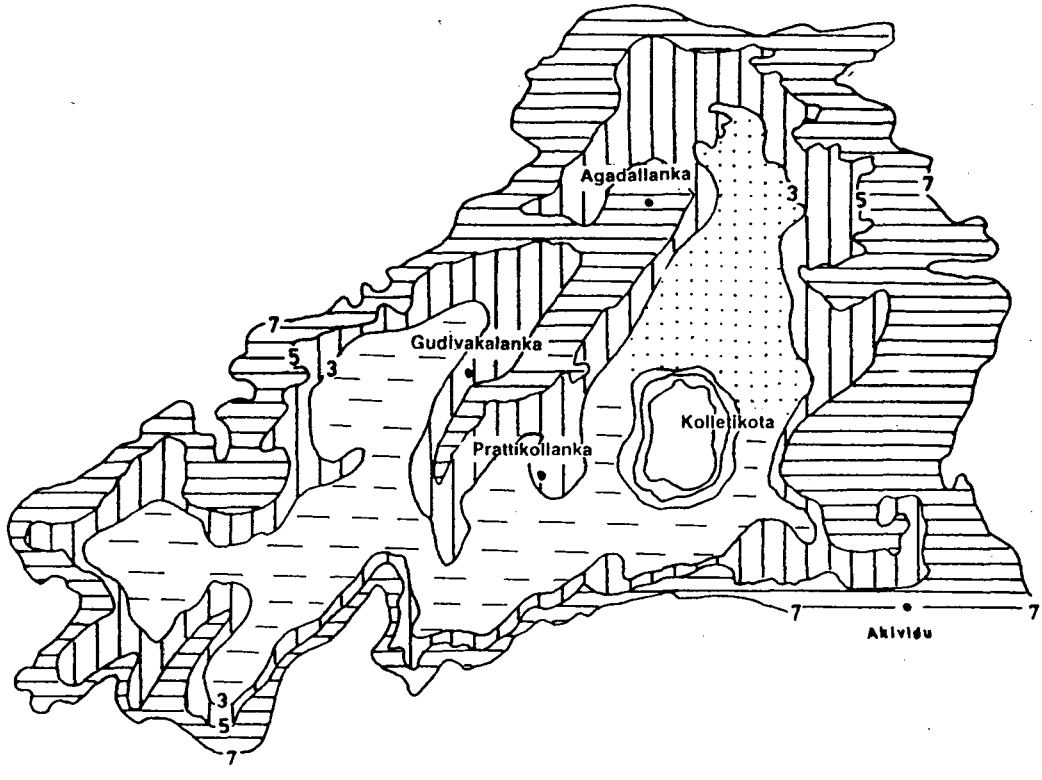
This zone extends between the contours 3 feet and 5 feet around the lake. This zone has the fish tanks of the various co-operatives. There are a few tanks below 3 feet, mainly belonging to the private entrepreneurs. These tanks may be shifted to more appropriate areas since tanks at this level may have a detrimental effect on the core zone. Pollution and further encroachment into the lake have to be mitigated.

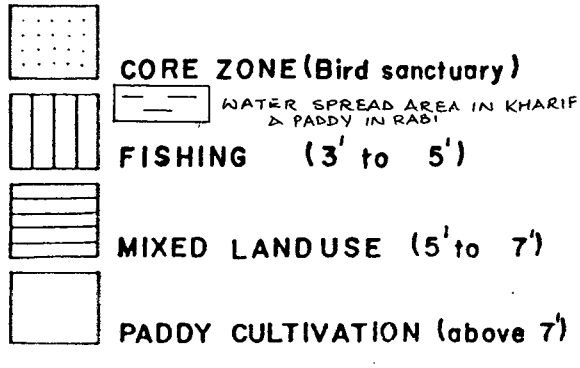
The tanks should be regulated in terms of spacing and number. They should be 2 kms. apart and occupy 10 percent of the lake. This is essential for the free flow of water in the lake. It is advisable to avoid activities like road building in this area. The human interventions must be kept to the minimum, the lake should not get fragmented by crossbunding and roads.

Zone III :

This zone is a mixed landuse zone extending from 5 feet to 7 feet. There are a few fish tanks extending above 5 feet. From February to May *Rabi* crop is grown at lower contour levels. A zone for mixed landuse is ideal since there are chances of submergence upto 7 feet. Therefore depending upon peak levels landuse predominantes. In the lean fishing season the *Rabi* crop will be more important. In monsoon season when the water level is higher fishing activities may be predominant.

CONTOUR MAP OF KOLLERU LAKE





Map 5

Zone IV :

The cultivation zone is the peripheral zone. It extends above 7 feet. The frequency of submergence is less above this level. If the water level is properly regulated, water management according to crop needs is efficient. The *Kharif* and *Rabi* crops can be grown, although in years of flood the *Kharif* crop may suffer losses. Crop varieties that are flood resistant may be popularised.

Table 3 : Zonation of Kolleru Lake.

Zone	Contour Extent	Function
Core Zone	Area Below 3 feet	Bird Sanctuary
Zone II	3-5 feet	Fishing
Zone III	5-7 feet	Mixed Landuse (fishing and cultivation)
Zone IV	Area Above 7 feet	Cultivation

CHAPTER V

SUMMARY AND RECOMMENDATIONS FOR LAKE CONSERVATION

Summary

The Kolleru lake ecosystem has been experiencing considerable development stress in recent times. The stress is manifesting itself in various forms. The deterioration of the lake environment, and problems faced by the inhabitants are essentially due to development activities and population pressure.

This study is an attempt at understanding some of these impacts on the lake environment and zonation as a management strategy.

The Kolleru lake environment is a complex wetland system which is influenced by the catchment between the two important south Indian rivers Krishna & Godavari. The lake environment is influenced by the hydrology and landuse. These are the two significant factors of transformation in the lake. The rainfall of the catchment has considerable influence on the lake hydrology and consequently on landuse. The rainfall, as analyzed spatio temporally and seasonally brings out certain patterns. The rainfall is higher in the upland region of the catchment as compared to the delta. Seasonally, the maximum rainfall occurs in the South-West monsoon period. This rainfall has an impact on the peak level of the lake. The relationship between rainfall and peak levels is evident from the seasonal change in lake levels.

However, there are certain other factors which influence the levels in the lake. Therefore, the correlation between the two parameters is not highly significant. The other factors which influence the lake levels, development related. The fragmentation of the lake

due to crossbunding, road network and excess withdrawal of water for various activities are the predominant factors. The pressure of population on the lake is further manifested by various problems.

- The tree cover in the peripheral areas is extremely limited leading to runoff and sedimentation.
- The encroachment into the lake for agriculture and aquaculture has increased multifold.
- The pollution of the lake and eutrophication has an adverse impact on the lake ecosystem.

The causal factors of pollution are essentially agricultural waste and industrial effluent.

- The bird population has been seriously affected by the encroachment into the nesting and roosting area of the birds. Consequently, certain species common to this area have become non-existent.

The lake is a suitable habitat for a variety of birds, particularly water birds. The lake is also a resource region for aquaculture.

The management strategy for the lake should focus on these problems. The zonation of the lake has been based on the various activities around the lake. The zones are concentric with various functions. The core zone has been delineated in the eastern part of the lake it includes a few depopulated villages and the island of Kolletikota. This region can be developed into a bird sanctuary, the conditions suitable for pelicanry can also be created. This region will need careful monitoring.

The next zone is the fishing zone which has been delineated in the area of maximum fish tanks. The tanks falling outside this zone are very few in number, hence only a few tanks will have to be evacuated.

Beyond this zone are the mixed, i.e., fishing and cultivation zone and the zone for cultivation. Specific function have to be assigned to each zone depending on the water needs in order to provide a framework for guidelines of use.

In the process of working out the zones, many problems faced by the lake have come to light. The zonation strategy would be unsuccessful in its objective i.e., conservation of the lake, if these problems are not enumerated and suitable measures recommended.

The problems faced by the lake are -

1. Siltation of the lake at the rate of 2.5 cms per year resulting in flooding of catchment area and loss of flood absorption capacity. The cause is the lack of vegetation cover in the catchment area.
2. Obstruction of waterways by indiscriminate construction of roads and excavation of fish ponds.
3. Inadequate capacity of Upputeru drain to provide for flood discharges.
4. Depletion of lake level in summer to as low as the 3ft contour which leads to further encroachment into the lake for agricultural purposes. This also leads to inadequacy of water for aquaculture.
5. Pollution of the lake from agricultural pesticides and chemicals and from release of water from pisciculture tanks which are rich in unused feed faecal decomposed matter.
6. Destruction of wild life habitat: The habitat value of the lake has been considerably disrupted due to large scale human activity such as cutting of trees, fragmentation of lake by roads and fish ponds, release of pollutants. Consequently, the pelicans have deserted this area The populations of birds has fallen drastically. There has been a change in aquatic life-floral and faunal.

Recommendations

The problems regarding Kolleru lake need to be addressed within an ecological frame to ensure development of the lake and its catchment area. The measures recommended to deal with these problems can be divided into various categories. The measures pertain to hydrology, landuse, environmental i.e., pollution and conservation activities and social aspects. They are-

1. A regulator should be constructed at Upputeru to facilitate maintaining a minimum water level of 5ft. Within this area the water bird habitat and fish ponds will have sufficient water. Moreover, this regulator will prevent the tidal salt water to enter the lake.
2. The Upputeru may be widened and deepened to increase the discharge capacity to atleast 15,000 cusecs as compared to the present discharge capacity of 10,000 cusecs.
3. Water quality has to be controlled and monitored. Mainly the industrial waste draining into the lake should be treated to the standards prescribed by the Pollution Control Board.
4. Domestic waste waters and sewage from the neighbouring towns and villages should be treated before they enter the lake.
5. Measures should be taken for diverting pollutants and waste from all sources- industrial, domestic and agricultural, away from the lake. In fact a treatment plant may be set up to facilitate the whole operation.
6. The AP government should set up a water quality monitoring station at Kolletikota, kaikaluru or Eleru to regularly monitor the effluent water quality from various sources and also the water quality of the lake.

The measures recommended for land use are complementary to the zonation pattern.

1. The core area should be developed as a protected area having least human interference. Therefore, the human settlement may need to be relocated. Considerable planning needs to be done for ensuring that the core area is created with least problems to human settlements at the same time.
2. The fish ponds within this area would have to be abandoned, the fish ponds may be allocated within the fishing zone.
3. There is need for strict regulation on the further expansion of fish ponds and their spacing. Introduction of any new schemes should be undertaken only after assessing the impact of such addition to the lake environment. In fact in view of the present concentration of fish tanks it may be discouraged altogether.
4. The existing fish ponds obstructing the free flow of water should be removed or remodelled.
5. The construction of roads across the lake, thus compartmentalising the lake should be stopped with immediate effect. The existing roads may be transformed suitably to allow the flow of water. The free flow and mixing of lake water is very essential for the ecological health of the lake.
6. The zones above the fishing zone i.e., the mixed activities and cultivation zone, have to be maintained functionally. The functions which have been assigned may be put in more regulatory form after changes such as evacuation of fish tanks have been carried out.

The environmental aspects includes the measure to be taken in the catchment area and conservation practices to be adopted for the lake.

1. Removal of undesirable weeds in the lake would be beneficial in lowering the nutrient

levels of the lake and reducing the eutrophication of the lake. The core area may be left undisturbed in this respect.

2. Research for the use of these weeds productively may be carried out. Probably as manure or in industries, particularly paper industry.

3. Afforestation in the catchment area, particularly around the lake, will be of considerable merit as it will reduce runoff and siltation of the lake. This may be complemented by soil conservation schemes to prevent soil erosion.

4. Check dams may be constructed on the inlets draining into the lake to reduce the transportation of silt.

5. An extensively surveyed check list should be prepared for all the flora and fauna including avifauna that are characteristic to the lake and its surrounding areas. This would infact be essential for the efficient development of the core area as a bird sanctary.

6. Ecological impact assessment: The introduction of any activity in the lake or changes in zone structure or regulation should be carried out after a thorough impact assessment of these changes, to ensure that hasty steps do not cause any hindrance to the conservation process.

A conservation strategy is incomplete and unsuccessful without the involvement and participation of the local people. The social aspect is an intrinsic part of conservation activities and ecosystem development. It is recommended to -

1. Create an awareness programme for the local people which addresses the significance of the lake as a unique ecosystem, the lake uses, and the limits to such use. The programme should also outline the importance of the core area and the wildlife. The programme should be non-technical and may be arranged in a way be so as to

facilitate the local people in understanding the facts at their own level.

2. The displaced population in the vicinity of the core area has to be specially looked after. They may be relocated in the Upputeru area. Facilities for Brackish water pisciculture and salt production may be established which confirm to ecological standards.

3. There is a need for family planning and literacy programmes. The other civic amenities also need to be ensured within the environmental framework.

These measures may not necessarily ensure the perfect preservation scheme for the lake ecosystem. However, they definitely ensure a workable solution. The conservation strategy has to be changed according to the varying demands of the ecosystem.

A lake committee consisting of technical staff such as geologists, hydrologists, ecologists and planners may be set-up to overlook the conservation efforts.

There is need for a monitoring and research institute which collects database on all aspects and analyses the impact of various activities. In fact, overall planning may be carried out with assistance from 'Geographical information systems' (GIS) which would be particularly useful in creating and updating the database and monitoring changes in lake.

The regulation of zone functions, monitoring the infrastructure for the lake and awareness among the local people will assist in the conservation of Kolleru lake ecosystem.

APPENDIX I

BED AND BELT VILLAGES IN KOLLERU AREA

Eluru Taluk

1. Koniki (Belt)
2. Satyavolu (Belt)
3. Mupparu (Belt)
4. Ponangi (Belt)
5. Manuru (Bed)
6. Kalakurru (Bed)
7. Sriparru (Belt)
8. Gudivakalanka (Bed)
9. Jalipadu (Belt)
10. Chataparru (Belt)
11. Pedapadu (Belt)
12. Punukellu (Belt)

Fadepalli Gudem Taluk

13. Thokalapalli (Belt)
14. Bynapalli (Belt)
15. Devaragopavaram (Belt)
16. Pedanindrakolanu (Belt)
17. Nidamaruu (Belt)
18. Venkatapuram (Belt)
19. Adivikolanu (Belt)
20. Chanamilli (Belt)
21. Timmaraogudem (Belt)

Bhimavaram Taluk

22. Krovvidi (Belt)
23. Bhavayapalem (Belt)
24. Gummuluru
25. Kollaparu (Belt)
26. Peadkapavaram (Belt)
27. Chinakapavaram (Belt)
28. Siddhapuram (Belt)
29. Kolleru (Bed)
30. Akividu (Belt)
31. Dharmapuram (Belt)

Kaikaluru Taluk

32. Pallevada (Belt)
33. Bhujabalapatnam (Belt)
34. Atapaka (Belt)
35. Kaikalur (Belt)
36. Someswaram (Belt)
37. Alapadu (Belt)
38. Singapuram (Belt)
39. Gonepadu (Belt)

Mandavalli Taluk

40. Kolletikota (Bed)
41. Penchikalamarru (Bed)
42. Kottada (Bed)
43. Nandigamalanka (Bed)
44. Penumakalanka (Bed)
45. Ingilipakalanka (Bed)
46. Takkellapadu (Bed)
47. Nutchimilli (Bed)
48. Kovvada (Bed)
49. Manuguluru (Bed)
50. Dayuampadu (Bed)
51. Chintapadu (Bed)
52. Pillipadu (Bed)
53. Pulaparru (Bed)

Bhimadole Taluk

54. Komatilanka (Bed)
55. Kokkirayalanka (Bed)
56. Prathikollanka (Bed)
57. Paidichintapadu (Bed)
58. Mallavaram (Bed)
59. Chettunnapadu (Bed)
60. Agadallanka (Bed)
61. Pulla (Belt)
62. Kaikavaram (Belt)
63. Amberpeta (Belt)
64. Dosapadu (Belt)
65. Kovvali (Belt)
66. Pothunuru (Belt)
67. Gundugolanu (Belt)
68. Bhimadule (Belt)

APPENDIX II

Rainfall Normals (mm)				
Station / Month	Eluru	Chintalapudi	Nuzuid	Gudivada
January	5.8	6.9	7.9	6.6
February	10.7	9.4	9.9	9.1
March	11.9	11.4	17.5	12.2
April	17.8	27.4	19.3	25.4
May	39.4	51.6	49.0	47.7
June	114.3	142.5	115.8	112.3
July	202.7	254.0	223.5	187.5
August	186.9	223.5	12.4	166.4
September	186.7	174.5	170.7	145.8
October	150.4	116.8	138.7	160.8
November	37.7	50.3	67.1	89.9
December	3.8	5.3	4.1	6.9
Annual	1088.1	1073.6	1005.9	970.6

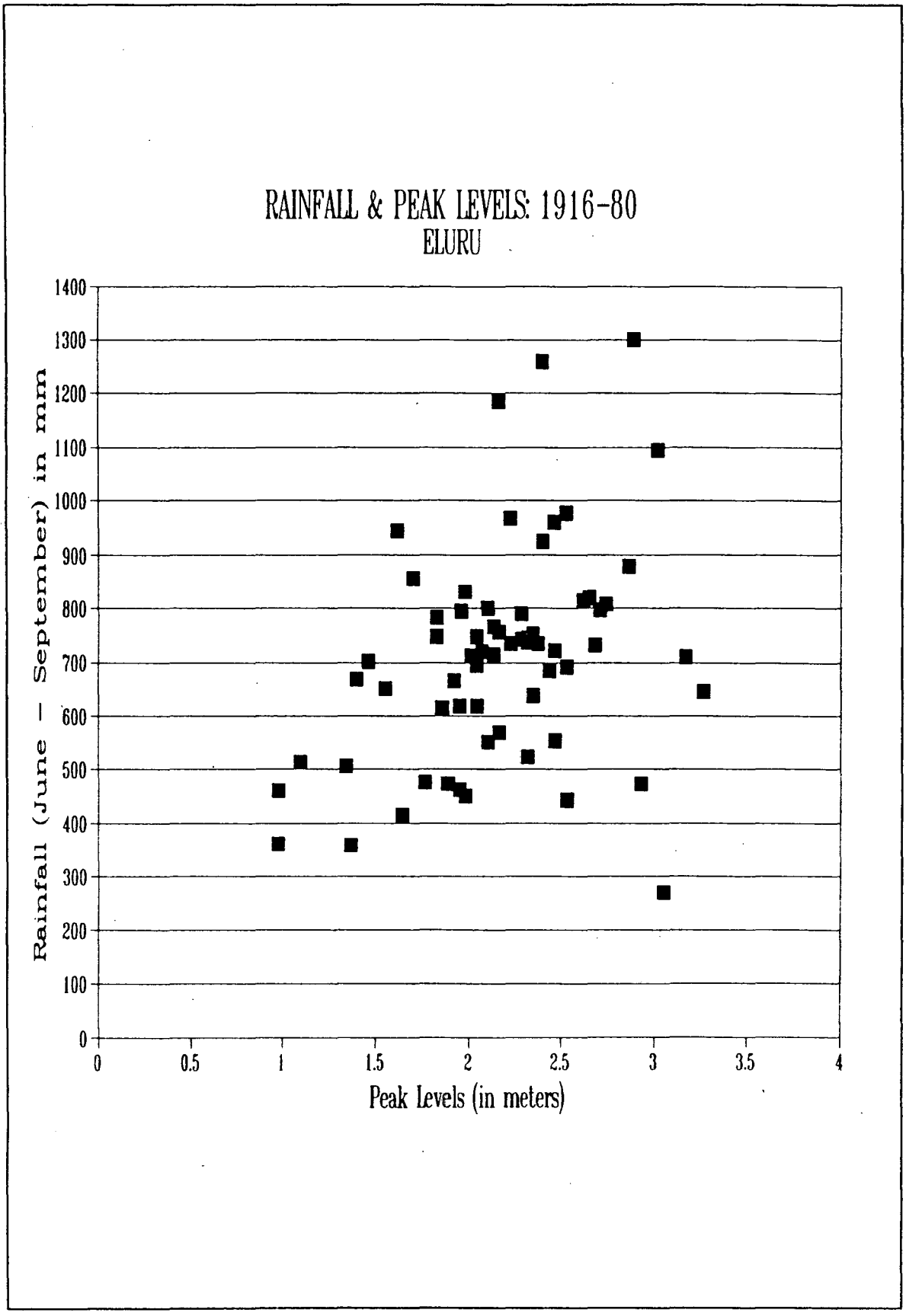

RAINFALL & PEAK LEVELS: 1916-80
ELURU
Rainfall (June - September) in mm
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Peak Levels (in meters)

Fig. 1

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