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Acknowledgement

This project was funded by Kerala Research Programme for Local Level Development (KRPLLD), Centre for Development Studies, Thiruvananthapuram. We are grateful to Dr. K. Narayanan Nair, Programme Coordinator, KRPLLD for sanctioning this project.

We are thankful to Dr. M.Baba, Director, Centre for Earth Science Studies for permission to take up this project and providing facilities to execute it. Dr. K.Soman, Head, Resources Analysis Division (RAD) is thanked for extending facilities. Smt. Mahamaya Chattopadhyay, Scientist, RAD was thanked for providing useful suggestions related to morphometric analysis. Dr.P.P. Ouseph, Head, Chemical Sciences Division (CSD) is thanked for extending laboratory facilities.

Sri. C.S. Satheesh Kumar and Sri. V. Raviendren, Project Fellows, CSD assisted in water sample collection and laboratory analysis. Smt. Asha, Y.A., Sri. Manu.M.Nair and Smt. Sreelekha, C., Project Fellows of RAD took part in GIS application. Sri. Sooraj. S, Assistant Geologist, Department of Mining and Geology helped during field work. Smt.Sudha. S attended to drafting of maps. Ms.Reema Rani, M.V. did the typographical job. Smt. A.Balkeez provided secretarial assistance. Services rendered by all of them are highly appreciated. Sri. P. Ramachandran Nair, Driver is thanked for help during field work.

A large number of local people assisted us during field survey. We take this opportunity to thank all of them for their services.

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Abbreviations

A	-	Arecanut
ANERT	-	Agency for Non-conventional Energy and Rural Technology
BOD	-	Biological Oxygen Demand
C	-	Coconut
Ca	-	Calcium
Car	-	Cardamom
CD Block	-	Community Development Block
Ch	-	Cashew
DO	-	Dissolved Oxygen
El	-	Elavu
FC	-	Faecal Coliforms
Fr	-	Fruits
KSLUB	-	Kerala State Landuse Board
GCA	-	Gross Cropped Area
GIS	-	Geographic Information System
Gi	-	Ginger
Gin	-	Gingelly
HYV	-	High Yield Variety
IGBP	-	International Geosphere Biosphere Programme
ITC	-	International Institute of Aerospace Survey and Earth Science
J	-	Jack
M	-	Mango
Mg	-	Magnesium
MT	-	Mixed Trees
N	-	Nutmeg
NO_2-N	-	Nitrite
NO_3-N	-	Nitrate
P	-	Paddy
Pe	-	Pepper
pH	-	Hydrogen ion concentration
Pin	-	Pineapple
Pl	-	Plantains
PO_4-P	-	Phosphate
PRA	-	Participatory Rural Appraisal
SMT	-	Settlement with Mixed Tree Crops
TCA	-	Total Cropped Area
TDS	-	Total Dissolved Solids
Te	-	Tea
TH	-	Total Hardness
TSS	-	Total Suspended Solids
Veg	-	Vegetables

Abstract

The Chalakudi river basin having an area of 1525 km^2 is an inter State river with 320 km^2 of area falling in the State of Tamil Nadu. There are six reservoirs, whose combined area is around 35 km^2. Average rainfall received by this basin is 3365 mm. Topography is dominantly undulated with 60% of the area lying above 15% slope category. Around 49% of the basinal area is covered by natural forest vegetation. The western part of the basin lying between Ernakulam and Trichur experiences considerable growth of population and consequent increase in built up areas. Population density of the basin was around 923 persons/km^2 according to 1991 census. Landuse/ land cover of this basin is undergoing changes at various levels both within the forest and non-forest areas.

This project was taken up to assess the extent of landscape change; environmental impact, particularly related to water quality of these changes; underlying factors contributing to these changes; future trend of change; and consequences of these changes. Four hypotheses were envisaged to provide the study frame and they were subsequently tested with analytical results.

Detailed analysis of the entire basin was taken up covering physiography, geology, hydrogeology, drainage, soil, climate, irrigation, landuse, agricultural landuse, population and work participation to provide an overall background of the study area. Five sample sites were chosen for detailed investigation based on this analysis. These sites were distributed in lowland, midland and highland segments and in forest areas. Paddy land was diverted to accommodate various other uses in all the segments. Area under paddy came down from 52% in 1966-67 to 21% in 2003 in the lowland segment. This change was from 40% in 1966-67 to 7.6% in 2003 in the segment covering Chalakudi town and surroundings. Changes in plantation crops and forest area were noticed in the highland segment fringing the forest area. Settlement with mixed tree crops were growing within the forest area.

Landscape change was in the form of clay mining, rock quarrying, terracing of land and filling up of lowlands. Areas of divergence (elevated part/ raised area) were increasing

at the expense of areas of convergence (low-lying area) in lowland segment. However, level of land went down due to clay mining and rock quarrying both in the lowland segment and midland segment.

Analyses of water quality in four seasons covering the entire stretch of the river from the reservoir to the confluence highlighted that the river stretch adjoining the urban area remained polluted throughout the year. River segment adjoining the industrial areas, prawn farms and fallow rice lands were also polluted in some season or other. River water and well water were graded for pollution level and correlation with landuse was established.

Perception of local people about landuse change, underlying causes and consequences had been documented through questionnaire survey and PRA. Main factors contributed to these changes as cited by local people were higher profit in other crops, labour shortage, land required for housing, low productivity of crop, disease and water shortage. People's perception about impact of landuse change varied depending on the respondent's proximity to the problem/ issue. Both land and water were found to be affected due to landuse/ land cover changes.

Trend of change and the consequences as brought out by this study are matters of concern for environmental resource management of this basin. Regulatory measures to arrive at proper landuse mix, waste management in the urban area micro watershed based conservation approach, integrated river basin management plan and a decentralised action programme were some of the activities recommended to ameliorate the situation.

CHAPTER 1
INTRODUCTION

1.1 Introduction

There has been an upsurge in concern about landscape change both at regional and global scale during last couple of decades. It is now well realized that one of the major factors affecting sustainability is change in the pattern and level of landscape, more particularly, landuse (Pulliam, 1995). Monitoring changes in overall patterns of landscape is essential. The IGBP (International Geosphere Biosphere Programme) emphasized on site specific case studies specially to address the question of human impact and environmental sustainability. This involves periodic assessment of changes in the amount, distribution, and size of different types of landuse/landscape units including both human created and natural and semi natural types. It is now well documented that with the increasing human activity the natural landscape is undergoing significant changes which in turn tend to affect societal well being. Conceiving these studies in a framework of assessment it will be possible to infer functional changes in the landscape, assuming that there is basic understanding of conditions and processes within the unit and an understanding of unit by unit interactions within a segment. Changes in physical processes are often related to human induced activities, which are subject to modification due to the changes in physical system. Historical change involving technological and cognitive adaptations, as well as hierarchical articulation of impacting forces, complicate specification of such impacts (Blaikie and Brookfield, 1987). Large scale aggregate data are not adequate either to understand the process or to influence decision makers at the ground level or operational level.

Landscape change always takes place at the micro level as the proximate causes and effects are inherently local, although the impact can be felt at the global level due to aggregate nature of the effects. The concept of extended or integrated environmental impact assessment was articulated to capture these aggregate effects. It is noted that, in spatial scale at which a phenomenon is examined, the importance of causal factors may change. One of the issues raised in this context is that there has been the tendency in analyses of global and regional landuse changes excluding from consideration certain types of social changes that are viewed as being only locally specific (Turner, 1999). This tendency has limited the scope of identifying societal origin of environmental problems and thereby importance of local level initiatives in reversing the trend is underestimated.

There is growing interest in incorporating human-environment theories in the landscape change research as it can contribute significantly in understanding the anthropocentric driving forces leading to the changes. Theoretical land-change studies exemplify this approach, employing various concepts and theories, such as the induced-intensification thesis to guide the development of their empirical models (Geoghagan et. al., 2001). However, there is a problem of integration as goal of land change studies is often to explain spatial patterns, because the practitioners come from different modeling traditions than those interested in agricultural change and because these studies are commonly restricted in terms of the kinds of data that can be incorporated into their models (Laney, 2001). The induced – intensification thesis incorporates behaviours of land managers, agro-ecological and socio-cultural conditions, and land-cover modifications. Multiple cover modification are central to global-change studies investigating the biogeochemical and biodiversity impacts of landscape change (Skole et al., 1994; Lambin et al., 1999).

The theoretical framework for landscape change analysis is given in Fig. 1.1. Factors involved in landscape change analysis ranges from social factors to policy issues. It may be noted that policy issues are often considered as macro factors governed externally, sometimes beyond the control of the locality.

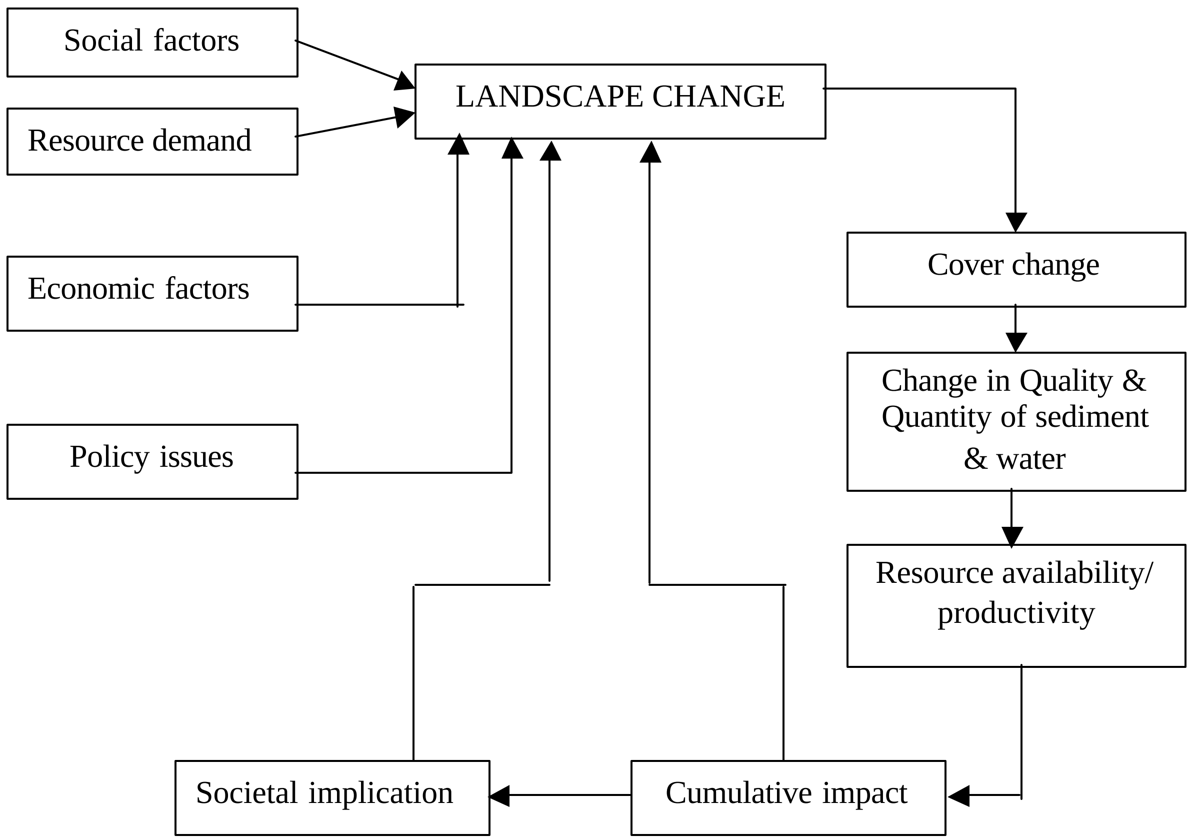

Fig. 1.1 FRAME WORK OF LANDSCAPE CHANGE ANALYSIS

This study was taken up in the Chalakudi basin. Five sample sites were selected for conducting in-depth analysis and to test various hypotheses spelt out for this study.

1.2 Objectives

The objectives of the project include:

1. to assess the extent of landscape change both spatial and temporal in past 30-40 years
2. to analyse environmental impact of these changes particularly related to water quality (ecological linkages)
3. to workout possible human induced factors/processes leading to these changes (socio-cultural-economic linkages)

4. to analyse future trend of change and
5. to bring out societal consequences of these changes

1.3 Hypothesis

The general hypothesis for landuse/land cover change may be spelt out in the equation given below:

LC = PS*DF*I

LC = Landscape/land use change

PS = Proximate source of ongoing human activities

DF = Demand factor consisting of population, consumption & economy

I = Institutional factors (policy, culture etc)

This relationship is not always linear and contributions of different factors are also not same. However this equation provides a comprehensive idea about the dynamics of landscape/ landuse change.

Disaggregating the landuse/land cover change scenario in terms of specific coverage, accounting for the major factors leading to the change and considering the consequences of these changes the following hypotheses are designed:

Hypothesis 1

Expansion of agriculture and related activities have contributed in reduction of natural forest.

(i) Expansion of forest plantation caused deforestation,

(ii) Expansion of plantation agriculture resulted in deforestation,

(iii) Construction of reservoirs also contributed in forest clearance.

Hypothesis 2

Population expansion and resulting pressure on residential landscape, industrial landscape, and infrastructure have induced conversion of agricultural land to non-agricultural purposes. This has led to

(i) Loss of prime agricultural land,
(ii) Shrinking of natural area like wetlands,
(iii) Utilisation of more and more marginal lands.

Hypothesis 3

Major ecological/environmental problems in lowland and midland area had cropped up due to land conversion. These are related to

(i) Deterioration of water quality,
(ii) Fall in water table,
(iii) Reduction in flood spread area (spill area).

Hypothesis 4

External as well as local issues contributed to the landscape/landuse change.

(i) Government policy particularly grow more food and promotion of certain crops had induced these changes,
(ii) Local issues like demand for land to accommodate non-agricultural activities, unfavourable out turn from crop cultivation, lack of irrigation and crop disease have contributed in landscape change.

1.4 Methodology and data source

Topographical maps (1:250,000, 1:50,000 and 1:25,000 scales), Airphoto (1:15,000 scale), and PAN images (1:25,000 scale) were used to generate landscape related information. The high resolution PAN images helped identify roads, settlements and landuse. Landuse and landscape changes were worked out by comparing time-series data since 1966-'67.

Information related to rainfall were collected from the Hydrology Section of Irrigation Department and Kerala State Electricity Board, Govt. of Kerala. Water samples were collected from the river and wells in various seasons and they were analysed for selected physico chemical and microbiological parameters in CESS laboratory.

Data on demography, socio-economic aspects and crop statistics were obtained from the office of the Registrar General, Department of Economics and Statistics, State Planning Board and Grama panchayats.

Questionnaire survey was conducted at the household level covering all five sample sites. Participatory Rural Appraisal (PRA) techniques were employed to generate data on societal consequences of landuse change to corroborate the findings from questionnaire survey. A series of thematic maps were prepared covering various items. Landuse change map had been worked out by overlaying the maps in GIS environment. Suitable graphs, charts and tables were prepared to support the findings.

The crop combination study had been carried out by the least squared deviation method proposed by Thomas (1963). It is the modified version of the method developed by Weaver (1954). It is purely a statistical method and takes into consideration percentages of crops to total cropped area.

1.5 Organisation of the Report

This report has been organised under seven chapters. Chapter-1 is the introductory part dealing with general introduction, objectives, methodology etc. Detailed description of the study area has been provided in the second chapter. Sample sites for in-depth analysis were selected based on this description. The third chapter presents landuse/ landcover change for each sample site. Environmental impacts are dealt in Chapter 4. The hypotheses spelt out in introductory chapter are tested and the results are given in Chapter 5. Local people's perception about landuse change and its consequences are discussed in Chapter 6 and the Chapter 7 presents conclusions.

CHAPTER 2
STUDY AREA AND ITS OVERALL CHARACTERISTICS

2.1 Introduction

The Chalakudi river basin has been taken up for this study. It covers an area of 1525 km^2 of which 320 km^2 fall in the neighbouring State of Tamil Nadu. Being an inter State river with rich water potential it has drawn considerable attention of water resource managers. There are six reservoirs, namely Sholai Ar I & II, Parambikulam, Thunnakadavu, Peruvaripulum and Poringalkuttu in this basin (Fig. 2.1). The Sholai Ar-I is in Tamil Nadu. This basin spreads over Palghat, Ernakulam and Trichur district covering 25 panchayats and 2 municipalities in Kerala. Some of the panchayats falls partly in this basin. However, for demographic and other secondary source data the entire panchayat has been taken up. Total area of these 25 panchayats and 2 municipalities is around 2000 km^2. Total population of the basin was 6.8 lakh in 1991. This section presents detailed description of the study area covering all aspects. Purpose of this section is to provide a detailed background of this basin with all its specialties and to elucide the logic of selecting sample sites.

2.2 Physiography

The Chalakudi river is a tributary of the Periyar although it is considered as a separate river in listing 44 rivers in Kerala. It joins the Periyar river around 30 km upstream from the coast or confluence point of Periyar with the Lakshadweep sea near Azhikkod. The Chalakudi river traverses all the physiographic units in the State. The Sholai Ar reservoir is above 600 metre altitude. Three other reservoirs namely Parambikulam, Tunnakadavu and Peruvarippalam are in the altitudinal range of 300 to 600 m. The Poringalkuttu reservoir is located below 300 m altitude. Relief map (Fig. 2.2) shows altitudinal distribution. Compared to the relief character of the State where 42% area lie above 100 m altitude this basin has larger area in >100 m category. All three zones, lowland, midland and highland are well developed. Variations in altitude have contributed to the diversity of landuse pattern, based on which the sample sites were selected.

2.3 Climate

Climate is the composite physical state of atmosphere at a specified locality for a specified interval of time (Landsberg, 1958). It is determined not only by a single weather element but by the combination of several of them operating simultaneously. Apart from the physical and biological aspects, issues like the number of rainy days, form and intensity of precipitation, temperature range, humidity and evapotranspiration also play significant roles (Subramanyam, 1980).

The climate data were collected from the Kerala State Electricity Board (KSEB) at Thiruvananthapuram and Hydrology Department at Thrissur. A brief description of each parameter is given below.

2.3.1 Rainfall

Rainfall data were collected from Kerala State Electricity Board and Hydrology section of Public Works Department, Govt. of Kerala. There are 31 rainfall stations distributed throughout the basin.

The monthly average of rainfall for all 31 stations are provided in Table 2.1. The average rainfall for the basin as a whole is 3365 mm. It can be discerned from the Table 2.1 that bulk of the rainfall precipitates during the south-west monsoon period. Rainfall in other periods is considerably less compared to the south-west monsoon period. The maximum rainfall is received during the month of June (basin average – 772 mm). Southwest monsoon spreads over the months of June, July, August and September. Around 72% of annual rainfall is received during this season. Northeast monsoon commences from October to December, when this basin receives about 17% of annual rainfall. The period extending from January to April is the pre-monsoon season during

Table 2.1 MONTHLY AVERAGE RAINFALL (MM) (1980-2002), CHALAKUDI RIVER BASIN

Sl. No.	Station	June	July	August	September	October	November	December	January	February	March	April	May	Total
1	Potta	725.00	678.00	457.00	190.00	259.00	123.00	53.00	18.00	4.00	14.00	86.00	155.00	2762.00
2	Chalakudi	734.00	676.00	461.00	309.00	325.00	127.00	58.00	45.00	8.00	13.00	118.00	174.00	3048.00
3	Thumburmuzhi	782.00	769.00	583.00	331.00	375.00	178.00	82.00	209.00	25.00	50.00	153.00	229.00	3766.00
4	Vettilampara	763.00	790.00	636.00	267.00	366.00	137.00	65.00	24.00	29.00	39.00	159.00	230.00	3505.00
5	Kannankuzhy	938.09	878.45	620.15	367.05	393.15	184.92	63.85	40.90	39.27	68.88	170.92	251.52	4017.15
6	Poringalkuttu	855.00	921.00	658.00	348.00	319.00	125.00	61.00	36.00	22.00	36.00	112.00	188.00	3681.00
7	Meerafloor	242.00	426.00	200.00	384.00	114.00	38.00	7.00	83.00	12.00	15.00	69.00	33.00	1623.00
8	Manalaroo	794.00	798.00	623.00	212.00	200.00	121.00	40.00	5.00	23.00	28.00	63.00	93.00	3000.00
9	Karapara Estate	1005.00	1135.00	770.00	303.00	297.00	101.00	51.00	10.00	12.00	38.00	131.00	154.00	4007.00
10	Chandramalai Estate	942.64	1041.30	1561.34	203.95	442.66	171.31	24.04	60.13	43.00	46.06	55.18	101.49	4693.10
11	Meenampara	634.64	747.90	589.73	150.18	203.91	159.09	45.89	77.00	32.00	21.00	58.40	94.45	2814.19
12	Thunakkadav	316.00	316.00	221.00	111.00	157.00	116.00	31.00	14.00	17.00	30.00	79.00	94.00	1502.00
13	Peruvaripalam	316.00	316.00	214.00	127.00	127.00	128.00	33.00	28.00	14.00	34.00	78.00	113.00	1528.00
14	Parambikulam	410.00	422.00	286.00	157.00	202.00	108.00	33.00	16.00	26.00	42.00	103.00	128.00	1933.00
15	Sholayar dam	976.00	985.00	776.00	465.00	323.00	134.00	45.00	45.00	30.00	53.00	111.00	192.00	4135.00
16	Sholayar P.H.	902.00	961.00	61.00	472.00	348.00	143.00	55.00	62.00	38.00	58.00	145.00	198.00	3443.00
17	Sugam	487.75	395.05	261.35	220.30	1357.00	1842.00	15.90	-	-	39.20	24.00	103.40	4745.95
18	Pannimedu	1166.48	1077.93	1436.25	393.14	392.54	154.33	54.58	42.75	29.85	57.88	122.63	163.31	5091.67
19	Lower Shikelmudi	946.45	786.05	606.06	309.55	296.65	151.39	58.92	40.78	294.00	44.56	102.71	151.29	3788.41
20	Malakkapara	993.21	1099.85	792.55	408.67	322.79	135.49	49.68	36.05	47.64	38.44	118.22	300.89	4343.48
21	Sholayar Nagar	1374.43	1148.29	1001.29	509.14	348.71	179.71	77.33	61.25	30.75	64.86	106.57	140.00	5042.33
22	Thellickel	412.57	371.70	289.27	141.71	157.10	155.60	42.27	27.06	20.80	29.19	91.05	86.66	1824.98
23	Shkkelmudy	858.00	785.97	605.48	313.19	287.46	134.80	64.76	27.86	36.96	53.97	106.48	121.50	3396.43
24	Monicia	913.15	930.78	668.32	373.62	287.02	154.76	55.00	31.19	32.89	62.83	171.99	11.00	3692.55
25	Sholayar Estate	846.44	657.16	600.12	298.37	232.20	147.53	416.50	85.06	36.28	91.50	125.16	132.43	3668.75
26	Karamala	637.33	626.16	458.33	251.22	198.41	125.88	58.44	18.61	13.08	39.53	89.47	137.77	2654.23
27	Nallachathu	744.86	653.71	580.52	252.70	243.45	163.72	64.48	35.29	39.67	71.54	152.43	147.56	3149.93
28	Palagupadi Estate	551.20	461.20	503.80	59.00	194.60	83.20	112.00	132.00	57.00	46.00	26.67	88.00	2314.67
29	Mudies Group	892.10	863.52	642.75	343.79	227.03	173.85	44.43	33.53	30.18	57.30	139.95	159.64	3608.07
30	Nadur	805.33	788.15	599.12	307.79	255.78	160.05	79.84	59.60	35.88	147.80	136.40	165.28	3541.02
31	Sirigundra	974.73	888.15	627.50	361.21	321.13	226.95	49.34	80.98	59.75	68.98	139.22	193.82	3991.76
	Average	**772.24**	**754.85**	**593.22**	**288.41**	**308.83**	**196.24**	**64.23**	**47.90**	**36.74**	**48.37**	**107.89**	**146.16**	**3365.08**

which the basin receives comparatively less rainfall (11%). Spatial distribution of rainfall shows that annual rainfall varies from 1502 mm in Thunakkadavu to 5092 mm in Pannimedu. Sholai Ar nagar is another place where annual average rainfall is more than 5000 mm. Correlating to rainfall data with physiography it may be observed that rainfall increases from the west to east upto foothill zone and thereafter it decreases further east over the high altitude region. Fig. 2.3 brings out this relation clearly.

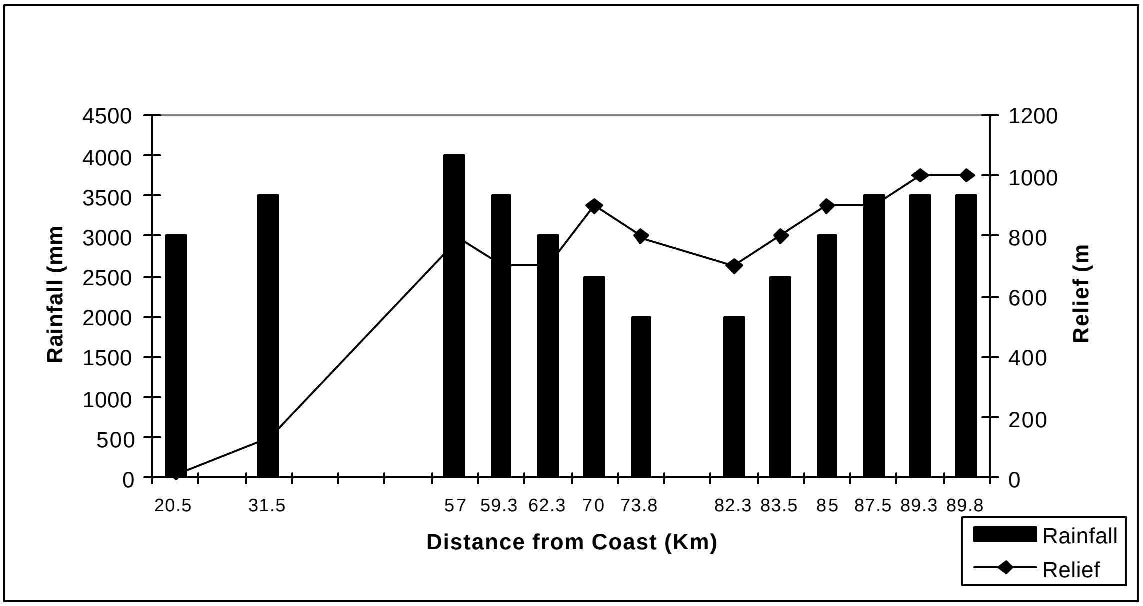

Fig. 2.3 RAINFALL – ALTITUDE RELATIONSHIP

Orographic impact on rainfall distribution pattern is well evident. There is not a single month without shower. This contributes to the high water yield of the basin.

Ombrothermic diagrams (Figs. 2.4, 2.5 and 2.6) have been prepared by combining the average monthly rainfall and temperature for selected stations (Kannankuzhy, Thellickel and Karapara) to show the wet and dry months. The figures bring out that in all the three stations the highest peak of monsoon is during the months of June and July. But the wet condition prevails in the basin from March onwards.

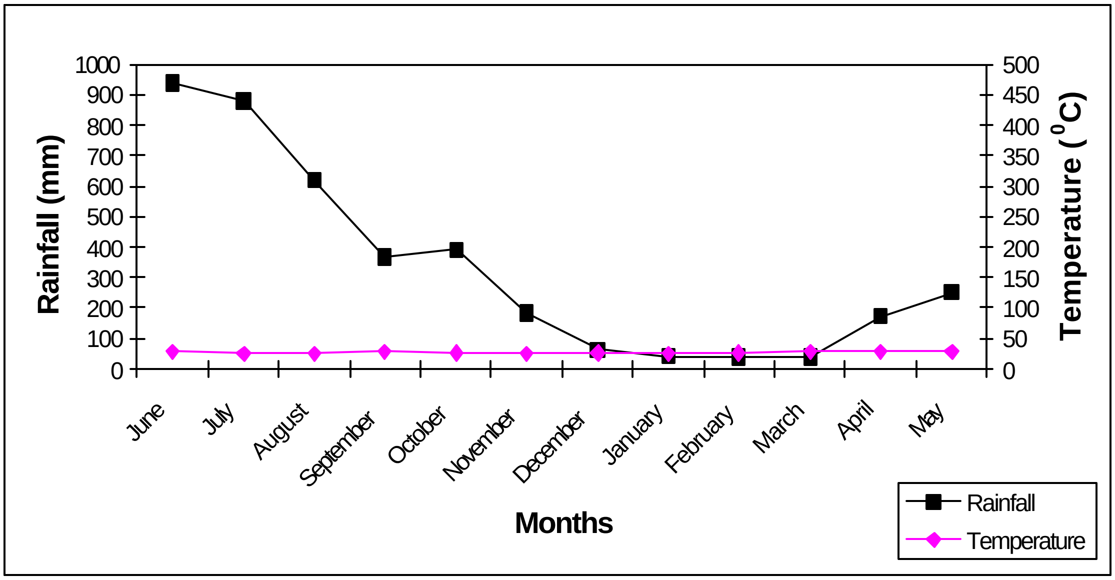

Fig. 2.4 OMBROTHERMIC DIAGRAM – KANNANKUZHI

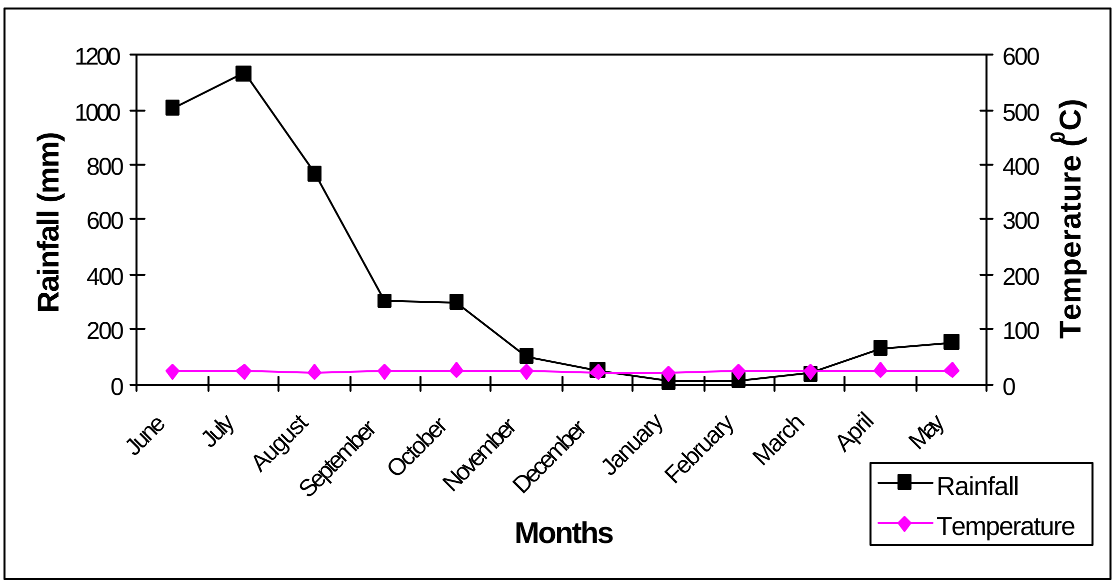

Fig. 2.5 OMBROTHERMIC DIAGRAM – KARAPARA

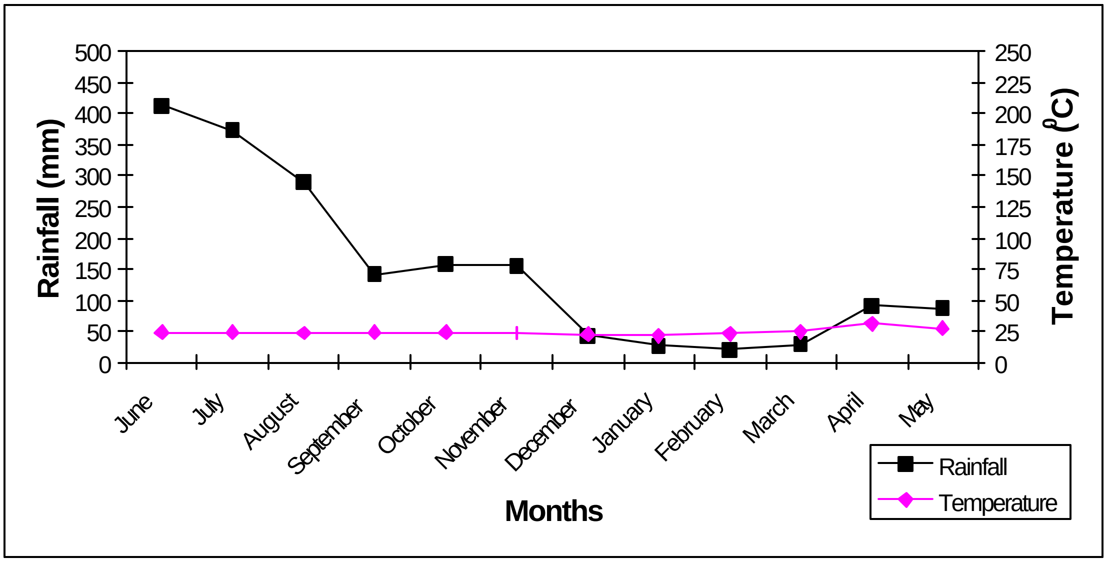

Fig. 2.6 OMBROTHERMIC DIAGRAM – THELLICKEL

2.3.2 Temperature

According to Thornthwait's classification, Kerala belongs to the 'Pe Humid Province'. The mean monthly temperature varies between a maximum value of 38.65^{0}C during the month of April and a minimum of 13.12^{0}C during January. The maximum and minimum temperature reach their peaks during summer/ premonsoon period. March and April are normally the hottest months. The maximum temperature in the basin is recorded in the months of March and April. The lowest minimum temperature (16.1^{0}C) is experienced at Karapara, a high elevated area. The plantation crops like tea, coffee, cardamom and orange grown in this area indirectly indicate cold humid condition due to high altitude. Monthly maximum and minimum temperature values for three selected stations of the basin are presented in the Table 2.2.

2.3.3 Relative Humidity

The humidity data for selected three stations are presented in the Table 2.3. It reveals that the basin remains highly humid throughout the year. However during the southwest monsoon relative humidity is slightly high compared to the rest of the years.

2.3.4 Evapotranspiration

The water balance studies of the Kerala State have shown that there is a well defined period of moisture stress ranging from 14 to 21 weeks in various parts of the State. The details of evapotranspiration data available for two stations are given in Table 2.4.

The premonsoon period is characterised by high stress during the months of January, February, March and April. Low stress period spreads over the monsoon months and it becomes relatively low in the months of June and July. The highest value of evapotranspiration recorded is 155 mm in the month of March.

2.4 Geology

Geologically the area is occupied by the rock formations belonging to the Archean age group (GSI, 1981). The dominant rock type of the study area is charnockite. The western part of the study area is mainly composed of biotite gneiss. The central part is occupied mainly by charnockites. The major rock type in the eastern part is hornblende-biotite gneiss. Other rock formations in the area include pink granite, dolerite, quatzofeldspathic gneiss, garnet-biotite gneiss and quartz syenite. The Chalakudi river is a structurally controlled basin. Lineaments control higher order drainage pattern. Tributaries of Chalakudi river (4^{th} order onwards) and the main river itself follow lineaments. The river flows in east-west direction upto Kadukutty from where it takes a southward direction and confluence with the Periyar river. This change in direction within the alluvial stretch in all probability indicates structural control.

2.5 Geomorphology

Geomorphologically the study area exhibits wide variations. Two third portion of the basin is under hilly area. The main processes operative in the basin are structural-denudational and fluvial.

Table 2.2 MONTHLY AVERAGE TEMPERATURE (^{0}C) (1982-'83) TO 1987-'88), CHALAKUDI RIVER BASIN

Station	June		July		August		September		October		November		December		January		February		March		April		May	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Kannankuzhy	28.33	27.40	27.40	23.54	28.33	23.43	29.60	25.14	29.78	22.74	29.49	21.16	31.29	21.83	31.41	19.90	32.68	20.92	33.45	22.55	32.26	23.47	32.10	24.34
Karapara	24.54	21.43	24.67	20.09	24.40	19.87	25.79	20.05	27.29	20.66	27.34	18.85	26.68	17.82	22.37	16.13	28.17	17.11	30.37	16.46	28.88	19.76	28.91	21.42
Thellickel	28.12	19.74	27.87	20.36	27.25	19.80	28.97	18.74	30.33	17.68	27.42	19.33	29.31	16.00	29.75	13.12	31.89	14.08	33.01	16.71	38.65	23.00	33.32	21.17

Table 2.3 MONTHLY AVERAGE HUMIDITY (%) (1982-'83 TO 1987-'88), CHALAKUDI RIVER BASIN

Station	June		July		August		September		October		November		December		January		February		March		April		May	
	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.	8 hrs.	12 hrs.
Kannankuzhy	89.88	84.19	89.58	85.31	90.35	85.00	87.99	81.68	88.58	80.15	85.63	77.79	82.17	77.03	79.04	64.05	81.11	66.79	81.90	69.29	80.99	72.09	84.00	73.84
Karapara	81.08	82.45	75.55	81.55	80.65	82.33	80.87	81.08	79.78	80.84	66.86	81.83	76.48	81.41	78.78	80.73	76.33	78.53	73.37	76.90	77.04	81.74	81.37	80.50
Thellickel	91.06	89.17	92.06	86.68	90.74	91.65	91.83	91.51	91.40	90.79	90.99	91.46	91.51	86.65	89.26	91.84	91.09	91.54	90.44	91.84	91.56	92.97	91.98	92.06

Table 2.4 MONTHLY AVERAGE EVAPOTRANSPIRATION (MM) (1980-'81 TO 1987-'88), CHALAKUDI RIVER BASIN

Station	June	July	August	September	October	November	December	January	February	March	April	May
Kannankuzhy	65.80	69.73	76.13	96.88	85.28	83.08	100.30	117.72	129.08	155.12	131.58	115.06
Thellickel	64.37	60.68	67.04	68.56	73.54	70.88	67.33	87.56	99.44	116.00	111.88	85.31

The structural hills are found in the eastern part of the basin. Abrupt rise in altitude and near level plain along foothills indicate influence of geological structure on topography. Shifting of river course and channel orientation noticed in fluvial terrain can be attributed to structural control. Ridges and valleys were demarcated and different slope classes were identified. The high ranges in the eastern part of the catchment are characterised by rugged, steeply sloping terrain, with narrow ridges. Brief description of each unit is provided here. Geomorphological units, their area coverage and characteristics are given in the Table 2.5.

Escarpment (S_7) are characterised by near vertical slope with bare rock feature. It covers about 7 sq.km of the total basinal area, which is about 0.5 % of the total area. Escarpments are distributed in the northern part of Tamil Nadu Sholayar reservoir. A long escarpment located at the north-eastern part of Parambikulam reservoir is observed at Perumkundru Malai at an elevation of 1733m. Southeastern parts of Parambikulam reservoir also show escarpments in fragments. Another big patch is located in the south western part of Parambikulam reservoir. Steep scarps are found in Vazhachal water fall. The scarp slopes bordering the mountains are morphostructural feature.

Very Steep Slope (S_6) occupies about 5 % of the total basin. Area falling under this category of slope is observed on the extreme eastern part of the basin. An isolated patch is observed in south of Tamil Nadu-Sholayar reservoir at Sholayar Mala. The northern tip of the basin is also characterised by this type of slope category.

Steep Slope (S_5) cover about 13% of the total area. It is mainly observed in the surrounding areas of Parambikulam reservoir except the western part. Isolated patches of this category are found to be distributed within the moderately steep slopes to the extreme eastern part of the basin. Northern, eastern and western part of Porigalkuttu reservoir are characterised by this slope category. An isolated patch is observed in the midland region to the north of Kodasseri.

Table 2.5 GEOMORPHOLOGIC UNITS AND THEIR AREAL EXTENT, CHALAKUDI RIVER BASIN

Process	Unit	Mapping symbol	Areal Extent		Principal Characteristics/ landuse/ land cover
			(Km^2)	(%)	
Denudational/ Structural	Escarpment	S7	7.19	0.46	Near vertical slope with bare rock faces
	Very Steep Slope (>55 %)	S6	77.79	5.11	Tea, coffee plantation and forest
	Steep Slope (38-55 %)	S5	192.58	12.63	Mainly forest. Eucalyptus and softwood plantation
	Moderately Steep Slope (25-38 %)	S4	394.61	25.87	Mainly forested area
	Moderate Slope (15-25 %)	S3	300.95	19.73	Teak and eucalyptus plantation
	Gently Moderate Slope (5-15%)	S2	162.85	10.68	Rubber and teak plantations Midland area
	Gentle Slope (<5 %)	S1	119.97	7.87	Lowland and midland segment. Bounding slope of Valleys and floodplains, Settlement with mixed tree crops.
	Residual Hill	R	1.09	0.07	Lithological/ structural in origin, altitudinal variation from 20 m to 80 m. stone quarries observed here.
	Ridge crest	T	47.31	3.10	Flat topped in midland, narrow in hilly region. Roads follow ridgeline in midland and lowland regions.
Fluvial	Flood plain/valley	V	154.63	10.14	Flat bottomed, mainly used for agricultural practices especially paddy
	Levee		16.38	1.07	Result of fluvial process, relatively higher than back swamps, settlement with mixed tree crops prominent here.
	Sedimented portion of reservoir		0.85	0.06	Peripheral sedimental part only
	Reservoir		33.59	2.20	Six reservoirs
	Water body		15.40	1.01	Other than reservoirs

Moderately Steep Slope (S_4) occupies 26% of the total area of the basin. This is the major slope category observed in the entire basin. In some places it is the continuation of steep and very steep slope, but it is also found in association with gently moderate slope.

Moderate Slope (S_3) occupies around 20% of the total area of the basin. A large patch of land under this slope category is found in the southern and eastern part of the Tamil Nadu Sholayar reservoir. This area is part of the plateau landscape.

Gently Moderate Slope (S_2) starts from eastern part of Varigaliar. It occupies about 11 % of the total area of the basin. A large patch of this slope category is observed in western part of Tunnakadavu reservoir and Parambikulam reservoir with isolated patches of moderately steep slope. The southwestern part of Poringalkuttu reservoir is also characterised by this slope category. An isolated patch of gently moderate slope is observed in the lowland near Pichanikad and Mampra area.

Gentle Slope (S_1) occupies around 8 % of the total area of the basin. It starts from Kanjirapally, eastern part of Chalakudi town. This slope category surrounds the valleys and backswamps. Land, around confluence of the Chalakudi with the Periyar is characterised by slope of <5%.

Residual hills (R) or isolated hills mostly with elevation of 20-40 m are observed in the midland and lowland area of the basin with gentle slopes. This unit occupies about 0.1% of the total area of the basin.

Ridge (T) occupies about 3 % of the total area. They are narrow and elongated in the eastern part of the basin with NE-SW orientation. The ridges are found to be in E-W direction in the northern and western part of the Poringalkuttu reservoir. In the midland region, the ridges are flat topped primarily covered by laterites.

Flood Plain/valley (V) occupies about 10% of the total basin. It has developed in the lower course of the river. Back swamps are observed near the confluence of Periyar and Chalakudi. Gentle side slopes bound these valleys. Levee formation is observed after Kanjirapalli. It occupies about 1% of the total area of the basin.

2.6 Terrain

Slope was the principal criteria to classify land as presented under geomorphology section in the foregoing discussion. In order to have a comprehensive land classification the approach of terrain analysis has been followed (Fig. 2.7). It takes into account of all geomorphic characteristics in addition to landuse and environmental characteristics (Table 2.6). The method used here follows the classification scheme developed by Chattopadhyay & Chattopadhyay (1995) based on ITC scheme of terrain classification (Vanzuidam, 1983).

2.7 Hydrogeomorphology

Study on hydrogeomorphology is necessary to understand the condition of groundwater, which is a dynamic and replenishable natural resource but in hardrock terrain and in hilly areas, where slope stability problem are conspicuous in nature, there groundwater is of limited extent and its occurrence is essentially confined to fractural and weathered zones (Saraf and Choudhary, 1998).

The hydrogeomorphological condition of an area depends upon geology, terrain, nature of over burden and lineament distribution. Valley fills are potential sites of high groundwater reserve.

Terrain features determined by slope, relief, dissection index, drainage density, soil cover and landuse are various indicators governing the groundwater potential of the area. Generally lateritic terrain, transitional zones, low-rolling terrain and valley fills are potential zones of groundwater. Potential aquifer may occur in hard rock terrain with weathered zones a top. Groundwater potential is poor due to slope stability problems in the hilly areas and scarp slopes. The details of hydrogeomorphological characteristics are given in Table 2.7.

Table 2.6 TERRAIN UNITS AND THEIR CHARACTERISTICS, CHALAKUDI RIVER BASIN

Unit name	Symbol	Slope (%)	Dissection	Relative relief (m)	Broad soil type	Landuse	Environmental evaluation	Area	
								sq. km.	%
Transitional plain	P	<10	N	<20	A,S,Co,L	3a, 3b, 7	Clay-laterite interface	93.27	6.12
Low rolling terrain	D_1	<15	L	>20	L,A	3a, 3b, 7	Crop diversion, localised erosion	249.26	16.34
Moderately undulating terrain	D_2	<25	M	<40	L	3a, 3b, 7, 4a	Erosion in places, stagnant productivity	42.33	2.78
Highly undulating terrain	D_3	<35	H	>100	L, Re	3b, 7, 4a	Deforested and erosion affected landslides	200.56	13.15
Hilly area	D_4	>35	H	>300	Re, V	4a, 5a, 5b, 5c	Deforested and erosion affected	927.99	60.85
Scarp slope	D_6	>100	H	>300	Re, R, V	5a, 5c	Landslide, erosion affected	8.51	0.56
Floodplain	F_1	<05	N	<20	A	2a, 7	Narrow, discontinuous, water logging during monsoon, partly reclaimed	3.08	0.20

Dissection: N-Non dissected, L-Low dissected, M-Moderately dissected, H-Highly dissected,
Soil type: A-Alluvium, L-Laterite, Re-Residum, R-Rock, V-Variable shallow soil
S-Sand, Co-Colluvium
Landuse: 2a-Seasonal crop, 3a-Tree crops mainly coconut, 3b-Mixed tree crops, 4a-Plantation of tea, coffee & cardamom,
5a-Forest, 5b-Forest plantation, 5c-grass, 7-settlement

Table 2.7 HYDROGEOMORPHOLOGIC FEATURES OF THE CHALAKUDI RIVER BASIN

Map Annotation	Unit name	Geology	Groundwater potential	Remarks
PB	Transitional phase	Hb-Biotite gneiss	Moderate-good	Top weathered zone forms potential aquifer Fracture/ lineament zones from potential bore well sites. Massive rocks have poor yields. The thick overburden soil is good for dug wells.
PL	Transitional phase	Laterite	Good	Dug wells perform well in this area. good recharge due to its topographical disposition
D_1L	Low rolling terrain	Laterite	Good	Dug wells perform well in this area. Good recharge due to its topographical disposition. Quality of the water needs to be ascertained
D_1B	Low rolling terrain	Biotite gneiss	Moderate to good	Weathered zone forms potential aquifer. Fractured rocks good sites of r bore wells.
D_1C	Low rolling terrain	Charnockite gneiss	Good to moderate	Dug cum bore wells are likely to yield more. Weathered zones form good aquifer
D_2L	Moderately undulating terrain	Laterite	Good to moderate	Dug wells perform well. Wells sustain if proper groundwater recharge measures are taken
D_2C	Moderately undulating terrain	Charnockite gneiss	Moderate	Ground water recharge measures to be adopted for dug wells for sustainability
D_3C	Highly undulating terrain	Charnockite gneiss	Moderate to good	Run-off zone – good in lineaments and fracture. GWR where slope permits
D_3P	Highly undulating terrain	Pink granite	Moderate to poor	Run-off zone – good in lineaments and fracture- GWR where slope permits
D_4H	Highly undulating terrain	Hornblende-biotite gneiss	Moderate to poor	Run-off zone – Search for lineaments/ fracture-GWR where slope permits
D_4C	Hilly area	Charnockite gneiss	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problem
D_4P	Hilly area	Pink granite	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problem
D_4H	Hilly area	Hornblende-biotite gneiss	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problems
D_6P	Scarp slope	Pink granite	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problems
D_6H	Scarp slope	Hornblende-biotite gneiss	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problems
D_6C	Scarp slope	Charnockite gneiss	Poor	Run-off zone – GWR is not possible/ advisable due to slope stability problems

P, D1-D6 – Terrain units
B, L, C – Rock components
GWR – Groundwater recharge

2.8 Morpho-conservation

Study on morpho conservation is intended to help identifying areas warranting conservational measures. Apart from the engineering properties of rocks, landscape fragility depend upon the slope steepness and slope stability. Since slope steepness is a matter of prime importance for the type and rate of erosion and mass movement, emphasis has been given on slope classification. Study on morpho conservation has been done in 1:250,000 scale.

There are five slope classes in addition to the terrain unit of isolated/ elongated hills. Information like straight slope, irregular slope, distinct convexity of slope, escarpments, slope direction, area of potential erosion and mass movement are gathered. The slope classes and area under each slope class are given in the Table 2.8.

Table 2.8 AREA DISTRIBUTION UNDER EACH SLOPE CLASS, CHALAKUDI RIVER BASIN

Slope	Class %	Area	
		Sq. km.	%
S_1	<05	13.57	0.85
S_2	05-15	44.11	2.89
S_3	15-25	173.10	11.35
S_4	25-35	405.32	26.58
S_5	>35	819.69	53.75
D_5-S_5		33.60	2.20
Reservoirs		35.61	2.34
Total		**1525.00**	**100.00**

The northeastern part of the Poringalkuttu Reservoir is an area of potential erosion and mass movements. The northern part of the Tekkadi reserved forests is also an area of potential erosion and mass movements. About 53.75% of the total area of the basin comes under the slope class S_5 (slope %- >35).

2.9 Drainage

Drainage basin analysis provides the foundation for understanding a geohydrological system in quantitative terms. The Chalakudi river basin with an area of 1525 Sq. Km. is an important drainage system of Kerala. It drains part of the central Kerala. The basin is elongated in shape. It is formed by the confluence of five major streams, viz. Parambikulam, Kuriarkutty, Sholayar, Karapara and Anakayam. Kannankuzhy thodu, a fifth order stream joins the main river at the downstream (Fig. 2.8). The river originates from the Westernghats at an elevation of 2380 m above mean sea level. The slope is steeper in the upper course of the river giving it a greater velocity and energy for erosional activity. The main river is 143 km long. Basin parameters of this VII order stream have been computed (Tables 2.9 and 2.10). The average drainage density for the whole basin is 2.07 km/sq.km. It is important to note that six reservoirs have been impounded arresting all the main tributaries. These reservoirs act as the local base level. The drainage pattern is dendritic in nature. The water fall at Athirappalli at an elevation of 100 m perhaps indicates a knick point. This site is being investigated for its potential for generating hydroelectricity. The stream meanders prominently throughout its course. In the youth and mature stage it is mainly due to variation in the slope and also structure and in the old stage it is due to deposition within the channel bed. Shoals are found in various stretches of the river, which can be attributed to the construction of the reservoirs arresting regular river flow.

The shape of the basin and drainage pattern indicates that Chalakudi differs considerably from the adjoining basins. It is also one of the basins, which has high water resource potential.

Table 2.9 MORPHOMETRIC PARAMETERS, CHALAKUDI RIVER BASIN

Stream order	No. of segments	Bifurcation ratio	Length (Km)	Average length (km)	Area (Km^2)	Drainage density (Km/Km^2)
1	3275		1904.97	0.58	-	
		4.32				
2	758		570.02	0.75	728.01	
		4.49				
3	169		283.34	1.68	667.47	
		4.57				
4	37		194.99	5.27	09.790	2.07
		6.17				
5	6		68.21	11.37	38.821	
		3.00				
6	2		48.39	24.20	791.59	
		2.00				
7	1		83.62	83.62	1525.00	

Table 2.10 SOME OBSERVATIONS ABOUT MORPHOMETRIC ANOMALY, CHALAKUDI RIVER BASIN

Stream Order	No. of Segments	Remarks
7	1	
6	2	
5	6	2 V order directly join the VII order
4	37	8 IV order directly join the VII order and 3 directly join the VI order. There are 26 IV order streams under V order. 12 are making V orders and 14 are independent within the V order basin
3	169	19 III order directly join the VII order, 17 directly join VI order, 28 directly join V order, 74 III order make IV orders and 31 are independent III order streams within the IV order basin
2	758	54 II order directly join VII order, 34 directly join VI order, 60 directly join V order, 134 directly join IV order and 138 independent II orders are within the III order basin. 338 II orders make III order.
1	3275	There are number of I order streams directly joining all the higher orders. 1516 I order streams make II orders.

2.10 Soil

Soil formation has been influenced mainly by climate, geology, relief and other biotic interactions. There are 38 soil types demarcated in the State (KSLUB, 1995). This basin exhibits as many as 12 soil types. These are : $K0_5$, $K0_7$, $K0_9$, $K0_{11}$, K_{28}, $K0_{30}$, $K0_{31}$, $K0_{32}$, $K0_{33}$, $K0_{35}$, $K0_{36}$, K_{38}. Description of soil types and area under each category are given in Table 2.11.

The soils in the western part of the basin is well drained gravelly clay type. Very deep, well drained, gravelly clay soils on gently sloping coastal laterites with moderate erosion are found. Near the confluence of Periyar and Chalakudi river and its upper parts. Adjacent to this part very deep, gravelly clay soils on gently sloping midland laterites with moderate erosion are seen. Forest area is mainly occupied by clayey soils on moderately steeply sloping high hills with moderate erosion associated with gravelly loam soils on gentle slopes. In the central portion of the basin the major type is loamy soils and some portions are occupied by gravelly clay soils associated with rock out crops.

Table 2.11 SOIL TYPES AND THEIR DESCRIPTION, CHALAKUDI RIVER BASIN

Soil type	Description	Major soils	Inclusions	Area (sq. km.)
$K0_5$	Very deep, imperfectly drained, clayey soils with shallow water table on level lands with valleys, with slight erosion	Fine, mixed, typic dystropepts	Fine, mixed, typic dystropepts	10.36
$K0_7$	Very deep, well drained, gravelly clay soils on gently sloping coastal laterites, with moderate erosion, associated with very deep, well drained, gravelly clay soils with moderate surface gravelliness	Clayey skeletal, kaolinitic, typic kandiustults	Loamy-skeletal, mixed ustoxic dystropepts	142.38
$K0_9$	Very deep, well drained, gravelly clay soils with moderate surface gravelliness on moderately steeply sloping laterite mounds, with moderate erosion; associated with deep, well drained, gravelly clay soils on gentle slopes	Clayey skeletal, kaolinitic, oxic humitropepts	Clayey skeletal, kaolinitic, ustic kandihumults	4.47
K_{11}	Very deep, well drained, gravelly clay soils on gently sloping midland laterites and valleys, with moderate erosion; associated with deep, well drained, clayey soils with coherent material at 100 to 150 cm on gentle slopes	Clayey, kaolinitic, ustic kandihumults	Clayey skeletal, kaolinitic, oxic humitropepts	149.22

Contd……

K_{28}	Moderately deep, well drained, moderately calcareous, gravelly loam soils with moderate surface gravelliness on gently sloping foothills and valleys, with moderate erosion; associated with moderately shallow, some what excessively drained, gravelly clay soils with strong surface gravelliness and coherent material at 50 to 75 cm on moderate slopes, severely eroded	Loamy-skeletal, mixed typic ustropets Clayey skeletal, mixed typic ustropets	Loamy-skeletal, mixed lithic ustorthents	10.50
K_{30}	Very deep, well drained, clayey soils on moderately sloping high hills with thick vegetation, with moderate erosion; associated with deep, well drained, gravelly clay soils with moderate surface gravelliness on moderately steep slopes	Clayey, mixed ustic palehumlts Clayey-skeletal, mixed, ustic haple humults	Clayey-skeletal, mixed, ustic humitropepls	3.50
K_{31}	Very deep, well drained, gravelly loam soils on steeply sloping medium hills with thick vegetation, with moderate erosion; associated with very deep, well drained, clayey soils on moderate slopes	Fine-loamy, mixed, ustic humitropepts	Rock land	148.38
K_{32}	Deep, well drained, loamy soils on gently sloping low hills with isolated hillocks, with moderate erosion; associated with deep, well drained, loamy soils with coherent material at 100 to 150 cm on moderate slopes, severely eroded	Fine-loamy, mixed ustic humitropepts Fine-loamy, mixed ustic humitropepts	Fine, mixed ustic humtropepts Clayey-skeletal, mixed, ustic humtropepts	53.94
K_{33}	Deep, well drained, gravelly clay soils on moderately sloping medium hills with thin vegetation, with severe erosion; associated with rock out crops	Fine, kaolinitic, one humitropepts	Fine-loamy, mixed ustic palehumults	210.52
K_{35}	Deep, well drained, gravelly clay soils with coherent material at 100 to 150 cm on moderately sloping isolated hillocks, with severe erosion; associated with moderately shallow, well drained, gravelly loam soils with coherent material at 50 to 75 cm on very gentle slopes, moderately eroded	Clayey-skeletal, kaolinitic, oxic humitropepts Fine-loamy, mixed oxic humitropepts	Clayey, mixed, ustic haplohumults Fine, mixed ustic humitropepts	55.88
K_{36}	Very deep, well drained, clayey soils on moderately steeply sloping high hills with thick vegetation, with moderate erosion; associated With deep, well drained, gravelly loam soils on gentle slopes	Clayey, mixed, ustic haplohumults	Fine, mixed, ustic humitropepts Roch land	307.65
K_{38}	Very deep, well drained, clayey soils on moderately steeply sloping high hills with thin vegetation, with moderate erosion; associated with rock out crops	Clayey, mixed, ustic palehumults rockland	Fine, mixed, ustic humitropepts Fine-loamy, mixed ustic humtropepts	108.20

2.11 Land capability

Land capability of the Chalakudi basin (upto the Kerala State boundary) has been assessed based on the soil mapping units as provided by KSLUB (1995). Land capability classes include, class IVes, IIIsw, IIIes, Ive, Ives-VIII, IIIes-Ives, IIIsw-IIIs, VIe-VIII, Vie-Vies. Descriptions of these land capability classes are given in the Table 2.12.

Table 2.12 LAND CAPABILITY CLASSES AND THEIR AREAL EXTENT, CHALAKUDI RIVER BASIN

Land capability sub class association	Soil mapping units	Area
IVes	K09,K28,K35	70.12
IIIsw	K05	8.98
IIIes	K07,K11	295.73
Ive	K31	145.32
IVes-VIII	K33	206.32
IIIes-IVes	K32	55.63
VIe-VIII	K38	108.87
VIe-VIes	K36	314.03

Key to land capability class

Class III - moderately good cultivable lands

Class IV - fairly good, cultivable lands

Class VI - will suited for forestry or grazing

Class VIII - land suited only for wild life and recreation

Key to land capability subclass

Symbols

e-erosion and run off, s-soil, w-wetness/drainage

The basin has moderately good cultivable land, and fairly good cultivable lands in the western part. The central portion of the basin is mostly suited for forestry. Near the Paramikulam reservoir the land is suited for wild life.

2.12 Irrigability

Canal irrigation is quite successful in the Chalakudi river basin. Irrigability of land is a parameter to assess success of irrigation projects. Various irrigation classes were identified depending on the data obtained from KSLUB.

Land irrigability classes are based on the degree of limitations for sustained use under irrigation, and on physical and socio-economic factors. The land irrigability classes and their area coverage are given in the Table 2.13.

Table 2.13 LAND IRRIGABILITY CLASSES AND THEIR AREAL EXTENT, CHALAKUDI RIVER BASIN

Land irrigability sub class association	Area
4sd-s	4.45
3sd	8.65
3st	301.67
4sd-4s	143.87
4sd-6	66.78
4sd-3sd	53.62
3sd-3s	17.86
NI	608.10

Key to irrigability class limitations for sustained use under irrigation

2. moderate limitations
3. severe limitations
4. marginal lands
5. not suitable

Key to irrigability subclass limitations

s-soil, d-drainage, t-topography

Severe limitations of soil and topography are found for irrigation in the western part of the basin. Adjacent to this in the northern part there are marginal lands with respect to soil and drainage.

2.13 Natural Vegetation

This river basin is one of the basins in Kerala, that has sizable area under natural vegetation cover. However, progressive decline in natural vegetation cover can be marked.

Areal extent of forest, non-forest and plantation portions of the Chalakudi river basin has worked out (Table 2.14). It is observed that forest area has decreased by 6% and forest plantation have increased by 16% during this 33 years period. It may be noted that major changes in forest areas have taken place prior to 1966-'67 as. By this time all the reservoirs were impounded and plantation agriculture was already introduced. The areas falling within Tamil Nadu covering about 320 km^2 are within forest area. Forest plantations increased within the jurisdiction of Kerala State. If 320 sq.km. area is deducted from the forest area it is found that Kerala part of Chalakudi basin had 41% under forest cover in 1966-'67, which had come down to 37% in 1997. The peripheral zone between forest and non-forest area is under stress in the Kerala side.

Table 2.14 AREAL EXTENT OF FOREST, NON-FOREST AND PLANTATION, CHALAKUDI RIVER BASIN

Landuse category	Area 1966-'67		Area 1997		Change in area	
	(km^2)	%	(km^2)	%	(km^2)	%
Non-forest area	813	53.3	760	49.8	-53	6.1
Forest	357	23.4	415	27.2	+58	16.3
Plantation	355	23.3	350	23.0	-5	1.4

Natural vegetation in this basin is dominated by wet evergreen, semi evergreen and moist deciduous types. The wet evergreen type is found in the eastern part extending within Tamil Nadu. Semi evergreen and moist deciduous type have grown in lower altitudes adjoining the wet evergreen type. Forest plantations have replaced mostly semi evergreen type of vegetation. The peripheral zone of forest in the Chalakudi basin is occupied by moist deciduous type of vegetation. Distribution of natural vegetation is given in Fig. 2.9.

The vegetation types include wet evergreen and semi evergreen types, moist deciduous, pure Reed area, pure Bamboo and plantations.

The tropical evergreen forests and semi evergreen forests are characterised by large and very tall trees in the first storey comprising Kunthirikkam (*Canarium strictum*), vellakil (*Dysoxylum malabaricum*), churuli (*Mesua ferrea*), vellayini (*Diptorocarpus indicus*), Kambagam (*Hopea praviflora*), chempunna (*Calophyllum elatum*), vedipla (*Culleria excelsa*), pali (*Palaquium ellipticum*), payini (*Vateria indica*) etc. There is a dense second storey and undergrowth of many farns and tall harbs.

Moist deciduous type is less diverse compared to the evergreen forests but contains several commercially valuable species like teak (*Tectona grandis*), Karimarudu venteak (*Lagersteemia lanceolata*), irul (*Xylia xylocarpa*), Venga (*Pterocarpus marsupium*) etc. The major feature of this forest is that the trees remain leafless during the period from December to June. The forest types of reed and bamboo form part of these major types of vegetation. Apart from these, forest plantations of teak, eucalyptus, anjali (*Artocarpus hirsuta*), softwood etc. are very common.

2.14 Irrigation

There were reports of failure of viruppu and mudakan crops in the Mukundapuram taluk in the event of failure of the North-East Monsoon. Following the efforts to meet the food crisis during the post-war development period an investigation of major irrigation schemes was made in 1943 in the then Cochin native State. The Chalakudi irrigation scheme has been installed as a result of the investigation.

The first stage of the project started in 1949 and it was commissioned in 1952 and completed in 1957. The project site is situated nearly 16 km east of Chalakudi town. The 2nd stage started in 1958 was commissioned in 1961 and was completed in 1966. The canals are designed to command maximum ayacut. They are laid over streams and valleys wherever necessary in masonry aqueducts. The natural drainage waters are taken over either by means of super passage or under tunnels.

The 2nd stage consisting of the extension of the canal systems to the right and left banks of the river was taken up after the 1st stage. The total length of main canals, branches and distributaries under both stages is 313.35 km.

There is no independent storage for Chalakudi irrigation system, but there are three reservoirs impounded for generating hydel power in the upper reaches. The source of irrigation water is the tail race and surplus water from Poringalkuttu Hydro electric project, and the drainage water from the catchment of Chalakudi river below the Poringalkuttu scheme and upstream of Chalakudi weir. The power houses of Kerala Sholayar and Poringalkuttu are operated at a pattern to suit the irrigation needs of the basin.

Length and area of the main and branch canals of right bank canal (RBC) are given in Table 2.15. The total length of right bank canal is 182.10 km and the total ayacut area is 6191.23 ha.

Table 2.15 LENGTH OF CANAL AND AYACUT AREA UNDER RIGHT BANK CANAL (RBC) SYSTEM: CHALAKUDI IRRIGATION PROJECT

Main canal	Branch canal	Length (km)	Ayacut area (ha.)	Ha/km*
Right Bank main canal		17.40	580.00	3.33
	Kundukuzhipadam	2.09	74.48	35.64
	Mettipadam	5.34	98.34	18.20
	Chalakudi-pariyaram	19.98	34.45	1.72
	Potta	2.01	58.99	20.34
	Kalakkikunnu	2.61	59.00	22.61
Right Bank main canal		16.40	444.46	27.10
	Kodakara	7.04	215.32	30.59
	Muriyadu	8.20	148.37	18.09
	Kallettumkara	3.49	117.02	33.53
	Thazhakkadu	2.41	199.30	82.70
	Kaduppasseri	3.02	119.71	39.64
	Alathur	1.32	38.60	29.24
Right Bank main canal		1.26	51.54	40.90
	Perambra	6.27	173.88	6.27
	Aloor	1.20	27.23	22.69
	Parayanthodu	3.80	93.05	24.49
	Anallur	1.49	98.30	65.97
	Kotenallur	4.10	86.08	20.99
	Annamanadu	1.43	75.63	52.89
Right Bank main canal		13.00	261.00	20.08
	Echippara	3.40	59.55	17.51
	Kuttikkadu-Kanjirappalli branch	16.74	769.63	45.98
	Mattathur	20.28	720.34	35.52
	Thessery	1.64	76.23	46.48
	Aneswaram	6.95	202.41	29.12
	Blachira	9.12	664.89	72.90
	Grand Total	**182.10**	**6191.23**	**34.00**

** Area irrigated per km of canal length*

Length and area of the main and branch canals of left bank canal (LBC) are given in Table 2.16. The total length of left bank canal is 170.63 and the total ayacut area is 8655 ha.

Table 2.16 LENGTH OF CANAL AND AYACUT AREA UNDER LEFT BANK CANAL (LBC) SYSTEM: CHALAKUDI IRRIGATION PROJECT

Main canal	Branch canal	Length (km)	Ayacut area (ha.)	Ha/km*
LBC main canal		33.20	1252.00	37.71
	KV main	6.60	300.37	45.51
	Kalady main	12.40	567.50	45.77
	Adichilly branch	7.70	146.28	19.00
	Bhootamkutty branch	6.40	78.32	12.24
	Meloor branch	8.05	299.63	37.23
	Poolani branch	3.22	134.89	41.92
	Thangachira branch	4.53	168.80	37.30
	kizhekkumari branch	2.82	141.13	50.12
	Chirangara branch	1.01	94.20	93.64
	Meloor south branch	4.97	356.00	71.66
	Koratty branch	1.21	121.56	100.71
	Konoor branch	1.55	23.83	15.37
	M.V. branch	4.43	165.42	37.38
	K.V. Branch	4.63	188.05	40.64
	Edakunny branch	3.60	176.20	48.94
	Marangadam	1.40	100.32	71.66
	Karukutty karayam parambu branch	6.20	363.10	58.56
	Mambra branch	2.97	188.92	63.61
	Peechanikkad	3.22	160.40	49.83
	Parakadavu branch	3.32	108.13	32.58
	Attara branch	1.80	151.63	84.24
	Azhakam branch	1.40	135.03	96.45
	Karukuttykara branch	2.60	198.11	76.20
	Manjapra branch	10.77	688.54	63.93
	Anappara branch	1.30	55.64	42.80
	Naduvattom branch	2.33	93.08	39.95
	Bhootamkutty south branch	1.70	96.22	56.60
	Kalady branch	5.20	151.16	29.07
	Komarapadam	4.00	197.07	49.27
	Vengoor branch	6.00	278.70	46.45
	Thottakam branch	2.60	998.89	384.19
	Chengamanadu	1.60	65.72	41.08
	Mudappilly branch	2.26	134.45	59.49
	Edalakkad	3.66	276.11	75.38
	Total	**170.63**	**8655.39**	**50.72**

** Area irrigated per km of canal length*

Total ayacut area served by main and branch canal served by Chalakudi project is 14846.62 ha and the total length is 352.79 km (Table 2.17).

TAable 2.17 CANAL LENGTH AND AYACUT AREA SERVED BY MAIN AND BRANCH CANAL UNDER CHALAKUDI IRRIGATION PROJECT

	Right Bank Canal		Left Bank Canal		Total	
	Length	Area (ha.)	Length	Area (ha.)	Length	Area (ha.)
Main canal	33.20	1252.00	48.06	1337.00	81.26	2589.00
Branch canal	137.49	7403.39	134.04	4857.23	271.53	12257.62
Total	**170.69**	**8655.39**	**182.10**	**6191.23**	**352.79**	**14846.62**

Panchayat wise ayacut area of certain selected panchayats are given in Table 2.18.

Table 2.18 DISTRIBUTION OF AYACUT AREA IN SOME SELECTED PANCHAYATS, CHALAKUDI RIVER BASIN

Name of panchayat	Geographical area (ha.)	Ayacut area (ha.)	Ayacut area per unit to panchayat area
Mukkannur	13.02	1025.42	78.76
Manjapra	21.00	837.23	39.87
Angamaly	24.05	41.82	1.74
Karukutty	33.57	1372.28	40.88
Koratti	23.42	1168.39	49.89
Kadukutti	17.63	175.08	9.93
Meloor	23.06	910.73	39.49
Annamanadu	25.08	688.94	27.47
Parakadavu	24.66	945.79	38.35
Thuravoor	12.33	491.02	0.40

2.15 General landuse

The landuse pattern and changing trend covering the entire basin were studied from 1:50,000 scale topographical maps for the year 1966-’67 and 1:50,000 scale IRS images for the year 1997. The eastern part of the basin is hilly, which constitutes two third portion of the basin and most parts are under natural vegetation cover. The forest and the plantation crops dominated the landuse pattern of the basin in 1966-’67 and also in 1997 (Tables 2.19 and 2.20). The forest area covered 53.3% of the total area of the basin in 1966-’67, and in 1997 it is around 50%. Change took place mainly in the segment falling within Kerala. 23% of the area was under different plantations crops like, tea, coffee, rubber, cardamom, eucalyptus, teak, cashew etc. 10 % of the area was under settlement with mixed tree crops. Paddy occupied 7% of the basin.

Landuse map of the entire basin in 1:50,000 scale for the year 1997 was also prepared to analyse the subsequent changes taken place. The area of paddy have change from 6.65% to 1.53%. The area of settlement with mixed tree crops, agglomerated settlement and teak plantation have increased considerably. In 1997 the plantation crops take coffee, tea, cardamom together constitute 5.55% of the total area of the basin. The area of forest is found to be decreased in 1997. The area under different landuse categories are presented in Table 2.20.

Table 2.19 LANDUSE CATEGORIES AND THEIR AREAL EXTENT–CHALAKUDI RIVER BASIN (1966-'67)

Landuse category	Area	
	Sq. Km	%
Paddy/low land	101.40	6.65
Tree crops in low land	6.70	0.45
Settlement with mixed tree crops in lowland	22.20	1.45
Settlement with mixed tree crops	143.60	9.40
Agglomerated settlement	3.00	0.20
Mixed tree crops	2.60	0.15
Other trees	0.80	0.05
Factory	0.45	0.05
Terrace cultivation	0.65	0.05
Teak plantation	125.10	8.20
Eucalyptus	14.20	0.95
Eucalyptus and softwood	18.40	1.20
Rubber	13.70	0.90
Cashew	0.10	0.01
Cinnamon	0.05	0.01
Cardamom	0.75	0.05
Tea and cardamom	9.50	0.60
Tea	87.70	5.75
Coffee and cardamom	39.10	2.55
Coffee	34.30	2.25
Coffee and tea	14.50	0.95
Forest	775.35	50.85
Open scrub	25.40	1.65
Scrub	4.55	0.30
Grass land	7.35	0.50
Tribal settlement	0.05	0.01
Stone quarry	0.10	0.01
Rock outcrop	6.00	0.40
Sheet rock	10.00	0.65
Vacant land	1.20	0.10
Reservoir	35.20	2.30
Water body	0.25	0.02
River	20.75	1.35
Total	**1525.00**	**100.00**

Table 2.20 LANDUSE CATEGORIES AND THEIR AREAL EXTENT–CHALAKUDI RIVER BASIN (1997)

Landuse category	Area	
	Sq. Km	%
Paddy/low land	23.30	1.53
Seasonal crops	6.97	0.46
Settlement with mixed tree crops	227.75	14.93
Agglomerated settlement	6.77	0.44
Mixed tree crops	16.37	1.07
Teak plantation	185.62	12.17
Rubber	17.24	1.13
Cardamom	1.35	0.09
Tea	38.74	2.54
Coffee and cardamom	12.61	0.83
Coffee	24.37	1.60
Coffee and tea	95.17	0.49
Forest	747.56	49.02
Grass land	12.22	0.80
Stone quarry	0.06	0.004
Oil palm	4.78	0.31
Waste land	6.58	0.43
Fallow land	2.22	0.15
Coffee, cardamom and tea	35.12	2.30
Sheet Rock	4.00	2.31
Reservoir	35.20	0.02
Water body	0.25	0.02
River	20.75	1.36
Total	**1525.00**	**100.00**

2.16 Agriculture

Like rest of the State agricultural practices in this basin is diversified. Crop pattern depends upon various factors ranging from agroclimate to socio-economic compulsions. Given an agroclimatic condition crop selection depends upon livelihood requirements and economies to fetch maximum returns. The socio-economic factors like land tenancy, size of holdings and fields, labour, capital, transportation facilities, market and the national and international policies all individually and collectively influence the agricultural practices, cropping patterns, crop combination, cropping intensity and the agricultural topography of a macro and micro region. Crop statistics for 25 panchayats and 2 municipalities for the period of 1996-97 were collected from various panchayat offices and Krishi Bhavan falling within the Chalakudi basin for the micro level studies. The data were analysed for seasonal crops, tree crops, plantation crops and forest and forest plantations. The seasonal crops and tree crops are again classified into food crops and non-food crops. Distribution of crops is briefly discussed here to provide an idea about the cropping pattern in the basin and panchayat level variation (Table 2.21).

2.16.1 Distribution of seasonal crops

The seasonal crops in the basin cover 48,725 hectares. Area under food crops is more compared to the -non-food-crops under this category. The important seasonal food crops grown in the basin are paddy, vegetables, plantains, tapioca, pulses, pepper, ginger, gingelly, pineapple and turmeric.

Paddy with a coverage of 36735 hectare is the predominant seasonal crop of the basin and it cover 67.25 % of the total seasonal crops. The well-drained alluvial soil are ideal for paddy cultivation. Paddy is the major seasonal crop in all the panchayats except Melur and Puthenvelikkara. In Melur, paddy comes second after plantains and in Puthenvelikkara paddy is the third major seasonal crop after turmeric and ginger.

It is revealed from an overall evaluation that the rice production in the region has witnessed a sharp decline. In Kerala, the area under rice sharply fell from 8.74 lakh ha. in 1972-73 to 5.032 lakh ha. in 1994-95. That is a reduction of 42.5 % in the past 21 years (KSI, 1994). Chalakudi river basin is not an exception in this regard. Various reasons have been cited to explain this decline. Detailed discussion on this issue will be attempted in the section on landuse change.

Plantain cover an area of 5211 hectares and ranks second among seasonal crops. Melur panchayat records maximum area (1415 ha.) under this crop. Except Kuzhur, Kodasseri, Thuravoor and Nelliyampathy all other panchayats have plantains cultivation. Pepper is the third major seasonal crop cultivated in the basin (2162 ha).

Table 2.21 AREA UNDER DIFFERENT CROP GROUPS (1996), CHALAKUDI RIVER BASIN

Sl. No.	Name of Panchayat	Geographical Area (Km^2)	Total seasonal crops (ha.)	Total food tree crops (ha.)	Total non-food tree crops (ha.)	Total tree crops	Total plantation crops (ha.)	Total food crops (ha.)	Total non-food crops (ha.)	Total Cropped area (ha.)
1	Poyya	19.78	954	75	855	930	3	1029	858	1887
2	Puthenvelikkara	16.99	3562	437	950	1387	5	3997	957	4954
3	Kunnukara	21.25	2259	45	965	1010	6	2304	971	3275
4	Kuzhur	19.11	1029	3	101	104	0	1032	101	1133
5	Mala	28.35	2427	40	2343	2383	0	2467	2343	4810
6	Alur	34.39	1074	0	1029	1029	9	1074	1038	2112
7	Kodakara	21.29	1579	33	929	962	39	1612	968	2580
8	Chalakudi (M)	25.23	1236	30	1393	1423	9	1266	1402	2668
9	Kadukutty	17.63	1747	12	30	42	0	1759	30	1789
10	Annamanada	25.08	1610	12	1600	1612	35	1622	1635	3257
11	Parakkadavu	24.66	2005	43	1225	1268	185	2048	1410	3458
12	Nedumbassery	23.14	2165	6	1032	1038	20	2171	1052	3223
13	Angamali (M)	24.05	2000	220	1025	1245	95	2215	1125	3340
14	Thuravoor	12.33	1030	0	469	469	400	1030	869	1899
15	Manjapra	21.00	937	18	385	403	50	955	435	1390
16	Mookkannur	13.02	1683	31	925	956	465	1711	1393	3104
17	Karukutty	33.57	3410	95	2510	2605	250	3505	2760	6265
18	Koretti	23.42	1685	84	232	1316	216	1769	1448	3217
19	Melur	23.06	3610	18	1989	2007	95	3628	2084	5712
20	Pariyaram	27.19	745	35	1650	1685	180	780	1830	2610
21	Ayyampuzha	43.88	1065	41	449	490	1454	1106	1903	3009
22	Athirappalli	489.00	382	50	325	375	209	432	534	966
23	Kodasseri	93.90	3123	0	3123	3123	3123	0	0	0
24	Mattathur	103.11	2223	345	1013	1358	1960	2568	4549	7117
25	Kizhakkancherry	112.56	3237	55	890	945	3200	3292	4090	7382
26	Nelliyampathy	576.54	0	0	29	29	4756	0	4785	4785
27	Kollengode	49.33	3532	0	90	90	0	3532	90	3622
	Total	**1922.86**	**50309**	**1728**	**28556**	**30284**	**16764**	**48904**	**40660**	**89564**

But five panchayats, namely, Kuzhur, Kodasseri, Thuravoor, Nelliyampathy and Kollengode have not accounted for pepper cultivation. Tapioca and ginger are other two seasonal crops, each of which covers more than 3% of total area under seasonal crops. Vegetables, turmeric and pulses are also cultivated in most of the panchayats. The other seasonal food crops like gingily, pineapple, pumpkin, groundnut, sweet potato, other tubercrops and other seasonal non-food crops like flowers, beetle and medicinal plants occupy negligible area in some of the panchayats.

2.16.2 Distribution of tree crops

Coconut, arecanut, nutmeg are the important non-food tree crops cultivated in the basin. The major food-tree crops include cashewnut, cloves, jack, mango, fruits and other trees.

The predominant tree crop is coconut, which covers an area of about 84% of the total area under tree crop. 25 panchayats account for more than 70% of their area under coconut. Coconut is the most common tree in all the panchayats of the basin. The coverage is very high in the panchayats located in the lowland and it comes down in hilly area. This spatial distribution indirectly indicates soil suitability for coconut plantation.

Arecanut is the second major tree crops after coconut. It covers an area of 2047 ha. Except the panchayats of Kodasseri, Kuzhur, Thuravoor, Nelliyampathy and Kollengode all the other panchayats have arecanut cultivation. Nutmeg is another important crop. It occupies 3% of the total cropped area. Area under cloves, jack, mango and fruit trees are marginal.

2.16.3 Distribution of plantation crops

The plantation crops grown in the basin include rubber, coco, tea, coffee, cardamom and mulberry. Rubber is the most dominant plantation crop in the basin. It covers around 12% of total cropped area of the basin. Except Kuzhur, Mala, Kadukutty, and Kollemkode all the other panchayats have rubber cultivation. It is widely distributed in the basin irrespective of the terrain conditions. Even the lowland areas are given for rubber cultivation. The other plantations crops like coco, tea, coffee, cardamom and mulberry are not widely distributed in all the panchayats. Tea, coffee and cardamom are grown only in Nelliyampathy panchayat in the hilly segment of the basin.

Area distributions under major crops are given in the Table 2.22.

2.16.4 Crop combination

Crop combination studies are essential to understand the agricultural system as the individual crops are rare and they are not grown alone, but they are raised in combination (Weaver, 1954). The diverse cropping pattern leads to the agricultural growth of the basin, which in turn contribute to economic betterment of the society. The diversity of crops varies from place to place because all the crops may not be equally important at every place. Some of them may be very significant, while others might be quite inconsequential. A thorough statistical analysis is therefore necessary for identifying the crops of significant importance (Mahmood, 1977). At the present instance crop combinations have been worked for seasonal crops, tree crops and total cropped area covering plantation crops also.

2.16.4.1 Crop combination - seasonal crops

On the basis of crop combination analysis of seasonal crops, 19 combination zones were identified to spread over 28 panchayats (Table 2.23). This indicates that the agricultural practice is highly diversified, which in another level points towards terrain variations even at the panchayat level. There are only three panchayats with paddy as the dominant crop. Paddy is the first ranking crop in all the panchayats except three panchayats namely, Melur, Athirappalli and Puthenvelikkara. There is only one panchayat, where six crops figure in the combination.

Table 2.22 DISTRIBUTION OF MAJOR CROPS (1996), CHALAKUDI RIVER BASIN

Name of Panchayat	Geographical Area (Km^2)	Paddy (%)	Vegetables (%)	Plantains (%)	Tapioca (%)	Pulses (%)	Pepper (%)	Coconut (%)	Aracanut (%)	Rubber (%)	Total cropped area
Poyya	19.78	39.48	0.11	3.18	3.29	2.65	1.06	42.40	2.91	0.16	1887
Puthenvelikkara	16.99	9.08	1.01	2.14	3.03	0.00	0.50	16.15	3.03	0.10	4954
Kunnukara	21.25	55.54	1.07	7.63	0.61	1.37	1.22	25.34	2.90	0.18	3275
Kuzhur	19.11	71.14	0.00	0.00	0.00	0.00	0.00	8.91	0.00	0.00	1133
Mala	28.35	25.20	2.95	11.14	0.00	2.31	8.86	36.49	8.86	0.00	4810
Alur	34.39	46.07	0.57	1.66	0.57	0.09	1.42	48.30	0.43	0.43	2112
Kodakara	21.29	40.31	1.16	8.26	2.29	4.26	4.92	28.80	7.21	1.51	2580
Chalakudi (M)	25.23	31.18	0.75	8.43	2.59	0.56	1.87	50.60	0.56	0.15	2668
Kadukutty	17.63	95.03	0.06	1.68	0.56	0.28	0.06	1.12	0.56	0.00	1789
Annamanada	25.08	38.38	0.00	6.45	0.61	0.92	3.07	46.05	3.07	1.07	3257
Parakkadavu	24.66	47.14	1.45	5.49	2.46	0.00	1.01	30.80	2.75	5.35	3458
Nedumbassery	23.14	58.33	0.78	3.41	1.55	0.47	1.55	30.47	1.55	0.62	3223
Angamali (M)	24.05	40.12	1.95	5.99	1.80	1.20	1.50	27.40	0.90	2.54	3340
Thuravoor	12.33	47.92	0.00	0.00	0.00	0.00	0.00	24.70	0.00	21.06	1899
Manjapra	21.00	43.52	4.32	7.19	2.88	0.36	2.88	23.38	1.80	3.60	1390
Mookkannur	13.02	43.50	1.03	5.32	1.29	0.16	1.61	25.62	0.32	14.50	3104
Karukutty	33.57	48.36	1.04	2.39	0.48	0.24	0.80	26.34	0.96	3.99	6265
Koretti	23.42	34.47	1.31	10.10	2.11	1.24	0.93	34.47	1.74	6.59	3217
Melur	23.06	21.88	0.53	24.77	12.43	1.40	1.66	33.61	0.61	1.66	5712
Pariyaram	27.19	13.79	1.92	8.62	1.72	0.96	0.57	49.81	11.49	6.90	2610
Ayyampuzha	43.88	15.95	0.66	2.66	0.33	0.33	5.65	13.63	1.00	48.19	3009
Athirappalli	489.00	0.00	1.04	6.21	6.21	0.21	25.88	32.61	1.04	21.64	966
Kodasseri	93.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Mattathur	103.11	20.19	1.18	3.03	0.79	1.85	3.06	11.35	2.39	27.40	7117
Kizhakkancherry	112.56	35.63	0.20	3.73	0.34	0.34	3.59	11.51	0.54	43.35	7382
Nelliyampathy	576.54	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.71	4785
Kollengode	49.33	91.99	0.00	0.83	0.00	0.00	0.00	2.48	0.00	0.00	3622
Chalakudi river basin	**1922.86**	**37.56**	**0.93**	**5.20**	**1.78**	**0.81**	**2.73**	**25.29**	**2.10**	**7.84**	**89564**

Table 2.23 CROP COMBINATION - SEASONAL CROPS, CHALAKUDI RIVER BASIN

Sl. No.	Combination	Crops	Panchayats
1	1 crop	Paddy	Kadukutty, Kodasseri
2	2 crops	P-Pl	Alur, Kunnukara, Nedumbassery, Mookkannur, Karukutty
3	2 crops	P-MT	Kuzhur, Thuravoor
4	2 crops	P-Gr	Kollengode
5	3 crops	P-Pl-PC	Annamanada, Kizhakkancherry
6	3 crops	P-PI-Ta	Parakkadavu
7	3 crops	PI-P-Ta	Melur
8	3 crops	PC-PI-Ta	Athirappalli
9	4 crops	P-Ta-Pl-Pu	Poyya
10	4 crops	Tur-Gin-P-Ta	Puthenvelikkara
11	4 crops	P-Pl-Ta-Gr	Koretti
12	4 crops	P-Pl-Ta-Pe	Chalakudi (M)
13	5 crops	P-Pl-Pe-Veg-Pu	Mala
14	5 crops	P-Pl-Gi-Veg-Ta	Angamali (M)
15	5 crops	P-Pl-Veg-Pe-Ta	Manjapra
16	5 crops	P-Pl-Veg-Tap-Pul	Pariyaram
17	5 crops	P-Pe-Pl-Pu-Ta	Mattathur
18	5 crops	P-Pl-Pe-Pu-Ta	Kodakara
19	6 crop	P-Pe-Gi-Pin-Pl-Tur	Ayyampuzha

Four crop combinations region characterises 4 panchayats. Paddy, tapioca, plantains, pulses, turmeric, ginger, groundnut, pepper are the 8 crops in this group showing four different crop combination.

2.16.4.2 Crop combination-tree crops

Crop combination based on seasonal crops alone provides only a partial picture, therefore crop combination using the same methodology has been worked out for tree crops.

12 combination zones have been identified based on this analysis. One-crop combination zone reveals the dominance of coconut. The panchayats namely, Alur, Chalakudi (m), Melur, Kuzhur, Thuravoor, Kodasseri, Nelliyampathy and Kollengode each has recorded coconut as single dominant crop (Table 2.24). Alur, Chalakudi (M) and Melur form a continuous block in the west central part of the basin.

This monocrop zone extends to Kollengode and Nelliyampathy through Kodasseri towards the eastern part of the basin. Altogether eight crops figured in the 12 combination zones.

Table 2.24 CROP COMBINATION-TREE CROPS, CHALAKUDI RIVER BASIN

Sl. No.	Combination	Crop	Panchayats
1	1 crop	C	Alur, Chalakudi (M), Melur, Kuzhur, Thuravoor, Kodasseri, Nelliyampathy, Kollengode
2	2 crop	C-A	Poyya, Annamanada, Nedumbassery, Pariyaram
3	2 crop	C-N	Karukutty, Mookkannur
4	2 crop	C-Ca	Athirappalli
5	3 crop	C-Ca-A	Puthenvelikkara, Kadukutty, Ayyampuzha
6	3 crop	C-A-N	Mala, Kunnukara, Parakadavu
7	3 crop	C-N-A	Manjapra
8	3 crop	C-A-Ca	Kodakkara
9	3 crop	C-A-M	Kizhakkancherry
10	4 crop	C-N-A-Ch	Koretti
11	4 crop	C-M-J-N	Anagamali
12	4 crop	C-Ch-A-Fr	Mattathur

2.16.4.3 Crop combination – Total cropped area

A third exercise on crop combination has been attempted by incorporating all the crops, seasonal, tree crops & plantation crops in combination. It will provide a comprehensive picture of total crop scenario in the basin. The methodology followed here is same as that followed for seasonal crop and tree crop. In all eight crops figured in the combination. Except Kunnukara and Nedumbassery all other panchayats are unique in itself with respect to crop combination (Table 2.25). Paddy is the first ranking crop in 15 panchayats. It may be noted here that when seasonal crops alone were considered as many as 25 panchayats have recorded paddy as the first ranking crop. Coconut is the dominant crop in nine panchayats and there are three panchayats with rubber as the first ranking crop. Spatial distribution indicates that rubber occupied 1st position in the panchayats lying along the northern and southern border of the central part of the basin. Maximum diversity in crop cultivation can be found in Mattathur panchayat followed by

Athirapalli (Fig. 2.10). Kadukutty maintained its monocropping character both under seasonal crop category and total crop category. This indicates that this panchayat is a predominately paddy growing panchayat.

Table 2.25 CROP COMBINATION - TOTAL CROPPED AREA, CHALAKUDI RIVER BASIN

Sl. No.	Combination	Crop	Panchayats
1	1 crop	Paddy	Kadukutty
2	2 crop	C-P	Alur
3	2 crop	P-Gr	Kolengode
4	3 crop	Paddy-Coconut-Pl	Kunnukara, Nedumbassery
5	3 crop	Paddy-Coconut-Rubber	Kodasseri
6	3 crop	Paddy-Coconut-Pl	Chalakudi
7	3 crop	Coconut-Car-Tapioca	Nelliyampathy
8	3 crop	P-MT-C	Kuzhur
9	4 crop	Coconut-Paddy-Tapioca	Poyya
10	4 crop	Coconut-Pl-Paddy-Tapioca	Melur
11	4 crop	Coconut-Paddy-Pl-Rubber	Koretti
12	4 crop	Paddy-Coconut-Pl-Rubber	Parakkadavu
13	4 crop	Paddy-Coconut-Nutmeg-Rubber	Karukutty
14	4 crop	Paddy-Coconut-Pl- Gingely	Angamali
15	4 crop	Paddy-Coconut-Rubber-MT	Thuravoor
16	5 crop	Coconut-Paddy-Pl-Pe-Arecanut	Annamanada
17	5 crop	Coconut-Paddy-Arecanut-Pl-Rubber	Pariyaram
18	5 crop	Paddy-Coconut-Rubber-Pl-Nutmeg	Mookkannur
19	5 crop	Paddy-Coconut-Pl-Vegetable-Rubber	Manjapra
20	5 crop	Rubber-Paddy-Coconut-Pe-Gingely	Ayyampuzha
21	5 crop	Rubber-Paddy-Coconut-Pl-Pe	Kizhakkancherry
22	6 crop	Paddy-Coconut-Pl-Arecanut-Pe-Pu	Kodakkara
23	6 crop	Coconut-Pe-Rubber-Pl-Tapioca-Ch	Athirappalli
24	6 crop	Coconut-Paddy-Pl-Pe-Arecanut-Nutmeg	Mala
25	7 crop	Turmeric-Gingely-Coconut-Paddy-Ch-Tapioca-Arecanut	Puthenvelikkara
26	8 crop	Rubber-Paddy-Te-El-C-Ch-Pe-Pl	Mattathur

2.16.5 Crop intensity - paddy

Crop intensity provides an idea about the number of times a land has been put to use. This is mainly worked out for seasonal crops. Single crop cultivation in a season is represented by 100%. When two crops are raised from a same field, it is 200% and for three crops it is 300%. With the given technology and use of HYV seeds it is possible to raise three crops from the single plot of land.

Intensity for paddy is found to be less than 200 in the panchayats of Poyya, Kodassri, Kizhakkancherry and Kollemkode. Kuzhur, Alur, Melur and Ayyampuzha panchayats fall in the class of 200 to 225. Average intensity for the entire basin is 232. There are 13 panchayats having below average valley. All the panchayats except Kodasseri, Poyya, Kizhakancherry and Kollengode raise two paddy crop in a year. As many as 9 panchayats record crop intensity of more than 250%. High crop intensity registered by all the panchayats can be attributed to irrigation facilities provided in this basin.

2.16.6 Distribution of paddy

Total area under paddy accounts for 36.2% of the total cropped area (TCA) in the basin. However, panchayat wise distribution shows vide variations. Paddy is more cultivated in two panchayats namely, Athirappalli and Nelliyampathy. The panchayats of Puthenvelikkara, Pariyaram and Ayyanpuzha each has less than 20% of TCA under paddy (Fig.2.11). For the names of panchayats refer Table 2.21. 9 panchayats have 20 to 40% of area under paddy. These panchayats are mainly concentrated in the district of Thrissur. Kadukutty has the highest coverage (95%) under paddy followed by Kollengode (92%). Kadukutty is located in West Central part of the basin, served by the Chalakudi irrigation scheme. Kollengode in Palakkad district and has a very small part in this basin.

2.16.7 Distribution of coconut

Area under coconut covers about 26% of total cropped area. Coverage varies from less than 1% in Nelliyampathy to 51% in Chalakudi (M) area. Kuzhur, Kadukutty, Nelliyampathy and Kollengode panchayats have less than 10% coverage. The panchayats of Puthenvelikkara, Muttathur, Kizhakkancherry and Ayyampuzha came in the next category (10 to 20%). The panchayats of Alur, Poyya, Annamanada, Pariyaram and Chalakudi municipality each have more than 40% of TCA under coconut.

2.16.8 Distribution of rubber

Rubber has emerged as an important crop in the basin like rest of the State. Area under rubber with respect to total cropped are is calculated and it is found that the lowland panchayats of Alur, Poyya, Puthenvelikkara, Kunnukara, Nedumbassery and Chalakudi municipality and the highland panchayat of Nelliyampathy each has less than 1% of area under rubber cultivation. This indirectly indicates the limits of rubber plantation both in the lowland and high altitudes. Ayyampuzha and Kizhakkanchery panchayats have more than 45% of the total copped area under rubber. Both these panchayats are located in the foothills.

2.17 Population

The Chalakudi river basin consists of twenty six panchayats and two municipalities. As many as fourteen panchayats and one municipality (Chalakudi) fall under Thrissur district; nine panchayats and one municipality (Angamali) are under Ernakulam district and three panchayats are coming under Palakkad district. Only seven panchayats and one municipality are fully coming under the basin. The rest of the panchayats are partly falling in this basin. Although the basin spreads over the State of Tamil Nadu in the eastern part for an area of 320 sq.km the present study is concerned about the area (1205 sq.km) administered by the State of Kerala.

Census data of the past three decades such as 1971, 1981 and 1991 have been considered for the detailed study (Census of India, 1971, 1981 and 1991). Although 2001 census was completed, panchayat level data are not yet published.

2.17.1 Distribution of population

According to 2001 census, the population of Kerala was 318.39 lakhs. The growth of population during 1991-2001 was recorded as +9.4 %. Kerala had a population density of 819 persons/sq.km in 2001 and the density of households was 142 houses/sq.km. The sex ratio of the State increased to 1058 females/1000 males from 1036 females/1000 males in 1991. The literacy rate of the state reached 90.92%. Around 32.30 % of the total population of the State was enumerated as workers. During this period (1991-2001), the population of Thrissur, Ernakulam and Palakkad districts were 29.75 lakhs, 30.98 lakhs and 26.17 lakhs respectively. The growth of population during 1991-2001 was recorded +8.7 % in Thrissur district, +9.98% in Ernakulam district and +9.86% in Palakkad district. The density of population was 981 persons/ sq.km in Thrissur, 1050 persons/sq.km in Ernakulam and 584 persons/sq.km in Palakkad districts in the year 2001. The sex ratio of Thrissur district were 1092 females/1000 males and in Ernakulam it was 1017 females/1000 males and for Palakkad it was 1068 females/ 1000 males. A literacy rate of 92.56% was recorded in Thrissur district, 93.42% in Ernakulam district and 84.31% in Palakkad district. The working population of Thrissur, Ernakulam and Palakkad districts were recorded as 32.16%, 36.07%, 36.17% respectively.

There are certain limitations in handling demographic data at panchayat level. Panchayats were reorganized from time to time; areal extent had changed and some panchayats were merged with urban area. In view of this, demographic data were presented for each census year, and comparability was attempted wherever permissible.

The data for Ayyampuzha panchayat for the period 1971 were not available. The name of Kallur-Vadakkumuri panchayat of Thrissur district has been renamed as Kadukutty in 1991.

According to 1971 census, the Chalakudi basin had a population of 5.20 lakhs which is 2.44 % of the total State population of 213.47 lakhs. The female population of the basin was slightly higher (50.51 %) than male population (49.49 %). In 1981, the total population of the basin had increased to 6.26 lakh or 2.46 % of total population of the State (Table 2.26). There was also a slight increase in the female population (50.78%) and a corresponding decrease in the male population (49.22%). The total population of the basin reached 6.80 lakhs during 1991 with proportion of male and female more or less same as was in 1981. It is important to note that population share of Chalakudi basin with respect to total population of the State had come down to 2.34% in 1991 from 2.46 % in 1981. This indicates that growth of population in the basin is comparatively less than that of the State.

Chalakudi municipality has the major share of population of the basin (7.02%) during 1971, which was followed by Mattathur (5.64%) and Alur (5.63%) panchayats. The lowest share was in Athirappalli panchayat. As many as 18 panchayats had recorded decrease in their share of total population in 1981. in this census period the lowest share of population was observed in Nelliyampathy (1.38%) panchayat and the highest was in Chalakudi municipality although with reduced value

There were 14 panchayats whose share in total population recorded declining trend in 1991, it may be noted that 13 panchayats showed fluctuating trend during the last two decades (1971-1991). Panchayats in the highland registered higher growth rate compared to those in the west section.

Table 2.26 DISTRIBUTION OF POPULATION (PERCENTAGE TO TOTAL POPULATION OF THE BASIN), CHALAKUDI RIVER BASIN

Panchayats	**1971**	**1981**	**1991**
Poyya	3.15	2.92	2.90
Puthenvelikkara	4.08	3.31	3.69
Kunnukara	2.84	3.27	2.82
Kuzhur	2.90	2.70	2.65
Mala	4.89	4.49	4.40
Alur	5.63	5.34	5.35
Kodakara	3.88	3.82	3.98
Chalakudi	7.02	6.51	6.44
Kadukutty	3.24	3.13	3.17
Annamanada	4.03	3.80	3.78
Parakkadavu	4.06	3.91	3.96
Nedumbassery	3.70	3.72	4.04
Angamali	2.42	4.40	4.34
Thuravoor	2.67	2.46	2.50
Manjapra	3.63	1.53	2.07
Mookkannur	2.09	1.97	2.44
Karukutty	4.36	3.98	3.55
Koretti	4.27	4.26	4.30
Melur	3.62	3.62	3.33
Pariyaram	4.59	3.02	2.99
Ayyampuzha	DNA	3.00	2.23
Athirappalli	0.29	1.42	1.32
Kodesseri	4.14	4.23	4.27
Mattathur	5.64	6.37	6.01
Kizhakkancherry	4.26	4.66	5.17
Nelliyampathy	1.37	1.38	1.40
Kollengode	4.43	4.28	4.05

DNA – Data Not Available

2.17.2 Growth of population

The population of Chalakudi basin increased from 519958 persons in 1971 to 626251 persons in 1981 and 680271 persons in 1991. The basin observed a growth rate of 20.20 % during 1971-’81 and 8.80% during 1981-’91. The growth rate was 30.83% during 1971-’91. The growth rate of State was 19.20%, 14.30% and 36.30% during 1971-’81, 1981-’91 and 1971-’91 periods respectively

Among the panchayats, Athirappalli recorded the highest growth rate of +494.47%, while Manjapra showed the lowest growth rate of –49.36% during 1971-’81 (Table 2.27). Three panchayats namely, Puthenvelikkara, Pariyaram and Manjapra recorded negative growth rate during the period. Puthenvelikkara is located in the lowland area while Manjapra and Pariyaram are located in the highland area. Negative growth rate can be attributed to out migration to nearest urban center, change in areal configuration of the panchayats and also readjustment of panchayat boundaries. Due to the non-availability of raw data from Census office, it was not possible to readjust the units and their population. But the demographic character of the State is undergoing significant changes (Bhut and Rajan, 1990).

During 1981-’91, the highest growth rate was experienced by Manjapra (46.70%) panchayat, followed by Mookkannur (35.60%) panchayat (Fig. 2.12). Both the panchayats are located in the Ernakulam district. While the lowest growth rate was observed in Ayyampuzha panchayat (-19%). During this period no negative growth rate was observed in the panchayats of Thrissur and Palakkad districts.

When the growth rates of two decades (1971-’91) were analysed, Athirappalli panchayat experienced very high growth rate (501.60%). It is located in the highland area. The Angamali municipality showed a growth rate of 135% and Kizhakkancherry panchayat, 58.80%. Two panchayats recorded negative growth during the period, namely, Manjapra (-25.60%) and Pariyaram (-14.70%). The rest of the panchayats in the basin have growth rates between 18% to 40% during 1971-’91. It may be noted that the panchayats of Palakkad district which are falling under Chalakudi basin never experienced a negative growth during 1971-’81, 1981-’91 and 1971-’91.

Table 2.27 GROWTH OF POPULATION, CHALAKUDI RIVER BASIN

Panchayats	1971-'81	1981-'91	1971-'91
Poyya	11.97	8.62	21.62
Puthenvelikkara	-2.43	21.14	18.19
Kunnukara	38.27	-6.23	29.66
Kuzhur	11.95	7.04	19.83
Mala	10.35	7.41	18.52
Alur	14.01	8.96	24.23
Kodakara	18.30	13.40	34.15
Chalakudi	11.53	7.58	19.99
Kadukutty	16.12	10.21	27.98
Annamanada	13.36	8.17	22.62
Parakkadavu	15.78	10.15	27.53
Nedumbassery	20.90	18.30	20.91
Angamali	118.89	7.36	135.01
Thuravoor	10.68	10.74	22.57
Manjapra	-49.26	46.73	-25.55
Mookkannur	13.16	35.57	53.34
Karukutty	9.82	-2.95	6.59
Koretti	20.16	9.88	31.91
Melur	14.58	5.11	20.43
Pariyaram	-20.80	7.69	-14.71
Ayyampuzha	-	-19.00	-
Athirappalli	494.45	1.20	501.57
Kodasseri	22.80	9.68	34.69
Mattathur	35.64	2.59	39.15
Kizhakkancherry	31.45	20.84	58.84
Nelliampathy	20.17	10.98	33.37
Kollengode	16.27	2.74	19.46
Chalakudi river basin	**20.40**	**8.66**	**30.83**

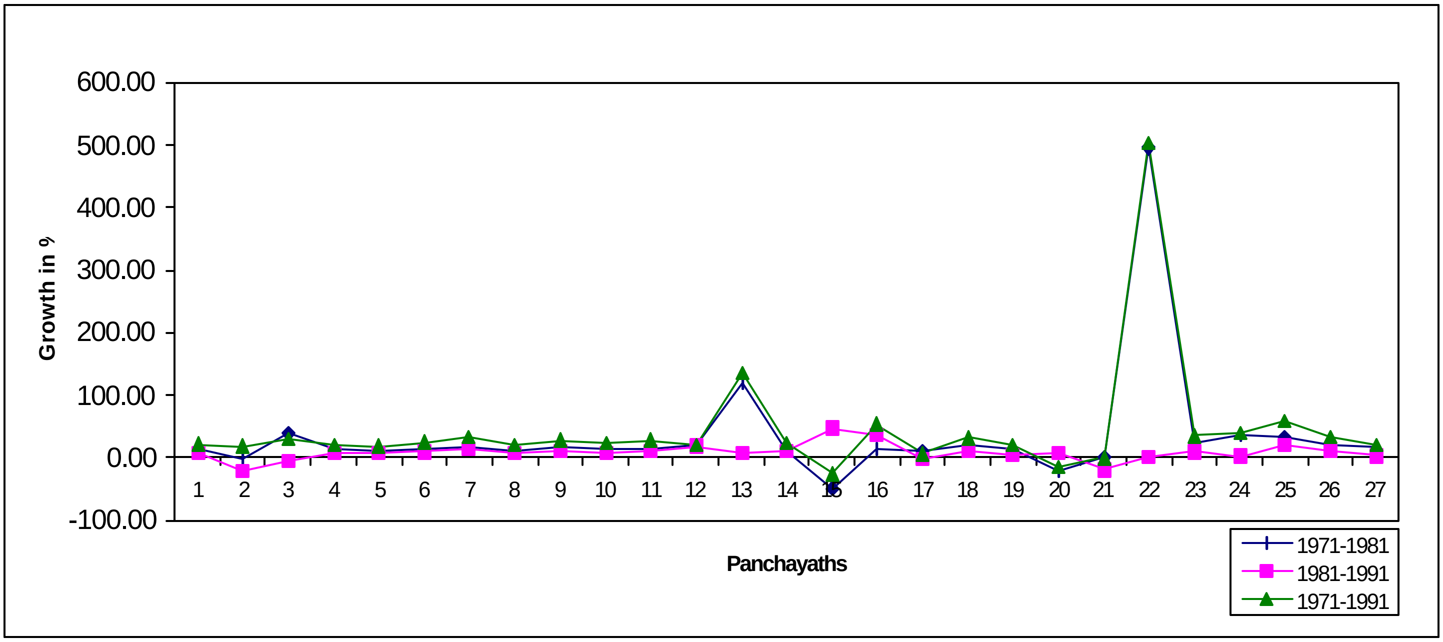

Fig. 2.12 GROWTH OF POPULATION, CHALAKUDI RIVER BASIN

2.17.3 Density of population

The density of population is a measure of nature of crowding of people in a given place. It indirectly indicates the load or stress that the area is subjected to. It depends many factors like physiography, drainage, location, availability of resources and amenities etc. During 1971 the Chalakudi river basin had a population density of 807 persons/sq.km as against the State's density of 549 persons/sq.km. During this census year the density of population of Thrissur, Ernakulam and Palakkad districts were 702, 729, 383 respectively. This suggests that the Chalakudi basin is a crowed place compared to the districts and State average. The highest density was observed in Angamali municipality (1899 persons/sq.km) followed by Chalakudi municipality (1489 persons/sq.km) (Table 2.28). Another two panchayats namely, Puthenvelikkara and Thuravoor showed a population density of 1286 and 1158 respectively. Density of population was the lowest in Athirappalli panchayat (Fig. 2.13). Here only 3 persons lived in one sq.km. Nelliyampathy panchayat showed a population density of 13 persons/sq.km. Both the panchayats are located in the hilly area.

Table 2.28 DENSITY OF POPULATION, CHALAKUDI RIVER BASIN

Panchayats	1971	1981	1991
Poyya	851	953	1035
Puthenvelikkara	1286	1255	1520
Kunnukara	702	971	929
Kuzhur	811	908	972
Mala	916	1011	1086
Alur	877	1000	1089
Kodakara	975	1154	1309
Chalakudi	1489	1660	1786
Kadukutty	984	1143	1259
Annamanada	860	975	1055
Parakkadavu	881	1020	1123
Nedumbassery	856	1034	1224
Angamali	1899	1177	1264
Thuravoor	1158	1282	1443
Manjapra	925	469	689
Mookkannur	858	971	1317
Karukutty	695	763	741
Koretti	975	1170	1286
Melur	840	963	1012
Pariyaram	903	715	770
Ayyampuzha	DNA	785	356
Athirappalli	3	19	19
Kodasseri	236	290	318
Mattathur	293	397	408
Kizhakkancherry	203	266	322
Nelliyampathy	13	16	17
Kollengode	481	559	574
Chalakudi river basin	**807**	**850**	**923**

DNA – Data Not Available

The density of population of the basin had increased to 850 persons/sq.km during 1981. The State showed a density of 655 persons/sq.km during this period and the population density of Thrissur, Ernakulam and Palakkad were 805, 1053, 456 respectively. Chalakudi municipality showed the highest density of population during this census year (1660 persons/sq.km). The population density of Angamali decreased to 1177 persons/sq.km. The reason may the increase in area of the panchayat. The area of the panchayat has increased from 6.81 sq.km to 24.05 sq.km during 1971 - 1981. During this period, nine panchayats and two municipalities showed a density of 1000 and more. The lowest density was observed in Nelliyampathy panchayat (16 persons/sq.km).

During 1991, the density of population of the basin reached to 923 persons/sq.km. against 749 persons/sq.km for the State as a whole. Thrissur, Ernakulam and Palakkad district showed population density of 903, 1170, 532 respectively during 1991. Chalakudi municipality retained its position by having the highest density of population (1786 persons/sq.km). During this period 13 panchayats and 2 municipalities recorded a density of more than 1000. The lowest density was observed in Nelliyampathy panchayat (17 persons/sq.km).

The density of population of the Chalakudi basin is more than the average population density of the State. The panchayats of Thrissur and Palakkad districts mainly contribute to the increase in population density of the basin. Two panchayats namely Athirappalli and Nelliyampathy have low density of population. The density figure has come down to this low figure due to inclusion of uninhabited area within the panchayats while counting for the total area.

When the density of population and population growth are correlated, it is found that they are negatively correlated. It may be inferred from here that high density panchayats will have low growth rate. Comparing growth of population density with that of density of households it emerges that growth rate of households density is more than that of population density in both the decades (Fig. 2.14). This indicates higher demand for lands required for settlement purposes.

2.18 Occupational structure

Occupational structure of the panchayats is provided in the Table 2.29. It may be noted that these are a variation of occupations from lowland to midland to highland. While selecting the sample sites these variations are also taken into account.

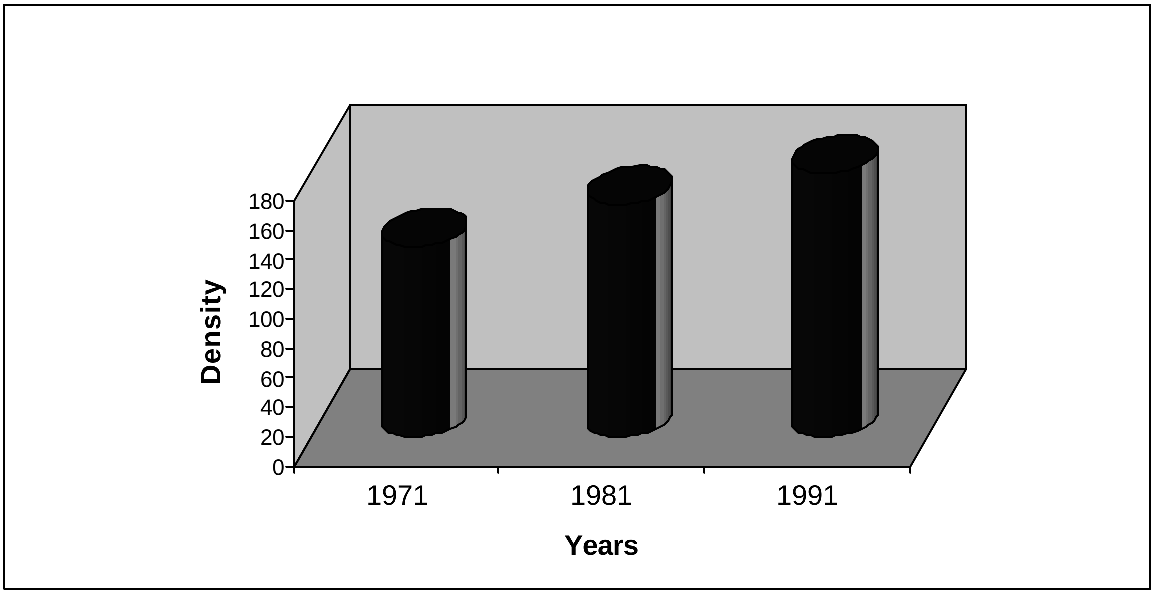

Fig. 2.14 DENSITY OF HOUSEHOLDS, CHALAKUDI RIVER BASIN

2.19 Selection of sample sites

Discussion on overall characteristics of the study area highlighted that biophysical setting, population distribution, landuse pattern etc record spatial variations within the basin. The landuse/land cover change scenario varies from the lowland to the highland. The proximate causes contributing to landuse change also vary in various parts of the basin. In view of these variations and in order to capture the micro level changes, associated factors and spatial variations of both cause and effect five sample sites were chosen under four environmental settings (Fig. 2.15). These are :

I Confluence of Chalakudi and Periyar – Lowland

II Chalakudi town and surroundings – Midland

III Thumburmuzhi and surroundings – Highland/ foothill

IV a Parambikulam reservoir and surroundings } Highland/high hill

IV b Karapara river and surroundings

Table 2.29 SECTORAL DISTRIBUTION OF WORKERS, CHALAKUDI RIVER BASIN

Name of panchayat	Primary workers			Secondary workers			Tertiary workers		
	1971	1981	1991	1971	1981	1991	1971	1981	1991
Poyya	54.87	32.72	43.77	15.28	1.81	12.17	29.85	65.47	44.06
Puthenvelikkara	43.61	19.53	41.10	31.05	6.61	18.54	25.34	73.85	40.37
Kunnukara	71.85	44.51	49.26	12.42	0.94	21.08	15.72	54.56	29.67
Kuzhur	71.17	58.54	57.07	11.95	4.46	12.32	19.06	37.00	30.61
Mala	52.23	32.62	44.21	17.95	2.17	13.51	29.81	65.22	42.28
Alur	63.01	51.84	50.02	17.90	1.70	17.25	19.09	46.46	32.73
Kodakara	65.49	48.01	45.66	14.48	5.67	22.42	19.88	46.32	31.92
Chalakudi	38.28	22.10	25.82	20.56	2.85	20.38	35.04	75.05	53.80
Kadukutty	55.93	34.26	43.66	20.64	2.02	23.01	23.43	63.72	33.32
Annamanada	60.40	44.78	51.60	16.15	3.43	17.44	23.45	51.78	30.97
Parakkadavu	70.72	51.42	53.86	12.19	4.91	13.77	17.09	43.66	32.37
Nedumbassery	64.93	45.91	39.72	16.52	1.63	29.98	18.55	52.45	30.30
Angamali	23.51	23.88	34.63	26.91	4.96	20.89	49.58	71.16	44.48
Thuravoor	63.63	43.98	48.25	20.71	10.96	19.97	15.66	45.06	31.78
Manjapra	73.81	50.49	60.92	7.12	17.00	13.18	19.07	41.88	25.90
Mookkannur	78.90	57.31	64.51	7.88	3.96	10.32	13.22	38.73	25.17
Karukutty	73.41	56.46	55.19	11.04	2.74	12.98	16.97	40.81	31.83
Koretti	53.27	37.80	39.94	29.22	1.53	30.12	17.51	60.67	29.94
Melur	71.59	55.19	54.28	11.07	2.27	14.60	17.34	42.54	31.12
Pariyaram	77.14	62.60	63.06	4.23	1.24	8.80	18.63	36.16	28.12
Ayyampuzha	-	48.04	80.62	-	3.38	5.02	-	48.58	14.36
Athirappalli	77.24	12.95	76.63	2.51	1.75	5.70	20.25	85.30	17.67
Kodasseri	84.59	69.67	65.09	5.88	2.63	10.50	9.53	27.70	24.44
Mattathur	75.29	43.98	62.97	5.63	2.36	13.19	12.54	53.66	23.84
Kizhakkancherry	82.75	70.38	77.88	8.12	2.66	6.69	9.13	26.96	15.43
Nelliampathy	83.46	0.43	92.05	6.81	0.12	1.41	7.49	99.46	6.54
Kollengode	66.26	58.33	63.55	11.46	3.85	8.72	22.27	37.82	27.73
Chalakudi river basin	**65.28**	**43.62**	**54.98**	**14.06**	**3.34**	**15**	**20.21**	**53.04**	**30.03**

Table 2.30 provides the list of panchayats falling under each of these sample sites and their demographic details. Segments I and II representing lowland and midland are dominated by workers of non-primary sectors. Segment III (highland) has more than 63% of total workers under primary sector. Of this 63% as much as 1/3rd is in non-agricultural sector. The segments of IV a & IV b, in the forest area have 92% of total workers in primary sectors and all of them are engaged in non-agricultural sector. Distribution of workers indirectly indicate the landuse pattern and resource sectors that are being utilised.

Table 2.30 SAMPLE SITES, PANCHAYATS AND THEIR DEMOGRAPHIC CHARACTERISTICS (SELECTED), CHALAKUDI RIVER BASIN

Segment	Bio-physical zone	Panchayats	Popul-ation	Primary workers		Secondary workers	Tertiary workers	Total workers
				Agricultural labourers and cultivators	Others			
I	Lowland	Mala, Annamanada, Kuzhur, Puthenvelikkara, Kunnukara, Nedumbassery, Parakadavu	177389	21473	26119	9625	18664	54865
II	Midland	Alur, Chalakudi (M), Mala, Kadukutty, Koretti, Melur, Pariyaram, Kadasseri	202319	29020	33866	12449	25416	71730
III	Highland	Athirappalli, Pariyaram, Melur, Karukutty, Manjapra, Ayyampuzha	108430	15809	23089	3835	9473	36399
IV a & IV b	Forest	Nelliyampathy	9785	7	3911	60	278	4249

CHAPTER 3
LANDUSE/LANDSCAPE CHANGE

3.1 Introduction

Landuse/landscape changes in each of this five segments have been studied and the results are discussed here. Data were extracted from Survey of India maps, Indian Remote Sensing (IRS images and field investigation. The year of 1966-67 is considered as reference year for which Survey of India maps were available. Changes in landscape and landuse have been worked out separately. Landuse change indicates change from one use or cover type to another use/ cover type, whereas, landscape change results alteration in topographic condition. Landscape change occurs through landuse change, however, separate treatments is required to decipher impact of landuse change.

3.2 Landuse change

Land apparently immobile, can be made highly dynamic through use. The existing landuse pattern reflects the interaction among various biophysical and socio-economic elements in any given area. Therefore, study on landuse and its change can lead to understand the underlying processes involved there in. Detection of landuse/ landcover change is one of the main objectives of this project. Analysis of landuse change is therefore a central theme.

The main task is to prepare time-series landuse maps of the sample segments. To understand the changes taken place in the area during a period of about 30-35 years the topographical maps for the year 1966-’67 and 1980-’81, aerial photographs of 1990 and satellite images of 2000 have been used. The maps of current landuse practices are finalised through field verification. Landuse change in each segment is described separately.

3.2.1 The confluence of the Chalakudi and the Periyar river and surroundings

The Segment I constitutes the area surrounding the confluence of Chalakudi river and the Periyar river. This segment spreads over an area of 82 sq.km. It falls within the lowland unit. The base map was prepared from the Survey of India Topographical sheet. The area under different landuse categories for the years 1966-'67, 1980-'81, 1990 and 2003 were calculated and the results are given in Table 3.1.

The different landuse categories and their areal extent had been identified from the Survey of India Topographical sheet (1:50,000 scale) for the year 1966-'67. The major landuse categories according to 1966-'67 were paddy and settlement with mixed tree crops. They together occupied about 95% of the total area of the segment. Because of the uniformity of the terrain the landuse categories are less in this segment compared to the segment in the eastern part of Chalakudi town.

Landuse map for the year 1980-'81 for the same segment had been prepared to work out the changes in landuse pattern during the period of 14 years. This map had been prepared from Survey of India Topographical maps of 1:25,000 scale. The area under paddy had reduced to 36 sq.km from 42.40 sq.km. Area under settlement with mixed tree crops had increased significantly. All other categories had also registered increase in area in 1980-'81 except rubber plantations, which had been reverted back to settlement with mixed tree crops in 1980-'81.

Landuse map for the year 1990 of this segment had been prepared for identifying the subsequent changes. This map had been prepared from the Air photo. In 1990, the area under paddy had decreased to 31.40 sq.km from 42 sq.km in 1966-'67. The area under mixed tree crops and settlement with mixed tree crops increased remarkably in 1990.

Table 3.1 LANDUSE CATEGORIES AND THEIR AREAL EXTENT - AROUND THE CONFLUENCE OF THE CHALAKUDI AND THE PERIYAR

Category	Area 1966-'67		Area 1980-'81		Area 1990		Area 2003	
	Sq. Km	%	Sq. Km	%	Sq. Km	%	Sq. Km	%
Paddy/low land	42.39	51.97	35.94	44.06	31.40	38.50	16.94	20.77
Tree crops in low land and mixed tree crops	0.38	0.47	1.75	2.15	3.11	3.81	-	-
Settlement with Mixed Tree Crops	35.14	43.09	40.55	49.72	43.10	52.85	49.06	60.15
Seasonal crops	-	-	-	-	0.63	0.77	6.50	7.97
Mixed tree crops	-	-	-	-	-	-	1.95	2.39
Rubber plantation	0.55	0.67	-	-	-	-	0.35	0.43
Agglomerated settlement/built-up	0.01	0.01	0.21	0.26	0.21	0.26	1.21	1.48
Fallow land	-	-	-	-	-	-	0.81	1.00
Cultivable fallow	-	-	-	-	-	-	0.12	0.15
Stone quarry	0.04	0.05	0.06	0.07	0.06	0.07	0.06	0.07
Abandoned stone quarry	-	-	-	-	-	-	0.20	0.25
Clay mine	-	-	-	-	-	-	1.19	1.45
Brick klin	-	-	-	-	-	-	0.04	0.05
Laterite quarry	-	-	-	-	-	-	0.04	0.05
Abandoned laterite quarry	-	-	-	-	-	-	0.04	0.05
River	3.05	3.74	3.05	3.74	3.05	3.74	3.05	3.74
Total	**81.56**	**100.00**	**81.56**	**100.00**	**81.56**	**100.00**	**81.56**	**100.00**

The landuse map of 2003 (Fig. 3.1) had been prepared from satellite images. It is finalized after field verification. Area under paddy had decreased to 21% at present. Some area under paddy are now left as fallow land. The stone quarry is also found to be non-usable. New additions to landuse patterns in 2003 are fallow land, cultivable fallow, laterite quarry, abandoned laterite quarry and clay mining area. Rubber plantations occupy certain area which was previously under settlement with mixed tree crops. The area under mixed tree crops and settlement with mixed tree crops increased considerably. The landuse change map of 1980-2003 is shown in Figs. 3.2 and 3.3.

Compared to 1966-67 landuse categories have increased from 7 classes to 15 classes. It may be noted that the category of tree crops in lowland, which was separately marked till 1990, had not been marked in 2002. This is due to the fact that a sizable area under lowland had been diverted in this decade to accommodate mixed tree crops & settlements. Therefore there is little use to mark this category as separate unit.

A landuse conversion matrix had prepared to elucidate the category-wise change (Table 3.2). Major changes are observed in paddy and settlement with mixed tree crops. The area of paddy had reduced to accommodate settlement with mixed tree crops. Mixed tree crops, seasonal crops, agglomerated settlement, fallow and clay mines. Some portions of the settlement with mixed tree crops have altered to agglomerated settlement and rubber plantation. The area of agglomerated settlement have increased considerably. Clay mine, abandoned stone quarry, laterite quarry, abandoned laterite quarry, tile factory and fallow land and seasonal crops are the new additional categories in 2003. Present landuse in parts of this segment is evident in the Plate 1.

Table 3.2 LANDUSE CONVERSION MATRIX - AROUND THE CONFLUENCE OF THE CHALAKUDI AND THE PERIYAR (1980-2003)

	2003														
1980	P	TLC/MT	SMT	SC	RUB	AS	Fallow	SQ	ASQ	CM	T	LQ	ALQ	River	1980 Total
P	16.94	1.90	7.79	6.50	-	0.69	0.93	-	-	1.19	-	-	-	-	35.94
TCL/MT	-	0.05	1.70	-	-	-	-	-	-	-	-	-	-	-	1.75
SMT	-	-	39.57	-	0.35	0.31	-	0.05	0.15	-	0.04	0.04	0.04	-	40.55
SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RUB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AS	-	-	-	-	-	0.21	-	-	-	-	-	-	-	-	0.21
Fallow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SQ	-	-	-	-	-	-	-	0.01	0.05	-	-	-	-	-	0.06
ASQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ALQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.05
2003 Total	-16.94	1.95	49.06	6.50	0.35	1.21	0.93	0.06	0.20	1.19	0.04	0.04	0.04	3.05	81.56
Change sq.km.	-19.00	+0.20	+8.51	+6.50	+0.35	+100	+0.93	+0.2	+0.04	+1.19	+0.04	+0.04	+0.04	-	
Change %	-112.16	+10.26	+17.35	+100	+100	+82.64	+100	+100	+100	+100	+100	+100	+100	-	

P - Paddy, MT - Mixed tree crops, SMT - Settlement with mixed tree crops, SC - Seasonal crops, R - Rubber,
AS - Agglomerated settlement, F - Fallow, SQ - Stone quarry, ASQ - Abandoned stone quarry, CM - Clay mine,
T - Tile factory, LQ - Laterite quarry, ALQ - Abandoned laterite quarry

3.2.2 Chalakudi town and surroundings

The Segment II covers Chalakudi town and its surroundings spreading over an area of 69 Sq. Km. This segment falls within the midland unit. Landuse maps have been prepared for the years 1966-67, 1980-81 1989 and 2003. The results are given in Table 3.3.

Major landuse categories according to 1966-'67 were paddy and settlement with mixed tree crops. They together occupied about 94 % of the total area of the segment. Valleys were mainly being used for paddy cultivation. Settlements were agglomerated in Chalakudi town and other pockets like Koretti and Anallur. It may be noted here that even in 1966-'67 lowlands were given for tree crops and settlement purposes, albeit marginal (0.37%).

Landuse data for subsequent years (1980-81, 1989 & 2003) as provided in Table 3.3 had brought out that area under paddy had decreased from 40% in 1966-67 to 7.6% in 2003. The rate of change was 2% per annum during the period 1966-67 to 1989 and 3.6% per annum during the period 1989 to 2003. Area under agglomerated settlement had progressively increased to 10% in 2003 (Fig. 3.4) for a mere 1% in 1966-67. Comparing 1989 and 2003 data during past 11 years more than 2.5% of land became fallow. The landuse change map of 1980-2003 is shown in Figs. 3.5 and 3.6.

Landuse change maps worked under GIS environment indicate two specific trend: (1) changes in the lowlands/paddy fields and (2) changes in the areas of tree crops and settlement with mixed tree crops. Tree crops and settlements are mainly in the laterite terrain, which is relatively higher compared to paddy fields. Thus ecologically they are under two different landscape systems. As a result the nature of changes and their consequences will be different. A landuse conversion matrix (Table 3.4) had also been worked out. The purpose of this matrix is to elucidate the category wise change, so that actual dynamics is evidenced. The major conversion had occurred to paddy (Plate 2). The area previously used for cultivation of paddy had been given to settlement with mixed tree crops, agglomerated settlements and another seven type of uses. Rubber had been introduced in the sites of mixed tree crops. Seasonal crops, fallow land, abandoned stone quarry, clay mine, waste land and open space are the new additions in 2003.

Table 3.3 LANDUSE CATEGORIES AND THEIR AREAL EXTENT – IN AND AROUND CHALAKUDI TOWN

Category	Area 1966-'67		Area 1980-'81		Area 1989		Area 2003	
	Sq. Km	%	Sq. Km	%	Sq. Km	%		
Paddy/low land	27.76	40.20	17.38	25.17	15.49	22.44	5.24	7.59
Tree crops in low land	0.16	0.23	0.59	0.84	1.17	1.70	-	-
Settlement with Mixed Tree crops in lowland	0.10	0.14	0.62	0.90	1.26	1.82	-	-
Seasonal crops	-	-	-	-	0.67	0.97	1.21	1.72
Settlement with Mixed Tree Crops	37.45	54.24	45.02	65.20	45.01	65.18	48.30	69.94
Agglomerated Settlement/built-up	0.77	1.12	1.85	2.69	1.99	2.88	6.68	9.67
Mixed Tree Crops	0.12	0.17	0.08	0.12	-	-	1.49	2.16
Rubber plantation	-	-	0.12	0.17	0.12	0.17	0.27	0.39
Fallow land	-	-	-	-	-	-	1.71	2.48
Fallow (vacant)	-	-	-	-	-	-	0.04	0.06
Industrial Area	0.34	0.49	0.97	1.40	0.97	1.40	0.98	1.42
Stone Quarry	0.01	0.01	0.05	0.07	0.03	0.04	0.02	0.03
Abandoned stone quarry	-	-	-	-	-	-	0.04	0.06
Brick Klin	-	-	0.01	0.01	-	-	-	-
Tile factory	-	-	-	-	-	-	0.11	0.16
Mud Quarry	-	-	0.01	0.01	-	-	-	-
Laterite Quarry	-	-	0.01	0.01	-	-	-	-
Abandoned laterite quarry	-	-	-	-	-	-	0.06	0.09
Clay mine	-	-	-	-	-	-	0.41	0.59
Waste dumping area	-	-	-	-	-	-	0.08	0.12
Open space	-	-	-	-	-	-	0.07	0.10
River	2.35	3.40	2.35	3.40	2.35	3.40	2.35	3.40
Total	**69.06**	**100.00**	**69.06**	**100.00**	**69.06**	**100.00**	**69.06**	**100.00**

Table 3.4 LANDUSE CONVERSION MATRIX – IN AND AROUND CHALAKUDI TOWN (1980-2003)

	2003																		
1980	P	SC	SMT/ SMTL	AS	MT/ TCL	R	FL	F	SQ	ASQ	BK/TF	MQ	LQ	ALQ	CM	WL	OS	R	1980 Total
P	5.24	1.21	5.13	2.55	0.82	0.15	1.75	-	-	-	-	-	-	-	0.4	0.08	0.05	-	17.38
SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SMT/SMTL	-	-	43.17	2.28	-	-	-	0.01	0.01	-	0.1	-	-	0.05	-	-	0.02	-	45.64
AS	-	-	-	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.85
MT/TCL	-	-	-	-	0.67	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67
R	-	-	-	-	-	0.12	-	-	-	-	-	-	-	-	-	-	-	-	0.12
FL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F	-	-	-	-	-	-	-	0.97	-	-	-	-	-	-	-	-	-	-	0.97
SQ	-	-	-	-	-	-	-	-	0.01	0.04	-	-	-	-	-	-	-	-	0.05
ASQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BK/TF	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-		-	0.01
MQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	0.01
LQ	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	0.01
ALQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
CM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.35	2.35
2003 Total	5.24	1.21	48.30	6.48	1.49	0.27	1.75	0.98	0.02	0.04	0.11	-	-	0.06	0.41	0.08	0.07	2.35	69.06
Change sq. km.	-12.14	+1.21	+2.66	+4.83	+0.82	+0.15	+1.75	+0.01	-0.03	+0.04	+0.1	-0.01	-0.01	+0.06	+0.41	+0.08	0.07	-	
Change %	-231.68	+100	-5.51	+72.31	+55.03	+55.56	+100	+1.02	-150	+100	+90.91	-100	-100	+100	+100	+100	-	-	

P - Paddy, SC - Seasonal Crops, SMT - Settlement with mixed tree crops, AS - Agglomerated settlement, MT - Mixed tree crops

R - Rubber plantation, FL - Fallow land, F - Fallow vacant, SQ - Stone quarry, ASQ - Abandoned stone quarry, BK/TF - Brick klin/Tile factory,

MQ - Mud quarry, LQ - Laterite quarry, ALQ - Abandoned laterite quarry, CM - Clay mine, WL - Waste land, OS - Open space, R - River

3.2.3 Thumburmuzhi and surroundings

The third segment for detailed study on landuse is selected to the eastern part bordering the forest area. Data for the years of 1966-'67, 1980-'81, 1987 and 2003 have been computed (Table 3.5). In this segment also paddy field recorded significant decrease in area from 25 % in 1966-'67 to 12 % in 1980-'81. Forest area had also reduced in this period. Three categories of landuse, namely Teak plantation, Cashew plantation and stone quarry were the new additions in 1980-'81.

Detailed analysis of maps had necessitated recognising two additional landuse categories, viz. vacant land and other trees for 1981 landuse map. Accordingly, some modifications had been worked out (refer Table 3.5). While data for the year 1987 was available from Air Photo and the 2003 map was based on field study. Oil palm was introduced after 1980-'81. Comparison of landuse maps of 1980-'81 and 1987 indicated that oil palm had replaced the rubber plantation. In this period also paddy continued to show declining trend. It had decreased from 12% to 4.90% and by 2003 all paddy fields had been diverted. Cashew plantation was completely replaced by rubber plantation in 2003. There is also a decrease in the category of area under settlement with mixed tree crops. This is because some of the mixed tree cropped area within this category was given way for rubber plantation in 2003 (Fig. 3.7). Considerable increase in area under oil palm had also been marked. New paper pulp factory covered certain area under the category of settlement with mixed tree crops. Grasslands were marked within the forest area.

The forest area had decreased from 40.7% in 1966-67 to 16.6 % in 2003. Area under settlement with mixed tree crops increased form 8.6 % to 37.78%.

A landuse conversion matrix had also been worked out (Table 3.6). The major conversion had occurred to paddy and forest. The area previously used for cultivation of paddy had been given mainly for settlement with mixed tree crops and also for, seasonal corps, mixed tree crops, agglomerated settlement, recreational area, rubber and teak plantation. The area of forest had reduced to accommodate rubber plantation, teak plantation, oil palm (Plates 3, 4 and 5), settlement with mixed tree crops and seasonal crops. Some area of deforestation is also observed in 2003. The area of cashew plantations has changed to rubber and seasonal crops. The landuse change map of 1980-2003 is shown in Figs. 3.8 and 3.9.

Table 3.5 LANDUSE CATEGORIES AND THEIR AREAL EXTENT – IN AND AROUND THUMBURMUZHI

Category	Area 1966-'67		Area 1980-'81		Area 1987		Area 2003	
	Sq. Km	%	Sq. Km	%	Sq. Km	%	Sq. Km	%
Paddy/low land	7.07	25.34	2.82	12.31	1.37	4.91	-	-
Seasonal crops	-	-	-	-	-	-	0.85	3.05
Settlement with Mixed Tree Crops	2.40	8.60	7.76	26.74	7.46	26.75	10.54	37.78
Mixed tree crops	1.59	5.70	0.16	0.57	2.51	9.00	0.08	0.29
Agglomerated settlement	-	-	-	-	-	-	0.20	0.72
Recreational area	-	-	-	-	-	-	0.18	0.65
Rubber plantation	3.12	11.18	4.85	17.41	4.88	17.49	3.56	12.80
Teak plantation	-	-	0.48	1.72	0.48	1.72	1.27	4.55
Cashew plantation	-	-	0.49	1.76	0.49	1.75	-	-
Forest	11.36	40.71	8.99	32.22	8.16	29.24	4.63	16.59
Forest blank	-	-	-		-	-	0.76	2.72
Oil palm	-	-	-		0.19	0.68	3.15	11.29
Grass land	-	-	-		-	-	0.27	0.97
Vacant land	-		0.07	0.25	0.08	0.29	-	-
Factory	-	-	-		-	-	0.13	0.47
Sheet rock	0.09	0.32	0.01	0.04	0.01	0.04	-	-
Stone quarry	-	-	0.001	0.004	0.001	0.004	0.01	0.04
River	2.27	8.14	2.27	8.14	2.27	8.14	2.27	8.14
Total	**27.90**	**100.00**	**27.90**	**100.00**	**27.90**	**100.00**	**27.90**	**100.00**

Table 3.6 LANDUSE CONVERSION MATRIX - IN AND AROUND THUMBURMUZHI (1980-2003)

	2003																		
1980	P	SC	SMT	MT	AS	RA	R	T	CH	Fo	FB	OP	G	V	F	SR	SQ	R	1980 Total
P	-	0.18	2.21	0.08	0.05	0.05	0.09	0.12	-	-	-	-	0.04	-	-	-	-	-	2.82
SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SMT	-	-	6.42	-	0.15	0.13	0.60	0.10	-	-	-	-	0.23	-	0.13	-	-	-	7.76
MT	-	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16
AS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	0.20	0.93	-	-	-	1.16	0.04	-	-	-	2.52	-	-	-	-	-	-	4.85
T	-	-	0.09	-	-	-	0.24	0.15	-	-	-	-	-	-	-	-	-	-	0.48
CH	-	0.31	-	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-	-	0.49
FO	-	0.16	0.67	-	-	-	1.28	0.86	-	4.63	0.76	0.63	-	-	-	-	-	-	8.99
FB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
QP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	-	-	0.06	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	0.07
F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	0.01
SQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.001	-	0.001
R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.27	2.27
2003 Total	-	0.85	10.54	0.08	0.20	0.18	3.56	1.27	-	4.63	0.76	3.15	0.27	-	0.13	-	0.011	2.27	27.90
Change sq.km.	-2.82	+0.85	+2.78	-0.08	+0.20	+0.18	-1.29	+0.79	-0.49	-4.36	+0.76	+3.45	+0.27	-0.07	+0.13	-0.01	0.010	-	-
Change %	-100	+100	+26.38	-100	+100	+100	-36.24	+62.20	-100	-94.17	+100	+100	+100	-100	+100	-100	90.91	-	-

P - Paddy, SC - Seasonal crops, SMT – Settlement with mixed tree crops, MT - Mixed trees, AS - Agglomerated settlement,

RA - Recreational area, R - Rubber, T - Teak, CH – Cashew, Fo - Forest, BF - Forest blank, OP - Oil palm, G - Grassland,

V - Vacant land, F - Factory, SR - Sheet rock, SQ – Stone quarry, R - River

3.2.4 Parambikulam reservoir area

This segment site is under forest area in the high ranges. Five landuse categories had been identified through interpretation of Survey of India topographical maps for the year 1975-'76. There was not much landuse variation in earlier maps except reservoir. Major landuse categories according to 1975-'76 were forest, teak plantation, agglomerated settlements, tribal settlements and some amount of rocky waste (Table 3.7).

Table 3.7 LANDUSE CATEGORIES AND THEIR AREAL EXTENT - AROUND PARAMBIKULAM RESERVOIR

Category	1975-'76		1990		2003	
	sq.km.	%	sq.km.	%	sq.km.	%
Forest	50.60	44.73	47.06	41.60	47.06	41.60
Teak	39.86	35.23	40.12	35.47	40.25	35.58
Tribal settlement	0.36	0.32	0.36	0.32	0.45	0.40
Agglomerated settlement	0.29	0.26	0.29	0.26	0.25	0.22
Other forest plantation	-	-	2.12	1.87	2.14	1.89
Forest blank	-	-	0.31	0.27	0.32	0.28
Grassland	-	-	0.64	0.57	0.64	0.57
Rocky waste	2.37	2.10	2.58	2.28	2.37	2.10
Reservoir	18.93	16.74	18.93	16.74	18.93	16.74
River	0.70	0.62	0.70	0.62	0.70	0.62
Total	**113.11**	**100.00**	**113.11**	**100.00**	**113.11**	**100.00**

Landuse map for the year 1990 of this segment had been prepared from aerial photographs for detecting changes. Some portion of forest had given place to teak and other forest plantations. Patches of grasses were observed between teak plantations. Forest blanks were also found.

Current landuse map (2003) of this area had been prepared through field verification (Fig. 3.10). There were not much change observed during the period 1990 to 2003. The area under teak plantation is found to have decreased and that under other forest plantation has increased. However, the change are marginal, limited to less than 1 %. The landuse change map from 1975 to 2003 is shown in Fig. 3.11. Plate 6 shows the reservoir and surroundings.

A landuse conversion matrix had been prepared (Table 3.8). The area of forest had changed to teak plantation, other forest plantation and forest blank. Grassland, other forest plantations and forest blank are the new categories in 2003.

Table 3.8 LANDUSE CONVERSION MATRIX -AROUND PARAMBIKULAM RESERVOIR (1975-2003)

	2003										
1975	F	T	TS	AS	OFP	FB	GL	RW	RC	R	1975 Total
F	47.06	1.94	-	-	1.28	0.32	-	-	-	-	50.60
T	-	38.31	0.05	-	0.86	-	0.64	-	-	-	39.86
TS	-	-	0.36	-	-	-	-	-	-	-	0.36
AS	-	-	0.04	0.25	-	-	-	-	-	-	0.29
OFP	-	-	-	-	-	-	-	-	-	-	-
FB	-	-	-	-	-	-	-	-	-	-	-
GL	-	-	-	-	-	-	-	-	-	-	-
RW	-	-	-	-	-	-	-	2.37	-	-	2.37
RC	-	-	-	-	-	-	-	-	18.93	-	18.93
R	-	-	-	-	-	-	-	-	-	0.70	0.70
Total 2003	47.06	40.25	0.45	0.25	2.14	0.32	0.64	2.37	18.93	0.70	113.11
Change sq.km.	-3.54	+0.39	+0.90	-0.04	+2.14	+0.32	0.64	0.00	0.00	0.00	-
Change %	-7.52	+0.97	+200	-16	+100	+100	-	-	-	-	-

F – Forest, T - Teak, TS - Tribal settlement, AS - Agglomerated settlement, OFP - Other forest plantation, FB - Forest blank, GL - Grass land, RW - Rocky waste, Re - Reservoir, R - River

3.2.5 Lower Karapara river area

As in the Parambikulam reservoir portion, landuse maps for the year 1975-‘76, 1990 and 2003 had been prepared. The landuse categories according to 1975-‘76 consisted mainly of forest, settlements, coffee, tea and open scrubs. It was found that some portion of forest area had been converted to open scrubs. Forest blanks are also recorded as a n additional category. The categories of cardamom, forest blank and rock outcrops could be marked in 1990. Extension of grassland was found to have increased from 1976 to 1990 (Table 3.9). Since 1990 the area under grasslands remained the same. However the rate of increase of landuse change was higher in the period between 1975-‘76 to 1990 than that in the period of 1990 to 2003. A conversion matrix from 1975 to 2003 is prepared (Table 3.10). The landuse map of 2003 and landuse change map of 1975-2003 is shown in Figs. 3.12 and 3.13 respectively.

Table 3.9 LANDUSE CATEGORIES AND THEIR AREAL EXTENT-AROUND LOWER KARAPARA RIVER

Category	1975-'76		1990		2003	
	sq.km.	%	sq.km.	%	sq.km.	%
Forest	43.31	54.20	37.62	47.07	37.62	47.07
Open scrubs	3.99	4.99	7.54	9.44	7.54	9.44
Cardamom	-	-	2.78	3.48	2.94	3.68
Coffee	23.98	30.01	17.56	21.98	17.51	21.91
Tea	6.29	7.87	10.47	13.10	10.36	12.97
Settlement	1.75	2.19	1.75	2.19	1.75	2.19
Agglomerated settlement	0.18	0.23	0.18	0.23	0.18	0.23
Forest blank	-	-	1.20	1.50	1.20	1.50
Grassland	0.07	0.09	0.37	0.46	0.37	0.46
Institutional area	0.19	0.24	0.19	0.24	0.19	0.24
Rocky outcrop	-	-	0.10	0.13	0.10	0.13
River	0.14	0.18	0.14	0.18	0.14	0.18
Total	**79.90**	**100.00**	**79.90**	**100.00**	**79.90**	**100.00**

Table 3.10 LANDUSE CONVERSION MATRIX – AROUND LOWER KARAPARA RIVER (1975-2003)

	2003										
1975	F	OS	T, C, Ca	S	AS	FB	GL	IA	RO	R	1975 Total
F	37.62	3.66	-	0.33	-	1.40	0.3	-	-	-	43.31
OS	-	3.88	-	0.01	-	-	-	-	0.10	-	3.99
T, C & Ca	-	-	30.27	-	-	-	-	-	-	-	30.27
S	-	-	-	1.75	-	-	-	-	-	-	1.75
AS	-	-	-	-	0.18	-	-	-	-	-	0.18
FB	-	-	-	-	-	-	-	-	-	-	-
GL	-	-	-	-	-	-	0.07	-	-	-	0.07
IA	-	-	-	-	-	-	-	0.19	-	-	0.19
RO	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	0.14	0.14
2003 Total	37.62	7.54	30.27	2.09	0.18	1.40	0.37	0.19	0.10	0.14	79.90
Change	-5.69	3.55	-	0.34	-	1.40	0.30	-	0.10	-	-
Change %	-15.12	47.08	-	16.27	-	100	81.08	-	100	-	-

F - Forest, OS - Open scrubs, T, C & Ca - Tea, coffee & cardamom, S - Settlement, AS - Agglomerated settlement

3.3 Landscape change

Landscape change is primarily a result of landuse change. Studies in three segments are presented here. Ecological impact of landuse change partly takes place through landscape change, which is manifested through redistribution of materials, change in slope form and hydrological condition. Brief discussion on the three segments will elucidate the points further.

3.3.1 The confluence of the Chalakudi and the Periyar river and surroundings

This segment is dominated by fluvial landforms. The major landscape categories identified for the year 1980-81 included back swamps, levee, lateritic garden land and alluvial garden land. They together comprises about 86% of the total study area (Table 3.11). Back swamps were mainly used for paddy cultivation. Settlement with mixed tree crops were observed in the levee, lateritic garden land and alluvial garden land. The lateritic garden lands are usually at an elevation of about 10 m and above.

Three additional landscape categories could be identified in the year 2002-03. They are clay mines, fallow land and abandoned stone quarry. Intensive clay mining activities are prominent in these areas as this locality has a good reserve of clay (Plate 7). The clay mining sites are well recorded in satellite image. The cultivable fallow lands are the agricultural land which remains presently uncultivated. The abandoned stone quarries are found in certain places. Rain water accumulates in these sites, which are hardly used. Management of these abandoned quarries is a serious issue concerning the whole State. Considerable reduction in the area under back swamps and valleys were noticed, where as the area under alluvial garden land and urban landscape showed an increasing trend during this period.

Changes were detected by superimposing the landscape map of 1980-'81 and 2002-'03. The landscape change during the period are depicted through Fig. 3.14. To avoid the overcrowding of categories a part of the actual study is represented here. 24 %

of the total study area experienced changes of one type or other during a period of 2 decades.

Table 3.11 LANDSCAPE CATEGORIES AND THEIR AREAL EXTENT – AROUND THE CONFLUENCE OF THE CHALAKUDI AND THE PERIYAR

Category	1980-'81		2002-2003	
	Sq. Km	%	Sq. Km	%
Back Swamps	28.31	34.27	11.23	13.60
Valleys	4.04	4.89	1.84	2.23
Levee	12.95	15.69	12.93	15.65
Alluvial garden land	17.01	20.59	34.28	41.50
Lateritic garden land	12.86	15.57	12.65	15.30
Urban landscape	0.11	0.13	0.22	0.27
Clay mine	-	-	1.09	1.32
Fallow land (cultivable & water logged)	-	-	0.88	1.07
Stone quarry	0.06	0.07	0.18	0.22
Abandoned stone quarry	-	-	0.04	0.05
Braided bar	1.11	1.34	1.11	1.34
River/water body	6.15	7.45	6.15	7.45
Total	**82.60**	**100.00**	**82.60**	**100.00**

Landscape in the low-lying areas can be broadly classified as zone of convergence and zone of divergence in view of their surface hydrological functions. Landscape change leads to alter these functions. The back swamps and valleys (zone of convergence) had reduced to accommodate alluvial garden land, urban landscape, clay mine and fallow land (Table 3.12). Some portions of the levee, alluvial garden land and lateritic garden land had also been altered to urban landscape. The temporal changes in the urban-sprawl reflect urbanisation trend around the back swamps and valleys. The urban landscape, the zone of intensive human action, had increased by 200 times. The wetland was initially found as a single patch of marshy waterfowl habitat with some open water body. It had been fragmented into a large number of landscape units over the years and the human activity had caused reduction of the waterfowl habitat. The operations at clay mines and stone quarries had resulted in changing the positive relief (upland) to negative relief (ditches).

Table 3.12 LANDSCAPE CONVERSION MATRIX- AROUND THE CONFLUENCE OF THE CHALAKUDI AND THE PERIYAR (1980-2003)

	2003												
1980	Le	BS	AG	LG	V	UL	CM	FL (C & W)	BB	SQ	ASQ	R	1980 total
Le	12.93	-	-	-	-	0.02	-	-	-	-	-	-	12.95
BS	-	11.23	15.19	-	-	-	1.06	0.83	-	-	-	-	28.31
AG	-	-	16.97	-	-	0.04	-	-	-	-	-	-	17.01
LG	-	-	-	12.65	-	0.05	-	-	-	0.16	-	-	12.86
V	-	-	2.12	-	1.84	-	0.03	0.05	-	-	-	-	4.04
UL	-	-	-	-	-	0.11	-	-	-	-	-	-	0.11
CM	-	-	-	-	-	-	-	-	-	-	-	-	-
FL	-	-	-	-	-	-	-	-	-	-	-	-	-
BB	-	-	-	-	-	-	-	-	1.11	-	-	-	1.11
SQ	-	-	-	-	-	-	-	-	-	0.02	0.04	-	0.06
ASQ	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	6.15	6.15
2003 total	12.93	11.23	34.28	12.65	1.84	0.22	1.09	0.88	1.11	0.18	0.04	6.15	82.60
Change in sq.km	-0.02	-17.08	+17.27	-0.21	-2.2	+0.11	+1.09	+0.88	-	+0.12	+0.04	-	-
Change in %	-0.15	-60.33	+101.53	-1.63	-54.46	+100	+100	+100	-	+200	+100	-	-

Le-Levee, BS-Back Swamps, AG-Alluvial Gardenland, LG-Laeritic Gardenland, V-Valley, UL-Urban Landscape, CM-Clay Mine, FL-Fallow Land (cultivable & water logged), BB-Braided Bar, SQ-Stone Quarry, ASQ-Abandoned Stone Quarry, R-River

In other words high relief areas were being converted to depressions. The alluvial garden lands (zone of divergence) had increased from 21% to 42%. Back swamps and valleys were mostly converted to this category. Settlement expansion is the major underlying cause leading to this change. When the back swamps and valleys are changing to settlement and other agricultural practices which are unsuitable to wetland condition, the water holding capacity of the soil will be affected. This will have adverse effect in the ground water resources of the region on the long run.

3.3.2 Chalakudi town and surroundings

To analyse the landscape changes taken in the area during a period of 12 years, two time series of maps had been prepared. Landscape map of the year 1980-'81 was based on the Survey of India topographical map (1:25,000 scale) and the landscape map of the year 2003 was prepared from the imagery.

The major landscape categories identified in 1980-'81 include valley, backswamps, levee, lateritic garden land, alluvial garden land and urban/ industrial landscape (Plate 8). Lateritic garden land was the major landscape category. It occupied about 52.38% of the total area of the basin followed by the valley occupying 22.53% of the total area of the basin (Table 3.13).

Table 3.13 LANDSCAPE CATEGORIES AND THEIR AREAL EXTENT - IN AND AROUND CHALAKUDI TOWN

Category	1980-'81		2003	
	Area	%	Area	%
Backswamps	3.54	5.13	0.84	1.22
Valley	15.63	22.63	4.44	6.43
Levee	1.21	1.75	1.21	1.75
Lateritic garden land	36.24	52.48	33.89	49.07
Alluvial garden land	7.84	11.35	17.82	25.81
Urban landscape	2.09	3.04	5.14	7.44
Industrial landscape	0.11	0.16	0.63	0.92
Stone quarry	0.03	0.04	0.01	0.01
Mud quarry	0.01	0.01	-	-
Lateritic quarry	0.01	0.01	-	-
Clay mine	-	-	1.01	1.46
Abandoned stone quarry	-	-	0.02	0.03
River	2.19	3.17	2.19	3.17
Water body	0.16	0.23	0.16	0.23
Cultivable fallow	-	-	1.70	2.46
Total	**69.06**	**100.00**	**69.06**	**100.00**

The valleys and back swamps were mainly used for paddy cultivation. Settlement with mixed tree crops were the major landuse practiced in levee, lateritic garden land and alluvial garden land. Three additional landscape categories could be identified in the year 2002-'03. These were clay mines, fallow land and abandoned stone quarry. Two landscape categories namely mud-quarry and latertic quarry were not identifiable in the year 2003. The area under valleys and backswamps had reduced and the area under lateritic garden land and alluvial garden land had increased during this period. Amongst these the area of alluvial garden land had increased considerably. It is observed that the areal extent of valleys and backswamsps had reduced to accommodate alluvial garden land, urban/ industrial landscape and clay mines and fallow land (Fig. 3.15). The landscape change matrix (Table 3.14) highlights these conversions.

Table 3.14 LANDSCAPE CONVERSION MATRIX – IN AND AROUND CHALAKUDI TOWN (1980-2003)

	2003															
1980	BS	V	Lev	LG	AG	UL	IL	SQ	ASQ	MQ	LQ	CM	CF	R	WB	1981 Total
BS	0.84	-	-	-	1.32	0.08	-	-	-	-	-	1.00	0.3	-	-	3.54
V	-	4.44	-	-	9.05	0.74	-	-	-	-	-	1.42	1.4	-	-	15.63
Lev	-	-	1.21	-	-	-	-	-	-	-	-	-	-	-	-	1.21
LG	-	-	-	33.88	-	1.84	0.52	-	-	-	-	-	-	-	-	36.24
AG	-	-	-	-	7.45	0.39	-	-	-	-	-	-	-	-	-	7.84
UL	-	-	-	-	-	2.09	-	-	-	-	-	-	-	-	-	2.09
IL	-	-	-	-	-	-	0.11	-	-	-	-	-	-	-	-	0.11
SQ	-	-	-	-	-	-	-	0.01	0.02	-	-	-	-	-	-	0.03
ASQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MQ	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	0.01
LQ	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	0.01
CM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	-	-	2.19	-	2.19
WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16	0.16
2003 Total	0.84	4.44	1.21	33.89	17.82	5.14	0.63	0.01	0.02	-	-	1.01	1.7	2.19	0.16	69.06
Change	-2.7	-11.2	-	-2.35	+9.98	+3.05	+0.52	-0.02	+0.02	-0.01	-0.01	1.01	1.7	-	-	-
Change in %	-321	-252.48	-	-6.93	+56	+59.34	+82.54	-200	+100	-100	-100	+100	100	-	-	-

BS - Back swamps, V - Valley, Lev - Levee, LG - Lateritic gardenland, AG - Alluvial gardenland,
UL - Urban landscape, IL - Industrial landscape, SQ - Stone quarry, ASQ - Abandoned stone quarry,
MQ - Mud quarry, LQ - Laterite quarry, CM - Clay mine, CT - Cultivable fallow, R - River, WB - Water body

3.3.3 Thumburmuzhi and surroundings

This segment is adjacent to the hilly forest area. Two time series maps had been prepared. Landscape map of the year 1980-'81 was prepared using the Survey of India topographical map (1:25,000 scale) and the landscape map of the year 2003 was prepared from the image.

Major landscape categories identified in the year 1980-'81 included a valley, slope, terraced slope and hill area. Sloping land constitutes 36% of the total area of the segment. Terraced slope and valley constitute 21.5% and 10.10% of the total area, respectively (Table 3.15). Garden land and urban/industrial landscape were the additional categories identifiable in 2003 (Fig. 3.16). These units mostly occupy the valley segment.

The category of slope had given place to terraced slope, industrial area and agglomerated settlement (Table 3.16). Slope configuration changes with terracing while the length of slope increased resulting in longer travel time for water and sediment, it also facilitates infiltration.

Table 3.15 LANDSCAPE CATEGORIES AND THEIR AREAL EXTENT - IN AND AROUND THUMBURMUZHI

Category	1980-'81		2003	
	Area	%	Area	%
Valley	2.82	10.10	0.16	0.57
Slope	10.06	36.06	8.55	30.65
Terraced slope	6.00	21.51	9.04	32.40
Hill	6.75	24.19	4.95	17.74
Urban/industrial landscape	-	-	0.10	0.36
Garden land	-	-	2.83	10.14
River	2.27	8.14	2.27	8.14
Total	**27.90**	**100.00**	**27.90**	**100.00**

Table 3.16 LANDSCAPE CONVERSION MATRIX – IN AND AROUND THUMBURMUZHI

(1980-2003)

	2003								
1980	H	V	TS	S	IL	AS	GL	R	1980 Total
H	4.95	-	1.74	0.06	-	-	-	-	6.75
V	-	0.18	0.01	-	0.01	-	2.62	-	2.82
TS	-	-	6.00	-	-	-	-	-	6.00
Slope	-	-	1.52	8.45	0.06	0.03	-	-	10.06
IL	-	-	-	-	-	-	-	-	-
AS	-	-	-	-	-	-	-	-	-
GL	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	2.27	2.27
Total 2003	4.95	0.18	9.27	8.51	0.07	0.03	2.62	2.27	27.90
Change sq.km.	-1.8	-2.64	+3.27	-1.55	+0.07	+0.03	+2.62	-	-
Change %	-36.36	-1466.67	+35.28	-18.21	+100	+100	+100	-	-

H - Hill, V - Valley, TS - Terraced slope, S - Slope, IL - Industrial landscape,
AS - Agglomerated settlement, GL - Garden land, R - River

Impact of terracing is yet to be fully realised. It accrues a number of benefits with respect to land and water arrangement, no doubt, however, it also restricts movement of sediments and associated nutrients that may affect certain nutrient cycles.

CHAPTER 4
ENVIRONMENTAL IMPACT/CONSEQUENCES

4.1 Introduction

Environmental impact/consequences of landuse/landscape changes have been discussed in this section. Water is considered to be an indicator that reflects condition of a drainage basin. Amount of water that comes out from a watershed depends upon a number of factors, of which the dynamic one is the landuse/land cover. Quality of water reflects the quality of ground cover, given similar geoecological conditions. This chapter intends to discuss quality variation in the surface and well water as related to landuse/land cover change.

4.2 Quality of river water

Water samples have been collected from 28 locations distributed throughout the basin from Poringalkuttu reservoir to confluence of Chalakudi river with the Periyar. Landuse variations were taken into consideration while selecting sample sites (Fig. 4.1). Brief description of all sample location and landuse pattern is given in Table 4.1. Water samples were anlysed for time point. July, 2..1, August, 2001, November, 2001, March, 2002 and June 2002. Both physico-chemical and microbiological analysis were attempted. Altogether 15 sites had been selected for sampling in and around Chalakudi town during the months of July, 2001. Confluence points of tributaries, which drain into the main river had been considered as sampling site in order to infer the contributors to water quality status at the micro-watershed level.

The samples were analysed for individual chemical parameters. Nitrate and phosphate provide valuable insight into current landuse practices. Nitrate, specifically, can be directly correlated to high anthropogenic discharge, as one would expect from a highly urbanised area. Nitrate and phosphate can also be attributed to excessive fertilizer application observed within areas of intense tree crop cultivation, found in the landuse category of settlement with mixed tree crops. Station 13 shows high values of NO_3-N,

NO_2-N, Ca and Conductivity during the month of July, 2001 (Table 4.2). This is due to the human activities in the urban area. Whereas, the reason for high nitrate values for stations 8 and 10 are the uses of fertilizers and also the human impacts. Station 10 represents a large watershed and thus the dilution of nitrate was high. Though station 8 represents a smaller area the concentration of nitrate was high. The station 19 showed high values of hardness and conductivity. The hardness can be attributed to the fish feeds and high conductivity was possibly due to saline water intrusion.

Table 4.1 DESCRIPTION ABOUT THE RIVER WATER SAMPLING SITES, CHALAKUDI RIVER BASIN

Stn.	**Location**	**Landuse Pattern**
1	Poringalkuttu Reservoir	Forest
2	From the main river	Forest
3	A tributary near Vettilampara	Rubber plantation
4	Kannankuzhi thodu, a fifth order basin of Chalakudi, near the bridge at Kannankuzhi	Forest
5	A tributary near Arurumuzhi	Plantation
6	From the main river	Oil palm
7	From the main river	Mixed tree crops
8	3 km east of Kanjirapalli from a tributary	Settlement with mixed tree crops
9	From the main river near Kanjirapally	Settlement with mixed tree crops
10	Kappa thodu, 600 m north-east of Pariyaram near the bridge	Settlement with mixed tree crops
11	From the main river, near the bridge, $1^1/_2$ km south of Chalakudi town	Settlement with mixed tree crops
12	From a tributary draining from Chalakudi town	Urban settlement
13	1 km north of Chalakudi town near the bridge on a tributary of Chalakudi river	Urban settlement
14	600 m north-west of PWD Rest House, Chalakudi town, near the bridge at the confluence point of tributaries draining northern part of Chalakudi town	Uncultivated paddy
15	From a tributary north of Chalakudi town	Paddy
16	From a tributary	Paddy
17	From a tributary	Settlement with Mixed Tree crops
18	From a tributary	Paddy
19	500 m northeast of Annallur near the bridge on a tributary	Paddy
20	$1^1/_2$ km southwest of Annallur near the bridge on a tributary	Paddy
21	From the main river, near the bridge in Kadukuty	Settlement with Mixed Tree crops
22	From a tributary, south of Kadukutty	Settlement with Mixed Tree crops
23	From the main river, east of Annamanada	Settlement with Mixed Tree crops

Contd…

24	From the main river, east of Poovattusseri	Settlement with Mixed Tree crops
25	From the main river, west of Muzhikulam	Settlement with Mixed Tree crops
26	From the main river, east of Elanthikara, before it joins with the river Periyar	Settlement with Mixed Tree crops
27	From the river Periyar, after Chalakudi river joins	Settlement with Mixed Tree crops
28	From the river Periyar, before Chalkudy river joins	Settlement with Mixed Tree crops

There were 15 sample sites during July, 2001 (Table 4.2). Sample numbers increased to 20 in the month of August, 2001 and 28 for the month of November. This was necessary after analysing the first set of results for the month of July, when it was understood that for meaningful results appropriate sample with baseline characteristics were required.

Physico-chemical analysis covering 17 parameters and microbiological analysis covering 3 items were provided in Tables 4.3 and 4.4. The station 13 recorded the highest NO3-N and low pH. The station 12 also showed similar character in the moth of August, 2001.

Water quality varies over the months due to fluctuations of rainfall and discharge. It also varies spatially on account of landuse change.

Correlation had been worked out for Total Dissolved Solids (TDS) and Total Phosphorous for samples taken from Chalakudi river (Fig. 4.2). Due to turbid nature of river water in the monsoon months all samples appears to be concentrated (ref. Table 4.3).

NO_3-N was the highest in station 12 during the month of November, 2001. Microbiological analysis had been done covering total coliforms, faecal coliforms and faecal streptococci of all the samples collected in the month of August and November. It was found that water in the river stretch flowing through urban area (samples 12 and 13) was highly affected (Tables 4.5 and 4.6).

Correlation had been worked out for Total Dissolved Solids (TDS) and Total Phosphorous (Fig. 4.3).

Table 4.2 PHYSICO - CHEMICAL PARAMETERS - CHALAKUDI RIVER BASIN, JULY, 2001

Stn	pH	DO mg/l	NO_2 - N mmol/l	NO_3 - N mmol/l	PO_4- P mmol/l	Conductivity mmhos	Chloride mg/l	Total Alkalinity mg/l	TH mg/l	Ca mg/l	Mg mg/l	TSS mg/l	TDS mg/l	Total Phosphorous mmol/l
4	6.43	7.00	0.10	0.73	0.05	27	81.14	20	20	1.34	4.05	0.004	14.43	0.52
5	6.68	6.60	0.15	1.97	0.05	24	40.57	30	5	2.67	0.31	0.003	12.78	0.52
8	7.10	6.34	0.15	25.04	0.10	40	40.57	10	20	2.67	3.24	0.004	24.30	1.87
10	7.02	6.45	0.02	22.82	0.10	42	40.57	30	10	2.67	0.81	0.014	22.10	0.90
11	6.90	7.00	-	8.35	2.55	37	40.57	20	20	2.67	3.24	0.014	19.41	6.17
13	7.04	0.69	16.69	118.50	6.11	246	101.42	40	50	8.02	4.80	-	-	18.90
14	7.26	5.75	0.15	15.90	1.85	77	50.71	30	10	2.67	0.81	-	-	5.70
19	6.82	-	0.19	3.78	0.05	76	101.42	20	20	2.67	3.24	-	35.89	3.90
20	7.04	4.26	0.41	7.61	0.02	57	40.57	30	20	5.34	1.62	0.003	41.51	5.92

Table 4.3 PHYSICO - CHEMICAL PARAMETERS - CHALAKUDI RIVER BASIN, AUGUST, 2001

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosphorous	Total Iron
	Water	Atm.		mg/l	mg/l	μmol/l	μmol/l	μmol/l	μmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(μmol/l)	(μg/l)
1	23.5	23.0	6.94	8.88	3.40	0.48	12.15	2.63	33	2.03	16	12	3.21	0.97	0.0016	16.97	10.20	18.6
4	22.5	24.0	6.26	8.88	2.96	0.02	1.27	2.95	23	2.03	16	40	1.60	8.74	0.0040	16.20	16.40	18.6
5	23.0	24.0	6.11	9.34	2.98	0.16	2.42	2.04	21	2.03	16	12	1.60	1.94	0.0036	16.40	13.80	987.4
6	23.0	23.5	6.35	9.77	3.26	0.80	28.90	2.50	29	2.03	16	12	3.21	0.97	0.0320	16.73	16.40	9.31
8	25.0	24.5	6.10	5.92	1.33	0.36	24.90	2.95	44	2.03	12	16	3.21	1.94	0.0004	26.40	12.10	18.6
9	23.0	22.0	6.20	8.29	5.03	1.03	3.64	2.87	54	2.03	20	20	6.41	0.97	0.0016	29.50	2.82	27.9
10	24.0	22.0	6.50	7.40	2.52	0.06	11.06	2.85	40	2.03	16	16	4.81	0.97	0.0004	20.40	19.10	27.9
11	24.0	23.0	6.83	7.99	2.81	0.18	1.87	2.85	31	2.03	16	12	4.81	Nil	0.0008	17.06	11.20	23.2
12	27.0	25.5	6.07	0.89	ND	0.06	35.70	8.45	367	8.11	36	48	14.43	2.91	0.0056	166.10	48.90	37.2
13	27.0	25.0	5.93	0.89	ND	0.16	98.50	5.04	253	2.03	28	44	14.43	5.83	0.0016	109.00	1.17	251.5
14	28.0	24.0	6.26	6.96	2.96	0.14	9.60	2.20	103	20.28	30	20	3.21	4.86	-	16.90	23.00	-
15	27.5	25.0	5.96	6.36	2.81	0.02	18.00	1.59	52	2.03	16	46	3.21	1.94	0.0396	28.10	3.91	102.4
16	25.0	23.0	6.24	5.48	3.41	0.16	3.98	1.59	55	2.03	20	16	3.21	1.94	0.0408	36.50	21.50	79.1
17	25.0	24.0	6.95	-	-	0.20	10.75	2.19	60	2.03	20	18	4.81	1.45	0.0016	30.06	15.10	Nil
18	29.0	25.0	6.06	7.40	2.81	0.10	78.80	2.35	71	2.03	20	20	6.41	0.97	0.0020	34.90	2.82	32.6
19	28.0	25.0	6.47	7.10	2.66	0.04	3.38	1.46	74	3.04	40	16	6.41	Nil	0.0024	25.60	12.70	Nil
20	28.0	24.0	6.46	6.36	2.22	0.36	3.62	2.29	55	2.03	16	12	4.81	Nil	0.0032	26.70	6.85	288.7
21	25.0	24.0	6.00	7.99	2.07	0.42	56.70	2.40	37	1.01	12	20	3.21	2.91	0.0040	18.60	9.59	Nil
22	29.0	24.0	6.70	7.84	3.40	0.06	29.00	1.46	68	2.03	12	24	4.81	2.91	0.0028	33.60	9.79	Nil
23	26.0	24.0	6.09	7.55	3.55	0.08	6.36	4.37	55	3.04	16	20	4.81	1.94	0.0056	27.60	35.81	Nil

Table 4.4 MICROBIOLOGICAL ANALYSIS, CHALAKUDI RIVER BASIN, AUGUST, 2001

Station	Total Coliforms	Faecal Coliforms	Faecal Streptococci
1	750	12	ND
4	700	6	ND
5	550	ND	ND
6	2050	31	ND
8	2450	38	40
9	86	21	ND
10	8000	7500	80
11	105	25	ND
12	380000	108000	25000
13	128000	58000	14000
14	130000	ND	ND
15	24000	9000	ND
16	1960	ND	ND
17	570	180	30
18	1500	ND	1000
19	310	ND	ND
20	200	90	ND
21	150	100	ND
22	250	46	16
23	180	2	ND

Unit: Colony forming unit (Cfu)/mlfor Water; Cfu/gm for Sediment
ND : Not detected at the time of enumeration
**Sediment not collected*

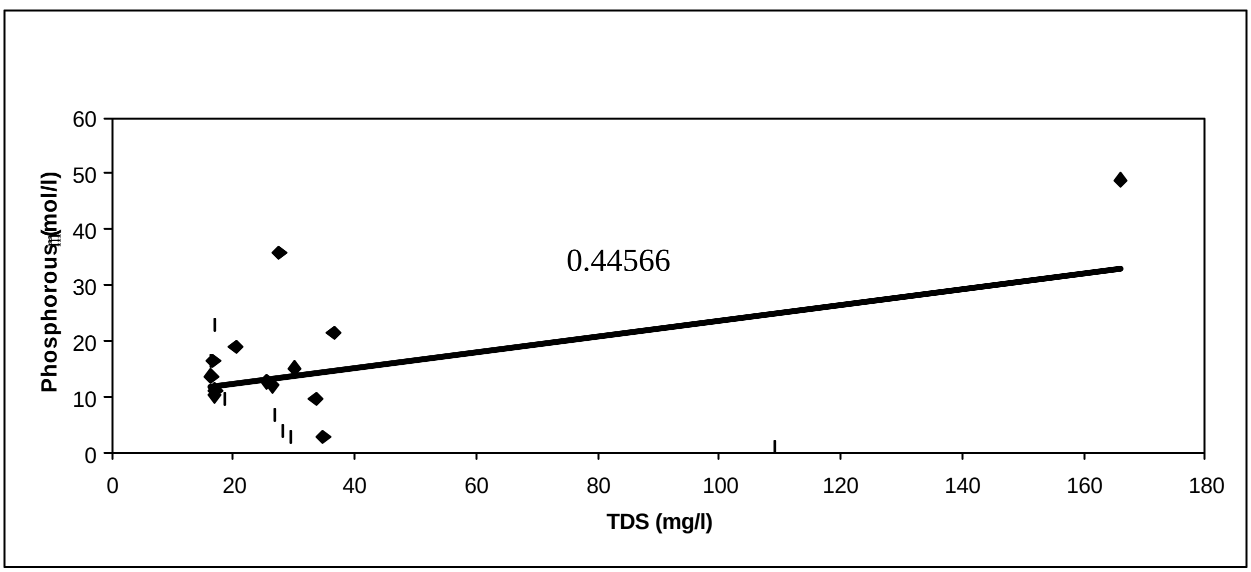

Fig. 4.2 TDS Vs. TOTAL PHOSPHOROUS, CHALAKUDI RIVER BASIN, AUGUST, 2001

Table 4.5 PHYSICO - CHEMICAL PARAMETERS - CHALAKUDI RIVER BASIN, NOVEMBER, 2001

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosph-orus (µmol/l)	Total Iron (µg/l)
	Water	Atm.		mg/l	mg/l	µmol/l	µmol/l	µmol/l	µmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
1	26.5	28.0	6.65	8.17	2.61	0.10	0.33	1.81	34	12.41	16	10	3.21	0.97	0.0036	18.76	12.28	ND
2	25.0	30.0	6.61	8.68	1.93	0.06	6.90	1.86	34	16.55	18	12	4.81	2.43	0.0040	18.99	4.04	10.92
3	26.0	25.0	6.71	7.39	1.46	0.26	0.55	2.07	24	16.55	12	6	1.60	-	0.0040	14.22	15.07	ND
4	24.0	26.5	6.60	8.68	0.62	0.02	0.23	2.34	25	8.27	16	8	2.40	0.49	0.0016	17.76	14.96	ND
5	25.0	27.0	6.48	8.84	0.50	0.12	0.11	3.35	22	16.55	14	6	2.40	0.49	0.0052	17.76	15.79	49.14
6	25.0	28.0	6.60	8.90	0.42	0.06	1.32	2.22	33	12.41	12	10	2.40	0.97	0.0076	18.04	11.87	393.12
7	28.0	31.0	6.66	8.17	0.20	0.06	3.30	2.22	32	20.69	14	10	2.40	0.49	0.0020	18.02	12.58	158.34
8	26.0	27.0	6.26	6.78	0.15	0.10	27.15	2.27	40	12.41	14	12	4.01	0.97	0.0036	22.70	8.67	32.76
9	25.0	24.5	6.55	8.23	1.04	0.04	10.20	2.29	48	8.27	14	18	4.01	0.97	0.0048	26.42	1.90	ND
10	24.0	24.5	6.65	7.55	0.61	0.16	19.00	2.29	40	16.55	12	12	2.40	1.94	0.0036	21.77	10.68	60.06
11	27.0	28.5	6.51	8.06	1.70	0.06	10.75	2.63	39	16.55	14	10	4.01	-1.46	0.0052	21.80	10.68	ND
12	30.0	32.0	6.53	0.63	0.46	59.96	105.49	6.99	457	105.47	38	48	15.23	2.43	0.0156	203.10	22.79	3494.40
13	27.0	25.0	6.76	1.27	1.13	0.02	13.45	5.76	217	49.64	26	38	11.22	8.75	0.0076	102.50	14.72	1919.6
14	27.0	25.0	6.38	1.78	1.10	-	3.20	1.40	126	28.96	26	24	8.02	0.97	0.0016	61.02	8.31	840.84
15	26.0	26.5	6.26	6.36	0.56	0.04	9.25	1.93	52	20.69	14	14	4.01	0.97	0.0016	28.12	4.51	ND
16	25.0	26.5	6.71	5.43	0.09	0.08	27.72	1.57	58	28.96	18	14	4.81	0.49	0.0032	31.53	11.51	616.98
17	25.0	25.0	6.67	7.80	0.77	0.04	12.65	2.53	58	16.55	22	16	5.61	1.94	0.0044	33.13	8.90	262.08
18	32.0	31.0	6.65	8.21	1.09	0.04	4.85	1.57	73	24.82	20	18	4.81	1.46	0.0028	37.44	6.53	0.83
19	28.0	30.0	6.58	6.41	0.31	0.02	14.85	1.37	69	24.82	16	14	3.21	0.49	0.0024	36.31	10.92	60.06
20	29.0	32.0	6.66	5.22	0.22	0.02	0.88	2.56	60	16.55	18	22	4.81	0.49	0.0036	32.74	10.80	ND
21	29.0	29.5	6.89	7.90	1.40	0.06	1.54	1.69	39	16.55	14	12	1.60	0.97	0.0044	22.40	11.87	327.60
22	31.0	32.0	7.02	7.95	4.74	0.04	4.95	0.87	64	24.82	12	16	4.81	3.89	0.0092	34.62	7.60	283.92
23	28.0	28.5	5.45	7.84	4.26	0.08	4.95	1.69	44	20.69	20	28	11.22	1.94	0.0056	25.70	17.92	ND
24	28.0	29.0	6.63	7.34	0.23	0.02	13.09	2.24	66	20.69	16	22	6.41	1.46	0.0084	34.46	11.63	ND
25	28.5	30.0	6.61	7.12	4.30	0.04	2.31	2.29	56	16.55	14	18	4.81	1.46	0.0128	30.48	21.25	ND
26	25.0	29.0	6.89	6.77	1.00	0.08	0.33	1.52	59	12.41	16	18	4.81	8.26	0.0060	32.46	12.46	ND
27	29.0	28.0	5.73	8.02	1.20	0.04	5.39	1.45	498	140.66	16	52	7.21	1.46	0.0016	226.50	13.53	16.38
28	29.0	30.0	6.61	7.97	2.53	0.10	1.32	1.49	67	20.69	16	14	3.21	1.46	0.0040	34.40	12.10	65.52

Table 4.6 MICROBIOLOGICAL ANALYSIS - CHALAKUDI RIVER BASIN, NOVEMBER, 2001

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
1	20	ND	ND
2	40	ND	5
3	45	20	52
4	30	15	5
5	105	ND	10
6	ND	ND	5
7	ND	ND	5
8	130	65	ND
9	75	ND	ND
10	165	100	ND
11	315	25	ND
12	14000	11500	6500
13	2000	1500	2200
14	200	50	ND
15	800	100	ND
16	75	ND	10
17	565	40	10
18	20	ND	10
19	20	ND	ND
20	35	20	ND
21	200	100	ND
22	30	ND	ND
23	1250	95	ND
24	35	ND	ND
25	20	ND	ND
26	215	5	ND
27	160	ND	ND
28	195	ND	ND

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration

The water quality analysis had been carried out for dry season during the month of March, 2002. The water level in the main river and the sampling stations on the tributaries were found to be low, which was quite natural given the time of the year. Three stations (stations 13, 16 and 20) were dry during the sampling period. Physico-chemical analysis and microbiological analysis had been carried out for all the samples. The analytical results are presented in Tables 4.7 and 4.8.

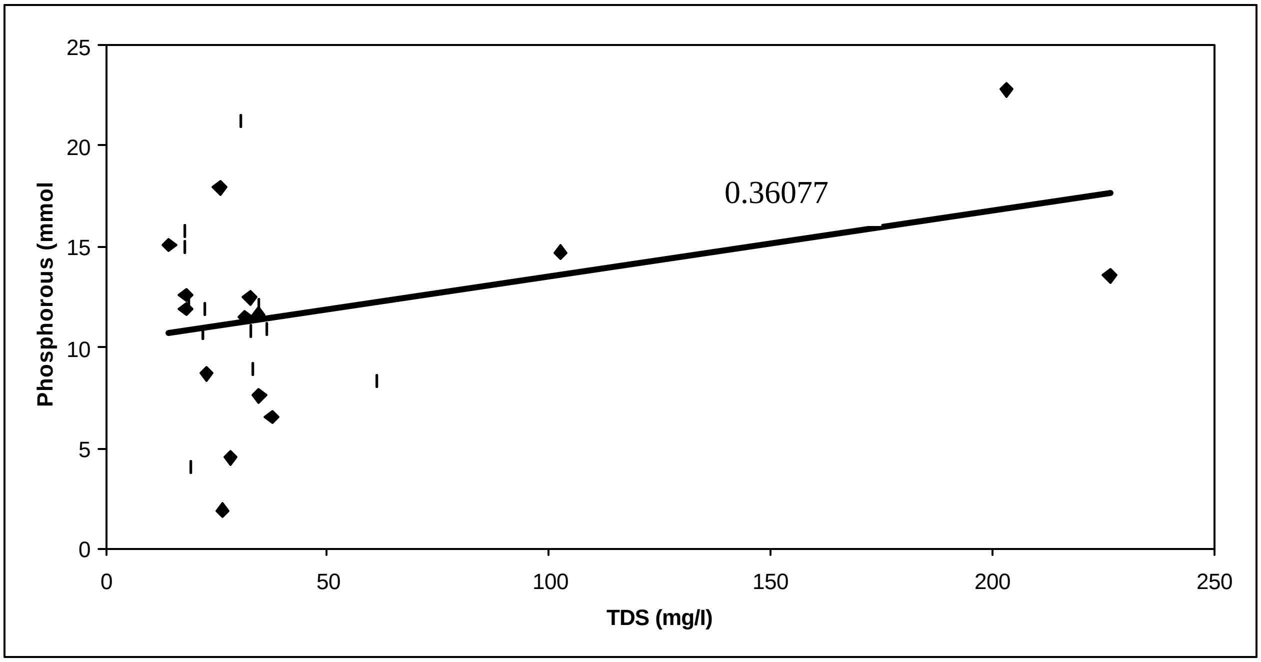

Fig. 4.3 TDS Vs. TOTAL PHOSPHOROUS, CHALAKUDI RIVER BASIN, NOVEMBER, 2001

Conductivity level was very high in the down stream station during the dry period which can be attributed to increased salinity due to low fresh water flow resulting in limited dilution. Nitrate concentration shows fluctuating trend when compared to other seasons, whereas phosphate values were higher than that of August and November.

Table 4.7 PHYSICO - CHEMICAL PARAMETERS - CHALAKUDI RIVER BASIN, MARCH, 2002

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosphorous	Total Iron
	Water	Atm.		mg/l	mg/l	mmol/l	mmol/l	mmol/l	mmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(mmol/l)	(mg/l)
1	28.0	29.0	6.63	8.05	3.95	0.14	3.72	3.00	36	17.82	20	14	10.00	1.00	0.0048	19.40	3.20	ND
2	24.0	25.5	6.47	7.17	4.24	0.31	2.58	3.26	36	21.38	20	12	10.00	0.49	0.0012	20.28	7.01	ND
3	23.5	28.0	6.72	14.35	10.25	0.36	7.01	3.71	38	24.94	20	10	10.00	-	0.0032	20.38	9.81	146.02
4	27.0	25.0	6.37	3.22	ND	0.24	4.06	2.61	47	21.38	24	10	10.00	-	0.0016	42.97	11.01	ND
5	24.5	27.0	6.30	2.78	ND	0.72	5.87	6.08	67	28.50	24	26	20.00	1.46	0.0028	65.70	12.81	ND
6	27.0	25.0	6.40	7.03	2.79	0.46	7.89	3.11	34	17.82	16	8	6.00	0.49	0.0016	22.84	7.01	112.32
7	31.0	32.0	6.60	7.47	1.61	0.34	7.43	3.99	34	21.38	16	8	8.00	-	0.0024	49.39	17.61	89.86
8	25.0	23.0	6.00	5.56	0.88	0.19	5.87	5.27	36	24.94	24	10	10.00	-	0.0012	26.52	20.22	ND
9	27.0	22.0	6.49	5.56	2.34	0.22	13.59	4.10	41	10.69	20	12	8.00	0.97	0.0020	26.72	22.02	ND
10	26.0	21.0	6.68	6.15	4.80	0.14	9.88	4.83	45	17.82	16	30	20.00	2.43	0.0016	35.32	12.41	ND
11	32.0	33.0	6.07	7.91	5.27	0.14	14.64	4.13	53	17.82	16	12	8.00	0.97	0.0028	32.85	14.81	ND
12	25.0	25.5	6.63	3.07	2.97	90.47	38.96	27.96	663	81.95	148	80	70.00	2.43	0.0732	324.20	88.66	123.55
13	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
14	26.0	26.0	6.57	4.98	3.22	0.14	10.11	3.39	63	24.94	28	16	10.00	1.46	0.0016	109.50	21.42	39.31
15	26.0	25.0	6.22	6.59	3.95	0.82	4.43	4.78	51	21.38	16	14	12.00	0.49	0.0018	28.08	20.42	640.22
16	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
17	26.0	26.0	6.35	5.71	1.32	0.31	4.99	5.12	45	17.82	16	14	12.00	0.49	0.0048	28.27	16.81	ND
18	26.5	26.0	6.16	6.44	2.93	0.36	7.01	5.17	53	21.38	16	14	12.00	0.49	0.0172	41.05	15.81	628.99
19	35.0	30.0	6.26	6.15	4.98	0.17	6.45	2.15	77	28.50	16	14	10.00	0.97	0.0032	41.02	14.81	ND
20	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
21	32.0	31.0	6.82	8.63	5.99	0.14	2.54	4.52	52	14.25	20	14	8.00	1.46	0.0028	36.97	19.41	78.62
22	30.0	33.0	6.26	3.95	0.73	0.34	0.85	6.84	362	85.51	16	130	100.00	7.29	0.0020	179.40	22.42	ND
23	30.0	24.0	6.37	5.42	ND	0.60	3.81	5.43	151	35.63	20	52	46.00	1.46	0.0004	80.04	25.62	56.16
24	30.0	26.5	6.00	5.86	3.52	2.05	12.19	6.27	263	67.70	16	92	90.00	0.49	0.0008	132.40	24.62	39.31
25	30.0	25.0	6.01	7.32	7.17	0.36	5.80	5.87	206	49.88	12	68	64.00	0.97	0.0012	113.50	35.23	39.31
26	31.0	27.0	6.12	6.73	3.80	0.12	2.87	5.61	387	150.52	16	150	150.00	-	0.0052	293.30	35.83	61.78
27	29.0	26.0	6.69	7.47	3.08	0.22	1.21	7.75	1702	4666.12	44	1900	250.00	400.95	0.0100	8137.00	29.62	ND
28	29.0	26.0	6.71	5.12	3.66	0.17	0.36	7.28	1848	5268.20	44	2150	350.00	437.40	0.0156	7922.00	30.42	308.88

ND - Not Detected

NW - No Water

Table 4.8 MICROBIOLOGICAL ANALYSIS - CHALAKUDI RIVER BASIN, MARCH, 2002

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
1	1500	400	20
2	5500	ND	50
3	1400	ND	ND
4	70	20	50
5	1000	ND	40
6	150	40	ND
7	350	40	ND
8	480	ND	ND
9	100	ND	ND
10	2000	ND	10
11	100	5	ND
12	6750	1100	3000
13	NW	NW	NW
14	85	ND	ND
15	90	50	5
16	NW	NW	NW
17	2000	45	45
18	245	25	200
19	450	ND	35
20	NW	NW	NW
21	40	ND	ND
22	10	ND	ND
23	120	10	ND
24	20	ND	ND
25	1210	650	20
26	130	20	40
27	20	ND	ND
28	30	ND	ND

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration
NW: No Water

Correlation have been worked out for Total Dissolved Solids (TDS) and Total Phosphorous for the samples taken from Chalakudi river for the month of March, 2002 (Fig. 4.4). The DO values are very low in the sampling stations within the urban settlement area. The DO levels below 5mg/l indicate severe pollution often anthropogenic in nature.

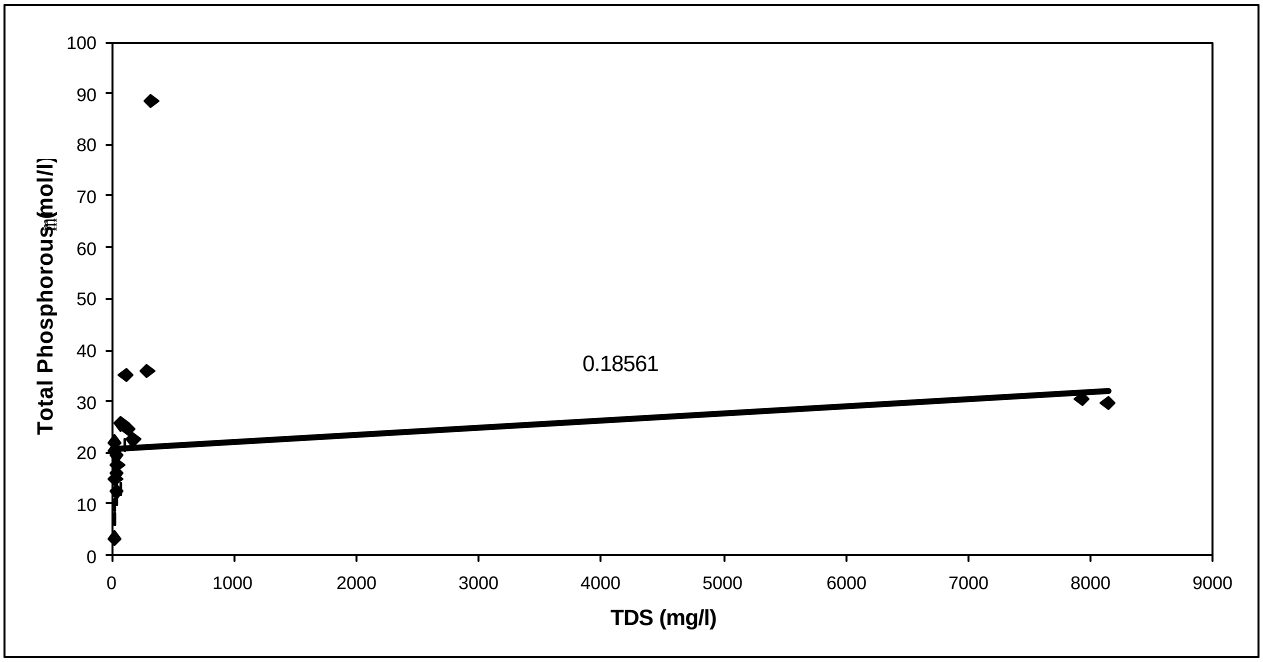

Fig. 4.4 TDS Vs. TOTAL PHOSPHOROUS, CHALAKUDI RIVER BASIN, MARCH, 2002

The distribution of DO and FC are inversely proportional and that of nitrate and FC are directly proportional.

Physico-chemical analysis and microbiological analysis had been carried out for the sample collected during the month of June, 2002 and the analytical results are presented in Tables 4.9 and 4.10.

Table 4.9 PHYSICO - CHEMICAL PARAMETERS - CHALAKUDI RIVER BASIN, JUNE, 2002

Stn	Temp ^0C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosphorous	Total Iron
	Water	Atm.		mg/l	mg/l	mmol/l	mmol/l	mmol/l	mmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(mmol/l)	(mg/l)
1	25.0	27.0	6.02	8.68	2.40	0.58	20.02	2.12	46	27.93	24	16	4.81	0.97	0.0048	25.00	12.79	182.80
2	23.5	27.0	6.09	8.08	2.84	0.03	15.59	1.54	30	27.93	28	28	1.60	5.83	0.0060	17.80	5.97	182.80
3	22.0	27.5	7.09	7.78	2.54	0.11	7.69	2.70	26	19.95	20	40	3.21	7.78	0.0072	16.14	5.50	187.80
4	24.0	28.0	6.81	7.33	1.94	0.28	5.52	3.43	27	23.94	20	8	3.21	0.24	0.0108	17.40	6.21	324.00
5	25.5	27.0	6.58	8.98	2.85	ND	5.22	3.69	24	51.87	20	20	1.60	3.89	0.0016	15.20	6.91	71.00
6	25.0	27.0	6.03	7.93	1.50	0.14	13.69	3.34	32	27.93	36	32	3.21	5.83	0.0088	18.50	6.33	45.70
7	26.0	28.0	6.84	7.78	2.99	0.17	11.46	2.63	30	27.93	24	20	4.81	1.94	0.0068	22.20	5.97	5.07
8	25.0	25.0	7.08	7.03	2.54	0.08	22.00	3.34	43	23.94	24	20	4.81	1.94	0.0136	26.10	6.80	ND
9	25.0	27.5	6.06	7.63	1.00	0.06	11.50	3.08	29	27.93	40	20	3.21	2.92	0.0028	18.00	6.91	ND
10	25.0	25.0	5.80	7.03	2.54	ND	17.78	3.53	47	27.93	28	24	4.81	2.92	0.0064	28.10	6.44	162.40
11	25.5	28.0	5.86	5.39	1.02	ND	13.63	3.24	37	19.95	16	20	1.60	3.89	0.0010	25.00	6.21	137.10
12	26.0	24.0	6.08	1.31	NC	0.30	74.87	5.46	324	71.82	90	68	20.84	3.89	0.0072	150.30	11.03	193.00
13	26.0	24.0	6.24	1.58	NC	0.11	58.53	3.92	244	51.87	8	64	19.24	3.89	0.0076	120.00	9.50	380.00
14	26.0	24.5	6.16	0.87	NC	0.14	11.88	1.22	65	39.90	28	36	4.81	5.83	0.0052	35.50	5.50	5.07
15	25.5	24.5	6.35	2.69	NV	0.08	11.48	1.48	48	23.94	28	16	6.41	0.24	0.0148	26.70	5.74	96.50
16	26.5	27.0	6.62	5.54	NC	0.50	17.93	2.50	55	31.92	32	16	9.62	0.97	0.0076	33.30	4.92	177.80
17	26.5	27.0	6.29	4.21	NC	0.11	26.80	2.95	58	27.93	32	24	6.41	1.94	0.0096	34.70	5.39	452.00
18	27.5	30.0	6.70	7.18	1.16	0.14	17.55	2.50	54	23.94	24	16	4.81	0.97	0.0056	31.40	5.03	533.00
19	26.5	29.0	6.21	3.59	NC	0.06	18.19	1.89	73	31.92	32	32	6.41	3.89	0.0092	38.90	7.50	157.40
20	27.0	29.0	6.16	3.93	NC	0.38	23.02	3.11	68	23.94	24	20	8.02	0.24	0.0084	36.20	8.09	177.73
21	25.0	29.0	6.48	5.39	1.12	0.06	17.21	3.11	39	23.94	24	20	4.81	1.94	0.0004	24.70	8.21	35.55
22	28.0	29.5	6.32	4.80	NC	ND	25.84	2.02	70	27.93	24	24	6.41	1.94	0.0020	37.20	7.03	192.96
23	25.0	23.0	6.90	6.58	1.34	0.03	16.04	2.76	40	23.94	24	20	4.81	1.94	0.0132	22.50	7.50	101.56
24	26.0	24.0	5.86	6.13	1.19	0.03	16.06	3.56	37	31.92	24	28	80.20	1.94	0.0040	29.40	7.39	279.29
25	26.0	25.0	5.77	6.13	2.24	0.06	14.46	3.56	51	27.93	24	16	6.41	0.24	0.0040	28.50	8.33	111.72
26	27.0	25.0	6.39	5.98	0.74	0.03	13.55	3.15	62	27.93	20	16	6.41	0.24	0.0040	34.01	7.27	132.03
27	26.0	26.0	5.95	4.49	2.84	0.08	19.85	3.34	172	51.87	32	28	6.41	2.92	0.0296	86.60	7.39	157.42
28	26.0	27.0	6.87	6.28	2.09	0.19	13.03	2.66	185	63.84	24	60	6.41	10.69	0.0068	95.10	7.39	228.51

Table 4.10 MICROBIOLOGICAL ANALYSIS - CHALAKUDI RIVER BASIN, JUNE, 2002

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
1	40	10	10
2	140	80	10
3	50	ND	180
4	160	30	50
5	20	10	20
6	180	170	3230
7	180	60	180
8	130	40	40
9	220	20	40
10	340	40	10
11	180	100	ND
12	1785	800	5500
13	500	300	1100
14	20	ND	ND
15	30	10	ND
16	390	90	100
17	120	ND	10
18	80	10	20
19	280	ND	ND
20	250	20	ND
21	80	ND	ND
22	5	ND	ND
23	10	ND	ND
24	20	ND	ND
25	60	ND	10
26	10	ND	ND
27	10	ND	ND
28	10	ND	ND

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration

The DO values are low (1.31) in the urban settlement area and the stations in the fallow land. This factor can be attributed to the increasing surface discharge rate during the monsoon season following the dry period, causing an influx of relatively polluted water in to the surface channel leading to a slight but noticeable decrease in DO concentration. Due to absence of proper waste disposal techniques, the surface water in the urban environment is polluted by faecal discharge directly from man or that of animals and this has been proven in the widespread distribution of microbial pathogens. The survival of these pathogens, once discharged into a water body, is highly variable depending on the quality of the receiving waters, particularly the turbidity, oxygen levels, nutrients and temperature. These micro organisms demand more oxygen for their growth and therefore water oxygen level is seriously depleted. Conductivity level was less compared to the dry period which can be accredited to the monsoonal rainfall resulting dilution with fresh water.

Nitrate concentration shows higher values during this period compared to the dry season in almost all the stations except stations 9 and 11. This may be due to the high discharge after the dry period. With the onset of monsoon impure and stagnant water are drained out first. The sampling stations, 9 and 11, where nitrate concentrations are less, fall along the main river. As a result the rate of dilution is higher in these two stations compared to the stations along the tributaries. But the stations along the main river in the downstream of the urban settlement record high concentration of nitrate, which can be attributed to high concentration of settlements with inadequate sanitation facilities. The release of untreated human waste within the urban hydrological environment can be directly linked to the high nitrate contamination levels. Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth and decay. The phosphate values are showing a declining trend compared to the dry period. Phosphorous is rarely found in high concentration in freshwater as it is actively taken up by plants. As a result there can be considerable seasonal fluctuations in concentration of phosphate in surface water. Domestic waste water (particularly those containing detergents), industrial effluents and fertilizer run-off contribute to elevated levels of phosphate in surface water. The stations 4 and 6, where washing activities are practiced the concentration of phosphate is showing higher values. Correlation have been worked out for Total Dissolved Solids (TDS) and total phosphorus (Fig. 4.5). This indicates the direct relation between sediment discharge and Total Phosphorous. The seasonal variation of DO, pH, conductivity, Nitrate and Phosphate are presented in the Figures 4.6, 4.7, 4.8, 4.9 and 4.10.

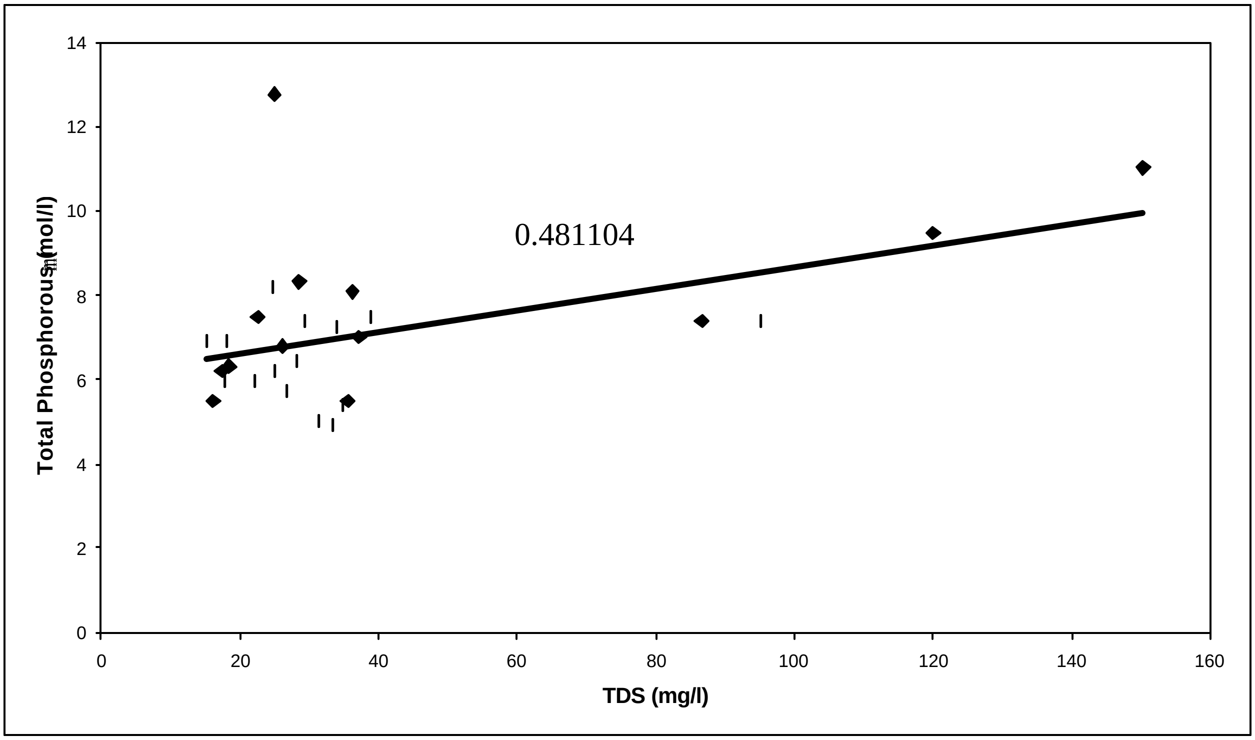

Fig. 4.5 **TDS Vs. TOTAL PHOSPHOROUS, CHALAKUDI RIVER BASIN, JUNE, 2002**

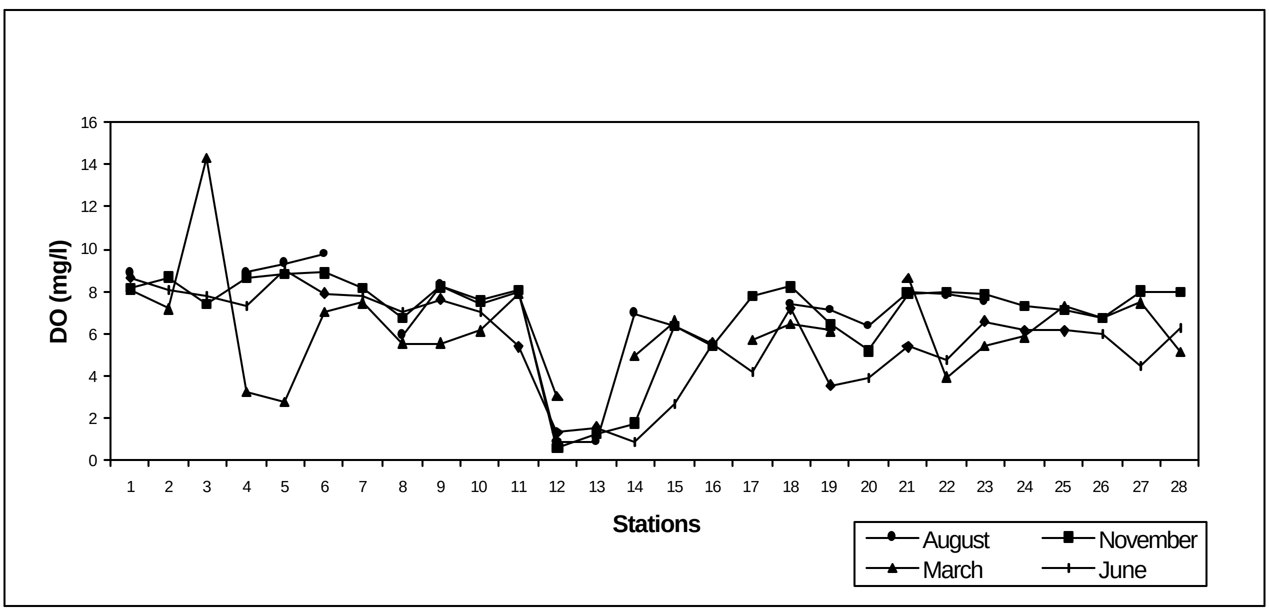

Fig. 4.6 **SEASONAL VARIATION OF DO, CHALAKUDI RIVER BASIN**

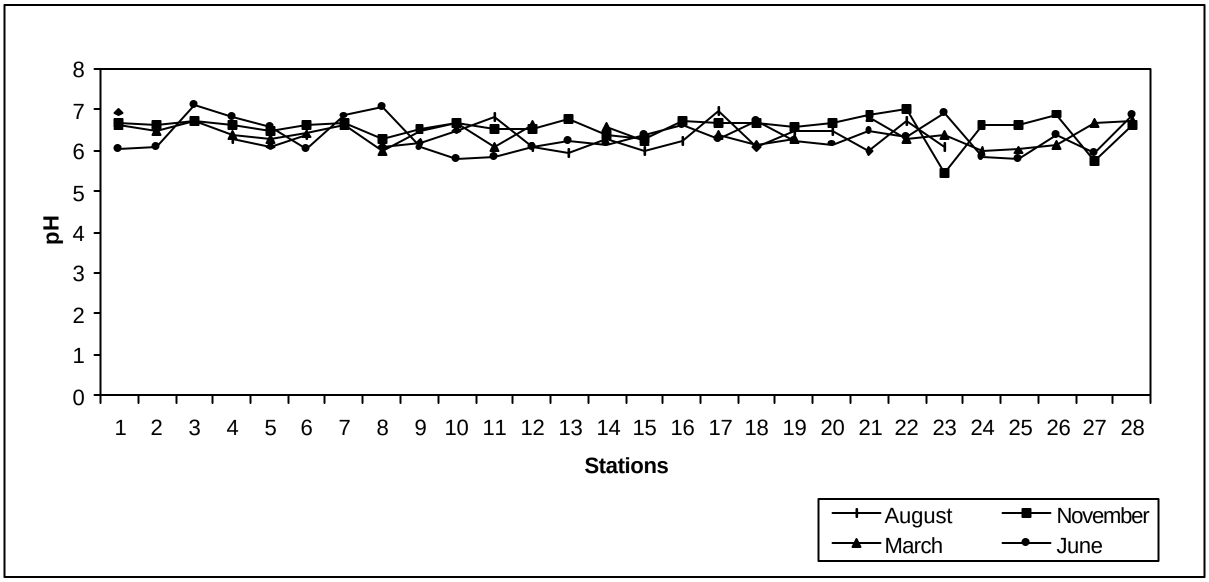

Fig. 4.7 SEASONAL VARIATION OF pH, C2HALAKUDI RIVER BASIN

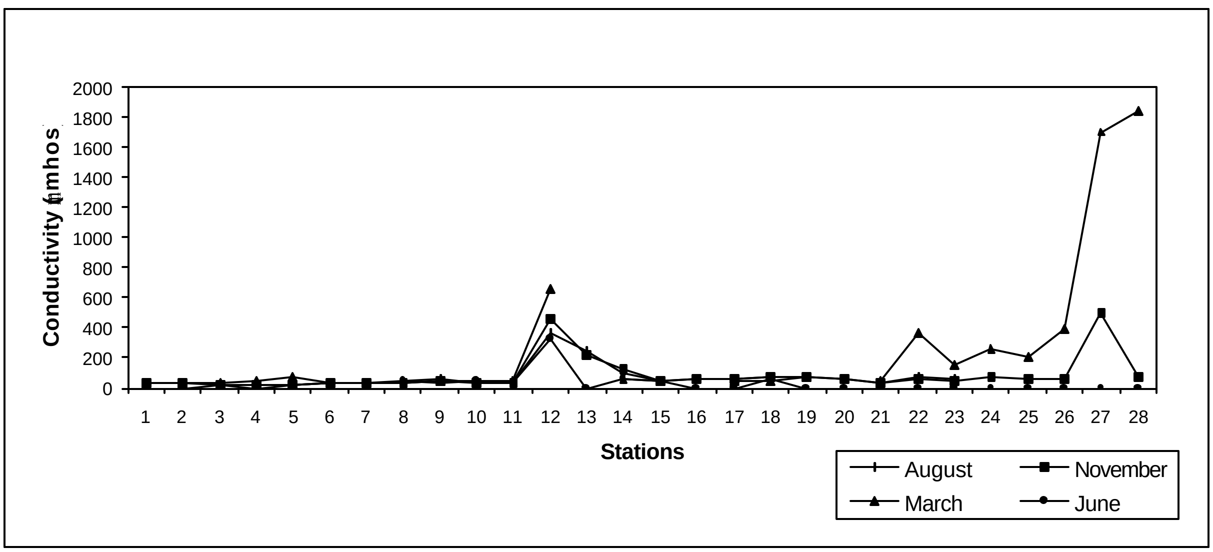

Fig. 4.8 SEASONAL VARIATION OF CONDUCTIVITY, CHALAKUDI RIVER BASIN

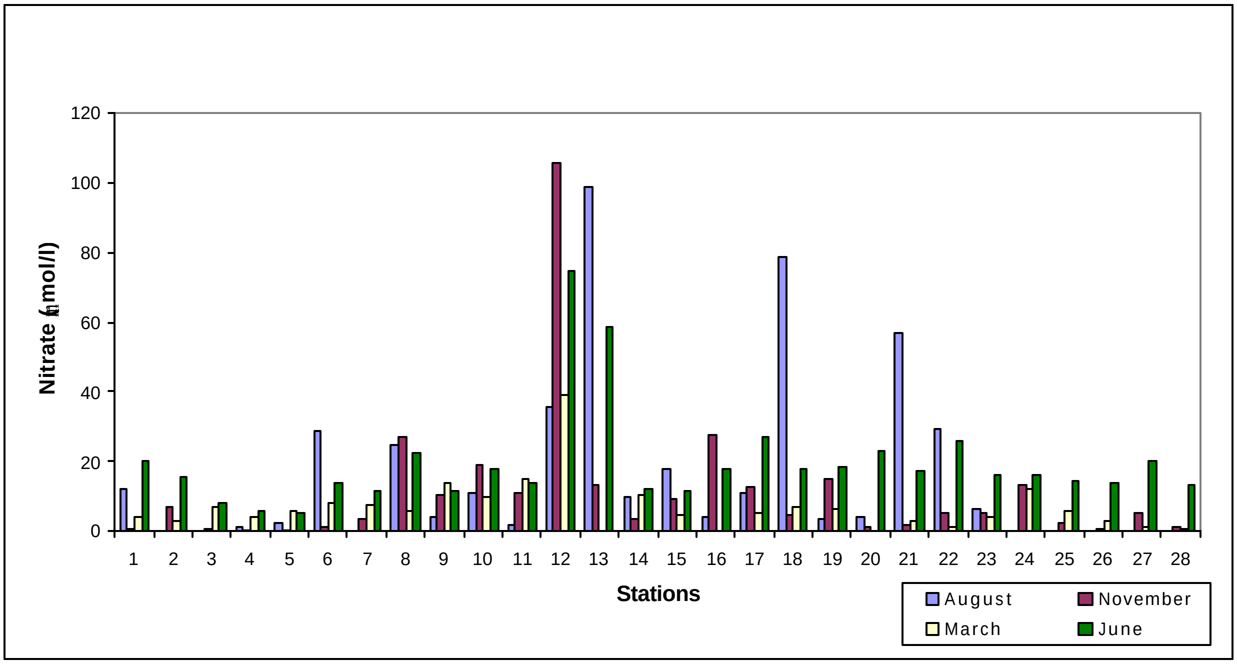

Fig. 4.9 SEASONAL VARIATION OF NITRATE, CHALAKUDI RIVER BASIN

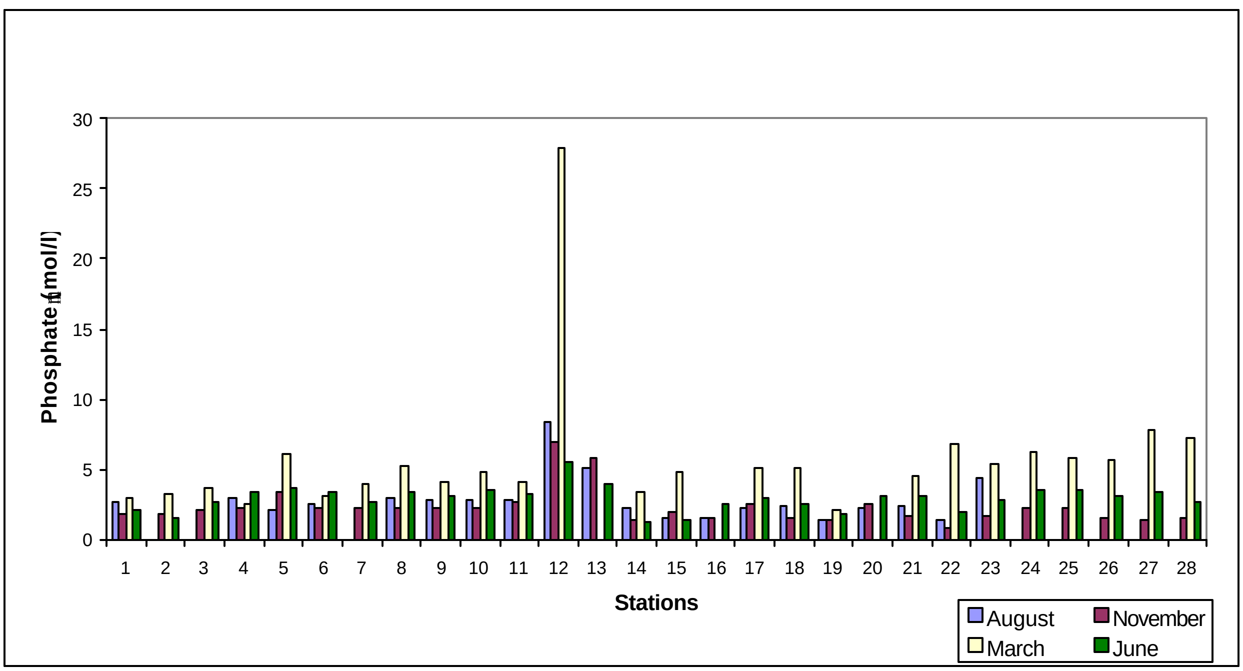

Fig. 4.10 SEASONAL VARIATION OF PHOSPHATE, CHALAKUDI RIVER BASIN

The Chloride values are showing an increasing trend. High concentration of chloride can make water unpalatable and, therefore, unfit for drinking or livestock watering.

The seasonal variations of DO, nitrate and that of chloride with respect to FC are worked out for river water (Figs. 4.11, 4.12 and 4.13). The distribution of DO and FC are inversely proportional and that of nitrate and FC and chloride and FC are directly proportional. Within the urban environment where faecal coliform count is the highest, DO concentration are low. FC levels decrease in the residential area and they are hardly found in the forest areas. DO concentration increases due to relative absence of faecal matter upon which the bacteria breed. The increase in surface water discharge as a consequence of rainfall results in an influx of relatively clean water leading to dilution of the faecal matter.

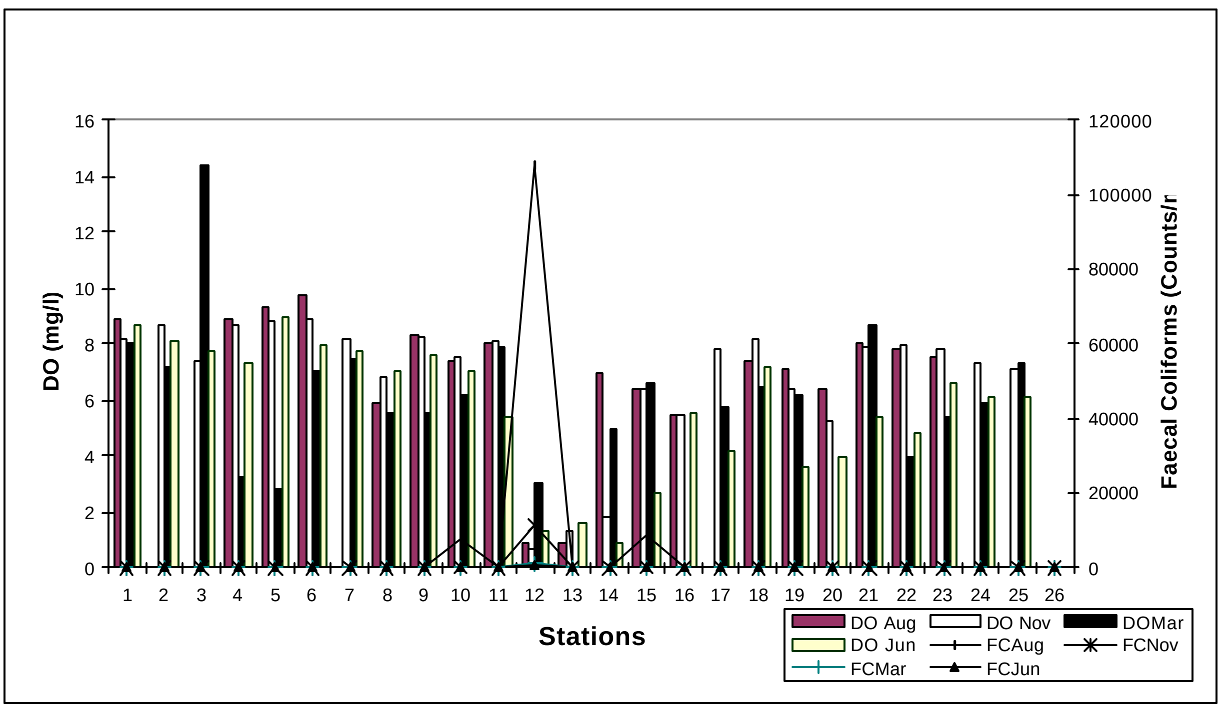

Fig. 4.11 DO Vs. FAECAL COLIFORMS, CHALAKUDI RIVER BASIN

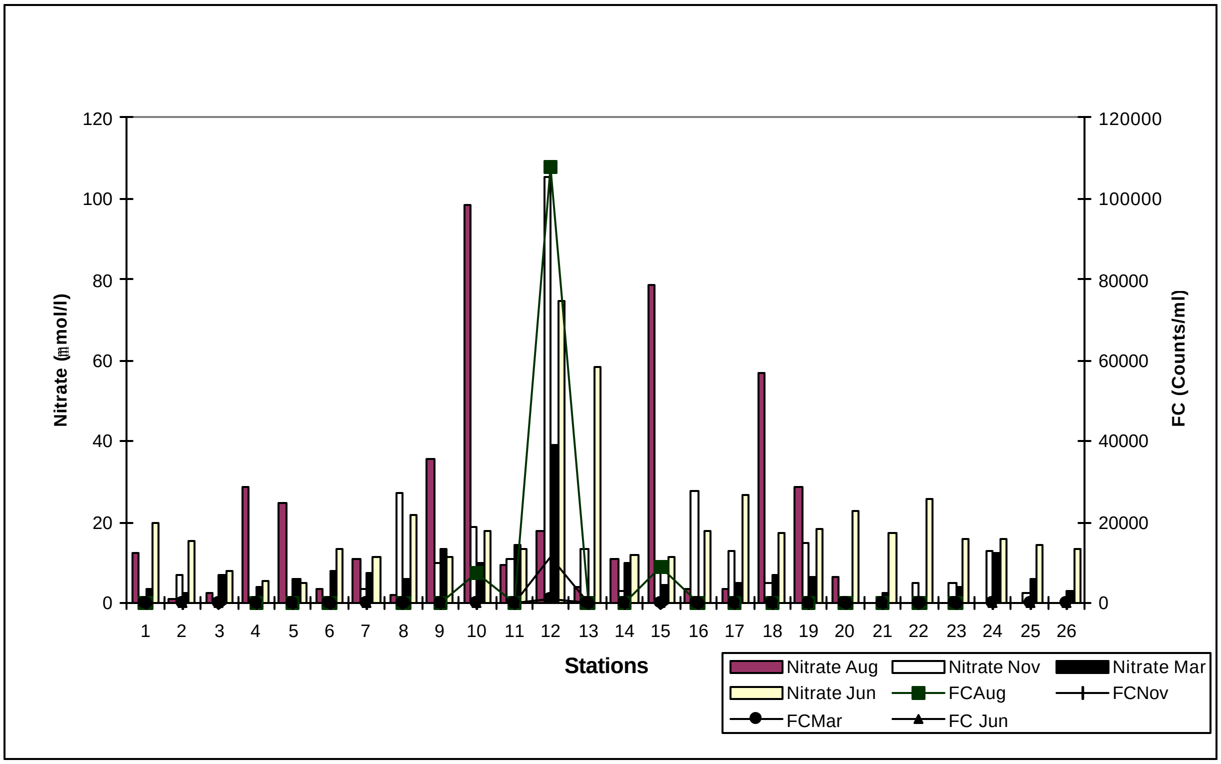

Fig. 4.12 NITRATE Vs. FAECAL COLIFORMS, CHALAKUDI RIVER BASIN

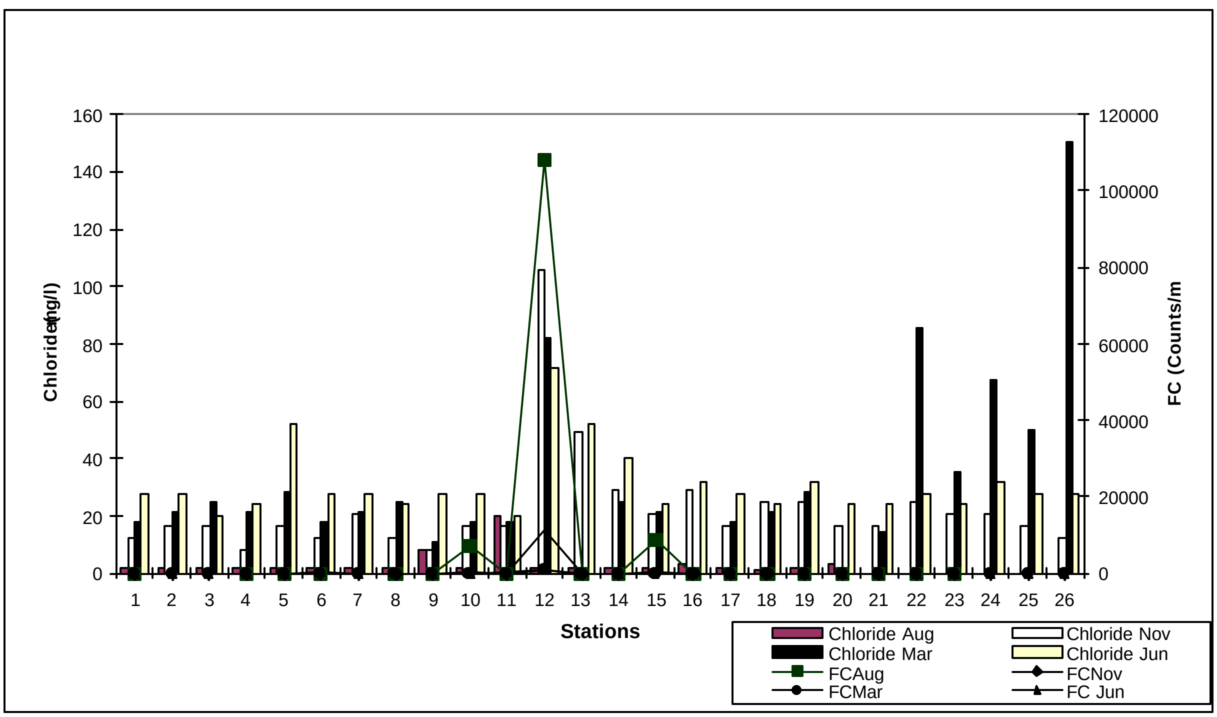

Fig. 4.13 CHLORIDE Vs. FAECAL COLIFORMS, CHALAKUDI RIVER BASIN

Due to the stagnancy of water in the reservoir, micro organisms found it a favourable ground for its growth. The main source of energy for micro organism is decomposition of organic material. With short retention times, this material is mainly derived from the inflow into the reservoir.

4.3 River Zonation

Zonation of the Chalakudi river had been attempted individually based on the water quality data for month of August, 2001, November, 2001, March, 2002 and June, 2002. Considering the analytical results of water samples collected for the month of August, 2001, November, 2001, March, 2002 and June, 2002 an overall grading had also been done. Landuse pattern was correlated with gradation. The zoning had been done for a stretch from Poringalkuttu reservoir up to the confluence point of the Chalakudi river with the Periyar river.

pH, conductivity, nitrate and phosphate values were considered for grading the river (Chapman, 1996). The standard values for nitrate and phosphate are 0.05mg/l-0.2mg/l and 0.002mg/l-0.025mg/l respectively. These values were considered for classifying the samples under the grades of low, medium and high. For pH, the values ranging from 6.2 to 7.0 was taken as non polluted and the outliers on both side are considered as polluted. A separate classification was followed for conductivity with values <30, 30-100 and >200 μs/cm to denote low, medium and high categories, respectively.

Based on these four parameters and observations for three months, each sample was graded on a scale of I to IV, where grade I is highly polluted and grade IV is non polluted (Tables 4.11, 4.12, 4.13 and 4.14). Landuse boundaries corresponding to these samples were considered to zone the river. Taking into consideration the grading for these

Table 4.11 RATING FOR WATER QUALITY GRADATION, CHALAKUDI RIVER, AUGUST, 2001

Station	pH		Conductivity (µmhos)			Nitrate (mg/l)			Phosphate (mg/l)			Grade
	Polluted (<6.2 & >7.0)	Non-polluted (6.2-7.0)	Low (<30)	Medium (30-100)	High (>100)	Low (<0.05)	Medium (0.05-0.2)	High (>0.2)	Low (<0.002)	Medium (0.002-0.025)	High (>0.025)	
1		$		$				$			$	II
4		$	$				$				$	IV
5	$		$				$				$	II
6		$	$					$			$	II
8	$			$				$			$	I
9		$		$				$			$	II
10		$		$				$			$	II
11		$		$			$				$	III
12	$				$			$			$	I
13	$				$			$			$	I
14		$			$			$			$	I
15	$			$				$			$	I
16		$		$				$			$	II
17		$		$				$			$	II
18	$			$				$			$	I
19		$		$				$			$	II
20		$		$				$			$	II
21	$			$				$			$	I
22		$		$				$			$	II
23	$			$				$			$	I

Grade I - Highly polluted

Grade II - Moderately polluted

Grade III - Marginally Polluted

Grade IV - Non-polluted

Table 4.12 RATING FOR WATER QUALITY GRADATION, CHALAKUDI RIVER, NOVEMBER, 2001

Station	pH		Conductivity (µmhos)			Nitrate (mg/l)			Phosphate (mg/l)			Grade
	Polluted (<6.2 & >7.0)	Non-polluted (6.2-7.0)	Low (<30)	Medium (30-100)	High (>100)	Low (<0.05)	Medium (0.05-0.2)	High (>0.2)	Low (<0.002)	Medium (0.002-0.025)	High (>0.025)	
1		$		$		$					$	IV
2		$		$				$			$	II
3		$	$			$					$	IV
4		$	$			$					$	IV
5		$	$			$					$	IV
6		$		$			$				$	III
7		$		$			$				$	III
8		$		$				$			$	II
9		$		$				$			$	II
10		$		$				$			$	II
11		$		$				$			$	II
12		$			$			$			$	I
13		$			$			$			$	I
14		$			$		$				$	II
15		$		$				$			$	II
16		$		$				$			$	II
17		$		$				$			$	II
18		$		$				$			$	II
19		$		$				$			$	II
20		$		$			$				$	III
21		$		$			$				$	III
22		$		$				$			$	IV
23	$			$				$			$	I
24		$		$				$			$	II
25		$		$			$				$	III
26		$		$		$					$	IV
27	$				$			$			$	I
28		$		$			$				$	III

Grade I - Highly polluted
Grade II - Moderately polluted
Grade III - Marginally Polluted
Grade IV - Non-polluted

Table 4.13 RATING FOR WATER QUALITY GRADATION, CHALAKUDI RIVER, MARCH, 2002

Station	pH		Conductivity (μmhos)			Nitrate (mg/l)			Phosphate (mg/l)			Grade
	Polluted (<6.2 & >7.0)	Non-polluted (6.2-7.0)	Low (<30)	Medium (30-100)	High (>100)	Low (<0.05)	Medium (0.05-0.2)	High (>0.2)	Low (<0.002)	Medium (0.002-0.025)	High (>0.025)	
1		$		$				$			$	II
2		$		$			$				$	III
3		$		$				$			$	II
4		$		$				$			$	II
5		$		$				$			$	II
6		$		$				$			$	II
7		$		$				$			$	II
8	$			$				$			$	I
9		$		$				$			$	II
10		$		$				$			$	II
11	$			$				$			$	I
12		$			$			$			$	I
13												
14		$		$				$			$	II
15		$		$				$			$	II
16												
17		$		$				$			$	II
18		$		$				$			$	II
19		$		$				$			$	II
20												
21		$		$			$				$	III
22		$			$		$				$	II
23		$			$			$			$	I
24	$				$			$			$	I
25	$				$			$			$	I
26	$				$		$				$	I
27		$			$		$				$	II
28		$			$	$					$	II

Grade I - Highly polluted Grade III - Marginally Polluted

Grade II - Moderately polluted Grade IV - Non-polluted

Table 4.14 RATING FOR WATER QUALITY GRADATION, CHALAKUDI RIVER, JUNE, 2002

Station	pH		Conductivity (µmhos)			Nitrate (mg/l)			Phosphate (mg/l)			Grade
	Polluted (<6.2 & >7.0)	Non-polluted (6.2-7.0)	Low (<30)	Medium (30-100)	High (>100)	Low (<0.05)	Medium (0.05-0.2)	High (>0.2)	Low (<0.002)	Medium (0.002-0.025)	High (>0.025)	
1	$			$				$			$	II
2	$			$				$			$	II
3	$		$					$			$	III
4		$	$					$			$	III
5		$	$					$			$	III
6	$			$				$			$	II
7		$		$				$			$	III
8	$			$				$			$	II
9	$		$					$			$	II
10	$			$				$			$	II
11	$			$				$			$	II
12	$				$			$			$	I
13		$			$			$			$	II
14	$			$				$			$	II
15		$		$				$			$	III
16		$		$				$			$	III
17		$		$				$			$	III
18		$		$				$			$	III
19		$		$				$			$	III
20	$			$				$			$	II
21		$		$				$			$	III
22		$		$				$			$	III
23		$		$				$			$	III
24	$			$				$			$	II
25	$			$				$			$	II
26		$		$				$			$	III
27	$				$			$			$	I
28		$			$			$			$	II

Grade I - Highly polluted

Grade II - Moderately polluted

Grade III - Marginally Polluted

four months an overall grading has been worked out for each sample like highly polluted, moderately polluted, seasonally polluted and non-polluted (Table 4.15).

The stations adjoining the urban settlement showed high pollution (Grade I) in all the seasons (Fig. 4.14). With high density of population and lack of proper waste disposal techniques the urban areas were more prone to pollution. This area was polluted even in monsoon months also.

The stations on the downstream near industrial area was also highly polluted in overall grading. The release of untreated industrial wastes of high organic matter into the river resulted in a marked decline in oxygen concentration and release of nitrite in the downstream of the industrial effluent discharge point. But during the monsoon month of June, this area was marginally polluted which showed that monsoonal dilution was effective.

Some of the areas under settlement with mixed tree crops were moderately polluted in all four months and some were seasonally polluted. Agricultural waste and human waste contribute to pollution in this area. The major point source of pollution originated from the collection and discharge of domestic waste waters, from the intensive indoor rearing of livestock or certain agricultural activities. Most other agricultural activities, such as pesticides spraying or fertilizer application were considered as diffused or non-point source. But detrimental effect on water quality posed by the application of nitrogen based fertilizers was found to be of secondary importance with respect to methods of human waste disposal.

The stretches of river coming under paddy and fallow land was also moderately polluted. Use of fertilizer could be the most significant sources of pollution in the region with intensive agriculture.

Table 4.15 GRADING OF RIVER IN DIFFERENT SEASONS, CHALAKUDI RIVER

Stn.	Grades					Location	Landuse Pattern
	August 2001	November 2001	March 2002	June 2002	Overall Grading		
1	II	IV	II	II	II	Poringalkuttu Reservoir	Forest
2	SNT	II	III	II	II	From the main river	Forest
3	SNT	IV	II	III	II	A tributary near Vettilampara	Rubber plantation
4	IV	IV	II	III	III	Kannankuzhi thodu, a fifth order basin of Chalakudi, near the bridge at Kannankuzhi	Forest
5	II	IV	II	III	II	A tributary near Arurumuzhi	Plantation
6	II	III	II	II	II	From the main river	Oil palm
7	SNT	III	II	III	II	From the main river	Mixed tree crops
8	I	II	I	II	IA	3 km east of Kanjirapalli from a tributary	Settlement with mixed tree crops
9	II	II	II	II	I B	From the main river near Kanjirapally	Settlement with mixed tree crops
10	II	II	II	II	I B	Kappa thodu, 600 m north-east of Pariyaram near the bridge	Settlement with mixed tree crops
11	III	II	I	II	II	From the main river, near the bridge, 11/2 km south of Chalakudi town	Settlement with mixed tree crops
12	I	I	I	I	I A	From a tributary draining from Chalakudi town	Urban settlement
13	I	I	NW	II	I A	1 km north of Chalakudi town near the bridge on a tributary of Chalakudi river	Urban settlement
14	I	II	II	II	I B	600 m north-west of PWD Rest House, Chalakudi town, near the bridge at the confluence point of tributaries draining northern part of Chalakudi town	Fallow land
15	I	II	II	III	I B	From a tributary north of Chalakudi town	Paddy
16	II	II	NW	III	I B	From a tributary	Paddy
17	II	II	II	III	I B	From a tributary	Settlement with Mixed Treecrops
18	I	II	II	III	I B	From a tributary	Paddy
19	II	II	II	III	I B	500 m northeast of Annallur near the bridge on a tributary	Paddy
20	II	III	NW	II	II	11/2 km southwest of Annallur near the bridge on a tributary	Paddy
21	I	III	III	III	III	From the main river, near the bridge in Kadukuty	Settlement with Mixed Tree crops
22	II	IV	II	III	II	From a tributary, south of Kadukutty	Settlement with Mixed Tree crops
23	I	I	I	III	I A	From the main river, east of Annamanada	Settlement with Mixed Tree crops]
24	SNT	II	I	II	II	From the main river, east of Poovattusseri	Settlement with Mixed Tree crops
25	SNT	III	I	II	II	From the main river, west of Muzhikulam	Settlement with Mixed Tree crops
26	SNT	IV	I	III	II	From the main river, east of Elanthikara, before it joins with the river Periyar	Settlement with Mixed Tree crops
27	SNT	I	II	I	II	From the river Periyar, after Chalakudi river joins	Settlement with Mixed Tree crops
28	SNT	III	II	II	II	From the river Periyar, before Chalkudi river joins	Settlement with Mixed Tree crops

SNT - Sample Not Taken   Grade II - Moderately Polluted   I A - Highly Polluted (Round the year)   III - Non-Polluted/Low Pollution
NW - No Water   Grade III - Marginally Polluted   I B - Moderately Polluted
Grade I - Highly Polluted   Grade IV - Non-Polluted   II - Seasonally Polluted

The stretch of river flowing through plantation crops was non-polluted for over all gradation. But it was marginally polluted during the dry season. The forest area, where no anthropogenic activity was noticed, was also marginally polluted in the dry season. The animal waste and the submerged biomass contributed to this condition.

The monsoonal dilution effect was observed in majority of the water sampling sites. This dilution is an important natural process which indicates that the river still has self ameliorating capacity.

4.4 Quality of well water

Landuse change affects groundwater also. In order to assess the impact water samples from nine selected wells were collected corresponding to water samples from the river.

Locations of the well water sample sites were given in Table 4.16. Physico-chemical and microbiological analyses of well water samples were done for the moths of August, 2001, November, 2001, March, 2002 and June, 2002. (Tables 4.17, 4.18, 4.19, 4.20, 4.21, 4.22, 4.23 and 4.24).

Table 4.16 DESCRIPTION ABOUT THE WELL WATER SAMPLING SITES, CHALAKUDI RIVER BASIN

Stn.	Location	Landuse Pattern
W1	Chalakudi town near the market	Agglomerated Settlement
W2	1 km north of Chalakudi town near the bridge	Agglomerated Settlement
W3	East of Chalakudi town	Near the paddy field
W4	Beside the main river near Kanjirapalli	Settlement with Mixed Tree crops
W5	Near Kannapalli	Settlement with Mixed Tree crops
W6	Beside the main river near Kanjirapalli near the paper pulp factory	Settlement with Mixed Tree crops
W7	Near Kanjirapalli	Settlement with Mixed Tree crops
W8	Near the Clay mine at Anallur	Settlement with Mixed Tree crops
W9	North of Chalakudi town near the factory	Settlement with Mixed Tree crops

Table 4.17 PHYSICO - CHEMICAL PARAMETERS - WELL WATER, CHALAKUDI RIVER BASIN, AUGUST, 2001

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosph-orus (mmol/l)	Total Iron (mg/l)
	Water	Atm.		mg/l	mg/l	mmol/l	mmol/l	mmol/l	mmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
W1	25.0	25.5	5.54	3.11	2.07	0.16	56.75	0.98	179	3.04	20	16	14.43	4.86	0.0024	86.10	8.80	18.6
W2	25.0	27.0	5.76	1.78	1.48	0.02	22.30	2.50	215	4.06	36	56	16.03	3.88	0.0048	105.20	11.30	23.2
W3	25.5	24.5	4.97	2.37	1.19	0.02	54.60	1.76	86	2.03	8	16	1.60	2.91	0.0060	45.80	9.00	931.6
W4	25.0	23.0	5.35	2.96	2.66	0.60	53.60	2.57	106	2.03	12	24	4.81	2.91	0.0056	47.20	11.50	9.31
W5	25.0	23.5	5.53	2.96	0.30	0.16	45.80	2.95	121	3.04	16	20	4.81	1.94	0.0016	57.90	0.78	Nil
W6	25.0	23.0	5.67	3.55	3.25	0.46	59.18	3.38	490	11.16	20	88	19.34	9.72	0.0044	216.60	22.30	18.6
W7	24.0	24.0	6.33	6.07	2.67	0.30	58.50	2.77	139	3.04	28	36	9.62	2.91	0.0004	65.05	8.21	Nil
W8	25.0	24.0	7.12	7.40	4.00	0.24	4.70	4.39	254	2.03	100	108	35.27	4.86	0.0024	116.10	34.80	125.7
W9	24.0	23.0	5.77	4.30	0.16	0.54	30.50	1.77	56	4.06	12	12	3.21	0.97	0.0040	30.80	14.00	9.31

Table 4.18 PHYSICO - CHEMICAL PARAMETERS - WELL WATER, CHALAKUDI RIVER BASIN, NOVEMBER, 2001

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosph-orus (mmol/l)	Total Iron (mg/l)
	Water	Atm.		mg/l	mg/l	mmol/l	mmol/l	mmol/l	mmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
W1	25.0	25.0	5.71	3.49	0.23	0.02	26.18	0.75	166	28.96	42	42	13.63	8.75	0.0036	82.26	9.97	ND
W2	25.0	24.0	6.33	1.12	0.41	0.02	6.38	3.04	203	33.10	8	52	14.43	0.97	0.0040	97.04	17.57	54.6
W3	25.5	30.0	4.66	2.71	0.42	0.32	37.20	1.93	81	26.69	15	12	3.21	-	0.0048	42.33	9.61	ND
W4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W5	25.0	30.0	6.46	4.19	0.75	0.14	26.73	2.82	94	28.96	16	16	5.61	0.49	0.0040	46.02	18.99	ND
W6	25.0	27.0	6.41	2.07	0.65	0.78	130.46	3.81	354	82.74	20	60	9.66	8.75	0.0024	178.30	16.86	ND
W7	24.0	25.0	6.56	4.66	0.96	0.04	44.40	2.72	142	29.96	20	20	8.02	2.92	0.0028	80.18	10.09	ND
W8	25.0	30.0	7.48	6.04	0.19	0.06	4.25	5.09	227	20.68	82	98	33.67	3.40	0.0032	181.60	12.58	ND
W9	24.0	25.0	5.83	5.73	0.03	0.06	7.81	2.00	62	20.69	10	6	2.40	0.97	0.0040	33.03	13.65	ND

Table 4.19 PHYSICO - CHEMICAL PARAMETERS - WELL WATER, CHALAKUDI RIVER BASIN, MARCH, 2002

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phoshorous	Total Iron
	Water	Atm.		mg/l	mg/l	μmol/l	μmol/l	μmol/l	μmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(μmol/l)	(μg/l)
W1	26.5	27.0	5.34	3.51	3.36	3.38	38.79	6.08	219	39.19	20	26	22.00	0.97	0.0052	118.90	35.03	ND
W2	28.5	25.0	5.72	2.34	2.19	0.51	56.53	6.34	167	28.50	20	30	20.00	2.43	0.0080	88.10	36.43	ND
W3	25.0	26.0	5.35	2.93	2.78	0.48	78.08	6.45	89	24.94	8	12	8.00	0.97	0.0024	47.42	32.62	ND
W4	26.0	32.0	5.82	2.49	2.34	0.27	79.45	7.89	111	24.94	20	20	12.00	1.94	0.0156	55.62	40.03	ND
W5	26.0	32.0	6.48	5.42	1.91	0.22	78.21	8.67	107	28.50	40	18	12.00	1.46	0.0016	57.37	42.03	ND
W6	25.5	21.5	6.48	4.39	3.23	0.23	65.95	ND	68	21.38	24	24	18.00	1.46	0.0048	35.53	38.63	ND
W7	24.0	22.5	6.50	2.93	2.83	8.28	33.64	6.40	202	21.38	60	64	54.00	2.43	0.0364	97.21	43.03	ND
W8	28.0	31.0	6.56	6.15	3.22	0.92	61.03	9.90	237	24.94	104	94	54.00	9.72	0.0020	121.10	42.83	179.71
W9	26.0	25.0	5.95	4.68	1.17	0.19	28.56	7.13	54	28.50	12	30	8.00	5.83	0.0044	33.30	43.63	263.95

ND - Not Detected

NW - No Water

Table 4.20 PHYSICO - CHEMICAL PARAMETERS - WELL WATER, CHALAKUDI RIVER BASIN, JUNE, 2002

Stn	Temp ^{0}C		pH	DO	BOD	NO_2 - N	NO_3 - N	PO_4- P	Conductivity	Chloride	Alkalinity	TH	Ca	Mg	TSS	TDS	Total Phosph-orus	Total Iron
	Water	Atm.		mg/l	mg/l	μmol/l	μmol/l	μmol/l	μmhos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	(μmol/l)	(μg/l)
W1	26.5	28.0	5.37	2.24	NC	0.17	41.24	1.61	208	59.85	24	48	14.43	6.80	0.0028	101.80	1.74	198.04
W2	25.0	24.0	5.84	1.65	NC	0.14	44.56	4.27	255	39.90	40	84	32.06	0.97	0.0068	121.00	3.74	ND
W3	26.0	29.0	4.70	2.39	0.74	0.11	45.13	3.11	91	39.90	12	16	4.81	0.97	0.0228	58.70	2.80	ND
W4	26.0	30.0	5.45	3.59	0.60	0.03	44.17	5.33	114	43.89	24	32	6.41	3.89	0.0064	23.00	4.21	ND
W5	26.0	30.0	5.46	3.14	1.79	0.27	45.15	5.46	186	59.85	24	36	6.41	4.86	0.0008	96.20	3.74	10.16
W6	25.5	27.5	5.55	2.69	1.04	0.80	35.48	4.75	875	243.40	32	108	30.46	7.78	0.0048	433.00	3.86	66.01
W7	26.0	27.0	5.04	5.39	1.05	0.25	44.32	3.53	165	51.87	28	40	9.62	3.89	0.0184	84.30	3.86	ND
W8	26.5	29.0	6.60	4.79	0.59	0.06	34.06	6.52	245	27.93	36	104	36.87	2.92	0.0016	121.00	3.74	553.50
W9	25.5	28.0	5.31	2.79	NC	0.42	45.37	4.97	82	31.92	24	12	4.81	0.97	0.0160	43.40	3.86	20.31

NC - Not Countable

Table 4.21 MICROBIOLOGICAL ANALYSIS - WELL WATER, CHALAKUDI RIVER BASIN, AUGUST, 2001

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
W1	800	100	100
W2	400	ND	ND
W3	100	ND	ND
W4	200	ND	ND
W5	900	ND	ND
W6	105	36	180
W7	900	3	20
W8	250	ND	ND
W9	460	20	180

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration
* *: Sediment not collected*

Table 4.22 MICROBIOLOGICAL ANALYSIS - WELL WATER, CHALAKUDI RIVER BASIN, NOVEMBER, 2001

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
W1	70	55	5
W2	140	20	ND
W3	ND	ND	5
W4	-	-	-
W5	25	15	ND
W6	1140	1200	ND
W7	120	20	ND
W8	ND	ND	5
W9	20	ND	ND

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration

Table 4.23 MICROBIOLOGICAL ANALYSIS - WELL WATER, CHALAKUDI RIVER BASIN, MARCH, 2002

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
W1	3900	40	135
W2	225	ND	5
W3	ND	ND	ND
W4	170	ND	10
W5	250	ND	10
W6	300	80	10
W7	800	90	ND
W8	3250	ND	ND
W9	2250	170	2000

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration
NW: No Water

Table 4.24 MICROBIOLOGICAL ANALYSIS - WELL WATER, CHALAKUDI RIVER BASIN, JUNE, 2002

Stn	Total Coliforms	Faecal Coliforms	Faecal Streptococci
W1	20	10	20
W2	800	ND	100
W3	10	ND	ND
W4	30	ND	90
W5	90	40	ND
W6	2100	480	70
W7	80	20	ND
W8	30	ND	ND
W9	40	10	ND

Unit: Colony forming unit (Cfu)/ml for Water; Cfu/gm for Sediment

ND : Not detected at the time of enumeration

Water quality varies over the months due to fluctuations of rainfall and discharge. It is also controlled by various other factors like structure and composition of underlying rock formation, landuse pattern practiced in the catchment area and other anthropogenic activities. Water quality varies during the dry period due to low discharge.

The well waters are found to be contaminated during March. The concentration of nitrate, phosphate and total phosphorous values indicate the trend. Four wells out of nine wells were affected by faecal coliforms also. The effect of septic tank discharge in relation to the coliform count of the groundwater will be discussed later. DO values were found to be low here.

During March well water was found to be more polluted than surface water. The release of untreated human waste within the hydrological environment can be directly attributed to the high contamination and Faecal coliform levels. The surface water and groundwater polluted by faecal discharge directly from man or that of animals had been proven in the widespread distribution of microbial pathogens in the area.

The well water was found to be more polluted than surface water during the month of June. The depth of the ground water table in urban area was 5 to 6 metres bgl. The shallow groundwater level is of particular importance when dealing within methods of human waste disposal and subsequent localized groundwater contamination.

Infiltration rates are lower in urban areas due to comparatively high built up area. Relatively high nitrate contamination was witnessed in groundwater here. This could be partially attributed to the reduced infiltration rates (hence low groundwater recharge) resulting in localized pockets of higher groundwater pollution which could be on account of principally different anthropogenic activities witnessed here.

Although there is degree of uncertainty with respect to the causative factor responsible for the spatial difference of groundwater nitrate contamination, the hydrological results provided a valuable insight into the differing anthropogenic influences within this area. The positive correlation found between nitrate and FC also supported this (Fig. 4.15).

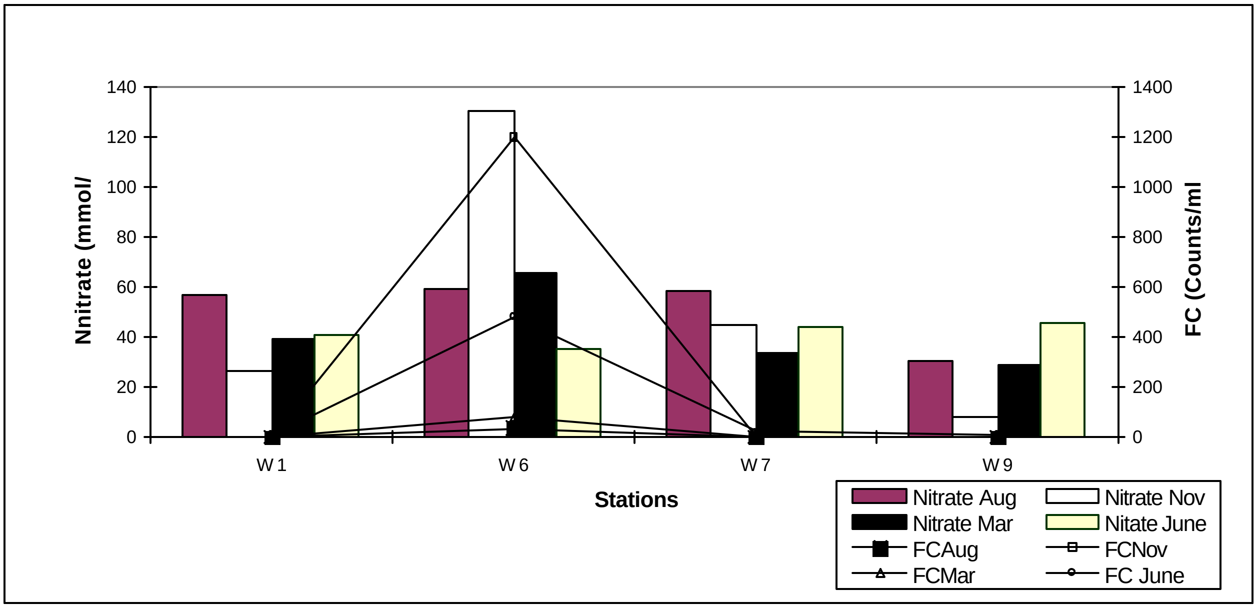

Fig. 4.15 NITRATE Vs. FECAL COLIFORM, WELL WATER, CHALAKUDI RIVER BASIN

Coliforms were found to be present in all the wells, and 5 out of 9 wells had faecal coliform contamination. The principal microbiological concern in groundwater is the health hazard posed by FC contamination. The FC contaminated wells are located in the urban area. So it is important to differentiate between the methods of human waste disposal in relation to their specific effect with regard to localized groundwater pollution. The distance of septic tank from the well is also important. Groundwater pollution by unsewed sanitation is most likely to occur when soils are thin or absent, where fissures allow rapid movement and where the water table is shallow. Due to shallow nature of the groundwater here, discharge of human waste by means of septic tank is of serious consequence to localized pathogen contamination.

FC contamination appeared to be influenced by monsoon rains in the urban area, with relatively higher levels in June than in March. This increase was presumably due to the monsoonal rains corresponding to the increasing rates of surface water infiltration within the shallow groundwater aquifer, resulting in relative dilution in the month of June with respect to March.

The seasonal variations of chloride and FC also showed that the influence and presence of faecal matter, especially in well 6. The excess presence of chloride in the well water indicated water pollution due to sewage. The presence of nitrites also indicated that the organic matter present in water was not fully oxidized. The amount of nitrites in potable water should be nil.

In the area under settlement with mixed tree crops and paddy, the agricultural landuse and cultivation practices are known to exert major influence on groundwater quality. Particular concern is the leaching of fertilizer and pesticides from regular, intensive cultivation with or without irrigation. The characteristics of soil also influence the scope for nutrient and pesticide leaching from a given agricultural activity and whether acid aerial deposition is neutralized. Increased fertilizer application is not, however, the only source of nitrate leaching in groundwater. Nitrate leaching from unfertilized grasslands or natural vegetation is normally minimal, although soils in such areas contain sufficient organic matter to be a large potential source of nitrate. Seasonal variations of DO, pH, Nitrate and Phosphate for the samples taken from the wells are presented in the Figures 4.16, 4.17, 4.18, 4.19 and 4.20.

Correlation worked out for Total Dissolved Solids (TDS) and Total Phosphorous (Figs. 4.21, 4,22, 4,23 and 4,24) is found to be positive. Seasonal variations of DO with respect to faecal coliform were also worked out (Fig. 4.25). The distribution of DO and FC were inversely proportional. The response to anthropogenic impacts is also highly variable. As a consequence, there is no universally applicable standard which can define the base line for chemical or biological quality of waters.

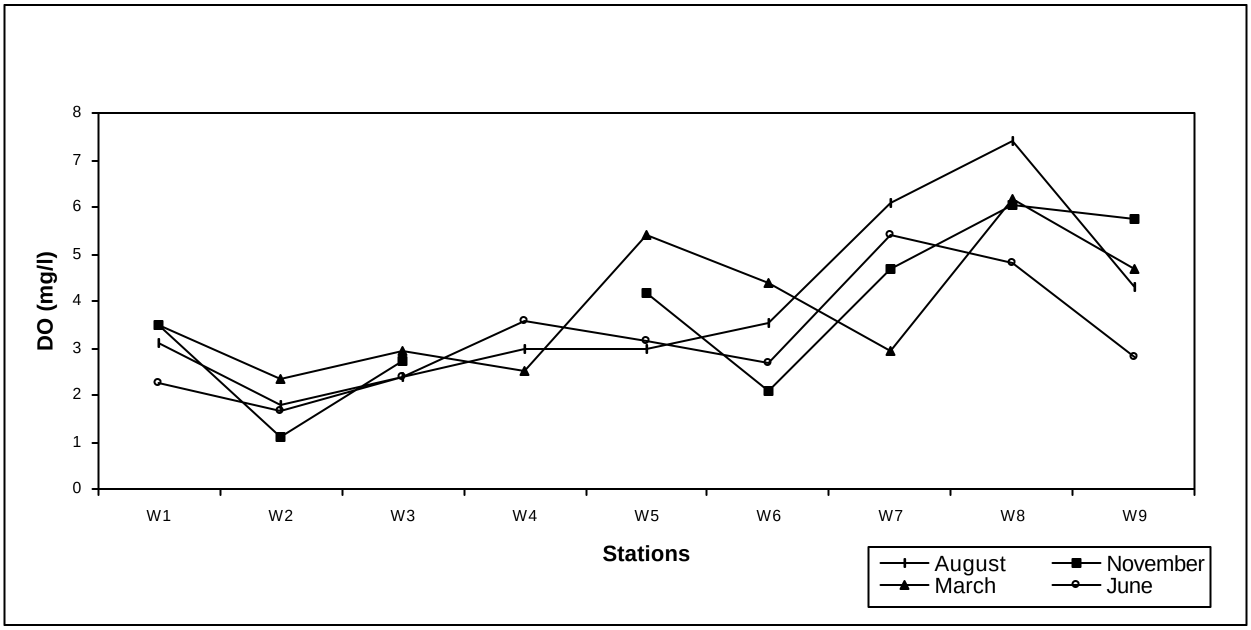

Fig. 4.16 SEASONAL VARIATIONS OF DO, WELL WATER, CHALAKUDI RIVER BASIN

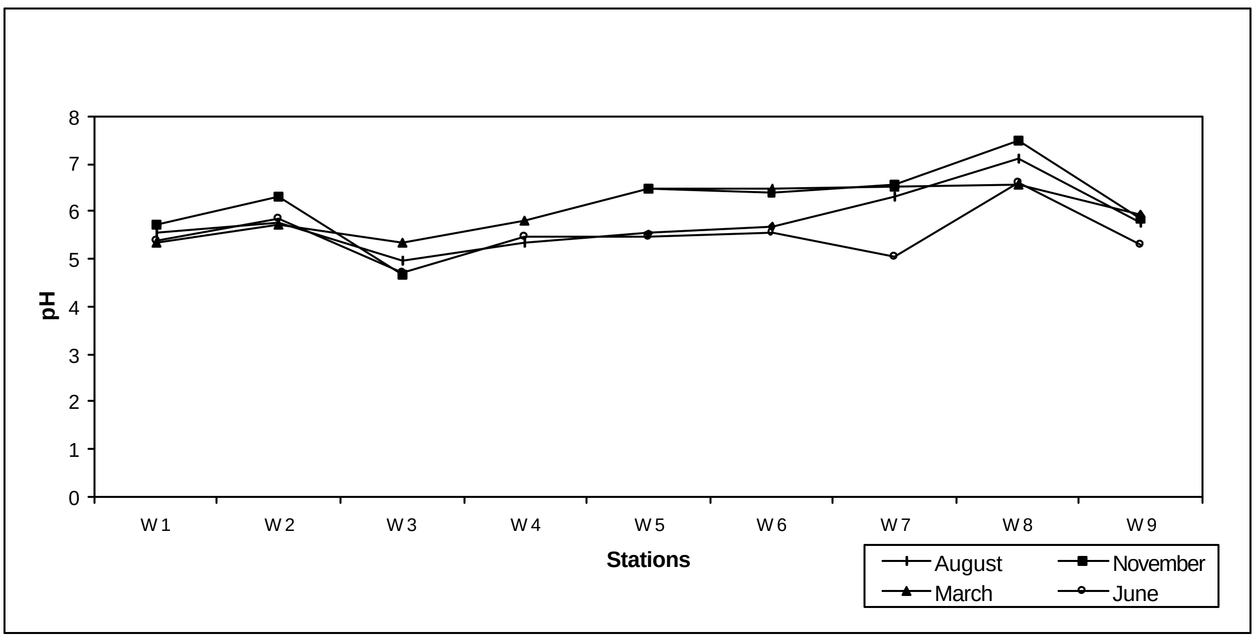

Fig. 4.17 SEASONAL VARIATIONS OF pH, WELL WATER, CHALAKUDI RIVER BASIN

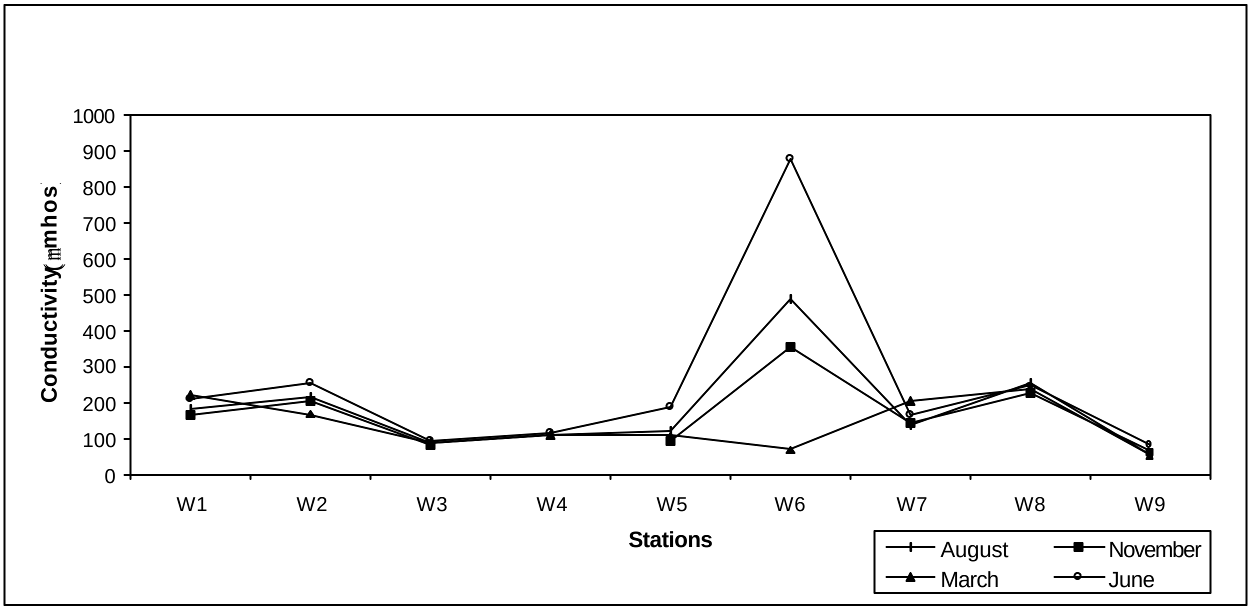

Fig. 4.18 SEASONAL VARIATIONS OF CONDUCTIVITY, WELL WATER, CHALAKUDI RIVER BASIN

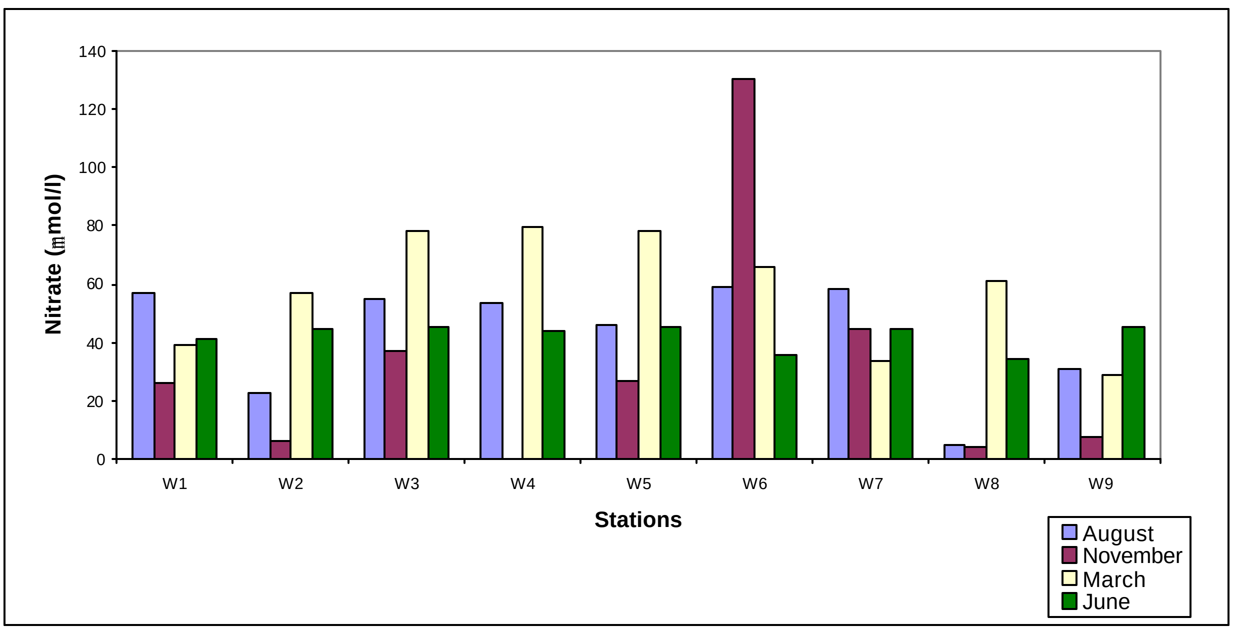

Fig. 4.19 SEASONAL VARIATIONS OF NITRATE, WELL WATER, CHALAKUDI RIVER BASIN

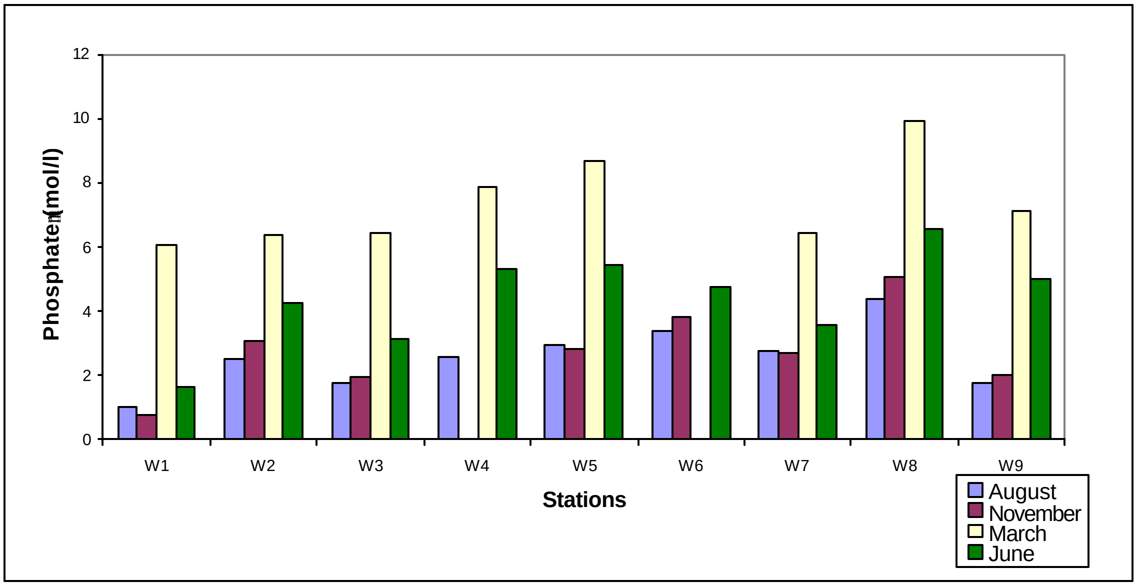

Fig. 4.20 SEASONAL VARIATIONS OF PHOSPHATE, WELL WATER, CHALAKUDI BASIN

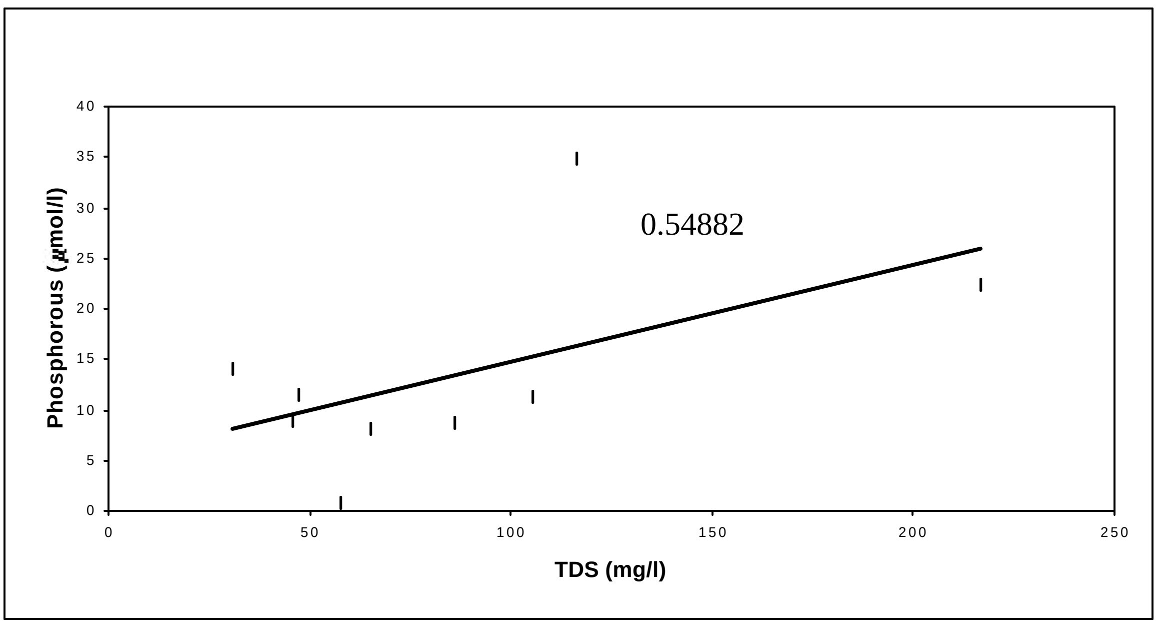

Fig. 4.21 TDS Vs. TOTAL PHOSPHOROUS, AUGUST, 2001, WELL WATER, CHALAKUDI RIVER BASIN

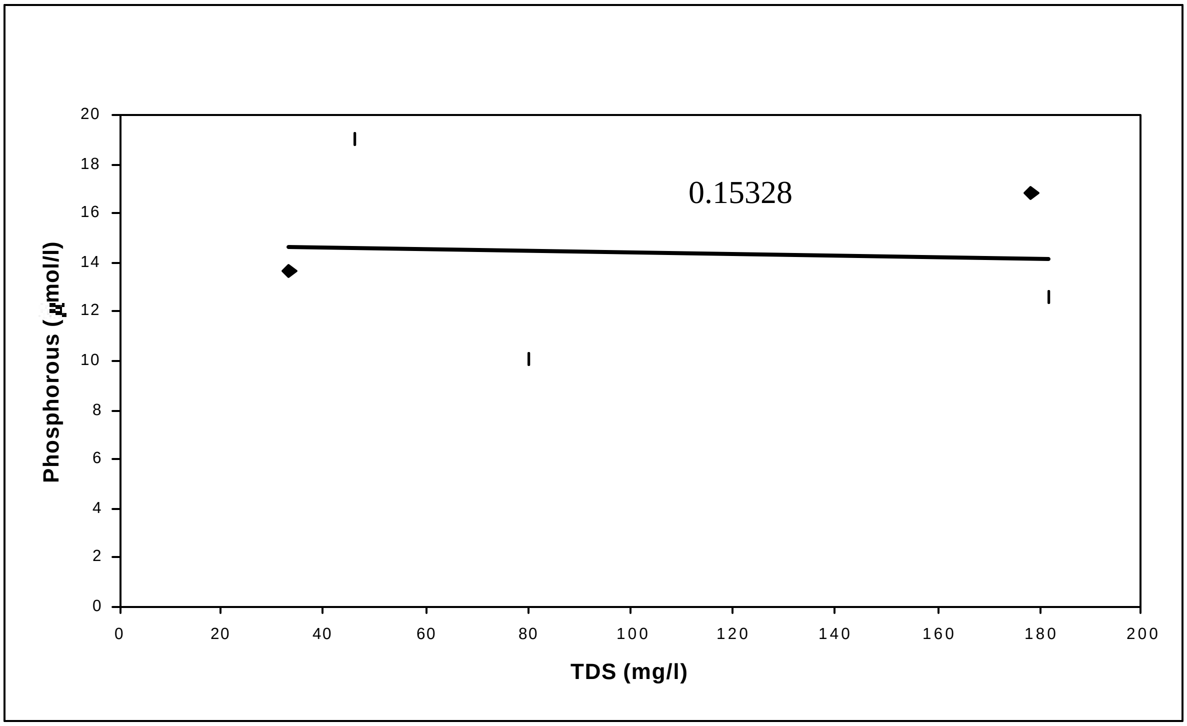

Fig. 4.22 TDS Vs. PHOSPHOROUS, NOVEMBER, 2001, WELL WATER, CHALAKUDI RIVER BASIN

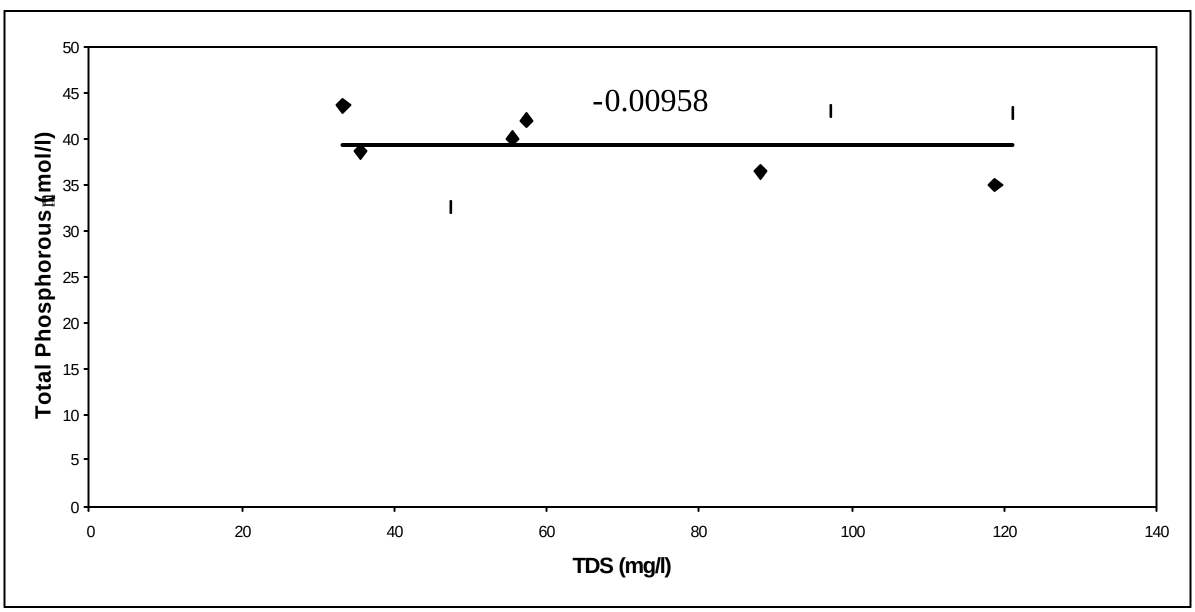

Fig. 4.23 TDS VS. TOTAL PHOSPHOROUS, MARCH, 2002, WELL WATER, CHALAKUDI RIVER BASIN

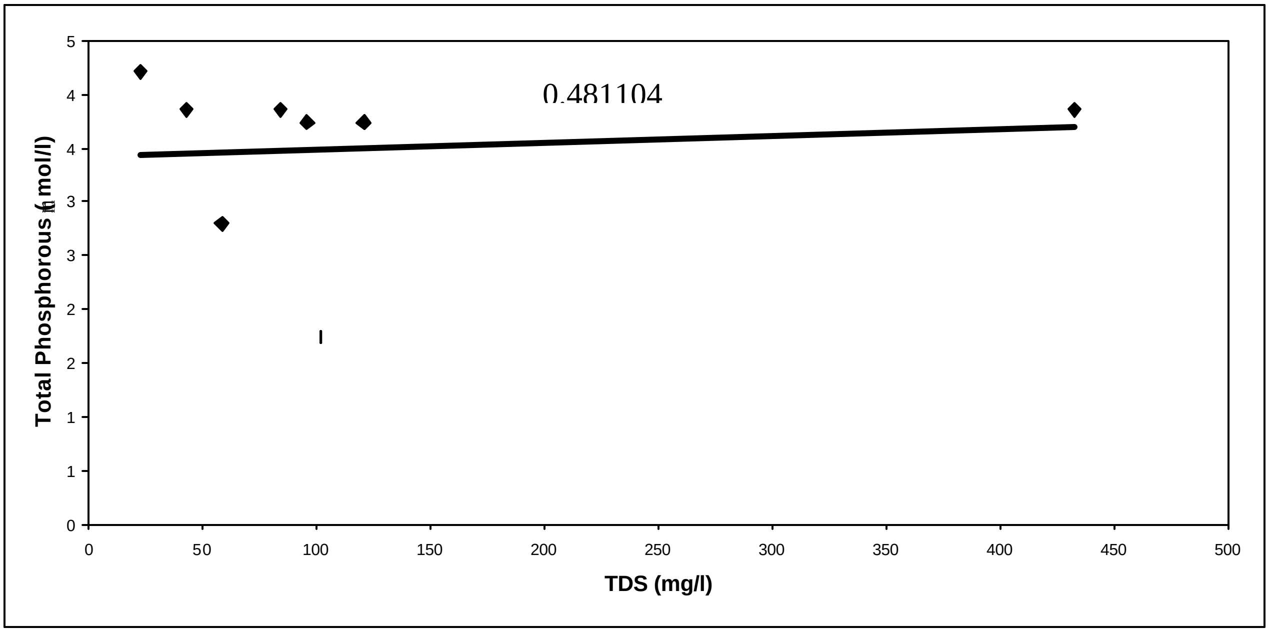

Fig. 4.24 TDS Vs. TOTAL PHOSPHOROUS, JUNE, 2002, WELL WATER, CHALAKUDI RIVER BASIN

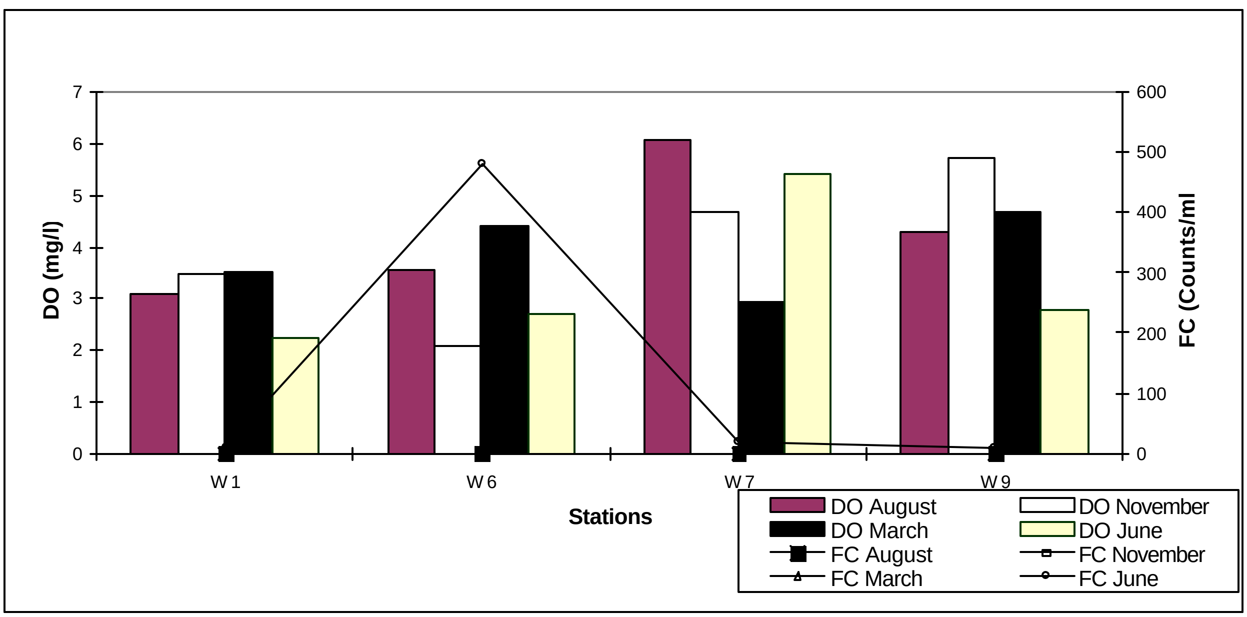

Fig. 4.25 DO Vs. FECAL COLIFORM, WELL WATER, CHALAKUDI RIVER BASIN

4.5 Groundwater zonation

Based on the analytical data water samples collected for the month of August, 2001 (monsoon) (Table 4.25), November, 2001 (post-monsoon) (Table 4.26), March 2002 (Dry period) (Table 4.27) and June (2002 (Monsoon (Table 4.28) zonation of groundwater sample was attempted. Considering all the data together an overall grading had also been done (Table 4.29). Landuse pattern was correlated with this gradation. The procedure followed for the gradation of surface water was adopted for groundwater also.

The wells near the urban settlement showed high pollution in the dry season. In overall grading the wells in the urban settlement were moderately polluted. The well near the paper pulp factory at Kanjirapally was highly polluted in overall grading. It might be due to the release of untreated industrial waste of high organic matter into the river. Here high pollution was observed in monsoon (August 2001 and June 2002). Some of the groundwater locations under settlement with mixed tree crops showed moderate pollution. Agricultural waste and human waste contributed to pollution in this area.

4.6 Impact on well water depth and fluctuation

The importance of hydrology in the assessment, development, utilization and management of water resources has been realized at all levels. Study of groundwater regime is one of the important fields of hydrology. The qualitative and quantitative availability of groundwater is generally influenced by varying geologic, physiographic and climatic conditions. Falling of water level, land subsidence, contamination etc are manifestations which indicates that the management of this precious resource is not adequate.

Table 4.25 RATING FOR WATER QUALITY GRADATION, GROUNDWATER, CHALAKUDI RIVER BASIN – AUGUST, 2001

Station	pH		Conductivity			Nitrate			Phosphate			Grade
	Polluted <6.2 & >7.0	Non polluted 6.2-7.0	Low <30	Medium 30-100	High >100	Low <0.05	Medium 0.05-0.2	High <0.2	Low <0.002	Medium 0.002-0.025	High >0.025	
W1	$				$		$				$	II
W2	$				$	$					$	II
W3	$			$		$					$	III
W4	$				$			$			$	I
W5	$				$		$				$	II
W6	$				$			$			$	I
W7		$			$			$			$	III
W8		$			$			$			$	II
W9	$			$				$			$	II

Table 4.26 RATING FOR WATER QUALITY GRADATION, GROUNDWATER, CHALAKUDI RIVER BASIN – NOVEMBER, 2001

Station	pH		Conductivity			Nitrate			Phosphate			Grade
	Polluted <6.2 & >7.0	Non polluted 6.2-7.0	Low <30	Medium 30-100	High >100	Low <0.05	Medium 0.05-0.2	High <0.2	Low <0.002	Medium 0.002-0.025	High >0.025	
W1	$				$	$					$	II
W2		$			$	$					$	III
W3	$			$				$			$	III
W4												-
W5		$		$			$				$	III
W6		$			$			$			$	II
W7		$			$	$					$	III
W8		$			$		$				$	III
W9	$			$			$				$	II

Table 4.27 RATING FOR WATER QUALITY GRADATION, GROUNDWATER, CHALAKUDI RIVER BASIN – MARCH, 2002

Station	pH		Conductivity			Nitrate			Phosphate			Grade
	Polluted <6.2 & >7.0	Non polluted 6.2-7.0	Low <30	Medium 30-100	High >100	Low <0.05	Medium 0.05-0.2	High <0.2	Low <0.002	Medium 0.002-0.025	High >0.025	
W1	$				$			$			$	I
W2	$				$			$			$	I
W3	$			$				$			$	II
W4	$				$			$			$	I
W5		$			$			$			$	II
W6		$		$				$			ND	III
W7		$			$			$			$	II
W8		$			$		$				$	III
W9	$			$			$				$	II

Table 4.28 RATING FOR WATER QUALITY GRADATION, GROUNDWATER, CHALAKUDI RIVER BASIN, JUNE , 2002

Station	pH		Conductivity			Nitrate			Phosphate			Grade
	Polluted <6.2 & >7.0	Non polluted 6.2-7.0	Low <30	Medium 30-100	High >100	Low <0.05	Medium 0.05-0.2	High <0.2	Low <0.002	Medium 0.002-0.025	High >0.025	
W1	$				$		$				$	II
W2	$				$		$				$	II
W3	$			$			$				$	II
W4	$				$	$					$	III
W5	$	$			$	$					$	III
W6	$	$			$			$			$	I
W7	$	$			$			$			$	I
W8		$			$		$				$	III
W9	$			$				$			$	II

Table 4.29 GRADING OF GROUNDWATER IN DIFFERENT SEASONS, CHALAKUDI RIVER BASIN

Station	Grades				Overall grading	Location	Landuse pattern	Gradation of surface water
	August 2001	November 2001	March 2002	June 2002				
W1	II	II	I	II	II A	Chalakudi town near the market	Agglomerated settlement	I A
W2	II	III	I	II	II A	1 km north of Chalakudi town near the bridge	Agglomerated settlement	I A
W3	III	III	II	II	II	East of Chalakudi town	Near the paddy field	I B
W4	I	No sample	I	III	I	Beside the main river near Kanjirapally	Settlement with mixed tree crops	I B
W5	II	III	II	III	II A	Near Kannapalli	Settlement with mixed tree crops	I B
W6	I	II	III	I	I	Beside the main river near Kanjirapally near the paper pulp factory	Settlement with mixed tree crops	I B
W7	III	III	II	I	IIB	Near Kanjirapalli	Settlement with mixed tree crops	I B
W8	II	III	III	III	III	Near the clay mine at Anallur	Settlement with mixed tree crops	II
W9	II	II	II	II	II	North of Chalakudi town near the factory	Settlement with mixed tree crops	I B

Grade I - Highly polluted
Grade II - Moderately polluted
Grade III - Marginally polluted
Grade IV - Non-polluted

Grade I - Highly polluted
Grade II - Moderately polluted
Grade II A - Moderately polluted in March
Grade II B - Moderately polluted in June
Grade III - Non polluted/ no pollution

4.6.1 Water table Contour

Water occupying the pores and interstice within a geological stratum to its level of saturation is commonly referred to groundwater. Water table of a region is controlled by its physiography, geological formation, extent of weathering rocks, rainfall and vegetation cover. Groundwater moves from level of higher energy to levels of lower energy, where by its energy is essentially the result of elevation and the resultant pressure.

Altogether 60 wells had been selected for monitoring the depth to water table based on the geologic and geomorphic condition of the terrain. Contour lines for well water depth could not be drawn in the highland portion of the basin due to the non-availability of wells to monitor. So a stretch starting from Vettilampara, the eastern part of the basin, to the confluence point of Periyar river and Chalakudi river has been taken. The depth to water table of wells in different season and the characteristics of wells were given in Table 4.30.

4.6.1.1 Depth to water level, November, 2001

The depth to water level as measured during November, 2001 was in the range of 0.75 to 7.5m bgl in major part of the basin. The average level was around 4m bgl. Shallow water levels of 0.75m bgl was recorded in Painkavu area falling in the lowland part of the basin. The water level of 3-6m bgl was observed to cover 50% of the area. The area of deep water level in the range of 6.5-7.5m bgl occurred as isolated pockets.

4.6.1.2 Depth to water level, March, 2002

The analysis of water level data collected from the wells during the month of March, 2002 showed that the depth to water level in the basin was generally in the range of 1.5 to 8.5 m bgl, the average being 5m bgl. The deep water level was seen near Thirumukkulam. Though the area falls under lowland terrain, the clay mining sites near this area is perhaps the reason for considerably low water table in this area.

Table 4.30 DEPTH OF WELLS IN DIFFERENT SEASONS AND THEIR CHARACTERISTICS, CHALAKUDI RIVER BASIN

Well No.	Total depth	Diameter	Depth to water table				Characteristics
			November, 2001	March, 2002	June, 2002	July, 2003	
1	9.00	1.50	4.50	7.00	3.00	3.25	Laterite, 80m, settlement with mixed tree crops, sloping towards main river
2	7.00	1.50	4.00	5.50	3.00	1.70	Laterite, Highland,100m, Forest, Sloping towards main river
3	3.50	1.50	2.00	2.75	0.50	0.55	Laterite, 60m, treecrops, sloping towards main river
4	7.00	1.50	4.00	5.50	3.25	2.15	Laterite, Settlement with mixed tree crops, below 60m sloping towards tributary
5	9.00	1.50	6.50	8.50	5.00	3.90	Laterite, Settlement with mixed tree crops, below 40m sloping towards a tributary
6	5.50	3.00	2.00	3.50	1.00	0.95	Laterite, Rubber, 40-60m, sloping towards main river
7	3.25	1.50	1.25	2.75	1.25	1.00	Laterite, Reclaimed paddy, lowland, below 10m, sloping towards main river
8	2.00	2.00	1.00	1.75	1.00	0.95	Hard rock, lowland, 20m, settlement with mixed tree crops, sloping towards main river
9	2.00	1.00	1.00	1.75	1.00	1.45	Laterite, lowland, below 20m, settlement with mixed tree crops, sloping towards main river
10	6.00	1.50	4.00	5.75	3.50	5.50	Hard rock, lowland, 20m, settlement with mixed tree crops, sloping towards main river
11	7.50	2.00	4.00	5.00	2.00	3.30	Laterite, lowlnd, settlement with mixed tree crops, less than 20m, sloping towards main river
12	7.75	2.00	3.75	4.75	3.00	2.00	Laterite, lowlnd, settlement with mixed tree crops, above 20m, sloping towards tributary
13	7.00	1.25	4.50	6.50	3.00	3.10	Laterite, lowlnd, settlement with mixed tree crops, below 20m, sloping towards main river
14	5.50	1.50	4.00	5.00	3.50	2.85	Laterite, ridge top, above 20m, settlement with mixed tree crops, sloping towards main river
15	7.00	2.50	6.50	6.85	6.00	6.65	Laterite and hard rock, ridge top, settlement with mixed tree crops, 20-40m, sloping towards tribuatary
16	6.50	2.00	5.50	6.00	4.50	4.10	Laterite, setlement with mixed tree crops, 20m, sloping towards main river
17	8.00	2.00	6.50	7.50	5.50	5.70	Laterite, Settlement with mixed tree crops, 20m, sloping towards main river
18	4.50	1.50	3.00	4.00	2.25	2.35	Laterite and clay, lowland, 20-40m, settlement with mixed tree crops sloping towards tributary
19	7.00	3.00	6.25	6.75	5.10	4.93	Clay, lowland, 20-40m, settlement with mixed tree crops sloping towards tributary
20	7.25	2.50	4.25	5.25	3.25	3.80	Laterite, below 20m, lowland, settlement with mixed tree crops, sloping towards main river
21	8.50	2.00	5.00	6.50	4.00	3.95	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
22	8.50	1.50	4.00	6.00	3.50	SN	Laterite, settlement with mixed tree c rops, below 20m, sloping towards main river
23	2.75	1.75	1.25	2.25	0.75	1.40	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river

Contd…

Well No.	Total depth	Diameter	Depth to water table				Characteristics
			November, 2001	March, 2002	June, 2002	July, 2003	
24	4.50	1.50	2.00	3.50	1.00	2.00	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
25	7.50	1.75	4.50	6.50	4.75	3.15	Laterite, ridge top, 20-40m, settlement with mixed tree crops
26	4.50	2.00	3.00	4.00	2.50	1.20	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
27	6.00	1.50	3.00	5.50	2.00	3.35	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
28	3.00	1.50	1.00	2.00	0.50	1.35	Laterite and clay, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
29	2.50	1.50	0.75	1.50	0.50	SN	Laterite and clay, lowland, paddy, below 20m, sloping towards tributary
30	3.00	1.50	1.00	2.00	0.50	SN	Laterite and clay, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
31	6.00	1.50	3.00	5.00	2.00	2.08	Laterite, lowland, below 20m, settlement with mixed tree crops, sloping towards tributary
32	10.00	2.50	3.00	7.50	5.50	3.12	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
33	4.50	2.50	1.50	2.00	1.00	1.40	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
34	6.50	1.50	5.00	6.00	4.50	2.70	Sandy soil, lowland, settlement with mixed tree crops sloping towards main river
35	7.75	2.00	5.75	6.00	5.00	5.90	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
36	8.00	2.00	5.00	6.50	4.50	4.35	Laterite and clay, lowland, paddy, below 20m, sloping towards main river
37	5.00	1.00	1.00	3.00	0.25	0.40	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
38	6.00	2.00	2.00	3.00	2.00	1.9	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
39	5.75	1.75	3.25	4.00	3.00	1.90	Laterite, lowland, below 20m, paddy, sloping towards tributary
40	5.00	2.50	1.00	3.00	1.00	SN	Clay, 20-40m, settlement with mixed tree crops sloping towards tributary
41	8.25	3.00	4.25	6.50	3.75	2.50	Laterite, 20-40m, settlement with mixed tree crops sloping towards tributary
42	8.00	2.00	5.00	7.75	4.00	4.50	Laterite, side slope, 20-40m, settlement with mixed tree crops, sloping towards tributary
43	7.00	2.00	4.00	5.50	2.50	3.50	Laterite, lowland, below 20m, paddy, sloping towards tributary
44	4.50	1.25	2.00	3.00	1.50	2.00	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
45	7.50	2.00	3.50	5.50	2.75	2.80	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
46	7.00	2.00	2.50	4.50	1.50	2.50	Laterite, settlement with mixed tree crops, below 20m, sloping towards main river
47	5.00	1.50	2.00	3.00	2.50	3.70	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary

Contd….

Well No.	Total depth	Diameter	Depth to water table				Characteristics
			November, 2001	March, 2002	June, 2002	July, 2003	
48	5.00	1.50	1.50	2.50	2.00	SN	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
49	5.00	1.50	2.00	4.00	1.50	1.50	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
50	5.00	1.50	2.50	4.00	1.50	2.00	Laterite, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
51	5.00	3.00	2.00	3.00	0.85	0.80	Laterite, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
52	3.75	2.00	1.75	2.50	1.00	1.60	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
53	8.00	2.50	5.00	6.50	4.00	2.35	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
54	8.00	2.50	4.50	6.50	4.00	3.30	Laterite, settlement with mixed tree crops, below 20m, sloping towards tributary
55	4.00	1.00	2.00	3.00	1.00	0.75	Clay, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
56	6.25	2.00	4.25	5.00	3.75	4.7	Sandy soil, lowland, settlement with mixed tree crops, below 20m, sloping towards main river
57	3.00	1.00	1.50	2.50	1.50	SN	Clay, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
58	3.50	1.00	1.50	2.00	1.00	1.00	Laterite, lowland, settlement with mixed tree crops, below 20m, sloping towards main river
59	10.00	2.25	7.50	8.50	7.00	SN	Laterite, lowland, settlement with mixed tree crops, below 20m, sloping towards tributary
60	6.00	3.00	2.00	4.00	1.50	1.05	Laterite, lowland, settlement with mixed tree crops, below 20m, sloping towards main river

4.6.1.3 Depth to water level, June 2002

During the month of June, the water level rose in most of the wells. Depth to water level varied from 0.25m to 7m bgl in June. Water level was at 3.8m bgl on an average. More than 45% of wells showed the water table at 2m and less than 2m bgl. However, wells with more than 5m bgl were also found in some isolated pockets.

4.6.1.4 Depth to water level, July 2003

The analysis of water level data collected from wells during the month of July 2003 show that the depth to water level in the basin is generally in the range of 0.40 to 6.65 mbgl. The minimum depth is found near Chalakudi town. The maximum depth is found at Kizhakkumuri.

4.6.2 Water table fluctuations

Water table fluctuation was generally due to the difference between supply and withdrawal of groundwater. When recharge exceeds discharge, water level rises and it falls under reverse condition. Since under most natural circumstances recharge to discharge from the same groundwater catchment occurs simultaneously, groundwater level fluctuation, in fact, reflects the net changes of storage resulting form the interaction of these two components. The seasonal fluctuations of different wells were given in Table 4.31.

4.6.2.1 Water table fluctuations - November, 2001-March, 2002

The analysis of water level data of November, 2001 with respect to march, 2002 showed that the water level fluctuated from 0.35m to 2.75m bgl. The lowest fluctuation of 0.35m bgl was observed at Naluketu and the highest fluctuation of 2.75m bgl was observed at Urumpumkunnu.

4.6.2.2 Water table fluctuations - March, 2002-June, 2002

Compared to March, 2002, level of water table rose in most wells during June, 2002. The water level fluctuation was in the range of 0.50m to 4m bgl. The highest fluctuation was observed in the eastern most well near Vettilampara, which was the eastern most station located at the hilly terrain of the basin.

The analysis of water level data of November, 2001 with respect to June, 2002 indicate that the water level in the basin, in general, had risen. The fluctuation was in the range of 0 to 2.5m bgl. It is observed that 85% of the wells showed fluctuation below 1m bgl. Some of the stations had no fluctuations at all. In certain wells a fall of water level of 0.25 to 2.5m bgl was observed. The fall of 2.5 m bgl was observed in Kunnapillisseeri, located in the lowland part of the basin, which is 1km away from the Chalakudi river.

Table 4.31 WATER TABLE FLUCTUATIONS IN DIFFERENT SEASONS, CHALAKUDI RIVER BASIN

Well No.	Total depth	Depth to water table				Fluctuations			
		November, 2001	March, 2002	June, 2002	July, 2003	Nov-Mar	Mar-Jun	Nov-Jun	June-July
1	9.00	4.50	7.00	3.00	3.25	-2.50	4.00	1.50	-0.25
2	7.00	4.00	5.50	3.00	1.70	-1.50	2.50	1.00	1.30
3	3.50	2.00	2.75	0.50	0.55	-0.75	2.25	1.50	-0.05
4	7.00	4.00	5.50	3.25	2.15	-1.50	2.25	0.75	1.10
5	9.00	6.50	8.50	5.00	3.90	-2.00	3.50	1.50	1.10
6	5.50	2.00	3.50	1.00	0.95	-1.50	2.50	1.00	0.05
7	3.25	1.25	2.75	1.25	1.00	-1.50	1.50	0.00	0.25
8	2.00	1.00	1.75	1.00	0.95	-0.75	0.75	0.00	0.05
9	2.00	1.00	1.75	1.00	1.45	-0.75	0.75	0.00	-0.45
10	6.00	4.00	5.75	3.50	5.50	-1.75	2.25	0.50	-2.00
11	7.50	4.00	5.00	2.00	3.30	-1.00	3.00	2.00	-1.30
12	7.75	3.75	4.75	3.00	2.00	-1.00	1.75	0.75	1.00
13	7.00	4.50	6.50	3.00	3.10	-2.00	3.50	1.50	-0.10
14	5.50	4.00	5.00	3.50	2.85	-1.00	1.50	0.50	0.65
15	7.00	6.50	6.85	6.00	6.65	-0.35	0.85	0.50	-0.65
16	6.50	5.50	6.00	4.50	4.10	-0.50	1.50	1.00	0.40
17	8.00	6.50	7.50	5.50	5.70	-1.00	2.00	1.00	-0.20
18	4.50	3.00	4.00	2.25	2.35	-1.00	1.75	0.75	-0.10
19	7.00	6.25	6.75	5.10	4.93	-0.50	1.65	1.15	0.17
20	7.25	4.25	5.25	3.25	3.80	-1.00	2.00	1.00	-0.55
21	8.50	5.00	6.50	4.00	3.95	-1.50	2.50	1.00	0.05
22	8.50	4.00	6.00	3.50	SN	-2.00	2.50	0.50	-
23	2.75	1.25	2.25	0.75	1.40	-1.00	1.50	0.50	-0.65
24	4.50	2.00	3.50	1.00	2.00	-1.50	2.50	1.00	-1.00
25	7.50	4.50	6.50	4.75	3.15	-2.00	1.75	-0.25	1.60
26	4.50	3.00	4.00	2.50	1.20	-1.00	1.50	0.50	1.30

Contd…

Well No.	Total depth	Depth to water table				Fluctuations			
		November, 2001	March, 2002	June, 2002	July, 2003	Nov-Mar	Mar-Jun	Nov-Jun	June-July
28	3.00	1.00	2.00	0.50	1.35	-1.00	1.50	0.50	-0.85
29	2.50	0.75	1.50	0.50	SN	-0.75	1.00	0.25	-
30	3.00	1.00	2.00	0.50	SN	-1.00	1.50	0.50	-
31	6.00	3.00	5.00	2.00	2.08	-2.00	3.00	1.00	-0.08
32	10.00	3.00	7.50	5.50	3.12	-4.50	2.00	-2.50	1.88
33	4.50	1.50	2.00	1.00	1.40	-0.50	1.00	0.50	-0.40
34	6.50	5.00	6.00	4.50	2.70	-1.00	1.50	0.50	1.80
35	7.75	5.75	6.00	5.00	5.90	-0.25	1.00	0.75	-0.90
36	8.00	5.00	6.50	4.50	4.35	-1.50	2.00	0.50	0.15
37	5.00	1.00	3.00	0.25	0.40	-2.00	2.75	0.75	-0.15
38	6.00	2.00	3.00	2.00	1.90	-1.00	1.00	0.00	0.10
39	5.75	3.25	4.00	3.00	1.90	-0.75	1.00	0.25	1.10
40	5.00	1.00	3.00	1.00	SN	-2.00	2.00	0.00	-
41	8.25	4.25	6.50	3.75	2.50	-2.25	2.75	0.50	1.25
42	8.00	5.00	7.75	4.00	4.50	-2.75	3.75	1.00	-0.50
43	7.00	4.00	5.50	2.50	3.50	-1.50	3.00	1.50	-1.00
44	4.50	2.00	3.00	1.50	2.00	-1.00	1.50	0.50	-0.50
45	7.50	3.50	5.50	2.75	2.80	-2.00	2.75	0.75	-0.05
46	7.00	2.50	4.50	1.50	2.5	-2.00	3.00	1.00	-1.00
47	5.00	2.00	3.00	2.50	3.70	-1.00	0.50	-0.50	-1.20
48	5.00	1.50	2.50	2.00	SN	-1.00	0.50	-0.50	-
49	5.00	2.00	4.00	1.50	1.50	-2.00	2.50	0.50	0
50	5.00	2.50	4.00	1.50	2.00	-1.50	2.50	1.00	-0.50
51	5.00	2.00	3.00	0.85	0.80	-1.00	2.15	1.15	0.05
52	3.75	1.75	2.50	1.00	1.60	-0.75	1.50	0.75	-0.60
53	8.00	5.00	6.50	4.00	2.35	-1.50	2.50	1.00	1.65
54	8.00	4.50	6.50	4.00	3.30	-2.00	2.50	0.50	0.70
55	4.00	2.00	3.00	1.00	0.75	-1.00	2.00	1.00	0.25
56	6.25	4.25	5.00	3.75	4.70	-0.75	1.25	0.50	-0.95
57	3.00	1.50	2.50	1.50	SN	-1.00	1.00	0.00	-
58	3.50	1.50	2.00	1.00	1.00	-0.50	1.00	0.50	0
59	10.00	7.50	8.50	7.00	SN	-1.00	1.50	0.50	-
60	6.00	2.00	4.00	1.50	1.05	-2.00	2.50	0.50	0.45

Note: Positive values (+) in the fluctuations indicate a rise in the water level and the negative (-) indicates a fall *in the water level.*

Zero values indicate that there is no fluctuation

4.6.2.3 Water table fluctuations - November, 2001 – June, 2002

Correlation had been worked out for Depth to water table and water table fluctuations (Figs. 4.26, 4.27 and 4.28) for each season. It was found that they are positively correlated.

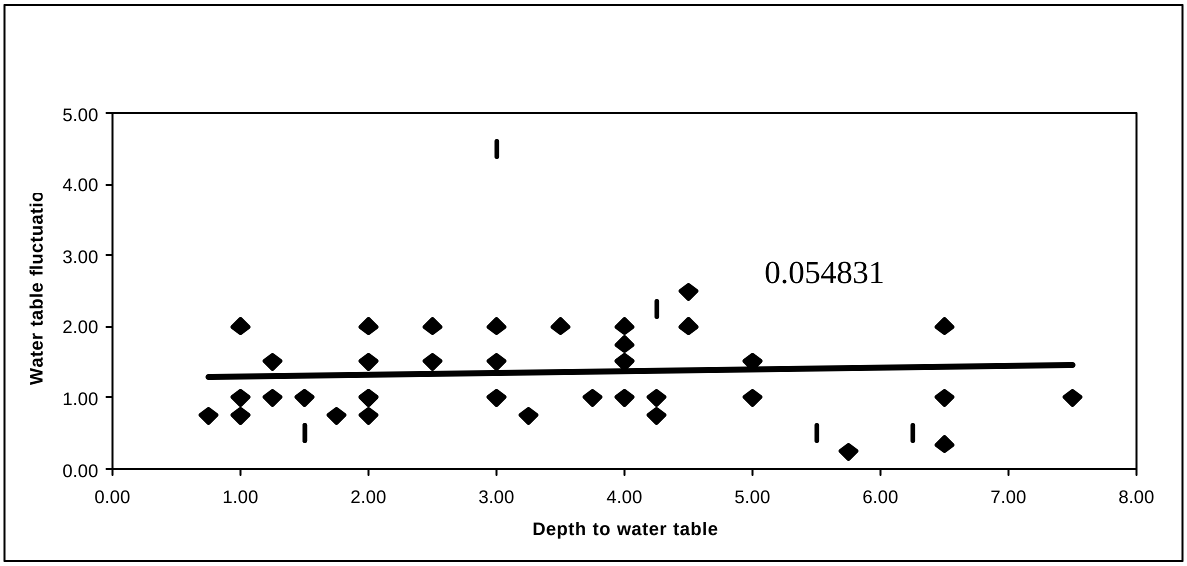

Fig. 4.26 DEPTH TO WATER TABLE Vs. WATER TABLE FLUCTUATION, NOVEMBER, 2001

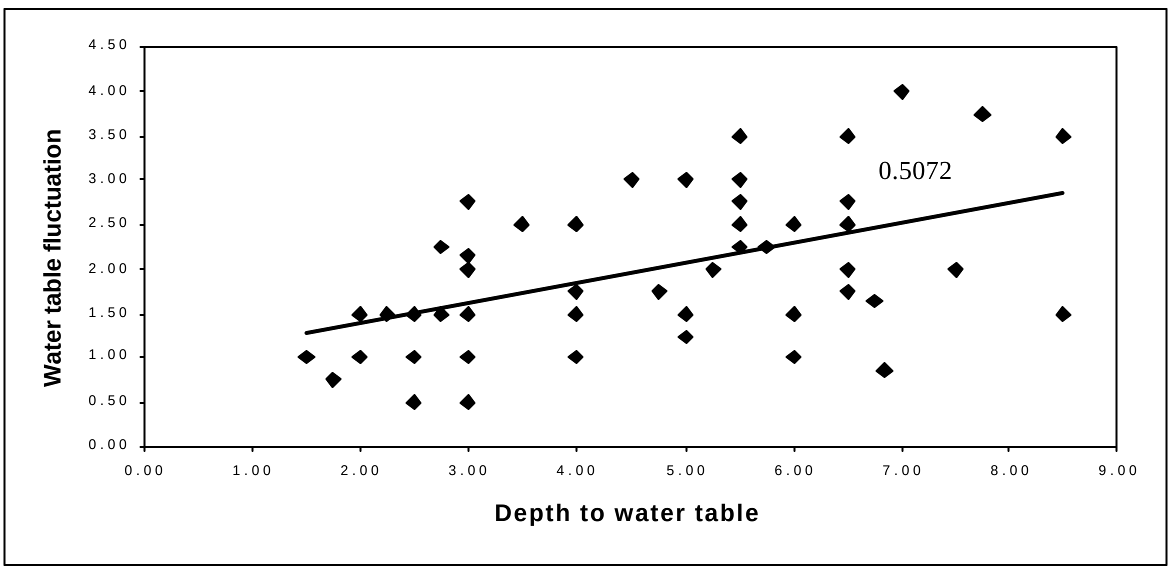

Fig. 4.27 DEPTH TO WATER TABLE Vs. WATER TABLE FLUCTUATION, MARCH, 2002

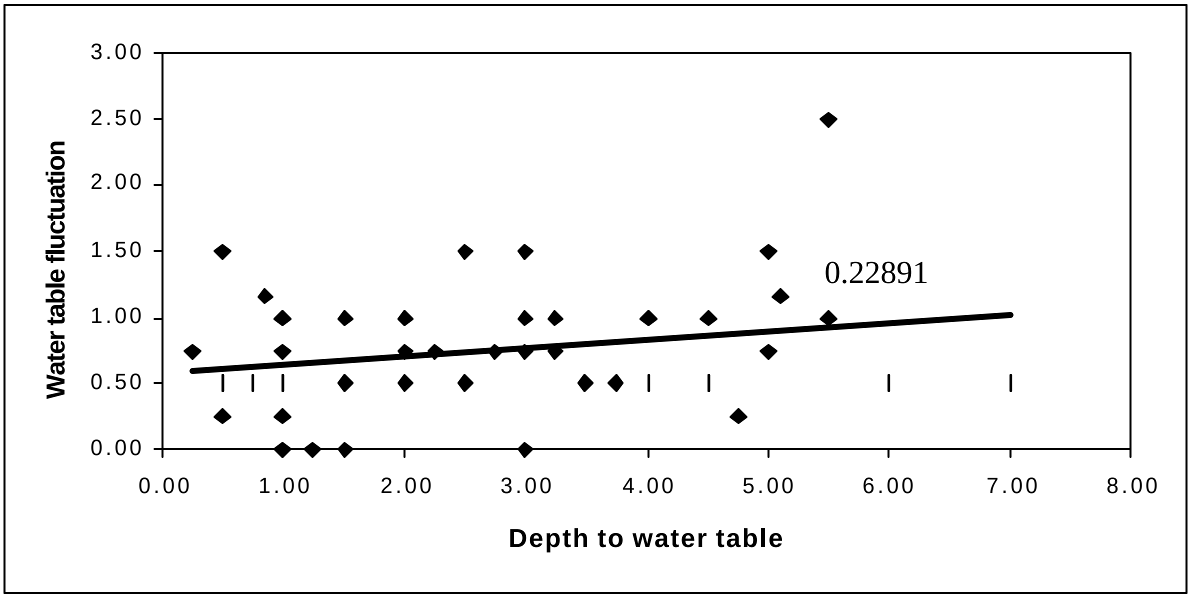

Fig. 4.28 DEPTH TO WATER TABLE Vs. WATER TABLE FLUCTUATION, JUNE, 2002

4.6.2.4 Water table fluctuations - June, 2002 – July, 2003

The analysis of water fluctuation data of June, 2002 with respect to July, 2003 show that more than 43% of the wells observed a fall in water level during this period. A fall of 2 mbgl was observed near Pariyaram and a rise in water level of 1.88 mbgl was observed near Puliyanam. Only two places in the basin in the lower part of the basin observed no fluctuation during this period.

CHAPTER 5

LANDUSE/ LANDSCAPE CHANGE: CAUSES AND CONSEQUENCES – LOCAL PEOPLE'S PERCEPTION

5.1 Introduction

Trends of landuse change in five segments since 1966-'67, the drivers of landuse change and environmental consequences have been discussed in previous chapters. This chapter deals with local people's perception about landuse change and its consequences. The study had been attempted through sample survey. Survey procedure followed here and the results area described below.

5.2 Sample survey procedure

A preliminary sample survey was conducted in the panchayats falling under the Chalakudi river basin in the 2nd week of November 2002 to receive local people's response for the causes and impacts of landuse change and also to understand the socio-economic condition of the people living therein. Detailed survey was conducted in all 5 segments during January – February, 2003.

Altogether 100 samples were collected from these 5 segments. 25 each from the Segment I (confluence point of Chalakudi and Periyar), Segment – II (Chalakudi town and surroundings) and Segment – III (Thumburmuzhi and surroundings). 13 samples were taken from the Segment IV a (Parambikulam reservoir and surroundings), and 12 samples were from Segment IV b (Karapara river and surroundings). The respondents included mainly of farmers and general people. A PRA was also conducted in different places in the first three segments. A sample questionnaire is given in the Appendix.

The questionnaire covered the following eight major items.

(i) Identification particulars
(ii) Household information
(iii) Habitation analysis
(iv) Amenities in the house
(v) Detailed of land possessed, agriculture and allied activities
(vi) Market status
(vii) Natural calamities
(viii) Impact of landuse change

Out of five segments two segments (IV a and IV b) that fall within the forest area are different in their characteristics with very low population. The issues are also different. Accordingly, discussions here are attempted separately.

The results obtained from this survey covering the first three segments i.e. (i) confluence of Chalakudi and Periyar (lowland), (ii) Chalakudi town and surroundings (midland) and (iii) Thumburmuzhi and surroundings (highland) are presented in the first section. Apart from individual issues in the segments a comparative picture is also presented here.

5.3 Identification particulars

When these three segments were considered 75% of the respondents were from Thrissur district and the rest from Ernakulam district. The taluks covered include Mukundapuram (75%), Alwaye (17%) and Paravoor (8%).

5.4 Household information

The majority of the people who were interviewed and their family members were in the age group of 25 to 50 years. Of which majority were males. Majority of the respondents had their education upto school level. However, there are some people with higher degrees also.

In the highland segment (Segment - III) 96% of the respondents depend agriculture for their main source of income, and in the lowland (Segment - I), 76% depend on agriculture as their main source of income. Dependence on agriculture came down to 68% in the midland segment (Segment - II) where the Chalakudi town is located. The main occupation of the people who resides in Chalakudi town is business and govt. jobs. There are some depending mainly on jobs outside the locality and even outside the country, on business and on pension. Agriculture is the secondary source of income for 24%, 32% and 4% of the respondents in the lowland, midland and highland respectively.

About 30% of the respondents settled here 25 to 50 years back. Another 25% settled here before 50 years back (25%). About 75% of the respondents have 3 to 7 rooms in their houses. All the respondent in the three segments have their own houses and majority of the respondents live in the concrete house. All the respondents have wells in their premises and some families use well water for domestic purposes including drinking.

28% in the lowland segment complained about water shortage during dry periods in their wells while in highland segment 36% complained about water shortage and in town area 56% complains about water shortage. In the lowland segment where the land is mainly used for agricultural purposes, there is sufficient water which helps even during years of over all water storage.

All the houses are electrified and have toilet facilities. Wood and LPG are mainly used as fuel for cooking purposes.

5.5 Amenities in the house

A list of amenities in the house were noted down mainly to classify the respondents based on their economic conditions and standard of living. Income groups identified based on these information.

72% in the lowland segment of the respondent came under high income group and 24% came under middle income group. While in the midland segment only 48% were in the high income group and 36% in middle income group, in the highland 44% were in the high income group and another 44% were in the middle income group. The rest of the respondents in all the segments were classified under the low income group.

5.6 Detailed of land possessed, agriculture and allied activities

The type of land possessed by each family varied from lowland to highland. Lowland, garden land, plantation land were the different types of land owned by respondents in the segments. Majority of the respondents had their land holding as single fragment, but there were respondents whose land holdings were fragmented in different segments.

Because of the uniformity of the land and soil type, the landuse categories were less in the lowland segment. It increased towards the midland segment, and the highland segment showed maximum crop diversity (Table 5.1). The crop combination differs from one segment to other. Coconut-plantains-nutmeg-paddy were the combination in the lowland segment. It is coconut-paddy-arecanut-nutmeg in the midland segment and coconut-arecanut-rubber-nutmeg-pepper-plantains are the crops of highland segment. Mango and jack as subsidiary crops are cultivated in all the segment (refer Table 5.1). As there is hardly any family practicing monocropping the total number in the column when added may be more than 100.

Table 5.1 MAIN CROPS CULTIVATED

Crops	Lowland (%)	Midland (%)	Highland (%)
Paddy	48	44	8
Coconut	100	92	100
Aracanut	40	52	60
Tapioca	4	4	8
Rubber	4	8	48
Cashew	8	12	4
Plantains	72	64	56
Pepper	28	24	36
Nutmeg	60	56	64
Mixed tree crops	-	4	-
Vanila	-	4	-
Anthurium	-	4	-
Coco	-	4	4
Pineapple	-	-	4
Crop association/diversity	C-Pl-N-P	C-Pl-N-A-P	C-N-A-Pl-R
Subsidiary crops			
Jack	76	80	92
Mango	84	72	88

Note: Number represents percentage of total respondents in each segment for each item

5.6.1 Landuse conversion

Trends of landuse change in each segment has been brought out in Chapter 3. it is reported that there are changes in all segments. Many types of crops had been replaced by other crops. Paddy, aracanut, cashew and mixed crops are the crops were mainly replaced by other crops. However, the main conversion had occurred to paddy land, which is quite intensive lowland segment. Paddy land here had been converted to a number of other crops like, coconut, plantains, mixed tree crops etc. In many places the area under paddy had been reclaimed for the purpose of constructing houses (Table 5.2).

Arecanut had been changed to accommodate coconut and mixed tree crops (Table 5.3). In the highland segments, the mixed tree crops were replaced by rubber, but in many places rubber had given way to mixed tree crops. Highland segment reported forest area changing to settlement, mixed tree crops and rubber. It had been widely reported that barren lands were given for settlements and mixed tree crops in all the segments.

Table 5.2 LANDUSE CONVERSION – PADDY

Conversion	**Lowland (%)**	**Midland (%)**	**Highland (%)**
Paddy to coconut and house plot	8	-	-
Paddy t plantains	8	-	-
Paddy to mixed tree crops	4	8	19
Paddy to coconut	24	16	8
Paddy to settlement with mixed tree crops	8	-	20
Paddy to aracanut and then aracanut to rubber	4	-	-
Paddy to wasteland	4	-	-
Paddy to coconut and then constructed house in coconut garden	4	-	-
Paddy to settlement with mixed tree crops	4		
Paddy to rubber	-	-	4
Paddy to tapioca	-	-	4

Table 5.3 LANDUSE CONVERSION – OTHER CROPS

Conversion	Lowland (%)	Midland (%)	Highland (%)
No conversion	8	24	20
Aracanut and coconut to mixed tree crops	4	4	-
Aracanut to mixed tree crops	4	-	4
Aracanut and coconut to nutmeg and also constructed house in the plot	4	-	-
Aracanut to settlement with mixed tree crops	-	-	4
Coconut and arecanut to rubber	-	-	4
Coconut to nutmeg	4	-	-
Coconut to settlement with mixed tree crops	-	4	-
Forest to settlement with mixed tree crops	-	-	4
Forest to house and rubber	-	-	4
Forest to rubber	-	-	4
Cashew to coconut	4	4	-
Barren to coconut and mixed tree crops	4	-	-
Barren to settlement with mixed tree crops	4	16	8
Barren to mixed tree crops	-	-	4
Barren to rubber	-	-	4
Tapioca to settlement with mixed tree crops	4	4	-
Pepper to mixed tree crops	-	4	-
Mixed tree crops to rubber	-	-	4
Mixed tree crops to settlement with mixed tree crops	12	8	-
Rubber to mixed tree crops	-	-	4
Planted nutmeg in between mixed tree crops	4	-	-
Planted coco, nutmeg, pepper in between coconut	-	4	-
Planted rubber in between coconut	-	4	-
Constructed house in between rubber	-	4	-

5.6.2 Reason for landuse conversion

A variety of reasons were identified for landuse conversion and it vary from crop to crop and from segment to segment. The principal reason identified by the local people are crop diseases, higher profit, high labour cost, labour shortage and need for housing.

The reason for conversion of aracanut was the same in all the segments. The diseases caused the conversion of aracanut trees. All the respondents who converted cashew to coconut said they converted for higher profit. People used to convert coconut and aracanut to rubber earlier. But with the decrease in market value of rubber there is a tendency to convert rubber to other mixed tree crops. Construction of house is one of the compulsion for landuse conversion as reported by many respondents.

As the conversion of paddy is more widely debated and complicated, it is dealt separately. Conversion of paddy is observed in all the segments. Paddy is a crop which has been converted to a variety of other crops over the years. But the reason for conversion of paddy varies from segment to segment. 33% of the respondents in each of the lowland and midland and 17% of the respondents in the highland converted their paddy field for higher profit (Table 5.4). 26%, 33% and 34% of the respondents in the lowland, midland and highland respondents complaints that they converted paddy because of water shortage. Other problems like labour shortage, water logging and productivity also contributes to landuse change. Housing is an issue both in the lowland and in the highland segments. Availability of land suitable for settlement siting are in short due to various reasons.

Table 5.4 REASONS FOR PADDY CONVERSION

Reason	Lowland (%)	Midland (%)	Highland (%)
For profit and housing	7	-	17
Low productivity for paddy	7	-	-
For profit	33	33	17
High labour charge	13	-	8
Water shortage	26	33	34
Water logging	7	-	-
Housing	7	-	8
Water shortage and labour problem	-	17	-
Labour shortage	-	17	8
Less productivity and high labour charge	-	-	8

5.6.3 Years of landuse conversion

The conversion of each crop and its years of conversion were also analysed. It is found that in all the three segments conversion of paddy mainly for coconut started two decades back. But conversion of paddy to plantains and keeping the land as uncultivable fallow were reported in less than 10 years time and in some places it was more than ten years. In the highland segment, paddy had been changed to rubber in 2 decades time. Table 5.5 provides the details of conversion in all three segments. The trend of conversion is not a recent phenomena and can be traced two to three decades back. Similar observations was made by Kerala Statistical Institute (1994) in their study on paddy land conversion.

Table 5.5 YEARS OF LANDUSE CONVERSION

Landuse conversion	Lowland (%)			Midland (%)			Highland (%)		
	< 10 yrs	10-20 yrs	>20 yrs	< 10 yrs	10-20 yrs	>20 yrs	< 10 yrs	10-20 yrs	>20 yrs
Paddy	15	21	26	-	15	15	7	15	24
Aracanut	-	4	7	5	-	-	4	4	4
Pepper	-	-	-	5	-	-	-	-	-
Cashew	-	4	-	-	5	-	-	-	-
Tapioca	4	-	-	-	-	5	-	-	-
Mixed tree crops	-	-	7	5	5	5	7	-	-
Planted tree crops	-	4	-	5	-	-	-	-	-
Barren land	4	4	-	5	-	15	-	4	15
Rubber	-	-	-	5	-	-	4	-	-
Coconut	-	-	-	5	-	-	-	-	-
Forest	-	-	-	-	-	-	4	-	7

5.6.4 Economic background and landuse conversion

One of the points of investigation was to understand the relationship between economic background of the respondents and their role in landuse conversion. People of all economic group alter their landuse, but the reason may be different. As much as 45% of the respondents in the low land segment who had converted paddy land belonged to the high economic group (Table 5.6).

Table 5.6 LANDUSE CONVERSION AND ECONOMIC BACKGROUND

Landuse conversion	Lowland (%)			Midland (%)			Highland (%)		
	H	M	L	H	M	L	H	M	L
No conversion	8	-	-	8	14	-	14	6	-
Paddy	45	10	3	11	8	4	9	23	6
Aracanut	3	8	-	-	4	-	-	6	3
Pepper	-	-	-	-	-	4	-	-	-
Cashew	3	-	-	4	-	-	-	-	-
Tapioca	3	-	-	4	-	-	-	-	-
Mixed tree crops	8	-	-	4	4	-	-	3	-
Planted tree crops	3	-	-	4	4	-	-	-	-
Barren land	3	3	-	11	-	4	9	9	-
Rubber	-	-	-	4	-	-	3	-	-
Coconut	-	-	-	-	-	4	-	-	-
Forest	-	-	-	-	-	-	3	6	-

5.6.5 Landuse conversion and size of holdings

Landuse conversion bears certain relation with land holdings also. In the lowland segment, 8% of the people having medium size holdings had not changed the landuse pattern. In the midland segment, 8% of the people who had small size of holdings and 12% of people with medium size of holdings had not changed the landuse. But in other type of conversion people having different size of land holdings had also changed landuse. In the highland segment, 4% of respondents having large size of land holdings and 16% of the people with middle size of land holdings had also not changed the landuse.

The conversion of crops had been done in small as well as in large land holdings. Respondents who had not changed the landuse possessed land of more than one acre. In the midland segment, respondents having less than one acre had also changed the landuse pattern. Again respondents having more than 3 acres of land had converted paddy land to coconut garden and other mixed tree crops, and also for constructing houses in the plot.

Those who held less than one acre land replaced paddy by plantains. Respondents who have changed aracanut also had a holding of more than 3 acres.

5.6.6 Economic background and landuse type

The survey brought out that people of medium and low income group in the lowland and midland segments cultivated paddy. While in the highland segment only the high income group are engaged in paddy cultivation.

In the lowland segment 67% of the medium income family cultivated paddy and 100% of the low income family cultivated paddy. But only 28% of the high income group cultivated paddy. But coconut cultivation is practiced by people of all income groups.

78% of the medium income group people and 50% of the low income group people cultivated paddy in the midland segment. But only 17% of the high income group people cultivated paddy.

In the highland segment, 18% of the high income group cultivated paddy. Here people of medium and low income groups were not in paddy cultivation. 45% of both high medium income groups cultivated rubber and 33% of low income group also planted rubber.

5.6.7 Landuse conversion and land type

People in the segment I possessed Lowland, garden land and lands suitable for plantation. 21% people who had converted paddy possess both lowland and garden land. The rest of the people who had converted paddy possess only garden land. People who had converted cashew to coconut owned by garden land and plantation land. 50% of the people who had converted barren land and 33% of the people who had converted arecanut and coconut possessed lowland and garden land. All other conversion in the lowland segment occurred in the garden land.

In the midland segment, 83% of the respondents possessing garden land had not diverted their landuse practices. The rest possessed lowlands. 80% of the respondents who had converted paddy possessed both lowland and garden land and only 20% owned lowland. 75% of the respondents who had converted barren land had garden land and the rest possesed lowland. People who had converted pepper to mixed tree crops, cashew to coconut, constructed house in between rubber, posses lowland and garden land. Respondents who had planted rubber in b/w coconut posses lowland, garden land and plantations.

In the highland segment, 52% of the people possessed plantation land. 56% of the people who had converted paddy possessed garden land. 22% owned both garden land and plantation land. 11% possess lowland and lowland and garden land.

5.6.8 Agricultural profit and landuse conversion

32% of the respondents in the highland segment opined that the agricultural production was profitable. While in the midland segment 28% said it was profitable and in the lowland segment only 16% were of the opinion that the agriculture was profitable (Table 5.7). Though more people depend on agriculture in the lowland segment, they were of the opinion that it was not profitable. In the lowland segment, 12% said that compared to other type of cultivation paddy was not profitable. Though there were many reasons for the non-profit of paddy cultivation, economic loss and water shortage were common reasons cited in all the three segment (Table 5.8).

Table 5.7 AGRICULTURAL OPERATIONS AND PROFIT

	Lowland (%)	Midland (%)	Highland (%)
Profitable	16	28	32
Not profitable	68	72	68
Paddy is not profitable	12	-	-
Fluctuation with market value	4	-	-

The availability of labour in time, especially for operation like transplanting and harvesting, was a major problem as per the assessment of the cultivators. In spite of the wide network of irrigation systems, paddy cultivation often faces difficulties in getting the right quantity of water at the right time of the crop cultivation.

Tabel 5.8 REASONS FOR NON-PROFIT

	Lowland (%)	**Midland (%)**	**Highland (%)**
High labour charge	41	27	23
Less market value	22	11	23
Less productivity, high labour charged water shortage	5	-	6
Diseases to plants	22	11	-
Diseases to plants and less market value	-	-	18
Water shortage	5	11	12
Less productivity and diseases to plants	5	-	-
High labour charge and diseases to plants	-	-	-
High labour charge and labour shortage	-	6	-
High cost of production and less profit	-	11	-
High labour charge and less market price	-	6	6
Diseases to plants and water logging	-	6	-
Water shortage and less productivity	-	6	-
Less area under cultivation	-	5	-

All the respondents in the highland segment opined that profit increased as a consequence of landuse change. However opinions were not so clear in other two segments (Table 5.9). In fact 4% of respondents in lowland segment indicated that profit had decreased on account of landuse change. In the midland segment 4% said the water shortage was observed when the landuse had been changed.

Table 5.9 LANDUSE CONVERSION AND PROFIT

	Lowland (%)	Midland (%)	Highland (%)
Profit increased	52	40	100
Water shortage observed	-	4	-
Profit decreased	4	-	-
No comments	42	56	

5.6.9 Landuse conversion and land value

The value of land increased with landuse change. In midland segment 80% opined that the price of land had increased when the landuse changed (Table 5.10). In the lowland segment 68% of the respondents were of the same opinion. No change in price value of the land was observed by 28% in lowland, 12% in midland and 25% in the highland segment. In the lowland and midland segments 4% each were of the opinion that the land price decreased when the landuse had changed, however, 4% in the midland segment said the price value of the land depended the market value of the crop. These differences indicate location specific issues and relevance of proximate causes in landuse conversion and land price.

Table 5.10 LANDUSE CONVERSION AND PRICE OF THE LAND

Price of land	Lowland (%)	Midland (%)	Highland (%)
Price increased	68%	80%	75%
Price decreased	4%	4%	-
No change	28%	12%	25%
Depends on the market value of the crop	-	4%	-

5.6.10 Impact of landuse conversion

The survey was also conducted to understand people's opinion about the impact of landuse conversion. Specific issues enquired were groundwater, surface water, sand mining and clay mining.

5.6.10.1 Groundwater and surface water

Ground water fluctuation due to landuse change were noticed by 28% of the respondents in the lowland segment and 4% in the midland segment and 20% in the highland segment (Table 5.11). 12% in the lowland segment and 9% in the highland segment opined that the groundwater quality is also affected by landuse change. The surface water quantity and quality is reported to be affected by landuse change. 44% in Segment I and 12% in Segment II and 55% in Segment III expressed their opinion about reduction of surface water quantity and 12% in Segment I and 4% in Segment II also opined about surface water quality change in association with landuse change (Table 5.12).

Table 5.11 LANDUSE CONVERSION AND GROUND WATER FLUCTUATION

	Lowland (%)	Midland (%)	Highland (%)
Water level decreased	28	4	20
Groundwater depends on irrigation of land	-	4	-
Groundwater is affected by canal water fluctuation	-	12	-
Water in the paddy field affects the groundwater fluctuation	-	4	-
No comments/ No charge	72	76	80

Table 5.12 IMPACT OF LANDUSE CONVERSION ON WATER QUALITY AND QUANTITY (SURFACE AND GROUNDWATER)

Surface water quantity	**Lowland (%)**	**Midland (%)**	**Highland (%)**
Decreased	44	12	55
No change/ No command	56	88	45
Surface water quality			
Decreased	12%	4%	-
No change/ No comments	88	96	100
Ground water quantity			
Decreased	24	12	25
No change/ No comments	72	92	75
Ground water quality			
Decreased	12	4	-
No change/ No comments	88	96	100

5.6.10.2 Sand mining

Sand mining activities were concentrated mostly in the lower course of the river. When the impact of sand mining were analysed 36% each in lowland segment and midland segment and 32% in the highland segment responded that well water decreased as a result of river bed mining (Table 5.13). These people were directly affected by well water fluctuation in association with sand mining activity. People living away from the river could not relate water table fluctuation with sand mining.

Table 5.13 IMPACT OF SAND MINING

Possible impacts	**Lowland (%)**	**Midland (%)**	**Highland (%)**
Well water level decreased	36	36	32
No change/ No comments/ No sand mining	64	64	68

5.6.10.3 Clay mining

Clay mining activities were observed in the lowland and midland segments. 40% respondents in the lowland segment and 20% in the midland segment observed that the well water level decreased in the wells near the clay mining sites (Table 5.14). 16% of respondents in the lowland segment pointed out that land could not be used for any other purposes after the clay mining.

Table 5.14 IMPACTS OF CLAY MINING

Possible impacts	**Lowland (%)**	**Midland (%)**	**Highland (%)**
Well water level decrease	40	20	-
Land cannot be used for other purposes	16	-	-
No change/ No comments/ No sand mining	44	80	100

5.7 Around Parambikulam reservoir

The entire segment falls in the Nelliyampathy panchayat of Chittur taluk of Palakkad district. It is under the forest range of Parambikulam of Nemmara forest division.

Patches of tribal settlement were witnessed in this segment. Samples were collected from four different tribal settlements. 46 % of the total samples were collected from Kadar's colony. 38% were collected from Anjam colony and 8 % each from Earth Dam colony and Muduvas colony. The people who lived in Kadar's colony and earth dam colony were Kadars and the people who lived in the Muduvas colony were Muduvas and the people who lived in the Anjam colony were Malamanushiar.

Majority of the people in these settlements were of the age group of 25-50 years with domination of male population. 51 % of the total respondents were illiterates and 12% had their education below SSLC level.

All the respondents in the Kadar's colony were labourers. They worked for the forest department. They were also engaged in honey collection from the forest. The respondents of earth dam colony, Muduvas colony and Anjam colony were engaged in agriculture.

All the respondents in the Kadar's colony, Muduvas colony, earth dam colony had settled 25 to 50 years back. But people in the Anjam colony had settled only 6 years back. They were living in the forest earlier. Now the government had given them land in the forest and also constructed houses for them. 3 acres had been given for 14 settlements. The houses of Kadar's colony had 4 rooms but in the other settlement the houses have only 3 rooms. The people in the Kadar's colony and earth dam colony live in the huts. But in the Muduvas colony and Anjam colony all the houses were found to be concrete.

All the respondents in these settlements depended on pipe water for drinking. Toilet facilities were not available in all the settlements. The houses were not electrified. In Muduvas colony 'ANERT' had placed a solar lamp. All the respondents use wood for cooking.

Cultivation was not observed in the Kadar's colony. The houses were closely packed and there was hardly any land for cultivation. But coconut and plantains were cultivated in earth Dam colony. In Muduvas colony and in Anjam colony coconut, tapioca, plantains, pepper, areacanut, spinach, coraianda were raised. Mango and jack were cultivated as subsidiary crops. Vegetable cultivation was also observed there.

Soil loss was observed in all the agricultural land due to topographic condition and the land was ill managed against soil loss.

All the respondents who cultivated agricultural products depended on river water for irrigation. Chemical fertilizers were not applied to the plants and pesticide application was also not reported. Seeds and seedlings were made by the farmers themselves.

All the respondents sold agricultural products in the market. The nearest market is Parambikulam which is 1 km from their house. But the main market is at Pollachi which is 60 km away form the house.

All the respondents in the earth dam colony and Maldives colony were engaged in the animal husbandry.

So far as the economic conditions of these settlements were concerned, it is observed that tribes who resided at Anjam colony, Muduvas colony and earth dam colony had better living conditions and economic status compared to the people at Kadar's colony. Though the Kadar's colony was located at Parambikulam, people in this colony fully depended on forest department for their main source of income. The other 3 settlements were located inside the forest.

38 % of the respondents opined that they had faced natural calamities during the past 5 years. All of them said that it was in the form of windfall and drought, which caused loss of agriculture and crops. People hardly received any financial support for this calamity.

5.8 Around lower Karapara river

This Segment IV b falls in the Nelliyampathy panchayat of Chittur taluk of Palakkad district. The people settled here are all labourers from Tamil Nadu who works in the plantation of tea, coffee and cardamom.

Majority of the people interviewed here belong to the age group of 25 to 50 years. Of this 58% were males. 55% of the respondents were illiterates. While 25% had education up to the SSLC level.

25% of the respondents were permanently employed in the estate while 75 % were labourers. 50% of the respondents settled here 25 to 50 years back and another 25 % settled here 10 to 25 years back. The estate management had constructed house for the labourers. 75% of the respondents lived in the tiled houses while 25% lived in the concrete houses. All the houses had 3 rooms each. Drinking water is provided by regular supply by pipes. 25 % of the respondents practiced animal husbandry. Fuel wood was in regular use for cooking purposes.

5.9 PRA Analysis

PRA was conducted in various places of the basin and results of the exercise were briefly presented here.

Labour shortage was a problem for the cultivation of paddy. There was also lack of coordination between the cultivators and labourers. Negligence in maintenance work of canals, sub canals and field channels at the proper time causes water deficiency in some areas. People who had taken loan were unable to pay back because the agriculture production was less than expected. The crop insure scheme for paddy is not practical, as individual cultivator will not be benefited unless the entire crop in the C.D Block was damaged as the scheme is based on block level data on productivity to assess the extent of damage. Krishi Bhavan provides subsidy to fertilizers to some groups

It was opined that the present system of wages paid for harvesting was against the interest of labour and the wage received by them was considerably less than that paid for other operations in the paddy field. This was reported to be one of the reasons for the scarcity of labourers in harvesting.

Clay mining disfigured landscape and also created safety hazards. Opening up a clay mine in the middle of a paddy field will drive the neighbouring farmers to finitration and cause the abandonment of this cultivation and eventually selling out. After the quality clay deposit is exhausted, the land is abandoned without any attempt at restoration.

Conversion of paddy fields for pisciculture (aquaculture) may not appear to be a major problem like the other alternatives. However, the intensive use of herbicides, pesticides and nutrients could very well contribute to local environmental hazards, and therefore requires careful monitoring.

CHAPTER 6
TESTING OF HYPOTHESIS

6.1 Introduction

The four hypothesis envisaged for this study as spelt out in the chapter I were tested and results were discussed in Chapter 3 and Chapter 4. This Chapter is intended to provide consolidated details for each of the hypothesis and related issues.

6.2 Hypothesis-1

Expansion of agriculture and related activities have contributed in reduction of natural forest.

This hypothesis was examined in the context of three issues as discussed here.

(i) Expansion of forest plantation caused deforestation

Study covering the entire basin had brought out that there was a reduction of forest area form 813 sq.km. in 1966-67 to 760 sq.km in 1997. Forest and agricultural plantation had increased for 357 sq.km. to 415 sq.km.

The segment-III of our sample study covering Thumburmuzhi and surrounding borders the forest area. Detailed study in this segment showed that a forest patch of 11.36 sq.km. had been reduced to 8.20 sq.km in a span of 15 years from 1966-67 to 1989. Out of this deforested 3.16 sq.km , 0.76 sq.km. was given for forest plantation, which works out to be 24% of total deforested area.

(ii) Expansion of plantation agriculture resulted in deforestation

Agricultural plantations in the highland section covering tea, coffee, and cardamom, recorded an increase of area from 186 km^2 in 1966-67 to 212 km^2 in 1997 or an increase of about 14% in a period of 30 years for the entire Chalakudi basin. Considering the area that falls within the Kerala State, agricultural plantation accounted for 15.4% in 1966-67, which had increased to 17.6% in 1997.

Sample survey in segment III indicated that out of 3.16 km^2 deforested area agricultural plantation occupied 1.64 km^2 or 52% of total deforested area in the area of investigation.

(iii) Construction of reservoirs also contributed in forest clearance

Vegetation submerges when a reservoir is impounded. Kerala has a number of reservoirs, constructed for production of hydroelectricity and irrigation. There are six reservoirs that together covers an area of 35.2 km^2. The reservoirs in Tamil Nadu part of the basin accounts for 7.42 km^2 and that in Kerala part of the area covered 27.78 km^2.

As all the reservoirs are located within the forest area, it can be reasonably inferred that equal amount of forest area was lost due to construction of reservoirs.

6.3 Hypothesis 2

Population expansion and resulting pressure on residential, industrial and infrastructure have induced conversion of agricultural land to non-agricultural purposes.

The following issues were specifically examined with data support to validate the hypothesis:

(i) Loss of prime agricultural land and shrinking of natural area like wetlands

These two issues are related as most of the prime agricultural lands are also considered as wetlands in Kerala.

Paddy lands in the basin had declined from 101 km^2 in 1966-67 to 23 km^2 in 1997, or a reduction of 77% in 30 years.

Study in three segments, indicated that segment-I (lowland) had lost 67% of its wetlands, segment-II had lost 81% and segment-III had witnessed conversion of all 7 sq.km of paddy fields in a time span of 35-36 years (1966-67 to 2003).

The segment-II is around Chalakudi urban area. This segment is under considerable pressure due to increasing urbanisation and consequent demand of land for residential, industrial and infrastructural purposes. Increase in area under settlement with mixed tree crops, as observed in the landuse change matrix (refer Table 3.4) indicates pressure on prime agricultural lands. Another indirect impact of increasing population pressure is higher demand for brick making clay. Around 0.40 sq.km or 8% of area under paddy field had been given for clay mining in segment-I and it was 1.23 sq.km (9% of paddy fields) in segment-II.

(ii) Utilisation of more and more marginal land

More and more marginal lands were brought into use with expansion of agriculture. Fallow lands, pastures and vacant space were reducing at a very faster rate. Wasteland and fallow lands in the basin account for less than 1% of total basinal area falling within Kerala. Investigation in the segment-III indicated that vacant lands recorded in 1987 had been fully reclaimed for other use by 2003. Segment-I and segment-II hardly possessed any area under these categories, which is a reflection of high demand for land and diversion of all types of lands.

6.4 Hypothesis 3

Major ecological/ environmental problems in lowland and midland area had cropped up due to land conversion.

This hypothesis is tested in the context of (I) deterioration of water quality, fall in water table and reduction in flood spread area.

(i) Deterioration of water quality due to land conversion

Water quality is associated with rock type, soil, vegetation and landuse type. Change of landuse pattern from one type to another results in water quality problem. In order to capture this, river water quality had been analysed for four seasons and collecting samples from different stretches of river under various landuse types. Combing data from all seasons the river has been graded and it is found that the urban area around Chalakudi town is polluted in all the season (refer Table 4.15). The segment of the river flowing through the forest is non-polluted. Major land conversion had taken place in the lowlands and midlands. River water in these stretches are seasonally polluted. Pollution level goes up during dry season and during monsoon pollution level is diluted due to monsoon discharge. Pollution of well water can also be lined to landuse condition (refer Fig. 4.29).

(ii) Fall in well water table as a consequence of landscape/ landuse change

River bed deepens due to sand mining and consequent changes in configuration of river thalweg. It is widely reported from different parts of the State that excessive sand extraction had resulted in lowering of riverbed which in turn affected the well water level in surrounding areas.

Similarly, due to clay mining from the paddy fields new base levels were created and water level in the surrounding wells were affected.

In order to investigate this problem depth to water level had been measured in selected wells distributed in all three segments. Data were collected for the months of June, 2002 and July, 2003 to compare the water levels. It is admitted that long term observations are needed to decipher the impact, however, in view of non-availability of data and limited duration of the project, for two years were used to get an idea about the trend.

Data on depth to water table had been provided (ref. Table 4.30). Ten wells were monitored in segment-I and it was found that in July, 2003 well water depths had gone down compared to June, 2003 in 27 wells. Again maximum drop of 3.95 m was also noticed for a well (No. 55) located in the lowland. This high drop of water table in the lowland is attributable to clay mining.

The wells in the segment-II also showed variations. Out of 10 wells monitored in this segment three wells had shown higher levels compared to the previous year. Decline in rest seven wells varied form 1 m to 4.55 m (Table 6.31). Wells with high fluctuations are located in higher ground adjoining the main river. Change in pizometric head due to sand mining has resulted in fall in well water table. Similar fluctuations were marked in third segment also.

(iii) Reduction in flood spread area

Flood spread areas or spill areas shrink due to conversion of lowland/ wetland to dryland. Once an area is reclaimed by dumping new soils local elevation changes and the reclaimed area is no more available for water storage. Back swamps and other wetlands used to accommodate excess run off generated during monsoon. Water spread areas reduce on account of reclamation in one hand, on the other hand, increase in built up area causes high production of surface run off and low infiltration. The synergetic effect is aggradation of flood.

Landscape change maps and tables of segment I and II (Figs. 1, and Tables 3.7 and 3.9) highlight that area under back swamps had declined from 34% in 1980-81 to 14% in 2003 in segment I and 51% in 1980-81 to 1% in 2003 under segment II. The land classified as valley recorded reduction from 5% in 1980-81 to 2% in 2003 in segment-I and from 23% in 1980-81 to 6% in 2003 in segment-II.

Reduction in areas under backswamps and valleys directly contribute to decrease in spill areas.

Hypothesis – 4

External as well as local issues contribute to landscape/land use change

Landscape change is governed by factors operative at local level and also ex-situ. The proximate causes play very important role no doubt, however, decision at higher levels have important bearing on landuse characteristics.

Two issues are examined at present instance.

(i) Government policy particularly grow more food and promotion of certain crops have induced these changes.

A special drive was given by the Government to expand area under agricultural operations with 'grow more food campaign'. Wetlands were reclaimed. Forests were cleared and other vacant lands were put to use for increasing food production.

Introduction of plantation crop like rubber with government subsidy had prompted many farmers, irrespective of holdings to change their cropping pattern and grow rubber. Area under rubber had increased by 26% in the Chalakudi basin as a whole. This increasing trend could be recorded in Segment II and III.

Government decisions to increase area under forest plantations had also resulted in reduction of natural vegetation in the basin.

(ii) Local issues like demand for land to accommodate non-agricultural activities unfavourable out turn from crop cultivation, lack of irrigation and crop disease have contributed to landuse change.

Questionnaire survey and PRA conducted in various places had brought out this point. Reasons for landuse changes were spelt out by actual users and it was found that local causes played decisive role in landuse change dynamics.

Change in pattern and underlying reasons vary spatially and therefore proximate causes differed from one area to other, which was well manifested in discussion on local people's perception in landuse change and consequences in the next chapter.

Testing of hypothesis was a part of the overall analysis under this study. However, it was separately treated to consolidate and highlight certain points. A chart (Table 6.1) is given here to elucidate the drivers of landuse change, assumed to be active in this basin.

TABLE 6.1 DRIVERS OF LANDUSE/ LAND COVER CHANGE IN CHALAKUDI RIVER BASIN (1850-2002)

Year	Global	National	State	Local
1850				Leasing of land in the high hills
1900	Invention of automobiles and use of rubber tyres		Extension of tea cultivation. Introduction of rubber plantation	
1920				Major migration from lowland to highland
1930				Hydroelectric project
1940	India attain independence	Formation of rubber board	Extension of irrigation project/ Grow more food campaign	
1950		Formation of Kerala State	I[st] five year plan preparation	Chalakudi irrigation project stage-I
1960			Land reform act	Chalakudi irrigation project stage-II
1970				Expansion of irrigation canals and other minor irrigation schemes and formation of beneficiaries', societies Population - 519958
1980			Promulgation of environmental laws	Expansion of irrigation canals and other minor irrigation schemes and formation of beneficiaries', societies Population - 626251
1990		Opening up of economy		Introduction of panchayat plan Population - 680271
2000		Opening up of economy	Landuse conversion act	Introduction of panchayat plan

CHAPTER 7
CONCLUSION

7.1 Conclusion

This project on “Landscape change and its environmental and human dimensions: selected micro level case studies under different biophysical settings in Chalakudi basin, Kerala” was taken up with certain specific objectives. Discussions in the foregoing six chapters had brought out the characteristics of the study area, landuse/landscape change, environmental impacts and other consequences as perceived by local people. Four hypotheses, spelt out in the section under objectives had been tested and briefly presented in the last chapter (chapter 6). This chapter - 7 is intended to present final conclusions and certain recommendations specific to some activities.

The Chapter I was introductory to provide an outline of the project. The framework of this study was developed and theoretical underpinnings of such problems were deliberated. Apart from setting up hypotheses, methodology and data source were also described in this chapter - I.

The study area was introduced through second chapter and detailed characteristics were discussed. The Chalakudi river is a 7^{th} order stream with total basinal area of 1525 km^2. Out of this 1525 km^2 around 300 km^2 fall in Tamil Nadu. There are six reservoirs impounded on various tributaries and also on the main river. Of these six reservoirs one lies in Tamil Nadu State. Average rainfall of the basin is 3365 mm. Rainfall increases from west to east till foothill zone from where it decreases further east and then it increases again within the Ghat section. This basin is well endowed with water resources. However, rainfall deficit is experienced during the months of January to March. Geomorphologically terrain here is undulating. More than 60% of total area lies in the slope category of above 15%. Average drainage density is 2.07 km/km^2. Detailed analysis has brought out that there are drainage anomalies at various levels. Structural control on drainage line development is well evidenced. There are 12 soil types distributed throughout the basin. Around 25% of area is covered by K36, which is very deep, well drained clayey soils. This unit is followed by K33, which is deep, well-drained, gravelly clay soil. According to land capability class and sub-class the soil units fall in III sw, III es, IV es, VI e, VI es and VIII classes. Natural vegetation has reduced by 6% from 1966-67 to 1997. As on 1997 the Kerala part of the Chalakudi basin has only 37 % of area under forest cover.

The Chalakudi basin is well served by irrigation projects. Total length of canal is around 353 km, which irrigates 148 km^2 of ayacut area. Seasonal crops account for 55 % of total cropped area. Paddy is the main seasonal crop followed by plantain, pepper and tapioca. Coconut is the main tree crop. Rubber plantation covers 7.6% total cropped area of the basin. There is a decrease in area under paddy from 6.65% of total basinal area in 1966-67 to 1.53 % of total basinal area in 1997. Crop combination analysis indicated that 19 combination zones are spread over 28 panchayats. The diversity in agricultural scenario is well manifested. This basin has a population density of 923 person/km^2 as in 1991. This figure is well above the State average (749 persons/km^2). Population density of the basin was higher than the State average in all three census periods. Primary sector dominated the occupational structure both in 1971 and 1991 census periods, when it accounted for more than 50% of total workers. Proportion of workers came down to below 50% in 1981. Workers in Tertiary sector had increased from 20.2% in 1971 to 30% in 1991.

Considering all aspects of basin, ie, physiography, drainage, soil, climate, landuse, population distribution and work participation, five sample sites were chosen for detailed analysis. These are : (i) area surrounding the confluence of Chalakudi and Periyar (low land), (ii) Chalakudi town and surroundings (midland), (iii) Thumburmuzhi and surroundings (highland/foothill), (iv a) area surrounding Parambikulam reservoir and (ivb) areas around lower Karapara river. The sample sites of iva and ivb are located within the forest area dominated by high hills with elevated terrain. There are variations in economic conditions of people living in these sample areas.

Landuse/landscape changes in each of these segments are studied and details are given in Chapter-3. Topographical maps of 1966-67 formed the base to compute changes. Subsequent to 1966-67, three time points of 1980-81, 1988-89/90 and 2003 were considered for this study.

Diversification of landuse increased over the years. Area under paddy had come down from 52% in 1966-67 to 21% in 2003 in the low land segment covering the area surrounding the confluence point of the Chalakudi and the Periyar river. Area under settlement with mixed tree crops had increased by 40% in 35-36 years' span from 1966-67 to 2003. Landuse categories in 2003 had gone up to 15 types from 7 types recorded in 1990. Clay mining, brick kilns, laterite quarries and fallow lands were marked only in 2003. It is observed from the landuse conversion matrix that the units of paddy and settlement with mixed tree crops had given place to a number of other landuse types. In other words high diversification was marked in these two categories. Landuse change in the 2nd segment covering Chalakudi town and its surroundings indicates that paddy field in this segment had decreased from 40% in 1966-67 to 7.6% in 2003. Area under settlement with mixed tree crops and agglomerated settlements both had increased significantly. Prime agricultural land and garden lands under settlement with mixed tree crops were directly brought under built up areas to accommodate growing population pressure on account of urbanization. Two categories, namely, tree crops in low land and settlement with mixed tree crops in lowland could be marked from 1966-67 till 1989. These two categories indicate the trend of change. Lowlands were initially given for growing tree crops and gradually land levels were raised. After a couple of years settlements sprang up in these sites. High demand for settlements had resulted in conversion of paddy fields directly to built up areas without passing through intermediate stages.

The third segment, Thumburmuzhi and surroundings is located in the foothill zone. An area of about 28 km^2 were studied and it was found from landuse change statistics that paddy fields, which covered 25.3o% of total area in 1966-67 had been completely diverted to accommodate other crops in 2003. Areas under settlement with mixed tree crops had increased by around 340% from 1966-67 to 2003. Area under forest had come down from 41% of total area in 1966-67 to 17 % in 2003. New plantations were also introduced. Landuse conversion matrix had brought out that forests had been replaced by rubber plantation, teak, oil palm, settlement with mixed tree crops and seasonal crops like banana. Area under cashew had also been given for rubber and seasonal crops.

The landuse change in forest areas covering two sites (i) Parambikulam reservoir area and (ii) Karapara river area are less conspicuous. Forest area around Parambikulam reservoir had decreased by 7% from 1975-76 to 2003. Areas under tribal settlements had marginally increased. Karapara area had also shown change in forest areas. The rate of landuse change was higher in the period between 1975-76 to 1990 compared to the period from 1990 to 2003. It indicates certain amount of stabilization in landuse pattern.

Study on landscape change was confined to the first three segments. Landscape change is a corollary to landuse change. Once landuse type changes, more often than not, landscape is also altered. Landforms under riverine conditions are mainly back swamps, levees and valleys/floodplain. Back swamps were converted to garden lands and clay mines and in some cases they are also kept as fallow land without putting to any use. Settlement expansion is the major driving force leading to these changes. When back swamps and valleys are diverted to accommodate settlement and other agricultural practices the wetland condition of these areas are altered, which can potentially affect hydrological regime.

Stone quarry, laterite quarry and clay mining turn positive relief (raised areas) to negative relief. There is a stone quarry, which now acts as fresh water reservoir. Landscape changes in the highland areas are confined to terracing of hill slopes and conversion of valleys to garden land and urban/industrial landscape. Slope configuration changes with terracing while length of slope increases resulting in longer travel time for water and sediment. It also enhances infiltration.

What is important to note is that landuse change is wide spread with various intensity. Extensification of landuse is taking place almost in all segments. Landuse conversion is not restricted to paddy or forest area alone. Even crop types change over time. One type of plantation gives place to other type of plantation.

The chapter four was devoted to study environmental impact/consequences of landuse change: The study addressed the quality issue of surface and subsurface water in this basin. Analysis of river water quality based on 28 samples brought out that there are seasonal and also spatial variations of water quality in this basin. pH in the month of July, 2001 varied from 6.43 in station 4 to 7.26 in station 14. The lowest pH value in August, 2001 was 5.93 recorded in station 17. pH value showed decreasing trend during monsoon. River zonation was attempted based on analyses of physicochemical parameters. The station adjoining the urban settlement showed high pollution in all the seasons. Lack of proper waste disposal facilities and high concentration of population had contributed to higher pollution level. The river water adjoining the urban center was not diluted even in monsoon months. The stretches adjoining the industrial area and sites of prawn farming also showed higher pollution level, however monsoonal dilution was effective in these segments.

Certain river stretches flowing under settlement with mixed tree crops were moderately polluted. Agricultural waste and human waste contributed to pollution in this area. Discharge of domestic waste water to the field and through the fields to the rivers was a major cause. Intensive indoor rearing of livestock had added further problems. Fertiliser and pesticides used in the paddy fields also contributed to higher pollution level. The stretch of river flowing through plantation crops was non-polluted for over all gradation. But it was marginally polluted in dry season. The reservoir was also found to be affected due to local human waste and decomposed biomass, submerged during impounding.

Quality of well water was also studied for physico-chemical as well as microbiological parameters. Well water was found to be more polluted in the month of

June, whereas river water was more polluted during the month of March. Nitrate contamination was high in well water. Positive correlation was found between nitrate and fecal coliforms. Five out of nine wells examined were contaminated by fecal coliforms. Soil quality, construction of bottom-unsealed septic tanks and short distance between septic tank and well combindly contributed to this scenario. Total dissolved solids and phosphorous were correlated to some extent and recorded seasonal variation. Correlation value is 0.55 during the month of August, 2001. Based on analytical data spanning over four seasons the wells were graded and it was found that well water was moderately polluted with exception of two cases, where pollution level was high. The wells adjoining the urban center were more polluted compared to other areas. Impact of landuse on water quality is well manifested through these findings.

Sand and clay mining affects level of well water. As many as 60 wells were monitored for the months of November 2001, March 2002, June 2002 and July 2003. Comparing the values for the months of June 2002 and July 2003 it was observed that nine wells had experienced no fluctuation or marginal fluctuation in one-year period. Well location is one of the main factor controlling water level fluctuations. Clay mining lowers the base level of the wetland and the adjoining wells are affected. Similar is the case with sand mining from the rivers.

Perception of local people about landuse change, underlying causes and consequences had been documented through questionnaire survey and results were presented in chapter 5. Altogether 100 samples were collected from 5 segments : 25 each from segment I, II and III and 13 samples from segment IVa and 12 samples from segment IVb. PRA was also conducted in few places. A comparative picture of segment I, II and III had brought out spatial variability in drivers of landuse change. It also had highlighted the commonality of causes across the biophysical zones. Landuse change is evident in all areas. Higher profit was cited as one of the major causes for changing paddy land particularly in the lowland and midlands. Water shortage was the main reason in highland and in the midland, it was as important as profit but in the lowland, water shortage was the 2nd most important reason after profit. Other reasons cited were labour problem, need for housing, high labour cost and low productivity. Land conversion had started decades back. KSI (1994) even recorded diversion of paddy fields prior to 1960s. Inquiring into the non profiting nature of paddy cultivation it was learnt that high labour charge, less market value, diseases and small holdings etc combindly contributed in this matter. With landuse change most of the respondents could make profit, however, some farmers in the lowland segment had experienced decrease in profit by changing their landuse pattern. One of the main incentives of landuse change is value addition. Unit price of land had increased after conversion in all three segments. People's responses were also sought in the matter of impact of landuse conversion on surface and ground water quality. So far as surface water quality was concerned 44% of the respondents in the lowland reported that water quality decreased due to landuse change in general. The proportion went to 55 % in the highland. However, people have a problem to relate water quality with landuse change in general. Decrease in water table due to sand mining had been reported by more than 30 % of respondents in all the segments. In case of clay mining the proportion was around 40% to relate water table lowering with clay mining. PRA analysis had also brought out the similar results.

All four hypotheses, envisaged for this project were tested and results were discussed with specific references.

Landuse changes are related to proximate causes as well as external factors. This global trend is also found in this basin. There are remarkable microlevel variations in landuse change, which are not always ecologically conducive.

The main findings can be listed as follows:

- The Chalakudi basin with six reservoirs and well-laid irrigation canals is undergoing considerable changes in the matter of landuse in all biophysical segments. There are variations in nature of landuse change from one segment to another. The underlying reason also vary spatially.

- ✶ Deforestation continues unabated. Natural vegetation has been replaced by plantations. Teak is a major forest plantation. Other important plantations are tea, coffee, cardamom in the high altitudes and rubber and oil palm in the foothills. High altitude plantations grow at the expense of forest and lower altitude plantations replace open scrub and one type of plantations by other.

- ✶ Landuse change and associated landscape change record spatial variations. The maximum change is recorded in the category of lowland /paddy fields. The availability of labour in time, especially for operations like transplanting and harvesting appears to be a major problem as pointed out by the cultivators. There is a lack of coordination between the cultivators and labourers, both groups are organized politically and socially. The present system of wages in kind (*pathom* and *theerpu*) paid for harvesting is against the interests of labour as the wages received by them (in monetary terms) is considerably less than that paid for other operations in the paddy field.

- ✶ Continued fragmentation of holdings, initially due to land reforms and now as a result of family property division hinders smooth cultivation mainly on account of increase in the number of holders and consequent diversity of aspirations and vested pursuit.

- ✶ Clay mining is a major threat to the conservation of paddy fields. The environmental damage caused by this practice is painfully obvious. But so is the compulsion to sustain these industries which are providing thousands of jobs. However, the tile industry is in a crisis and cannot hope to survive without an overall modernization including technological change and product diversification to high values products. But this is a long term process and the industry needs smooth transition. So a regulated system of clay mining in paddy fields may be allowed.

- ✶ Ecological functions of paddy fields or lowlands are seldom understood by various stakeholders. Societal causes to look into these problems needs to be translated into a prudent resource management plan with concrete operational steps.

- ✶ There are areas of intense landuse change that has resulted in landscape alteration. Low-lying areas have been turned into garden land and thus the land levels are altitudinally raised. Rock quarrying, laterite mining and clay mining have created ditches of considerable depth and size.

- ✶ Landuse change is related to proximate causes having direct link to economic conditions. Government policy issues also contributed to landuse change. Discussions on policy issue was not attempted in this report due to limited scope of the project.

- ✶ Water quality is affected due to landuse change. Areas adjacent to the urban area is highly affected. Both surface water and ground water face quality problem.

- ✶ People related to environmental problems that have direct bearing on their livelihood. Direct impacts are also well perceived by local people, however, indirect impacts or secondary and tertiary impacts are difficult to comprehend by local people.

- ✶ Even in a well irrigated basin like Chalakudiwater shortage is one of the reasons for landuse change as opined by local people. Despite the wide network of irrigation system in the Chalakudi river basin, paddy cultivation often faces difficulties in getting the right quantity of water at right time for the crop. The main reason for this situation is attributed to the lack of maintenance of the canals, sub canals and field channels at the proper time and the inefficiency and even non-cooperation of the government machinery.

- ✶ Decrease in soil fertility and consequent decline in productivity due to over use of chemical fertilizers has been reported. There is a felt need to adopt a proper balance between organic and chemical fertilizers. But the depletion of cattle wealth in farmer's households and absence of an institutional mechanism for the production and supply of organic manure have led to a scarcity of organic manure. Green manure is also not available due to the change in the cropping pattern.

7.2 Recommendations

Considering basin characteristics, problems encountered in different parts of the basin, their consequences and people's response to various issues the following recommendations were made :

- ❖ Regulatory measures may be introduced to arrive at proper landuse mix and to systematise landuse change at different levels. This is necessary considering the extent of change and its long ranging impact.

- ❖ Waste management in the urban area should be given priority as both surface water and ground water are affected in the urban area and its vicinity.

- ❖ Micro watershed based conservation approach and water harvesting needs to be undertaken to maintain adequate flow in the river.

- ❖ Abandoned mining sites can be used for water harvesting with introduction of proper landscaping measures. These water bodies can be used for minor irrigation purposes.

- ❖ Appropriate landuse practices can be introduced in the newly created fallow lands due to non cultivation of paddy. These prime lands are rendered unproductive at present. This is quite paradoxical given land scarcity faced by the State.

- ❖ To overcome the problem of water shortage in the agricultural fields even within canal commands the programme of micro watershed management can be introduced. Proper utilisation of ponds can contribute in this context.

- ❖ Clay mining has seriously altered landscape configuration. Certain regulatory measures at the local level may help in ameliorating the situation.

- ❖ Excessive sand mining affects river geometry and ground water condition. Certain restrictions on mining operations will be helpful.

- ❖ As local people find it difficult to relate environmental issues with off site impacts, there is a need for creating awareness at the local level.

- ❖ An integrated river basin management programme can be designed by incorporating all issues centring around landuse change and work plan for each micro watershed can be prepared. This will help developing hierarchical action plan and assigning appropriate roles to the local bodies/ panchayats.

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