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GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT
PUBLIC WORKS DEPARTMENT

MICRO LEVEL REAPPRAISAL STUDY

PARAVANAR RIVER BASIN

VOLUME I

INSTITUTE FOR WATER STUDIES
THARAMANI, CHENNAI-600113.

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PREFACE

The Institute for Water Studies is established with an objective to assess, plan, and manage the Water Resources in Tamil Nadu in a scientific manner. This Institute carries out Multi-Disciplinary research activities in all the River Basins of Tamil Nadu for effective Water Resources Management.

The River basin boundaries were delineated initially in 1:2,50,000 scale and recently River Basin boundaries are delineated in bigger scale, 1:50,000. Micro level studies have been completed for 16 River Basins except for Cauvery River basin. The Micro level study reports have been shared with the concerned officers of Water Resources Department and other line departments.

In order to update the Micro Level study reports, incorporating the changes taken place thereafter with regard to land use and water utility, with latest available data and using the River Basin boundaries in 1:50,000 scale, Micro level Reappraisal studies for the River Basins are taken up. Accordingly, Reappraisal studies for Kodaiyar, Vaippar, Vaigai, Vellar, Palar, Tamiraparani and Pennaiyar River Basins have been completed. The Micro level Reappraisal study of Paravanar River Basin has been taken up during the year 2016 - 2017.

The first report on Paravanar River Basin was prepared in the year 1997 under State Framework Water Resources Plan. The second report on Paravanar River Basin was prepared in the year 2008 under Micro level study reports, using the tools and data base of GIS and its simulations for river basin planning.

The Micro level Reappraisal study of Paravanar River basin (2016-17) was taken up to assess the present water potential, demand and balance prevailing in the basin, expected future water availability / balance, water demand for various sectors by taking into account the available data upto 2016. The water balance of the River Basin is carried out in various scenarios to explore the availability of water for future. Various thematic maps of the Paravanar River basin were prepared using GIS and the developments required within the basin for effective utilization and management of Water Resources are analysed.

Necessary strategic action plan for improving the potential of Paravanar River Basin are recommended, which may be considered for implementing in the State water plan and future planning of water resources in the State for the benefit of the society and better management of Water Resources in the Basin.

06/3/17

Chief Engineer & Director, WRD
Institute for Water Studies

ACKNOWLEDGEMENT

We express our heartfelt thanks to the Principal Secretary to Government, Public Works Department for unrelenting support and encouragement for carrying out the Micro level reappraisal study of Paravanar River Basin.

We express our deep sense of gratitude to Er.R.Subramanian, Chairman, Cauvery Technical Cell cum Inter State Waters Wing, Chennai, for generously providing us with valuable comments and feedback for the Micro level reappraisal study of Paravanar River Basin.

We sincerely thank the Engineer-in-Chief, WRD & Chief Engineer (General), PWD, for valuable support for carrying out the Micro level reappraisal study of Paravanar River Basin.

We extend our thanks to the Chief Engineer, WRD, State Ground & Surface Water Resources Data Center, Chennai – 113 and the Chief Engineer, WRD, Chennai Region, for giving Surface Water data and hydrological & meteorological data respectively, which are fundamental in carrying out the Micro level reappraisal study of Paravanar River Basin.

We also thank the Superintending Engineer, WRD, Vellar Basin Circle, Cuddalore, the Executive Engineer, WRD, Vellar Basin Division, Virudhachalam and the Executive Engineer, WRD, Coleroon Basin Division, Chidambaram for their assistance and contributions for the preparation of this study report.

We extend our special thanks to the Chief General Manager / Chief Regional Manager, NLC India Ltd., Chennai, for providing the logistic support during the field visit and the Chief General Manager (Geology and Coal Block), NLC India Ltd., Neyveli and his team members for discussion, providing data and arranging the visit to mines.

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contributing the requisite data to carry out the Micro level Reappraisal study of Paravanar River Basin.

We also thank the Government Press, Chennai, for their contribution in printing this report in a nice manner.

Extreme care has been taken to the correctness of data published in the book. They are as given by the field Engineers. Any correction to be made may kindly be intimated to our Institute, for correcting the same in the future reports.

We hope this effort on Water Resources planning for Paravanar River Basin will be useful to Water Resources Department and other line departments in taking necessary effective steps to improve the management of Water Resources in Paravanar River Basin.

06/3/17

Chief Engineer & Director, WRD
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Abbreviations

ADD	Acute Diarrhoea Disease
AED	Agricultural Engineering Department
ARS	Artificial Recharge Structures
BCM	Billion Cubic Meter
BCR	Benefit Cost Ratio
BGA	Blue Green Algae
bgl	below ground level
CCA	Culturable Command Area
CGWB	Central Ground Water Board
CMWSSB	Chennai Metropolitan Water Supply and Sewerage Board
CPCL	Chennai Petroleum Corporation Ltd
CPHEEO	Central Public Health and Environmental Engineering Organsiation
CROPWAT	Crop Water Requirement
C&SRO	Cauvery & Southern Rivers Organization
CWC	Central Water Commission
CU	Consumptive Use
CV	Coefficient of Variation
DIC	Directorate of Industries and Commerce
DIC	District Industries Centre
DO	Dissolved Oxygen
DRIP	Dam Rehabilitation and Improvement Project
EC	Electrical Conductivity
EFR	Environmental flow Requirement
ERDAS	Earth Resources Data Acquisition System
ENE-WSW	East North East –West South West
ESP	Exchangeable Sodium Percentage
ETc	Evapo Transpiration of a crop
ETo	Evapo transpiration
EW	East West
FAO	Food and Agriculture Organisation
FCC	False Colour Composite
FRP	Fibre Reinforced Plastic
GEC	Groundwater Estimation Committee
GIS	Geographic Information System
GSVA	Gene Set Variation Analysis
GOI	Government of India
GoTN	Government of Tamil Nadu

GPS	Global Positioning System
GSDP	Gross State Domestic Product
IAMWARM	Irrigated Agriculture Modernization and Water bodies Restoration and Management
IDW	Inverse Distance Weighted
IMD	Indian Meteorological Department
IMR	Infant Mortality Rate
IPM	Integrated Pest Management
INM	Integrated Nutrient Management
IUD	Intra –Uterine Device
IRS	Indian Remote Sensing Satellite
Kc	Crop Coefficient
LISS	Low Imaging Sensing Satellite
Mcum	Million Cubic Meters
MGD	Million gallons per day
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MMR	Maternal Mortality Rate
MNRE	Ministry of New and Renewable Energy
MoEF	Ministry of Environment and Forest
MoWR	Ministry of Water Resources
MRS	Monthly Run off Simulation
MSL	Mean Sea level
MSME	Micro Small and Medium Enterprise
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MT	Metric Tonnes
NABARD	National Bank for Agriculture and Rural Development
NABFINS	NABARD Financial Services
NADP	National Agricultural Development Program
NBSS	National Bureau of Soil Survey
NE	North East
NE-SW	North East –South West
NGO	Non Governmental Organization
NLC	Neyveli Lignite Corporation
NNE	North North East
NNE-SSW	North North East- South South West
NNE-SW	North North East-South West
NNW-SSE	North North West- South South East
NPK	Nitrogen, Phosphorous, Potassium

NWDA	National Water Development Agency
NW-SE	North West- South East
O & M	Operation and Maintenance
PAN	Panchromatic (Single Band B/W data)
PET	Potential Evapo Transpiration
PGPR	Plant Growth Promoting Rhizobacteria
PWD	Public Works Department
RF	Reserve Forest
ROAF	Real Organic Agriculture Federation
RRR	Repair Renovation Restoration
RSC	Residual Sodium Carbonate
RWH	Rain Water Harvesting
SAR	Sodium Adsorption Ratio
SG &SWRDC	State Ground &Surface Water Resources Data Centre
SIPCOT	State Industries Promotion Corporation of Tamil Nadu
SPIC	Southern Petro Chemical Industries Corporation
SPC	State Planning Commission
SRI	System of Rice Intensification
SSI	Sustainable Sugarcane Initiative
SW	South West
SWaRMA	State Water Resources Management Agency
SWIC	Single Window Information Centre
SWP	State Water Plan
TACID	Tamil Nadu Corporation for Industrial Infrastructure Development
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited.
TBL	Top Bund Level
TDS	Total Dissolved Solids
TH	Total hardness
TIDCO	Tamil Nadu Industrial Development Corporation
TIIC	Tamil Nadu Industrial Investment Corporation
TMC	Thousand Million Cubic feet
TNAU	Tamil Nadu Agricultural University
TNPCB	Tamil Nadu Pollution Control Board
TWAD Board	Tamil Nadu Water Supply and Drainage Board
UNDP	United Nations Development Programme
USGS	United States Geological Survey
UFW	Unaccounted for Water
VES	Vertical Electrical Soundings
WHO	World Health Organisation

WRD	Water Resources Department
WRMS	Water Resources Management Studies
WUA	Water User Association
WAPCOS	Water and Power Consultancy Services

MICRO LEVEL REAPPARAISAL STUDY

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MICROLEVEL REAPPRAISAL STUDY OF PARAVANAR RIVER BASIN

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CHAPTER 1

INTRODUCTION

AND

DESCRIPTION OF THE BASIN

CHAPTER 1

INTRODUCTION AND DESCRIPTION OF THE BASIN

1.1 River Basins as units of planning

River basin is a ‘Hydrological unit’ enclosing an area drained by streams and channels that feed a river at a particular point. River basins are inherently complex systems comprising of many interdependent components. River basins are delineated based on the drainage pattern and ridges using mainly the Survey of India topographic sheets and Digital Elevation Models. All the precipitation that falls on these slopes will either evaporate, used by plants and other living organisms, sink into the ground or end up in the river after various natural and man-made uses. **River basin boundaries are hydrological boundaries as far as the surface water is concerned.** Administrative boundaries do not sync with the hydrological boundary. Adopting the hydrological boundary for managing the water resources is more scientific. It helps to quantify the water resources of a defined place i.e. a River Basin. Even though groundwater is not bound by surface hydrological boundary, it has the impact / connectivity with the surface water by way of recharging from surface flow, return flow from irrigated lands, seepages from storage structures, etc. Estimation of groundwater and surface water resources based on river basin concept is more scientific. Computation of sectoral water demands are also to be done River Basin wise so that the status of each River Basin can be assessed whether it is a surplus or deficit river basin. Hence, the rationale of choosing a river basin as the unit for the planning is to optimise the use of water resources in that basin.

The development of water resources in a river basin is a means to reach the socio-economic objectives of production, income, employment and quality of life. Therefore, water resources development should be considered in the wider context of regional planning. The task of planning and management of water resources can be very effectively carried out on a River basin wise structure for all intra and interstate rivers using scientific techniques.

In Tamil Nadu there are 34 rivers including one west flowing river. All these 34 rivers are grouped into 17 River basins for the purpose of hydrological studies for water resources planning activities. (**Plate : PAR 01**)

The main results of the river basin plan to be included in the State Water Plan are:

(1) Inventory of development plans and attributes of the plans which are relevant to their prioritisation;

(2) Institutional and legal deficiencies revealed in the basin with their proposed modifications.

The feedback is schematically presented in **Fig. 1.1.**

1.2 Objectives of present report & its updates

One of the internationally accepted human rights is the access to safe drinking water which is the basic need for human health and development (WHO 2001). The general health and life expectancy of the people is reported to be adversely affected due to lack of the availability of clean drinking water in many developing countries of the world (Nash and McCall 1995).The water demand for domestic, irrigation, industries, livestock, power generation and other uses are governed by socio-economic and agricultural factors, including the present and future population size, income level, urbanization, market facilities, remunerative prices, cropping patterns, etc. An analysis of the water availability, water utilisation and allocation plan for different competing water users and water balance form the core of a river basin plan.

The rivers are the most important source of fresh water, both for human consumption and agricultural / industrial usage. Groundwater is also used to meet the growing agricultural, industrial and household requirements. Population growth, socioeconomic development, technological and climate changes has increased the demand for potable water manifolds in the past few years.

In addition to mismatch problems between demands and resources, other important problems that hamper the safe water supply are considered. The problems encountered are water logging, salinity, pollution, environmental degradation, inefficient use of water, under utilisation of resources, seawater intrusion in coastal regions, natural calamities like floods and droughts, climate change etc. and health related problems. These problems are locally assessed and possible solutions are evolved in the planning process for decision making at higher levels.

Agriculture sustains life and irrigation sustains agriculture. Productivity is the index for the development of the State and the Nation. Hence, any water conservation and management in the agriculture sector, which consumes about 85% of the water resource, will lead to appreciable savings in water, which can be allocated to other sectors.

All the above factors triggered to take up micro level study and preparation of this report.

The process of the present planning study, is presented concisely in **Fig. 1.2.**

The planning process as demonstrated in this report is based on the data collected and collated for creating the databases using latest scientific techniques such as Geographic Information System and simulation models. The various models and databases used for earlier report have been updated accordingly for an adjustable scientific assessment of water resources and of sectoral water demands for the present and future. Accordingly the future-planning and “Action Plan” have been revised, updated and recommended.

1.3 Basin –Specific Data

Water resource planning which is people oriented and resource based requires extensive data on Rainfall, Geology, Soil, Geomorphology, Hydrogeology, Hydrology, Climatology, Water quality, Environment, Socio-economic, Health, Agricultural, Population, Livestock, Industries, etc. are collected for analysis.

Socio-economic, agricultural and livestock statistics are collected and presented on the basis of administrative units, which generally do not coincide with river basin boundaries. To obtain basin-specific socio-economic data, one has to re-group the data of administrative units into river basin wise. For administrative units situated in two or more river basins, the values of the variables were split between those basins in proportion to the area contained in the respective river basins.

The results derived from analysis are shown pictorially for easy understanding using ARC GIS, Quantum GIS, ERDAS Imagine and Log plot apart from MS Office. Aerial photographs in the scale of 1:50,000 scale and Satellite imageries of Indian Remote Sensing Satellites are extensively used for interpretation and analysis. The Digital Elevation Model of Shuttle Radar Topographic Survey of USGS was also used to some extent.

1.4 Location and Extent

Paravanar River basin which is a leaf shaped river basin lies within Cuddalore District of Tamil Nadu. It is the second smallest River Basin of Tamil Nadu. The basin falls in the survey of India Topo sheet Nos: 58M / 6, 58M / 7, 58M /10 &14 and 58M / 11 in scale 1:50,000 lying in between the latitude 11º18’ to11º45’ North and longitude 79º18’ to 79º45’East. Paravanar Basin is bounded on the North by Pennaiyar river basin, in the South and West by Vellar river basin and on the East by Bay of Bengal. (**Plate : PAR 01A**). The Geographical extent of Paravanar basin **872.34 Sq km.**

FIG. 1.1 FLOWCHART OF WATER PLANNING – STATE AND RIVER BASIN PLANS

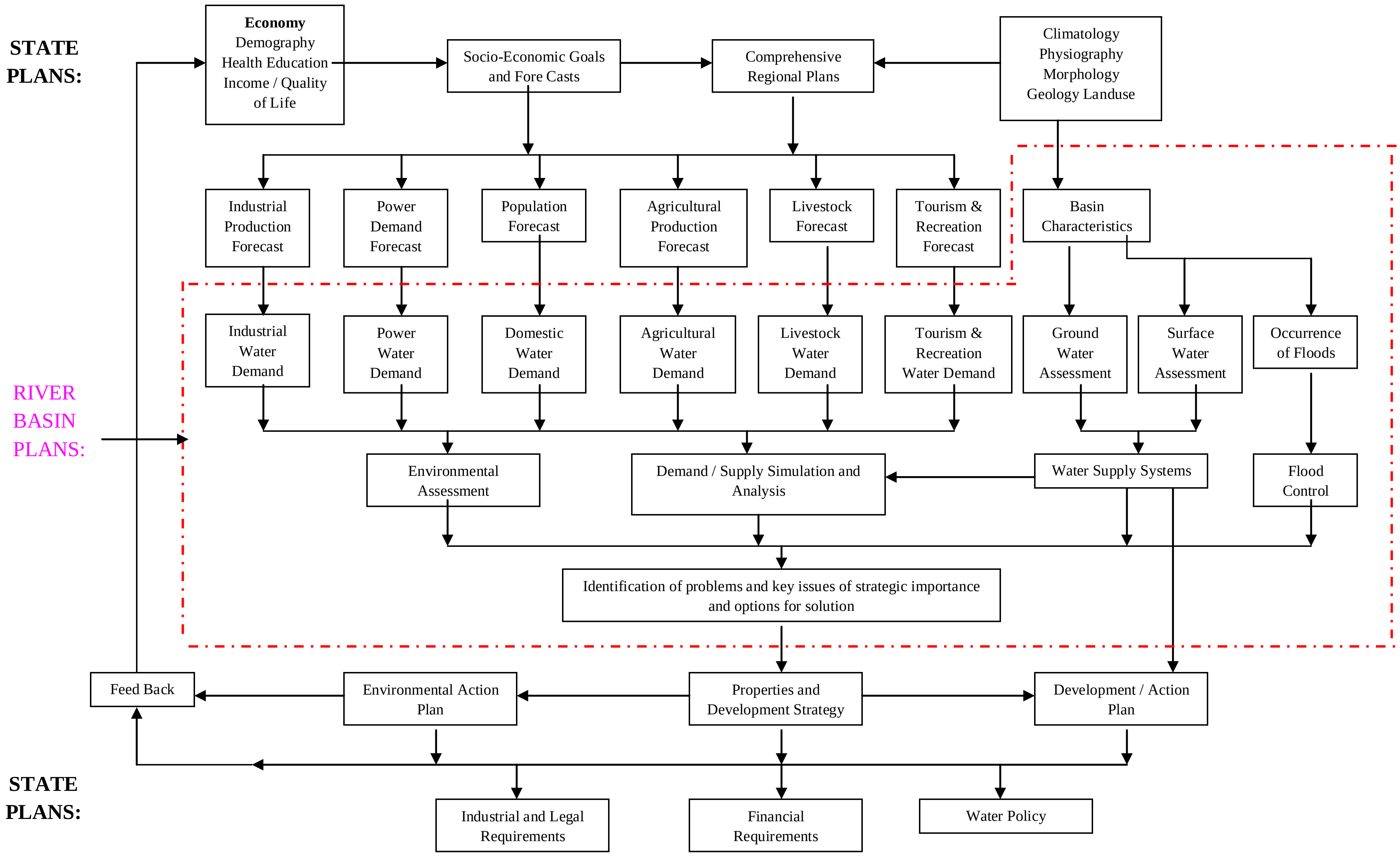
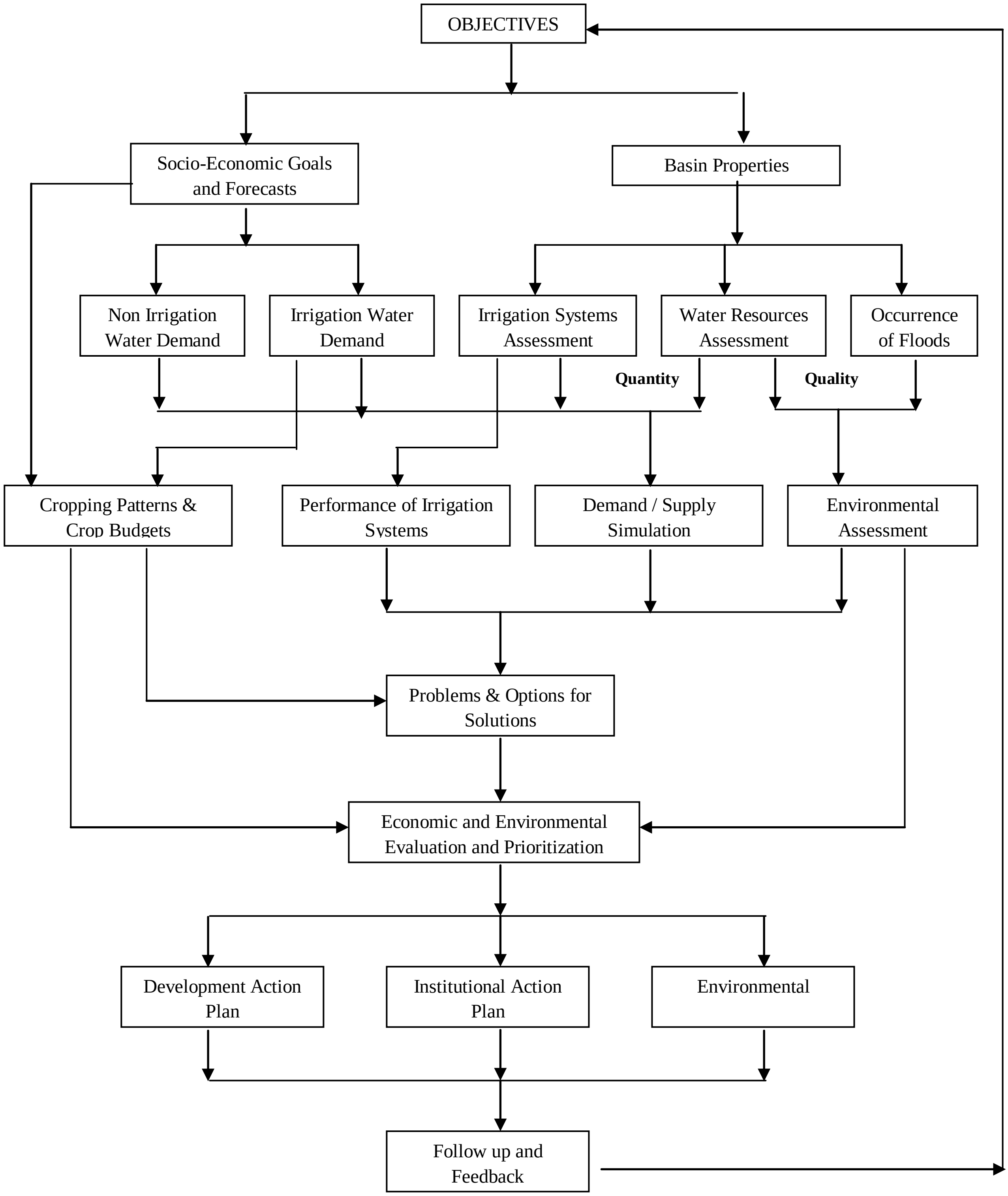


Fig. 1.2 FLOWCHART OF RIVER BASIN PLANNING



CHAPTER 2

BASIN FEATURES

CHAPTER 2

BASIN FEATURES

2.1 General

Paravanar river basin is located in the North Eastern coastal part of Tamil Nadu. The coastal length of this basin is 13.9 Km, and the mean sea level along the coast line is 0.54 m. In this basin, district and taluk head quarters, major towns are well connected with Road and Railway network. National Highways such as "NH 45C", "NH 45A" and "NH 532" and State Highways such as "SH 70" and "SH 138" are passing through this basin. Similarly railway lines between Virudhachalam and Cuddalore, Cuddalore and Porto Novo are passing through this basin (**Plate : PAR 02**).The whole basin lies within Cuddalore district with 23.58 % of the district area. This basin comprises of one full taluk and part of four taluks (**Plate : PAR 03**). There are seven Community Development blocks, out of which six are partly and one fully falls in the basin (**Plate : PAR 04 and Table 2.1A**). It has 193 Revenue villages (**Plate : PAR05 and Table 2.1B**).The major settlements of this basin are Neyveli township, Kurinjippadi, Nellikuppam, Kammapuram, Vadalur, Karunguzhi, Kattugudalur, Valaiyamadevi, Erumbur, Kullanchavadi and Bhuvanagiri. The basin is typically covered by sedimentary rock types of Tertiary to Recent age.

Mean annual rainfall is about 1197.70 mm. Maximum precipitation occurs during the North-East monsoon. Though the basin receives moderate to heavy rainfall during North East monsoon, it frequently faces water scarcity problems.

The upper part of the basin is drained by river Paravanar and lower part of the basin drained by Uppanar, based on that, two sub basins were delineated (**Plate : PAR 06**).

TABLE 2.1A
PARANAR BASIN

SUB BASIN WISE BLOCK AREA						
S.No	**Sub basin**	**Area (Sq.km)**	**Taluk**	**Block Name**	**Sub basin Block Area**	**Sub basin Block**
1	Paravanar	435.016	Chidambaram	Bhuvanagiri	46.16	27
			Virudhachalam	Kammapuram	187.05	53
			Kurinjipadi and	Kurinjipadi	164.44	41
			Panruti	Panruti	31.10	9
			Virudhachalam	Virudhachalam	6.27	2

2	Uppanar	437.325	Chidambaram	Bhuvanagiri	62.59	37
			Cuddalore	Cuddalore	44.78	17
			Cuddalore, Panruti and Kurinjipadi	Kurinjipadi	231.28	58
			Panruti	Panruti	36.27	11
			Chidambaram	Parangipettai	62.41	24
				Total	**872.34**	

Table 2.1B
PARAVANAR BASIN
SUB BASIN WISE VILLAGE LIST & ITS PERCENTAGE

Sub Basin : Paravanar			**Area : 434.94 Sq Km**		
1	**2**	**3**	**4**	**5**	**6**
Village Name	**Taluk Name**	**District Name**	**Sub basin Village area (Sq Km)**	**Village area (Sq Km)**	**Sub basin area - Village %**
Parvatipuram	Kurinjipadi	Cuddalore	10.436	10.436	100
Neyveli Township	Kurinjipadi	Cuddalore	25.317	25.317	100
Kattalai	Chidambaram	Cuddalore	3.044	5.205	58
Valaiyamadevi(Mel Padi)	Chidambaram	Cuddalore	3.309	4.363	76
Valaiyamadevi(Kil Padi)	Chidambaram	Cuddalore	8.858	10.474	85
Turinjikkollai	Chidambaram	Cuddalore	7.178	7.190	100
Erumbur	Chidambaram	Cuddalore	0.728	4.951	15
Nellikkollai	Chidambaram	Cuddalore	1.715	2.591	66
Pinnalur	Chidambaram	Cuddalore	5.313	7.165	74
Talaikkulam(Vada)	Chidambaram	Cuddalore	3.918	4.874	80
Kummadimulai	Chidambaram	Cuddalore	1.042	3.590	29
Ellaikudi	Chidambaram	Cuddalore	1.051	1.051	100
Nattamedu	Chidambaram	Cuddalore	0.018	4.660	0
Marudur	Chidambaram	Cuddalore	0.042	1.801	2
Jayamkondan	Chidambaram	Cuddalore	1.515	2.786	54
Uluttur	Chidambaram	Cuddalore	0.218	1.900	11
Prasannaramapuram	Chidambaram	Cuddalore	0.757	1.312	58
Talaikkulam(Ten)	Chidambaram	Cuddalore	0.024	2.348	1
Settiya(Shatia Tope)	Chidambaram	Cuddalore	0.087	5.652	2
Ambapuram	Chidambaram	Cuddalore	2.979	3.863	77
Kulakkudi	Chidambaram	Cuddalore	4.362	4.421	99
Mudappuli	Virudhachalam	Cuddalore	0.039	2.508	2
Semakottai RF	Virudhachalam	Cuddalore	7.421	22.363	33
Iruppu	Virudhachalam	Cuddalore	13.930	15.947	87

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Periyakappankulam	Virudhachalam	Cuddalore	8.674	8.674	100
Mudanai	Virudhachalam	Cuddalore	12.821	13.335	96
Kulappakkam(Uttangal)	Virudhachalam	Cuddalore	1.878	4.401	43
Kolliruppu	Virudhachalam	Cuddalore	4.993	4.993	100
Alandarkollai	Virudhachalam	Cuddalore	3.452	3.452	100
Gangaikondan	Virudhachalam	Cuddalore	10.107	10.107	100
Periyakkurichchi	Virudhachalam	Cuddalore	9.507	9.507	100
Seppalanattam	Virudhachalam	Cuddalore	7.610	7.610	100
Kottagam	Virudhachalam	Cuddalore	3.716	3.716	100
Uyyakkondaravi	Virudhachalam	Cuddalore	2.729	2.729	100
Mangati	Virudhachalam	Cuddalore	4.025	4.025	100
Kilpadi	Virudhachalam	Cuddalore	1.842	1.842	100
Melpadi	Virudhachalam	Cuddalore	1.209	1.209	100
Melpapanappattu	Virudhachalam	Cuddalore	2.517	2.517	100
Neyveli	Virudhachalam	Cuddalore	3.071	3.071	100
Veppangurichi	Virudhachalam	Cuddalore	3.355	3.355	100
Vadakkuvellur	Virudhachalam	Cuddalore	8.385	8.385	100
Ammeri	Virudhachalam	Cuddalore	11.088	11.088	100
Ammeri RF	Virudhachalam	Cuddalore	4.035	4.035	100
Chinnakappankulam	Virudhachalam	Cuddalore	1.616	1.616	100
Mummudi Cholagan	Virudhachalam	Cuddalore	4.164	4.878	85
Aziznagar	Virudhachalam	Cuddalore	5.770	5.770	100
Mangalam	Virudhachalam	Cuddalore	7.460	7.460	100
Kunankurichchi	Virudhachalam	Cuddalore	4.043	4.043	100
Uttangal	Virudhachalam	Cuddalore	8.446	8.446	100
Kuppanattam	Virudhachalam	Cuddalore	0.616	9.991	6
Kammapuram	Virudhachalam	Cuddalore	8.367	12.935	65
Adanur(Uttangal)	Virudhachalam	Cuddalore	0.749	2.223	34
Dharmanallur	Virudhachalam	Cuddalore	0.001	6.036	0
Agaram(Uttangal)	Virudhachalam	Cuddalore	6.459	6.567	98
Arasakkuli	Virudhachalam	Cuddalore	2.086	4.001	52
Narimanam	Virudhachalam	Cuddalore	3.570	3.570	100
Kovil Kuppam	Virudhachalam	Cuddalore	0.756	0.756	100
Kotteri RF	Virudhachalam	Cuddalore	0.095	0.095	100

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Kotteri	Virudhachalam	Cuddalore	2.708	4.251	64
Velangulam RF	Virudhachalam	Cuddalore	4.273	4.273	100
Iruppu RF	Virudhachalam	Cuddalore	0.080	0.080	100
Apaddharanapurm	Kurinjipadi	Cuddalore	3.961	3.961	100
Kanjamanathapuram	Kurinjipadi	Cuddalore	1.550	1.550	100
Ellayappampettai	Kurinjipadi	Cuddalore	6.373	7.698	83
Virupakshi	Kurinjipadi	Cuddalore	1.481	3.717	40
Adur Agaram	Kurinjipadi	Cuddalore	1.881	7.121	26
Guruvappampettai	Kurinjipadi	Cuddalore	1.833	1.833	100
Puduppettai(Mel)	Kurinjipadi	Cuddalore	0.918	1.130	81
Budampadi	Kurinjipadi	Cuddalore	1.441	1.778	81
Kurinjipadi	Kurinjipadi	Cuddalore	7.082	7.082	100
Rajakuppam	Kurinjipadi	Cuddalore	3.513	3.513	100
Arangamangalam	Kurinjipadi	Cuddalore	5.439	5.439	100
Kalkunam	Kurinjipadi	Cuddalore	4.773	4.773	100
Maruvay	Kurinjipadi	Cuddalore	3.664	3.664	100
Karunguzhi	Kurinjipadi	Cuddalore	8.349	8.349	100
Nayinakuppam	Kurinjipadi	Cuddalore	2.865	2.865	100
Kulakkudi	Kurinjipadi	Cuddalore	4.109	4.109	100
Serakuppam	Kurinjipadi	Cuddalore	5.606	5.606	100
Perperiyankuppam	Panruti	Cuddalore	5.210	7.428	70
Virasingankuppam	Panruti	Cuddalore	1.098	2.736	40
Nadukuppam	Panruti	Cuddalore	0.373	3.762	10
Vallam2	Panruti	Cuddalore	1.333	6.786	20
Vallam1	Panruti	Cuddalore	0.894	3.472	26
Kattugudalur	Panruti	Cuddalore	6.898	10.579	65
Marungur	Panruti	Cuddalore	9.708	19.407	50
Vegakollai	Panruti	Cuddalore	0.124	24.401	1
Vadakkumelur	Kurinjipadi	Cuddalore	4.878	4.878	100
Vadakuttu	Kurinjipadi	Cuddalore	11.274	11.617	97
Annadanampettai	Kurinjipadi	Cuddalore	0.004	2.473	0
Kilur	Kurinjipadi	Cuddalore	10.951	14.594	75
Tenkuttu	Kurinjipadi	Cuddalore	4.181	4.181	100
Terkumelur	Kurinjipadi	Cuddalore	4.313	4.313	100
Vanadarayapuram	Kurinjipadi	Cuddalore	3.686	3.686	100

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Narimanam RF	Virudhachalam	Cuddalore	2.707	3.482	78
Neyveli Township	Panruti	Cuddalore	24.566	24.566	100
Velangulam RF	Virudhachalam	Cuddalore	2.840	4.273	66
Mel Kangayankuppam	Panruti	Cuddalore	0.157	1.944	8
Sorattur	Panruti	Cuddalore	5.304	5.653	94
Sattamangalam	Virudhachalam	Cuddalore	0.037	3.589	1
Kachchirayanattam	Virudhachalam	Cuddalore	0.071	4.209	2

Sub Basin : Paravanar		Area : 434.94 Sq Km			
Village Name	**Taluk Name**	**District Name**	**Sub basin Village area (Sq Km)**	**Village area (Sq Km)**	**Sub basin area - Village %**
Turinjikkollai	Chidambaram	Cuddalore	0.011	7.190	0
Erumbur	Chidambaram	Cuddalore	0.938	4.951	19
Nellikkollai	Chidambaram	Cuddalore	0.876	2.591	34
Pinnalur	Chidambaram	Cuddalore	1.852	7.165	26
Talaikkulam(Vada)	Chidambaram	Cuddalore	0.955	4.874	20
Kummadimulai	Chidambaram	Cuddalore	2.548	3.590	71
Nattamedu	Chidambaram	Cuddalore	4.643	4.660	100
Puvalai	Chidambaram	Cuddalore	7.554	7.554	100
Periyappattu	Chidambaram	Cuddalore	2.841	8.108	35
Silambimangalam	Chidambaram	Cuddalore	0.631	7.659	8
Manikkollai	Chidambaram	Cuddalore	3.180	3.389	94
Palvattunnan	Chidambaram	Cuddalore	2.251	2.251	100
Alamelumangapuram	Chidambaram	Cuddalore	2.553	2.553	100
Vayalamur	Chidambaram	Cuddalore	4.936	4.936	100
Velangippattu	Chidambaram	Cuddalore	2.902	3.476	83
Villiyanallur	Chidambaram	Cuddalore	1.084	8.812	12
Kottattai	Chidambaram	Cuddalore	1.257	8.149	15
Sendirakkillai	Chidambaram	Cuddalore	3.769	3.769	100
Periyakummati	Chidambaram	Cuddalore	0.859	3.209	27
Manjakkuli	Chidambaram	Cuddalore	3.116	4.361	71

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Marudur	Chidambaram	Cuddalore	1.759	1.801	98
Jayamkondan	Chidambaram	Cuddalore	1.271	2.786	46
Uluttur	Chidambaram	Cuddalore	1.682	1.900	89
Prasannaramapuram	Chidambaram	Cuddalore	0.555	1.312	42
Talaikkulam(Ten)	Chidambaram	Cuddalore	2.325	2.348	99
Krishnapuram	Chidambaram	Cuddalore	3.371	3.371	100
Krishnapuram(Vada)	Chidambaram	Cuddalore	3.014	3.014	100
Vadakkutittai	Chidambaram	Cuddalore	2.364	2.364	100
Sattappadi	Chidambaram	Cuddalore	2.874	3.774	76
Mel Manakkudi	Chidambaram	Cuddalore	1.815	2.025	90
Kil Manjakkudi	Chidambaram	Cuddalore	5.390	5.390	100
Tachchakkadu	Chidambaram	Cuddalore	3.226	3.226	100
Arumudevan(Bhuvanagiri	Chidambaram	Cuddalore	3.575	3.575	100
Mutlur(Bhuvanagiri)	Chidambaram	Cuddalore	0.236	3.143	7
Adivarahanallur	Chidambaram	Cuddalore	2.791	4.955	56
Ayipuram	Chidambaram	Cuddalore	2.182	2.351	93
Kuriyamangalam	Chidambaram	Cuddalore	6.035	6.035	100
Cnitteri	Chidambaram	Cuddalore	1.780	1.780	100
Terkutittai	Chidambaram	Cuddalore	3.353	3.792	88
Alambadi(Kasba)	Chidambaram	Cuddalore	3.972	3.972	100
Odaiyur	Chidambaram	Cuddalore	3.216	3.576	90
Siyappadi	Chidambaram	Cuddalore	0.802	1.275	63
Settiya(Shatia Tope)	Chidambaram	Cuddalore	1.473	5.652	26
Manjakkollai	Chidambaram	Cuddalore	2.876	3.704	78
Ambapuram	Chidambaram	Cuddalore	0.883	3.863	23
Vandarayanpattu	Chidambaram	Cuddalore	0.744	1.223	61
Adivarahanattam	Chidambaram	Cuddalore	1.311	3.359	39
Chokkankollai	Chidambaram	Cuddalore	2.188	2.626	83
Bhuvanagiri (Kil)	Chidambaram	Cuddalore	0.458	4.058	11
Budarayanpettai	Chidambaram	Cuddalore	3.374	3.395	99
Suttukkuli	Chidambaram	Cuddalore	1.140	1.194	96
Bhuvanagiri(Mel)	Chidambaram	Cuddalore	0.467	2.586	18

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Kulakkudi	Chidambaram	Cuddalore	0.059	4.421	1
Ellayappampettai	Kurinjipadi	Cuddalore	1.325	7.698	17
Kanjamandanpettai	Kurinjipadi	Cuddalore	1.329	1.329	100
Peddunayakkankuppam	Kurinjipadi	Cuddalore	3.545	3.545	100
Tambipettai	Kurinjipadi	Cuddalore	3.061	3.061	100
Palaiyam	Kurinjipadi	Cuddalore	5.236	5.236	100
Krishnankuppam	Kurinjipadi	Cuddalore	3.178	3.178	100
Timmarvayuttankuppam	Kurinjipadi	Cuddalore	0.905	0.905	100
Vellakkarai	Cuddalore	Cuddalore	5.544	22.031	25
Cuddalore N.T	Cuddalore	Cuddalore	0.186	34.655	1
Pachchaiyankuppam	Cuddalore	Cuddalore	2.269	4.003	57
Karaikkadu	Cuddalore	Cuddalore	1.341	6.698	20
Kudikkadu	Cuddalore	Cuddalore	6.558	6.558	100
Annavalli	Cuddalore	Cuddalore	8.260	8.260	100
Sedappalaiyam	Cuddalore	Cuddalore	6.418	6.418	100
Ramapuram	Cuddalore	Cuddalore	7.672	14.659	52
Gangamanayakkan Kuppam	Cuddalore	Cuddalore	1.784	1.784	100
Valudalambattu	Cuddalore	Cuddalore	12.702	13.218	96
Ambalavanampettai	Kurinjipadi	Cuddalore	4.079	4.079	100
Ayikuppam	Kurinjipadi	Cuddalore	4.661	4.661	100
Agaram	Kurinjipadi	Cuddalore	10.431	10.431	100
Tondamanattam	Cuddalore	Cuddalore	5.886	8.367	70
Tiyagavalli	Cuddalore	Cuddalore	12.022	14.344	84
Alappakkam	Cuddalore	Cuddalore	1.283	1.283	100
Tiruchchopuram	Cuddalore	Cuddalore	5.702	6.476	88
Kambalimedu	Cuddalore	Cuddalore	2.792	2.792	100
Anukkambattu	Kurinjipadi	Cuddalore	4.676	4.676	100
Kodandaramapuram	Cuddalore	Cuddalore	4.549	4.549	100
Kayalpattu	Cuddalore	Cuddalore	7.766	7.766	100
Andarmullippallam	Cuddalore	Cuddalore	3.134	6.757	46
Tanur	Kurinjipadi	Cuddalore	2.325	2.325	100
Puvanikuppam	Kurinjipadi	Cuddalore	9.269	9.269	100

Village Name	Taluk Name	District Name	Sub basin Village area (Sq Km)	Village area (Sq Km)	Sub basin area - Village %
Idankondambattu	Kurinjipadi	Cuddalore	6.199	6.199	100
Akkatimmapuram	Kurinjipadi	Cuddalore	0.736	0.736	100
Adinarayanapuram	Kurinjipadi	Cuddalore	6.680	6.680	100
Sirupalaiyur	Kurinjipadi	Cuddalore	4.139	4.139	100
Karuveppambadi	Kurinjipadi	Cuddalore	0.876	0.876	100
Tirttanagari	Kurinjipadi	Cuddalore	6.007	6.007	100
Ranganathapuram	Kurinjipadi	Cuddalore	14.448	14.448	100
Tayilgunampattanam	Kurinjipadi	Cuddalore	4.657	4.657	100
Kesavanarayanapuram	Kurinjipadi	Cuddalore	1.281	1.281	100
Virupakshi	Kurinjipadi	Cuddalore	2.236	3.717	60
Adurkuppam	Kurinjipadi	Cuddalore	2.071	2.071	100
Kannadi	Kurinjipadi	Cuddalore	7.654	7.654	100
Kundiyamallur	Kurinjipadi	Cuddalore	6.941	6.941	100
Kottavancheri	Kurinjipadi	Cuddalore	4.952	4.952	100
Adur Agaram	Kurinjipadi	Cuddalore	5.240	7.121	74
Puduppettai(Mel)	Kurinjipadi	Cuddalore	0.212	1.130	19
Budampadi	Kurinjipadi	Cuddalore	0.337	1.778	19
Toppukkollai	Kurinjipadi	Cuddalore	1.450	1.450	100
Sembankuppam	Cuddalore	Cuddalore	4.746	4.746	100
Marungur	Panruti	Cuddalore	3.639	19.407	19
Kadampuliyur	Panruti	Cuddalore	0.399	20.163	2
Alagappasamudram	Panruti	Cuddalore	0.552	5.848	9
Vegakollai	Panruti	Cuddalore	22.430	24.401	92
Vadakuttu	Kurinjipadi	Cuddalore	0.342	11.617	3
Puliyur	Panruti	Cuddalore	23.631	24.925	95
Annadanampettai	Kurinjipadi	Cuddalore	2.469	2.473	100
Vengadampettai	Kurinjipadi	Cuddalore	5.347	5.347	100
Peyiganattam	Panruti	Cuddalore	3.440	3.440	100
Madanagopalapuram	Panruti	Cuddalore	2.040	2.395	85
Silambanathanpettai	Panruti	Cuddalore	9.247	16.109	57
Kilur	Kurinjipadi	Cuddalore	3.643	14.594	25
Miralur	Chidambaram	Cuddalore	1.638	3.752	44
Chinnakummatti	Chidambaram	Cuddalore	2.040	5.505	37
	Total area of the basin		**872.341**		

2.1.1 Neyveli Lignite Corporation

The “Neyveli Lignite Corporation”, a “Navratna” Government of India Enterprise functioning under the administrative control of Ministry of Coal, is located within this basin. The Lignite mine is an open cast mine with overburden thickness of 72 to 110 m. The Lignite seam thickness is between 10 to 23 m. Number of Excavation Benches in the mine is 5 and the height of each excavation Bench is between 20-25 m.

There are three mines operating in Neyveli, Mine I, Mine II and Mine IA.

The salient features of the three mines and the respective thermal power stations as on April 2012 are given in **Table 2.2** (Velan, 2013 IJEAT)

Table 2.2 Salient Features of the Three Mines

Particulars	Unit	Mine I	Mine IA	Mine II & Expn
Mining Area	Sq.Km	27.00	12.00	41.22
Capacity/Annum	MT	10.50	3.00	15.00
Lignite Reserve	MT	429.00	120.00	595.69
OB Thickness	Mts.	45 to 110	55 to 110	45 to 103
Lignite Thickness	Mts.	8 to 26	6 to 24	8 to 22
Average Stripping Ratio	Tons: M^3	1:5.5	1:7	1:5.5
Mining Started on	Date	25.05.1957	30.07.2001	14.04.1981
Lignite First Exposed	Date	24.08.1961	24.03.2003	30.09.1984
Overburden Excavated	MM^3	1631.53	210.57	1332.29
Lignite Mined	MT	298.92	26.91	212.41
Linked Power Station	Name	TPS - I (600 MW) & TPS-I Expn. (2 x 210 MW)	ST-CMS (Pvt.) (250 MW)	TPS - II (7 X 210) TPS-II Expn. (2 x 250 MW)
Generation Capacity	MW	1020	250	1970

2.1.2. Impact of Neyveli Lignite Mine on Water Resources in Paravanar basin.

2.1.2.1 Impact on soil and irrigation

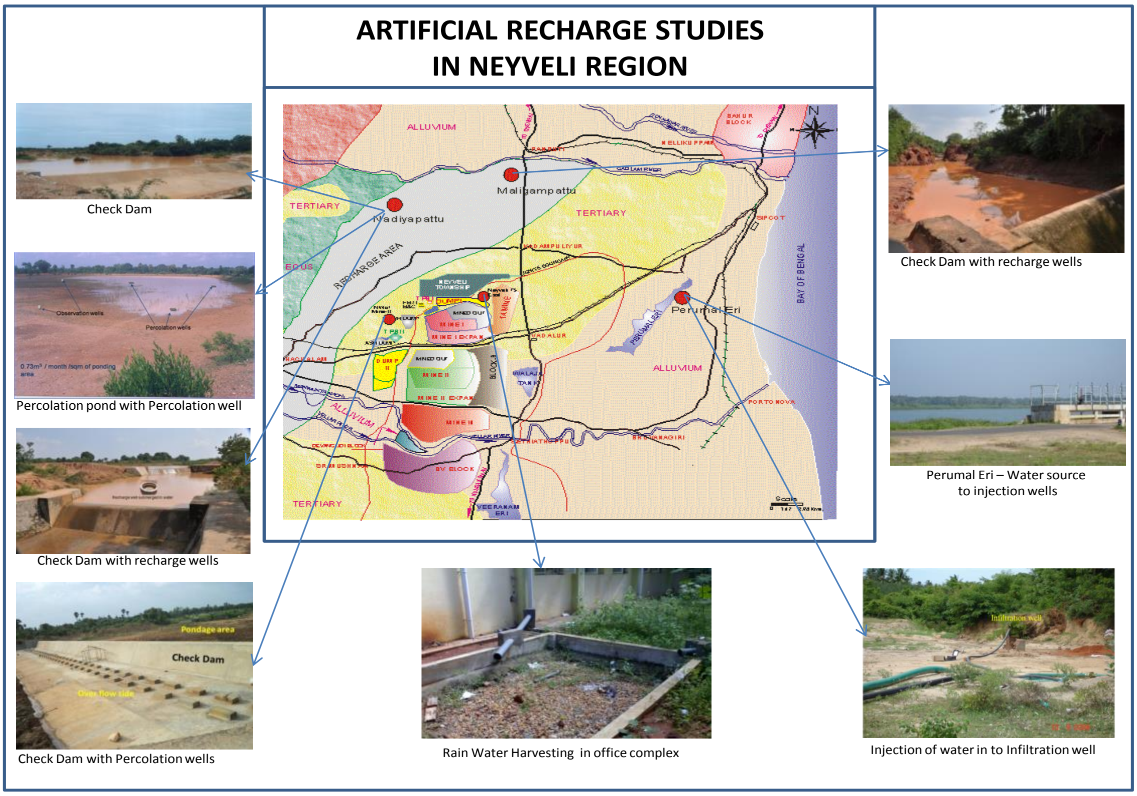
The Ground water pumped from the mines flows to Perumal Tank which is utilized for irrigation. The impact of the mine water on the soil was studied. The results obtained from various laboratory tests conducted to ascertain the quality status of soils in Perumal tank command area indicated, that the mine drainage water used for irrigation in the tank command has no adverse effect on the soils to hamper the crop growth. In fact, it was observed that the mine drainage component of irrigation water helped to increase the soil pH and kept it in the favorable zone of 6.5 to 7.5, so that the macro nutrients and micro nutrients are made available to crop growth (Murugappan et al JIPC 2006). The soil status in groundwater irrigated locations was found to be slightly acidic and need suitable treatment for raising the pH. This is very essential for improving crop growth. The higher organic carbon content reported in the soils of the Kundiyamallur canal command could be attributed to the entry of coal dust particles present in suspension in the mine drainage along with the irrigation water discharged from the tank. The content of organic carbon in soils of other canal commands were reported to be comparatively lower due to the fact that most of the suspended coal dust particles and fly-ash settled down at the tank bottom and relatively clear water was discharged for irrigation through the remaining off-taking canals of the tank which are comparatively in higher levels.

2.1.3. Impact on Groundwater Regime

Lignite is being mined at Neyveli for five decades by depressurizing the aquifer by pumping the groundwater for safe mining, since the Neyveli Lignite field is faced with a complex hydrological problem due to the pressurized water in confined aquifers below the lignite seam. A huge reservoir of ground water exists below the entire lignite bed, exerting an upward pressure of 6 to 8 kg/cm^2. The pressure of the artesian aquifer is being controlled by pumping groundwater. This aquifer is considered as most important water source for drinking and irrigation. The confined aquifer below the lignite seam is about 150-400 m thick in the Neyveli area. If the excavation is continued without reducing the upward thrust of the confined aquifer, it will result in the bursting of lignite bed and flooding of the mine.

New cone of pressure relief with a radius of 6.4 to 8 km (4 to 5 miles) has formed around the mine cut with a general decline of 4.5 to 6 m **(**15 to 20 ft) in pressure surface in that area. Around the mine, the ground is either flat or undulating with elevations ranging from 80 to 20 m (262.467 to 65.6168ft) above mean sea level with a general slope to the South and South-East. Approximately 32,000 gallons of water per minute from Mines-I and 48,000 gallons per minute from Mine-II are pumped out to Walajah tank which also receives the flow from Sengal Odai and the surplus of Walajah tank joins with the Kanniyakoil odai and forms as Paravanar River, which in turn drains into the Perumal tank, located at a radius of nearly 10 km (Murugappan, et al JIPC 2006). The water drained out from the Neyveli lignite mines is the only source of irrigation water in the nearby command areas during non-monsoon periods. Such water received through the streams / canals reaching the nearby tanks including Perumal tank has been utilized for irrigation in the respective command areas for more than two decades. In the absence of sufficient rainfall during the monsoon period, water for irrigation is augmented from the mine's drainage reaching the Permual tank throughout the year. This continuous receipt of mine drainage by the tank enables irrigating crops grown during the non-monsoon period also.

2.1.4. Water Resources Management Activities of NLC



2.1.5 Industrial Pollution in Paravanar Basin:

Small and large scale SIPCOT industries were situated on the banks of river Uppanar. Heavy metals have been discharged into the ecosystems by means of various industrial and other anthropogenic activities. In order to study the industrial pollution, the sediments of Perumal tank and the Uppanar River which were found very close to the industrial area have been chosen to assess the concentration of heavy metals. The study revealed that both the water bodies show the accumulation of heavy metals like Cr, Cu, Ni, Zn and Co at an alarming rate. There is an urgent need to control the industrial pollution and save the above two water bodies for the welfare of the present and future generations (Arul & Lawrence, IJSR, 2013).

2.2 Physiographic features

The general topographic trend is falling towards South and South East direction. The basin is a plain and upland terrain is devoid of any hill and related morphologies. The upland characteristic is due to the presence of "Cuddalore sand stone". There is a steady fall in the elevation, starting from 110 m in the highlands of Cuddalore sandstone area, NorthWest of Neyveli Lignite Corporation to 20 m towards the South-Eastern direction along Karunguzhi, Kurinjipadi and to the North-Eastern part. Further down on the East, the basin area has a flat topography, below 20 m contour to mean sea level near the coast. The terrain is drained by Paravanar river in the west and middle of the basin and in the east it is drained by Uppanar. The maximum elevation is 110 m MSL and the minimum elevation is 0.54 m MSL. Contours of 100 m to 20 m are traversing across the basin. The total area of the basin is 872.341Sq.Km in which the upper Paravanar basin (Paravanar sub basin) spreads about 435.01 Sq.Km and the lower Paravanar basin (Uppanar sub basin) spreads about 437.33 Sq.Km. The Eastern boundary is part of East coast of Tamil Nadu. The physiography map of Paravanar basin is shown in **Plate: PAR 07**.

2.3 Drainage

As said in para 2.2, the main rivers drained in this basin are Paravanar and Uppanar. The river takes its name since it flows as a spread sheet of water ("Paravanar" in Tamil means spreading river). This river is not a matured river and is seasonal or ephemeral. The Paravanar river originates from the streams in the highlands at northwest of Neyveli lignite corporation area, i.e from Semmakottai Reserve forest, at an altitude of about 100 m above MSL near Raghavankuppam and Kovilankuppam villages respectively. These two streams join near Mudanai village. Another stream originates from Ammeri Reserved Forest, near Vadakiruppu village. All the above mentioned streams meet at north of Mummudi Cholagan village and flows towards east and drains into Walajah tank near Maduvanmedu village at south of NLC mines. The Sengal Odai originates near Mulaikuppam village and Kanniyakovil Odai originates at South East of Neyveli township. These two odai merges at West of Ellaikudi village, where river Paravanar originates and flows in to Perumal tank. The water pumped from the Lignite mines contributes more to the flow in the River. Even though the basin receives remarkable rainfall, because of the coastal topography and the sedimentary formation, drainage networks are not well developed (**Plate: PAR 08B**).

From the Walajah tank, few streams flow towards East and flows into Satapadi tank. The surplus of the tank forms Uppanar river. On its course, towards North East, the river receives surplus water of Perumal tank near Periyapakkam, Anniyampettai and Pundiyankuppam Villages. The Uppanar river confluences with Bay of Bengal on the North of Semabadakuppam South of Cuddalore O.T. The length of the Uppanar river course is about 24 Km. Along the course of Uppanar, there are number of sharp bends. These bends are also seen with cut off meanders / old course up to Thiyagavalli village. Indications of emerged coastline of Paravanar river basin is noticeable. The backwaters often invade into the Uppanar, and make the surface water in the Uppanar “saline”. Hence the river Uppanar takes its name (Uppanar means “Salty River” in Tamil). The drainage map of Paravanar basin comprising Paravanar and Uppanar sub basins is shown in **Plate: PAR 08A**.

There are 37 tanks in the basin under the control of WRD / PWD, out of which 16 tanks have ayacut more than 100 hectares. All the WRD tanks of this basin are assigned unique codes. The major tanks,which receive Neyveli Lignite mine water and cater to the irrigation throughout the year, are Walajah and Perumal Tanks.

2.4 Geology

Geologically this basin is made up of Sedimentary formations. About 70% of the basin area is occupied by Cuddalore sandstone of Tertiary Age, consisting of laterite, sandstone, clay, silt, sand, etc. The remaining 30% of the basin area is covered by river alluvium and coastal alluvium of Recent age **(Plate: PAR 09**). The Miocene Cuddalore Sandstones of the Tertiary are well developed in this basin. Out of two discontinuous patches occurring in North of Cauvery, one forms this basin. The thickness of the sand ranges between 40 and 80 feet. These alluvial formations also act as potential unconfined aquifers. This alluvium consists of unconsolidated sands, gravels, and clays.

The borehole lithological details are given in **Table 2.3 (Annexure 2.1 of Vol II)** and the locations of these boreholes are shown in **Plate: PAR 09A**. Some of the boreholes which are bearing Lignite seams are shown as Lithological chart in **Plate: PAR 09B**. A Lithological fence diagram is given in **Plate: PAR 09C**, to have an idea of assumed lithology in between two bore wells. Also a cross section of local lithology given by NLC is shown in **Plate: PAR 09D**.

The stratigraphic sequence of the basin is furnished below:

ERA	Age	Series	Formation	Lithology
	Quaternary	Recent to	River alluvium	Sand, silt, gravel and clay
		Sub recent	Coastal alluvium	Mainly sand in the form of stabilized sand dunes.
	-------------		-------------------	
C		Unconformity	--	
E N	Tertiary			Laterite, sand stone, clay and lignite
O Z		Mio- Pliocene	Upper Cuddalore	
O	-------------			
I	Eocene		Lower Cuddalore	Coarse to medium sand, gravely sand, clayey sand and clay
C			--------------------	
		Unconformity	-	
				Black clay

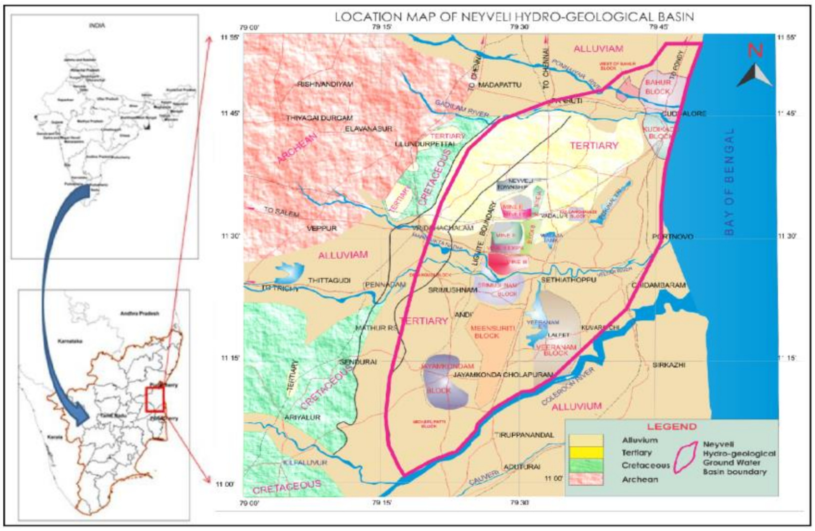
Tertiary system is almost represented by Miocene- Pliocene series, which consists of Upper Cuddalore formation and Lower Cuddalore formation (named after the town of Cuddalore). The Upper Cuddalore formation is characterised by Laterite, sand stone, clay and lignite which overlies on the Lower Cuddalore sandstone formation. The Lower Cuddalore formation mainly consists of coarse to medium sand, gravelly sand, clayey sand and clay. Gravelly sand intercalated with clay beds are commonly seen in this formation.

Thickness of Cuddalore sandstone varies from West to East in the basin area. In the East of Virudhachalam town, thickness of the Cuddalore sand stone seems to be 30m and it gradually extends to more than 500m towards the coast. The lateritic exposures are observed in several places around Neyveli, Vadalur, Kurinjipadi, and Kullanchavadi areas. Only thin seams of lignite are found to occur around Virudhachalam town where as in the mine area, its thickness is 18m occurring at a depth of 60m to 80m below ground level. Confined aquifer occurs below the depth of lignite bed. The confined aquifers are deep in nature. In general these aquifers are found to occur from the depth of 100m to 450m below ground level. Two decades before many artesian bore wells existed around Neyveli and now the bore wells have become sub artesian due to over exploitation of groundwater.

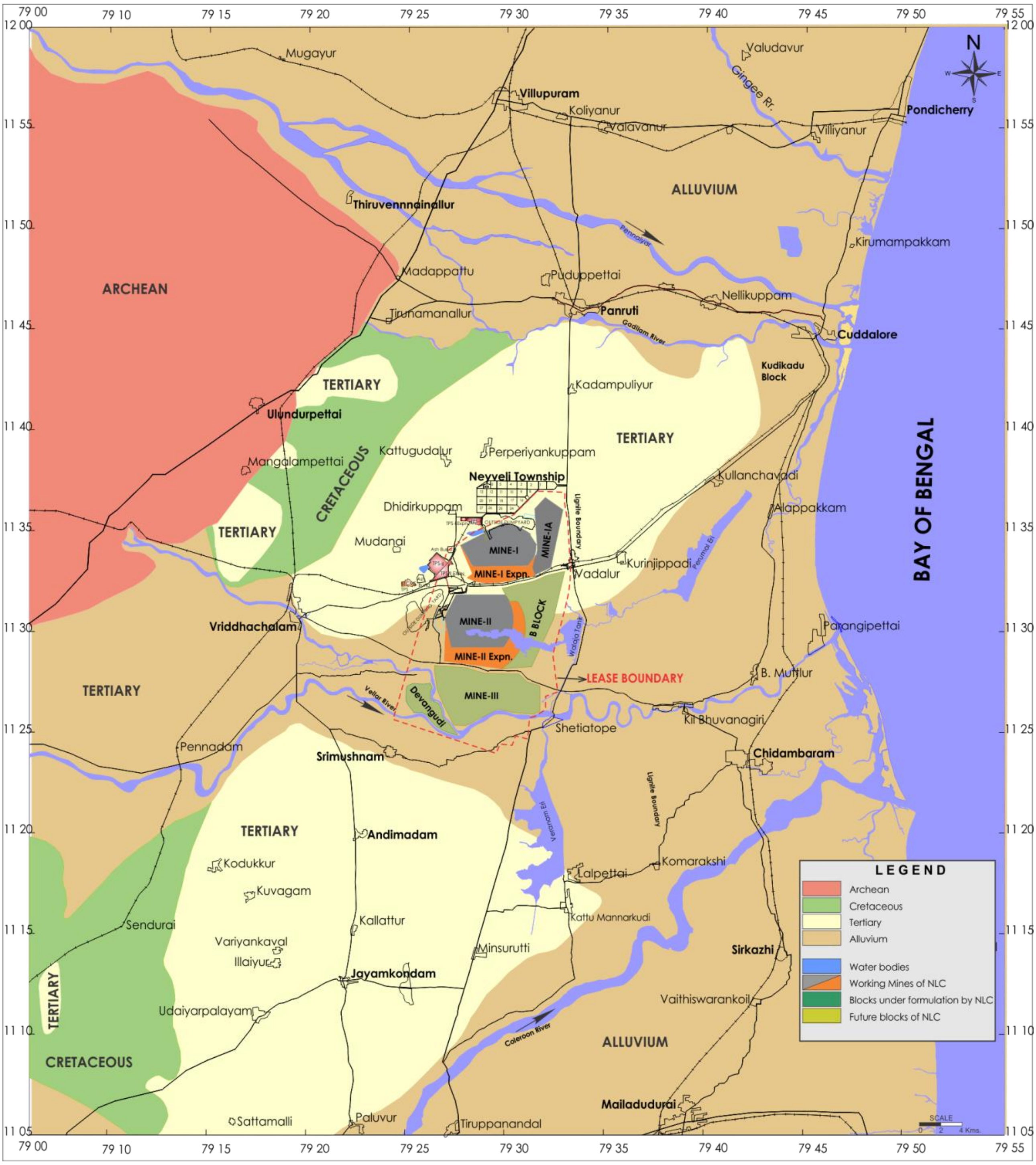
Quaternary formation includes the recent alluvium and coastal alluvium. They are under lained by Cuddalore sandstone, which consists of sand, silt and clay. Thickness of alluvial formation varies from 20 to 40m. The coastal alluvium covers beach, beach ridges and swales. Beach is very narrow and its width is limited to 0.5 Km. It is running parallel to the coast consisting of fine to medium grained sand. The Beach ridges are parallel to the coast and several such ridges are observed clearly through satellite imagery. The beach ridges are mainly observed in the villages Sendirakillai, Velangipattu and Manikollai ridge and Kumarapettai, Periyakuppam and Chittiraipettai ridge

These ridges are also running beyond the basin areas in north to south directions and the height of the ridges vary from 3 to 5m. The ridges are also called as stabilized sand dunes. Thick vegetation is observed in the beach ridges. Swales occur in between ridges where the groundwater potential seems to be moderate to poor. Dry crop cultivations are observed in the swales.

Neyveli Hydro Geological basin
(Courtesy: Neyveli Lignite Corporation, Neyveli)



MAP SHOWING GEOLOGY AND LIGNITE MINE IN NEYVELI LIGNITE SECTOR



2.5 Geological structure

Geological structures are the features in rock formations created during its formation or in due course, due to tectonic movements and by external processes, i.e., denudations. The most common geological structures include fault, fold, fractures, geological formation contact zones, etc. Lineaments are probable fractures on Earth's crust. These structures can be identified from satellite imageries and the same need to be verified in the field for better results.

The lineaments were picked up from the satellite imagery of Indian Remote Sensing Satellite, IRS P6, geocoded, acquired during February 2013 (**Plate: PAR 10**). Paravanar basin is made up of sedimentary formations including sandstones of Tertiary and alluvium of Recent age. Due to the heavy over burden, deciphering (identification) of lineaments of this basin is somewhat vague.

The structural features control the river flows/courses in many cases. They represent shear, fault and fracture zones. These zones are regarded as high potential for groundwater and also suitable for artificial recharge. The landforms and the lineaments have considerable influence on the aquifer characteristics. Greater influence is effected when the lineament with open fractures are overlain by porous, loose unconsolidated fluvial landforms.

The lineaments may act as good conduits for sub surface movement of groundwater in multi direction and form linear aquifers, based on its length, breadth and its intensity. The open fractures can be identified for artificial recharge and for storing groundwater as underground reservoir. Intersections of lineaments are found to be potential groundwater zones. The bore well, which is located along the lineament and in the lineament intersection zones will yield good amount of groundwater which have been proved in the field.

IRS FCC image is analyzed and a Geological structure / lineament map was prepared (**Plate: PAR 11**).

The North West portion of the basin, due to the Tertiary upland, which is full of cashew plantations, has hidden the Earth's morphological characteristics and so the lineaments could not be identified. And in the eastern side of the basin, due to the coastal morphology which is having high thickness of river / coastal alluvium, the signatures of lineaments are buried which leaves less scope to observe the lineaments.

In the middle and southern side of the basin, three sets of lineaments are deciphered from the Satellite imageries. They are NW –SE, NE –SW, more or less in North – South direction. Among the above, NW –SE lineaments are predominant. Most of the NW –SE and NE – SW lineaments are intersecting with each other. The NW-SE lineaments are found to occur near Chatram, Kattiyankuppam, Krishnankuppam, Annadanampettai and Chinnadanakuppam. The N-S direction lineament is traversed through Karaikkadu, Sembankuppam, Alappakkam villages. The NE – SW lineament are found near Krishnapuram, Mel Vadakattu and east of Ranganathapuram.

Lineaments and its prospects with regard to ground water are given in **Table 2.4**

Table 2.4 Lineaments and its Prospects

Feature	Description	Properties	Groundwater Prospects
Lineament	Linear feature may be a geological formation contact / fault /shear or fractured jointed zone.	Infiltration is good in fracture/ jointed lines and in geological contact	Good
Lineament intersection zone	Irregular fractures with varying density, crisscross and conjugate system of joints	Recharge from run- off water, water bodies acting deep conducive of groundwater from long distance	Very Good.

Strand lines:

Strandlines are linear structural features. These are noticed in the eastern part of the basin. The Strand lines are the indicators of progradation / emerging coast. They traverse in North East and South West direction and almost parallel to the present coast. The linear nature of the Perumal tank also suggests the influence of Strandlines. The above indications need a detailed study in the field to confirm the emerged coast / progradation of the delta of the adjoining basins Pennaiyar and Vellar in the north and south respectively.

2.5.1. Lineament and Drainage

Most of the drainages exhibit the influence of the lineament / geological structural features in general. As far as this river basin is concerned, due to its sedimentary nature and the presence of upland occupying most part of the river basin, no evidence of influence of lineament and structural control over river courses is observed, except in the course of Lower Paravanar river (Uppanar river). The Paravanar River which originates and flows down in almost North South direction takes a sudden turn towards North East and join the Perumal tank. The sudden change of course in direction may be the indication of structural control over the river course.

2.5.2 Lineament and Geology

As far as this basin is considered, it is made up of sedimentary formations which is highly suitable for groundwater exploration and for artificial recharge of groundwater. Due to the overburden thickness, the lineaments picked up in this basin are vague and need field verification. The lineament ascertained in the field in any of the formations of Paravanar basin can be considered as more productive and promising. **Plate: PAR 12** shows the map of Geology with lineament.

2.6 Geomorphology

Geomorphology is the science of landforms and its genesis. It is an inter-relative description of relief features of the Earth. Landforms develop through the combined influence of exogenous geomorphic processes and endogenous neotectonic processes. Climate has a pronounced effect on the development of landforms. Space imagery provides the best means of identifying landforms and process. Landforms of various genetic types are identified from the satellite images (of IRS R2 LISS IV February, 2013), based on the different recognition elements. But a thorough knowledge of the various genetic aspects of landforms and experience in identifying the landforms from satellite imagery for correlating in the field is necessary. It is to be noted, that the landforms are typical with respect to the type of formation such as igneous, metamorphic and sedimentary. Geomorphic studies are indispensable in understanding the occurrence of groundwater, selecting the site for storage structures and artificial recharge to augment groundwater resources. The Geomorphology map of Paravanar river basin was prepared and shown as **Plate: PAR 13**.   .

Geomorphically, this basin comprises land forms of sedimentary origin. These landforms indicate that the basin is subjected to the denudational, fluvial and marine actions. The coastal area indicates the progradation of delta and is undergoing severe erosion.

2.6.1 Denudation Landforms

Tertiary Upland

In the West and Northern side of the basin, upland of Tertiary age is found. It occupies nearly 70% of the basin area. The Tertiary upland is the older sedimentary geomorphic units of this basin, having very gentle slope towards East composed of sands, ferruginous sand stone, gravels, clay and clay stones popularly known as "Cuddalore sand stones". It is the most potential aquifer system of the State. This geomorphic unit can be observed in and around Neyveli, Vadalur, Kurinjipadi, Kattugudalur areas. The eastern side of this unit boundary is bounded by Perumal Tank.

Groundwater occurs in both shallow and deep water table aquifers. Layers of potential confined aquifers occur below the lignite seams. Artesian aquifers occurred around Neyveli in yesteryears. First two confined aquifers occur immediately below the lignite seams within the depth range of 122 m bgl and the third aquifer occurs between 122 m and 305 m bgl.

2.6.2 Fluvial Geomorphology

Flood plain

When the river floods, it spills over on either banks of the river and dumps lot of sediments. Such flood plains express remarkable tone in the images owing to the moisture influx and also due to thick vegetation. However certain stretches of the river show development of such flood plains only on one side of the banks which indicate the preferential shifting of the river in one direction. Sometimes, rivers which once have a wide spread floodplain, subsequently either due to reduction of incoming water or due to lateral rejuvenation develops a narrow and restricted flood plain, i.e., younger flood plain. The younger flood plains are preferable for groundwater exploration. The floodplains are conspicuous in this basin. As far as this basin is concerned, the flood plains were formed on either side of the river for considerable width.

Paleo Channel

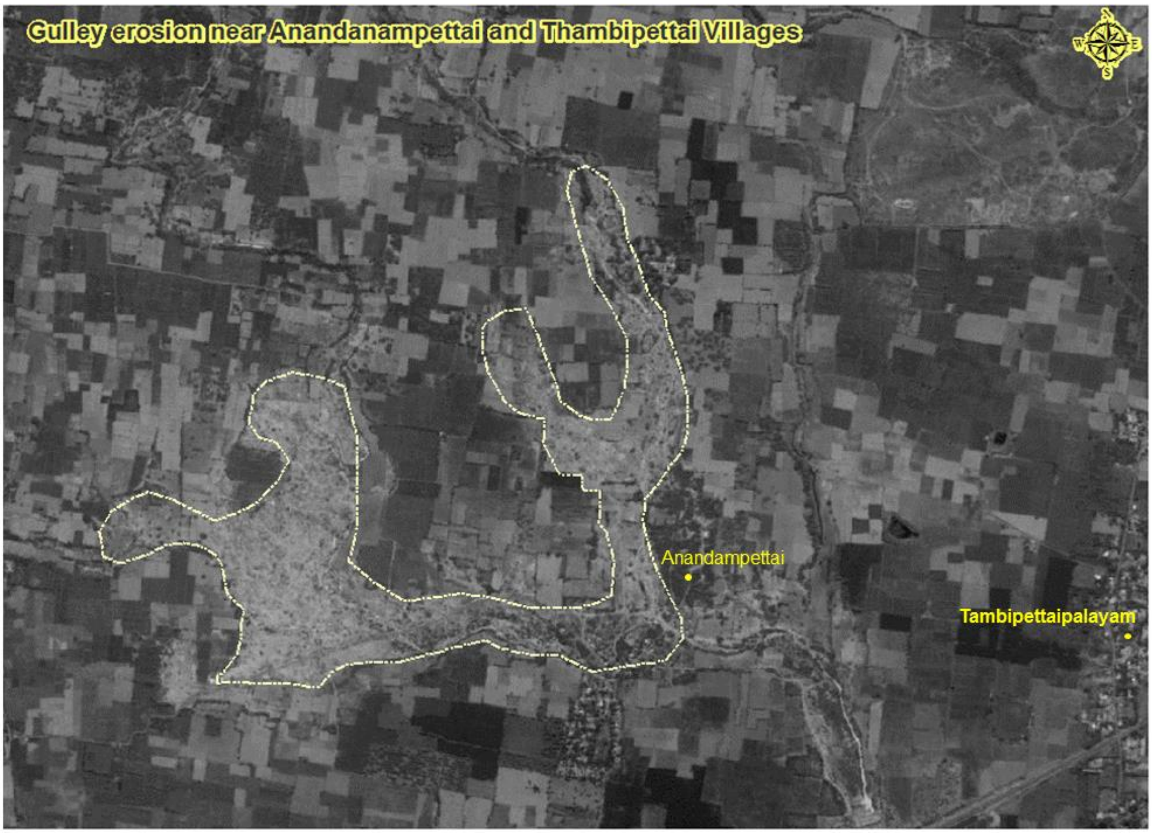
River migrates due to various reasons like tectonic movements, climatic changes, flash and unprecedented floods and coast line changes. Due to such phenomenon, the river leaves its original course and takes altogether a new course. Such left out course are termed as old river course or buried channels or paleo channel as they get buried due to subsequent geomorphic processes. These paleo channels hold and conduct groundwater and forms perennial source of groundwater as they are continuously recharged from the rivers. These are indicated by the low swirling pattern formed in the low land, adjacent to the stream beds which are lack of other natural drainage lines and chains of ponds. Paleo channels are found in the Uppanar sub basin and predominant in East of Pettankuppam and Anaiyampettai areas.

Meanders

Meanders exist along the Uppanar river on the coastal plain, which gives more potable groundwater. Typical meander is observed in between east of Koramedu and Nagarjuna oil refinery which is located in the coastal side of the basin.

Gulley erosion

These are the erosional plains that are formed by stream action along its course. It is found in the up land of tertiary of this basin. Deep gulley with flat bottom is common in this area. These geomorphic unit is observed in the middle part, in and around of Anandanampettai and Thambipettai where the streams flow down to Perumal tank.



2.6.3 Coastal Geomorphology

Coastal Plain

Coastal zone or coastal plain is a delicate transitional zone situated in between land and sea. The coastal process that develops the coastal geomorphic features is poly zonal in character. The major geomorphic agents are waves, currents, tides and winds which are working in the background, defined by the structure of rock, climatic conditions, vegetation cover and human activities. Sea level movements too have to be looked into for explaining the coastal landform. Small hamlets like Pundiankuppam, Sangolikuppam and Kudikkadu in the eastern side of the basin fall under this geomorphic unit.

Beach

Beach and sand bars are the dominant depositional landforms along the coast. Beaches are developed in the gently sloping areas and they are the accumulation of temporary deposits of sand, gravel and pebble on the shore between the low tide level and the coastline. The beach grows in size during the periods of less active wave attack but may get eroded by waves in storms. In this basin, the beach is very narrow one and under active development.

Beach ridges

This land form exists very near to coast, in low tidal shorelines. Marine process with the intercalations of river deposits formed series of beach ridges parallel to the coast, which is predominant. The occurrence of many beach ridges indicates the emergence of coastal plain. A long narrow beach ridge traversing in NE –SW direction, passing through Palvattunnam and Manikollai is remarkable.

High rate of sedimentation and landforms in the coastal plain suggests that the coastal plain would have been under a deltaic plain of adjoining rivers namely Manimuktha and Gadilam. Marine depositional landforms like beach ridges and the sand dunes causes Uppanar river course run in the inter - dunal depression.

The beach and the coastal plain of this river basin are now under severe alteration due to the Cuddalore port.

Sand dune

Along the beach ridges, there is a number of migrating and stabilized sand dune composed of sand parallel to the coast. After the emergence of coastal plain, Aeolian action intensified and the sand dunes are formed. Some of the sand dunes are still under migration while the others are stabilized due to vegetal cover. These types of sand dunes are observed south of Thiruchopuram and east of Pettankuppam.

Tidal flat deposits and Paleo tidal flats

These depositional landforms are formed due to the action of tidal waves. The paleo tidal flats are the older formations of tidal flats. Generally the tidal flats are very gently sloping towards the coast comprising of fine sand, silt and pebbles brought by the rivers and reworked by the sea. The paleo tidal flats and tidal flat deposits are the predominant coastal land forms of this basin. It is found in Alamelumangapuram, Puvalai in the southern side Sattikkupam, Rajapettai, and Nochikkadu in the north eastern side of this basin.

Strand line

A number of strandlines depict the pro gradation of Paravanar delta during the Holocene period and is mapped in this area. These strand lines are running North to South and North – North-East to South West (NNE-SW) directions.

Channel Island

In the mature stage of rivers, due to the loss of velocity and energy, obstructions within the river course causes the formation of Channel Island. Such channel island is observed in the coastal area of this basin. Two Channel Islands are also found in East and South-Eastern side of the Pundiankuppam and Kudikkadu in the Eastern portion of the basin respectively.

Swale

This is the land form between the point bars or beach ridges and sometime occupied with water. Such landform is observed near Tachchakadu and east of Karaikkadu.

The characteristics of each geomorphic unit, lithology, texture and groundwater prospects of the units are described in the **Table 2.5**.

Table 2.5 Characteristics of Geomorphic Units

Sl. No.	Geomorp-hic units	Lithology	Description	Groundwater prospects.
1	Tertiary uplands	Mainly laterites capping over metasediments	Occupying elevated land, medium to coarse texture with less drainage density. Infiltration and permeability are good. Prone to erosion.	Good.
2.	Flood plain	Primarily comprises of unconsolidated materials like gravels, sand and silt.	A flat surface adjacent to stream composed of unconsolidated fluvial sediments. Permeability is good.	Moderate to good.
3.	Buried channel/ Paleo Channel	Comprises of unconsolidated material like gravels, sand and silt.	A linear low lying surface parallel or in connection with the existing river or streams. Intensive cultivation practices are seen.	Very good.

4.	Paleo deltaic plain	Sand and clay and silt.	Gently sloping land, medium to coarse texture with less drainage density. Infiltration and permeability are good. Prone to erosion.	Very Good Quality is variable in the coast.
5.	Tidal flats and paleo tidal flats.	Constitute fine sand, silt and mud	Flat surface formed by tides comprising of mostly mud and fine sand of varying grain size and lithology.	Quality will be poor to saline.
6.	Beach	Un consolidated sand / silt deposited by tidal waves.	Narrow stretch of unconsolidated sand / silt deposited by tidal waves along the shore line.	Moderate. Quality is variable
7.	Beach Ridge	Unconsolidated sand / silt.	A linear ridge of unconsolidated sand / silt parallel to the shore line. Infiltration and permeability are good in this landforms	Good. Infiltration and permeability are good.
8.	Sand Dune	Sand formations of different shapes and sizes	Heaps of sand of different shapes and sizes formed by wind action.	Good. Quality may be varying.

2.6.4. Lineament and Geomorphology

A comparative study is attempted to correlate the lineament with different geomorphic units of this basin. The lineaments are superimposed with Geomorphology features to study the influence of lineaments over the Geomorphic units (**Plate: PAR 14**). A favorable Geomorphic unit in respect of groundwater occurrence with lineament / linear features will result in to a good zone for groundwater exploration and artificial recharge to groundwater aquifers.

In this basin, the major geomorphic units such as Tertiary upland exhibits lineament in NE-SW and NW-SE directions. Lineaments also observed in the eastern part of this geomorphic unit.

Some NE-SW and NW-SE lineaments are observed in the flood plain in the southern part of the basin. These two Geomorphic units of this basin are of sedimentary origin, which is highly favorable for groundwater exploration both in respect of geomorphic and geological formations. The lineaments traversing through these geomorphic units may be taken up for further detailed studies. The other geomorphic units are not exhibiting any type of linear features due to its genesis.

In the following **Table 2.6**, lineaments which are traversing and the points of these intersection of lineaments inferred from the imagery are given for further field survey to confirm the lineaments and for suggesting groundwater exploration and recharge.

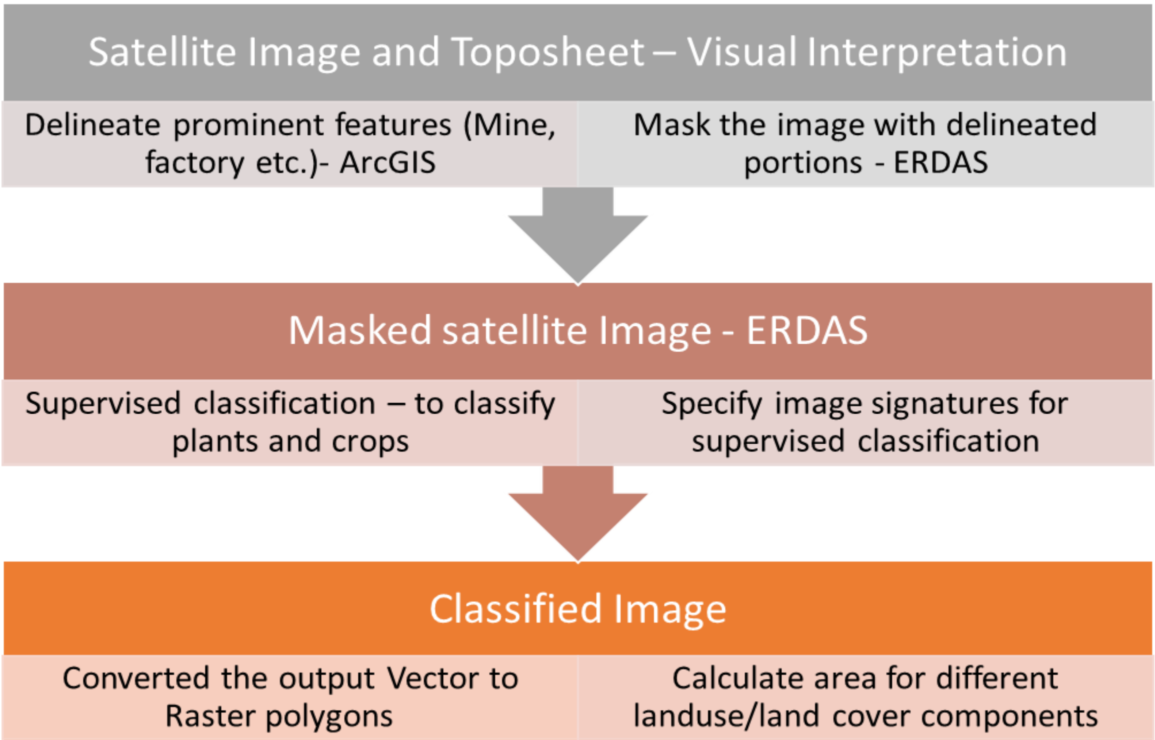
Table 2.6 Lineament and their Intersections

Point of intersection		**Lineament traverse**	
Revenue village No.	**Village name**	**Revenue village No.**	**Village name**
64	Mudanal	114	Annavalli
155	Maruvai	118	Valudalampattu
171	Vegakollai	174	Puliyur
139	Ranganathapuram	121	Agaram
59	Kulakudi	6	Thurinjikollai
46	Alambadi (Kasba)	1	Parvathipuram
181	Kilur	14	Puvalai
120	Ayikuppam	171	Vegakollai
140	Tayilkunampattanam	62	Iruppu
143	Adurikuppam	103	Arangamangalam
151	Kurinjipadi	9	Pinnalur
		29	Uluthur
		173	Vadakuttu
		186	Neyveli Township
		187	Uttangal

2.7 Land use

The term land use relates to the human activities associated with specific piece of land, on the Earth surface (Lillesand and Kiefer 1987). It is necessary to understand the land use and land cover pattern for sustainable use of the land and to determine the potential of an area mostly in respect to cultivation. Since the land use and land cover pattern is spatial and time dependent, it is not wise to rely on one time field data. And so the study of an area of interest by Remote Sensing method is very effective and time saving. Comparison of land use and land cover patterns of the same area in two different periods helps in understanding the variation in utilization and degradation of land.

Paravanar river basin land use map has been previously studied and prepared on 1:2,50,000 scale in the year 2004 using IRS P6 LISS-III & PAN merged FCC data of 29th February 2004 by visual interpretation and digital image processing classification methods. In the present study, IRS P6 LISS-IV FCC data of 19th February 2015 is used. It has been carried out by both visual interpretation and digital image processing using the software ERDAS Imagine 2014. The methodology adopted for the work is given in the flowchart below:



The land use and land cover classification of the Paravanar river basin for the year 2015 is shown in the **Table 2.7**. The respective landuse map is presented in **Plate: PAR 15**.

Table 2.7 Landuse Classification

Sl. No.	Landuse Category I Level	II Level	III Level	Area (Sq km)	Percentage (%)
1	Built up Land	Settlement	Urban	21.513	2.467
			Rural	65.250	7.480
		Factory	Factory	8.729	1.001
2	Mining	Mining	Open cast mining	76.380	8.756
3	Agriculture	Wet Crop / Irrigated Land	Paddy, Sugarcane, Banana and harvested Land	456.703	52.354
		Dry crop/Rainfed land	Cholam, Kambu and Groundnut	14.444	1.656
		Plantation	Cashew plantation	114.110	13.081
		Groves	Groves - Coconut, Mango	6.400	0.734
4	Fallow	Current Fallow	Current Fallow	1.593	0.183
		Fallow	Fallow	1.041	0.119
5	Forest	Reserved forest	Reserved forest	14.220	1.630
		Forest Blanks	Forest Blanks	3.488	0.400
6	Barren/ Uncultivable/ Waste Land	Barren land	Barren land	1.956	0.224
		Scrub land	Scrub land	35.115	4.025
		Salt affected / Sandy area	Salt affected / Sandy area	10.731	1.230
7	Water body/Wetland	Water body	Tank	35.220	4.037
			River/Streams/Canals	4.630	0.531
		Wetland	Water logged area	0.815	0.093
				872.341	**100.00**

2.7.1 Built up Land

Built up Land comprises of rural and urban settlement and development of factories. In the Paravanar Basin, the urban and rural settlements cover up to 86.76 Sq Km which is 9.95% of the total basin. This settlement includes Neyveli new township, Kurinjipadi, Nellikuppam, Kammapuram, Vadalur, Karunguzhi, Kattugudalur, Bhuvanagiri and other small villages.

Factories like Nagarjuna oil refinery and Thermal power stations I and II are the major factories in this basin. The Nagarjuna oil refinery which refines petroleum products is situated near the coast of Kurinjipadi block and occupies 3 Sq Km area. The thermal power station I is linked to Lignite Mine I and the station II is to the Lignite Mine II of Neyveli. The power generation capacity of the power stations I and II are 1020 MW and 1970 MW (Velan.M, IJET 2013) respectively and areal extent of the same are 2.12 and 3.6 Sq Km respectively.

2.7.2 Mining

The lignite resource in the Cuddalore sandstone is excavated by open cast mining technique. In this method highly equipped machineries are used to unearth the overburden (Clay and Sandstone), transport the coal and dispose the waste. There are two mining units in Neyveli. The Mine I and Mine II have respective lignite reserve of 429 MT and 595.69 MT (Velan.M, IJET 2013). The Mine IA has been started with reserve of 120 MT. The combined area of Mine I and IA in 2015 is 37 Sq Km and that of Mine II is 41 Sq Km.

2.7.3 Agriculture

Agriculture in an area depends on both surface and groundwater. The groundwater in Paravanar basin occurs in both confined and unconfined aquifers of which the Neyveli artesian aquifer plays a major role in providing water for various human needs. This confined aquifer is pumped out continuously to keep the hydrostatic pressure low. The pumped water is diverted to thermal power station tanks and two other irrigation tanks, viz., Walajah tank and Perumal tank. These tanks are the major water bearers in the basin and the cultivation depends mainly on them.

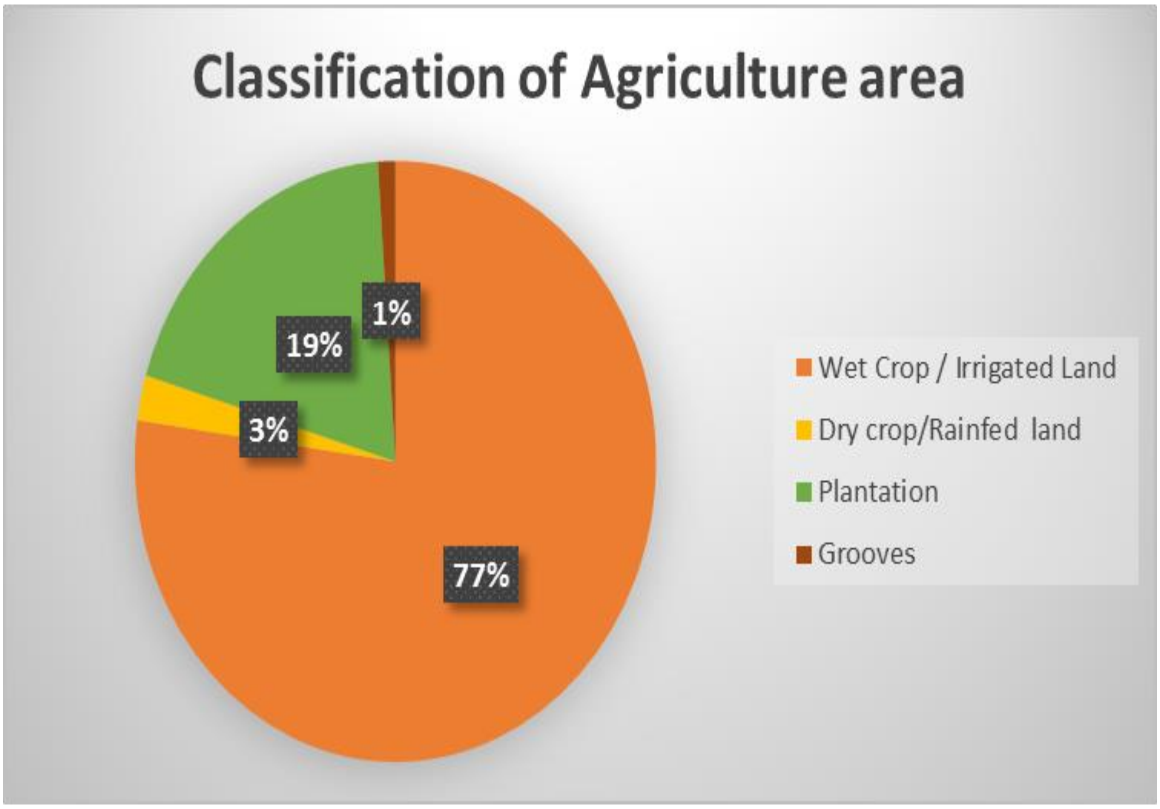
The land is mainly occupied for agricultural purposes which includes both wet and dry crop.

Wet crop: are crops which require plenty of water supply for the growth and this comprises of Paddy, Sugar Cane and Banana. Most of the area in the basin is agriculture land cultivating wet crops (456.7 Sq Km).

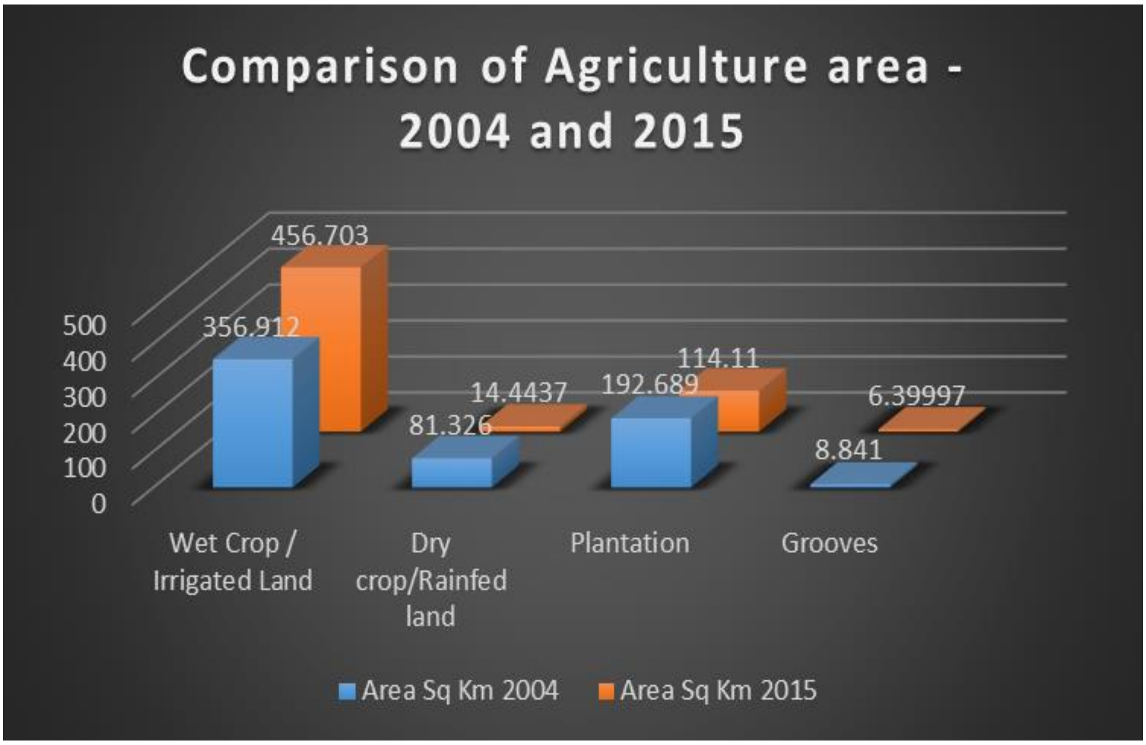
Dry crop: are also called as rain fed crops as they are cultivated in such areas where the water source is mostly rainfall. The cropping period controlled by the monsoon season. The dry crops grown in this area are Cholam, Kambu (Millet) and Groundnuts. The dry crops are cultivated over 14.44 Sq Km in the basin.

Cashew plantation: is the major plantation in the basin. This covers up to 114.11 Sq Km of the basin area. Cashews are being cultivated in Panruti and Kurinjipadi blocks of Cuddalore district.

Groves: or orchards in the basin comprises of Mango and Coconut. Very few patches of groves are grown in this basin for an area up to 6.4 Sq Km.



A comparison of areas occupied for different agriculture purposes for the years 2008 (Paravanar Microlevel study) and 2015 (Present study) has been made and is shown in the following graph. This shows a significant increase in the wet crop in 2015 than 2008 and except this all the other crops were grown in comparatively larger area in 2008 than that of 2015. The variation in the crop cultivation is because of the dry 2008 (Drought year) and comparatively good rain received 2015.



2.7.4 Fallow Land

Fallow is the type of land that is left uncultivated intentionally for about five years whereas the current fallow is the stage of crop rotation in which the land is not used to raise a crop at a particular year. Ground may be fallowed as part of a larger crop rotation plan.

In the Paravanar basin, 1.04 Sq Km area surrounding cashews and groves is fallow. Two patches of land near Neyveli township and Thermal Power Station I are deliberately left fallow since 2011 (Source: Google Earth). Hence these lands are classified under current fallow land group.

2.7.5 Forest

In the Paravanar basin, forest is classified into reserved forest and forest blanks.

Reserved forest: are natural areas which enjoy judicial and / or constitutional protection under the legal systems. This term was used to designate protected forest areas in British India, under the Indian Forest Act, 1927. The Paravanar basin has 14.22 Sq Km of reserved forest and is Velangulam RF, Ammeri RF, Semmakottai RF and Narumanam RF. Among them Semmakottai and Narumanam RF comprises of Cashew plants and the remaining two RF are covered by scrubs.

Forest blanks: are areas within a forest, reserved forest where the land is barren and not covered by any woods, crops or scrubs. This kind of lands is noticed in Ammeri RF, Semmakottai RF and Narumanam RF of the basin.

2.7.6 Barren / Uncultivable / Waste Land

This classification includes Barren land, Scrub land and Salt affected / Sandy area.

Barren Land: is dry and bare land with sparse or no vegetation and plants. This is attributed to the poor soil quality, presence of thin or no soil layer, climatic conditions etc. In the Paravanar basin, very small area of 1.96 Sq Km is barren with no favorable condition for cropping.

Scrub land: term is self-explanatory, i.e. the land covered by scrubs. The Paravanar basin has 35.12 Sq Km scrub land in 2015 but in 2004 it was only 10.68 Sq Km.

Salt affected / Sandy area: constitute of land leached by salt and has salty soil cover, sandy beach and sand dunes. The Tertiary sandstone are vulnerable to leaching of salt in one place and deposition nearby. This increases the sodium and chloride concentration in soil which makes the soil unsuitable for growing of plants.

The sandy beaches are costal and eolian deposit and are components of the coastal region. As mentioned in para 2.4 sand dunes in the basin belong to the sub recent age. The Salt affected / Sandy area combined to make a land cover of 10.73 Sq Km.

2.7.7 Water body / Wetland

Water body includes tanks and rivers. The tanks include WRD maintained tanks, Panchayat union tanks and water stored in the mines. The Paravanar and Uppanar Rivers are shown in this category. The combined area of tanks and rivers is 39.85 Sq Km. Among them, the most predominant water bodies Walajah and Perumal tanks cover 6.73 and 14.09 Sq Km respectively which is of about 47% in the total water bodies.

The wet land symbolizes water logged area. Waterlogging refers to the saturation of soil with water. In the Paravanar basin, water logged area present in the swales of sub recent age and in the coastal region.

2.7.8 Land Use and Lineament

GIS overlay analysis techniques was used to integrate the lineament layer with the land use layer generated from IRS P6 LISS-IV FCC data of 19th February 2015 (**Plate : PAR 16**).

Lineaments frequency and density is more and good in the eastern part. Crop land covers large area around this lineament zone. More groundwater extraction and fractures frequency is really found in and around the crowded lineament zone. It clearly indicates that the major development of cropland is seen around Perumal tank.

Further, South East part of the basin area is also exhibiting prominent lineaments. Lineaments are showing good frequency and density. More number of cut off meanders and old courses of rivers are picked up very well in this area. Groundwater potential is good in this area because the land forms are developed by the tectonic lineaments (near Murattu channel, Satapadi and Keelmanakudi). Hence crop land intensity is more and thus more people go far II crop and III crop to grow all pulses.

Cashew plantation area is not embedded with prominent lineament but few lineaments are noticed near Kunakurichchi. Dry crop area around Umangalam shows moderate to good frequency of lineament for targeting deep aquifers.

2.8 Geophysics

Introduction.

The Geophysical prospecting plays a dominant role to meet out the demands of groundwater. With the knowledge of hydro geological conditions of an area, the practical results can be easily determined. Some of the important geophysical methods are the Electrical, Seismic, and Gravity and Magnetic method. Of these, Electrical Resistivity method has been widely used for the practical application in detecting the groundwater.

Electrical Resistivity Method.

The basis of electrical resistivity technique is Current **(I)** passed into the ground through two metal electrodes. The potential difference "(▲V)" is measured through two more electrodes called potential electrodes. The ratio of " ▲V/ I" gives resistance **(R)**, and multiplying **R** with the geometrical factor **(K)** of the electrode separation, the resistivity **'ρ'** which is inverse of conductivity of the ground can be determined.

The value **ρ** corresponds to the true resistivity if the ground is homogeneous and isotropic. When it is obtained from the measurements over a layered or heterogeneous ground, it is only an apparent resistivity and is denoted as **'ρa'** the quantity being used in the interpretation of electrical methods.

Resistivity of Geological Formations

The resistivity of geological formations are heterogeneous and it depends on the porosity, density and quality of water in the aquifer. The resistivity of highly weathered saturated gneisses of Archaean age ranges from 27 to 125 ohm-mts: and of hard, massive, crystalline complex ranges from 200 to 2000 ohm-mts. Dry rocks whether non-porous or porous are practically non-conductors but the resistivity decreases with increasing amount of pore-water. Unsaturated geological materials have higher resistivity than the same material saturated with water. Saturated clayey sediments have low resistivity, clayey sand and gravel deposits that are saturated with groundwater of high ionic strength have very low resistivity. The geological formation would give a low resistivity value if it is porous and saturated with water and also if the water is saline. When this study is combined with surface geological studies, it will indicate the area favourable for prospecting. Further this study can indicate the depth, thickness and nature of aquifer, estimate the depth to fresh rock and salinity of the formations.

The Paravanar river basin is comparatively a smaller river basin with an area of approximately 872.341 sq.km. **Plate: PAR 17** shows 99 locations of Vertical Electrical Soundings (Statement GP-1) and 44 bore holes (Statement No.GP-2) used for Geophysical study of this basin. Based on the data of Vertical Electrical Soundings (VES) conducted in this basin, iso-resitivity contours at 10m, 60m and 100m depth below ground level has been created vide **Plate : PAR 18, 19 and 20**.

The information obtained from borehole lithology is utilized as attributes in the GIS platform for creating the thematic map showing the spatial distribution of unconsolidated formation and its thickness of the basin (restricted to the total depth of the bore well) (**Plate : PAR 21)**. According to the depth of occurrence, the depth to unconsolidated formation is classified in three categories viz. 1.Shallow depth (40-130 m bgl), 2. Intermediate depth (130-180 m bgl) and 3. Deeper depth (180-472 m bgl). Shallow (Pink colour) aquifer generally made up of sand/gravel/sandstone widely exists in the western and eastern parts of the basin. The aquifer occurring at moderate depth (light green) exists in the central and western parts of the basin. The aquifer occurring at deeper depth (dark green) exists in the central and northeastern part of the basin. Here the aquifer is made up of sedimentary formation (alluvium / sandstone).

This classification gives an understanding of the subsurface scenario and its spatial distribution in this basin.

It is inferred from the available borehole data, the alluvial aquifer of this basin exists up to a depth of 40 to 60 m below ground level; the sandstone aquifer occurs up to a depth of 100 to 200 m below ground level. The sandstone aquifer occurs up to a depth of 400 to 500 m below ground level in some parts of this basin. These depths may extend further deep and the exact depth cannot be ascertained from the availability data.

From the data analyzed, it has been found that the shallow aquifer is extending generally from 40 to 130 m from ground level in the western and southeastern parts of the basin in between Kappankulam and Neyveli (western part), in and around Krishnapuram, east of Kuppam, west of Tiruttinalnagar, small isolated pockets exist in North east of Neyveli Township, north of Thyagavalli and south of Thyagavalli (northern & eastern part of the basin). The central and northeastern parts of the basin comprise of deep sedimentary formation aquifer made up of alluvium / sandstone, existing up to a depth of 180 and 472 m bgl, in and around Neyveli Township, Kurinjipadi, Kaikanam & Karunguzhi (central part of the basin), north & west of Thyagavalli (north eastern part of the basin). The aquifer of this region may be productive zones where it is saturated with potable groundwater.

2.9 Soil and its characteristics

"Soil is a natural body developed by natural forces acting on natural materials. It is usually differentiated into horizons of mineral and organic constituents of variable depth which differ from the parent material in morphology, physical properties, constitutions, Chemical properties, composition and biological characteristics."

The three important characteristics of soil should be

- Natural formation
- Differentiation into horizon

- Morphological, chemical and biological differences between parent material and soil horizons.

The soil is a natural medium for plant growth and soil supplies nutrients for growing plant and in turn plant manufacture feed for animals, food and fiber for man. Some soils are naturally productive and support luxuriant crops of great value with very little human effort. Majority of soils must be fertilized, irrigated, drained or limed to make them desirably productive.

The predominant soil types found in the Paravanar River are:

- Alfisols
- Entisols
- Inceptisols
- Vertisols

Soil is one of the most important non-renewable basic natural resources on the earth's surface. The emergence of all civilizations and their continued prosperity have depended on the understanding and rational use of this basic resource by mankind. Great attention has been paid throughout the world to the study of soils, their geographic distribution and extent, behavior, potentials and problems and suitability for various uses.

The soils of the Paravanar River Basin have been shown in **Plate: PAR 22**. The predominant soil types found in Paravanar river basin are Alfisols, Entisols, Inceptisols and Vertisols. Due to different stage of weathering of parent material, the above soil types are met within combination. The types of soils along with their sub groups are described below :

Alfisols:

The central concept of Alfisols is that of a soil that has an ochric epipedon, an argillic subsurface horizon moderate to high base saturation and in which water is held at tension less than 15 bars at least 3 months each year. The soils have marks of processes that translocate silicate clays without excessive depletion of bases and without dominance of the processes that lead to the formation of mollic epipedon. Some of the red and lateritic soils have been classified as Alfisols. The following two sub groups are identified in this soil type :

1. Kandic Paleustalfs:

The soils are very deep, well-drained, fine kaolinitic clayey soils on gently sloping lands, moderately and severely drained.

2. Kanhaplic Haplustalfs:

The soils are moderately deep well-drained, fine, loamy mixed soils on nearly level lands with slight erosion.

Entisols:

These soils show little or no evidence of development of Pedogenic horizons. Absence of marks of any major pedogenic process is the differentiating features of this group of soils. The reasons may be lack of time for horizons to form or inherit parent material or both. Often, erosion at a rate much faster than soil development prevents development of any horizon diagnostic of the orders other than Entisols. The variability of clay and organic matter along the depth of the pedon is due to layering of alluvia. Resistant nature of the parent material like quartzite, bedrock etc. prolongs the period of undistinguished horizonation. Two sub groups are identified under Entisol in Paravanar river basin as described below:

1. Typic Ustipsamments

The soils are very deep, excessively drained, sandy soils on very gently sloping plains.

2. Aquic Ustipsamments

The soils are very deep, sandy soils on nearly level lands, moderately eroded, and imperfectly drained.

Inceptisols:

The soils of humid regions that have altered horizons that have lost bases or iron and aluminium, but retain weatherable minerals. They do not have an alluvial horizon enriched either with silicate clay that contains aluminium or with an amorphous mixture of aluminium and organic carbon. The alluvial horizons in Inceptisols have clay enrichment not sufficient to qualify for argillic horizon. Horizons of accumulation of translocated silica, iron or bases are permitted. Those, not permitted are named diagnostic horizons of accumulation that contain translocated aluminum, either in the layer lattice or amorphous clays or diagnostic horizons that contain accumulation of gypsum or more soluble salts. Virtually all of the pedogenic processes are active to some extent, but none predominates. The Inceptisols have features that indicate pedogenic immaturity. In Paravanar river basin three sub groups are identified in this soil type as detailed below:

1. Fluventic Ustropepts:

   The soils are very deep, moderately well drained, calcareous, clayey soils of nearly level lands, moderately eroded.

2. Oxic Ustropepts:

   The soils are very deep, well drained, fine loamy soils on gently sloping lands, moderately eroded.

3. Typic Ustropepts:

   The soils are deep, fine loamy, well-drained.

Vertisols:

The soils are clayey that have deep wide cracks at sometime of the year and have high bulk density between the cracks. The unique properties of this type are high content of clay, pronounced change in volume with change in moisture, deep wide cracks at some season, evidences of soil movement in the form of slicken sides, gilgai microrelief and wedge-shaped structural aggregates that are tilted at an angle from the horizontal. During summer, cracks develop and when it rains, water runs into cracks and some of the surface soils falls or washes into the cracks before the whole soil become moist and the cracks close. Because of these movements, these soils have been said to swallow or churn themselves and this is the reason of mixing of soils layers in the solum. Under this group of soil only one sub group is identified in Paravanar river basin. i.e. Typic Chromusterts.

Typic Chromusterts:

These have a chroma, moist of 1.5 or more and colour value, moist less than 3.5 and a value dry less than 5.50 throughout the 30 cm of the pedon. i.e. surface soils are grey in colour, calcareous imperfectly drained. The cracks remain open more than 150 cumulative days in most years.

SOIL TEXTURE AND AREA COVERED IN PARAVANAR RIVER BASIN.
(Plate: PAR 23 - map of Paravanar basin showing Soil texture)

Texture	Area in Sq.Km	Area in %
Clay	229.606	26.33
Clay loam	90.443	10.37
Loamy sand	51.446	5.90
Sand	0.642	0.07
Sandy clay	20.397	2.34
Sandy clay loam	263.344	30.20
Sandy loam	7.540	0.86
Silty loam	18.001	2.06
No soil	190.923	21.85
Total	**872.341**	**100.00**

SOIL ORDER AND AREA COVERED IN PARAVANAR BASIN.

Soil Order	Area in Sq.Km	Area in %
Alfisols	70.078	8.04
Entisols	13.065	1.50
Inceptisol	492.774	56.51
Vertisols	105.501	12.10
No soil cover	190.923	21.85
Total	**872.341**	**100.00**

Soil Resource mapping of Tamil Nadu was initiated in 1986 as a collaborative project between the National Bureau of Soil Survey and Land use planning, Regional Centre, Bangalore and Soil Survey and Land use Organization, Department of Agriculture, Tamil Nadu to prepare a comprehensive, reliable and uniform database on soil resources of Tamil Nadu. The list of mapping unit falling in the Paravanar River Basin is given in **Table 2.8**. and the respective map is shown in **Plate: PAR 23A**.

Based on the accompanying NBSS Report on land use (Soil Resources of Tamil Nadu for Land use Planning, Executive Summary Report, NBSS Publication No.46(b), 1997) and the corresponding soil classification, the irrigable soils of the Paravanar River Basin were identified. The main properties of irrigable soils are summarized in **Table 2.9** and their interpretative classifications for land capability, crop production, and irrigability, sustainability for Rice, Sugarcane, Groundnut and Cotton are given in **Table 2.10**.

Based on the soil properties and their classification, the basin soils were grouped for irrigation planning purposes, into five major groups denoted as Type I, II, III, IV and Type V. The intention is to determine uniform cropping patterns, which would be associated to the soil types mainly for the assessment of future scenarios. The soil types are described as follows.

Type-I Soils:

They are mostly with medium texture, well and moderately well drained, mostly moderately deep to deep, mostly with 1-3% slope and with none to various degrees of erosion problems. These soils are classified for irrigation mainly as 3s, for land capability as II to IV, and for crop suitability: rice – NR, sugarcane NR, groundnut – S2 and S3 and cotton – S1 to S3. The soils are irrigable and suitable for crops like groundnuts, cotton, pulses, millets, maize, sorghum, vegetables and tree crops.

Type-II Soils:

They are of fine texture, imperfectly drained, moderately deep to deep, with 1-3% slope, with none to moderate soil erosion problems. These soils are classified for irrigation as 2d and 3d, for land capability as II and for crop suitability: rice – NR, sugarcane – NR, groundnut – S3 and cotton – mainly S1 and some S3. The soils are irrigable and suitable for field crops such as cotton, sorghum and some fodder crops which are relatively tolerant to imperfect drainage. In spite of the above mentioned NR classification for sugarcane, it can be concluded that in the future with improved irrigation methods and systems, Type-II soils with lower slopes, could also be cultivated by sugarcane.

Type-III Soils:

They are mostly of fine texture, mostly imperfectly drained, moderately deep to deep, mostly with 1-3% slope, with none to moderate erosion problems. These soils are classified for irrigation mainly as 2d and 2s, for land capability as II and for crop suitability: rice – mainly S2, sugarcane – mainly S2, groundnut – mainly S3 and cotton – mainly S2. Type-III soils are irrigable and suitable for rice and sugarcane and also to relatively tolerant to imperfect drainage other crops such as cotton, sorghum and some fodder crops.

Type IV Soils

They are similar to type III soils, however due to salinity problems the corrective measures should be taken. The pH (negative logarithm of hydrogen ion concentration) is more than 8.5 (>8.5) hence, the soil is saline in nature.

Application of Gypsum (Calcium Sulphate) into a field is the best method to correct the high pH level to normal pH level (pH7).

Sl. No.	pH Level	Application of Gypsum (Recommended dose /acre)
1	8.5-8.9	500 kg
2	9.0	1000 kg
3	9.1	1400 kg
4	9.2	1800 kg
5	9.3	2200 kg
6	9.4	2600 kg
7	9.5	3000 kg (very bad condition)
8	9.6	3400 kg
9	9.7	3800 kg
10	9.8	4200 kg
11	9.9	4600 kg
12	>10	5000 kg

Type V Soils:

These soils include non-irrigable soils, such as rock outcrops, dunes, flooded areas, steep slopes, etc.

Based on this study and the corresponding soil map, the irrigable soils of Paravanar River Basin were identified. The soils were classified for crop suitability purposes into three types.

Type I : Irrigable, suitable for cotton, groundnut

Type II : Irrigable crop soils with limitations

Type III : Non-irrigable soils, not suitable for cultivation

The soils main properties for these classifications are summarized in Table 2.2. and the interpretative classifications for land capability for crop production, irrigability and suitability for rice, sugarcane, groundnut and cotton are given in Table 2.3. Based on the soil properties and their classification the Basin irrigable soils could be grouped for planning purposes into major soil-crop suitability groups denoted Type – I, Type – 2, and Type-3.

Type I : Soils are moderately good cultivable lands having erosion and soil problems, well drained, medium depth, very gentle 1-3 % slope, moderately suitable for crops like cotton and groundnut.

Type II : Good cultivable lands having drainage problems, associated with moderate limitations of calcareousness, salinity, sodicity and soil texture, moderately well drained, medium depth, nearly flat 0-1% slope, moderately suitable for crops like paddy, groundnut, cotton and sugarcane with limitations.

Type III : Fairly cultivable lands having erosion and soil (Heavy root crop like Vetiver is to keep the soil) problems, imperfectly drained to excessively drained, medium depths, nearly level to gently slope 0-3%, not suitable for cultivation of crops like paddy, sugarcane, cotton and groundnut.

The different mapping unit numbers related with different type of soils are given in the following Table:

Sl.No.	**Type of Soil**	**Mapping Unit Numbers**
1.	Type – I	158 & 251
2.	Type – II	241
3.	Type – III	193 & 199

Table 2.8 Soils – Paravanar Basin

Mapping Unit (*)	Description	Classification
158	Very deep, well drained, clayey soils on gently sloping lands, moderately and severely eroded; *associated with;* moderately deep, well drained, loamy soils on nearly level lands with slight erosion.	Fine, Kaolinitic, Kandic Paleustalfs. Fine-loamy, mixed, Kanhaplic Haplustalfs
193	Very deep, somewhat excessively drained, sandy soils on very gently sloping plains, slightly eroded.	Mixed, Typic Ustipsamments
199	Very deep, imperfectly drained, sandy soils on nearly level lands, moderately eroded; *associated with;* very deep, excessively drained, sandy soils.	Mixed, Aquic Ustipsamments Mixed , Typic Ustipsamments
241	Very deep, moderately well drained, calcareous, clayey soils of nearly level lands, moderately eroded; *associated with;* very deep, imperfectly drained, calcareous, cracking clay soils.	Fine montmorillonitic, Fluventic Ustropepts Fine montmorillonitic, Typic Chromusterts
251	Very deep, well drained, loamy soils on gently sloping lands, moderately eroded; *associated with;* deep, well drained, loamy soils.	Fine-loamy, mixed, Oxic Ustropepts Fine, loamy, mixed, Typic Ustropepts

(*) - Soil association according to NBSS Publication No.46/b, 1997

Table 2.9 Soil Major Properties

Type	Unit (*)	Drainage	Ground Water Depth	Surface Texture	Available water (mm/m) (**)	Soil Depth (cm)	Slope
I	158	WD	4	ls	100-150	>150	b
	251	WD	4	sl	50-150	>150	b
II	241	MWD	3	c	150-200	>150	a

III	193	SweD	2	ls	<50	>150	b
	199	ID	1	ls	<50	>150	a

(*) - Soil association according to NBSS Publication No.46/b, 1997

(**)- Per 1 m of soil depth or the entire column if the soil is shallower.

Drainage:

WD - Well Drained
SweD - Somewhat excessively Drained
ID - Imperfectly Drained
MWD - Moderately Well Drained

Ground Water Depth (m)

1 - Shallow (<1)
2 - Moderately Shallow (1-2)
3 - Moderately Deep (2-5)
4 - Deep (>5)

Surface Texture:

ls - Loamy sand
c - Clay
sl - Sandy loam

Slope:

a - Level to nearly level (0-1%)
b - Very gently sloping (1-3%)

Table 2.10 Land Classification

Type	Unit (*)	Capability	Irrigability	Rice	Groundnut	Cotton	Sugarcane
I	158	llles-llls	3s	NR	S2ng	S2n	NR
	251	llle	3s	NR	S2ng	S2n-N2	NR
II	241	llw	2d	S2xt	S2xt-S3xt	S3c	S2x-S2xd
III	193	lVes-lVe	4s	N2	N2	N2	N2
	199	lVes-lVe	6s-6t	N2	N2	N2	N2

(*) - Soil association according to NBSS Publication No.46/b, 1997

Capability:

llles- llls	-	Moderately good cultivable lands having erosion and soil problems, associated with moderately good cultivable lands having soil problems.
lVes- lVe	-	Fairly good cultivable lands having erosion and soil problems, associated with fairly good lands having erosion problems
llw	-	Good cultivable lands having drainage problems.
llle	-	Moderately good cultivable lands having erosion problems.

Irrigability:

2d	-	Lands that have moderate limitations of drainage for sustained use under irrigation.
3s	-	Lands that have moderate limitations of soil for sustained use under irrigation.
4s	-	Lands that have very severe limitations of soil for sustained use under irrigation.
6s-6t	-	Lands not suitable for sustained use under irrigation due to soil and topographic limitations.

Rice:

NR	-	Lands not relevant for rice
N2	-	Lands permanently not suitable
S2xt	-	Moderately suitable lands having moderate limitations of Calcareousness / Salinity / Sodicity and soil texture.

Groundnut:

S2ng	-	Moderately suitable lands having moderate limitation of fertility and gravelliness
N2	-	Lands permanently not suitable
S2xt- S3xt	-	Moderately suitable lands having moderate limitations of drainage, associated with marginally suitable lands having severe limitation of drainage.

Cotton:

S2n	-	Moderately suitable lands having moderate limitation of fertility
N2	-	Lands permanently not suitable
S3c	-	Marginally suitable lands having severe limitation of climate
2n-N2		Moderately suitable lands having moderate limitation of fertility associated with permanently not suitable lands

Sugarcane:

NR	-	Lands not relevant for sugarcane
N2	-	Lands permanently not suitable
S2x-	-	Moderately suitable lands having moderate limitations of
S2xd		Calcareousness / Salinity / Sodicity and soil texture.

2.10 Social and Demographic Characteristics

Population trend and population dynamics are important indicators of the present and future water requirement in the Basin. Also, the social characteristics of the population such as literacy level, level of housing, electrification, in house facilities, urbanization trend, are having indirect bearing on water planning. The nature of employment viz., agricultural , industrial etc., in the Basin also would reflect on the water requirement.

The Paravanar River Basin falls in Cuddalore district. Hence the above said characteristics of population in Cuddalore district play a role in predicting the social and demographic characteristics in Paravanar River Basin. An analysis of all these parameters in Paravanar River Basin is described hereunder.

2.10.1 Population in Paravanar River Basin

23.5% of total area of Cuddalore District (872.341 sq.km out of 3706 sq.km) covers the Paravanar River Basin and population of Cuddalore districts in Paravanar River Basin as per census 2011 is given below in **Table 2.11**. The population of Paravanar River Basin constituted 30% percent of total Cuddalore District population.

Table 2.11 Population in Paravanar River Basin (in Million)

S. No	Name of the District	Population as per census 2011			Population as projected to 2016		
		Rural	Urban	Total	Rural	Urban	Total
1.	Cuddalore	0.461	0.324	0.785	0.491	0.358	0.849
	Total	**0.461**	**0.324**	**0.785**	**0.491**	**0.358**	**0.849**

Source: *Census 2011*

There are 2 sub Basins in Paravanar River Basin. The villages and towns falling under each sub basin are sorted out using GIS and its corresponding population is taken up from Census 2011. The population details of each sub basin are given in **Appendix 2.2.** The Sub Basin wise Population of Paravanar River Basin is given in the **Table 2.12**. The population of Paravanar River Basin is projected for the years 2016, 2020, 2023, 2030 and 2040 which is detailed in Chapter 7.

Table 2.12 Sub Basin wise Population in Paravanar River Basin (in Million)

S. No	Name of Sub basin	As per census 2011			As projected to 2016		
		Rural	Urban	Total	Rural	Urban	Total
1.	Paravanar	0.188	0.120	0.308	0.200	0.133	0.333
2.	Uppanar	0.273	0.204	0.477	0.291	0.225	0.516
	Total	**0.461**	**0.324**	**0.785**	**0.491**	**0.358**	**0.849**

Source: Census 2011

2.10.2 Population Growth Rate

The decadal growth rate of Cuddalore District from 2001 to 2011 is 14.06%. The percentage decadal variation of rural population and Urban population of Cuddalore district is 12.23% (1.22% per year) and 17% (1.7% per year) respectively.

. The population of Paravanar River Basin assessed from the Census 2011 is projected for the present year 2016 sub basin wise using the formula,

$$\mathbf{P_t = P_o\,(1+X)^t}$$

Where Pt = Population after 't' years

Po = Population in the beginning years

X = Annual growth rate

t = Period in years.

The average Growth Rate of Rural and Urban Population in Paravanar River Basin is taken as 1.3% and 2% respectively. The projected population in Paravanar River Basin for 2016 is given below in **Table 2.13:**

Table 2.13 Projected Population in Paravanar River Basin for 2016 (in Million)

S. No	Name of Sub basin	Area in Sq.km	Total Rural Population		Total Urban Population		Total	
			2011	**2016**	**2011**	**2016**	**2011**	**2016**
1	Paravanar	435.016	0.188	0.200	0.120	0.133	0.308	0.333
2	Uppanar	437.325	0.273	0.291	0.204	0.225	0.477	0.516
	Total	**872.341**	**0.461**	**0.491**	**0.324**	**0.358**	**0.785**	**0.849**

Source: Census 2011

2.10.3 Population Density

Population density is a measurement of population per unit area. The Sub Basin wise population density of Paravanar River Basin is given in Table **2.14.** The population density is higher in Uppanar sub Basin (1181 persons per sq.km) and lower in Paravanar sub Basin (765 Persons per sq.km).

Table 2.14 Sub Basin wise population density in the Paravanar River Basin

Sl. No	Name of the sub Basin	Area (Sq.km)	Total population 2016	Density (Persons/Sq.km)
1.	Paravanar	435.016	332983	765
2.	Uppanar	437.325	516377	1181
Total		**872.341**	**849361**	
Average population Density				**974**

2.10.4 Population by Sex

The sex wise distribution of population in Paravanar River Basin in 2016 is given in **Table 2.15**:

Table 2.15 District wise Population by Sex in Paravanar River Basin (in Million)

Sl. No	Name of the District	Area of the district in the Basin (Sq.km)	Total Population 2016	Population of Male	% Male	Population of Female	% Female
1	Cuddalore	872.341	0.849	0.427	50.29	0.422	49.71

2.10.5 Sex Ratio

Sex ratio is the demographic concept that measures the proportion of males to females in a given population. Changes in gender composition largely reflect the underlying social, economic and cultural patterns of the society in different ways.

Sex Ratio is expressed as number of females for every 1000 males. The Uppanar Sub Basin has a high sex ratio of 997 females to every 1000 males and Paravanar Sub Basin has a low sex ratio of 975 females to every 1000 males The sex wise distribution of population in all the sub basins of Paravanar River Basin is given below in **Table 2.16:**

Table 2.16 Sexwise population distribution in the Paravanar River Basin

Sl. No	Name of the Sub Basin	Population			Male %	Female %	Total %	Sex Ratio
		Male	Female	Total				
1	Paravanar	0.169	0.164	0.333	50.64	49.36	100	975 females for 1000 males
2	Uppanar	0.259	0.258	0.516	50.07	49.93	100	997 females for 1000 males
	Total	**0.427**	**0.422**	**0.849**	**50.29**	**49.71**	**100**	988 females for 1000 males

2.10.6 Literacy Level

The literacy level of the population is also a vital social indicator of the standard of living and social status. The literacy rate of the Paravanar River Basin is worked out sub basin wise and is given in **Table 2.17.** The overall literacy rate of Paravanar River Basin is found to be 66 %.

Table 2.17 Details of Literacy level in Paravanar River Basin

(Population in Million)

Sl. No	Name of the Sub Basin	Literacy Population			Total Population			% Literacy of Population		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
1	Paravanar	0.125	0.100	0.225	0.169	0.164	0.333	74.06	60.98	67.62
2	Uppanar	0.183	0.153	0.336	0.259	0.258	0.516	70.69	59.42	65.19
	Total	**0.308**	**0.253**	**0.562**	**0.427**	**0.422**	**0.849**	**72.19**	**60.03**	**66.14**

Source: Census 2011

2.10.7 Population Dynamics

Population growth would be reflected on analyzing crucial parameters such as birth rate, death rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR) and life expectancy trends of the population. The details of registered births and deaths in Cuddalore District for the period 2012 is given in **Table 2.18,**

Table 2.18

Details of Births and Deaths Registered in Districts covered in Cuddalore District

Sl. No.	Name of the District	Mid – Year Estimated Population	Births	Deaths	Infant Deaths	Still Births	Maternal Deaths
1.	Cuddalore	2649072	40287	13454	224	263	-

2.10.8 Family Welfare & Impact of Family Planning

Tamil Nadu is pioneer in the implementation of Family Welfare Programme. It is being implemented in Tamil Nadu since 1956 purely on voluntary basis. It is viewed and implemented as a people's programme involving the active co-operation of many sectors and participation of the community at large. The aim of the programme at the early stage was to reduce births by fixing contraceptive targets only. But, now it has been changed to bring down fertility through improving maternal and child health care. The "Target oriented approach" has been shifted to "Community Needs Assessment Approach" in which the needs of the community have to be assessed based on the requirements of the people in the implementation of family welfare and maternity child health programmes.

The overall emphasis and priority given by the Government of India and Government of Tamil Nadu for family welfare and family planning has led to the establishment of institutions to promote family planning knowledge, at rural and urban areas. The Deputy Director of Medical and Rural Health Services and Family Welfare is the implementing authority of family welfare schemes. The adoption of family planning practices reveal that sterilization has been the most favourable method, followed by the use of IUD (Intra – Uterine Device).

Family welfare Programme details for the districts covered by the Paravanar Basin for the period of 2013-14 is given in **Table 2.19**

Table 2.19

Details of Family Welfare Programme in Cudddalore District during the year 2013-14

Name of the District	Sterilization	IUD	Oral Pill Users	Users of Conventional Contraceptives
Cuddalore	10693	18529	229	5451

Source: Director of family welfare, Chennai – 6

2.10.9 Level of Housing

The level of housing is an indicator of water requirement and of urbanization trend. Households that have electricity, water and toilet available within the premises would be using more water in comparison with those that do not have these facilities within the premises. The details of households in Paravanar River Basin is given in **Table 2.20.**

Table No 2.20 Number of Households in Paravanar River Basin (2011)

Sl.No	Name of the Sub Basin	Number of House Holds
1	Paravanar	76040
2	Uppanar	116920
	Total	**112960**

Source: Census of India 2011

2.10.10 Industrial employment

The resources available in the basin also have a direct link with the water planning for the basin .The various resources available in the districts falling in the Paravanar River Basin are discussed hereunder.

Neyveli Lignite Corporation, a Public Sector enterprises incepted in the year 1956 has a chequered history. A pioneer among the public sector undertakings with complex industries under its fold which provides employment to around 13000 people. The other major industries available are Mineral base, wood/wood based, paper and paper product industry etc. Cuddalore district has got strong base on handicrafts industries. Traditional handicrafts units are spread over across the district. Around 2782 handicrafts units such as jewellery, wood works, ceramic , leather , pottery, garment making etc are functioning in the Cuddalore district providing employment to about 5000 persons.

There are 108 small scale industries, 7 medium scale industries and 40 large scale industries in Paravanar River Basin. The water requirement for the industrial purpose for large & medium and small scale industries are estimated as 73.009 Mcum and 0.186 Mcum respectively. The projected future water demand for large & medium scale industries for the targeted year 2020, 2023, 2030 & 2040 are estimated as 96.372 Mcum, 119.501 Mcum, 148.181 Mcum & 183.745 Mcum respectively. The projected future water demand for small scale industries for the targeted year 2020, 2023,2030 & 2040 are estimated as 0.246 Mcum, 0.304 Mcum,0.475 Mcum & 0.855 Mcum respectively,

The District Industries Centre and the Single Window Committee headed by the Collector help industrialists in getting the needed clearances from various Government Organizations. The committee co-operates all district level officers necessary to handle the requests seeking by the entrepreneurs for minor and medium industries. Other institutions like SIPCOT, TIDCO, TIIC and Directorate of Industries and Commerce provide valuable support for major industries.

The District Industries Centre was started on the objective to find out the Micro Small Medium Enterprises (MSME) in the District. Also it helps those Enterprises to tackle their hurdles faced by the MSME's under one roof. The District Industries Centre functioning at the district level, provides all the services and support facilities to the entrepreneurs for setting up Small and medium Industries.

The District Industrial Centre is offering assistances in form of various subsidies to the Entrepreneurs. Through motivation campaigns, Entrepreneur Development programme for Women, Small scale industries registration, concession & subsides subsidy for asset creation for intellectual property etc, the DICs motivate the entrepreneurs.

In Paravanar River Basin, the District Industrial Centers are functioning at Cuddalore District. With the minimum of 25 members industrial co-operative Societies are formed as to provide employment opportunities to the members. The DIC is providing managerial skill and marketing of goods produced by the members. The Government has notified the following Backward blocks for State Capital Subsidy at 15 % in Cuddalore District,

Table No 2.21 District wise list of Backward Blocks

Sl. No.	Name of District	Backward Blocks in the District	Backward Blocks in the Paravanar River Basin
1	Cuddalore	Annagramam Kammapuram Kattumannarkoil Kumaratchi Kurinjipadi Mangalur Mel-Bhuvanagiri Nallur Parangipettai	Kurinjipadi Kammapuram Bhuvanagiri Parangipettai

Source: Directorate of Industries & Commerce

Industrial Policy has been pursued by the Tamil Nadu Government with a main objective to achieve massive increase in employment by promoting Small Industries and Rural Industries. In accordance with this policy, promotion of large and medium scale industries as well as small-scale industries have been aimed at the districts of the Tamil Nadu, in collaboration with Tamil Nadu Industrial Investment Corporation (TIIC), Tamil Nadu Industrial Development Corporation (TIDCO) and Tamil Nadu Corporation for Industrial Infrastructure Development (TACID).

For this purpose, a thrust has been given to establish, promote and develop the rural industries and the Government also in active move in promoting Self-Employment opportunity in Urban and Rural areas by extending financial assistance through banking sector for the establishment and development of small industries.

CHAPTER 3

HYDRO METEOROLOGICAL CHARACTERISTICS

CHAPTER 3

HYDROMETEOROLOGICAL CHARACTERISTICS

3.1 General

Various climatic variables such as rainfall, temperature, wind direction and evapotranspiration together with physiographic factors such as drainage pattern, slope and aspect factors play significant role in the Hydrometeorology of a river basin. Hydrometeorology, like many other branches of meteorology, developed in response to pressing demands for information related to rainfall statistics for use in the safe and economical design of water resource projects.

The study made on the hydro-meteorological characteristics of the Paravanar river basin includes analysis of rainfall, temperature, humidity, wind speed, sunshine and evaporation. The study of the rainfall pattern, its distribution in time and space and its variability and probability of occurrence is highly useful for water resources evaluation and planning.

Paravanar River Basin has an area of 872.341 Sq.Km. and the entire basin lies in Cuddalore district only. 13 Rain gauge stations positioned in and around the basin are considered for analysis. These Rain gauge stations are maintained by Public Works Department & Revenue Department. Climate Data for analysis are taken from the station adjacent to Paravanar basin, which is maintained by PWD, since this Basin does not have climate station in it.

A detailed study has been made on the hydro meteorological parameters for Paravanar River Basin and the results are furnished below.

3.2 Rainfall

3.2.1 Rain gauge Stations

One rain gauge station lying inside the Paravanar River Basin, and the twelve rain gauge stations situated in the adjoining basins are considered. In that, considering the distribution of rain gauge station and the availability of data for the period of 45 years, only seven stations are considered for detailed analysis. The details of influencing and non-influencing rain gauge stations in Paravanar River basin are given in the **Table 3.1 (a) and (b)**. For the purpose of rainfall analysis, month is taken as a time step.

3.2.2 Monsoon and Non-monsoon periods

Paravanar river basin lies within the tropical monsoon zone. Based on the hydro-meteorological features of the basin, year is divided into two periods (i.e) 1) Monsoon period spanning from June to December and 2) Non-monsoon period spanning from January to May. The monsoon period is further sub-divided into Southwest monsoon period spanning from June to September (4 months) and Northeast monsoon period spanning from October to December (3 months). Similarly, the non-monsoon period is further sub-divided into winter period spanning from January & February (2 months) and summer period spanning from March to May (3 months). The monsoon period is hydrological significant for water resources analysis.

The monthly and season-wise rainfall for 7 rain gauge stations are given in the **Appendix 3.1**. The Thiessen Polygon Map is given in **Plate: PAR 24.** Probable Mean Areal rainfall analysis for 25%, 50%, 75%, 90% and the average for southwest, northeast, winter, summer and annual rainfall for all the sub basins have been analysed and tabulated in **Table 3.2 to 3.3**. The season wise Isohyets maps (**Plate : PAR 25 to 29)** are presented.

Table 3.1 (a)

Influencing Raingauge Stations of Paravanar River Basin

S. No	Station Code	Block	Taluk	District	Source	Lat	Long	Data Availability Period
1	Chidambaram	Mel Bhuvanagiri	Chidambaram	Cuddalore	REV	11°24'00"	79°41'17"	1971-2015
2	Cuddalore	Cuddalore	Cuddalore	Cuddalore	REV	11°45'23"	79°45'57"	1971-2015
3	Kothuvacheri	Kurinjipadi	Cuddalore	Cuddalore	PWD	11°31'13"	79°38'07"	1971-2015
4	Panruti	Panruti	Panruti	Cuddalore	REV	11°45'51"	79°33'01"	1971-2015
5	Parangipettai	Parangipettai	Cuddalore	Cuddalore	Uni.Campus	11°29'31"	79°45'56"	1978-2015
6	Sethiathope Anicut	Mel Bhuvanagiri	Virudhachalam	Cuddalore	PWD	11°26'07"	79°32'22"	1971-2015
7	Virudhachalam - Taluk office	Virudhachalam	Cuddalore	Cuddalore	REV	11°31'04"	79°20'05"	1971-2015

Table 3.1 (b) Non-Influencing Raingauge Stations of Paravanar River Basin

S. No	Name of Raingauge Station	Block	Taluk	District	Source	Latitutde	Longitude	Data availability Period
1	Annamalai University	Mel Bhuvanagiri	Chidambaram	Cuddalore	Uni.Campus	11°23'11"	79°43'20"	1976-2014
2	Srimushnam	kammapuram	Virudhachalam	Cuddalore	PWD	11°24'05"	79°24'00"	1976-2014
3	Vanamadevi.	Cuddalore	Kattumannarkoil	Cuddalore	Agri	11°44'31"	79°38'35"	1976-2013
4	Kuppanatham	Virudhachalam	Virudhachalam	Cuddalore	REV	11°31'42"	79°21'35"	1977-2015
5	Palur	Cuddalore	Panruti	Cuddalore	PWD	11°44'49"	79°38'10"	1999-2014
6	Bhuvanagiri	Mel Bhuvanagiri	Chidambaram	Cuddalore	PWD	11°26'30"	79°38'41"	1990-2015

Table 3.2 - Paravanar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Paravanar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	436.1	350.4	292.0	230.3	361.9
NE	866.7	699.1	500.1	313.3	703.0
Winter	21.5	6.3	0.8	0.0	35.5
Summer	110.6	53.6	29.1	16.9	81.6
Annual	1376.0	1192.3	969.6	745.5	1181.9

Table 3.3 - Uppanar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Uppanar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	395.82	314.80	234.16	174.39	317.41
NE	980.04	796.70	561.10	390.32	781.60
Winter	31.38	8.96	1.14	0.00	41.07
Summer	104.60	7.00	19.97	8.31	73.40
Annual	1396.58	1205.00	963.58	758.49	1213.48

3.2.3 Dependable Rainfall

The 25%, 50%, 75% and 90% dependable rainfall for Paravanar River Basin are tabulated below in **Table 3.4 :**

Table 3.4 - Dependable Rainfall in mm – Paravanar Basin

Name of the basin	Paravanar Basin			
Season	**Dependability**			
	25%	**50%**	**75%**	**90%**
SW	415.9	332.6	263.1	202.4
NE	923.3	747.9	530.6	351.8
Annual	1386.3	1198.6	966.6	752.0

3.2.4 Frequency Analysis

The range of annual precipitation and their frequency have been analysed and furnished in **Table 3.5**. From the table it is noticed that rainfall exceeding 1000mm occurred maximum of 90% of the study period (1971-2016) in Chidambaram and minimum of 60% of study period in Kothuvacheri and Virudhachalam. Rainfall in the range of 900-1000mm occurred nearly 15% of the study period in Kothuvacheri, Virudhachalam - Taluk office. Rainfall in the range of 800-900mm occurred in nearly 10% of the study period in Sethiathope Anicut, Virudhachalam - Taluk office. 600 to 800mm rainfall occurred nearly 15% of the study period in Kothuvacheri. 400 to 600mm rainfall occurred nearly 2% of the study period in Kothuvacheri, Panruti, Parangipettai. Less than 200 mm rainfall is not occurred in any of the stations considered.

Table 3.5 - Annual Rainfall Frequency Distribution

Sl. No	Name of Stations	Study Period in Yrs	Exceeded 1000 mm	900 to 1000 mm	800 to 900 mm	600 to 800 mm	400 to 600 mm	200 to 400 mm	Less than 200 mm
1	Chidambaram	45	41	1	2	1	0	0	0
2	Cuddalore	45	37	2	3	3	0	0	0
3	Kothuvacheri	45	27	7	2	7	1	1	0
4	Panruti	45	28	3	4	6	1	3	0
5	Parangipettai	45	37	1	2	4	1	0	0
6	Sethiathope Anicut	45	35	2	5	3	0	0	0
7	Virudhachalam - Taluk office	45	27	7	5	6	0	0	0

3.2.5 Moving Average

The 5 years moving average graph for the annual rainfall has been drawn for the two sub basins. A linear fit has also been shown along with moving average curve. The details are given in **Appendix 3.2**.

The Paravanar, Uppanar sub basins are showing the slightly increasing trend line.

3.2.6 Maximum, minimum and average rainfall

The maximum, minimum and average annual rainfall for the two sub basins have been analysed and tabulated in **(Appendix-3.1)**

- Maximum Rainfall of this basin is 1213.48 mm [in Uppanar Sub basin]
- Minimum Rainfall of this basin is 1181.91 mm [in Paravanar Sub basin]
- Average annual rainfall of the Paravanar River Basin is 1197.70 mm

And each sub basin rainfall details are tabulated below **in Table 3.6**

Table 3.6 - Rainfall Details of the Paravanar Basin

Sl. No.	Name of the Sub-basin	No. of influencing Raingauge Stations	Rainfall range in mm(1971 - 2015)					Annual Average Rainfall in mm
			Annual	NE	SW	Winter	Summer	
1	Paravanar	4	1713.00 To 628.30	1278.0 To 199.60	582.12 To 212.80	309.70 To 0.0	408.40 To 0.00	1181.90
2	Uppanar	6	1999.00 To 464.20	1505 To 227.60	670.70 To 141.60	359.40 To 0.00	326.76 To 0.00	1213.50

3.2.7 Statistical Analysis

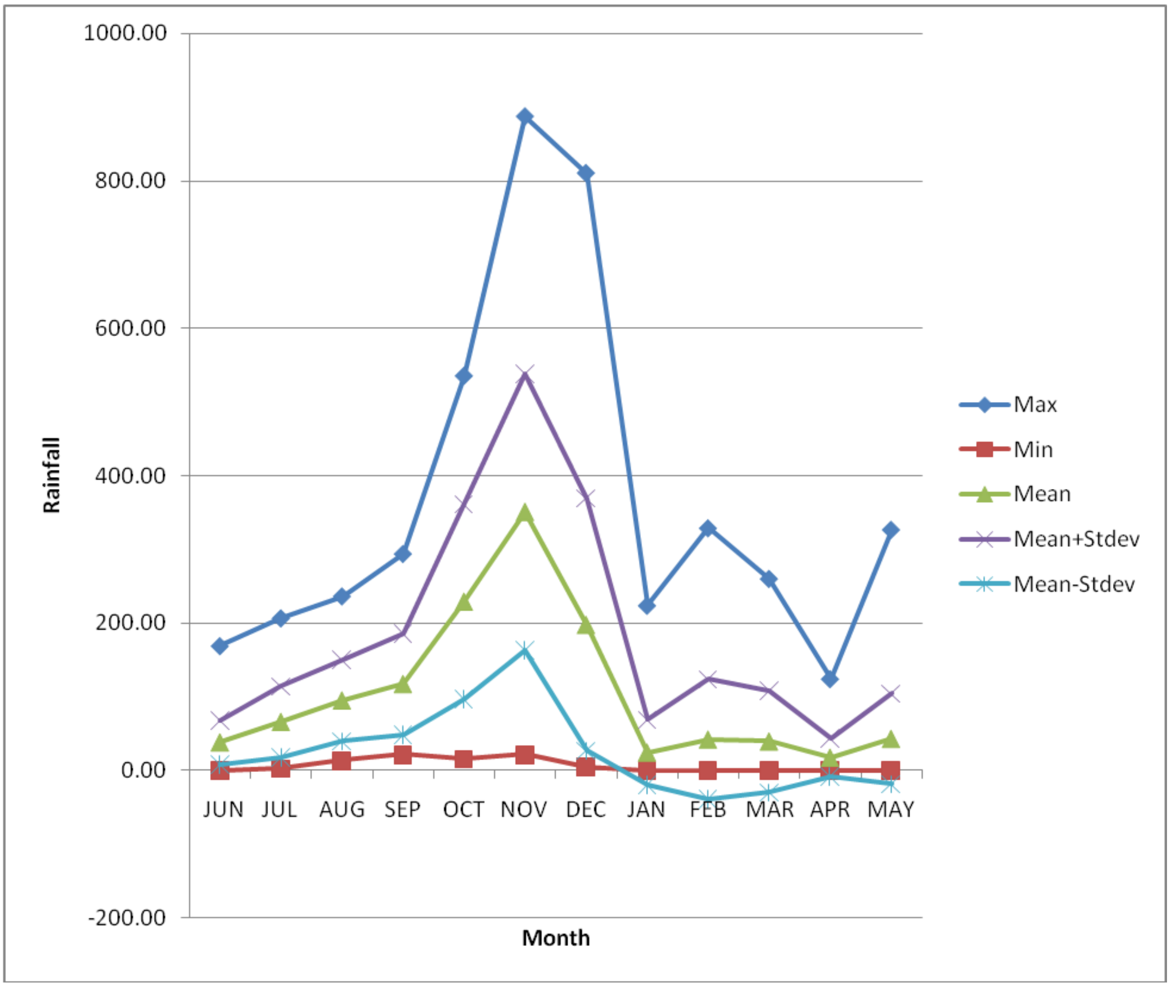
The statistical analysis for the rainfall data has been done for all the sub basins for the various seasons namely southwest, northeast, winter, summer and annual. The statistical results namely, Standard Deviation, Coefficient of variation, Skewness and Kurtosis have been analysed and tabulated in **Appendix 3.3.**

The average value of the Paravanar River Basin statistical Parameters are:

- Standard Deviation - 305.65
- Coefficient of variation - 0.26
- Skewness - 0.02
- Kurtosis - -0.33

The Statistical Parameters represent the rainfall distribution pattern with respect to the arithmetic mean of the rainfall data. Based on the Statistical data a model graph representing the rainfall details for Lower Paravanar Sub-basin is given below in **Fig 3.1**

Fig.3.1 Statistical Parameters of Uppanar Sub-basin (1971-72 to 2015-16)



3.2.8 Moisture Index for Climatic Classification

A study has also been made on the moisture factor existing in the basin area. The annual water surplus or the annual water deficit is the difference between the annual average rainfall and the potential evapotranspiration. The potential evapotranspiration is derived from Penman Monteith method through CROPWAT model. (PET is annual evapotranspiration value).

Climatic classification is based on Moisture Index. Moisture Index varies from -100% to +100%.

$$\text{Moisture Index} = \frac{\text{Annual Water Surplus / Annual Water Deficit}}{\text{Annual Water need (i.e.) PET}} \times 100$$

The different Climatic zones for different Moisture Index ranges are given in **Table 3.7**

Table 3.7 Moisture Index for Climatic Classification

Moisture Index (%)	Type of Climate
+100	Per humid
+100 to +20	Humid
+20 to 0	Moist sub-humid
0 to -33	Dry sub-humid
-33 to -66	Semi-arid
-66 to -80	Arid
-80 to -100	Extremely arid

The annual evapo transpiration (i.e. PET) of Palur (1644.99mm/year) weather Station is adopted for calculating moisture Index. The Moisture index (Im) for all the 7 rain gauge stations and for all the sub basins has been worked out in **Table 3.8 and 3.9**.

Table 3.8 - Moisture Index (Im) for Climatic Classification

Sl. No	Station Name	Annual Ave. Precipitation (P) mm	PET mm	Difference between P&PET mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
1	Chidambaram	1489.8	1645	155.2	0	9.4	-9.4	Dry Sub-humid
2	Cuddalore	1357.9	1645	287.0	0	17.4	-17.4	Dry Sub-humid
3	Kothuvacheri	1144.8	1645	500.2	0	30.4	-30.4	Dry Sub-humid
4	Panruti	1136.9	1645	508.1	0	30.9	-30.9	Dry Sub-humid
5	Parangipettai	1355.4	1645	289.6	0	17.6	-17.6	Dry Sub-humid
6	Sethiathope Anicut	1324.9	1645	320.1	0	19.5	-19.5	Dry Sub-humid
7	Virudhachalam - Taluk office	1123.6	1645	521.4	0	31.7	-31.7	Dry Sub-humid

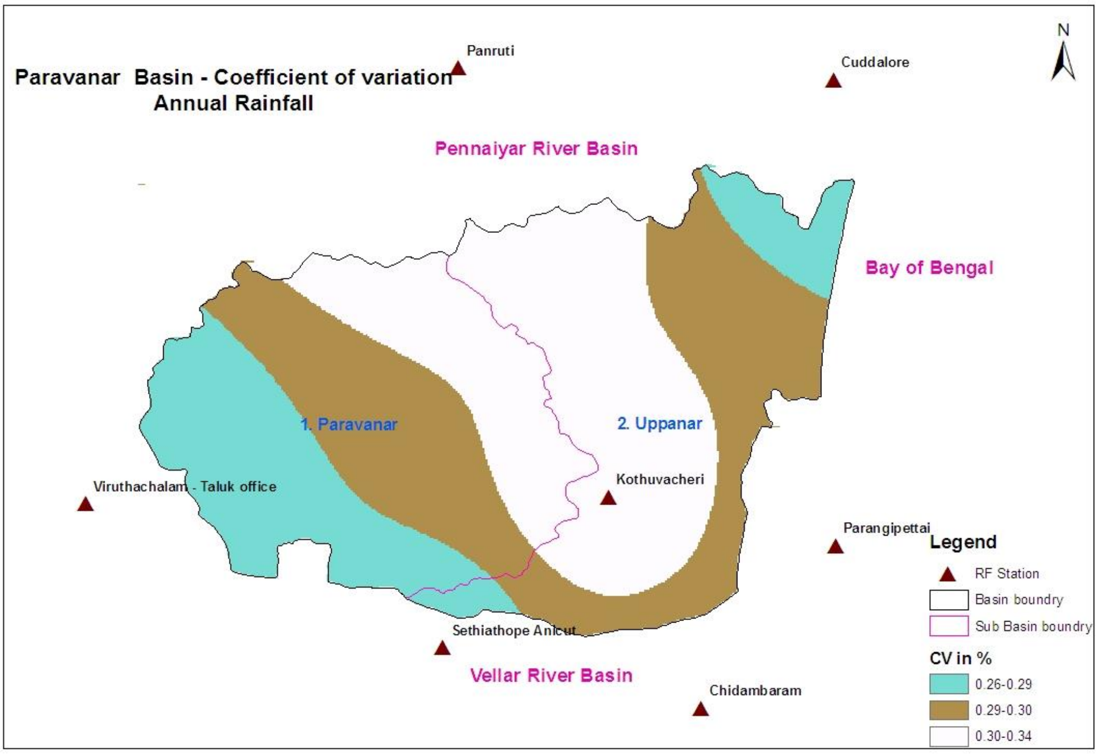
Table 3.9 - Moisture Index (Im) for Sub Basin wise Climatic Classification

Sl.No	Station Name	Annual Ave. Rainfall P mm	PET mm	Difference between P&PET mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
1	Paravanar	1181.9	1645	463.1	0	28.2	-28.2	Dry Sub-humid
2	Uppanar	1213.5	1645	431.5	0	26.2	-26.2	Dry Sub-humid

3.2.9 Spatial Variability of Rainfall as Deduced from Coefficient of Variation

An understanding of the spatial and temporal distribution and changing pattern in rainfall is a basic and important requirement for the planning and management of water resources.The distribution characteristics of the rainfall of Paravanar River basin data show certain patterns, which says precisely the spatial variability of rainfall in the study area. Coefficient of Variation (CV) has been computed using Standard Deviation and average annual rainfall. Based on the Spatial variability data from RF Station location points using an inverse distance weighted (IDW) technique, CV of Paravanar basin for annual rainfall arrived which ranges between 26% and 34%(1144 mm to 1377 mm) where as the mean annual Rainfall of the basin is 1197.70 mm. The annual spatial variation in the East of northeast part of the basin ranges from (26%-30%) and this portion receive rainfall in the range of 1260-1377 mm. This range shows positive deviation.

Fig.3.2 Coefficient of variation for mean annual Rainfall



The Central part of the basin shows the CV in the range of 0.3 to 0.34. This range also shows positive deviation as the annual rainfall ranges from 1200 mm to 1260 mm. Western part of the basin shows the CV in the range of 0.26 to 0.29. This region indicates negative deviation as the annual rainfall in the range of 1144 mm to 1260 mm.

3.2.10 Deviation in Rainfall from Mean

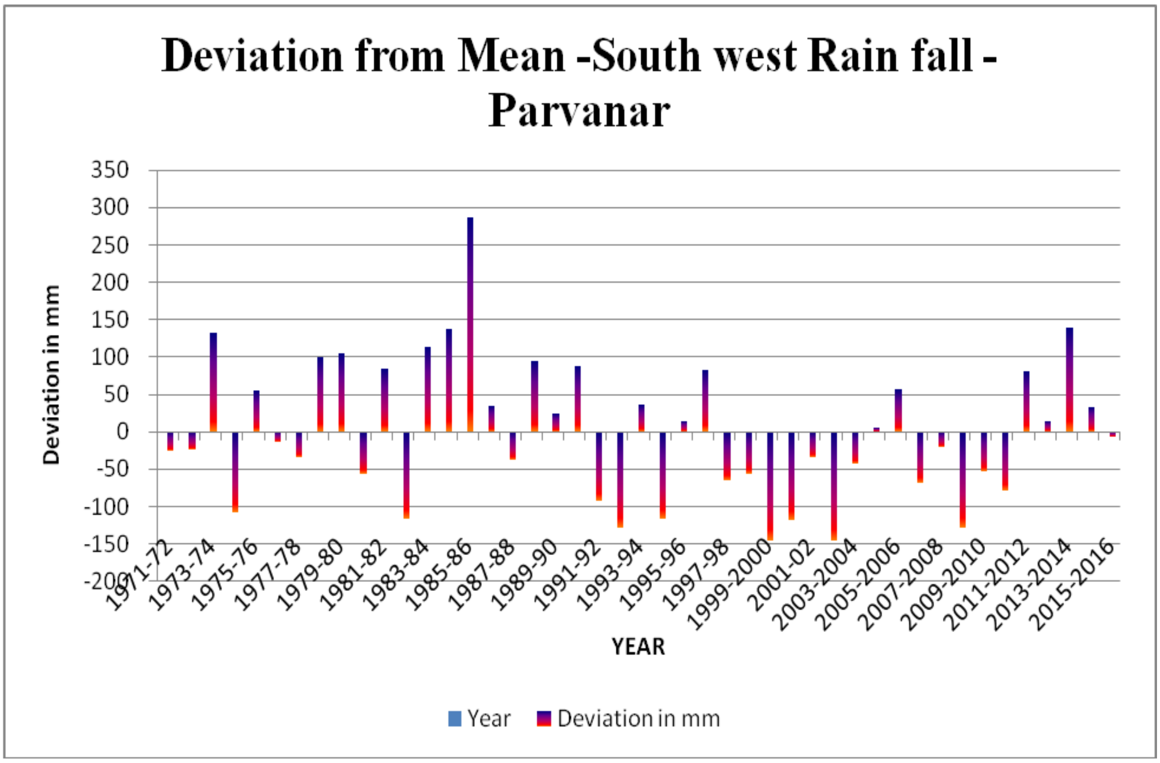


Fig.3.3 Deviation from mean South West monsoon Rainfall

The deficient or excess rainfall years are defined when rainfall of that year departs from the mean rainfall. The rainfall pattern over the basin for 45 years is found to be of alternating sequences of wet (+ve- Deviation) and dry (-ve - Deviation) periods. It is observed from the F**ig.3.3** the south west monsoon during the period of 1971-1990 in the basin shows negative deviation in the range of 25 mm to 125 mm for 8 years and positive deviation in the range of 25 mm to 275 mm for 11 years. In the period of 1990-2016 south west monsoon in the basin shows negative deviation in the range 25 mm to 150 mm for 15 years and only 5 years of positive deviation in the range of 25 mm to 175 mm.

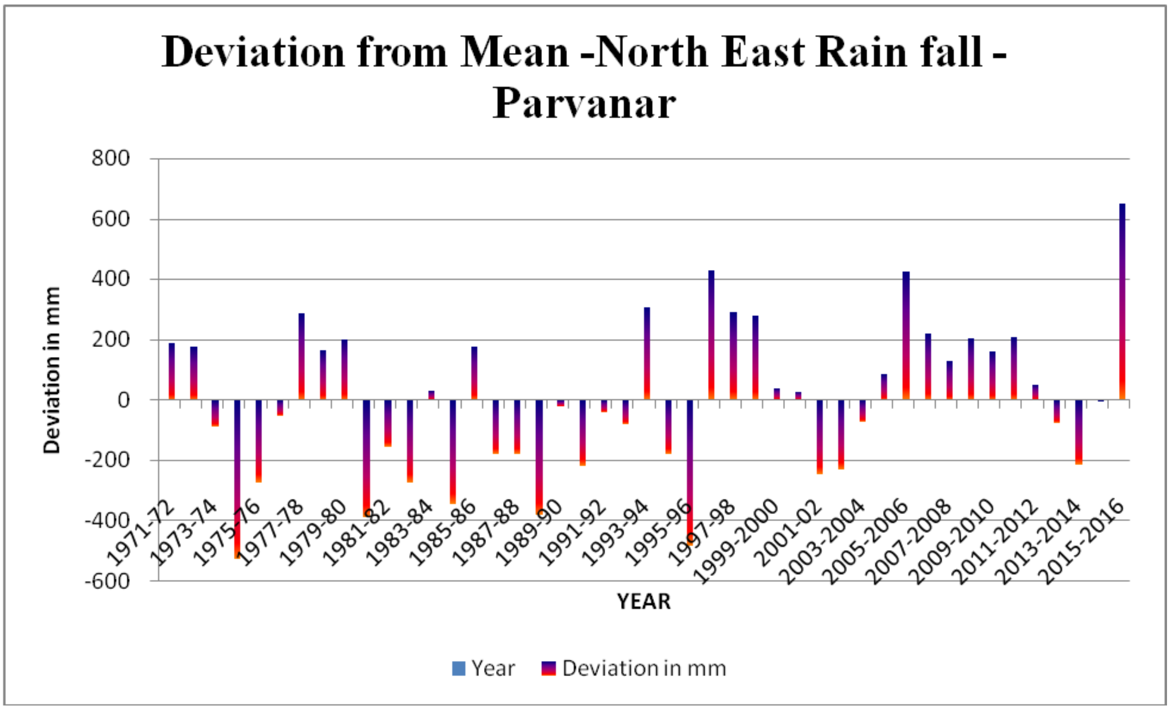


Fig.3.4 Deviation from mean North East monsoon Rainfall

From the **Fig.3.4** the North East monsoon during the period of 1971-1990 in the basin, Negative deviation of 50 mm to 450 mm found to be for 12 years and positive deviation for 7 years in the range of 50 mm to 300 mm. In the period of 1990-2016, North East monsoon in the basin, negative deviation of 50 mm to 500 mm found to be for 10 years and positive deviation for 15 years in the range of 50 mm to 650 mm.

From the **Fig.3.5** the Annual Rainfall during the period of 1971-1990 in the basin, Negative deviation in the range of 50 mm to 650 mm found to be for 11 years and positive deviation for 8 years in the range of 50 mm to 600 mm. In the period of 1990-2016 annual rainfall in the basin, Negative deviation in the range of 50 mm to 450 mm found to be for 10 years and positive deviation for 15 years in the range of 50 mm to 550 mm.

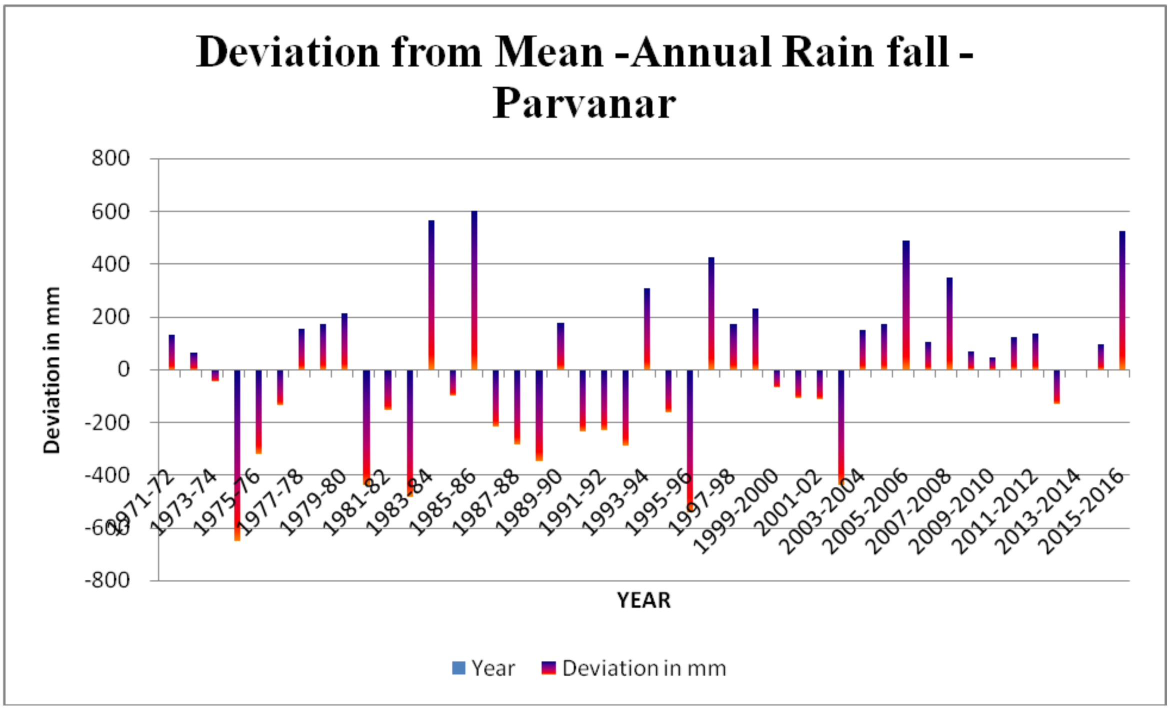


Fig.3.5 Deviation from mean annual rainfall

The above observations revealed the fact that the trend of south west monsoon is decreasing compare to that of North East monsoon over this basin. This Pattern is influencing on Annual rainfall pattern over this basin.

3.3 Climate

Climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate is different than weather, in that weather only describes the short-term conditions of these variables in a given region. Climate is the average weather in a place over many years. While the weather can change in just a few hours, climate takes hundreds, thousands, even millions of years to change.

As there is no climatic station in the basin, climatic data from the station adjacent to the basin, which is located close to the boundary is considered for analysis. The Location details of weather station considered for analysis are furnished in **Table 3.10** and its climatological values are listed in **Table 3.11**

Table-3.10 Weather Stations

SI. No	Name of the weather station	Block	Sub-basin	Maintained by
1	Palur	Annagramam	Gadilam	PWD

Table-3.11 Climatological Parameters

SI. No	Climatological Parameter (Annual Average)	Palur
1	Average monthly temperature Maximum in ^{0} Celsius	36.11
2	Average monthly temperature Minimum in ^{0} Celsius	19.98
3	Average mean temperature in ^{0} Celsius	28.04
4	Average relative humidity in %	73.73
5	Average wind velocity in km/hour	4.89
6	Average Sunshine hours / day	6.55
7	Average Pan Evaporation in mm/month	163.59

3.3.1 Temperature

The meteorological features of the basin have been studied from the data collected from weather station. Temperature is one of the basic factors under climatological features and it is one of the main parameter required to calculate the crop water requirement (i.e. reference crop evapo-transpiration). The maximum and minimum monthly average temperature observed in the climatological station. The monthly average Maximum and Minimum Temperature of the Palur station is 43.00^0 Celsius (Jun-2003), 14.00^0 Celsius (Jan-2002).

The average mean, average minimum and average maximum temperature for the Palur stations have been computed and tabulated in **Appendix 3.4.**

3.3.2 Relative Humidity

Relative humidity is the ratio of the partial pressure of water vapor in an air-water mixture to the saturated vapor pressure of water at a prescribed temperature. The relative humidity of air depends on temperature and the pressure of the system. The monthly average relative humidity of the Palur station varies from 89.73% (Nov2010) to 51.23% (May 2002) **Appendix-3.4**.

3.3.3 Wind speed

Wind velocity is an important meteorological parameter which has considerable influence on evaporation and evapotranspiration phenomena. Wind has direct impact on climate & vegetation and is linked with the circulation pattern of the monsoon. The monthly average wind velocity of the Palur station varies from 9.50 Kmph (June 2003) to 1.77 Kmph (Oct 2013) **Appendix 3.4.**

3.3.4. Sunshine

The monthly average sunshine hours of the Palur station varies from 10.05 hrs/day (April 2002) to 3.30 hrs/day (June 2013) (**Appendix 3.4**)

3.3.5 Evaporation

Evaporation is one of the main factors causing hydrologic cycle.The loss of water is caused due to evaporation. Hence, the estimation of evaporation in water body and transpiration from crop are an important task to find out the crop water requirement of the crops in that area. The monthly average Pan Evaporation in mm for the Weather station is tabulated and given in **Appendix 3.4**.

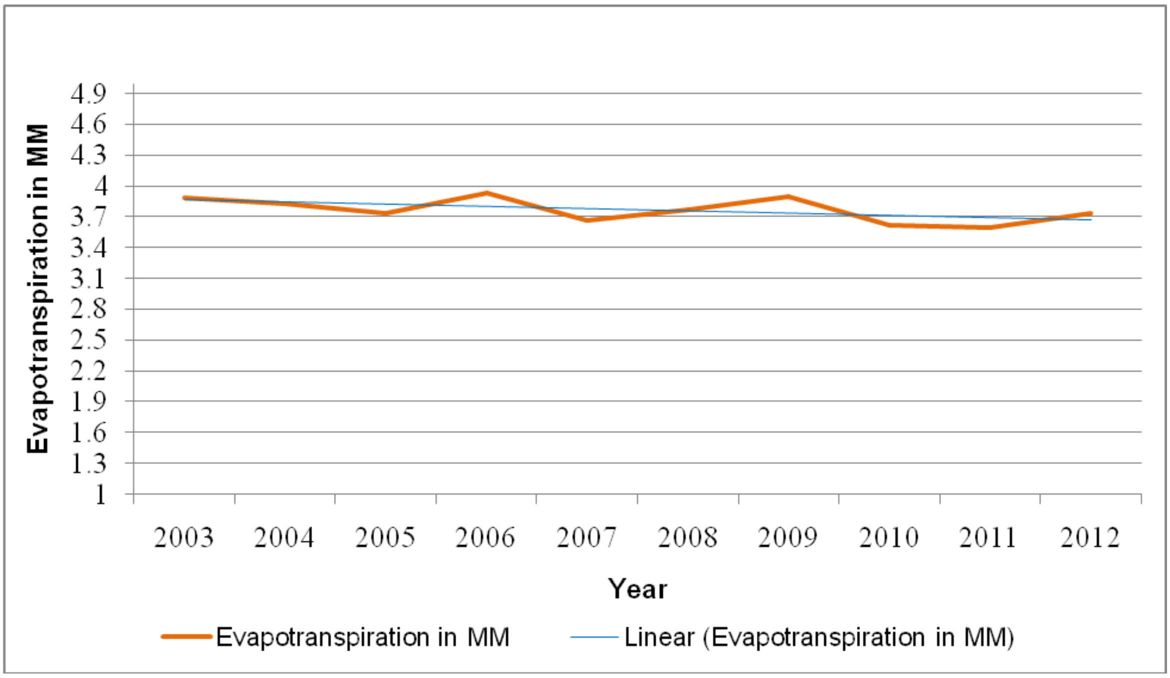
Evapotranspiration

The monthly average ETo in mm for the Weather station is estimated using Penman Montieth Method. The estimated ETo values for the station is given in **Appendix 3.4.**

Potential Evapotranspiration (PET)

Potential Evapotranspiration (PET) arrived for Palur station is 1645mm (Annual). The potential Evapotranspiration (PET) for each month has been calculated and tabulated in **Appendix 3.4.**There is not much variation in the trend of Potential Evapotranspiration for Palur (2003 to 2012) and is shown in **Fig 3.6.**

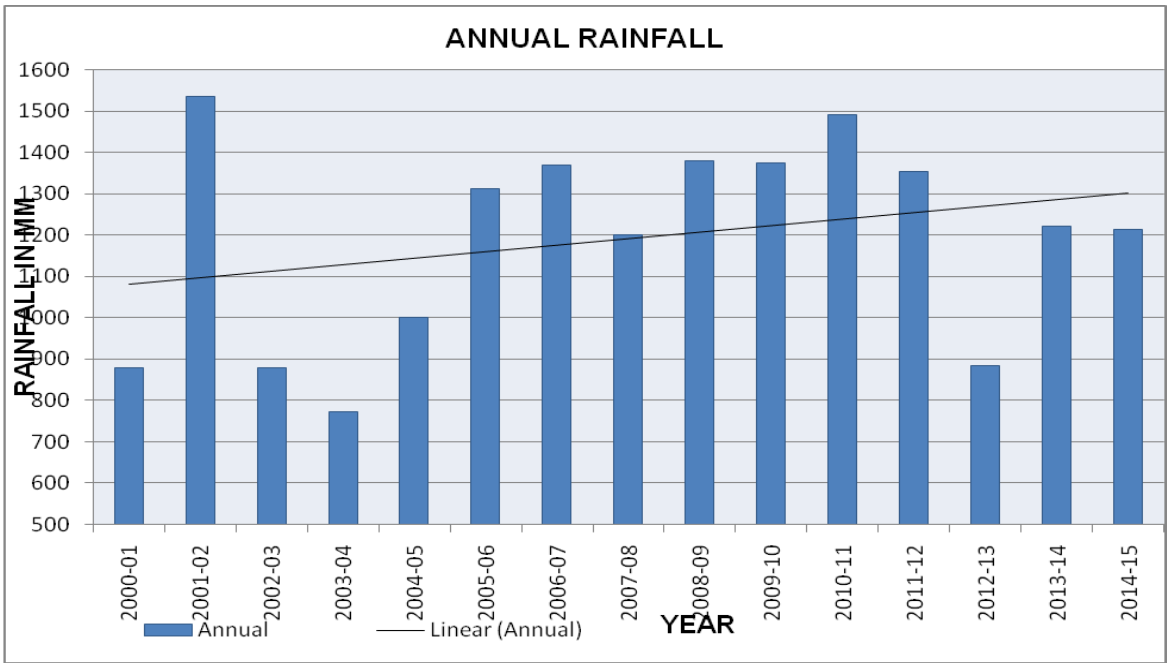
Fig.3.6 Evapotranspiration of weather Station in Palur

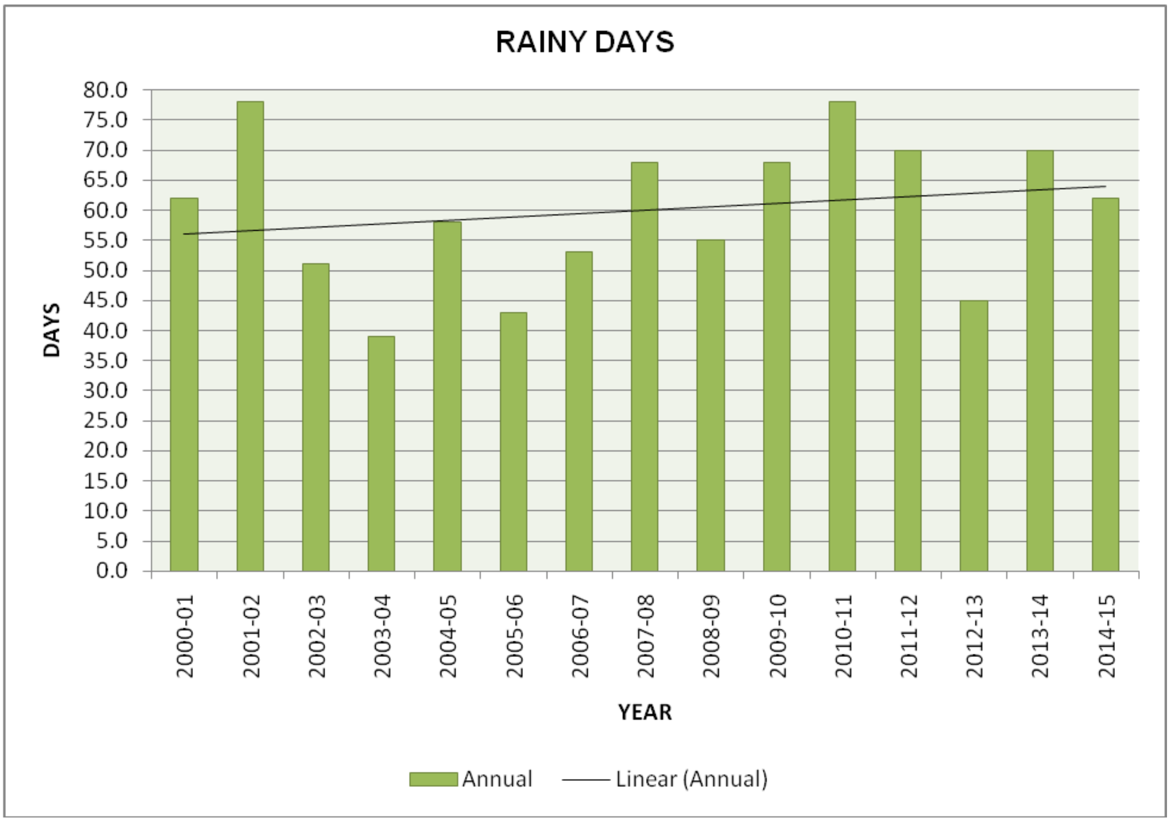


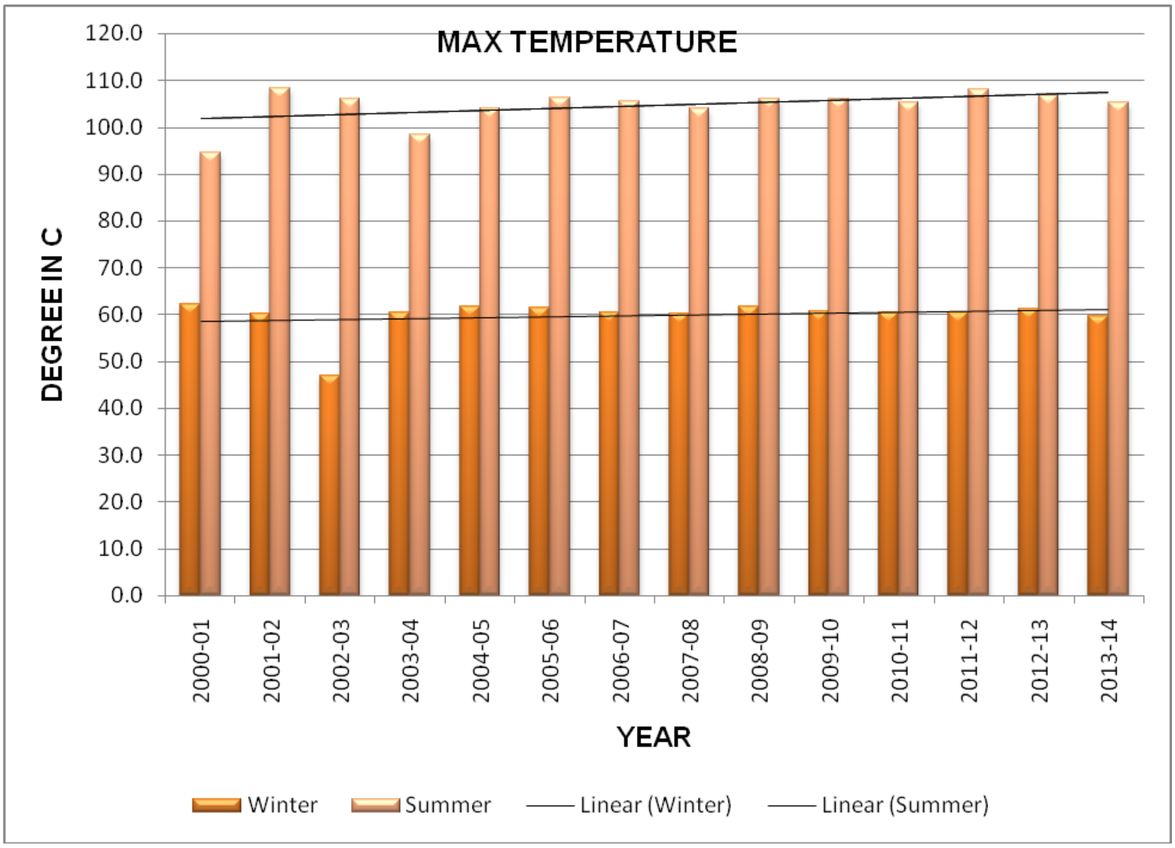
To study the climatic pattern of Paravanar river Basin, climatic data (2000-2012) of the weather station in Palur is taken for analysis and its results are given below:

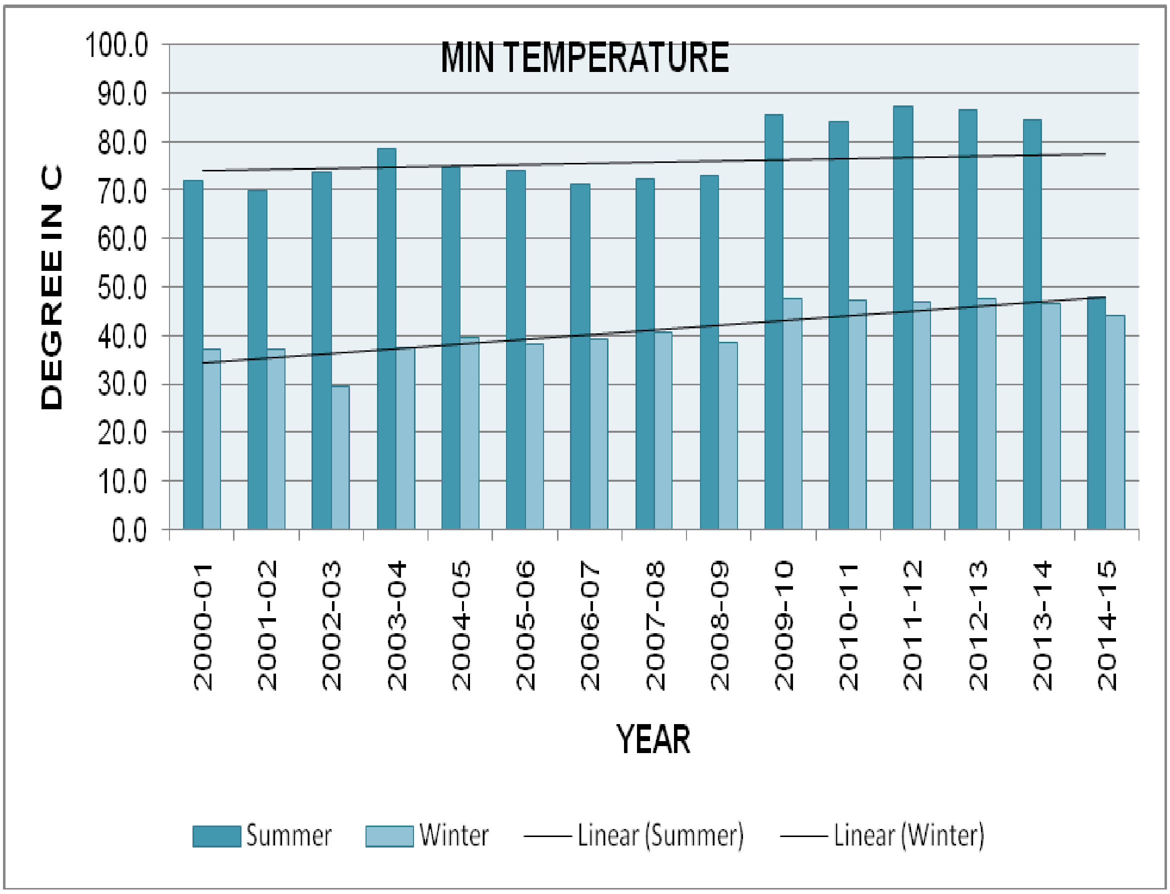
- The trend of annual rainfall increases
- The trend of number of rainy days also increases
- There is a marginal increase in summer & winter maximum temperature.
- Summer and winter minimum temperature trend shows increase in pattern.

Fig 3.7 Results of climatic data – Palur (2000-2015)






MAX TEMPERATURE
DEGREE IN C
YEAR
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
Winter
Summer
Linear (Winter)
Linear (Summer)


MIN TEMPERATURE
DEGREE IN C
YEAR
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
Summer
Winter
Linear (Summer)
Linear (Winter)

3.3.6 Drought Assessment

Indian Meteorological Department method for drought assessment is simple and widely used. In this method, drought is assessed on the basis of percentage of deviation of rainfall from the long-term annual mean rainfall. The percentage deviation (Di) is given by

$$\mathbf{Di} = \frac{\mathbf{Pi - \overline{P}}}{\mathbf{\overline{P}}} \mathbf{\times 100}$$

Where Pi is the annual rainfall in the year i and $\overline{P}$ is the long-term annual mean rainfall. The percentage deviation of rainfall Di and the category of drought assessment as per IMD are given below in **Table 3.12**

Table-3.12 Drought Assessment

Sl. No	Range of Di	Classification of drought	Category
1.	> 0	M0	No drought
2.	0 to - 25	M1	Mild drought
3.	-25 to -50	M2	Moderate drought
4.	< - 50	M3	Severe drought

Drought assessment has been carried out for the last fifteen years for all the seven rain gauge stations. The drought severity such as no, mild, moderate and severe drought for seven stations from the available data were found out and presented in **Table 3.13** and an abstract is also given in **Table 3.14**. It is observed from the **Table 3.13 & 3.14** that Mo (No Drought) is more than the M1, M2 & M3 (Mild, Moderate and Severe Drought). This basin is not drought prone. Some of the years have been moderately drought years. Severe drought conditions was felt only in one Station Panruti – (2011-12,2012-13, 2013-14,2014-15) which is located outside the northern boundary of this basin.

Drought frequency analysis for 15-year period (2001-02 to 2014-15) indicates that

- Panruti area faced **severe drought situation** 4 times out of 15 years.
- In Parangipettai, Chidambaram, Sethiathope Anicut, Virudhachalam - Taluk office Rain fall stations are faced Moderate drought situation 2 to 3 times out of 15 years.
- In general all rainfall stations in this basin toggle from no drought to mild drought in most of the years.

Table - 3.13 Meteorological Drought in Paravanar River Basin using IMD Method Drought

(MO - No Drought-M1 - Mild Drought, M2 - Moderate Drought, M3 - Severe Drought) (2001-02 to 2015-16)

Sl. No.	STATION CODE	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
1	Chidambaram	M0	M2	M1	M1	M0	M0	M0	M0	M1	M1	M1	M2	M1	M0	M0
2	Cuddalore	M1	M2	M1	M0	M0	M0	M0	M0	M0	M0	M0	M1	M1	M0	M0
3	Kothuvacheri	M1	M2	M0	M0	M0	M0	M0	M1	M0	M1	M0	M0	M0	M0	M0
4	Panruti	M1	M1	M0	M0	M0	M0	M0	M0	M1	M0	M3	M3	M3	M3	M0
5	Parangipettai	M1	M2	M1	M1	M0	M0	M0	M0	M0	M1	M0	M2	M2	M0	M0
6	Sethiathope Anicut	M1	M2	M1	M0	M0	M0	M0	M0	M0	M0	M0	M2	M0	M0	M0
7	Virudhachalam - Taluk office	M1	M2	M0	M0	M0	M2	M0	M0	M0	M0	M0	M1	M0	M1	M0

Table 3.14 - Abstract of Drought Assessment (From 2001-02 to 2014-15)

Sl.No.	STATION CODE	M0	M1	M2	M3
1	Chidambaram	7	6	2	0
2	Cuddalore	10	4	1	0
3	Kothuvacheri	11	3	1	0
4	Panruti	8	3	0	4
5	Parangipettai	8	4	3	0
6	Sethiathope Anicut	11	2	2	0
7	Virudhachalam - Taluk office	10	3	2	0

3.4 Summary

Paravanar River Basin is divided into two sub-basins based on the topography. The sub basin wise influencing rain gauge stations, area of influence of each rain gauge station, area of the sub basin and weighted area of the influenced rain gauge station, the annual average rainfall and the annual average weighted rainfall for each sub basin are given in **Table 3.15.** The 45 years annual average rainfall of the basin is 1197.70 mm.

The previous water plan study of Paravanar River Basin was carried out in the year 2007 by IWS. The data period considered in IWS study was from 1970-2007 and the average annual rainfall of the basin was reported as 1214.15 mm. When compared to the previous study, meager change is observed in the average annual rainfall of Paravanar River Basin (1.35%).

In general, Paravanar basin, receives more rainfall in North East monsoon than South West monsoon. There is only one Rain Gauge station in Uppanar sub basin and Paravanar sub basin does not have any rain gauge station and it is suggested to have one station since the area of the sub basin is nearly 500 Sqkm.

Both the sub basins have average annual rainfall of above 1000mm. The highest rainfall of 1213.48mm was received in Uppanar sub basin. Similarly lowest rainfall of 1181.91mm was received in Paravanar sub basin. On viewing the climatic pattern, it is observed that there is increase in number of rainy days, marginal increase in summer & winter maximum temperature and reasonable increase in summer & winter minimum temperature.

Table 3.15 - Influencing Rainguage Stations of each sub-basin

Sl.No	Sub Basin		Raingauge Station	RG Station Influencing Area in Sq.km	Sub basin Area in Sq.km	Weight in %	Annual average weighted rainfall for the Stations in mm	Annual average weighted rainfall for the sub-basin in mm
1	Paravanar	1	Sethiathope Anicut	108.94	435.01	0.25	1324.86	1181.91
		2	Panruti	47.50		0.11	1136.86	
		3	Virudhachalam - Taluk office	145.91		0.34	1123.56	
		4	Kothuvacheri	132.67		0.30	1144.81	
2	Uppanar	1	Sethiathope Anicut	18.13	437.33	0.04	1324.86	1213.4
		2	Parangipettai	36.36		0.08	1355.41	
		3	Cuddalore	72.46		0.17	1357.94	
		4	Panruti	42.51		0.10	1136.86	
		5	Kothuvacheri	256.23		0.59	1144.81	
		6	Chidambaram	11.63		0.03	1489.82	

CHAPTER 4

IRRIGATION AND AGRICULTURE

CHAPTER 4

IRRIGATION AND AGRICULTURE

4.1 INTRODUCTION

In Tamil Nadu, large chunk of population is engaged in agriculture activities. Agriculture continues to be the most predominant sector of the state economy as 70% of the population is engaged in agriculture and allied activities for their livelihood. Tamilnadu State has an area of 130 lakh hectares with gross cropped area of 59.95 lakh hectares.

The Gross State Domestic Product (GSDP) of 2014-15 at constant price stood at Rs.942735.89 crores with a growth rate of 8.65% where as the GSVA (Gene Set Variation Analysis) on Agriculture at constant prices showed a positive growth rate of 4.51%. (Source: Season and Crop Report Tamil Nadu 2014-15). This shows increasing share of Agriculture in the Gross State Domestic Product of the State.

The principle purpose of irrigation is augmenting the agriculture production. Intensive and extensive practices for cultivation of land depend mainly on the irrigation water. Medium & minor irrigation schemes are being implemented in the state for augmenting the irrigation for agriculture. The sources of irrigation in this Basin are minor irrigation tanks and the water pumped out from Neyveli mines.

The ayacut area of Paravanar river basin is 11,711.41 Ha (ayacut of both system and non-system tanks). In the year 2014-15, gross area irrigated is 0.52 lakh Ha and gross area sown is 0.75 lakh Ha. The main crops cultivated are Paddy, Sugarcane, Ground nut, Fruits & Vegetables, Banana, Blackgram, Cumbu and Cashew.

Soil found in the Cuddalore district can be divided into three main classes namely, the black of regur, the red ferruginous and the Arenaceous. The black soil prevails largely in the Chidambaram, Virudhachalam and Cuddalore Taluks. The Arenaceous exist near the coast in the taluks of Chidambaram and Cuddalore. Black clay is the most fertile kind of soil, the loam is the next best and the red sand & Arenaceous soils are the poorest. (Source: Sodhganga Report: Chapter 02 - Study area Cuddalore).

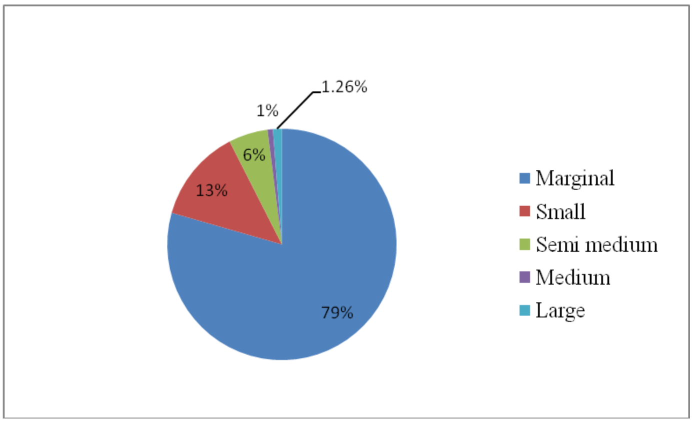
4.2 Land Holdings

According to the 2010-11 Agricultural census, the State had 81.18 lakh holdings with an operating area of 64.88 lakh Ha. Marginal farmers (area less than 1 Ha.) constitute 77%, who operated 35% of the total area. Small farmers (1 to 2 Ha) had a share of 15% and operated 25.3 % of the total area. Semi-medium (2 to 4 Ha) and medium farmers (4 to 10 Ha.) accounted for 7.5 % and operated 34.0% of the total area. Large farmers (more than 10 Ha.) had a share of 0.4% and operated 5.4% of total area. Average size of holding in the State was 0.80 Ha. In Tamil Nadu the per capita availability of land is only 0.19 Ha and the per capita net sown area is only 0.10 Ha. The category of agriculturists/farmers in Paravanar Basin on the land holding size is given in **Table 4.1 and in Fig 4.1**. Marginal farmers accounts for 79.41% in Paravanar Basin. (Source: Agriculture census 2010-11, Blockwise Number of Operational Holding and Area in Hectares)

Table -4.1 SUB BASINWISE NUMBER OF OPERATIONAL HOLDING

Social Group	Paravanar	Uppanar	Total	%
Marginal (less than 1 Ha)	26572	24744	51316	79.41
Small (1 to 2 Ha)	4081	4354	8435	13.05
Semi medium (2 to 4 Ha)	1689	1885	3575	5.53
Medium (4 to 5 Ha)	222	264	486	0.75
Larger (5 Ha & above)	353	459	812	1.26
Total	**32918**	**31706**	**64624**	

Fig 4.1 Land Holdings in Paravanar Basin



4.3 Crop Water Requirement

4.3.1 Crop Water Requirement Calculation

Water requirement of crop is the quantity of water needed for normal crop growth and yield, in a period of time at a place and may be supplied by precipitation or by irrigation or by both.

Water is needed mainly to meet the demands of evaporation (E), transpiration (T) and metabolic needs of the plants, all together is known as consumptive use (CU). Since water used in the metabolic activities of plant is negligible, being only less than one percent of quantity of water passing through the plant, evaporation (E) and transpiration (T), i.e. ET is directly considered as equal to consumptive use (CU). In addition to ET, water requirement (WR) includes losses during the application of irrigation water to field (percolation, seepage, and run off) and water required for special operation such as land preparation, transplanting, leaching etc.

WR = CU + application losses + water needed for special operations.

Water requirement (WR) is therefore, demand and the supply would consist of contribution from irrigation, Effective Rainfall (ER) and soil profile contribution including that from shallow water tables (S)

WR = IR + ER + S

Under field conditions, it is difficult to determine evaporation and transpiration separately. They are estimated together as evapotranspiration (ET). IR is the Irrigation Requirement.

The evapotranspiration of a crop (Etc in mm) under irrigation is obtained by the following equation:

ETc = Kc x ETo, Where ETo is the reference evapotranspiration and Kc is the crop coefficient.

The ET_0 is estimated by using Penmann Monteith method. The normal Reference Crop Evapo-transpiration values are tabulated in Chapter-3, **Appendix 3.4.**

4.3.2 Crop Parameters

The Kc stages and coefficients are taken from Food and Agriculture Organization (FAO) irrigation Paper No. 56 (Ref: Evapotranspiration - Guidelines for computing crop water requirements). The growth stage of a crop as in **Fig. 4.2** profoundly influences Kc values. The crop growing period can be divided into four distinct growth stages: (i) the initial stage (from sowing to about 10% ground cover), (ii) crop development stage (from 10% to about 70% ground cover), (iii) mid-season stage (including flowering and grain setting and yield formation stage), (iv) late season stage (including ripening and harvest).

In general, out of the four growth stages, the mid-season stage is the most sensitive to water shortages, as it is the period of the highest crop water need. Water shortage during the mid-season will reduce crop yields substantially. Important physiological and critical growth stages of crops for irrigation are tabulated in **Table 4.2.**

Fig 4.2 Growth Stage of a Crop

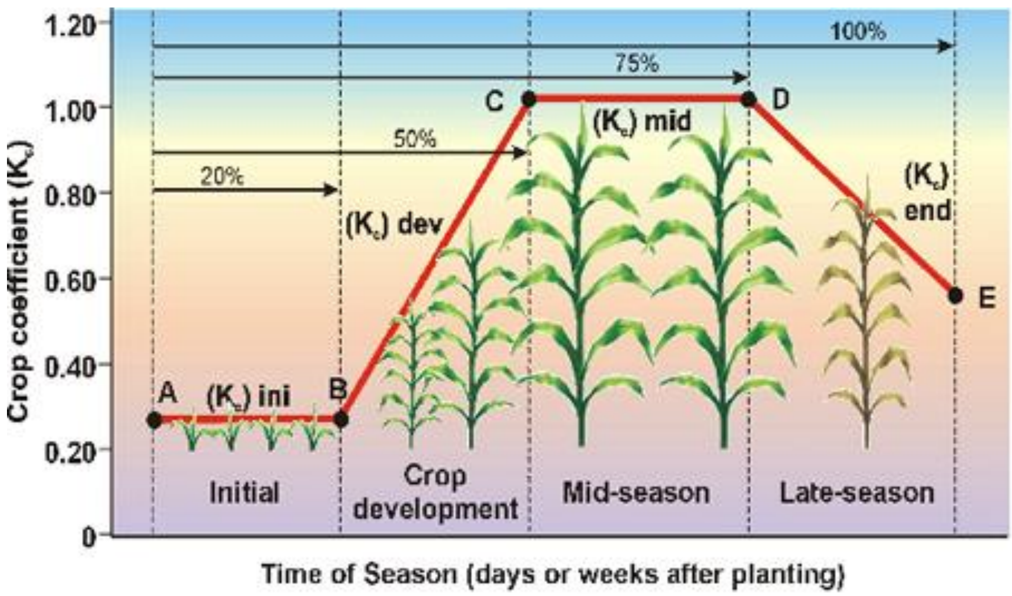


Table 4.2 Important physiological and critical growth stages of crops for irrigation

Sl. No.	Crop	Physiological stage	Critical Stage
1	Paddy	Early tillering, panicle initiation, flowering, milking and dough	Early tillering and flowering and milky
2	Sugarcane	Sprouting, tiller initiation, tillering and grand growth	Sprouting and grand growth
3	Groundnut	Emergence, flowering, pod formation and pod development	Flowering and pod development
4	Cotton	Branching, pre-flowering and boll formation	Flowering and boll formation
5.	Banana	Emergence, Flowering and Fruit Development	All Stages

4.3.3 Factors influencing crop water requirements for irrigation

The following are the factors which affect the water requirements of the crops.

1. **Influence of climate**: In hot climate the evaporation loss is more and hence the water requirement will be more and vice versa. Apart from sunshine and temperature, humidity and wind speed also influence crop water need. Hence it is to say that crops grown in different climatic zones will have different water needs.

2. **Influence of crop type on crop water needs**: The crop type has an influence on the daily water needs of a fully grown crop. i.e. the peak daily water needs of a fully developed maize crop will need more water per day than a fully developed crop of onion. The crop type has an influence on the duration of the total growing season of the crop. There are short duration crops, long duration crops and also perennial crops that are in the field for many years.

3. **Water table**: If the water table is nearer to the ground surface, the water requirement will be less & vice versa

4. **Ground Slope**: If the slope of the ground is steep the water requirement will be more due to less absorption time for the soil.

5. **Intensity of Irrigation**: It is directly related to water requirements, the more the intensity greater will be the water required for a particular crop.

6. **Conveyance Losses**: It is the loss of water in an irrigation channel due to absorption, seepage or percolation and evaporation. The absorption losses depends on type of soil, sub soil water, age of canal, amount of silt carried by canal and wetted perimeter.
7. **Method of Application of Water**: In Precision farming method, less water is required where as in flooding method, more water is required.

8. **Crop period**: It is the time normally in days that a crop takes from the instance of its sowing to harvesting. More the crop period, water requirement will be more.

4.3.4 Methodology to calculate irrigation demand

The block wise data on irrigated area for various seasons are collected from the Economics and Statistics Department. Average block wise crop area irrigated was transformed to the sub basin area by its block area proportion. Sub-basin wise average irrigated area of crops in Paravanar basin is given in **Table 4.3**. **Fig 4.3** shows sub basin wise distribution of average irrigated area of crops in this basin & **Fig 4.4** shows average irrigated area of major crops in this basin. As the rainfed crops are purely dependent on rainfall only, rain fed crops are not considered for calculating crop water requirements. Only irrigated crops raised with surface water and ground water or both are considered for calculating the water requirement of crop. Crop parameters and Basic water need for crops considered for calculating crop water requirement of this basin are tabulated in **Table 4.4** and **Table 4.5** respectively.

Fig 4.5 (**Appendix 4.13 of Vol- II)** explains about the methodology adopted in the calculation of Irrigation Demand. **Table 4.6** gives the Irrigation water requirement at 75% rainfall dependability in Paravanar sub basin and Irrigation Water Demand for 25%, 50%, 75%, 90%. Rainfall Dependability of entire basin is tabulated in **Tables 4.7, 4.8, 4.9, 4.10** respectively.

Fig 4.3 Sub basin wise irrigated area of crops in Paravanar Basin

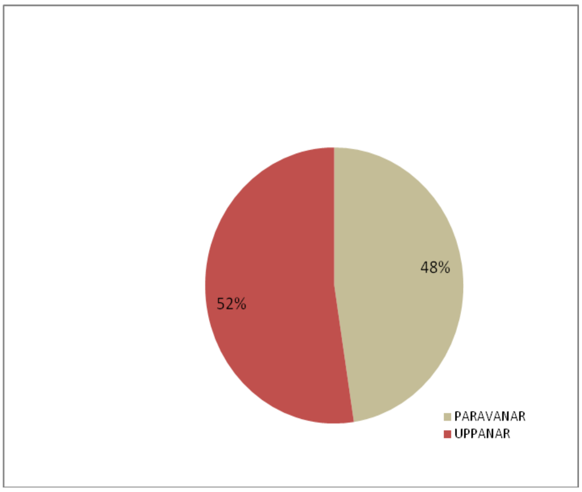


Fig 4.4 Irrigated area of Major crops in Paravanar Basin

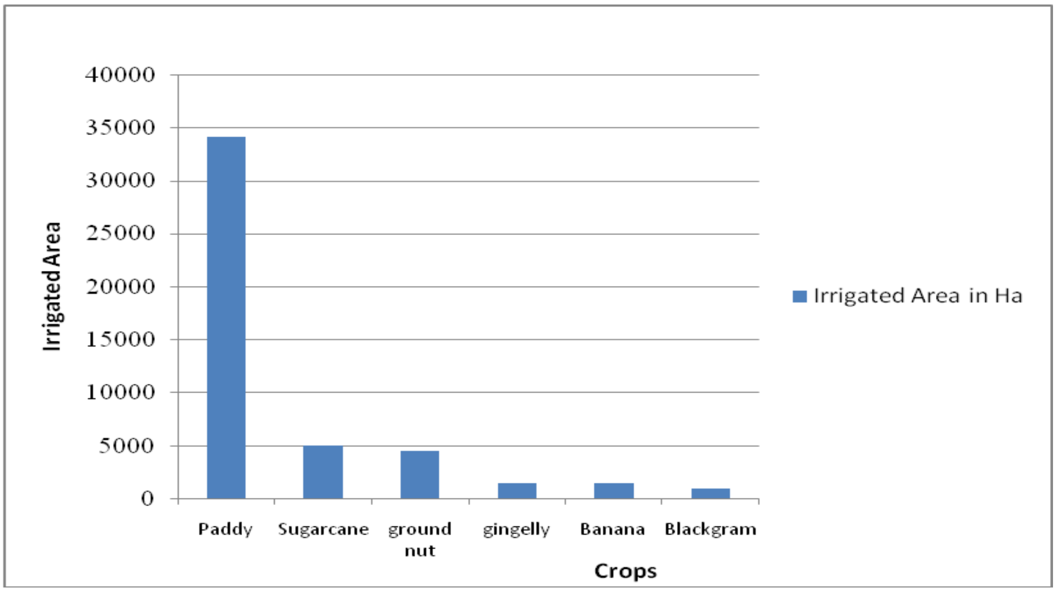


TABLE 4.3

SUB BASINWISE IRRIGATED AREA OF CROPS (Ha) - PARAVANAR BASIN

Crop	Paravanar	Uppanar	Total
Coconut - Per - Jan	260.90	450.21	711.11
Paddy - First Crop - June	12564.81	13012.81	25577.62
Paddy - Second Crop - Oct	4188.27	4337.60	8525.87
Cholam - Feb	0.00	1.70	1.70
Cumbu - Mar	396.20	504.88	901.08
Ragi - Jan	7.70	14.75	22.45
Maize - Jul	0.00	0.00	0.00
Red Gram - June	0.00	0.00	0.00
Black Gram - Jan	474.53	520.28	994.81
Green Gram - Jan	55.04	24.91	79.95
Other Cereals - July	152.65	173.93	326.58
Chillies - Jan	12.09	16.05	28.14
Onion-June	5.87	5.14	11.01
Fodder - Mar	396.79	607.86	1004.65
Condiments -Sep	0.00	0.00	0.00
Sugarcane - Dec	2599.33	2511.38	5110.71
Banana - Dec	471.96	1035.02	1506.98
Groundnut - Dec	1944.48	2602.53	4547.01
Cotton - Feb	16.47	26.37	42.84
Gingelly - Feb	689.25	876.49	1565.74
Fruits & Vegetables - June	372.99	392.04	765.03
Flowers - Per - June	73.22	86.45	159.67
Turmeric - June	3.14	1.07	4.21
TOTAL	**24685.69**	**27201.47**	**51887.15**

TABLE 4.4 CROP PARAMETERS IN PARAVANAR BASIN

Crop No.	Crop Name	Planting Date		Irrigation period	Kc Stages				Data for Kc calculations			Effective root		Allowable Depletion
					Stage-1	Stage-2	Stage-3	Stage-4	Wetting interval	Kc at mid season	Kc at harvest	Full depth (cm)	Time to full depth (days)	
		Month	Day	(days)	(days)	(days)	(days)	(days)	(days)					(%)
1	Coconut - Per – Jan	1	15	365	1	124	120	120	2	1.00	1.00	100	100	40
2	Paddy - First Crop - jun	6	1	115	25	30	35	25	1.2	1.10	0.90	15	20	33
3	Paddy - Second Crop - Oct	10	1	90	25	25	20	20	1.2	1.10	0.90	15	20	33
4	Cholam – Feb	2	15	85	15	25	25	20	8	1.06	0.55	150	40	55
5	Cumbu – Mar	3	15	80	15	20	25	20	8	1.00	0.30	125	35	55
6	Ragi – Jan	1	5	105	20	30	35	20	7	1.06	0.55	150	40	55
7	Maize – Jul	7	15	80	15	20	30	15	8	1	0.35	125	40	55
8	Red Gram – June	6	5	90	20	25	25	20	7	1.00	0.35	80	30	50
9	Black Gram – Jan	1	15	70	20	20	20	10	7	1.00	0.35	80	30	50
10	Green Gram – Jan	1	15	65	15	20	20	10	7	1.00	0.35	80	30	50
11	Other Cereals - July	7	1	90	20	25	25	20	7	1.05	0.9	75	70	70
12	Chillies – Jan	1	1	180	30	40	80	30	3	1.05	0.90	75	70	30
13	Onion-June	6	10	90	20	25	25	20	5	1	0.35	125	35	40
14	Fodder – Jun	6	20	90	20	25	25	20	5	1	0.35	80	30	50
15	Condiments –Sep	9	25	100	20	35	25	20	8	1.25	0.75	150	100	65
16	Sugarcane – Dec	12	15	330	40	80	160	50	6	1.25	0.75	150	100	65
17	Banana – Dec	12	15	300	30	70	150	50	6	1.10	1.00	75	100	35
18	Groundnut – Dec	12	20	105	20	25	45	15	7	1.15	0.60	70	45	50
19	Cotton – Feb	2	15	165	30	40	65	30	8	1.15	0.60	140	45	65
20	Gingelly – Feb	2	10	90	15	25	30	20	8	1.10	0.25	125	60	55
21	Fruits & Vegetables – June	6	15	95	10	25	30	30	2	1.05	0.90	50	35	30
22	Flowers - Per – June	6	1	100	20	30	40	10	6	0.95	0.85	100	50	20
23	Turmeric – June	6	5	150	35	35	55	25	5	1.1	0.9	125	60	30

TABLE 4.5 BASIC WATER NEED FOR CROPS IN PARAVANAR BASIN

Crop No.	Crop Name	Field application efficiency	Technical Irrigation											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		(%)	(mm)	(mm)	(mm	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	Coconut - Per - Jan	70												
2	Paddy - First Crop - jun	70						265.638	110	112	8			
3	Paddy - Second Crop - Oct	70	8									278.705	110	112
4	Cholam – Feb	70		50										
5	Cumbu – Mar	70			50									
6	Ragi – Jan	70	50											
7	Maize – Jul	70							50					
8	Red Gram - June	70						50						
9	Black Gram - Jan	70	50											
10	Green Gram - Jan	70	50											
11	Other Cereals - July	70							50					
12	Chillies – Jan	70	50											
13	Onion-June	70						50						
14	Fodder – Jun	70						50						
15	Condiments -Sep	70									50			
16	Sugarcane – Dec	70												50
17	Banana – Dec	70												50
18	Groundnut – Dec	70												50
19	Cotton – Feb	70		50										
20	Gingelly – Feb	70		50										
21	Fruits & Vegetables - June	70						50						
22	Flowers - Per - June	70						50						
23	Turmeric – June	70						50						

TABLE 4.6 IRRIGATION WATER REQUIREMENT AT 75 % RAINFALL DEPENDABILITY

S.No.	Crop Name	Crop Area (Ha.)	Crop Water Requirement in Mcum												Total Irrigation	
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mcum	Mcft
1	Coconut - Per – Jan	260.90	0.18	0.25	0.32	0.40	0.41	0.35	0.21	0.00	0.00	0.00	0.00	0.13	2.245	79.27
2	Paddy - First Crop –June	12564.81	0.00	0.00	0.00	0.00	0.00	63.35	25.34	14.07	1.01	0.00	0.00	0.00	103.767	3664.53
3	Paddy - Second Crop - Oct	4188.27	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.67	4.61	4.69	21.306	752.42
4	Cholam – Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00
5	Cumbu – Mar	396.20	0.00	0.00	0.20	0.63	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.363	48.14
6	Ragi – Jan	7.70	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.026	0.93
7	Maize – July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00
8	Red Gram – June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00
9	Black Gram – Jan	474.53	0.24	0.60	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.251	44.18
10	Green Gram – Jan	55.04	0.03	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.138	4.87
11	Other Cereals – July	152.65	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.076	2.70
12	Chillies – Jan	12.09	0.01	0.01	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.105	3.73
13	Onion-June	5.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.009	0.32
14	Fodder – Mar	396.79	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.00	0.00	0.00	0.00	0.00	0.450	15.91
15	Condiments -Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00
16	Sugarcane - Dec	2599.33	2.08	2.23	3.53	4.67	5.47	4.53	0.00	4.29	0.00	0.00	0.00	1.30	28.104	992.50
17	Banana – Dec	471.96	0.36	0.39	0.59	0.85	0.87	0.71	0.45	0.00	0.23	0.00	0.00	0.24	4.688	165.55
18	Groundnut - Dec	1944.48	1.68	2.37	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	7.777	274.63
19	Cotton – Feb	16.47	0.00	0.01	0.02	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.121	4.27
20	Gingelly – Feb	689.25	0.00	0.34	0.90	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.493	88.03
21	Fruits & Vegetables - June	372.99	0.00	0.00	0.00	0.00	0.00	0.24	0.32	0.07	0.00	0.00	0.00	0.00	0.627	22.14
22	Flowers - Per - June	73.22	0.00	0.00	0.00	0.00	0.00	0.07	0.06	0.00	0.00	0.00	0.00	0.00	0.127	4.49
23	Turmeric – June	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.007	0.23
	Total	**24685.69**	**4.92**	**6.28**	**8.81**	**7.85**	**7.33**	**69.50**	**26.70**	**18.44**	**1.24**	**11.67**	**4.61**	**7.33**	**174.68**	**6168.85**

TABLE 4.7 IRRIGATION WATER DEMAND (Mcum) AT 25 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.47	7.49	10.27	7.69	0.00	70.39	24.71	17.55	1.68	11.67	4.61	9.42	**169.94**
2	Uppanar	**5.53**	**8.69**	**12.17**	**9.43**	**6.26**	**70.47**	**33.74**	**24.99**	**7.23**	**16.68**	**4.77**	**7.93**	**207.90**
	Total	**10.00**	**16.19**	**22.44**	**17.12**	**6.26**	**140.86**	**58.45**	**42.53**	**8.91**	**28.35**	**9.38**	**17.36**	**377.84**

TABLE 4.8 IRRIGATION WATER DEMAND (Mcum) AT 50 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.61	6.38	9.88	7.79	0.00	67.93	36.22	14.07	1.01	15.17	4.61	7.20	**174.86**
2	Uppanar	3.70	7.89	11.20	8.22	8.96	71.79	34.39	22.38	6.25	11.83	4.77	7.93	**199.31**
	Total	**8.31**	**14.27**	**21.08**	**16.01**	**8.96**	**139.72**	**70.61**	**36.45**	**7.25**	**26.99**	**9.38**	**15.13**	**374.16**

TABLE 4.9 IRRIGATION WATER DEMAND (Mcum) AT 75 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.92	6.28	8.81	7.85	7.33	69.50	26.70	18.44	1.24	11.67	4.61	7.33	**174.68**
2	Uppanar	4.81	8.48	6.78	11.95	9.22	64.68	14.85	35.83	1.92	15.58	4.77	7.93	**186.81**
	Total	**9.73**	**14.77**	**15.58**	**19.80**	**16.55**	**134.18**	**41.56**	**54.27**	**3.16**	**27.25**	**9.38**	**15.26**	**361.49**

TABLE 4.10 IRRIGATION WATER DEMAND (Mcum) AT 90 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	**3.11**	**7.23**	**9.78**	**7.93**	**3.68**	**69.80**	**21.65**	**31.33**	**1.27**	**17.77**	**4.61**	**7.20**	**185.36**
2	Uppanar	5.69	8.87	11.97	8.99	7.46	68.91	37.97	38.78	2.30	11.83	4.77	7.93	**215.47**
	Total	**8.80**	**16.11**	**21.75**	**16.91**	**11.15**	**138.71**	**59.62**	**70.11**	**3.56**	**29.60**	**9.38**	**15.13**	**400.83**

4.3.5 Future Irrigation Water Demand – Lower Limit Scenario

This scenario is based on the identification of changes in the present cropping or cultivation pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin.

The lower limit for the future irrigation demand is determined taking into consideration the cultivation of SRI (System of Rice Intensification) paddy (70% paddy cultivation area) as recommended by agricultural department. Currently paddy cultivation area under SRI method is being emphasized by the agricultural department to the farmers. Since the objective of more agricultural produce for a drop of water is to be achieved, comparatively less water consuming practice of cultivation are considered for future planning purposes. Lower Limit Scenario of sub basin wise irrigated area of crops in Paravanar River Basin are tabulated in **Table 4.11** and irrigation Water Demand at 25%, 50%, 75%, .90% Rainfall Dependability of Lower Limit Scenario are tabulated in **Tables 4.12 to 4.15**. Savings in demand in implementing lower limit scenario pattern of crops in Paravanar River Basin is listed in **Table 4.16**

TABLE 4.11
SUB BASINWISE IRRIGATED AREA OF CROPS (Ha)
LOWER LIMIT SCENARIO

Crop	Paravanar	Uppanar	Total
Coconut - Per - Jan	260.90	450.21	711.11
Paddy I - June	3769.44	3903.84	7673.29
SRI Paddy I - June	8795.37	9108.97	17904.33
Paddy II - Oct	1256.48	1301.28	2557.76
SRI Paddy II - Oct	2931.79	3036.32	5968.11
Cholam - Feb	0.00	1.70	1.70
Cumbu - Mar	396.20	504.88	901.08
Ragi - Jan	7.70	14.75	22.45
Maize - July	0.00	0.00	0.00
Red Gram - June	0.00	0.00	0.00
Black Gram - Jan	474.53	520.28	994.81
Green Gram - Jan	55.04	24.91	79.95
Other Cereals - July	152.65	173.93	326.58
Chillies - Jan	12.09	16.05	28.14
Onion-June	5.87	5.14	11.01
Fodder - Jun	396.79	607.86	1004.65
Condiments -Sep	0.00	0.00	0.00
Sugarcane - Dec	2599.33	2511.38	5110.71
Banana - Dec	471.96	1035.02	1506.98
Groundnut - Dec	1944.48	2602.53	4547.01
Cotton - Feb	16.47	26.37	42.84
Gingelly - Feb	689.25	876.49	1565.74
Fruits & Vegetables - June	372.99	392.04	765.03
Flowers - Per - June	73.22	86.45	159.67
Turmeric - June	3.14	1.07	4.21
TOTAL	**24685.69**	**27201.47**	**51887.15**

TABLE 4.12 IRRIGATION WATER DEMAND (Mcum) AT 25 % RAINFALL DEPENDABILITY LOWER LIMIT SCENARIO

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.38	7.49	10.27	7.69	0.00	52.46	18.11	13.61	1.40	8.40	3.32	7.53	**134.65**
2	Uppanar	5.43	8.69	12.17	9.43	6.26	52.60	25.90	18.45	6.94	12.01	3.44	6.57	**167.90**
	Total	**9.81**	**16.19**	**22.44**	**17.12**	**6.26**	**105.05**	**44.02**	**32.06**	**8.34**	**20.41**	**6.75**	**14.10**	**302.55**

TABLE 4.13 IRRIGATION WATER DEMAND (Mcum) AT 50 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.51	6.38	9.88	7.79	0.00	50.80	27.75	10.13	0.72	10.92	3.32	5.89	**138.10**
2	Uppanar	3.60	7.89	11.20	8.22	8.96	53.64	26.43	16.35	5.96	8.52	3.44	6.57	**160.78**
	Total	**8.12**	**14.27**	**21.08**	**16.01**	**8.96**	**104.44**	**54.18**	**26.49**	**6.68**	**19.44**	**6.75**	**12.46**	**298.88**

TABLE 4.14 IRRIGATION WATER DEMAND (Mcum) AT 75 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.83	6.28	8.81	7.85	7.33	51.76	19.61	14.50	0.96	8.40	3.32	6.01	**139.66**
2	Uppanar	5.00	8.48	6.78	11.95	9.22	48.04	10.85	27.54	1.63	11.22	3.44	6.57	**150.71**
	Total	**9.83**	**14.77**	**15.58**	**19.80**	**16.55**	**99.80**	**30.45**	**42.04**	**2.59**	**19.62**	**6.75**	**12.59**	**290.37**

TABLE 4.15 IRRIGATION WATER DEMAND (Mcum) AT 90 % RAINFALL DEPENDABILITY

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	3.02	7.23	9.78	7.93	3.68	52.00	15.75	24.38	0.98	12.85	3.32	5.89	**146.82**
2	Uppanar	5.59	8.87	11.97	8.99	7.46	51.37	29.28	29.94	2.01	8.52	3.44	6.57	**174.00**
	Total	**8.61**	**16.11**	**21.75**	**16.91**	**11.15**	**103.36**	**45.03**	**54.32**	**2.99**	**21.37**	**6.75**	**12.46**	**320.81**

Table 4.16 IRRIGATION WATER DEMAND AT 75 % DEPENDABILITY

Sl. No.	Sub Basin	Present Irrigation Demand (Mcum)	Lower Limit Irrigation Demand (Mcum)	Savings in Demand
1	Paravanar	175	140	20.05%
2	Uppanar	187	151	19.32%
	Total	**361**	**290**	**19.69%**

4.4 Cropping Pattern

From time immemorial due to the good soil health and plentiful water availability, farmers have a set cropping pattern in command areas, tank-fed areas and well irrigated areas, which predominantly paddy, banana, sugarcane, coconut and other hydrophilic crops. Due to the changing rainfall pattern over the years, ground water depletion, lack of flows in the rivers, uncontrolled extraction of ground water scarcity of labour and hike in wages, the existing cropping pattern has ceased to be economically viable. Hence, it is the time to design a new alternate-cropping pattern based on the agro-climatic zone. This must be demonstrated in the farmer’s holdings by a massive research cum extension programmes in order to effectively utilize the natural resources and also to stabilize productivity and profitability.

4.4.1 Existing & Suggested Cropping Pattern in Paravanar Basin

The major crops cultivated in Paravanar Basin are Paddy, Sugarcane, Ground nut and Fruits & Vegetables. The irrigated area for the year 2014-15 in Paravanar Basin under different crops is 51887 Ha with paddy the main crop of the basin cultivated in 34103 Ha. In the remaining area, other crops are cultivated. Sub basin Vs Irrigated area of crops in Paravanar river basin in given in **Fig 4.6.**

The distribution of rain also plays a vital role in crop productivity. Existing cropping pattern during normal rain year (+19% to -19% of normal rainfall) and suggested cropping pattern for Poor rain year (-19% to -59% of normal rainfall) for the Districts covered in this basin are given in the **Table 4.17**.

Fig 4.5 Sub basin area Vs Irrigated area of crops

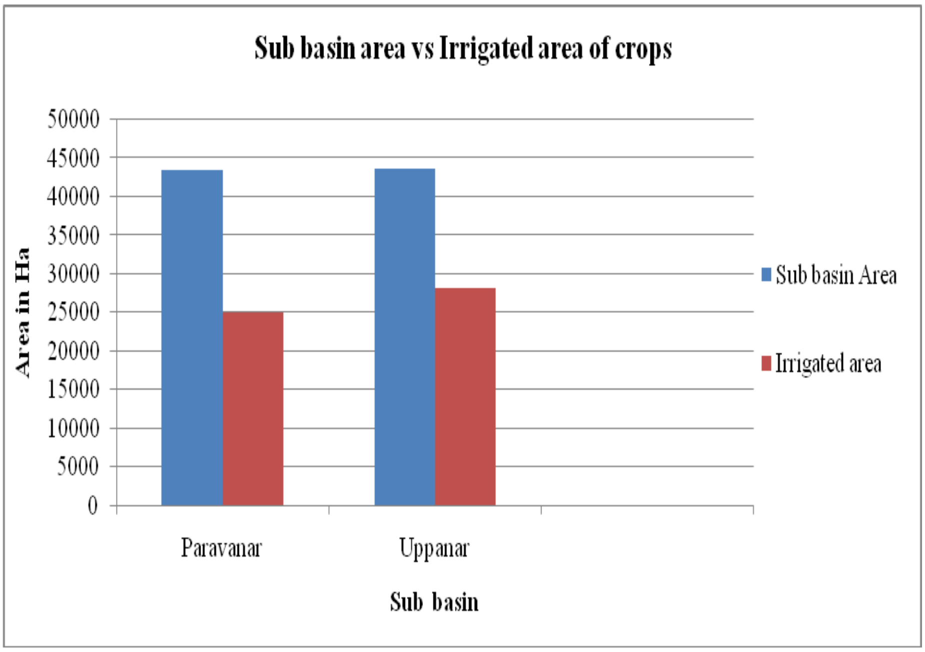


Table 4.17 Cropping Pattern

Areas	Existing cropping pattern	Normal year	Moderate drought year	Severe drought year
Tank fed areas	Rice (Aug-Jan) -Pulses (Jan-Apr)	Rice / Vegetables (Aug-Jan) - Gingelly/Pulses (Feb-May)	Pearl millet+clusterbean (Aug-Jan)- Pulses (Feb-Apr)	Fodder / Pulses (Nov-Feb)
Well irrigated areas	Sugarcane (Dec-Jan) – Ratoon sugarcane (Jan-Nov)- Rice (Dec- May) - Groundnut (June-Sep/Oct)	• Rice (Aug-Jan) – Groundnut (Feb-Apr)-Gingelly (Apr-Jun) • Maize (June-Sep) Marigold(Oct-Feb)- Pulses (Feb-May) • Vegetables (June-Oct)-Maize(Oct-Jan)-Pulses(Feb-May) • Sugarcane (Dec-Jan)-Ratoon sugarcane (Jan-Nov)-Rice (Dec-May)-Groudnut (June-Sep/Oct)	Vegetables (May-July)-Maize/Sunflower (Aug-Dec)-Groundnut, Gingelly (Jan-Apr)	Pearl millet / sorghum (July-Oct)- Maize,varagu, Gingelly, Groundnut (Nov-Feb) – Cluster bean/bhendi/lab lab/watermelon (Feb-May)

4.5 Organic farming

Organic Farming is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. This method primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (biofertilizers) to release nutrients to crops for increased sustainable production in an eco friendly pollution free environment.

Though the yield of crop is comparatively less in organic farming than in inorganic farming because the produce fetches higher price in the international market, corporate companies are encouraging the farmers to go for organic farming on contract basis to facilitate export of the certified produce to other countries.

Yet another benefit of using organic farming is seen during the heavy flood. Heavy rain lashed over in the four districts of Tamil Nadu namely Chennai, Cuddalore, Kancheepuram and Thiruvallur districts during the month of November and December 2015. Heavy loss caused to the farmer who planted crops in their fields due to inundation of flood water. Now the disaster prone Cuddalore District seeks organic farming as their alternate crop production method. (Refer article published in HINDU dated 25th December)

Organic farming approach involves following five principles:

- Conversion of land from conventional management to organic management
- Management of the entire surrounding system to ensure biodiversity and sustainability of the system.
- Crop production with the use of alternative sources of nutrients such as crop rotation, residue management, organic manures and biological inputs.
- Management of weeds and pests by better management practices, physical and cultural means and by biological control system
- Maintenance of live stock in tandem with organic concept and make them an integral part of the entire system

Need of organic farming

With the increase in population our compulsion would be not only to stabilize agricultural production but to increase it further in sustainable manner. The scientists have realized that the 'Green Revolution' with high input use has reached a plateau and is now sustained with diminishing return of falling dividends. Thus, a natural balance needs to be maintained at all cost for existence of life and property. The obvious choice for that would be more relevant in the present era, when these agrochemicals which are produced from fossil fuel and are not renewable and are diminishing in availability. It may also cost heavily on our foreign exchange in future.

The key characteristics of organic farming include

Protecting the long term fertility of soils by maintaining organic matter levels, encouraging soil biological activity, and careful mechanical intervention

- Providing crop nutrients indirectly using relatively insoluble nutrient sources which are made available to the plant by the action of soil micro-organisms
- Nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock manures
- Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited (preferably minimal) thermal, biological and chemical intervention
- The extensive management of livestock, paying full regard to their evolutionary adaptations, behavioural needs and animal welfare issues with respect to nutrition, housing, health, breeding and rearing
- Careful attention to the impact of the farming system on the wider environment and the conservation of wildlife and natural habitats

Disaster prone Cuddalore farmers' taking up organic farming

Boon to farmers: Organic farming method will help improve the quality of land and reduce air and water pollution.

CUDDALORE (TN), DEC 25:

- Repeatedly ravaged by natural disasters, the recent deluge following unprecedented rains being the latest, the farmers in Tamil Nadu's Cuddalore district have started diversifying like never before.
- From taking up organic farming to cashew shelling to cattle rearing, they are branching out to different areas connected to agriculture with the help of government agencies and NGOs that provide them training and micro—credit support.
- K Gopalakrishnan of V Kattupalayam, essentially a farmer, had some time back also taken up cashew procurement, shelling, processing and marketing. But, with the deluge having hit the cashew business, he is now contemplating taking up vermicomposting as a new alternative. Vermicomposting is the practice of using earthworms to convert organic waste into fertilizer.
- "It is all about syncing demand, supply, seasons and time. At the moment cashew shelling is at a slow pace. We expect it to pick up momentum after some time. During such lean period we give more attention to organic farming or some other local work," he says.

- Gopalakrishnan says he had previously produced and used vermicompost exclusively for his farms but “now I find that it can be sold and vermicomposting by itself could get me some additional income“.
- Also the treasurer of Real Organic Agriculture Federation (ROAF), Gopalakrishnan says farmers like him were now tapping the potential of micro—credit and seeking hands—on training on latest farm trends more and more.
- He said experts from government agencies like Krishi Vigyan Kendra and NGO “Real” provide information about current trends in the farming sector and train them in organic farming techniques. The NGO has also lent interest free loans, he added.
- “Earlier, we used to feel that we knew all available farms techniques. Now, after attending training sessions, we feel that science combined with traditional wisdom could make the difference,” he said.
- “Through our ROAF, several farmers have got Rs. 10,000 loan and our federation today lends tractor to farmers at concessional rentals which is as low as Rs. 100—200 a day while the going market rate is over Rs.1,000,” he said.
- Gopalakrishnan’s wife Soundaravalli, a key member of a local women’s self—help group, thanked NABARD Financial Services (NABFINS) for their micro—credit services.
- Due to such credit, she said, women in her village were gainfully employed. “Aided by such credit, (along with their own contribution) some of us have bought manual cashew outer—shell crushers, while others have gone for farming organic vegetables,” she said.
- (This article was published on December 25, 2015)

BIO FERTILIZERS:

Bio fertilizer is a substance which contains living microorganisms which, when applied to seeds, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Bio-fertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances. Bio-fertilizers can be expected to reduce the use of chemical fertilizers and pesticides. The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle and build soil organic matter. Through the use of bio-fertilizers, healthy plants can be grown, while enhancing the sustainability and the health of the soil. Since they play several roles, a preferred scientific term for such beneficial bacteria is "plant-growth promoting rhizobacteria" (PGPR). Therefore, they are extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements by supplying the organic nutrients through microorganism and their byproducts. Hence, bio-fertilizers do not contain any chemicals which are harmful to the living soil.

Types of Bio fertilizers

- Rhizhobium for legume crops
- Azotobactor/Azospirillum for Non legume crops
- Acetobactor for Sugarcane only
- Blue green Algae (BGA) and Azolla for low land paddy

Use of biofertilizers:

- Biofertilizers are known to play a number of vital roles in soil fertility, crop productivity and production in agriculture as they are eco friendly and cannot replace chemical fertilizers that are indispensable for getting maximum crop yields.
- It increases the crop yield by 20% to 30%.
- It replaces chemical nitrogen and phosphorus by 25%.
- It stimulates plant growth
- It activate the soil biologically
- It restores natural soil fertility
- It provide protection against drought and some soil borne diseases

In Cuddalore District, quantity of biofertilizers distributed for the year 2014-15 was 121.800 tonnes. Bio fertilizer details in various blocks of Paravanar Basin have been tabulated in **Table 4.18.**

TABLE 4.18 DISTRIBUTION OF BIO FERTILIZER IN BLOCKS OF PARAVANAR BASIN FOR THE YEAR 2014-15

Sl. No.	Block	Bio Fertilizers			
		No. of Production units	Quantity Produced in tonnes	Distribution target in Tonnes	Quantity distributed in tonnes
1	Parangipettai			13.00	13.00
2	Bhuvanagiri			11.00	11.00
3	Cuddalore	1	101	41.00	41.00
4	Kurinjipadi			35.20	35.20
5	Panruti			10.00	10.00
6	Kammapuram			11.60	11.60
	Total	**1**	**101**	**121.80**	**121.80**

Liquid bio-fertilizer unit in Cuddalore District

Liquid bio-fertilizer unit has been installed in Cuddalore on the premises of the office of the Joint Director of Agriculture at Semmandalam at a cost of Rs. 50 lakh.

The liquid bio-fertilizer produced in the unit would be filled in plastic bottles and sent to the market. The application of this fertilizer would be simple and easy.

Hitherto, the lignite based fertilizers such as azospirillium and rhizobium were being supplied to the farmers in powder form of 200gm packets. However, of late the State government had directed the fertilizer units to turn out the products in plastic bottles, for which it had evolved a formula. The regular form of fertilizers would have a shelf life of only six months, whereas the liquid bio-fertilizers could be effectively used for a period of two years.

The conventional form of fertilizers would require procedural aspects such as seed treatment and direct application, which would cause considerable delay in reaching the nutrients to the plants. In liquid form the fertilizer could be directly sprayed on the plants. The leaves would absorb the nutrients quickly.

MICRO IRRIGATION SCHEME (DRIP AND SPRINKLER IRRIGATION SYSTEMS :

Micro Irrigation is aimed at increasing the area under efficient methods of Irrigation namely drips and Sprinklers, in Horticultural and Agricultural crops. The main objective of micro irrigation is to enhance productivity, quality and profitability of the targeted crops. In Cuddalore District, this scheme is implemented by Agricultural Engineering Department for all the tree crops like Mango, Guava, Cashew, Amla, Sapota.

With increasing demand on water from various sectors, the availability of water is under severe stress. It has been recognized that the use of modern irrigation methods like drip and sprinkler irrigation are the ways for the efficient use of surface as well as ground water resources.

Under this scheme subsidy of 50% is given to farmers who install drip or sprinkler systems in their fields. The department of Agriculture is the nodal agency for Coconut and sugar cane in private sugar mills. The Department of Sugar is the nodal agency for sugar cane in the co operative sugar mills. Agricultural Engineering Department is responsible for fruit tree crops and the department of horticulture for vegetables, flowers, spices, medicinal plants and banana.

SUBSIDY DETAILS OF MICRO IRRIGATION SCHEME

Sl. No	Micro Irrigation Scheme	Nature of Farmer	Subsidy for one Hectare	Crops eligible	Max. Area allowable for one beneficiary family
	Drip Irrigation System	All farmers	50% cost of the Drip Irrigation system (or) as per GOI Guidelines based on crop spacing Whichever is less	Mango,Guava,Cashew, Amla,Sapota & Other Tree crops(Except Tea,Coffee,Rubber & Oil palm)	**5.00.0 Hectares.(Either Drip or Sprinkler or both)**

4.6 Water Saving Techniques in Crop Production

For some of the major crops grown in Paravanar basin, the following specific strategies can be adopted.

<u>Paddy</u>: The ***System of Rice Intensification***, known as SRI is a methodology for increasing the productivity of rice by changing the management of plants, soil, water and nutrients. This methodology is based on **four main principles** that interact with each other:

- Early, quick and healthy plant establishment
- Reduced plant density
- Improved soil conditions through enrichment with organic matter
- Reduced and controlled water application

The advantages are less seed requirement (5 kg / Ha), mat nursery method, young seedling transplantation (14 days old seedlings), single seedling in square planting method, water saving upto 50% using conoweeder to plough back the weeds, getting higher tillering which enhances yield and hence high income. Under 12th Five year plan (2012-2017) Agricultural Department is taking measures to cover 100% paddy area under SRI.

To encourage the farmers to go for SRI cultivation, the Government is providing an incentive of Rs.7500 per hectare under NFSM (Rice) which includes Cono weeder and other inputs. Farmers are also provided training on this method by the Agriculture Department as well as by Krishi Vigyan Kendra., Virudhachalam. In Cuddalore District, area under SRI Rice cultivation in Paravanar Basin for the year 2014-15 is 5338 Ha (Ref: Cuddalore District Agriculture Profile)

“நீர் மறைய நீர் கட்டு
நிறைய வரும் நெற் கட்டு”

System of Rice Intensification (SRI) method of Paddy cultivation

Sugarcane:

Sustainable Sugarcane Initiative (SSI) is a method that aims at providing practical options to the farmers in improving the productivity of land, water and labour, all at the same time. SSI is also expected to reduce the overall pressure on water resources and contribute to recovery of ecosystems. Sustainable Sugarcane Initiative is an innovative method of sugarcane production using less seeds, less water and optimum utilization of fertilizers and land to achieve more yields.

The major principles that govern SSI can be stated as below:

- Raising nursery using single budded chips
- Transplanting young seedlings (25-35 days old)
- Maintaining wide spacing (5 x 2 feet) in the main field
- Providing sufficient moisture through water saving efficient irrigation technologies viz., skip furrow, alternate furrow and sub surface drip irrigation
- Practicing intercropping with effective utilization of land
- Promotes mechanization in cultivation
- To promote drip irrigation, government provides 100 percent subsidy for small & medium farmers and 75 percent for large farmers

Sustainable Sugarcane Initiative (SSI)

When compared to the conventional furrows, irrigation water saving of 50% and 34.2% is achieved using Skip furrow method and Alternate furrow method respectively. In Cuddalore district, area under SSI method is 10 Ha.

Alternate Furrow Irrigation

Coconut: In the first year, irrigate on alternate days and from the second year till the time of maturity, irrigation shall be given twice a week and afterwards once in 10 days. The coconut husks at about 30 cm depth around the coconut trees at a radius of one meter and covering it up with earth will conserve soil moisture.

Use of coir waste as soil mulch around the tree to a thickness of about 3 cm is advantageous to conserve soil moisture especially under scarcity condition. By this water saving by 63 percent, yield increase by 7 percent and labour saving by 40 percent could be achieved.

Mulching

Vegetables: Drip irrigation at 75 percent of cumulative pan evaporation has registered increased yield up to 59 percent along with water saving up to 29 percent as compared to furrow irrigation at 0.8 irrigation water / cumulative pan evaporation.

With the existing area of cultivation in Paravanar Basin for some of the crops, by adopting Water saving techniques on cultivation, savings in water is given below:

Sl.No.	Crop	Cultivated area in Ha	Water requirement-conventional method (Mcum)	% of saving by adopting saving technique	Saving (Mcum)
1	SRI-Paddy	34103.49	255.05	40	102.02
2	SSI-Sugarcane	5110.71	52.90	40	21.16
3	Banana	1506.98	14.70	33.33	4.9
4	Coconut	711.11	6.01	63	3.79
5	Groundnut	4547.01	18.00	49.4	8.89
6	Vegetables	765.03	4.63	29	1.34
				Total	**142.10**

4.7 Economic benefits derived from water supply for irrigation – One hectare crop budget.

The crop budget for unit hectare involving inputs like fertilizers and other related expenditures, labour costs and net income have been worked out for irrigated wet crops and irrigated dry crops for Paravanar Basin. The cost of cultivation of crops in Tamil Nadu is also appended in **Appendix 4.1 to 4.12 of Volume-II.**

4.8 Summary

4.8.1 Conclusion

- The Gross irrigated area of crops in Paravanar Basin is reported to be 51887 Ha
- Irrigated area in Paravanar sub basin is 24686 Ha and in Uppanar sub basin is 27201 Ha.
- Out of the total area irrigated, about 66% is under paddy cultivation and 10% is under Sugarcane cultivation, remaining Pulses, Coconut and cashew.
- Net Irrigation demand of this basin at 75% dependable rainfall is 361.49 Mcum
- Net Irrigation demand of this basin at 50% dependable rainfall is 374.16 Mcum
- As per 2008 Paravanar study report, irrigation demand was given as 385.43 Mcum at 75% rainfall dependability with an irrigated area of 49,160 Ha.

4.8.2 Recommendation

- If entire paddy cultivation practice is changed to SRI cultivation 40% of water could be saved. About 102.018 Mcum of water can be saved.
- Using drip irrigation for the cultivation of Banana and Sugarcane water saving to the tune of 33.33% (4.90 Mcum) and 40 % (21.16 Mcum) respectively could be achieved.
- Using coir pith as soil mulch for coconut trees, 63% of Irrigation water could be saved. About 3.78 Mcum of water can be saved.
- Using micro irrigation method for the cultivation of Groundnut, 49.4% (8.89 Mcum) water can be saved.
- Using drip irrigation for the cultivation of Vegetables water saving to the tune of 29% (1.34 Mcum) could be achieved.
- During poor precipitation, suitable cropping pattern may be adopted with crops that require lesser irrigation like Millets, Green Manure, Fodder, Gingelly etc.
- By adopting water saving technique, irrigation demand which consumes 90% of total demand can be brought down, and that can be utilized as follows
    1. Can be used for other sectoral demands.
    2. Frequency/intensity of irrigation can be improved.
    3. This may cause benefit to the farmers.

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CHAPTER 5

SURFACE WATER RESOURCES

AND

IRRIGATION SYSTEM

CHAPTER 5

SURFACE WATER RESOURCES AND IRRIGATION SYSTEM

5.1 The River Basin

The Paravanar basin geographically lies in between latitude $11^{0}27$'N and $11^{0}43$'N and longitude $79^{0}23$'E and $79^{0}47$'E covering an area of about 872.34 Sq.km. The entire basin lies in Cuddalore district and is bounded by Pennaiyar basin in the north, Vellar basin in the south and Bay of Bengal in the east. This basin is a leaf shaped one with gentle to flat slopes having very low altitudes. Sub basins of this basin are Paravanar and Uppanar.

5.2 The River System

Paravanar river originates in the marginally high lands, Northwest of Neyveli Lignite Corporation in the Semakottai Reserve Forest area at an altitude of about 100 metres above MSL and it initially passes through Mathurai and Ammeri villages. The slope of the river course is not steep till it empties into Bay of Bengal. As it traverses in a flat terrain, the water that it carries spreads on either side of its course for a wider distance and hence it has derived the name Paravanar which means ‘Spreading river’ in Tamil.The river from its origin to Walajah tank, Walajah tank to Perumal tank and Perumal tank to the sea is called as Upper, Middle and Lower Paravanar respectively. The major tributaries to this river are Sengal Odai and Kanniyakoil odai. The flow diagram of Paravanar river is given in **Fig 5.1 & 5.2**. The irrigation System Map showing the locations of Anicuts are given in **Plate: PAR 30**

Paravanar sub basin

Paravanar sub basin covers an area of 435.016 Sq.km. Apart from Paravanar river, some minor streams also originates from this sub basin and enters into Walajah tank. The catchment area of Paravanar from its origin to Walajah tank is 186.48 Sq.km. Most of the catchment area lies in Neyveli Lignite Corporation (NLC) area. The river crosses the Virudhachalam – Cuddalore road at 46.1 Km. Because of the mining activities in the area, the course is often shifted here and there by the Neyveli Lignite Corporation. One portion of Paravanar empties in the middle of Walajah tank while the other portion empties just in front of the surplus weir cum regulator of Walajah tank, which is located at the extreme left bank of the tank. The drain which is emptying before the surplus weir cum regulator was excavated by NLC. It carries mostly a part of the pumped water of the mines. The ash-wash is carried by the pumped water and hence the water is generally black in colour. Lots of sediment is also carried by the water.

Another Odai called the Sengal odai (upper) empties along the left side, in front of the Surplus weir cum regulator of Walajah tank. The course runs on red soil and the soil has turned the colour of the water as red. Hence it is called as Sengal odai which means red course in Tamil. In addition to the drainage water of its own catchment it also carries the pumped water of NLC. Walajah tank also receives water from Vellar river through Vellar Rajan Channel taking off from Sethiathope anicut, the last anicut across Vellar.

Uppanar sub basin

The area of Uppanar sub basin is 437.33 Sq.km. The surplus course of Perumal tank is let down from the surplus arrangements at its right bank and this course joins with sea. This river is known as Uppanar. Perumal tank has three surplus arrangements, one old scour vent at Periya pattu, one by wash at Adoor Agaram and a new surplus arrangement at Poovanikuppam village.

The surplus course of Perumal tank from the surplus arrangements at its right bank is known as Uppanar (lower Paravanar) . It receives water from Upper Paravanar also, through the byewash. As there is backwater effect of the sea, the river water is saline and hence it has been named as Uppanar. This course finally confluences with Bay of Bengal at South of Cuddalore port. The length of the river course is about 25 km.

From Walajah tank, Paravanar traverses to Perumal tank. The free catchment area of this portion of the river from Walajah tank to Perumal tank is 367.62 Sq.km. and the combined catchment is 559.20 Sq.km. The length of this portion of the river (middle Paravanar) is about 9.4 km. It passes through the command area of Walajah tank and feed Perumal tank.

Before its confluence with the sea, a check dam has been constructed at Sangolikuppam across Pulikuthi Odai, a branch of Uppanar river, to avoid the sea water intrusion.

5.3 Surface Water Data

"Accurate information on the condition and trends of a country's water resource--surface and groundwater; quantity and quality--is required as a basis for economic and social development, and for maintenance of environmental quality through a proper perception of the physical processes controlling the hydrological cycle in time and space.... almost every sector of a nation's economy has some requirement for water information, for planning, development, or operational purposes." --WMO/UNESCO Report on Water Resources Assessment, p. 16.

With so many competing uses and a finite amount of water, we need to manage it in the best possible way, so that there is enough water, and of sufficient quality, for everyone. To make sound decisions, we need reliable data. The availability of surface water data in the Paravanar river basin is assessed from the flows measured from the two major tanks in the basin, namely, Walajah tank and Perumal tank.

Year wise flow data of the above two tanks for the period from 1970 to 2016 are given in **Appendix 5.1 of Vol- II**.

5.4 The Existing Surface Water Supply System

5.4.1. Existing Storage Reservoirs

There are no major reservoirs in this basin. Water needs of this basin are regulated by the two major tanks, namely Walajah and Perumal tanks and five small anicuts. The anicuts are,

1. Sengal Odai Anicut
2. Thambipettai Anicut
3. Rajakuppam Anicut
4. Sedapalayam Anicut and
5. Maruvai Anicut

5.4.2Walajah Tank

The Hydraulic particulars of Walajah tank is given in **Table 5.8**. Walajah tank is the first major tank which lies at the end of Upper reaches of Paravanar basin. It is a system tank as it also receives water from Sethiathope anicut, the last anicut across Vellar river through Vellar Rajan channel. Vellar Rajan channel also receives water from Veeranam tank through Veeranam New Supply sluices (VNSS) channel which empties into Vellar river in its right bank just about one Kilometer upstream of Sethiathope anicut. The length of the Vellar Rajan channel is 4.53 km. The carrying capacity of the channel at normal full supply depth of 1.98m is 24.07 cumec (850 cusec). However when there is higher demand, a discharge upto 28 cumec could be drawn through Vellar Rajan Channel by increasing the depth of flow by 0.30m above the normal full supply depth. After feeding a direct ayacut of 12,222 ha through nine branch channels, it empties into Walajah tank. In the command area of Walajah tank there are 8 minor tanks, which act as buffer storage to irrigate the lands under Walajah tank and the tanks are listed in **Table 5.10**. But at present there is no flow from Vellar Rajan Channel to Walajah tank. The major input to the tank is the pumping water from NLC mine II. There are 11 channels taking off from the tank sluices to feed the command area of 4612 Ha.

5.4.3 Perumal Tank

The source of supply of water to this tank is Walajah tank. It lies at the end of Middle reach of Paravanar river. The length of Middle Paravanar river which carries the surplus water from Walajah tank to Perumal tank is 9400m. Since this part of the river was very much silted up and encroached, improvements to Middle Paravanar was carried out by National water Management Project. The total command area of this tank is 2632 Ha fed by 11 channels taking off from the tank sluices. The total length of these channels is 60.36 km. But it is told by the farmers that the actual command area is still greater than this and this need to be verified.The tank has got a very lengthy bund and the length of the bund is 16 km. The hydraulic particulars of the tank and sluice details are given in **Table 5.9**. The discharge capacity of the surplus arrangement in the right bank of the tank is 13000 c/s. As the weirs are inadequate to dispose the maximum flood discharge of 18000 c/s an additional surplus regulator with 6 Nos. of vent size 5.00 m x 0.94 m each has been constructed at right side of Andarmullipallam sluice under National water

Management Project to dispose the extra flood discharge of 5000 c/s. The length of new surplus regulator is 4830 m.

5.5 Operation and Maintenance

In Paravanar basin, there are 37 tanks of which Walajah and Perumal tanks are provided with shutters on the surplus weir. There are very few tanks with uncontrolled weirs. However, the surplus weirs of all the small tanks are uncontrolled. These tanks do require periodical and annual maintenance.

Table 5.1 Tank Details of Paravanar River Basin

S.No	Name of the Sub basin	System Tank			Non System Tank		
		No	Capacity in Mcum	Ayacut in Ha	No	Capacity in Mcum	Ayacut in Ha
1	Paravanar	6	4.766	5716.75	10	3.412	1002.39
2	Uppanar	9	18.096	4254.07	12	2.15	673.15
	Total	**15**	**22.862**	**9970.82**	**22**	**5.562**	**1740.59**

For the Non-WRD tanks, the maintenance work presently undertaken by the local bodies is not adequate and necessary importance has to be given in all respects for restoring capacity as well as to avoid further deterioration.

5.6 Surface Water Potential

Surface runoff is the response of a catchment to precipitation reflecting the integrated effects of a wide range of parameters like catchment characteristics, climate and precipitation, intensity, duration, the direction of storm, orientation of the catchment, slope, soil, land use, climate, etc.

Monthly Runoff Simulation (MRS) Model assesses the surface water potential for 75% dependable yield for southwest, northeast and non-monsoon periods. The following influential rainfall stations having long-term records are considered for analysis.

Table 5.2 Raingauge stations considered for analysis

Sl. No.	Name of the Sub basin	Sub basin area (Sq.km)	No. of influencing Raingauge stations	Name of Raingauge station
1	Paravanar	435.01	4	Sethiathope Anicut, Panruti, Virudhachalam, Taluk Office, Kothavacheri
2	Uppanar	437.33	6	Sethiathope Anicut, Parangipettai, Cuddalore, Panruti, Kothavacheri, Chidambaram.
Total		**872.34**	**10**	

The Surface Water Potential may be estimated by the following methods:

1. Rainfall – Run-off Co-efficient Method
2. NWDA Approach
3. MRS Model

5.6.1 Rainfall – Run-off Co-efficient Method

Paravanar River Basin has a drainage area of 872.341Sq.km. A rational approach to obtain the Run-off of a catchment is by assuming a suitable Run-off Co-efficient.

The formula adopted to arrive at the yield, in Mcum is y = C x A x P is used, where,

A - area of catchment in Sq.km

P - weighted rainfall arrived from Thiessen Polygon

C - Run-off Co-efficient

It is a difficult process to decide the rainfall runoff factor. However, as adopted in the earlier reports prepared by IWS, runoff coefficient of 0.15 for the plains and the hilly area is nil in this basin. The runoff from each sub basin is cumulatively added to arrive at the basin yield. Surface water potential thus calculated using this method is **126.48 Mcum** as given below:

Table 5.3 Surface water Potential by Rainfall Runoff co-efficient Method

Sl. No.	Name of the Sub basin	Total Area in Sq.km	Plain Area in Sq.km	75% dependable Rainfall in mm	Surface Water Potential for Plain Area in Mcum	Total Surface Water Potential in Mcum
1	Paravanar	435.02	435.02	966.64	63.27	63.27
2	Uppanar	437.33	437.33	963.58	63.21	63.21
	Total	**872.34**	**872.34**	**966.66 (at an average)**	**126.48**	**126.48**

Annual Surface Water Potential of Paravanar River Basin calculated using Rainfall – Run-off Co-efficient Method is 126.48 Mcum at 75% dependability.

5.6.2 Surface Water Potential by NWDA Approach

Methodology adopted for working out Surface water potential:

I. The NWDA approach for working out Surface water potential is carried out in the Paravanar and Upanar sub basins of the Paravanar Basin. There are 10 rain gauge stations in Paravanar Basin. Monthly rainfall data is available for the period between 1971-72 and 2015-16. Weighted rainfall for the sub basin is computed by Thiessen polygon method using Arc GIS software.

II. Utilisations in the sub basins during monsoon period have been estimated considering the demand calculated.

III. Available observed in-flow data for Walajah tank and Perumal tank for the period from 1971-72 to 2015-16 is tabulated. By adding the inflows with the utilisations, Gross monsoon yield in Mcum is obtained. This yield, divided by the catchment area gives the Runoff in mm.

IV. Using the Runoff during monsoon and the corresponding figures of weighted average monsoon rainfall for each year for the period from 1971-72 to 2015-16, rainfall-runoff relationships are worked out based on regression analysis for the sub basin. The equation is $y = ax+b$. For Paravanar sub basin the equation is arrived as $y = 0.374x + 352.188$, for Uppanar sub basin the equation is arrived as $y = 0.348x + 420.158$.

V. The gross monsoon yield series of the sub basins for the period from 1971-72 to 2015-16 has been generated using the above equation and considering the corresponding weighted monsoon rainfall. From the yield series, the 75% dependable gross monsoon yield value of 293.89 Mcum for Paravanar sub basin and 317.08 Mcum for Uppanar sub basin are obtained.

VI. The major in-flow to the Walajah and Perumal tanks is the pumping water from NLC mine I and II . Since the observed in-flow data for Walajah tank and Perumal tank is taken into consideration while working out the surface water potential the quantity of water pumped from NLC mines is deducted from the potential arrived. Hence the surface water potential as per NWDA procedure for the sub basins is as follows:

Table 5.4 75% Dependable Surface Water Potential by NWDA approach

Sl. No	Name of Sub basin	75% Dependable Surface Water Potential in Mcum	Water pumped from NLC mines I & II	Actual potential in Mcum
(1)	**(2)**	**(3)**	**(4)**	**5 = (3)-(4)**
1	Paravanar	293.89	192	101.89
2	Uppanar	317.08		125.08
Total				**226.97**

(The details are given in **Appendix 5.4.1 to 5.4.8**.)

5.6.3 Surface Water Potential by MRS Model

(i) About the MRS Model

The Monthly Runoff Simulation (MRS) model belongs to a class of watershed models whose common base is the conservation of mass principle as applied to a watershed, requiring a balance between all the watershed water components, namely, rainfall, evaporation, surface runoff and groundwater replenishment. The models in existence differ in the inter-relationships between their various components, and their computational time-steps. Generally speaking, the shorter the time-step, the larger are the number of watershed parameters operated on by the model, and the more accurate is the model's output, conditional to the availability of data.

Perhaps, the most reputable watershed model is that developed by Stanford University, U.S.A., in the nineteen-sixties. The model operates at hourly time-steps, requiring hourly rainfall as input. The Sacramento model adopted by the U.S. National Weather Services operates at daily time-steps. Having applied these types of models in many parts of the world, it became apparent that for water resources projects in regions where the number of rainy days in a rainy month is fairly large, the model may replace the hourly and even the daily time-steps. Conversely, where the density of rain gauges is low the monthly model may even produce better results than the daily or hourly ones. These observations led to the development of the present monthly model, requiring easily accessible monthly rainfall as input. The model has since been successfully used and its applicability verified in many parts of the world having diverse climatic and geological conditions.

(ii) The MRS Model

The MRS model is a conceptual, distributed, deterministic model performing hydrological water balance computations in monthly time-steps. The inputs to the model are monthly rainfalls associated with catchment areas, mean monthly potential evapotranspiration and several empirical parameters such as a runoff coefficient and a soil moisture retention capacity. The outputs of the model are the total flow in the river, its surface and base flow components, and the recharge to groundwater (see Schematic Flowchart of the MRS model in Diagram A and Diagram B in VOL–II). The MRS model incorporates several applications such as Reservoir Operation and Probability Analysis, which are described in the next chapter. Detailed MRS Model descriptions are given in **Appendix 5.2 of Vol II**.

(iii) Model Calibration

Simulation by the MRS Model normally begins with evaluating the model parameters by way of reconstructing the model, the observed flows at a given location in the river. This process is called “model calibration”. Its application requires the input of rainfall data, usually in accordance with the Thiessen polygon method and the input of mean monthly potential evapotranspiration (PET) determined by the Penman method or by an evaporation pan adjusted by an appropriate coefficient.

It is a good practice to start calibration by force-closing the water balance (Rainfall versus all flow and groundwater components), adjust PET by way of V. Should V fall out of range, the calibration should be stopped and the input data reconsidered.

Having calibrated the model, it is then applied to long-term rainfall data, maintaining the same in Thiessen network and potential evapotranspiration.

The following are model parameters requiring evaluation, and their range as encountered in previous calibrations.

V	(evapotranspiration adjustment factor)	0.6 – 1.0
Z	(coefficient of runoff)	0.01 – 0.4
P	(fraction of impervious area)	0 – 1.0
M	SMAX (upper limit of SM)	20 – 300
C	(base flow recession rate)	0.5 – 0.98
G	GWMAX (upper limit of GW)	0 – 1000
B	(fraction of recharge becoming base flow)	0 – 1.0

The calibration process is the “trial and error”, guided by following “best fit” criteria with respect to simulated and observed (sim/obs) flows and by visual comparisons of monthly sim/obs hydrographs:

The “best fit” criteria are:

- ♦ Similarity in the annual means.
- ♦ Regression analysis yielding the highest correlation coefficient together with a small intercept in the annual regression equation.
- ♦ Same as above but monthly.

The model provides tabular and graphical facilities to implement the above mentioned comparisons and regression analysis.

Now, the following model parameters are adopted for assessment of surface water potential of Paravanar and Uppanar Sub- basins:

Paravanar Sub- basin :

V	(evapotranspiration adjustment factor)	0.7
Z	(coefficient of runoff)	0.18
P	(fraction of impervious area)	0.07
M	SMAX (upper limit of SM)	50
C	(base flow recession rate)	0.5
G	GWMAX (upper limit of GW)	500
B	(fraction of recharge becoming base flow)	0.05

Uppanar Sub- basin :

V	(evapotranspiration adjustment factor)	0.8
Z	(coefficient of runoff)	0.15
P	(fraction of impervious area)	0.055
M	SMAX (upper limit of SM)	50
C	(base flow recession rate)	0.5
G	GWMAX (upper limit of GW)	800
B	(fraction of recharge becoming base flow)	0.05

Table 5.5 75% Dependable Surface Water Potential by MRS method

Sl. No.	**Name of Sub basin**	**75% Dependable Surface Water Potential in Mcum**			
		SW	**NE**	**NM**	**Annual**
1.	Paravanar	19.78	47.71	29.26	96.76
2.	Uppanar	11.03	47.66	20.64	79.36
Total		**30.81**	**95.37**	**49.90**	**176.12**
South West Monsoon Potential **North East Monsoon Potential** **Non Monsoon Potential** **Annual Potential**		**30.81 Mcum** **95.37 Mcum** **49.90 Mcum** **176.12 Mcum**			

Surface Water Potential of Paravanar Basin is 176.12 Mcum.

The Sub basin wise MRS simulation runoff is given in **Appendix 5.3 of Vol II**.

In the Rainfall Run off coefficient method, Annual rainfall values were taken for computing the Surface water potential. In the NWDA approach, Rainfall values during the Monsoon period (June to December) was taken for analysis. The Monthly Runoff Simulation (MRS) Model considers Monthly rainfall values for computing the Surface water potential.

As the MRS model considers individual monthly rainfall values for analysis, the 75% dependable Annual Surface water potential value of 176.12 Mcum, calculated using MRS model is taken for Water Balance calculations, given in Chapter 8.

5.6.4 Quantity of water supplemented by Vellar Rajan Channel, off taking from Sethiathope across Vellar river in Vellar basin.

The total command area fed by Vellar Rajan Channel is 19,466 Ha of which the direct command area is 12,222 Ha and the balance 7,244 Ha is the command area of Walajah tank and Perumal tank, which is only 37% of the total command area fed by Vellar Rajan channel. At present, as reported by the Executive Engineer, WRD, Coleroon Basin Division, Chidambaram, there is no flow from Vellar Rajan Channel to Walajah tank. Hence, the quantity contributing to the surface water potential of Paravanar basin is taken as Nil.

5.6.5 Pumped water from Neyveli Lignite Corporation Mining area

Lignite is being mined in Neyveli area by open cut method. Below the lignite bed there is a good aquifer containing ground water under pressure. For open cast mining of Lignite, the artesian pressure has to be controlled by pumping sufficient quantity of ground water from wells arranged in a suitable pattern to cause and to maintain a local depression of groundwater level in the area of excavation. The groundwater pumping is continued round the clock since July 1961. The total discharge and the pumping pattern are being regulated according to the needs of mining operations. The quantity of water that is being pumped from the Neyveli first mine cut, at an average rate of 2.432 m3/sec or 76.70 Mcum /annum. Subsequently water was also pumped from the Neyveli second mine cut. The quantity of water that is being pumped from the Neyveli second mine cut at an average rate of 3.648 m3/sec or 115 Mcum/annum. The total average pumped quantity of water from the two units works out to 192 Mcum/annum. This quantity has been considered for arriving the Water balancing of this basin in chapter 8.

5.7 Surface Water Quality

Surface water quality deterioration is expected from the effluents led by NLC, ceramic factories in Vadalur, power plant located in and around Kurinjipadi and also from the municipal wastes. Therefore, it is suggested to create surface water sampling network for quality monitoring in the future for Paravanar river basin.

5.8 Issues in the Management of Surface Water Resources

5.8.1 Improving the Performance Of Existing Irrigation System

The source of feed to Perumal tank is Paravanar river. As the Paravanar course is drainage cum irrigation course, it will irrigate its command area during normal irrigation supply from Walajah tank. But during the flood period, as a flood carrier course, it has its own drawback of submerging its command area and it requires proper maintenance.

The limited carrying capacity of Vellar Rajan Channel is a constraint due to which the high flash floods in Vellar river of shorter duration could not be pushed through to the tanks for utilisation. In Paravanar basin, the surface system is sick and inefficient. The real problem is with the main distribution system. Drains carrying silt into the irrigation canals causes heavy siltation. The damaged and deteriorated conveyance systems including masonry structures are to be rehabilitated for their proper functioning. There is almost no control of water since most of the outlets are neither gated nor operated. The control structures are not easily approachable for regulation, measurement and monitoring the flows at various points for the system management.

5.8.2 Environmental issues

Many environmental issues are cropping up due to land and water pollution, which need immediate attention for addressing the issues. Sewage collection, industrial effluent treatment and recycling, removal of encroachments, regulation of sand/ mineral mining, optimal use of ground water, arresting seawater intrusion are some of the issues of concern.

The pumped water of NLC is let down the drains after using it in chemical plants and hence it carries unwanted chemicals in addition to silt and ash. Hence, the pumped water from NLC coming to Walajah tank is polluted by coal ash and chemicals. As the water from Neyveli mine cuts carries a lot of ash, the Walajah tank gets heavily silted up. Hence the capacity of the tank is reduced. Preventive measures must be taken to see that the water does not carry much silt.

5.8.3 Diversion of Original River Course

The original course of Paravanar has been altered by excavating a new channel by the Neyveli Lignite Corporation (NLC) at its own cost to discharge the water pumped from the mines. The Channel commences from Aziz nagar, near Kammapuram, joins with the old Pravanar course near Nallikollai village for a length of about 12 km. But the course excavation work is half way from Kammapuram to the point near Puttur Ka village. Again the new course has been excavated near Valayamadevi to the Old Paravnar Course. The reach between Puttur Ka Village and Valayamadevi is not yet excavated. Due to this diversion, the ayacut of Kathalai tank, Karivetti, M. Chozhagan, Sathapadi, U.Adhanur tank, Valayamadevi tank have been affected. A case has been filed under National Green Tribunal (SZ), Chennai for restraining them from altering or diverting or changing the old Paravanar course, vide, O.A.No. 203/2015 and M.A.No. 313/2015. The Schematic diagram of the new channel course is given in **Fig. 5.3 & 5.4**.

5.8.4 Flood Protection Measures

In general, flood occurs due to highly excessive rainfall much more than normal rainfall in a particular area. During cyclonic storms / low pressures the coastal area and adjacent coastal area of Cuddalore district receive excessive rainfall causing flood in those areas. The size of waterways and water-bodies of Paravanar basin are reduced due to weeds and siltation thereby run-off is get obstructed and cause flood. Neyveli Lignite Corporation is pumping very large quantity of water from its mines and letting that water into the water-bodies in Paravanar basin which also causing flood. In order to protect the water-bodies and waterways flood protection works were constructed in Paravanar Basin.

Table 5.6 List of Flood Protection Works Constructed by WRD in Paravanar Basin

Sl. No	Name of Work	G.O.No. & Date	Project Cost Rs. in lakh	Name of the Sub Basin	Remarks
1	Formation of flood bank and improving drainage facilities to Middle Paravanar River in Cuddalore district.	G.O (M.s) No.326 P W (I Spl.2) dt 10.11.10	680	Paravanar	Work Completed
2	Formation of Flood Bank and improving drainage facilities to Uppanar River from Thiruchopuram village to Sonanguppam village and to river Pennaiyar from Pondy-Cuddalore Highway Bridge to Thazhanguda village in Cuddalore district.	G.O (M.s) No.326 P W (I Spl.2) dt 10.11.10	1,018	Uppanar	Work Completed

5.8.5. Surface Water Monitoring and Evaluation Program

There is no discharge measuring sites in the supply and feeder channels. No S.W Flume or parshall flume exists in the channels below the irrigation sluice/ outlet. The discharge is calculated from the area of vent opening and the available driving head which is time consuming and not accurate.

The Evaluation Plan should invariably include:

1. Quantification of daily inflows received, diverted and surplused down the river.
2. Data on daily rainfall observations at the established stations in the catchment and command areas.
3. Data on daily storage in tank, discharge released through the irrigation sluice and over the surplussing weir. Revised capacity curves are required to be established from the contour survey of the tanks for those tanks which are heavily silted.
4. Determining the area irrigated season wise, crop wise, village wise, outlet / sluice wise for each tank.
5. Information on crop yields determined from sample crop cuttings in the command area.

6. Data on the no. of wells in the command of each tank, volume of water pumped in each cropping season, crop wise area irrigated exclusively from wells and in conjunctive use with surface water. Similar information should be collected for independent wells situated outside the tank command.

5.8.6. Suggestions for Meeting Future Needs

The following short term measures are suggested for effective utilization of water for irrigation :

1. By way of lining the unlined channels it would result in considerable savings and this quantum of water could be spared for other purposes.
2. Rehabilitating the channels including desilting, widening and encroachment removal etc, in order to effectively make use of the water available.
3. Equitable distribution of irrigation water by better water management.
4. In modern water management, drip and sprinkler irrigation plays a major role in effective use of the precious water to the crops and orchards which not only increase the irrigation efficiency but also the yield.
5. Conjunctive use of surface and ground water wherever possible.
6. In order to increase the overall efficiency of tank irrigation system, modernization and rehabilitation of tanks such as strengthening and standardization of earth bunds, improvements / reconstruction to the sluices, surplus arrangements, improvements to supply channels, field channels, surplus courses, providing measuring arrangements for the release of irrigation water as well as surplus water etc. to be done.
7. The invasive plants are quickly replacing our essential native plants. Innovative measures may be adopted to eradicate them and also can be managed by putting them to alternate use.
8. Action may be taken to take up drainage relief works, to protect the valuable cultivated lands from inundation.
9. Action may be taken to conduct silt surveys in tanks in this basin to find out the rate of siltation and to take suitable soil conservation measures including afforestation for these tanks.
10. Effective measures may be taken to utilize the surplus flow of Perumal tank.
11. Changing operational methods of tanks, i.e., creating special storage facilities exclusively for drought needs.

12. Renovating the old tanks and ponds, desilting of supply channel and constructing of water harvesting structures to improve irrigation potential.

13. Planning for effective rainwater harvesting and saving surface water going to sea during the flood.

14. Measures to reduce the salinity of surface water and groundwater in the coastal areas.

15. Creating more awareness among the people / stakeholders about the various issues encountered in the basin.

16. Providing better training to the farmers; educate them and carrier training to officials to meet the future challenges in the water resources sector.

5.9 Out Flows to Sea

Perumal tank is the last tank in this basin. The surplus water from Perumal tank flows to Lower Paravanar which in turn empties into the sea just south of Cuddalore Port. Apart from this, a portion of surplus water from the middle also joins lower Paravanar just below Perumal tank. In addition to this, the drainage water from the ayacut of Walajah tank and Perumal tank also joins lower Paravanar river. There is no anicut or measuring structure available at the tail end of Paravanar to know the surplus water flows to the sea. The data of surplus flow from Perumal tank is available for 45 years from 1971-72 to 2015-2016. Statistical analysis of the annual surplus flow for 25%, 50% and 75% dependability works out to 140.47 Mcum, 98.25 Mcum and 79.01 Mcum respectively. The average surplus flow is 117.54 Mcum. The reason for the large surplus flow is due to the continuous pumped quantity of water available from the NLC, in addition to the flood water generated from its own catchment.

Table 5.7 Flood surplus of Perumal tank in Paravanar basin

Sl.No.	Year		Flow in Mcum	Flow in descending Order in Mcum	m/n+1	Dependable flow in Mcum (Mcft)		
1	1971	-72	111.41	485.75	0.02	25%	50%	75%
2	1972	-73	100.31	225.12	0.04			
3	1973	-74	94.85	223.61	0.07			79.01
4	1974	-75	60.14	196.80	0.09	140.47 (4961)	98.25 (3470)	(2790)
5	1975	-76	93.00	176.49	0.11			
6	1976	-77	113.68	174.34	0.13			
7	1977	-78	151.44	160.01	0.15			

8	1978	-79	118.16	155.62	0.17			
9	1979	-80	174.34	154.63	0.20			
10	1980	-81	62.47	151.44	0.22			
11	**1981**	**-82**	**63.48**	**147.23**	**0.24**			
12	1982	-83	48.26	133.71	0.26			
13	1983	-84	105.38	132.18	0.28			
14	1984	-85	105.75	123.01	0.30			
15	1985	-86	160.01	118.16	0.33			
16	1986	-87	93.96	113.68	0.35			
17	1987	-88	93.66	111.41	0.37			
18	1988	-89	66.79	106.50	0.39			
19	1989	-90	86.22	106.49	0.41			
20	1990	-91	60.40	105.75	0.43			
21	1991	-92	90.28	105.38	0.46			
22	1992	-93	82.64	100.31	0.48			
23	1993	-94	88.75	98.25	0.50			
24	1994	-95	89.16	94.85	0.52			
25	1995	-96	61.83	93.96	0.54			
26	1996	-97	223.61	93.66	0.57			
27	1997	-98	106.49	93.00	0.59			
28	1998	-99	147.23	90.28	0.61			
29	1999	-00	123.01	89.80	0.63			
30	2000	-01	81.74	89.16	0.65			
31	2001	-02	75.86	88.75	0.67			
32	2002	-03	73.23	86.22	0.70			
33	2003	-04	106.50	82.64	0.72			
34	**2004**	**-05**	**132.18**	**81.74**	**0.74**			
35	2005	-06	176.49	76.28	0.76			
36	2006	-07	89.80	75.86	0.78			
37	2007	-08	196.80	73.23	0.80			
38	2008	-09	154.63	66.79	0.83			
39	2009	-10	155.62	63.48	0.85			
40	2010	-11	225.12	62.47	0.87			
41	**2011**	**-12**	**133.71**	**61.83**	**0.89**			
42	2012	-13	76.28	60.40	0.91			
43	2013	-14	98.25	60.14	0.93			
44	2014	-15	50.79	50.79	0.96			
45	2015	-16	485.75	48.26	0.98			
Average Flow			**117**					

5.10 Inter Basin Transfer of Water

Inter basin transfer of water from Vellar river basin to Paravanar river basin was through Vellar Rajan Channel. The Sethiathope anicut, which is the last anicut across Vellar, diverts the flood as well as normal flows to feed the Walajah tank and Perumal tank. It also diverts the normal flows to feed the direct ayacut under Vellar Rajan Channel. This system also receives the surplus water of Veeranam tank from Lower Coleroon anicut of Cauvery basin, just above the Sethiathope anicut on the right side of Vellar river. At present, the Executive Engineer, WRD, Coleroon Basin Division, Chidambaram, has stated that there is no flow/ quantity received from Vellar Rajan Channel to Walajah tank. Hence, at present the inter basin transfer of water to Paravanar basin from Vellar basin is almost Nil.

5.11 Conclusion and Suggestions:

The sub basin wise surface water potential for the basin is assessed using the following methods **1. Rainfall – Run-off Co-efficient Method 2. NWDA Approach 3.MRS Model.**

The Annual Surface Water Potential of Paravanar River Basin calculated using Rainfall – Run-off Co-efficient Method is 126.48 Mcum at 75% dependability and that by using MRS Model is 176.12 Mcum. Also the 75% dependable Monsoon yield (June to December) for the whole Paravanar river basin using NWDA approach works out to 224.97 Mcum.

As the MRS model considers individual monthly rainfall values for analysis, the 75% dependable Annual Surface water potential value of 176.12 Mcum, calculated using MRS model is taken for Water Balance calculations, vide Chapter 8.

In Paravanar river basin flow is measured in 2 tanks only. Automatic flow measuring devices may be installed in the tanks and other structures of the basin.

There has been 15 to 20 percent reduction in storage capacity of tanks due to siltation, foreshore encroachment and poor tank structures. Available water is further reduced due to poor water scheduling and losses in distribution system. Therefore necessary steps may be taken to improve and maintain the existing storage structures like anicuts, tanks etc. Availability of water can be improved by extending the period of tank storage by which it is possible to increase the recharge of ground water.

The surplus flow from the Perumal tank to sea is **98.25 Mcum** and **79.01 Mcum** at **50%** and **75%** dependability, respectively. Hence suitable action may be taken to utilize this surplus flow which flows into sea. For utilizing the above surplus flow the following proposals are proposed in Paravanar basin.

Table 5.8 New Schemes proposed in Paravanar River Basin

Sl.No.	Description of the Schemes	Cost Rs.in lakhs
1	Improving water retention capacity of Perumal tank in Kurinjipadi Taluk of Cuddalore District.	**4500.00**
2	Construction of a checkdam across Therkuveli odai near Ayikuppam Village in Kurinjipadi Taluk of Cuddalore District in Paravanar sub basin.	**121.00**
3	Construction of a checkdam across Sengal odai near Rajakuppam Village in Kurinjipadi Taluk of Cuddalore District in Paravanar sub basin.	**176.00**
4	Construction of a checkdam across Kattu odai in Peyiganattam Village near Thambipettai in Kurinjipadi Taluk of Cuddalore District in Uppanar sub basin.	**143.00**
	TOTAL	**4940.00**

Table 5.9

HYDRAULIC PARTICULARS OF WALAJAH TANK

	NAME OF TANK	**:**	**Walajah Tank**
	Maintained by (PWD / Panchayat Union)	**:**	**PWD**
1.	Name of District	:	Cuddalore
2.	Name of Taluk	:	Chidambaram
3.	Name of Block	:	Mel Bhuvanagiri & Kurinjipadi
4.	Name of		
	a) Village	:	Pinnalur, Maruvai, Karaimedu
	b) Panchayat Union	:	Mel Bhuvanagiri, Kurinjippadi
5.	Latitude Longitude	: :	$11^{o}30'$N $79^{o}37'$E
6.	Registered Ayacut	:	4610.28 Ha
7.	a) Whether this tank connected with M.S.L	:	Yes
	b) Whether the tank was standardized	:	Yes
8.	Catchment a) Free	:	-------
	b) Combined	:	186.48 Sq.km.
9.	Capacity of tank at F.T.L	:	2.57 Mcum
10.	Number of fillings	:	System tank supply from

			Vellar Rajan Channel of SAS 20 to 21
11.	Water Yield from		
	a) Catchment	:	14244 c/s
	b) Supply Channel	:	----
	c) Total	:	14244 c/s
12.	Type of Tank	:	System
13.	Name of River from which supply takes of	:	Vellar Rajan Channel of Sethiathope Anicut
14.	Head Sluice / Open Head	:	Vellar Rajan head sluice
15.	Details of Head Sluice		
	a) Sill Level	:	+10.45 m
	b) Size of Vent	:	26’. 0 “ x 8’.0”
	c) Depth of flow	:	7.5
	d) Discharge	:	850 C/S
	e) No. of days flow	:	6 Months
16.	Details of Supply Channel	:	Vellar Rajan Channel
	a) Length	:	4434 m
	b) Bed Width	:	7.62 m
	c) Depth of flow	:	7’.6”
	d) Fall	:	1 in 7000
17.	Standard of Tanks		
	a) F.T.L	:	+11.43 m
	b) M.W.L	:	+12.80 m
	c) T.B.L.	:	+14.94 m
	d)Area of Water Spread	:	0.07 Sq.km
	e)Depth of Storage w.r.to lowest sluice sill @8.38 m	:	3.05 m
	f)Capacity	:	2.57 Mcum
18.	Bund		
	a) Length	:	5.20 km
	b) Top Width		12 m
	c) Side Slopes		
	Front	:	1 ½ : 1
	Rear	:	2 : 1

19. Details of Sluice:

Name	@ LS in meter	Sill level in meter	Size of Vent in feet	Ayacut in Acre
Umaiyan Sluice	417.56	+10.30	1.6 x 1.1	150.00
Ambapuram Sluice	819.87	+8.71	1.6 x 2.8	790.00
Alambadi Sluice	1744.89	+8.38	1.0 x1.4	1081.00

Vadakkuthittai Sluice	2081.07	+9.49	1.1 x 1.3	1314.00
Thalaikulam Sluice	2116.12	+8.39	1.3 x 2.0	788.00
Krishnapuram Sluice	2207.56	+8.88	3.3 x 3.3	3014.00
Jayankondam Sluice	3007.62	+8.71	1.6 x 2.0	695.23
Kolakkudi Sluice	3007.62	+8.74	1.6 x 2.0	1164.58
Kothavacheri Sluice	3347.76	+8.91	2.2 x 3.6	1482.00
Maruvai Sluice	5141.73	+10.36	2.0 x 1.4	216.00
Arangamangalam Sluice	5086.86	+10.29	1.3 x 1.6	697.00
			Total Ayacut	**11391.81**

20. Details of Surplus Arrangements

Sl.No.	Description	Length in m	Head of Flow in m	Total Discharge
1	Weir – I	105.15	1.68	9949 C/S
2	Weir – II	37.79	1.68	3575 C/S
3	Bye Wash	105.16	1.68	720 C/S
				14244 C/S

1. Name of Upper Tank : Jamberi and Kammapuram Eri

2. Name of Lower Down tank : Sathapadi Tank, Chokkankollai Tank, Kothavacheri Tank, Nathamedu tank, Kumudimoolai Tank.

Lower down Tank Supply goes to : Kumudimoolai, Nathamedu, Chokkankollai, Sathappadi.

Whether there are any subsidiary sources benefited by this Tank. : NLC Water

Table 5.10

HYDRAULIC PARTICULARS OF PERUMAL TANK

	NAME OF TANK	**Perumal Tank**
	Maintained by (PWD / Panchayat Union)	**PWD**
1.	Name of District	Cuddalore
2.	Name of Taluk	Cuddalore
3.	Name of Block	Kurinjipadi
4.	Name of	
	a) Village	Kundiyamallur
	b) Panchayat Union	Kurinjipadi
5.	Latitude	11^{o}35’N

	Longitude	79^{o}40'E
6.	Registered Ayacut	2613.73 Ha
7.	a) Whether this tank connected with M.S.L	Yes
	b) Whether the tank was standardized	Yes
8.	Catchment a) Free	368 Sq. km.
	b) Combined	559 Sq. km.
9.	Capacity of tank at F.T.L	16.25 Mcum
10.	Number of fillings	2 to 3
11.	Water Yield from	
	a) Catchment	38894 c/s
	b) Supply Channel	----
	c) Total	36694 c/s
12.	Type of Tank	System
13.	Name of River from which supply channel takes of	Supply Sluice of Walajah Tank
14.	Head Sluice / Open Head	Walajah Tank Supply Head Sluice
15.	Details of Head Sluice	
	a) Sill Level	+33.27
	b) Size of Vent	7'. 0 " x 6'.0"
	c) Depth of flow	4'.3"
	d) Discharge	119.36 c/s
	e) No. of days flow	6 Months
16.	Details of Supply Channel	Paravanar
	a) Length	9500 m
	b) Bed Width	80 m
	c) Depth of flow	6'.6"
	d) Fall	1 in 2300
17.	Standard of Tanks	
	a) F.T.L	+5.14 m
	b) M.W.L	+6.51 m
	c) T.B.L.	+8.49 m
	Water Spread	13.12 Sq.km
	Depth of Storage w.r.to lowest sluice sill @ 1.95 m	3.19 m
	Capacity	5.14 Mcum
18.	Bund	
	a) Length	16 Km
	b) Top Width	Road Portion 18' to 28'
	c) Side Slopes :	
	Front	1 ½ : 1
	Rear	2 : 1

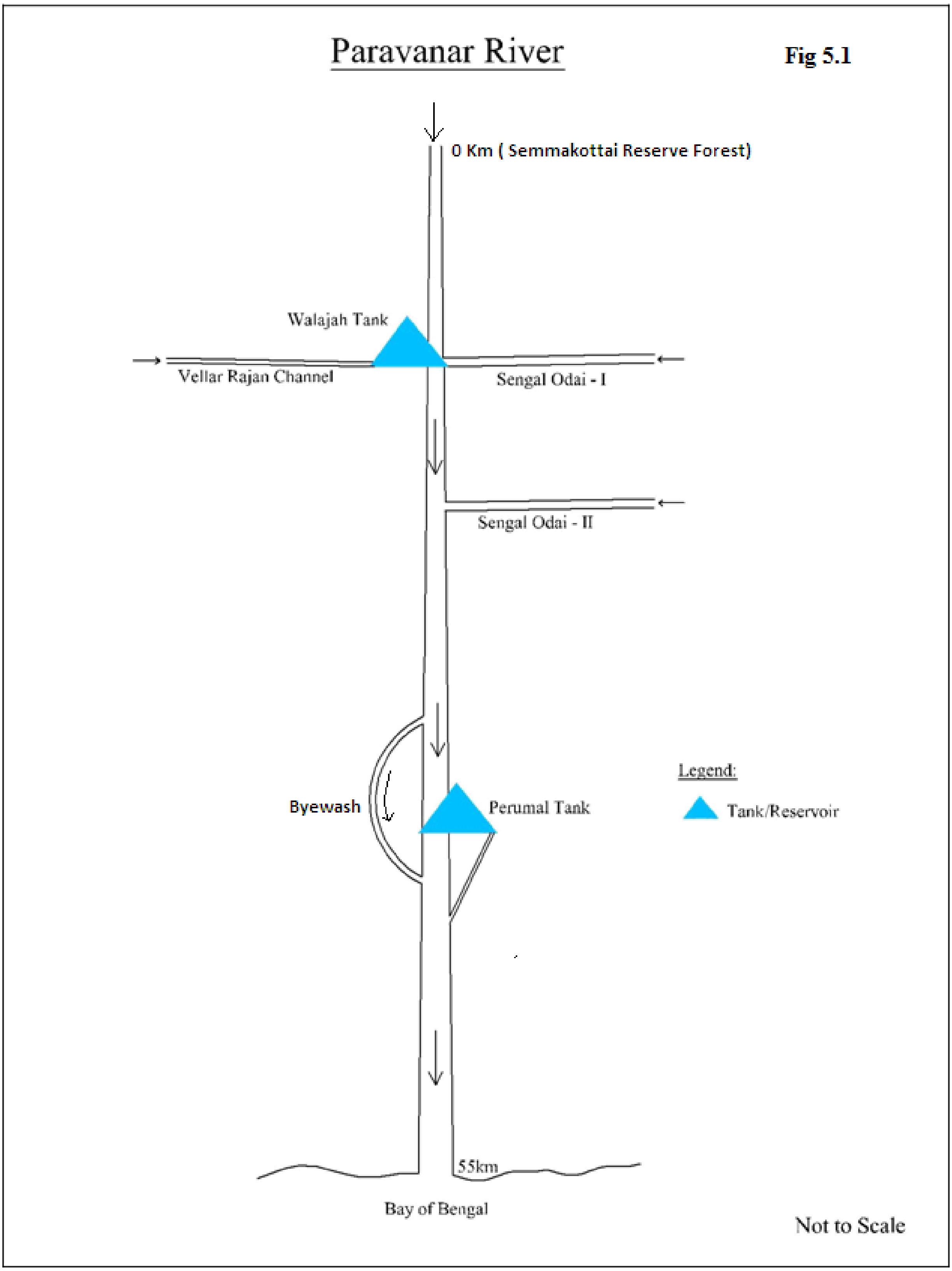
19. Details of Sluice

Name	@ LS in meter	Sill level in meter	Size of Vent in feet	Ayacut in Acre
Umaiyan Sluice	371.84	+1.95	1.60 x 1.60	850
Alappakkam Sluice	1600.12	+2.79	1.40 x 1.40	742
Andarmullipallam Sluice	2663.82	+3.66	1.60 x 2.10	615
SambareddipalayamSluice	4365.74	+2.74	1.60 x 1.60	536
New Thanur Sluice	4664.74	+1.95	1.60 x 2.00	500
Old Thanur Sluice	6343.80	+2.79	1.60 x 1.60	600
Theerthangiri Sluice	7866.50	+3.66	1.60 x 1.40	550
Sirupalaiyur Sluice	8885.40	+2.74	1.60 x 2.80	615
Kallaiyankuppam sluice	9443.77	+2.66	1.60 x 2.00	460
Mana Volkkai Sluice	11165.80	+2.79	1.60 x 1.40	470
Kundiyamallur Sluice	12459.62	+2.67	1.60 x 1.60	565
			Total Ayacut	**6503**

20. Details of Surplus Arrangements

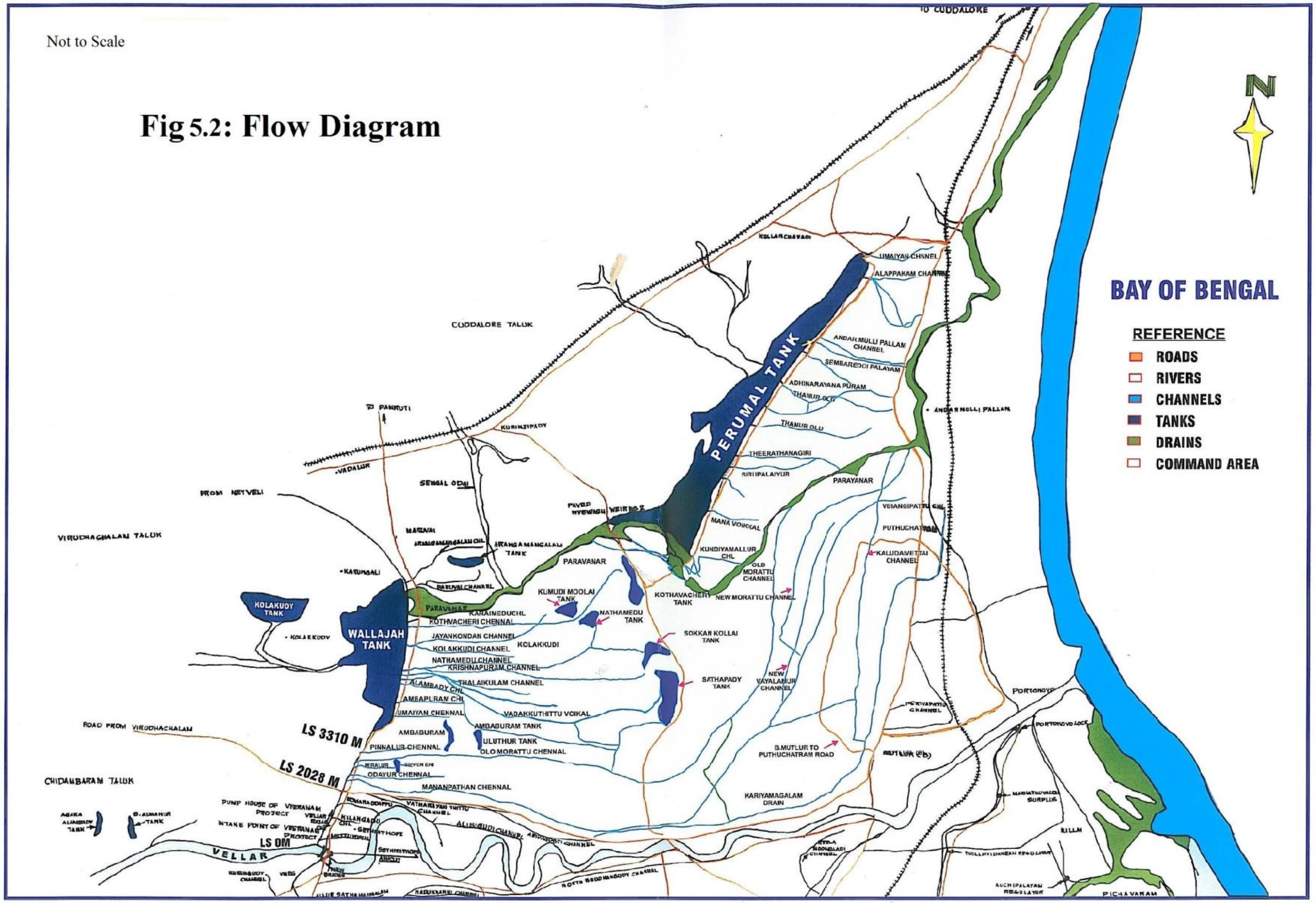
Sl.No.	Description	Length in m	Head of Flow in m	Total Discharge in Cusecs
1	Weir – I	131.67	1.98	38894
2	Weir – II	122.83	1.98	
3	Bye Wash	57.30	1.98	
4	New Surplus Regulator @ Poovanikuppam	6 x 5.50	0.91	1950
				40844

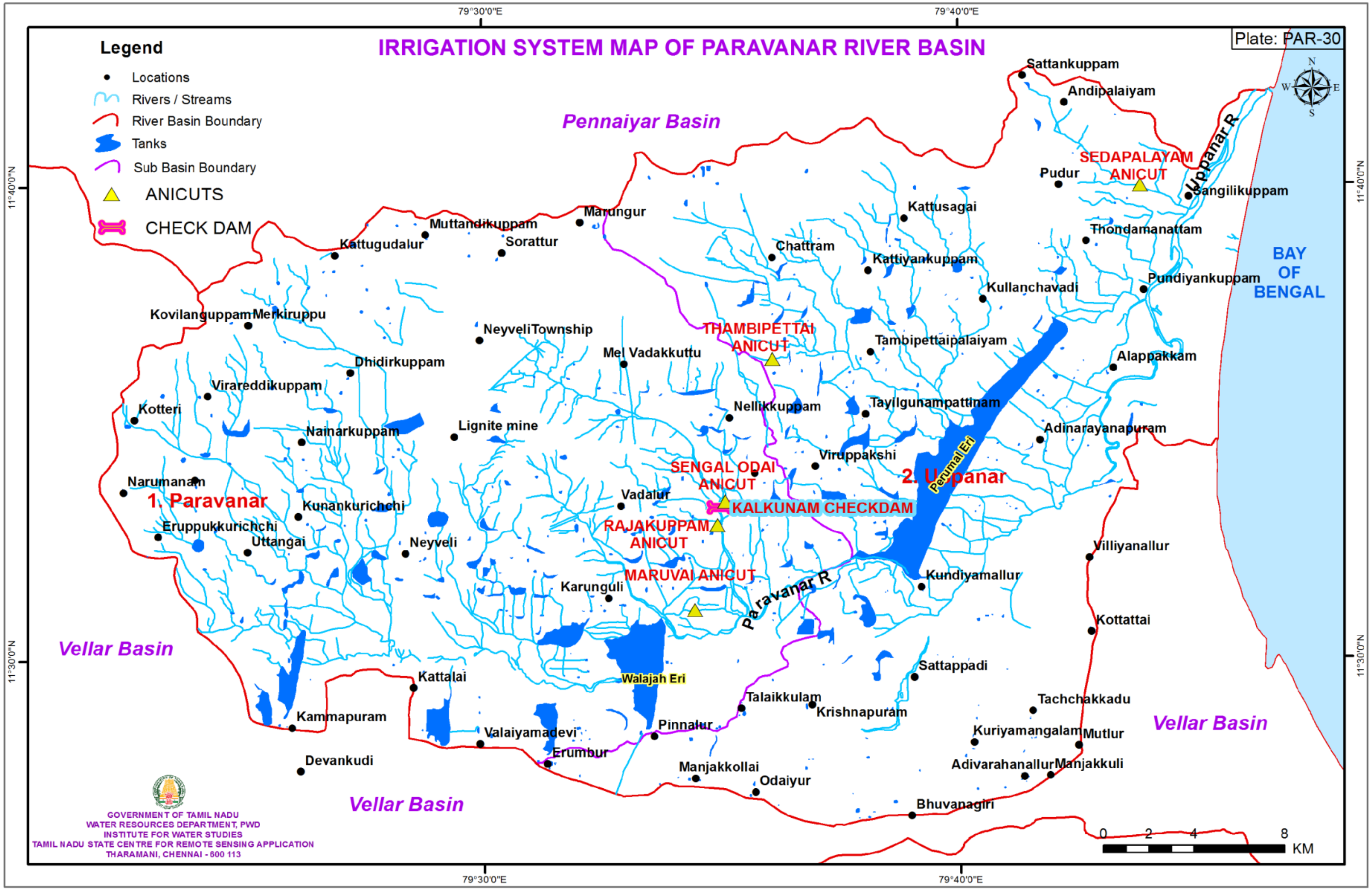
21.	Name of Upper Tank	:	Walajah Tank
22.	Name of Lower Down Tank	:	---
23.	If so, Lower Down Tank supply goes to	:	---
24.	Whether there is any subsidiary sources benefited by this tank	:	---


Paravanar River
Fig 5.1
0 Km (Semmakottai Reserve Forest)
Walajah Tank
Vellar Rajan Channel
Sengal Odai - I
Sengal Odai - II
Byewash
Perumal Tank
Legend:
Tank/Reservoir
55km
Bay of Bengal
Not to Scale

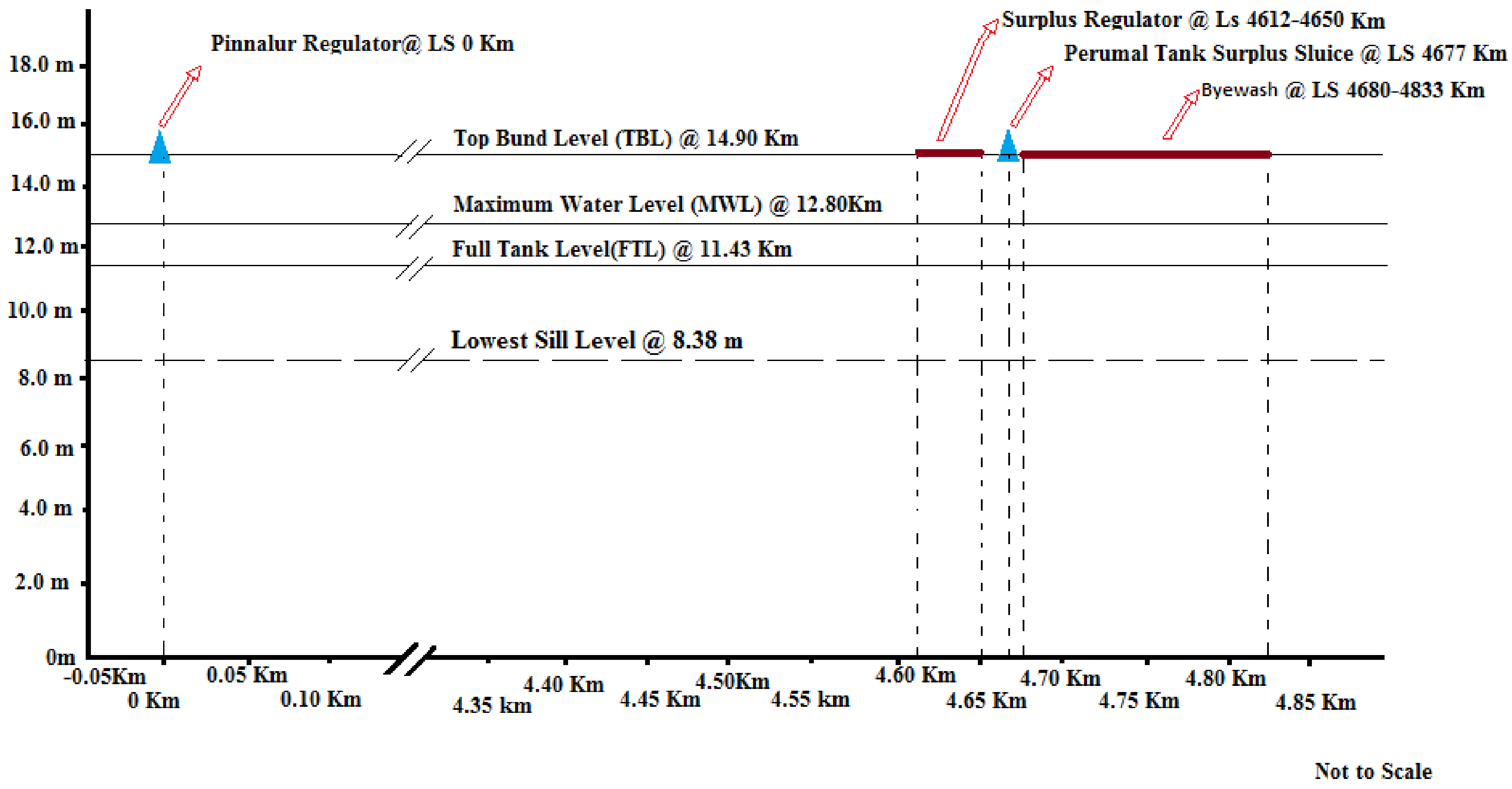
Not to Scale

Fig 5.2: Flow Diagram

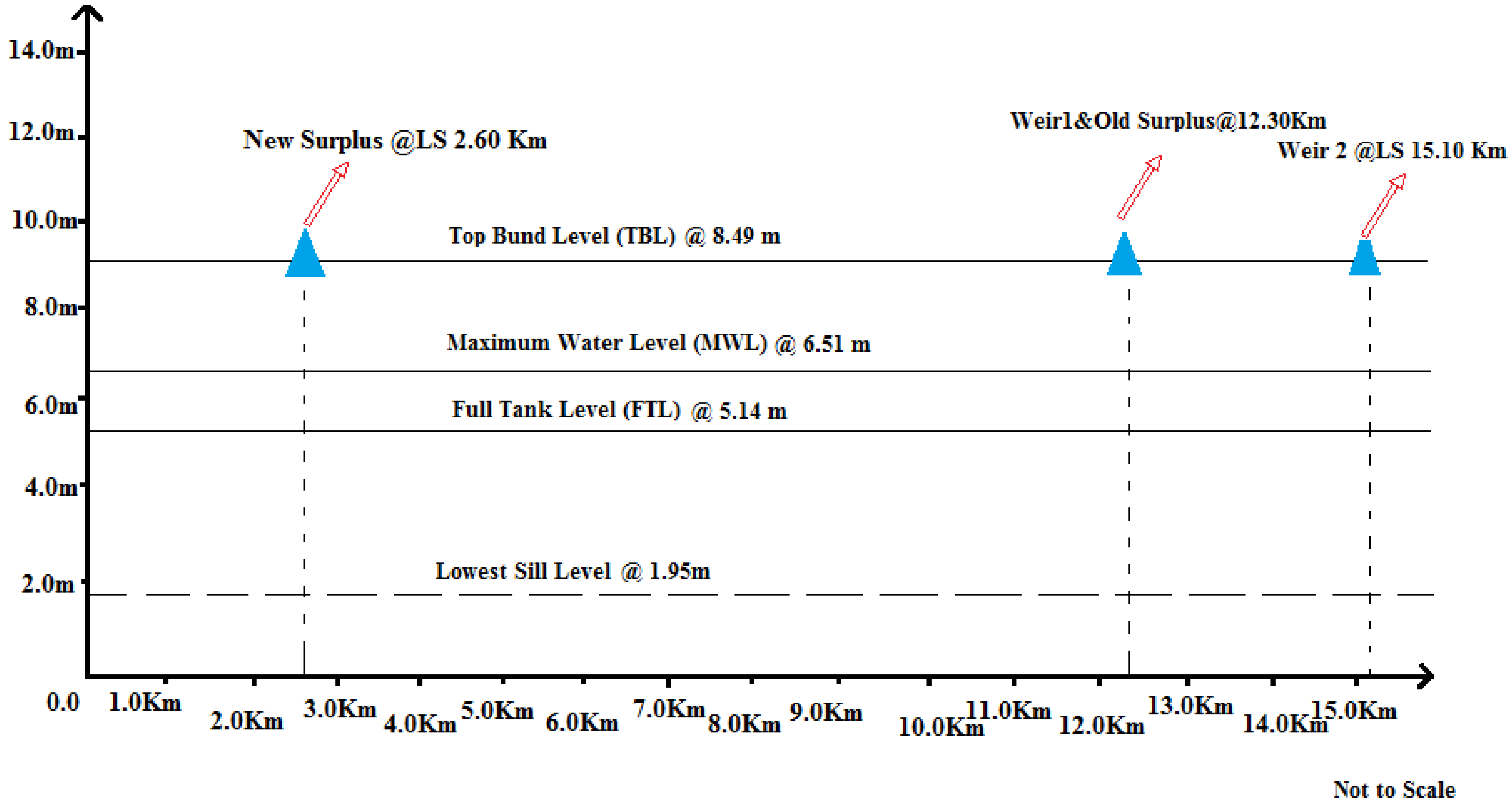



IRRIGATION SYSTEM MAP OF PARAVANAR RIVER BASIN
Plate: PAR-30
Legend
Locations
Rivers / Streams
River Basin Boundary
Tanks
Sub Basin Boundary
ANICUTS
CHECK DAM
Pennaiyar Basin
Vellar Basin
Vellar Basin
Vellar Basin
BAY OF BENGAL
1. Paravanar
2. Uppanar
Uppanar R
Paravanar R
Perumal Eri
Walajah Eri
SEDAPALAYAM ANICUT
THAMBIPETTAI ANICUT
SENGAL ODAI ANICUT
KALKUNAM CHECKDAM
RAJAKUPPAM ANICUT
MARUVAI ANICUT
Sattankuppam
Andipalaiyam
Pudur
Sangilikuppam
Kattusagai
Thondamanattam
Chattram
Kattiyankuppam
Pundiyankuppam
Kullanchavadi
Marungur
Muttandikuppam
Kattugudalur
Sorattur
Kovilanguppam
Merkiruppu
NeyveliTownship
Mel Vadakkuttu
Tambipettaipalaiyam
Alappakkam
Dhidirkuppam
Virareddikuppam
Nellikkuppam
Tayilgunampattinam
Kotteri
Lignite mine
Nainarkuppam
Adinarayanapuram
Viruppakshi
Narumanam
Vadalur
Kunankurichchi
Eruppukkurichchi
Uttangai
Neyveli
Villiyanallur
Karunguli
Kundiyamallur
Kottattai
Kattalai
Sattappadi
Talaikkulam
Tachchakkadu
Kammapuram
Krishnapuram
Pinnalur
Valaiyamadevi
Kuriyamangalam
Mutlur
Erumbur
Devankudi
Manjakkollai
Adivarahanallur
Manjakkuli
Odaiyur
Bhuvanagiri
79°30'0"E
79°40'0"E
11°40'0"N
11°30'0"N
0 2 4 8 KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

Longitudinal Section of Surplus Arrangement in Walajah Tank



Longitudinal Section of Surplus Arrangement in Perumal Tank



Details of Distribution channls in Paravanar Course

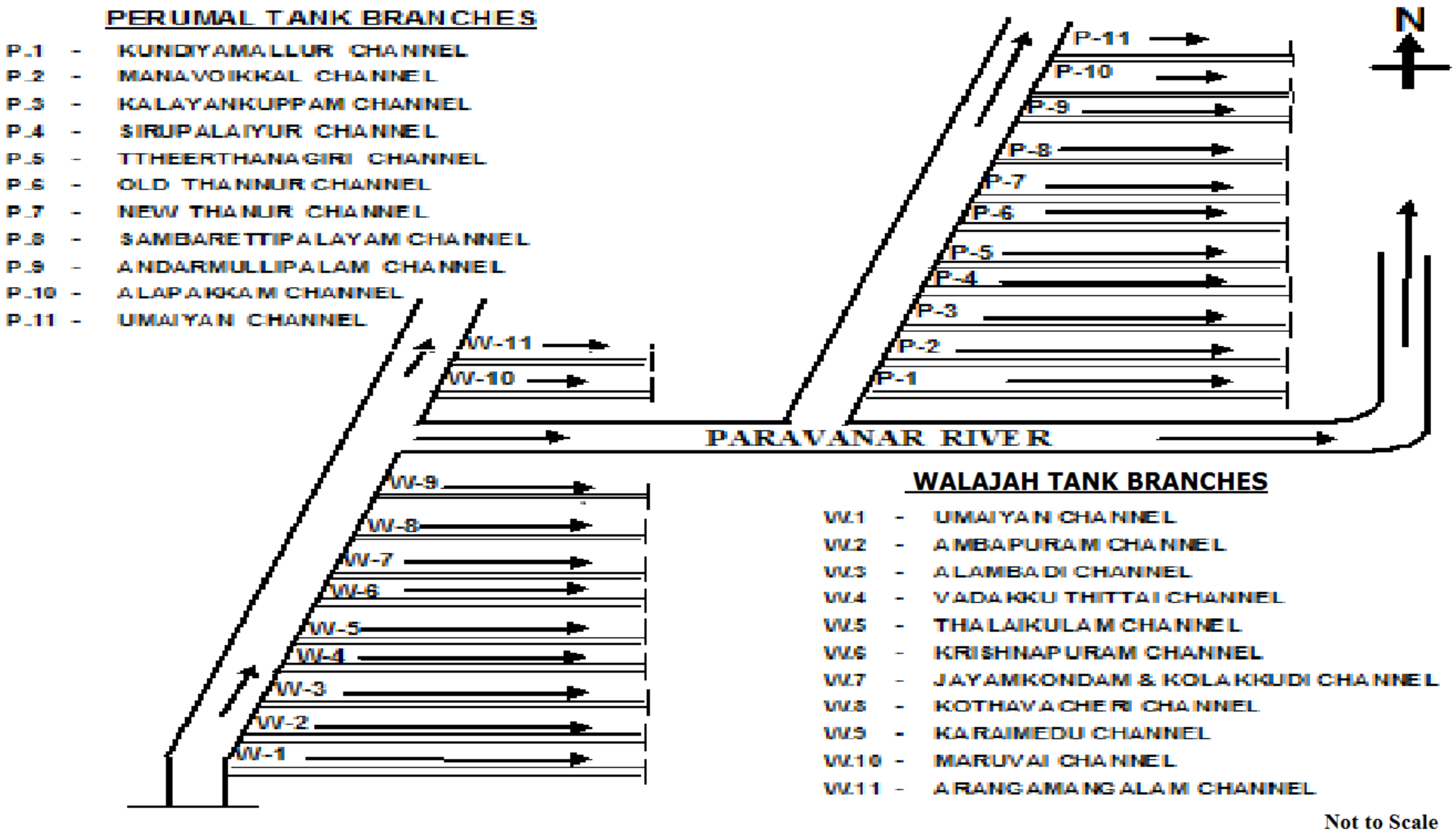
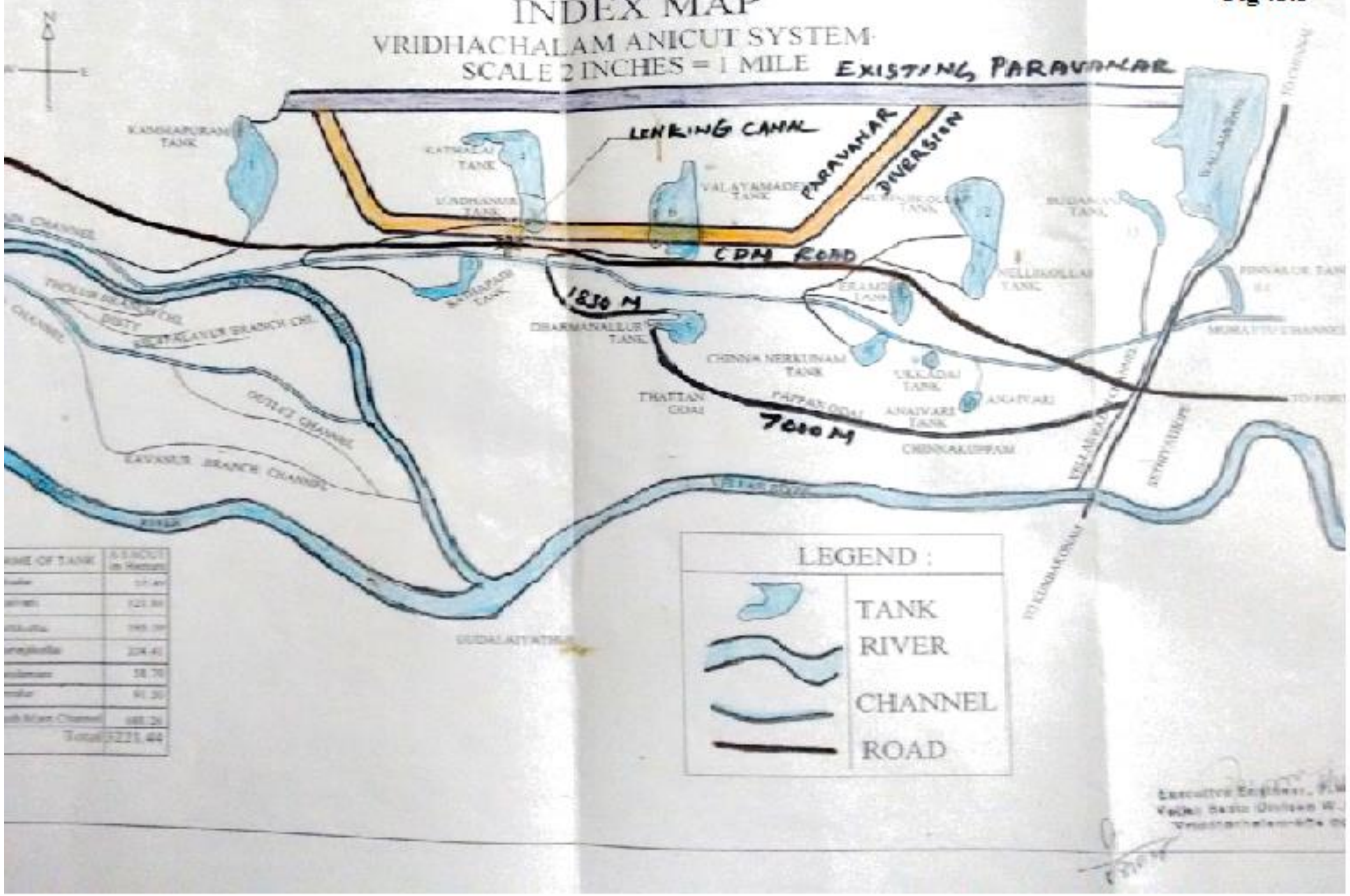


Fig :5.3


INDEX MAP
VRIDHACHALAM ANICUT SYSTEM
SCALE 2 INCHES = 1 MILE
EXISTING PARAVANAR
LINKING CANAL
PARAVANAR DIVERSION
CDM ROAD
1850 M
7000 M
KAMMAPURAM TANK
VALAYAMADEVI TANK
DHARMANALLUR TANK
CHINNA NERKUNAM TANK
THATTAN ODAI
ANAIVARI TANK
CHINNAKUPPAM
NELLIKOLLAI TANK
MUMATTU CHANNEL
OUTLET CHANNEL
LEGEND :
TANK
RIVER
CHANNEL
ROAD

NEW PARAVANAR COURSE

Fig 5.4

CHAPTER 6

GROUND WATER RESOURCES

AND

WATER QUALITY

CHAPTER 6

GROUNDWATER RESOURCES AND WATER QUALITY

6.1 Status of Groundwater

Water resources of a country are mainly classified as surface water and groundwater. Both the resources depend on the quantum of rainfall received. The major portion of the rainfall is stored in water bodies like reservoirs, tanks, lakes and ponds. A certain percentage of rainwater percolates below the ground depending on the type of soil and this stored water is called groundwater. Groundwater is tapped to meet the growing demand. Thus, there is depletion in ground water level. This has to be seriously looked into and steps should be taken to restore /recover the ground water level by suitable artificial recharge methods.

Groundwater resource plays a vital role as Nation's most valuable natural resource. Its ubiquitous occurrence, reliability and availability in all seasons have made it as the primary buffer against drought, playing pivotal role in ensuring the food security and livelihoods in many countries in the world. The total annual replenishable Groundwater Resources of India as on March 2011 has been reassessed as 433 Billion Cubic Meter (BCM) and net annual Ground Water availability is estimated at 398 BCM. Annual Groundwater draft (extraction) as on March, 2011 for all uses is 245 BCM. The stage of Groundwater Development is 62%. It is the most preferred source of water in various user sectors in India. Nearly 80% of India's domestic water needs and about 66.67% of its irrigation requirements are being met from groundwater resources (Planning Commission 2012).

Till 2009, the State Ground & Surface Water Resources Data Centre has assessed the dynamic Groundwater resources at macro size unit, viz., Block level. In 2011, the dynamic Groundwater resources estimation has been done at micro size unit, viz., Firka level. According to the 2011 report, net annual Ground Water availability is estimated at 19.38 BCM, annual Groundwater draft (extraction) for all uses is 14.93 BCM and nearly 77% of the available groundwater resources are being utilized in our State, leaving a balance of only 23% for further development and availability of groundwater resources in the State is very uneven.

Unlike stream flows, groundwater is very dependable. Ground water has emerged as the poverty reduction tool in India's rural areas. It substitutes surface water sources at the time of drought, which is a recurring phenomenon in Tamil Nadu.

For long term planning, development and management, a systematic and scientific assessment of groundwater resources is quite indispensable. The following sections explain the groundwater availability and status prevailing in Paravanar River basin.

6.2 Aquifers

6.2.1 General

While working on large and small-scale problems of groundwater hydrology, the Geologist or Engineer constantly faced with the question of finding reliable and representative values of the hydraulic characteristics of aquifers. Pumping tests in wells or bore wells play a prominent role in evaluating hydraulic properties of aquifers in different geological formations. The practical use and application of such tests have been enlarged by our recent understanding of groundwater hydraulics along with the development of methods of using the test data to calculate the principal factors for finding out the aquifer performance. The hydraulic parameters, i.e., Conductivity, Transmissivity, Specific Yield and Storage co-efficient are evaluated through pumping tests. These results are used for predicting the possible well yields, recharge rates of aquifers and also for developing optimum schemes of groundwater management.

6.2.2 Aquifer Parameters

For a quantitative understanding of most problems in hydrogeology, it is necessary to have an accurate knowledge of the aquifer parameters like co-efficient of Transmissivity (T), co-efficient of Storativity (S) and the Permeability (K). Among the various methods available for the determination of aquifer parameters, techniques involving pumping tests enjoy a leading position.

More or less 80 percent of Cuddalore district is covered by sedimentary formations of alluvial and tertiary deposits. The range of aquifer parameters for Alluvium, Tertiary, Cretaceous and Crystalline formations are furnished below:

The aquifer parameters of the geological formations in Paravanar River Basin are given in the following tables:

Table: 6.1 Aquifer parameter in Alluvium

S. No	Parameters	Range
1.	Well Yield in lps	2.50
2.	Specific Yield	7.20
3.	Transmissivity (T) in m^2/day	98.00
4	Permeability (k) in m/day	19.70

Table: 6.2 Aquifer parameter in Tertiary Formations

S. No	Parameters	Range
1.	Well Yield in lps	2.50
2.	Specific Yield	1.40 to 3.50
3.	Transmissivity (T) in m^2/day	46 to 134
4	Permeability (k) in m/day	16 to 33

Note:

lps = litre per second
m^2/day = metre square per day
m/day = metre per day

6.2.3 Groundwater Occurrence

The occurrence of groundwater depends on occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydro-chemical conditions.

Paravanar basin is encountered with hard massive formations of Granitic Gneiss, Charnockite, Pegmatites and Quartzites, which are the types of rocks encountered in the hard rock region.

All the observation wells existing in Paravanar basin area are falling in the district of Cuddalore. It is found that 39 wells are lying in Paravanar basin. An inventory of about 29 observation wells spread over the entire Paravanar basin has been scrutinized based on the availability of data, period ranging from four (4) years to forty three (43) years. The periodical water level fluctuations were examined, sub-basin wise, and geological formation wise, to understand the hydro-geological nature and groundwater occurrence.

Location details, i.e., district, sub-basin, latitude, longitude, elevation, etc. of these observation wells are presented in **Appendix 6.1.** Details of Observation Wells in Paravanar River basin are shown in **Plate: PAR 31.**

6.2.3 Occurrence of Groundwater in Paravanar River Basin.

Table 6.3 Number of observation wells in different Geological formations

Sl. No	Sub Basin	Geological formations & No of observation wells	
		Alluvium	Sand Stone
1	Paravanar	1	11
2	Uppanar	4	13

Groundwater occurrence in the two sub basins are given below:

Paravanar Sub Basin

The data of twelve (12) observation wells were analyzed and found that ground water level during post monsoon varies from 0.25 m (OW11310: Jan 2012) to 93.76 m (MWS 31582: Jan 2004) and during pre monsoon varies from 0.45m (OW11310: Mar 2012) to 95.72m (MWS 31582: Mar 2004) below ground level.

Uppanar Sub Basin

The data of seventeen (17) observation wells were analyzed and found that ground water level during post monsoon varies from 0.25m (OW11300: Jan 2012) to 25.75m (U33037: Feb 1996) and during pre monsoon varies from 0.45m (OW11300: Mar 2012) to 32.50m (U33040: May 1988) below ground level.

6.2.4 Neyveli Lignite Corporation:

A series of potential confined aquifer around Neyveli exists below the lignite seams. Lignite occurs in a series of seams between the depth range of 50m and 80m, below ground level whose thickness varies between 10m and 18m. To reduce the artesian pressure and keep the piezometric surface at safe level, extensive pumping is done, since 1961, through a battery of tube wells, and succeeded in keeping the water level at safe level below the mine floor.

6.3 Groundwater Flow Regime and Water Level Fluctuations

Monitoring of groundwater flow regime is an effort to obtain information on water levels. The groundwater regime responds to natural and anthropogenic stresses of recharge and discharge parameters with reference to Geology, Climate, Physiographic land use pattern and hydrologic characteristics. The natural conditions affecting the regime involve climatic parameters like rainfall, evapotranspiration, etc., and where as anthropogenic influences are desirable from the aquifer, recharge due to irrigation systems and other practices like waste disposal, etc.

Groundwater systems are dynamic and adjust continually to short-term and long-term changes in climate, groundwater withdrawal, and land use pattern. Water level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term systematic measurements of water levels provide essential data required to evaluate the changes in water resource over time to develop groundwater models and forecast trends; to design, implement and to monitor the effectiveness of groundwater management and protection programs.

It is imperative that water level measurements must be collected from an observation well without interruption over one or more decades in order to compile a hydrologic record that represents the potential range of natural water-level fluctuations and tracks the trend over time. But four years period is relatively short period for water level data analysis, but it is at least sufficient to provide a record of ground water level fluctuation for few seasons.

Contour maps showing the depths of groundwater table for pre monsoon and post monsoon for Jul 1984, Jan 1985, Jul 1994, Jan 1995, Jul 2004, Jan 2005, Jul 2014 and Jan 2015 have been prepared and are shown in **Plate: PAR 32 to PAR 39** respectively. Groundwater levels of the 29 observation wells are displayed in the form of hydrographs in **Appendix 6.8** for analysis of the long-term trends.

6.3.1 Water Level Fluctuations

Hydrographs of Ground water level data from 1972 to 2015 of the 29 observation wells have been prepared. Though 13 observation wells are having data for only 4 years period, they were also considered to understand the recent trend in groundwater level. The observation wells considered for the analysis, their location, period of data availability and their present condition are presented in **Appendix 6.1.**

The linear trend lines shown in the Hydrograph of observation wells were used to interpret the long-term trend in water level fluctuation. Rise or fall in water level in the range of 0-2 metre may not be significant in view of dynamic nature of groundwater resources (CGWB 2010). Hence, if long term water level depletion or rise as ascertained from the trend line, is greater than 3m, it is classified as high depletion or rise. If long term water level depletion or rise is in the range of 1-3 m, it is classified as moderate depletion or rise and if long term water level depletion/rise is in the range of 0-1 m, it is classified as slight depletion or rise.

It is observed from the 29 observation wells' Hydrograph that the long term linear trend lines of the 20 observation wells show rise and 9 wells show depletion in water level.

i) Long-term Rise in Water Level:

- High rise in water level (more than 3.00m) in the following 9 Observation Wells.

Table 6.4 High rise Observation Wells

Sl.No	Well No	Sub-Basin	District
1	U33048	Paravanar	Cuddalore
2	U33052		
3	U33056		
4	U33058		
5	U33039	Uppanar	
6	U33040		
7	U33043		
8	U33044		
9	U33045		

ii) Long-term Depletion in Water Level

- High depletion in water level (more than 3.00m) in the following 3 Observation Wells.

Table 6.5 High Depletion Observation Wells

Sl.No	Well No	Sub-Basin	District
1	OW11215	Paravanar	Cuddalore
2	OW11400		
3	MWS 31582		

iii) Annual Groundwater Level Fluctuations

Annual groundwater level fluctuations are significant in the sense that it indicates the level/degree of groundwater recharge. Annual water level fluctuation varies from 0.85 m to 9.90 m in Paravanar sub-basin and 0.98 m to 31.22 m in Uppanar sub-basin.

iv) Monsoon Groundwater Level Variation

- In Paravanar sub-basin, pre-monsoon groundwater level varies from 0.45 m to 3.32 m and post monsoon groundwater level varies from 0.25 m to 2.22 m
- In Uppanar sub-basin, pre-monsoon groundwater level varies from 10.20 m to 32.50 m and post monsoon groundwater level varies from 0.25 m to 32.22 m

6.3.2 Groundwater Flow Regime

The occurrence and movement of groundwater and its storage are controlled by the physiography, climate and the geological formation conditions like texture, lithology and structure, etc. A water table contour map serves as an important tool for finding the direction of groundwater flow. The water table contour map indicates that groundwater flows generally from west to east and north to south of the Paravanar basin.

Comparison of pre-monsoon and post-monsoon contour maps (depth to water table) for four different years (one year for a decade: Jul-84 & Jan-85, Jul-94 & Jan-95 and Jul-2004 & Jan-2005, Jul-2014& Jan-2015) have been prepared. The details of contour data are tabulated in **Appendix 6.2 of Vol-II**.

6.3.3 Groundwater Level Scenario

i) Pre-Monsoon:

In upper and down region, groundwater level is shallow (0.00m to 24.60m) during July 1984, July 1994, July 2004 and July 2014. In top region, groundwater level is deep to deeper (29.20m to77.50m) during July 1984, July 1994, July 2004 and July 2014. In tail end region, groundwater level is moderate (17.80m to 34.80m) July 1984, July 1994, July 2004 and July 2014 (Refer **Plate : PAR – 32 to PAR – 39)**.

ii) Post-Monsoon:

In upper region, groundwater level is shallow (8.20m to 27.30m) during January 1995, January 2005 & January 2015 and is moderate (21.06m to 30.35m) during January 1985. In down region groundwater level is shallow (7.40m to 27.30m) during January 1985, January 1995, January 2005 and January 2015. In tail end region the groundwater level is shallow (7.40m to 27.30m) during January 1985, January 1995, January 2005 and January 2015. In top region, groundwater level is deep to deeper (30.35m to 82.50m) during January 1985, January 1995, January 2005 and January 2015. In tail end region, groundwater level is moderate (21.50m to 38.25m) during January 1985, January 1995, January 2005 and January 2015 (Refer **Plate : PAR – 32 to PAR – 39)**.

6.3.4 Effect of Monsoon (Flash floods during October to December 2015)

Due to the very high rain fall during November & December 2015 the average groundwater level in the observation wells during December 2015 raised very significantly whilst comparing with December 2014 in Cuddalore district falling in Paravanar basin as stated below:

Sl. No	Well Type	District	Water Level - December 2014 (m)	Water Level - December 2015 (m)	Rise (m)
1	Observation Wells	Cuddalore	6.20	2.94	3.26

6.4 Categorisation of Firkas

The Chief Engineer, SG&SWRDC has categorized as on 2011, all the 1,129 revenue firkas in Tamil Nadu into Safe, Semi Critical, Critical and Over-Exploited categories depending upon the present stage of groundwater development. The criteria for categorization of assessment of firkas are as follows:

Sl.No	Stage of Groundwater Development	Categorization
1	<=70%	Safe
2	>70% and <=90%	Semi Critical
3	>90% and <=100%	Critical
4	>100%	Over Exploited

In general, the prime cause of over-exploitation is the rising demand for groundwater for agriculture. Cropping pattern and cropping intensity will alter the stress on groundwater. This problem is compounded by the free electricity/power to farmers since power is a main component in the cost of groundwater extraction. Thus power subsidy undoubtedly encouraging farmers to use groundwater (Planning Commission 2007).

Paravanar basin encompasses 13 firkas either fully or partially and all firkas are falling in Cuddalore district.

A map **(Plate: PAR 40)** showing the categorization of firkas falling in Paravanar Basin is also prepared.

The categorization of firkas in Paravanar Basin based on the level of Ground Water Development assessment as on March 2011 is given in **Table 6.6**.

Table 6.6 Categorization of Firkas

Sl. No.	Firka	District	Categorisation of Firkas (2011 Assessment)
1	Kammapuram (E)	Cuddalore	Over Exploited
2	Kammapuram (W)		Over Exploited

3	Kurinjipadi		Safe
4	Marungur		Safe
5	Sethiyathope		Semi CritIcal
6	Umangalam		Over Exploited
7	Virudhachalam (N)		Semi CritIcal
8	Bhuvanagiri		Safe
9	Kadampuliyur		Safe
10	Kullanchavadi		Safe
11	Manjakuppam		Critical
12	Parangipettai		Safe
13	Thiruvanthipuram		Over Exploited

Summary of Categorization of Firkas

Sl.No	Category	2011 Assessment
1	Safe	6
2	Semi Critical	2
3	Critical	1
4	Over Exploited	4

6.5 Groundwater Potential

6.5.1 Groundwater Potential in the State

Based on the Groundwater Estimation Committee Methodology-1997 (GEC-97), the firka wise groundwater potential was assessed as on 2011 by State Ground & Surface Water Resources Data Center (SG & SWRDC). Salient features of Groundwater Estimation Committee Methodology – 1997 (GEC-97) are given in **Appendix 6.3 of Vol II** and norms for spacing of wells are given in **Appendix 6.4 of Vol II**.

6.5.2 Groundwater Potential in the Study Area

Ground Water Potential Zone

Application of Remote sensing and GIS techniques are employed in the evaluation of groundwater potential zone in this river basin. GIS is a computerized information system with unique facilities for inputting, analyzing, overlying and managing the spatial and non spatial data. The data that was available for present study was in two forms – vector data (derived from existing map sources) and raster data (interpolated from point data or classified from satellite images). Database consists of the following themes like, geology, geomorphology, lineament, rainfall distribution, water level contour, landuse and soil were integrated and analysed. The spatial data were inverted to vector format by digitization. Buffer zones were created with 50 m width for the lineament and 75 m for the intersection of lineaments so as to study the influence and occurrence of groundwater. Interpolation techniques were used to find out the geographic values of point data such as rainfall, water level and depth to bedrock. The Inverse Distance Weighted (IDW) method was used for creating rainfall, depth to bed rock and water level map layers. IDW method with four nearest points was used in finding out the values for the unknown. In this technique, input data points surrounding a raster position are given a weight that is inversely proportional to the specified power of their distance from the pixel. Distance threshold could have been a better method but could not be used here, as the point data was sparse and distributed.

Soil layer was derived from the soil map prepared by the Agricultural University, Coimbatore on 1:50,000 scale. Slope and aspect information were directly obtained from the relief map. These theme layers were brought under GIS environment and analysed for generation of groundwater potential zone map. All data used for this analysis were converted into raster form. This was necessary as scores and weights assigned for each class in a map layer and a layer respectively, needs to be incorporated in the analysis.

Weighted overlay analysis was done in the raster form because of the excellent depth, speed and flexibility. Moreover, assigning scores for individual classes in the map layers and the weightings for the individual map layers is done in raster form in this technique. Raster data is a two-dimensional array of square grid cells. The various thematic grid layers were organized into a GIS database. The layers having various classes were organized into manageable classes through reclassification (using Arc View GIS Spatial Analyst software). Reclassification re-coded the existing attribute value for each grid cell, more appropriate to the queries being asked when the decisions to be made. The final result is in the form of a raster layer, where each grid cell acquired a value through the additive overlay process. The higher the value of the grid cell, the more preferred the cell is Groundwater Potential Zone. Thus a qualitative appraisal of groundwater potential in this river basin was made and shown in **Plate: PAR 41**.

From the analysis it is inferred that very good potential zones are identified along the river alluvium, flood plain areas of the basin and in lower portion of the basin. Very good groundwater potential is noticed in the eastern part of Kurinjipadi block and Bhuvanagiri and Parangipettai blocks. Good ground water potential zones occupied in major portion especially in the tertiary upland where cashew plantation is mostly practised. 70% of the area in Kurijipadi block has good potential. Moderate groundwater potential is noticed in the Panruti block and north of Kammapuram block. Poor groundwater potential zones are noticed in the western part of Kammapuram and eastern part of Kurinjipadi blocks.

The sub-basin wise groundwater potential and draft (extraction) are calculated from the firkas' potential and draft (extraction) on proportionate basis, i.e., based on the percentage of firka area falling in the sub-basin. The balance of groundwater potential available in each firka for further development is arrived by deducting the gross groundwater extraction from the net groundwater potential. If the balance groundwater potential is found to be negative, that negative value is ignored and the balance is taken as zero for that sub-basin. The sub-basin's groundwater potential, draft (extraction) and the balance is calculated by adding the proportionate quantity of all the firkas falling in that sub-basin.

The sub-basin wise groundwater potential, extraction and the balance groundwater potential and the stage of groundwater development are presented in **Table 6.7.**

Table 6.7 Groundwater Potential, Extraction and balance Potential

(Based on 2011 Projection)

Sl. No.	Sub-Basin	Net Annual Ground water Availability in sub basin (Mcum)	Gross Annual Groundwater Extraction in sub basin (Mcum)	Balance Annual Groundwater Availability in sub basin (Mcum)	Stage of Development (%)
1	Paravanar	124.46	227.58	32.41	182.85
2	Uppanar	148.71	95.40	74.08	64.15
	TOTAL	**273.17**	**322.98**	**106.49**	**118.23**

The firka-wise groundwater potential, extraction and balance potential available for future development are presented in **Appendix 6.5, 6.6 and 6.7 of Vol II**. The two sub-basins contribution in groundwater potential and extraction is represented in the doughnut graph in **Fig.6.1**. The inner doughnut represents the area of each sub basin, the middle doughnut represents the Net Potential of groundwater of each sub basin and the outer doughnut represents the Gross Extraction of groundwater of each sub basin.

Fig.6.1. Contribution of Each Sub Basin in Groundwater Potential and Extraction

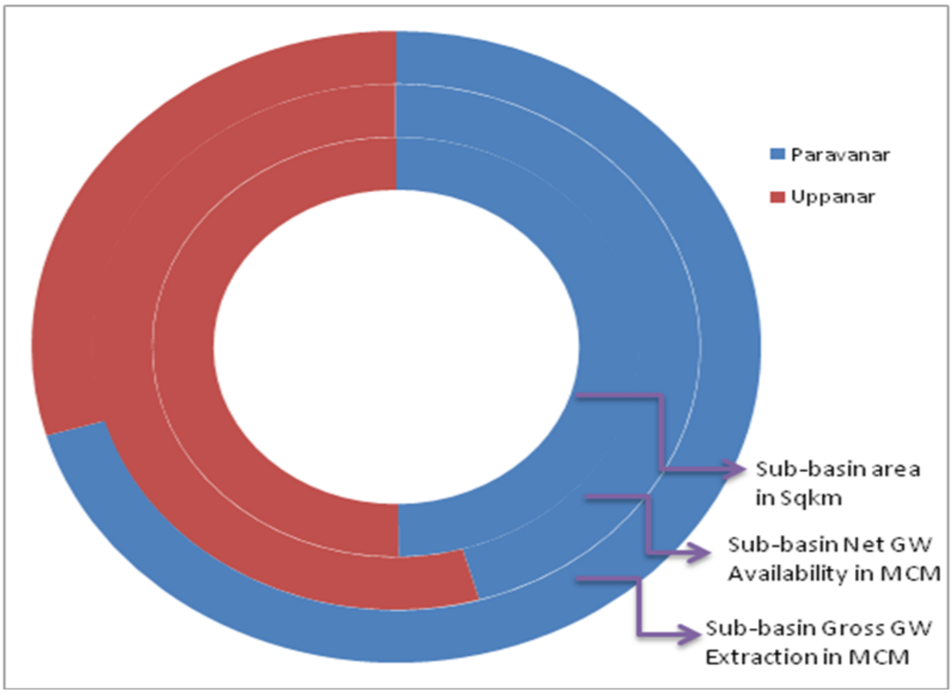
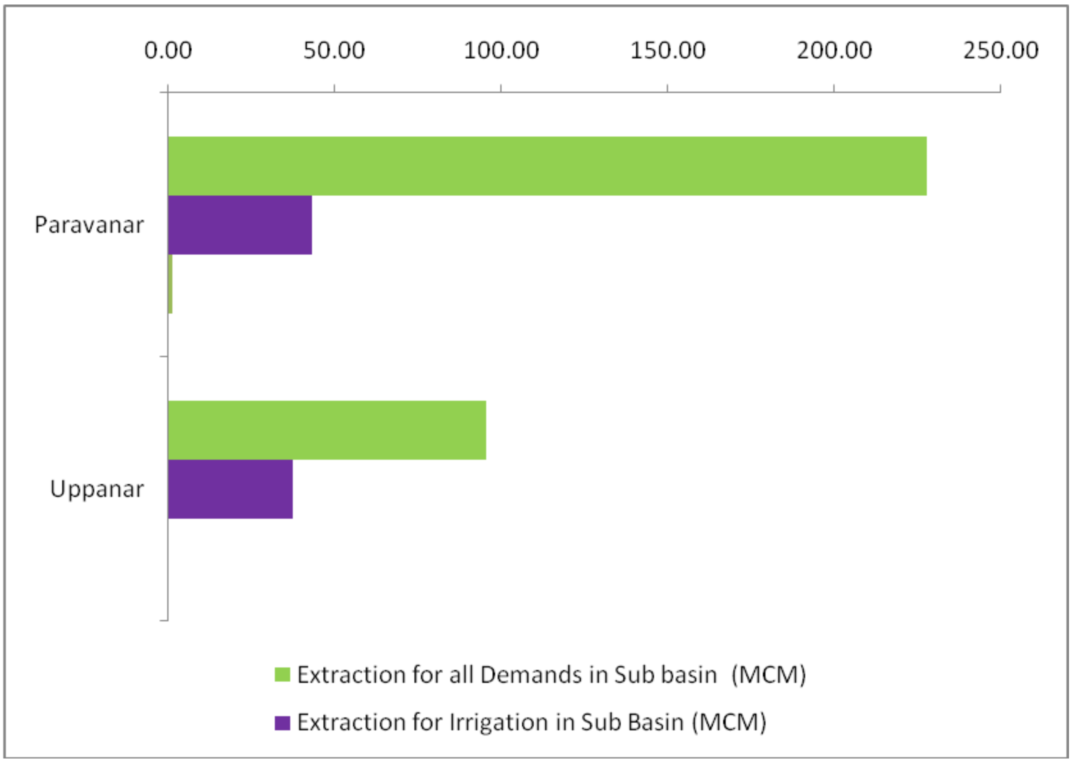


Table 6.8 shows the comparison of groundwater extraction for all demands and extraction for irrigation demand based on 2011 assessment.

Table: 6.8 Groundwater extraction for all demands and extraction for irrigation demand

Sl. No	Sub Basin	Extraction for irrigation in (Mcum)	Extraction for all demands (Mcum)	% of Irrigation demand
1	Paravanar	43.13	227.58	18.95
2	Uppanar	37.17	95.40	38.96
	Total	**80.30**	**322.98**	**24.86**

Fig.6.2 Groundwater extraction for all demands and extraction for irrigation demand



6.6. Groundwater Quality

6.6.1 Introduction

Quality of groundwater is as important as its quantity. Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water quality parameters that most affect the possible use of water.

Physical characteristics of water

Physical characteristics of water (Temperature, Colour, Taste, Odour etc.,) are determined by senses of touch, smell, sight and taste. For example temperature by touch, colour, floating debris, turbidity and suspended solids by sight, and taste and odour by smell.

Chemical characteristics of water

The chemical characteristics of natural water are a reflection of the soils and rocks with which the water has been in contact. In addition, agricultural and urban runoff and municipal and industrial treated wastewater impact the water quality. Microbial and chemical transformations also affect the chemical characteristics of water.

Inorganic indicators of water quality

Conductivity

The concentration of Total Dissolved Solids (TDS) is related to Electrical Conductivity (EC) or Specific Conductance. The conductivity measures the capacity of water to transmit electrical current. The conductivity increases as the concentration of TDS increases.

Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of salt dissolved in a water sample after the removal of suspended solids. TDS is residue remaining after evaporation of water. The spatial distribution of TDS for Paravanar basin is shown in **Plate: PAR 43.**

pH

The pH of water is defined as the negative logarithm of the $[H^+]$, where $[H^+]$ is the hydrogen ion concentration expressed in moles per litre (mol / L). The pH range is from 0 (extremely acidic) to 14 (extremely basic).

Major Cations

Calcium, Magnesium, Sodium and Potassium are the major cations in natural water. Calcium is the most prevalent cation in water.

Major Anions

Bicarbonate, Carbonate, Sulphate, Chloride, Nitrate and fluoride are the major anions in water. Bicarbonate is the principal anion found in natural water.

Hardness

Hardness represents the total concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, and is reported in equivalent $CaCO_3$. Other ions may also contribute to hardness. Hardness expressed as mg/L $CaCO_3$ is used to classify waters from soft to very hard. The spatial distribution of total hardness for Paravanar basin is shown in **Plate: PAR 44.**

Table 6.9 Classification based on Hardness

Hardness as mg/L $CaCO_3$	Classification
0 – 75	Soft
75 – 150	Moderately hard
150 – 300 Hard	Hard
>300	Very hard

Chloride

Chlorides are salts resulting from the combination of the gas chlorine with a metal. Some common chlorides include sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). The concentration of the chloride anions determines the water quality, because, the quality of water get worse due to the increase in this anion which limits the use of water for different purposes (Household, agriculture, industry etc.,). The spatial distribution of Chloride in Paravanar basin is shown in **Plate PAR 45.**

Biochemical Oxygen Demand (BOD)

Microorganisms such as bacteria are responsible for decomposing organic waste. The organic matters present in public water supply are dead plants, leaves, grass clippings, manure, sewage and even food waste. The bacteria will begin the process of breaking down these wastes. During this process, most of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live. Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high. As the waste is consumed or dispersed through the water, BOD levels will begin to decline. In addition to the above, the presence of Nitrates and phosphates in a body of water demand more oxygen and thus increase the requirement of the oxygen in the water body.

Nitrates and phosphates are plant nutrients which enable plant life and algae to grow quickly. When plants grow quickly, they also die quickly. This contributes to the organic waste in the water, which is then decomposed by bacteria. This results in a high BOD level. When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive.

Heavy Metals

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain.

Heavy metals are dangerous because they tend to **bio accumulate**. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Potential Sources of Groundwater Contamination

- **Storage Tanks**

May contain gasoline, oil, chemicals, or other types of liquids and they can either be above or below ground. If the above materials leak out and get into the groundwater, serious contamination occurs.

- **Septic Systems**

Septic systems are designed to slowly drain away human waste underground at a slow, harmless rate. An improperly designed, located, constructed, or maintained septic system can leak bacteria, viruses, household chemicals, and other contaminants into the groundwater causing serious problems.

- **Landfills**

Landfills are the places that our garbage is taken and buried. Landfills are supposed to have a protective bottom layer to prevent contaminants from getting into the water. However, if there is no layer or it is cracked, contaminants from the landfill (car battery acid, paint, household cleaners, etc.) can make their way down into the groundwater.

- **Chemicals**

The widespread use of chemicals is another source of potential groundwater contamination. Chemicals include products used on lawns and farm fields to kill weeds and insects and to fertilize plants, and other products used in homes and businesses. When it rains, these chemicals can seep into the ground and eventually into the water.

- **Atmospheric Contaminants**

Since groundwater is part of the hydrologic cycle, contaminants in other parts of the cycle, such as the atmosphere or bodies of surface water, can eventually be transferred into our groundwater supplies.

6.6.2 Objectives

The main objectives of the ground water quality assessment are as follows:

1. To understand the Ground water quality of the basin as an aid to better knowledge of the ground water regime for optimal management of ground water resources.
2. To determine long-term trends in ground water quality and to relate observed trends to human activities as a basis for informed decision-making.
3. To identify and monitor the locations of major pollutant sources.
4. To determine the ground water quality particularly with respect to its possible use as a source of drinking water, irrigation or other non-potable uses.
5. To determine the quality in the vicinity of public supply sources, threatened by point source pollution or saline intrusion, to protect the integrity of the water supply and maintain its use.

6.6.3 Data Source

The State Ground and Surface Water Resources Data Center, PWD, Tharamani, Chennai- 113, is monitoring Groundwater quality by collecting ground water samples from the observation wells in all the river basins in Tamil Nadu during the pre monsoon period (July) and the post monsoon period (January) every year since 1972 onwards. Major cations and anions are analyzed for the water samples collected from observation wells twice in a year. For this basin, water quality data of Cuddalore District were collected and the water quality assessment has been made for both the pre-monsoon and post monsoon periods for the year 2010 and 2014. Since the numbers of wells are very few, water quality data were collected from CGWB (Central Ground Water Board) and TWAD (Tamil Nadu Water & Drainage Board) in order to make the data network more dense and to improve the accuracy. The water sampling location for Paravanar basin is shown in **Plate: PAR 42.** Total Dissolved Solids, Chloride, Total Hardness, Alkalinity, Sulphate and Nitrate are considered as the deciding parameters for discussion. By using the GIS software, the water quality contour of Total Dissolved Solids, Total Hardness and Chlorides are generated.

Data from 19 observation wells were used to create the thematic maps for ascertaining the water quality status of this Basin. The water quality data of the neighboring wells were also taken for the interpolation of water quality contour. In some period of the year data from few wells are not available, due to the dryness of the well during the pre monsoon period. The sub basin wise water quality status is analyzed and given below.

Paravanar Sub Basin

Eight observation wells are in this sub basin. From the samples of the observation well, it is observed that the value of Total Dissolved Solids is found to be good i.e (<500 mg/l) in most of the wells. Rest of the wells falls within the permissible limit of 2000mg/l. Lower TDS value of 93mg/l is observed in Muthandikuppam village of Panruti taluk during the post monsoon period of 2014. Higher TDS value is observed in Santhamangalam village of Cuddalore district. Here the value observed is 1024 mg/l during the period July 2014 which is below the permissible limit of 2000 mg/l.

The chloride value falls within desirable quality range of 250mg/l in all the wells in this sub basin.

The Total Hardness value is within the desirable limit of 300 mg/l in almost all the wells while the value is within the permissible limit of 600 mg/l in a few wells.

Nitrate value is within the desirable limit of 45 mg/l in all the wells in this sub basin during the pre and post monsoon periods of 2014 and 2010. Nitrate value of 93 mg/l is observed in Neyveli village of Kurinjipadi taluk which is above the desirable limit.

From the analysis, it is revealed that, the quality of water is within the desirable limit in most of the wells, while, in some of the wells the value is moderate.

Uppanar Sub Basin

Eleven observation wells are in this sub basin. The Data from these wells reveal that the quality of water is good (<500 mg/l) to moderate (<2000 mg/l) in all the wells except Kullanchavadi village of Kurinjipadi taluk. The value of TDS ranges from 233 mg/l (Periyakumatti village of Chidambaram taluk) to 4823 mg/l (Kullanchavadi village of Kurinjipadi taluk). The high TDS value in Kullanchavadi may be due to local pollution. The value of TDS in Kullanchavadi during the post monsoon period is reduced to 363 mg/l. Generally the water quality is good during the post monsoon period due to dilution.

Regarding Total Hardness, 64% of the wells, falls within the desirable limit of 300 mg/l. 27% of the wells in the basin has moderate quality (300 – 600 mg/l) while 9 % of the wells has a poor quality which is above the permissible limit (>600 mg/l).

Chloride value ranges from good to moderate quality in all the wells except Kullanchavadi village. The high TDS eventually leads to higher chloride which results in poor quality of water. The lowest chloride value observed in this sub basin is 32 mg/l in Pathirakottai village of Cuddalore district.

Nitrate value is within the desirable limit of 45 mg/l in all the wells and the value ranges from 1 mg/l to 22 mg/l in this sub basin.

Generally the water quality is good to moderate in this sub basin.

6.6.4 Water Quality and Irrigation

Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the deciding parameters for irrigation water quality.

Table 6.10 Water Quality for Irrigation

Well_No	Village	Latitude	Longitude	EC	SAR	RSC
U33052	Muthandikkuppam	11.650	79.479	260	0.52	-0.60
HP31544	Kilpalaiyur	11.453	79.422	590	2.49	0.10
HP31546	Puduchathiram	11.542	79.723	940	6.34	0.80
U33087	Lalpuram	11.417	79.683	1940	5.96	-2.80
U33039A	Kullanchavadi	11.628	79.672	9030	12.21	-23.68
U33048	Abatharanapuram	11.561	79.554	640	1.72	-2.01
U33085A	Odaiyur	11.454	79.596	2520	8.72	6.80
HP31580	Vadalur	11.554	79.556	570	1.46	-1.38
OW11403	Pathirakottai	11.706	79.621	370	0.77	-1.32
HP31582	Marungar	11.655	79.535	230	0.30	-0.76
U33045	Vazisothanaipalayam	11.689	79.728	780	2.05	-1.79
INV31457	Kiliyanur	11.425	79.590	2270	5.88	-4.09
OW11314	Periyakumatti	11.489	79.716	410	1.33	-0.76

795	Neyveli	11.558	79.483	1220	3.17	-1.30
797	Santhamangalam	11.519	79.370	1600	3.04	-2.19
798	Vadalur	11.538	79.542	590	4.70	1.50
808	Annavalli	11.673	79.730	470	0.00	-0.67
809	Karaikadu	11.679	79.736	1025	0.00	-2.10
810	Vengadampettai	11.616	79.601	530	0.00	-1.92

Electrical Conductivity

The conductivity increases as the concentration of TDS increases. A lesser EC value is most suitable for irrigation (<2250 umhos/cm).

In Paravanar basin, the EC value is within the limit and the water is well suited for irrigation and it is practiced in the basin throughout the year.

Sodium Adsorption Ration (SAR)

Sodium adsorption ratio is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentration of solids dissolved in the water. The formula for calculating sodium adsorption ratio is:

$$\text{S.A.R.} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

The higher, the sodium adsorption ratio, the less suitable, the water for irrigation. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilt. This will lead to a decrease in infiltration and permeability of the soil to water leading to problems with crop production.

The **SAR value in this basin is within the range** and there is no particular problem in this basin.

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate index of irrigation water or soil water is used to indicate the alkalinity hazard for soil. The RSC index is used to find the suitability of the water for irrigation in clay soils which have a high cation exchange capacity. When dissolved sodium in comparison with dissolved calcium and magnesium is high in water, clay soil swells or undergoes dispersion which drastically reduces its infiltration capacity.

RSC is expressed in meq/l units.

The formula for calculating RSC index is:

$$\text{RSC index} = [HCO_3 + CO_3] - [Ca + Mg]$$

The RSC value in this basin is very less and hence there are no particular issues regarding RSC.

As far as Paravanar basin is considered about 50% of the basin is under irrigation. The major sources of water for irrigation are Perumal eri and Walajah eri. The water quality in the basin is of good to moderate quality and is suitable for agriculture.

Water quality related problems in irrigated agriculture

Salinity

Salts in soil or water reduce water availability to the crop to such an extent that yield is affected. The salinity in the basin is less and it has no impact in the yield.

Water Infiltration rate

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltered to supply the crop adequately from one irrigation to the next.

Since the SAR value is less, the infiltration rate and permeability of the soil is higher in the basin.

Specific ion toxicity

Certain ions (Sodium, Chloride or Boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields. No such specific ion toxicity is found in the basin.

Miscellaneous

Excessive nutrients reduce yield or quality, unsightly deposits on fruit or foliage reduces marketability, excessive corrosion of equipment increases maintenance and repairs. There are no excessive nutrients in the water sample and the problems due to it is nil in this basin.

Approach to Evaluating Water Quality

The four problems viz., Salinity, Infiltration, Toxicity and Miscellaneous are used for evaluation. Water quality problems are often complex and a combination of problems may affect crop production more severely than a single problem in isolation. The more complex the problem, the more difficult it is, to formulate an economical management programme for solution.

If problems do occur in combination, they are more easily understood and solved if each factor is considered individually. A number of factors are evaluated for each of the problem areas such as,

- The type and concentration of salts causing the problem
- The soil - water plant interactions that may cause the loss in crop yield
- The expected severity of the problem following long term use of the water
- The management options that are available to prevent, correct or delay the onset of the problem.

6.6.5 Measures to prevent the groundwater pollution:

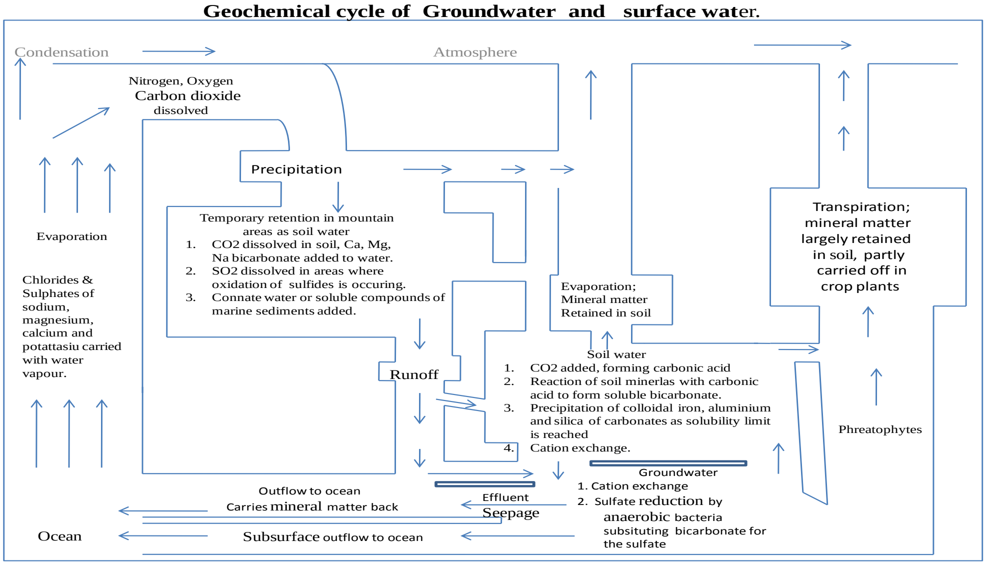
- Maintain the well and test the water quality annually.
- Keep household chemicals, paint and motor oil away from the water source such as well and dispose of them properly by taking them to a recycling center or household hazardous waste collection site.
- Restricting the use of pesticides and fertilizers.
- Install a well cap and keep it clear of leaves, mulch, dirt, and other materials.

- Practicing water conservation measures in the home and install low water use appliances.
- Effluents from sewage waste have to be properly treated and then only led into the rivers and streams. Otherwise, the metals, especially heavy metals such as iron, chromium, lead etc., may straight away seep into the groundwater table and pollute the entire water.

6.6.6 Conclusion

- Paravanar river basin is mainly covered by sedimentary formation and 70% of the basin is covered by Cuddalore sandstone of tertiary age consisting of laterite, sandstone, clay silt, sand etc. 30% is covered by river alluvium and coastal alluvium. The river basin is mainly restricted to tertiary and quaternary formations.
- pH value lies within the permissible limit of 6.5 to 8.5 in almost all the wells of this basin.
- Generally the water quality is good in Paravanar sub basin while in Uppanar sub basin the quality ranges from good to moderate quality. Higher TDS is observed in Kullanchavadi village of Kurinjipadi taluk. This may be due to local pollution.
- The nitrate value is within the permissible limit of 45 mg/l in all the wells in this basin. Value higher than 45 mg/l is observed in Neyveli village of Kurinjipadi taluk. The value observed is 93 mg/l and it may be due to the use of excessive fertilizers.
- Fluoride value is within the permissible limit of 1.5 mg/l in all the wells in this basin.
- Perumal eri and Walajah eri are the main sources of irrigation in this basin and about 50% of the basin area is under cultivation.
- In general, the quality of groundwater is “good to moderate” in Paravanar basin.
- Recharging rain water into the aquifers helps in utilizing the primary source of water and thereby improving the quality and quantity of existing groundwater through dilution.

Geochemical cycle of Groundwater and surface water.



6.7 Management of Groundwater Resources

Studies show that groundwater recharge and discharge conditions are reflection of the precipitation regime, climatic variables, landscape characteristics and human impacts. Hence, predicting the behavior of recharge and discharge conditions under changing climate is of great importance for groundwater conservation & management.

The groundwater crisis prevailing in the State is not the result of natural factors; it has been caused by anthropogenic actions. The number of wells drilled for irrigation both for food grains and for cash crops have rapidly and indiscriminately increased. India's rapidly growing population and changing lifestyles have also increased the domestic water demand. The water requirement for the industry also shows an overall increase. Hence, management of groundwater is extremely complex and it requires a combination of supply side and demand side management as described in the following sections.

6.7.1 Supply-side Management of Groundwater

Constructing Artificial Recharge Structures like check dams, percolation ponds, recharge pits, shafts or wells are considered to be the best option in rural areas for recharging groundwater where soil condition is favourable. On the other hand, roof-top rainwater harvesting, either for storage and direct use or for recharge into the aquifers is suited for urban habitations with its characteristic space constraints.

Structural measures have been taken by the Government to increase the groundwater availability. Various State Government agencies such as Water Resources Department, Agricultural Department, Agricultural Engineering Department, TWAD Board and Forest Department with and without Central Government assistance have taken up augmentation of ground water resources through artificial recharge structures.

Success of Artificial Recharge Structures (ARS) depends largely on geological and hydrological features of an area, site selection and design of ARS. While percolation ponds, check dams, recharge shafts and sub-surface barriers are effective structures in hard rock areas, recharge trench and recharge tube wells are more suitable in alluvial areas. In the coastal tracts, tidal regulators which impound the fresh water upstream and enhance the natural recharge, help control salinity ingress effectively. In case of urban areas and hilly terrains with high rainfall, roof top rain water structures are most useful.

Data pertaining to ARS constructed in the recent years were obtained from State Ground & Surface Water Resources Data Centre, WRD, PWD, Chief Engineer, Chennai Region, WRD, PWD and Agricultural Engineering Department. About 111 ARS works were completed in this basin through WRD and other departments. The details of ARS constructed in Paravanar basin are given in **Table 6.11 & Table 6.12**.

Table 6.11 List of Check Dams and ARS constructed by WRD in Paravanar Basin

Sl. No	Name of Work	G.O.No. & Date	Project Cost Rs. in lakh	Name of the Sub Basin	Remarks
1	Construction of Check Dam with Recharge Shaft across Nalodai near Sathipattu Village in Panruti taluk in Cuddalore district.	G O Ms No : 222 / PW (R2) Dept/dt 01.11.11	42.25	Paravanar	Work Completed
2	Construction of Check Dam with Recharge Shaft across Vadakku Odai near Karuppanchavadi Village in Kurinjipadi taluk of Cuddalore district.	G O Ms No : 222 / PW (R2) Dept / dt 01.11.11	24.20	Uppanar	Work Completed

Table 6.12 List of ARS constructed by AED in Paravanar Basin

Sl. No.	Sub Basin	Blocks	Type of ARS	No. of ARS
I. ARS in Over Exploited Blocks				
1	Paravanar	Kammapuram	Check Dam	6
			Percolation Pond with Recharge Shaft	1
			New Village Tank	1
2	Uppanar	Cuddalore	Check Dam	18
			Recharge Shaft	9
			Form Pond	2
II. ARS in Semi Critical Blocks				
1	Paravanar	Bhuvanagiri	Form Pond	10
2	Uppanar	Panruti	Check Dam	4
			Recharge Shaft	2
		Bhuvanagiri	Form Pond	5
III. ARS in Safe Blocks				
1	Paravanar	Kurinjipadi	Check Dam	1
		Virudhachalam	Check Dam	5
		Kurinjipadi	Form Pond	1
2	Uppanar	Kurinjipadi	Check Dam	25
			Recharge Shaft	5
			Percolation Pond with Recharge Shaft	2
			Form Pond	1
		Parangipettai	Form Pond	11

6.7.1.1 Artificial Recharge Measures

Kammapuram(E), Kammapuram(W) & Umangalam firkas in Paravanar sub-basin and Thiruvanthipuram firka in Uppanar sub-basin require intensive groundwater augmentation to restore the ground water in aquifers. Hence, promising groundwater recharge sites are identified with the application of GIS after giving appropriate weight-age for spatial and non-spatial parameters like geo-morphology, geology, lineament, depth to bed rock, soil, aquifer and rainfall level. Check dams and recharge shafts are proposed in “Over Exploited”, “Semi Critical” firkas to improve the groundwater potential. The details of the recommended Artificial Recharge Structures are given in **Table 6.13.**

Table 6.13 ARS Recommended by IWS and their Details

Sl. No	Details of proposed ARS	Location	Latitude	Longitude	Sub basin	Firka
ARS Recommended in Over Exploited Firkas						
1	Check Dam	Mudanai across stream flowing through mudanai village	79.4121	11.5692	Paravanar	Umangalam
2	Percolation Pond	Uttangal Mangalam RS	79.4226	11.5448	Paravanar	Umangalam
3	Percolation Pond	Vriddhagirikupp am	79.3884	11.558	Paravanar	Umangalam
4	Vertical Shaft	Ammeri RF	79.4184	11.5813	Paravanar	Umangalam
5	Vertical Shaft	Vadakku Vellur Big tank	79.4002	11.5402	Paravanar	Umangalam
6	Vertical Shaft	Terkiruppu Big tank	79.4286	11.6228	Paravanar	Umangalam
7	Check Dam	Kattalai across stream flowing through Karaimedu village	79.4777	11.4999	Paravanar	Kammapuram (W)
8	Vertical Shaft	Kammapuram Big Tank	79.4295	11.4873	Paravanar	Kammapuram (W)
9	Vertical Shaft	Kammapuram Small Tank	79.4256	11.4807	Paravanar	Kammapuram (W)
10	Vertical Shaft	Sattankuppam	79.6918	11.7017	Uppanar	Kammapuram (W)
11	Vertical Shaft	Ramapuram	79.6956	11.6868	Uppanar	Kammapuram (W)
ARS Recommended in Critical Firkas						
12	Check Dam	Amalyampettai across the river Uppanar	79.7214	11.5956	Uppanar	Manjakuppam
13	Check Dam	Sangolikuppam across the river Uppanar	79.7487	11.6565	Uppanar	Manjakuppam
14	Percolation Pond	Chonakanchavadi	79.7339	11.6388	Uppanar	Manjakuppam

ARS Recommended in Semi Critical Firkas						
15	Check Dam	Tiruvennainallur across stream flowing through Tiruvennainallur village	79.5716	11.5079	Paravanar	Sethiathope
16	Vertical Shaft	Valayamadevi Big tank	79.4837	11.4791	Paravanar	Sethiathope
17	Vertical Shaft	Erumbur Big tank	79.5199	11.4789	Paravanar	Sethiathope

Before constructing ARS in the above recommended sites (ref table 6.12), it is necessary to carry out a detailed study for each site taking into consideration of the rainfall, maximum surface runoff, the quantity of water available, geological and geomorphological characteristics, etc.

6.7.2 Demand-side Management of Groundwater

In general, irrigation sector consumes a larger share of ground water. So, water saving techniques in irrigation should be adopted. In Paravanar basin, groundwater extracted for irrigation is worked out as 80.30 Mcum while the total extraction is 322.98 Mcum, that is, only 24.86% of groundwater is being extracted for irrigation purpose.

Table: 6.14 Ground Water Potential and Demand as per 2011 Assessment

Sl. No	Sub Basin	Net Annual Ground-water Availability (Mcum)	Gross Annual Extract-ion for irrigation (Mcum)	Gross Annual Extract-ion for other purposes (Mcum)	Gross Annual Extract-ion for all demands (Mcum)	Irrigation demand in total demand (%)
1	Paravanar	124.46	43.13	184.45	227.58	18.95
2	Uppanar	148.71	37.17	58.23	95.40	38.96
	Total	**273.17**	**80.30**	**242.68**	**322.98**	**24.86**

Since the irrigation demand is only 18.95% in Paravanar basin, it is obvious that other sectoral demand like domestic, industrial are high in Paravanar basin especially in Umangalam firka due to rapid industrial growth and urbanization. In order to control the demand side management of groundwater in Paravanar basin, it is necessary to curtail the wastage to the maximum possible limit in domestic and industrial sectors.

6.8 Summary

It is found that 39 wells are lying in Paravanar basin and an inventory of 29 observation wells spread over the entire Paravanar basin has been scrutinized for study purpose based on the availability of data period, ranging from four (4) years to forty three (43) years. Sub basin-wise groundwater potential, extraction and balance have been worked out. Long-term trend in water level fluctuation has been analyzed and pre-monsoon & post-monsoon contours maps of shallow aquifers are drawn.

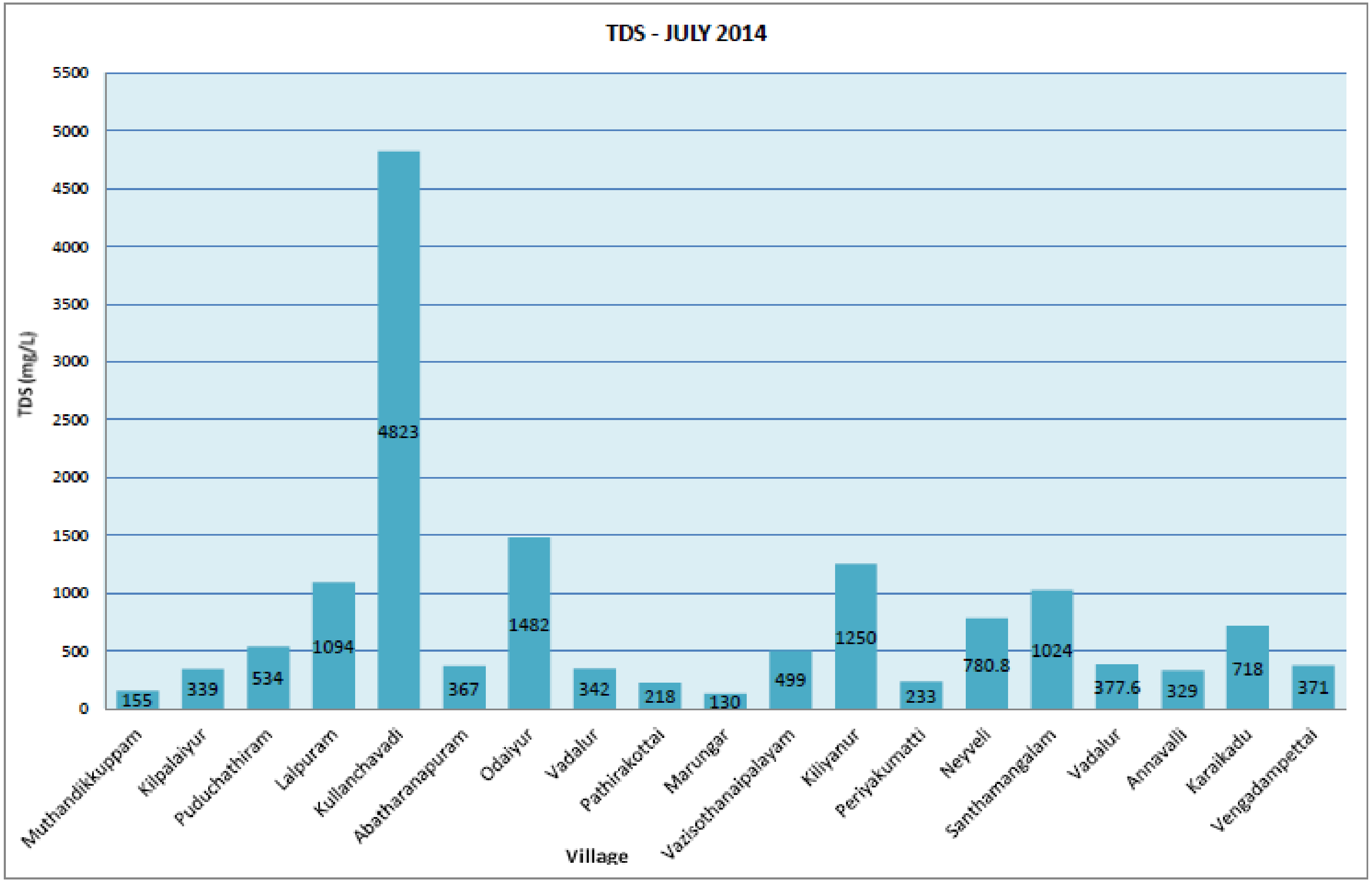
Findings:

- ❖ Hydrographs (depending on available of well data from 1972 to 2015) of the groundwater depths for the 29 observation wells have been prepared.
- ❖ Long-term water depth rise found in 20 observation wells and high rise in water depth (more than 3.00 m) found in 9 wells.
- ❖ Long-term water depth depletion found in 9 observation wells and high depletion in water depth (more than 3.00 m) found in 3 wells.
- ❖ In Paravanar sub-basin, pre-monsoon groundwater depth varies from 0.45 m to 3.32 m and post monsoon groundwater depth varies from 0.25 m to 2.22 m
- ❖ In Uppanar sub-basin, pre-monsoon groundwater depth varies from 10.2 m to 32.50 m and post monsoon groundwater depth varies from 0.25 m to 32.22 m
- ❖ Total annual groundwater availability of Paravanar Basin is 273.17 Mcum and total annual groundwater extraction of the basin is 322.98 Mcum. The balance groundwater available for further development is 106.49 Mcum.
- ❖ By comparing groundwater assessment made during 2009 (Block wise) and 2011 (Firka wise), it is observed that the total annual groundwater availability of Paravanar Basin has decreased by 16.35% (from 326.55 Mcum in 2009 to 273.17 Mcum in 2011) and total annual groundwater extraction in Paravanar basin has also decreased by 32.98% (from 481.89 Mcum in 2009 to 322.98 Mcum in 2011).
- ❖ Generally groundwater quality is good in Paravanar sub basin while in Uppanar sub basin the quality ranges from good to moderate quality. Higher TDS is observed.
- ❖ Two check dams one across Paravanar and the other across Uppanar had been constructed.

- ❖ Various types of Artificial Recharge Structures (ARS) were constructed: 37 structures in Over Exploited blocks, 21 structures in Semi Critical blocks and 51 structures in Safe blocks.
- ❖ Flood protection works in Paravanar and Uppanar sub-basins were constructed by Water Resources Department.
- ❖ In Paravanar sub basin, groundwater extracted annually for irrigation is worked out as 80.30 Mcum which is 24.86%, of the total annual groundwater extraction of 322.98 Mcum.
- ❖ It has been found from the observation wells that the average groundwater depth has increased very significantly during December 2015 whilst comparing with December 2014 due to very high rainfall during November & December 2015 in Cuddalore district of Paravanar basin.

Recommendations:

- ➢ Groundwater recharge is utmost priority in Kammapuram (E), Kammapuram (W) & Umangalam firkas in Paravanar sub-basin and Thiruvanthipuram firka in Uppanar sub-basin to replenish the groundwater where extraction is rampant.
- ➢ Small quantum of groundwater development is permissible in Kurinchipadi Bhuvanagiri, Kullanchavadi and Parangipettai firkas by suitable Artificial Recharge Structures.
- ➢ It is suggested to construct 11 Artificial Recharge Structures, like Check Dams, Vertical Shafts & Percolation Ponds in Over Exploited firkas; 3 Artificial Recharge Structures like Check Dams & Percolation Ponds in Critical firka and 3 Artificial Recharge Structures like Check Dams, Vertical Shafts & Percolation Ponds in Semi Critical firka to recharge the ground water in future.
- ➢ Domestic and Industrial demand should be managed prudently and the wastages have to be curtailed to the maximum possible extent in Umangalam firka to reduce the demand and eventually control over exploitation of groundwater.


TDS - JULY 2014
TDS (mg/L)
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
155
339
534
1094
4823
367
1482
342
218
130
499
1250
233
780.8
1024
377.6
329
718
371
Muthandikkuppam
Kilpalaiyur
Puduchathiram
Lalpuram
Kullanchavadi
Abatharanapuram
Odaiyur
Vadalur
Pathirakottai
Marungar
Vazisothanaipalayam
Kiliyanur
Periyakumatti
Neyveli
Santhamangalam
Vadalur
Annavalli
Karaikadu
Vengadampettai
Village

CHAPTER 7

PRESENT AND FUTURE WATER DEMANDS

CHAPTER 7

PRESENT AND FUTURE WATER DEMAND

7.1 Water use and Water demand

The term water use and water demand are often used interchangeably. However, these terms have different meanings.

7.1.1 Water Use

The following are the three types of water use,

- **Withdrawals or abstractions** ; Water is drawn from a surface or ground water source, and after use it flows to a natural water body, e.g., water used for cooling in industrial processes returns to a river. Such return flows are particularly important for downstream users provided they are properly treated for pollution.

- **Consumptive water use or water consumption ;** Water withdrawn or abstracted is used without any return flow. Water consumption is the water abstracted that is no longer available for reuse because it has evaporated, transpired, been incorporated into products and crops, consumed by man or livestock or otherwise removed from freshwater resources. Water losses during the transport of water between the points of abstractions and the point of use, (e.g., resulting from leakage from distribution pipes), are excluded from the consumptive water use figure. Examples of consumptive water use include steam escaping into the atmosphere and water contained in final products, i.e., it is the water that is no longer available directly for subsequent uses.

- **Non-Consumptive water use** ; The in situ use of a water body for navigation, in-stream flow requirements (to meet environmental demands), recreation, effluent disposal and hydroelectric power generation.

7.1.2 Water Demand

Water demand is defined as the volume of water required for various sectoral uses, such as, domestic, irrigation, industrial, livestock and power generation, etc.

The estimation of amount of water available and the water demand for various sectors within the basin helps in carrying out the water balance study for River Basin. In this chapter, the requirement of water for various sectoral uses such as domestic, irrigation, industrial, livestock & power generation in Paravanar River basin is estimated. Forecasting of the future water demand in all these sectors is also necessary to identify the options and strategies to mitigate future risks that might arise in water resource planning of a river basin. Hence, the estimated water demand in various sectors of the Paravanar River basin is projected to the future years 2020, 2023, 2030 & 2040 in this Chapter.

7.1.3 Gap in Supply and Demand

With the change in water use pattern there is a gap between supply and demand. Also the actual demand is found to be more or less than the estimated theoretical demand due to unexpected developments over a period , which also causes gap.

On the supply side the generation of water in a catchment area naturally fluctuates, both within years and between years. Water also occurs in different forms that often have different uses. Special reference is made to rainfall and its use in agriculture which cannot be determined in the same way as water flowing in rivers and occurring in aquifers. Dry land agriculture and other land uses do, however, influence the partitioning of rainfall into groundwater recharge, surface runoff and soil moisture storages and can, therefore, significantly influence water availability. Leakage in water supply pipes and the water wasted unaccounted are also the important factor.

On the demand side the following are the various parameters affect the demand at catchment level,

(1) Variability of water demands: Fluctuations in demand are normally much less than those on the supply side. However, for many types of water use, demand increases as water availability decreases (during the dry season).

(2) Degree of water consumption: Much of the water abstracted is typically converted into water vapour, which, in this form cannot be allocated to other users. Water uses that are non-consumptive allow to reuse the water (eg. recreational water uses). However, some non-consumptive uses alter the quality when this water is available for other users. At times water has to be released from dams for Hydro power generation when

demands from other water use sectors may be low. This results in water that is used for electricity generation being unavailable to other potential users when they need it.

(3) Return flows: Many uses of water generate return flows that in principle are available for other uses. However, return flows are often of lower quality than the water originally abstracted. This may severely limit their re-use. The quality of return flows may pose risks to public health and the environment.

In order to bridge the gap in supply and demand, the following improvements can be made,

- Leakage in water supply system has to be checked periodically and rectified.
- Improve the supply system and storage structures by removing the accumulated silt, weeds and plastic wastes.
- Constructing diversion structures across rivers / streams for diverting and storing flood water.
- Artificially recharge the Ground water by constructing check dams, anicuts and erection of recharge shafts.
- Construction of rain water harvesting structures for augmenting the water resources both at domestic level (houses) as well as in public sectors (offices, farms etc.)
- Improving the irrigation efficiency by rehabilitation of irrigation structures and adoption of new irrigation techniques.
- The industries need to be monitored for the quantity of ground and surface water used with respect to the sanctioned drawal limit by fixing metering devices.
- The quality of the water let out after use should be monitored and treated accordingly and recycled if possible.
- Recycling and reuse of water to the maximum possible extent to meet the growing domestic and industrial uses.

7.2 Domestic Water Demand

Domestic consumption of water per capita is the amount of water consumed per person for the purposes of ingestion, hygiene, cooking, washing of utensils and other household purposes including garden uses. This is an indicator of the quantity of water needed and/or available to individuals in particular communities for their basic needs. It helps to identify communities where these basic requirements are not being met enabling actions to be planned and priorities for water supply development to be set. With the increase in economic and social development of the people the per capita requirement of domestic water may also increase. Domestic water requirement is closely linked with several socio-economic and environmental indicators, such as population, growth rate, population density, growth rate of urban population, land use change, annual withdrawals of ground and surface water, and irrigation percentage of cultivable land etc,.

The per capita rate recommended by Central Public Health and Environmental Engineering Organization (CPHEEO) is given in **Table 7.1.**

Table 7.1: Per Capita Water Supply rate recommended by CPHEEO

Sl. No	Classification of towns/cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

In the above norms, **an additional 15%** should be included in each classification to meet "Unaccounted for Water (UFW)". The norms recommended by CPHEEO are adopted for estimating present and future domestic water demand.

The sub basin wise population of the Paravanar River basin as per census 2011, given in Chapter 2, of this report, is used for calculating the domestic water requirement.

7.2.1 Future Domestic Water Demand

The domestic water requirement may increase in future with the increase in Population, development in living standards of the people, etc., The TWAD Board has recommended the annual growth rate to be used for estimation of population in the river basin is given below:-

Population Sector	Annual Growth rates
Urban	0.020 (2 % per year)
Rural	0.013 (1.3 % per year)

The accepted average growth rate as described above is applied in the population projection calculation. Exponential growth formula is adopted for the population growth in the present study.

Exponential Growth Method

The exponential growth formula is

$$\mathbf{P_t = P_o (1+X)^t}$$

Where P_t = Population after't' years

P_o = Population in the beginning years

X = Annual growth rate

t = Period in years

Exponential interpolations of possible changes in trends of growth rates resulting from economic or cultural development, or differences in observed growth rates between various sub-basins or inter basin migrations are taken into account in this method of population projection.

The population of Paravanar River basin arrived in Chapter 2 sub basin wise is projected for the year 2016 and the target years 2020, 2023, 2030 & 2040. The sub-basin wise population projection for the Paravanar river basin for the present year 2016 and the target years 2020, 2023, 2030 & 2040 are arrived as **0.849 million, 0.905 million, 0.949 million, 1.061 million & 1.246 million,** respectively, and is given in **Table 7.2.**

Accordingly, the domestic water demand for the present year 2016 and the target years 2020, 2023, 2030 & 2040 have been worked out as **34.597 Mcum, 37.027 Mcum, 38.965 Mucm, 43.909 Mcum & 52.129 Mcum,** respectively, and are given in **Table 7.3.**

Table 7.2 Sub basin wise Projected Population for Paravanar River Basin

Population in Million

Sl. No.	Name of the Sub Basin	Population in 2011			Population during 2016			Population during 2020			Population during 2023			Population during 2030			Population during 2040		
		Rural	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
1	Paravanar	0.188	0.12	0.308	0.201	0.132	0.333	0.211	0.143	0.355	0.220	0.152	0.372	0.240	0.175	0.415	0.273	0.213	0.487
2	Uppanar	0.273	0.204	0.477	0.291	0.225	0.516	0.307	0.244	0.550	0.319	0.259	0.577	0.349	0.297	0.646	0.397	0.362	0.759
Total		**0.461**	**0.324**	**0.785**	**0.492**	**0.358**	**0.849**	**0.518**	**0.387**	**0.905**	**0.538**	**0.411**	**0.949**	**0.589**	**0.472**	**1.061**	**0.670**	**0.575**	**1.246**

Table 7.3 Sub basin wise Projected Domestic Water Demand for Paravanar River Basin

Water Demand in Mcum

Sl.No	Name of the Sub Basin	Water Demand 2016			Water Demand 2020			Water Demand 2023			Water Demand 2030			Water Demand 2040		
		Rural	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
1	Paravanar	5.856	7.496	**13.351**	6.166	8.113	**14.280**	6.410	8.610	**15.020**	7.016	9.890	**16.907**	7.984	12.056	**20.040**
2	Uppanar	8.503	12.743	**21.246**	8.954	13.793	**22.747**	9.308	14.637	**23.945**	10.189	16.813	**27.002**	11.594	20.496	**32.089**
Total		**14.359**	**20.238**	**34.597**	**15.121**	**21.906**	**37.027**	**15.718**	**23.247**	**38.965**	**17.205**	**26.704**	**43.909**	**19.578**	**32.552**	**52.129**

7.3 Irrigation Demand

The Government is aiming to achieve 100% food security in the State and also to create a venue for export of agricultural produce for economic upliftment of the farming community under various schemes. In the current five year plan, the state was aiming an annual growth rate of 5% in Agriculture and allied sectors (SPC – 12^{th} Five year plan) for sustainable agriculture development, employment generation and poverty alleviation so that the natural resources such as soil, water are to be used efficiently and equitably.

The requirement of irrigation water is arising out of the necessity to supplement water to the crops either due to aridity and drought or for ensuring the best possible crop returns. The Cropping pattern mainly depends on change in market and climatic conditions and also as per the farmer's choice. Irrigation water demand for 75% rainfall dependability of Paravanar River basin is tabulated in **Table 7.4**

Existing Cropping pattern in Paravanar Basin

The major crops cultivated in Paravanar basin are Paddy, Sugarcane, Ground nut, Fruits & Vegetables. The irrigated area for the year 2014-15 in Paravanar basin under different crops is 51887 ha Paddy, the main crop of the basin was cultivated in 34103 ha. In the remaining area, other crops were cultivated.

The distribution of rain also plays a vital role in crop productivity. Existing cropping pattern during normal rainfall year (+19% to -19% of normal rainfall) and suggested cropping pattern for poor rainfall year (-19% to -59% of normal rainfall) for the Districts covered in this basin are given in the **Table 7.5**

Table 7.4 Irrigation Water Demand at 75% rainfall dependability for Paravanar River Basin

Water Demand in Mcum

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Paravanar	4.92	6.28	8.81	7.85	7.33	69.50	26.70	18.44	1.24	11.67	4.61	7.33	**174.68**
2	Uppanar	4.81	8.48	6.78	11.95	9.22	64.68	14.85	35.83	1.92	15.58	4.77	7.93	**186.81**
	Total	**9.73**	**14.77**	**15.58**	**19.80**	**16.55**	**134.18**	**41.56**	**54.27**	**3.16**	**27.25**	**9.38**	**15.26**	**361.49**

Table 7.5 Irrigation water demand (Mcum) at 75 % rainfall dependability in Paravanar river basin (season wise)

Sl. No.	Sub Basin	Winter	Summer	South West	North East	Total
1	Paravanar	11.20	23.99	115.88	23.61	**174.68**
2	Uppanar	13.29	27.95	117.28	28.28	**186.81**
	Total	**24.49**	**51.94**	**233.16**	**51.89**	**361.49**

7.4 Industrial Water Demand

The department of Industries and Commerce has classified the industries as large, medium and small scale industries. The list of small, medium and large scale industries in Cuddalore, Chidambaram, Kurinjipadi, Panruti and Virudhachalam taluks along with their water requirement is collected from the Department of Industries and Commerce. From that, small, medium and large scale industries falling in Paravanar River basin are listed out. At present in the Paravanar River Basin there are 47 large and medium industries and 108 small scale industries. Accordingly, the present yearly requirement of water for Large & Medium and Small Scale Industries is estimated as **73.195 Mcum.**

7.4.1 Industrial water Demand Projection.

For forecasting the water demand of Industries for future years, a simple arithmetic increase of 8% per annum (as per the Annual Survey of Industries) over the present requirement has to be adopted. However, while comparing the previous reappraisal study of Paravanar River basin carried out during 2008, it is learnt that the number of small scale industries (SSI) in the Paravanar River basin found to have decreased at present. Hence, the estimated value of Industrial Water Demand in Paravanar River basin for the year 2016 for the Small Scale Industries **of 0.186 Mcum** may be taken for the target years 2020, 2023, 2030 and 2040 also and is given in **Table 7.6 (a).**

The large & medium scale industries have been found to be increased. The demand for the Large & Medium scale Industries (L&MI) are projected at the rate of 8% per annum for the target years 2020, 2023, 2030 & 2040. The present and future water demands for the years 2016, 2020,2023,2030 & 2040 of large & medium scale industries are estimated as **73.009 Mcum , 96.372 Mcum, 119.501 Mcum, 148.181 Mcum and 183.745 Mcum** respectively and are given in **Table 7.6 (b).**

The total Industrial water demands of Paravanar River Basin for the years 2016, 2020, 2023, 2030 & 2040 are estimated as **73.195 Mcum, 96.617 Mcum, 119.806 Mcum, 148.656 Mcm & 184.600 Mcum r**espectively and are given in **Table 7.7.**

Table 7.6 (a) Water Demand of Small Scale Industries

Sl.No.	Name of the Sub Basin	2016		2020		2023		2030		2040	
		Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum
1	Paravanar	39	0.101	51	0.133	64	0.165	100	0.258	179	0.464
2	Uppanar	69	0.085	91	0.112	113	0.139	176	0.217	317	0.391
Total		**108**	**0.186**	**143**	**0.246**	**177**	**0.304**	**276**	**0.475**	**496**	**0.855**

Table 7.6 (b) Water Demand of Large & Medium Scale Industries

Sl.No.	Name of the Sub Basin	2016		2020		2023		2030		2040	
		Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum	Number of Industries	Water Demand in Mcum
1	Paravanar	8	54.899	11	72.467	13	89.859	16	111.425	20	138.167
2	Uppanar	39	18.110	51	23.905	64	29.642	79	36.757	98	45.578
Total		**47**	**73.009**	**62**	**96.372**	**77**	**119.501**	**95**	**148.181**	**118**	**183.745**

Table 7.7 Total Industrial Water Demand

Water Demand in Mcum

Sl. No	Name of the Sub Basin	2016			2020			2023			2030			2040		
		L&MI	**SSI**	**Total**	**L&MI**	**SSI**	**Total**	**L&MI**	**SSI**	**Total**	**L&MI**	**SSI**	**Total**	**L&MI**	**SSI**	**Total**
1	Paravanar	54.899	0.101	**55.000**	72.467	0.133	**72.600**	89.859	0.165	**90.024**	111.425	0.258	**111.683**	138.167	0.464	**138.631**
2	Uppanar	18.110	0.085	**18.195**	23.905	0.112	**24.017**	29.642	0.139	**29.782**	36.757	0.217	**36.974**	45.578	0.391	**45.969**
Total		**73.009**	**0.186**	**73.195**	**96.372**	**0.246**	**96.617**	**119.501**	**0.304**	**119.806**	**148.181**	**0.475**	**148.656**	**183.745**	**0.855**	**184.600**

7.5 Live stock Water Demand

Tamil Nadu has vast resource of livestock and poultry, which play a vital role in improving the socio-economic conditions of rural masses. Livestock provides nutrient-rich food products such as milk, meat, egg, draught power, dung as organic manure and domestic fuel, hides and skin, and is a regular source of cash income for rural households. In the recent decade, demand for various livestock based products has increased significantly due to increase in per-capita income, urbanization, changing taste and preference and increased awareness about food nutrition. Also with the rapid increase in human population the demand for livestock based products also increases and there is a significant growth of certain species of livestock.

The 19th livestock census 2012, collected from the Department of Animal Husbandry and Veterinary Services contains the District wise population of different categories of Livestock. The District wise livestock populations are distributed to the sub basins of Paravanar River basin.

The norms of the Indian Council of Agriculture and Research for the live stock per capita water requirement have been adopted in the estimation of livestock water demand and are given in **Table 7.8**

Table 7.8 Per Capita Water Requirement for Live Stock

Sl. No.	Name	Standard Norms in lpcd
1	Cattle	110
2	Buffalo	150
3	Sheep	20
4	Goats	20
5	Horses & Ponies	150
6	Donkeys	40
7	Pigs	40
8	Dogs	15
9	Rabbits	0.35
10	Poultry	0.25

To predict the future livestock water demand in the basin, the present livestock population needs to be projected.

The growth rate of livestock population is calculated using the formula,

$$G = \{e^{(\ln(Yt/Yo)/t)} - 1\} \times 100$$

Where, G = Annual growth rate

Yo = Population of livestock species in base year

Yt = Population in t^{th} year

t = Number of years (Current year – Base year)

The census on livestock, poultry, agriculture implements and fisheries is conducted once in 5 years, since 1951. To calculate the growth rate of different species of livestock, the figures of 15th , 16th, 17th , 18th and 19th census of livestock conducted by the Department of Animal Husbandry, Tamil Nadu during 1989-94, 1994-97, 1997-2004 , 2004-2007, 2007 -2012 are taken to calculate growth rate of different species of livestock in Tamil Nadu and is given in **Appendix 7.1 to 7.3.** The average growth rate of 5 censuses in Tamil Nadu is used in the present study which is given in **Appendix 7.4** and in **Table 7.9.**

It shows that among the various species of livestock the growth rate of cattle, sheep, goat & poultry shows increasing trend because of the increasing need of the products from them. Hence for estimating the future livestock water demand, the present live stock demand arrived for various species of livestock was projected adopting the respective growth rate.

Table 7.9 Growth rate of various species of Livestock in Tamil Nadu

Sl. No.	Name of the Livestock	Annual growth rate in %
1	Cattle	0.34%
2	Buffalo	-4.19%
3	Sheep	0.14%
4	Goat	1.62%
5	Pig	-4.55%
6	Poultry	8.59%

From the 19th livestock census data the sub basin wise livestock population is arrived at, and projected for the year 2016 and for the target years 2020, 2023, 2030 & 2040 and are presented in **Table 7.10.** The livestock water demands for the years 2016, 2020, 2023, 2030 & 2040 are worked out as 4.666 Mcum, 4.733 Mcum, 4.797 Mcum, 4.992 Mcum & 5.421 Mcum, respectively, and presented in **Table 7.11.**

7.6 Power Generation (Hydro-Electric)

There was no Hydro-electric power station functioning within the Paravanar River basin. Hence there was no water demand for Power generation.

7.7 Total Water Demand

The sub basin wise total water demand of four sectors, i.e., Domestic, Irrigation, Livestock, and Industries of Paravanar River Basin for the year 2016 and the projected target years 2020, 2023, 2030 & 2040 are worked out as **473.95 Mcum, 499.87 Mcum, 525.06 Mcum, 559.05 Mcum & 603.64 Mcum,** respectively and are given in **Table 7.12.**

Table 7.10 Sub Basin wise Projected Livestock Population

Sl. No	Year	Livestock	Livestock Population		
			Paravanar	Uppanar	Total
1	2012	Cattle	42386	42388	84774
		Buffallo	3480	2654	6134
		Sheep	5149	1885	7034
		Goat	50936	51225	102161
		Pigs	1961	1196	3157
		Poultry	105502	267737	373239
		Total	**209414**	**367085**	**576499**
2	2016	Cattle	42965	42967	85933
		Buffallo	2932	2236	5169
		Sheep	5178	1896	7073
		Goat	54318	54626	108944
		Pigs	1628	993	2620
		Poultry	146697	372278	518975
		Total	**253718**	**474996**	**728714**
3	2020	Cattle	43553	43555	87107
		Buffallo	2471	1884	4355
		Sheep	5207	1906	7113
		Goat	57924	58253	116177
		Pigs	1351	824	2175
		Poultry	203976	517639	721615
		Total	**314482**	**624061**	**938543**
3	2023	Cattle	43998	44001	87999
		Buffallo	2173	1657	3831
		Sheep	5229	1914	7143
		Goat	60785	61130	121915
		Pigs	1175	717	1892
		Poultry	261185	662821	924007
		Total	**374546**	**772240**	**1146786**
3	2030	Cattle	45056	45058	90115
		Buffallo	1611	1228	2839
		Sheep	5280	1933	7213
		Goat	68022	68408	136430
		Pigs	848	517	1365
		Poultry	465026	1180118	1645144
		Total	**585844**	**1297263**	**1883107**
4	2040	Cattle	46612	46614	93226
		Buffallo	1050	801	1850
		Sheep	5355	1960	7315
		Goat	79881	80334	160215
		Pigs	532	325	857
		Poultry	1058220	2685491	3743712
		Total	**1191650**	**2815525**	**4007175**

Table 7.11 Sub Basin wise Livestock Water Demand

No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum		
				Paravanar	Uppanar	Total
1	2012	Cattle	**110**	1.702	1.702	3.404
		Buffalo	**150**	0.191	0.145	0.336
		Sheep	**20**	0.038	0.014	0.051
		Goat	**20**	0.372	0.374	0.746
		Pigs	**40**	0.029	0.017	0.046
		Poultry	**0.25**	0.010	0.024	0.034
			Total	**2.340**	**2.277**	**4.617**
2	2016	Cattle	**110**	1.725	1.725	3.450
		Buffalo	**150**	0.161	0.122	0.283
		Sheep	**20**	0.038	0.014	0.052
		Goat	**20**	0.397	0.399	0.795
		Pigs	**40**	0.024	0.014	0.038
		Poultry	**0.25**	0.013	0.034	0.047
			Total	**2.357**	**2.309**	**4.666**
3	2020	Cattle	**110**	1.749	1.749	3.497
		Buffalo	**150**	0.135	0.103	0.238
		Sheep	**20**	0.038	0.014	0.052
		Goat	**20**	0.423	0.425	0.848
		Pigs	**40**	0.020	0.012	0.032
		Poultry	**0.25**	0.019	0.047	0.066
			Total	**2.383**	**2.350**	**4.733**
4	2023	Cattle	**110**	1.767	1.767	3.533
		Buffalo	**150**	0.119	0.091	0.210
		Sheep	**20**	0.038	0.014	0.052
		Goat	**20**	0.444	0.446	0.890
		Pigs	**40**	0.017	0.010	0.028
		Poultry	**0.25**	0.024	0.060	0.084
			Total	**2.408**	**2.389**	**4.797**
5	2030	Cattle	**110**	1.809	1.809	3.618
		Buffalo	**150**	0.088	0.067	0.155
		Sheep	**20**	0.039	0.014	0.053
		Goat	**20**	0.497	0.499	0.996
		Pigs	**40**	0.012	0.008	0.020
		Poultry	**0.25**	0.042	0.108	0.150
			Total	**2.487**	**2.505**	**4.992**
6	2040	Cattle	**110**	1.871	1.872	3.743
		Buffalo	**150**	0.057	0.044	0.101
		Sheep	**20**	0.039	0.014	0.053
		Goat	**20**	0.583	0.586	1.170
		Pigs	**40**	0.008	0.005	0.013
		Poultry	**0.25**	0.097	0.245	0.342
			Total	**2.655**	**2.766**	**5.421**

Table 7.12 Sub Basin Wise Projected total Water Demand

Water Demand in Mcum

Sl. No	Name of the Sub Basin	2016					2020					2023				
		Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total
1	Paravanar	13.35	174.68	2.36	55.00	**245.39**	14.28	174.68	2.38	72.60	**263.94**	15.02	174.68	2.41	90.02	**282.13**
2	Uppanar	21.25	186.81	2.31	18.20	**228.56**	22.75	186.81	2.35	24.02	**235.92**	23.95	186.81	2.39	29.78	**242.93**
Total		**34.60**	**361.49**	**4.67**	**73.20**	**473.95**	**37.03**	**361.49**	**4.73**	**96.62**	**499.87**	**38.97**	**361.49**	**4.80**	**119.81**	**525.06**

Sl. No	Name of the Sub Basin	2030					2040				
		Domestic	Irrigation	livestock	Industries	Total	Domestic	Irrigation	livestock	Industries	Total
1	Paravanar	16.91	174.68	2.49	111.68	**305.76**	20.04	174.68	2.66	138.63	**336.01**
2	Uppanar	27.00	186.81	2.51	36.97	**253.29**	32.09	186.81	2.77	45.97	**267.63**
Total		**43.91**	**361.49**	**4.99**	**148.66**	**559.05**	**52.13**	**361.49**	**5.42**	**184.60**	**603.64**

7.8 Summary

While comparing the previous reappraisal study of Paravanar River Basin carried out during 2008, it is learnt that

1. The population has increased from 0.784 million to 0.849 million for the year 2016. Therefore the domestic water demand has increased from 25.309Mcum to 34.597 Mcum for the year 2016.
2. The livestock population has decreased in 2016 and hence the livestock demands have also decreased from 15.0 Mcum to 4.666 Mcum.
3. The number of large scale industries in the Paravanar River basin is found to have increased at present. Hence, the estimated Industrial Water Demand in Paravanar River Basin for the year 2016 has increased from 33.00 Mcum to 73.195 Mcum.
4. As per 2008 Paravanar basin study report, irrigation demand was given as 385.43 Mcum at 75% rainfall dependability with the then crop area of 49159.85Ha. The net irrigation demand of this basin for the year 2016 at 75% dependable rainfall is 361.49 Mcum.

The comparison between the reappraisal study of Paravanar River basin carried out during 2008 and 2016 is presented in the T**able 7.13**

Table 7.13 Comparison between the Micro level and Micro level Reappraisal studies of Paravanar River Basin carried out during 2008 and 2016

Domestic Demand in Mcum		Livestock Demand in Mcum		Industrial Demand in Mcum		Irrigation Demand in Mcum		Total demand in Mcum	
2008	**2016**	**2008**	**2016**	**2008**	**2016**	**2008**	**2016**	**2008**	**2016**
25.309	34.597	15.00	4.666	33.00	73.195	385.43	361.49	458.739	473.948

The total water demand of the four sectors, i.e., Domestic, Irrigation, Livestock, and Industries of Paravanar River Basin for the year 2016 was worked out as 473.948 Mcum**.** This shows that that there is 3.31% increase in water demand, when compared to the water demand during 2008.

CHAPTER 8

WATER BALANCE STUDY

CHAPTER – 8

WATER BALANCE STUDY

The main aim of water resources planning in each river basin is to find out whether the availability of water in the basin is enough to meet out its demand. If the availability of water is more than its demand, which is not the case in many basins, then ways and means have to be found out to use it effectively within the basin or by transferring the excess water to nearby deficit basins. If it is the other way, that is, if the availability of water is less than its requirements, then also we have to find ways and means to meet out its full demand. Better water management becomes very much necessary in such cases in addition to other approaches.

8.1 Water Potential of Paravanar River Basin

Total water potential is the sum of surface water potential and ground water potential. The surface water potential of Paravanar basin is estimated sub basin wise using Monthly Runoff Simulation Model and is furnished in Chapter 5. The ground water potential of the basin is estimated as per GEC norms and is furnished in Chapter 6. The total water potential of Paravanar river basin at 75% dependability is 449.29 Mcum as given below:

Surface water potential	= 176.12 Mcum
(Vide Chapter - 5)	
Ground water potential	= 273.17 Mcum
(Vide Chapter - 6)	-------------
Total Water Potential of the basin	= 449.29 Mcum

8.2 Water Demand of Paravanar River Basin

Total water demand is the sum of the sectoral demands such as domestic demand, irrigation demand, livestock demand, industrial demand and ecological demand. Domestic demand is calculated from the population of Paravanar river basin. Exponential growth formula is adopted for estimating the population growth. Irrigation demand is estimated using CROPWAT Model. Industrial water demand is calculated based on the requirement of Small, Medium and Large scale industries in the basin. The list of small, medium and large scale industries in Cuddalore, Chidambaram, Kurinjipadi, Panruti and Virudhachalam districts along with their water requirement is collected from the Department of Industries and Commerce. The norms of the Indian Council of Agriculture and Research for calculating the Livestock per capita water requirement has been adopted in the estimation of livestock water demand. In order to maintain the health and biodiversity of rivers a certain minimum quantum of flow, namely Environmental Flow Requirement (EFR), is to be maintained. Hence, in this assessment provisions are given for ecological requirements at a rate of 0.5% of surface Water Potential at 75% dependability for 2016 and at 1% for 2020,2023,2030 and 2040. The above demand calculations are detailed in **Chapter – 7**. The total water demand in Paravanar river basin for different planning period is tabulated below in **Table 8.1**:

Table 8.1

Total Sectoral Water Demand in Paravanar River Basin (75% dependability)

Sl. No.	Type of Demand	Total Demand in Mcum				
		2016	**2020**	**2023**	**2030**	**2040**
1	Domestic	**34.60**	**37.03**	**38.97**	**43.91**	**52.13**
2	Irrigation (including losses)	**480.78**	**480.78**	**480.78**	**480.78**	**480.78**
3	Live Stock	**4.67**	**4.73**	**4.80**	**4.99**	**5.42**
4	Industries	**73.20**	**96.62**	**119.81**	**148.66**	**184.60**
5	Ecological	**0.88**	**1.76**	**1.76**	**1.76**	**1.76**
	Total	**594.12**	**620.92**	**646.11**	**680.10**	**724.69**

Water Balance - 2016

Water Potential for the year 2016 = 449.29 Mcum

Water demand for the year 2016 = 594.12 Mcum

Deficit = 144.83 Mcum

% of deficit with respect to potential = 32.23 %

Paravanar basin is deficit by 144.83 Mcum (32.23%) at present, i.e., for the year 2016 based on 75% dependable values.

8.3 Water Balance at 75% Dependability – projected for 2020,2023,2030,2040

Water balance is also assessed for the years 2020, 2023, 2030 and 2040. As far as Water potential is concerned, there will not be much variation in the availability of Surface as well as Ground water in future, and hence, it is assumed that the present quantity of 449.29 Mcum will hold good for the future also. The present and the future demand is given in **Table 8.1**. Based on the above calculated values, water balance for the present and the future is given in **Table 8.2**.

Table 8.2
Water Balancing for Paravanar River Basin at 75% dependability
Water Potential, Demand and Deficit (Both long & short term)

Sector	2016	2020	2023	2030	2040
Total Water Potential (Surface Water + Ground Water Potential) in Mcum	449.29	449.29	449.29	449.29	449.29
Total Water Demand (Domestic + Livestock+ Industrial+ irrigation & Ecological Demand in Mcum	594.12	620.92	646.11	680.10	724.69
Total water deficit in Mcum	**144.89**	**171.69**	**196.88**	**230.87**	**275.40**
% of deficit with respect to potential	**32.25**	**38.22**	**43.82**	**51.39**	**61.31**

From the table, it seen that the basin is deficit by 32.25 % at present. For future years, the trend in the deficit seems to be increasing towards the year 2040, this is because of increase in population, livestock and industrialization.

Sub basin wise water balance statements at 75% dependability are given in **Table 8.4**, **Table 8.5**, **Table 8.6**, **Table 8.7** and **Table 8.8,** for existing scenario.

In 2016, Paravanar basin is deficit by 144.89 Mcum. Paravanar and Uppanar sub basins have a deficit percentage of the order of 37.2% and 27.4 % respectively. Water balance statements are also given for future years.

8.4 Water Balance at 50% Dependability

Water balance is also worked out for 50% dependable rainfall scenario. The total water potential value at 50% dependability is 497.15 Mcum, considering surface water potential at 50% dependability as per the output of MRS model. The irrigation demand values at 50% dependable rainfall as per the output of CROPWAT model is taken for calculation. Water balance of Paravanar river basin at 50% dependability is given in **Table8.3**. The water deficit at 75% dependability and 50% dependability are 32.25% and 22.94 % respectively. Sub basin wise water balance statements at 50% dependability are given in **Table 8.9**, **Table 8.10**, **Table 8.11**, **Table 8.12** and **Table 8.13,** for existing scenario.

Table 8.3

Water Balancing for Paravanar River Basin at 50% dependability
Water Potential, Demand and Deficit (Both long & short term)

Sector	2016	2020	2023	2030	2040
Total Water Potential (Surface Water + Ground Water Potential) in Mcum	497.15	497.15	497.15	497.15	497.15
Total Water Demand (Domestic + Livestock+ Industrial+ Agricultural Demand) in Mcum	611.22	638.26	663.45	697.44	742.04
Total water deficit in Mcum	114.07	141.11	166.30	200.29	244.89
% of Surplus with respect to potential	**22.94**	**28.38**	**33.45**	**40.28**	**49.25**

8.5 Simulation Studies for Water Planning

The following different planning scenarios for Paravanar river basin is considered :

1) Existing scenario

Tables 8.2 and 8.3 given above shows the water balance of Paravanar river basin in the Existing scenario.

2) Double tank scenario

In this scenario, two fillings per year for the tanks in Paravanar river basin is assumed. Hence, net capacity of the tanks is doubled.

3) No silt scenario

This scenario represents a condition, where the tanks are effectively desilted.

4) Decrease irrigation (lower limit scenario)

The scenario is based on the identification of changes in the present cropping pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin.

The lower limit for the future irrigation demand is determined taking into consideration of adaptation of latest Micro Irrigation

techniques and planting System of Rice Intensification (SRI) as recommended by agricultural department. Since the twin objectives of changing over to economic value addition of agricultural produce and higher priority for drinking water in future have to be achieved, comparatively less water consuming paddy variety and latest irrigation techniques as well as cropping pattern changes are considered for planning purposes.

5) Improving Efficiency

This scenario represents an irrigation system with loss taken as Nil.

The results of different scenarios are given in appendix. 8.1 to 8.40 , Volume II and the respective bar charts are given in **Figure 8.1 to Figure 8.5**.

Thus the Paravanar river basin is found to be deficit when simulated for existing, double tank, no silt scenarios and surplus for decrease in irrigation (lower limit scenario) demand and improving efficiency at 75% dependability.

8.6 Summary

Thus Paravanar river basin is found to be a deficit basin both at 75% and 50% dependable rainfall and surface water potential values for the existing scenario. At 75% dependability the deficit percentage is 32.25% during 2016 and it increases to 61.31% by 2040 due to increase in domestic, irrigation and livestock demands.

It is found that the irrigation demand accounts for about 90% of the total water demand. Hence steps may be taken to improve the percentage of water use efficiency by means of lining of canals, proper maintenance of irrigation structures and adopting micro irrigation techniques. Also more artificial recharge structures such as check dams, recharge shafts and percolation ponds may be provided in suitable locations in the basin for improving the water availability. Also viable and sustainable diversion of water from surplus basins to this deficit basin may also to be explored.

Table 8.4

Water balance at 75% Dependibility (Existing Scenario)

2016

		Paravanar	Uppanar	Total
Water potential in Mcum	Surface water potential (a)	96.76	79.36	**176.12**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**221.22**	**228.07**	**449.29**
Water demand in Mcum	Domestic demand (d)	13.35	21.25	**34.60**
	Irrigation demand (e)	232.32	248.46	**480.78**
	Livestock demand (f)	2.36	2.31	**4.67**
	Industrial demand (g)	55.00	18.20	**73.20**
	Ecological demand (h)	0.48	0.40	**0.88**
	Total water demand (i = d+e+f+g+h)	**303.52**	**290.60**	**594.12**
Surplus / Deficit in Mcum (c-i)		**-82.30**	**-62.53**	**-144.83**
Percentage		**-37.2%**	**-27.4%**	**-32.2%**

Deficit in Paravanar basin	=	**-144.83**	**Mcum**	**-32.2%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**46.84**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC and waste water reuse	=	**94.01**	**Mcum**	

Table 8.5

Water balance at 75% Dependibility (Existing Scenario)

2020

		Paravanar	**Uppanar**	**Total**
Water potential in Mcum	Surface water potential (a)	96.76	79.36	**176.12**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**221.22**	**228.07**	**449.29**
Water demand in Mcum	Domestic demand (d)	14.28	22.75	**37.03**
	Irrigation demand (e)	232.32	248.46	**480.78**
	Livestock demand (f)	2.38	2.35	**4.73**
	Industrial demand (g)	72.60	24.02	**96.62**
	Ecological demand (h)	0.97	0.79	**1.76**
	Total water demand (i = d+e+f+g+h)	**322.55**	**298.37**	**620.92**
Surplus / Deficit in Mcum (c-i)		**-101.33**	**-70.30**	**-171.63**
Percentage		**-45.8%**	**-30.8%**	**-38.2%**

Deficit in Paravanar basin	=	**-171.63**	**Mcum**	**-38.2%**
Pumped water from NLC mines	=	**192**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**61.84**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC and waste water reuse	=	**82.20**	**Mcum**	

Table 8.6

Water balance at 75% Dependibility (Existing Scenario)

2023

		Paravanar	Uppanar	Total
Water potential in Mcum	Surface water potential (a)	96.76	79.36	**176.12**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**221.22**	**228.07**	**449.29**
Water demand in Mcum	Domestic demand (d)	15.02	23.95	**38.97**
	Irrigation demand (e)	232.32	248.46	**480.78**
	Livestock demand (f)	2.41	2.39	**4.80**
	Industrial demand (g)	90.02	29.78	**119.81**
	Ecological demand (h)	0.97	0.79	**1.76**
	Total water demand (i = d+e+f+g+h)	**340.74**	**305.37**	**646.11**
Surplus / Deficit in Mcum (c-i)		**-119.52**	**-77.30**	**-196.82**
Percentage		**-54.0%**	**-33.9%**	**-43.8%**

Deficit in Paravanar basin	=	**-196.8**	**Mcum**	**-43.8%**
Pumped water from NLC mines	=	**192**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**76.68**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC and waste water reuse	=	**71.85**	**Mcum**	

Table 8.7

Water balance at 75% Dependibility (Existing Scenario)

2030

		Paravanar	Uppanar	Total
Water sources potential in Mcum	Surface water potential (a)	96.76	79.36	**176.12**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**221.22**	**228.07**	**449.29**
Water demand in Mcum	Domestic demand (d)	16.91	27.00	**43.91**
	Irrigation demand (e)	232.32	248.46	**480.78**
	Livestock demand (f)	2.49	2.51	**4.99**
	Industrial demand (g)	111.68	36.97	**148.66**
	Ecological demand (h)	0.97	0.79	**1.76**
	Total water demand (i = d+e+f+g+h)	**364.37**	**315.73**	**680.10**
Surplus / Deficit in Mcum (c-i)		**-143.15**	**-87.66**	**-230.81**
Percentage		**-64.7%**	**-38.4%**	**-51.4%**

Deficit in Paravanar basin	=	**-230.81 Mcum**	**-51.4%**
Pumped water from NLC mines	=	**192.00 Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**95.14 Mcum**	
Surplus in Paravanar basin considering pumped water from NLC and waste water reuse	=	**56.33 Mcum**	

Table 8.8

Water balance at 75% Dependibility (Existing Scenario)

2040

		Paravanar	Uppanar	Total
Water sources potential in Mcum	Surface water potential (a)	96.76	79.36	**176.12**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**221.22**	**228.07**	**449.29**
Water demand in Mcum	Domestic demand (d)	20.04	32.09	**52.13**
	Irrigation demand (e)	232.32	248.46	**480.78**
	Livestock demand (f)	2.66	2.77	**5.42**
	Industrial demand (g)	138.63	45.97	**184.60**
	Ecological demand (h)	0.97	0.79	**1.76**
	Total water demand (i = d+e+f+g+h)	**394.62**	**330.07**	**724.69**
Surplus / Deficit in Mcum (c-i)		**-173.40**	**-102.00**	**-275.40**
Percentage		**-78.4%**	**-44.7%**	**-61.3%**

Deficit in Paravanar basin	=	**-275.40**	**Mcum**	**-61.3%**
Pumped water from NLC mines	=	**192**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**118.14**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC and waste water reuse	=	**34.74**	**Mcum**	

Table 8.9

Paravanar River Basin - Sub basinwise Water balance at 50% Dependibility (Existing Scenario)

2016

		Paravanar	**Uppanar**	**Total**
Water sources potential in Mcum	Surface water potential (a)	119.95	104.03	**223.98**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**244.41**	**252.74**	**497.15**
Water demand in Mcum	Domestic demand (d)	13.35	21.25	**34.60**
	Irrigation demand (e)	232.56	265.08	**497.65**
	Livestock demand (f)	2.36	2.31	**4.67**
	Industrial demand (g)	55.00	18.20	**73.20**
	Ecological demand (h)	0.60	0.52	**1.12**
	Total water demand (i = d+e+f+g+h)	**303.87**	**307.35**	**611.22**
Surplus / Deficit in Mcum (c-i)		**-59.46**	**-54.61**	**-114.07**
Percentage		**-24.3%**	**-21.6%**	**-22.9%**

Deficit in Paravanar basin	=	**-114.07**	**Mcum**	**-22.9%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**46.84**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC waste water reuse	=	**124.77**	**Mcum**	

Table 8.10

Paravanar River Basin - Sub basinwise Water balance at 50% Dependibility (Existing Scenario)

2020

		Paravanar	Uppanar	Total
Water sources potential in Mcum	Surface water potential (a)	119.95	104.03	**223.98**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**244.41**	**252.74**	**497.15**
Water demand in Mcum	Domestic demand (d)	14.28	22.75	**37.03**
	Irrigation demand (e)	232.56	265.08	**497.65**
	Livestock demand (f)	2.38	2.35	**4.73**
	Industrial demand (g)	72.60	24.02	**96.62**
	Ecological demand (h)	1.20	1.04	**2.24**
	Total water demand (i = d+e+f+g+h)	**323.03**	**315.24**	**638.26**
Surplus / Deficit in Mcum (c-i)		**-78.62**	**-62.50**	**-141.11**
Percentage		**-32.2%**	**-24.7%**	**-28.4%**

Deficit in Paravanar basin	=	**-141.11**	**Mcum**	**-28.4%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**61.84**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC waste water reuse	=	**112.72**	**Mcum**	

Table 8.11

Paravanar River Basin - Sub basinwise Water balance at 50% Dependibility (Existing Scenario)

2023

		Paravanar	**Uppanar**	**Total**
Water sources potential in Mcum	Surface water potential (a)	119.95	104.03	**223.98**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**244.41**	**252.74**	**497.15**
Water demand in Mcum	Domestic demand (d)	15.02	23.95	**38.97**
	Irrigation demand (e)	232.56	265.08	**497.65**
	Livestock demand (f)	2.41	2.39	**4.80**
	Industrial demand (g)	90.02	29.78	**119.81**
	Ecological demand (h)	1.20	1.04	**2.24**
	Total water demand (i = d+e+f+g+h)	**341.22**	**322.24**	**663.45**
Surplus / Deficit in Mcum (c-i)		**-96.81**	**-69.50**	**-166.30**
Percentage		**-39.6%**	**-27.5%**	**-33.5%**

Deficit in Paravanar basin	=	**-166.30**	**Mcum**	**-33.5%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**76.68**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC waste water reuse	=	**102.37**	**Mcum**	

Table 8.12

Paravanar River Basin - Sub basinwise Water balance at 50% Dependibility (Existing Scenario)

2030

		Paravanar	**Uppanar**	**Total**
Water sources potential in Mcum	Surface water potential (a)	119.95	104.03	**223.98**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**244.41**	**252.74**	**497.15**
Water demand in Mcum	Domestic demand (d)	16.91	27.00	**43.91**
	Irrigation demand (e)	232.56	265.08	**497.65**
	Livestock demand (f)	2.49	2.51	**4.99**
	Industrial demand (g)	111.68	36.97	**148.66**
	Ecological demand (h)	1.20	1.04	**2.24**
	Total water demand (i = d+e+f+g+h)	**364.84**	**332.60**	**697.44**
Surplus / Deficit in Mcum (c-i)		**-120.43**	**-79.86**	**-200.29**
Percentage		**-49.3%**	**-31.6%**	**-40.3%**

Deficit in Paravanar basin	=	**-200.29**	**Mcum**	**-40.3%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**95.14**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC waste water reuse	=	**86.85**	**Mcum**	

Table 8.13

Paravanar River Basin - Sub basinwise Water balance at 50% Dependibility (Existing Scenario)

2040

		Paravanar	Uppanar	Total
Water sources potential in Mcum	Surface water potential (a)	119.95	104.03	**223.98**
	Ground water potential (b)	124.46	148.71	**273.17**
	Total water potential (c = a+b)	**244.41**	**252.74**	**497.15**
Water demand in Mcum	Domestic demand (d)	20.04	32.09	**52.13**
	Irrigation demand (e)	232.56	265.08	**497.65**
	Livestock demand (f)	2.66	2.77	**5.42**
	Industrial demand (g)	138.63	45.97	**184.60**
	Ecological demand (h)	1.20	1.04	**2.24**
	Total water demand (i = d+e+f+g+h)	**395.09**	**346.95**	**742.04**
Surplus / Deficit in Mcum (c-i)		**-150.68**	**-94.21**	**-244.89**
Percentage		**-61.7%**	**-37.3%**	**-49.3%**

Deficit in Paravanar basin	=	**-244.89**	**Mcum**	**-49.3%**
Pumped water from NLC mines	=	**192.00**	**Mcum**	
Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated	=	**118.14**	**Mcum**	
Surplus in Paravanar basin considering pumped water from NLC waste water reuse	=	**65.26**	**Mcum**	

Figure - 8.1

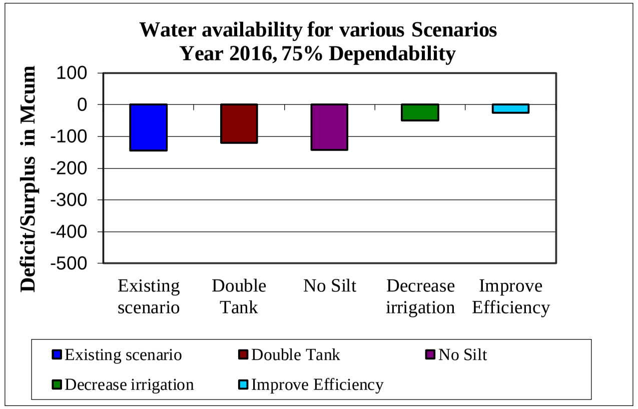
Paravanar River Basin - Water availability at 75% & 50% dependabilities during 2016 for various Scenarios

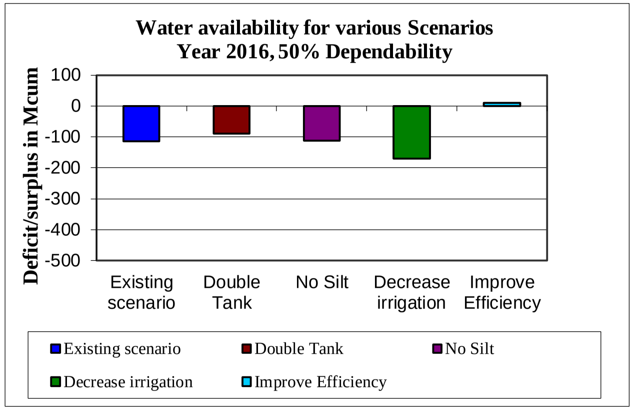
Water avilability during 2016 at 75% dependability

Sl.No.	Scenario	Deficit/surplus in Mcum
1	Existing scenario	-145
2	Double Tank	-119
3	No Silt	-142
4	Decrease irrigation	-50
5	Improve Efficiency	-26

Water availability during 2016 at 50% dependability

Sl.No.	Scenario	Deficit/surplus in Mcum
1	Existing scenario	-114
2	Double Tank	-89
3	No Silt	-111
4	Decrease irrigation	-170
5	Improve Efficiency	9





Description of Scenarios	
Existing Scenario	Present condition
Double Tank	Net capacity of the tanks is doubled, which means two fillings per year
No Silt	Condition when tanks are desilted
Decrease irrigation (Lower limit scenario)	1/3rd of the present Paddy and Sugarcane areas replaced by non-paddy crops like cholam, cumbu, ragi, Maize, redgram, black gram, green gram and fodder
Improve Efficiency	Condition where losses are taken as Nil

Figure - 8.2

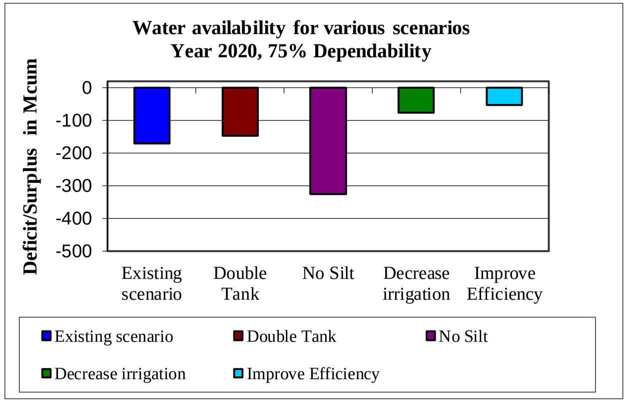
Paravanar River Basin - Water availability at 75% dependability during 2020 and 2023 for various Scenarios

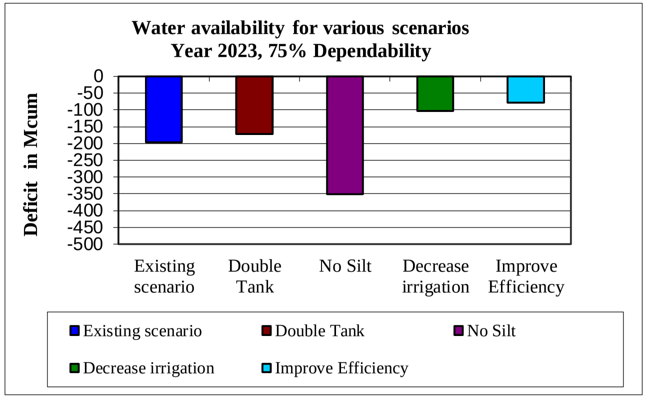
Water availability during 2020 at 75% dependability

Sl.No.	Scenario	Deficit/surplus in Mcum
1	Existing scenario	-172
2	Double Tank	-146
3	No Silt	-326
4	Decrease irrigation	-77
5	Improve Efficiency	-52

Water availability during 2023 at 75% dependability

Sl.No.	Scenario	Deficit in Mcum
1	Existing scenario	-197
2	Double Tank	-171
3	No Silt	-351
4	Decrease irrigation	-102
5	Improve Efficiency	-78





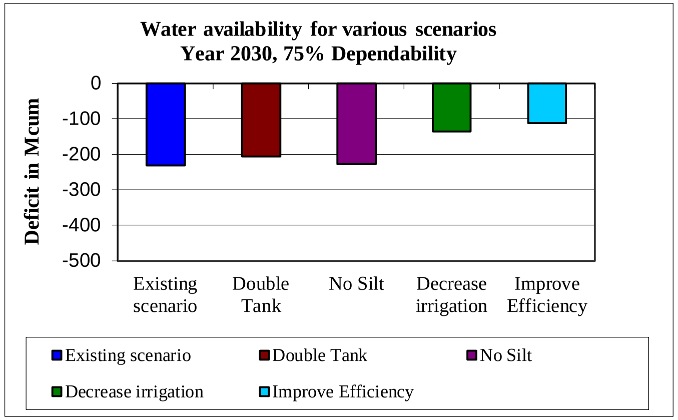
Description of Scenarios	
Existing Scenario	Present condition
Double Tank	Net capacity of the tanks is doubled, which means two fillings per year
No Silt	Condition when tanks are desilted
Decrease irrigation (Lower limit scenario)	1/3rd of the present Paddy and Sugarcane areas replaced by non-paddy crops like cholam, cumbu, ragi, Maize, redgram, black gram, green gram and fodder
Improve Efficiency	Condition where losses are taken as Nil

Figure - 8.3

Paravanar river basin - Water availability at 75% dependability during 2030 and 2040 for various Scenarios

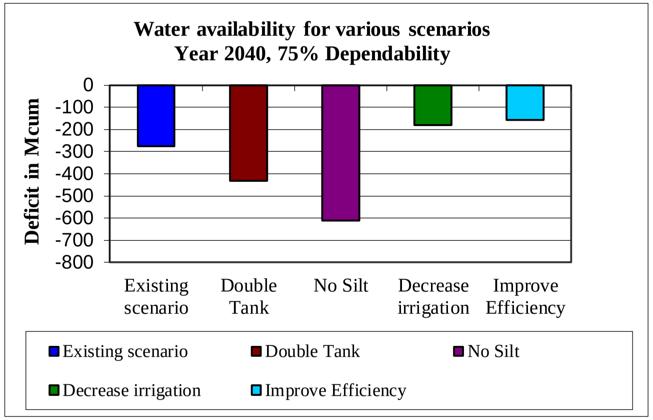
Water availability during 2030 at 75% dependability

Sl.No.	Scenario	Deficit in Mcum
1	Existing scenario	-231
2	Double Tank	-205
3	No Silt	-228
4	Decrease irrigation	-136
5	Improve Efficiency	-112



Water availability during 2040 at 75% dependability

Sl.No.	Scenario	Deficit in Mcum
1	Existing scenario	-275
2	Double Tank	-433
3	No Silt	-612
4	Decrease irrigation	-181
5	Improve Efficiency	-156



Description of Scenarios	
Existing Scenario	Present condition
Double Tank	Net capacity of the tanks is doubled, which means two fillings per year
No Silt	Condition when tanks are desilted
Decrease irrigation (Lower limit scenario)	1/3rd of the present Paddy and Sugarcane areas replaced by non-paddy crops like cholam, cumbu, ragi, Maize, redgram, black gram, green gram and fodder
Improve Efficiency	Condition where losses are taken as Nil

Figure - 8.4

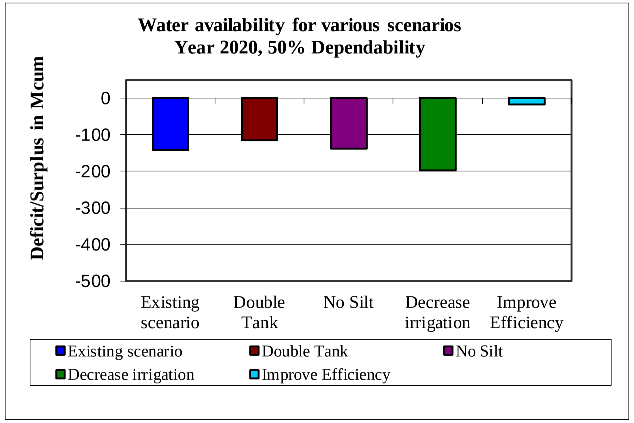
Paravanar river basin - Water Surplus at 50% dependability during 2020 and 2023 for various Scenarios

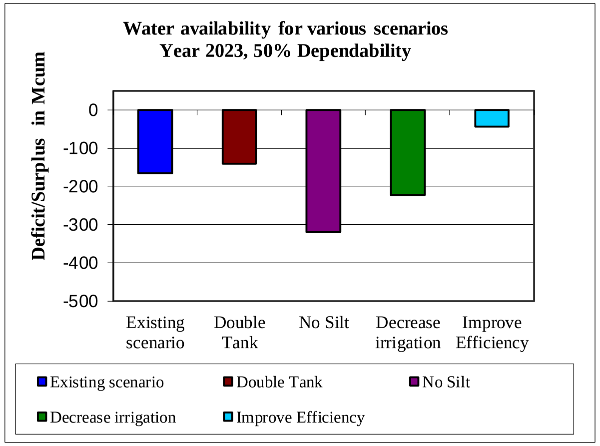
Water availability during 2020 at 50% dependability

Sl.No.	Scenario	Deficit/surplus in Mcum
1	Existing scenario	-141
2	Double Tank	-116
3	No Silt	-138
4	Decrease irrigation	-197
5	Improve Efficiency	-18

Water availability during 2023 at 50% dependability

Sl.No.	Scenario	Deficit/surplus in Mcum
1	Existing scenario	-166
2	Double Tank	-141
3	No Silt	-320
4	Decrease irrigation	-223
5	Improve Efficiency	-43





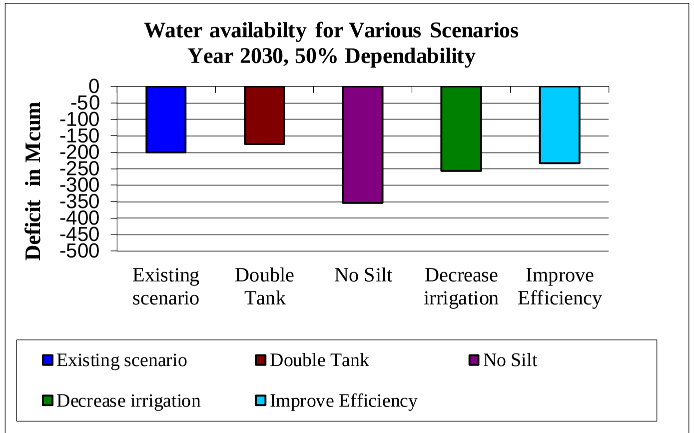
Description of Scenarios	
Existing Scenario	Present condition
Double Tank	Net capacity of the tanks is doubled, which means two fillings per year
No Silt	Condition when tanks are desilted
Decrease irrigation (Lower limit scenario)	1/3rd of the present Paddy and Sugarcane areas replaced by non-paddy crops like cholam, cumbu, ragi, Maize, redgram, black gram, green gram and fodder
Improve Efficiency	Condition where losses are taken as Nil

Figure - 8.5

Paravanar river basin - Water availability at 50% dependability during 2030 and 2040 for various Scenarios

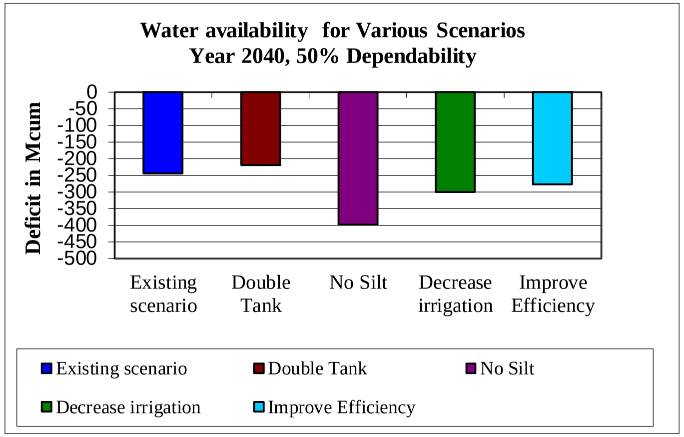
Water availability during 2030 at 50% dependability

Sl.No.	Scenario	Deficit in Mcum
1	Existing scenario	-200
2	Double Tank	-175
3	No Silt	-354
4	Decrease irrigation	-257
5	Improve Efficiency	-233



Water availability during 2040 at 50% dependability

Sl.No.	Scenario	Deficit in Mcum
1	Existing scenario	-245
2	Double Tank	-220
3	No Silt	-399
4	Decrease irrigation	-301
5	Improve Efficiency	-278



Description of Scenarios	
Existing Scenario	Present condition
Double Tank	Net capacity of the tanks is doubled, which means two fillings per year
No Silt	Condition when tanks are desilted
Decrease irrigation (Lower limit scenario)	1/3rd of the present Paddy and Sugarcane areas replaced by non-paddy crops like cholam, cumbu, ragi, Maize, redgram, black gram, green gram and fodder
Improve Efficiency	Condition where losses are taken as Nil

CHAPTER 9

ENVIRONMENTAL ASPECTS

CHAPTER 9

ENVIRONMENTAL ASPECTS

Introduction

It is a necessity to build a future in which humans live in harmony with nature. In order to protect our ecological security we need to focus our attention and to take necessary steps both locally and globally for the following objectives:

- Promoting the active involvement of rural and traditional communities in the sustainable management and conservation of natural resources.
- Working towards reduction in the extraction/exploitation of the resources and impacts of climate change.
- Minimizing pollution by reducing the use of toxic chemicals and ensuring improved management of toxic waste.
- Enhancing active participation of all sections of society in nature conservation and environmental protection through environmental education, awareness raising and capacity building.
- Ensuring that environmental principles are integrated for better development and practices.
- Promoting environmental governance through legislation, policy and advocacy.

Definition of Environment in ISO 14001:2004

The surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation. The term environment is derived from the French word 'environner' which means surroundings. It is the sum of all social, economical, biological, physical and chemical factors which constitute the surrounding of humans who are the both creator and moulders of the environment. According to ISO 14001:2004 environmental aspects is an element of an organization's activities or products or services that can interact with the environment.

The degradation of the environment has become a serious problem for the existence of human beings. Pollution of soil, water and air causes harm to living organisms as well as loss to valuable natural resources. To minimize this problem, knowledge of environmental aspect is essential.

This chapter deals with the environmental issues, viz, a deterioration of water quality, both ground and surface water due to the discharge of trade effluent and domestic waste into the water bodies as well as in land and over extraction of groundwater, sea water intrusion, etc. The other related issues dealt with are solid waste disposal, weeds, encroachment, major and minor minerals mining, sedimentation, catchment area degradation, use of chemical fertilizers and pesticides, salinity, natural calamities, public health, wild life, tourism, fisheries, socio-economic aspects, etc.

9.1 Pollution Sources

The major pollution sources identified in Paravanar basin are as follows.

- Agriculture
- Industries
- Domestic

9.1.1 Agricultural Pollution

Agricultural pollution refers to biotic and abiotic byproducts of farming practices that result in contamination or degradation of the environment and surrounding ecosystems and cause injury to humans and their economic interests. The pollution can come from a variety of sources, ranging from point source pollution to non point source pollution.

Wastes and residues from diverse agricultural activities such as planting and harvesting of row fields, tree and vine crops; the production of milk; the production of animal for slaughter; and the operation of feedlots- are collectively called agricultural wastes. In many areas the disposal of animal manure has created a critical problem, especially from feedlots and dairies.

9.1.1.1 Green Revolution

The introduction of high-yielding varieties of seeds and the increased use of fertilizers and irrigation are collectively known as Green Revolution, which provided the increase in production needed to make India self-sufficient in food grains, thus improving agriculture in India. Due to the rise in use of chemical pesticides and fertilizers there were many negative effects on the soil and land such as land degradation.

After the green revolution, the farmers have switched over from the natural manures to the chemical fertilizers and pesticides. To increase the food production to meet out the demand due to the increase in population, excessive chemical fertilizers are being applied. The chemical components in the agricultural runoff join the mainstream and induce the unwanted growth of the waterweeds. This reduces the velocity and Dissolved Oxygen (DO) in the water and also leads to more evapotranspiration losses.

9.1.1.2 Causes of Agricultural pollution:

Pesticides and fertilizers containing chemicals, contaminated water, pests and weeds, feeding the livestock with unnatural diet add to the process of agricultural pollution by way of emission.

Various types of chemical fertilizers used in the entire ayacut of this basin as well as pesticides applied on the crops contribute to pollution in the river. The entire area of Cuddalore district is around 3706 sq.km of which Paravanar River Basin covers 872.341 sq.km (ie 23.5% of total area of Cuddalore district). However the relevant data on pollution causing factors are given for entire Cuddalore district.

The main elements of agricultural pollution are phosphates, nitrates, potassium etc. The year wise consumption of fertilizers and Pesticides used in Cuddalore district is furnished in **Table 9.1 and 9.2**

Table 9.1

Consumption of fertilizers in Cuddalore District

Year	N	P	K	Total (NPK)
2009-2010	2113	1168	504	3785
2010-2011	2040	1253	508	3801
2011-2012	1117	646	167	1930
2012-2013	703	383	261	1347
2013-2014	2001	1056	482	3539
2014-2015	2181	1172	547	3900
Total (MT)	**10155**	**5678**	**2469**	**18302**

Source: Department of Agriculture, Chennai

Table 9.2 Consumption of Pesticides in Cuddalore District

Year	Liquid (litres)	Dust / Solid (kgs)
2009-2010	18306	4552
2010-2011	17746	4554
2011-2012	8373	2146
2012-2013	5096	761
2013-2014	13621	2631
2014-2015	14714	3015
Total (MT)	77856	17659

Source: Department of Agriculture, Chennai

The consumption of fertilizers Nitrogen, phosphorus and Ammonia (in M.T) are presented as chart in **Fig 9.1** and the consumption of Pesticides in Liquid form(in litres) and Dust/Solid form (in Kgs) are depicted as charts in **Fig: 9.2**

Fig 9.1 Consumption of fertilizers (Metric Tons of nutrients) in Cuddalore District

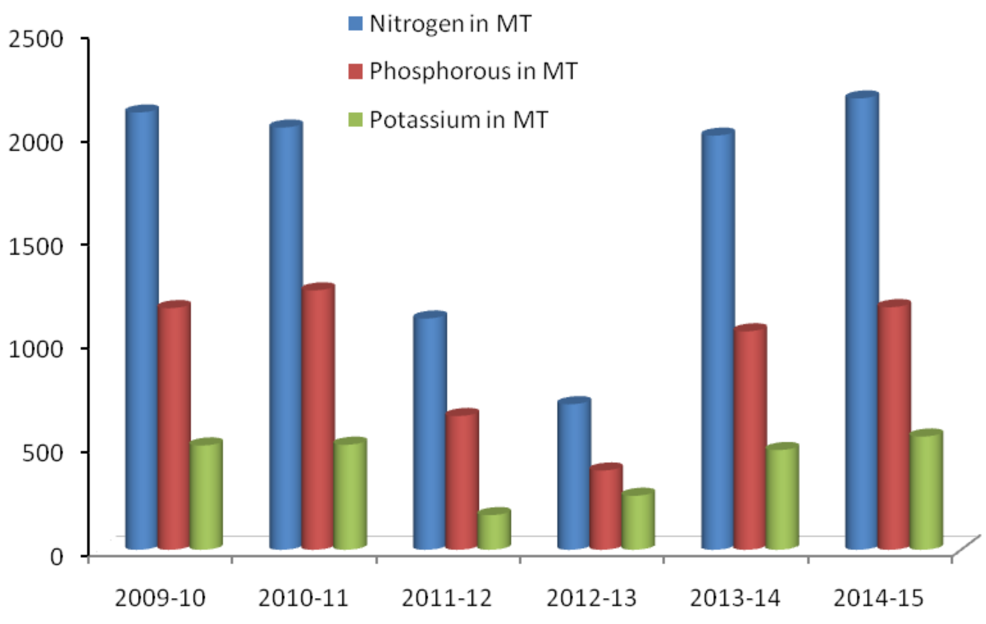
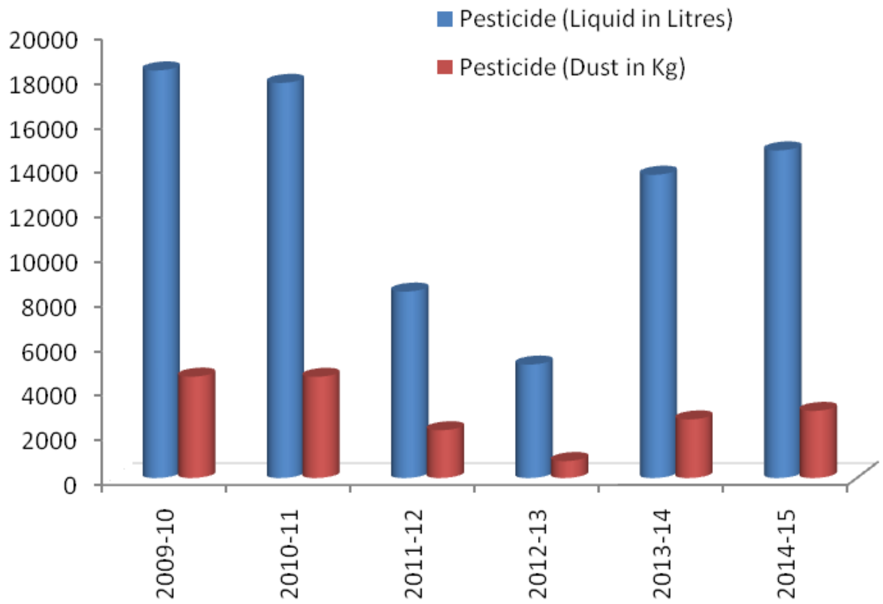


Fig 9.2 Consumption of Pesticides in Cuddalore District



9.1.1.3 Effects of Agricultural pollution

- The excess usage of potassium fertilizers has reduced the availability of micronutrients like calcium, zinc, manganese, and magnesium etc to the soil.
- High nitrate concentrations in drinking water causes blue baby syndrome which causes death in infants.
- Oil, degreasing agents, metals and toxins from farm equipment cause health problems when they get into drinking water.
- Fertilizers, manure, waste and ammonia turns into nitrate that reduces the amount of oxygen present in water which results in the death of many aquatic animals.
- The nutrients contained in fertilizers will not only promote the growth of crops but also of wild plants, weeds as well as algal and aquatic plants in rivers and lakes
- Excessive rates of fertilizer application adversely affect crop growth.

Mitigation measures:-

- Farmers may seek the advice of agricultural department for reducing the agricultural pollution.
- Encouraging crop residue management, green manuring, and organic manure and composting.

Organic farming may be practiced which has the following advantages

- Maintain the environment health by reducing the level of pollution.
- Reduces human and animal health hazards by reducing the level of residues in the product.
- Reduces the cost of agricultural production and also improves the soil health.
- Ensures optimum utilization of natural resources for short-term benefit and helps in conserving them for future generation.
- Improves the soil physical properties such as granulation, and good tilt, good aeration, easy root penetration and improves water-holding capacity.
- Improves the soil's chemical properties such as supply and retention of soil nutrients, and promotes favorable chemical reactions.
- Development of less intensive farming methods with reduced levels of fertilizer application.

9.1.2 Industrial Pollution

Industrial activities caused series of problems relating to environmental pollution. Industries are classified into three categories with respect to the pollution level. Highly polluting industries are categorized as **Red**, medium polluting industries are categorized as **Orange** and less polluting industries are categorized as **Green**.

Most of the industries are discharging their effluents directly into the water bodies or land. These affect the environment of the basin and also cause serious problems to the aquatic life.

The major pollutants from industries are,

- Soluble organics or oxygen demanding wastes.
- Suspended solids.
- Priority pollutants such as phenol and other toxic organics.
- Oil and grease.
- Heavy metals and cyanides.
- Colour and turbidity.
- Nitrogen and phosphorus.
- Pesticides.etc.

Tamil Nadu Pollution Control Board (TNPCB) is the authority for monitoring the quality of effluents from the industries. Individual treatment plants are installed by the industries. For a cluster of Industries Common Effluent Treatment Plant are installed.

In G.O. Ms. No. 213 Environment and Forest (EC-I) dept dt. 30.03.1989 the Government has ordered that no new industry is to be sited within 1 km from water resources. The TNPCB will examine the case and obtain the approval of the Government for setting up highly polluting industries away from water sources as stipulated in the guidelines.

The wastewater generated from the industries is assumed as 80% of the water demand and waste water generated for the year 2015 is given below in **Table 9.3**

Table 9.3 Waste Water generated in Mcum / year

Sl. No.	**Name of sub basin**	**Number of small, medium and large industries**	**Water utilized in Mcum per year**	**Waste water generated in Mcum per year (80 % of water demand)**
1	Paravanar	47	55.00	44.00
2	Uppanar	108	18.19	14.55
Total		**155**	73.19	58.55

Source: Analysis done in chapter 7

9.1.2.1 Effluent Disposal

The problems relating to the disposal of industrial solid wastes are associated with lack of infrastructural facilities and negligence of industries to take proper safe guards. The effluent from sewage treatment plants may be discharged in to waters bodies such as lakes, tanks, streams, or on land only after proper treatment. While discharging the effluents, the Industries should follow the general standards of Environment Protection Rules. The nature and degree of treatment given to the sewage is dependent upon the requirement imposed by the regulatory authorities.

9.1.2.2 Effluent Utilization:

CASE STUDY - Reuse of Municipal Effluent as Boiler Make-Up :

The Kodungaiyur STP is located in the vicinity of the Manali industrial area. From this STP, secondary effluent is supplied by the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) to the Chennai Petroleum Corporation Ltd (CPCL) at a cost of 11.85 Rs/m3. The reclaimed water provided to the CPCL Refinery are reused for cooling and for boiler make-up water production. The refinery also recycles in-house effluents which are utilised for the production of boiler makeup water and as cooling make-up. By ensuring continuous operation of Sewage Reclamation, Desalination and Zero Discharge Plants, CPCL has successfully implemented the concept of Recycling, Re-using and reducing the water resources consumption. Similarly all industries should work towards achieving Zero discharge.

Source: Chennai Petroleum Corporation Limited

Mitigation measures

- Recycled treated Effluents should be used in Industries for cooling process
- Sewage treatment units must be installed, operated and maintained.
- Agglomeration of industries shall be encouraged so that the by-product or waste of one industry may be a raw material for some other industries, which will lead to reduction of natural water requirements.
- The treated waste water of one industry may be used as input for cooling tower of other industries like Thermal plant, Pharmaceutical, petro chemical, Refineries, Fertilizer industries, and so on, so that the fresh water requirement for those industries getting reduced.
- The residue from the treatment plant may be utilized for manufacture of fertilizers.
- The industries may be encouraged to use the treated waste water for flushing the cisterns in rest rooms, so that the fresh water requirements get reduced.

9.1.2 Domestic Sector

In Paravanar river basin, domestic sewage pollution is also predominant and the small towns are discharging the sewage directly into the drains and streams nearby.

Practically there is zero discharge of domestic sewage in the case of villages. The reuse of domestic sewage generated from the Municipalities and Town Panchayats is warranted.

The wastewater generated from domestic sector has been calculated based on the per capita water supply norms adopted by the TWAD Board for Municipality, Town panchayats, etc. The generation of sewage in Rural and Urban areas in Paravanar river basin are shown in **Table 9.4** and **9.5** respectively**.**

Table 9.4 Generation of Sewage in Rural Areas

Collection of sewage is assumed as 80% of water demand:

Sl. No.	Name of the Sub basin	Projected Population in 2016 in millions	Water Demand 2016 in Mcum	Volume of sewage generated in Mcum/ year
1	Paravanar	0.201	5.856	4.68
2	Uppanar	0.291	8.503	6.80
Total		0.492	14.359	11.48

Source: Analysis done in chapter 7

Table 9.5 Generation of Sewage in Urban Areas

Collection of sewage is assumed as 80% of water demand:

Sl. No.	Name of the Sub basin	Estimated population in 2016	Water Demand 2016 in Mcum	Volume of sewage generated in Mcum/ year
1	Paravanar	0.132	7.496	6.00
2	Uppanar	0.225	12.743	10.19
TOTAL		0.358	20.238	16.19

Source: Analysis done in chapter 7

Sewage from Rural Areas = 11.48 Mcum per year

Sewage from Urban Areas = 16.19 Mcum per year

Total = 27.67 Mcum per year

9.1.3.1 WASTE WATER TREATMENT PROCESS :

The below diagram shows the typical process involved in the waste water treatment,

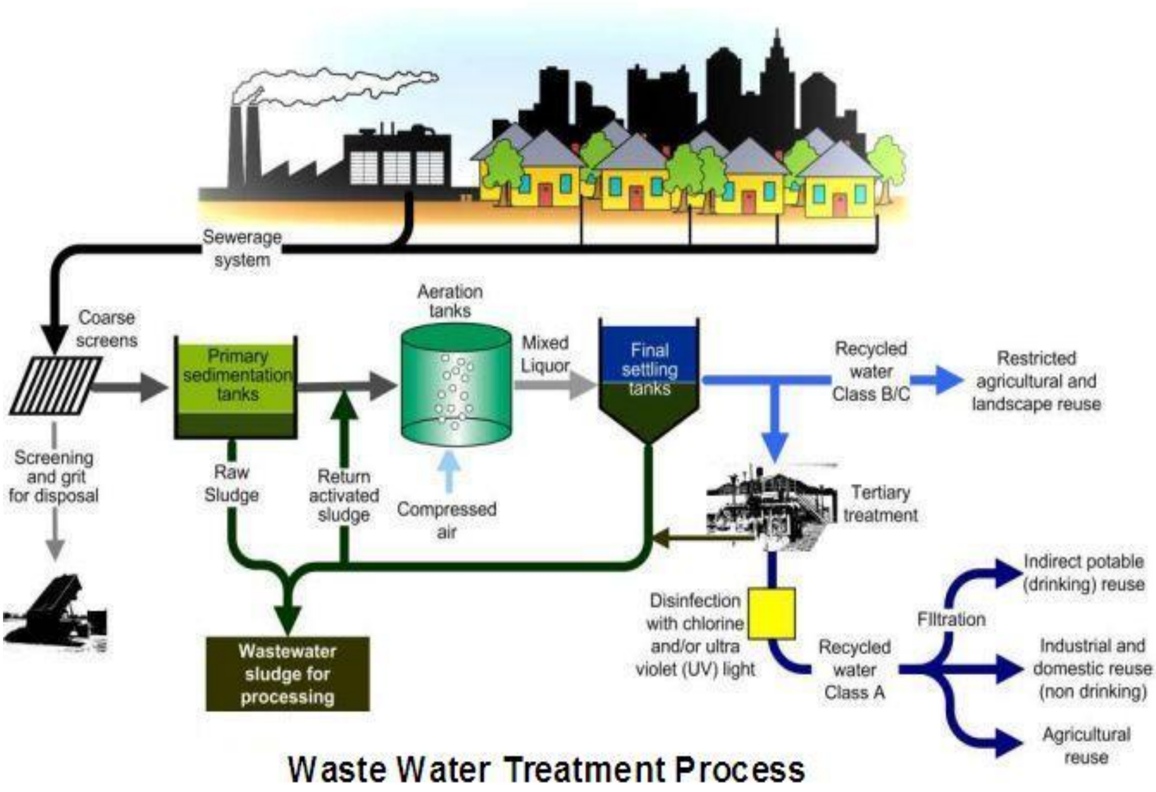


Fig 9.3 Waste Water Treatment Process

Here the recycled water from secondary treatment can be used for restricted agricultural and landscape reuse and the recycled water from the tertiary treatment after disinfection can be used for direct agricultural reuse, industrial and domestic reuse (CPCL, Chennai- using for Boiler make up). This water is further treated with RO process using the dual membrane technology and also further disinfection by Ultra Violet technology can be used for drinking purpose.

9.1.3.2 WASTE WATER MANAGEMENT:

CASE STUDY - Reuse of Municipal Effluent for Potable use:

neWater is the brand name given to reclaimed water produced by Singapore's Public Utilities Board. More specifically, it is treated wastewater (sewage) that has been purified using dual-membrane (via microfiltration and reverse osmosis) and ultraviolet technologies, in addition to conventional water treatment processes. The water is potable and is consumed by humans, but is mostly consumed by industries requiring high purity water. The quality of neWater consistently exceeds the requirements set by WHO guidelines and is cleaner than Singapore's other water sources.

Fig 9.4 :Bottles of neWater for drinking purpose

Sewage Farming

The nutrients in sewage like nitrogen, phosphorous and potassium along with the micronutrients as well as organic matter present in it could be advantageously employed for manufacture of fertilizer and enhancing sewage farming to add to the fertility and improve the drainage characteristic of the soil, along with the irrigation potential of the water content. Even application of treated effluent to land has to be carried out with certain precautions as it is not completely free from this risk.

A good sewage farm should be run on scientific lines with efficient supervision with the prime objective of not polluting the soil. Effluent from properly designed waste stabilization ponds is also suitable for application on land. Under no condition, application of raw sewage on sewage farms should be permitted.

Mitigation

- It is recommended to recycle/ reuse of waste water in a phased manner to meet the growing demand.
- For Non potable uses (Fire Fighting, Toilet Flushing etc) recycled waste water should be used.
- Open discharge of domestic effluents into the river must be completely stopped.
- Sanitary facilities have to be provided at public places.
- Awareness has to be created among the public to prevent pollution of water bodies.
- Public may be encouraged to reuse the treated water for different purposes like pisciculture, aquaculture, horticulture and irrigation.
- Subsidies may be provided by the Government to the communities for treating waste water.

9.2 Sedimentation

Sedimentation in tank, an indispensable process has become increasingly important since the sediment deposed inside the tank reduces the capacity of the tank thereby thwarts the purpose for which they were constructed. The loss of storage due to sedimentation gradually affects the regulation practices and the useful life of the tank. Considering the above facts systematic capacity surveys are required to assess the rate of siltation and evolve suitable remedial measures to minimize further erosion in the catchment and the silt brought in to the tank.

There are two major tanks in Paravanar river basin, viz.,

1. Walajah Tank and
2. Perumal Tank

The sedimentation study was conducted by the Water Shed Management Division, Institute of Hydraulics and Hydrology, WRD, Poondi and the details are given in **Table 9.6**

Table 9.6 List of tanks in which sedimentation studies conducted

Name of the Tank	Initial capacity in Mcum.	Present capacity in Mcum	Capacity loss in Mcum	Annual silting rate in Mcum / year	Average annual silting rate in %	Average annual silting load/sq.km catchment Mm^3/sq.km	Average annual silting load/ sq.km of water spread Mm^3/ sq.km
Walajah Tank ****	2.5689	1.6714	0.898	0.01	1.11	0.000052	0.0021
Perumal Tank	17.768	14.979	2.789	0.08	2.86	0.00025	0.006

Source: Executive Engineer, Water Shed Management, Pollachi, WRD,PWD

From the above table it is inferred that in Walajah tank, the loss in capacity was found to be 34.95%, in Perumal Tank the loss in capacity was found to be 15.69%.

**** NLC stated that under the corporate social responsibility scheme, the Corporation had taken up the project 'Jalaparyapatha' (Water Resource Augmentations). Under this scheme, the Corporation had spent Rs.13.72 Cr towards desilting the Walajah Tank to restore the capacity of the tank.

Source: NLC

Mitigation measures

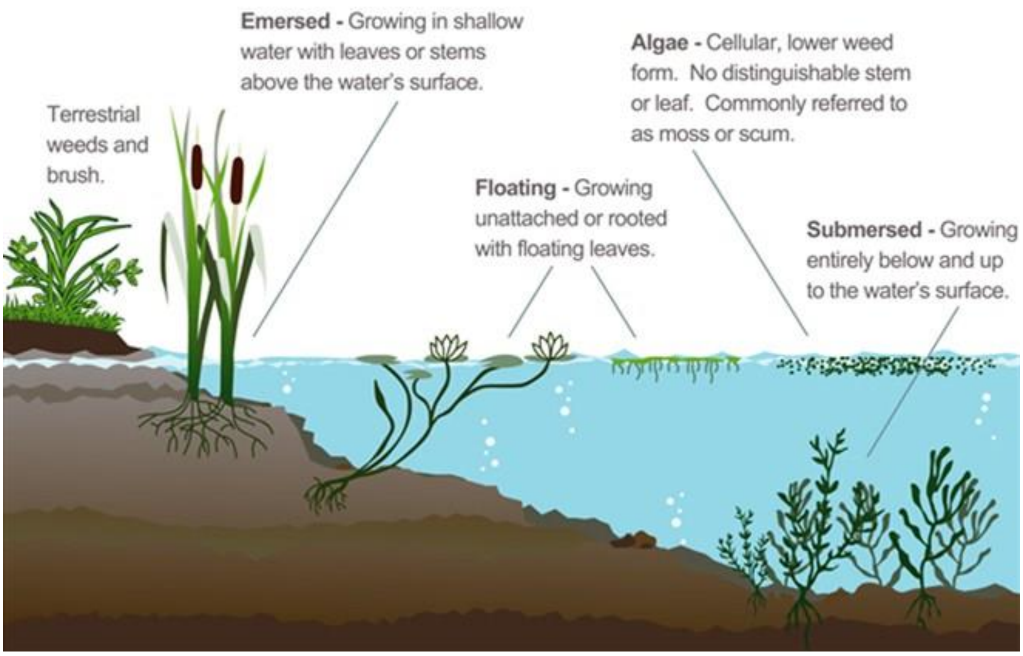
- The main reason for the sediment concentration in the Walajah tank and supply channel is the Neyveli pumping water.
- On analysing the average sediment composition of Walajah tank it is found that the sediment contains 7.02 % coarse sand, 53.73 % of medium sand, 20.03 % of fine sand and 19.22 % of clay and silt.
- On analysing the average sediment composition of Perumal tank it is found that the sediment contains 17.32 % coarse sand, 46.47 % of medium sand, 24.47 % of fine sand and 11.74 % of clay and silt.
- Construction of stilling basins at the pumping stations of NLC mines has been suggested.
- Construction of check dams at Kanniyakoil odai sub watershed and Thambipettai odai water shed has been suggested.

- Operation of tank may be arranged in such a way that more of suspended sediment water is withdrawn at appropriate time.
- Adoption of soil conservation measures by arresting soil erosion, agronomic and vegetative methods may be intensified.
- Watershed management including afforestation and the promotion of farming practices which reduce soil erosion is frequently advocated as the best way of cutting sediment deposition in tanks.
- Ensure environmentally acceptable methods for the disposal of dredged sediments, ensuring use for enhancement where appropriate.
- Eco-restoration may be done at appropriate places such as contour trenching, check dams, percolation ponds, etc.,
- Encourage tree planting

9.3 Water Weeds

Aquatic weeds are those unabated plants which grow and complete their life cycle in water and cause harm to aquatic environment directly and to related eco-environment relatively. These water plants make water bodies unfit and take the shape of noxious aquatic vegetation due to over growth. They are also responsible to reduce the available water resources by way of excess seepage or evapotranspiration process. The presence of excessive aquatic vegetation influences the management of water in water bodies.

Fig: 9.5 Types of water weeds



The most noxious weed is water hyacinth (*Eichhornia crassipes*). In India 60-70% of inland water is presently infested with aquatic weeds predominantly by water hyacinth. Water hyacinth registers 5% gain in weight every day. At least 80% of the plant body constitutes water and the loss through transpiration is also more and higher than the normal evaporation from the aquatic ecosystem.

Water weeds in tanks in Paravanar basin

Of the two major tanks in Paravanar basin, there is no problem of weeds in Walajah tank. But in Perumal tank there is abundant presence of White water lilly (Nymphaea alba L) and presence of water hyacinth in the surplus course of the tank.

Fig: 9.6 Weeds in Perumal Tank

Various reasons are attributed to the successful invasion of waterweeds. The damage by waterweed invasions is both ecological and economic.

DETRIMENTAL EFFECTS OF WEED INVASIONS

ENVIRONMENTAL

- Depletion of water resources
- Water Pollution
- Environmental health effects
- Sedimentation

ECONOMICAL

- Agriculture
- Inland fisheries
- Navigation
- Hydropower generation

9.3.1 Reasons for the abundance of waterweeds

1. Clearance of riparian vegetation along the bank of the river for industrialization and domestic purposes.
2. Invasion by exotic weeds.
3. Eutrophication of riverine ecosystem due to return flow and sewage entry.
4. Lack of proper waterweed management plan.
5. Lack of controlling measures of weed invasion.

9.3.2 Impact of waterweeds in the river system

1. Decrease in water quality.
2. Luxuriant growth of periphytes
3. Prevalence of water borne diseases.
4. Increased evapo-transpiration.
5. Raising of riverbed due to sedimentation.
6. Narrowing of water ways
7. Blockage of water canals and sluices.
8. Competition for space
9. Invasion in the agricultural fields.
10. During flood season, drainage systems are clogged which causes breaching of rivers, drainages and supply channel as well as inundation in the river corridors which causes epidemic diseases.

9.3.4 Method of controlling the Water weeds

The water weeds having become a menace in different parts of the river basin. Several methods are being recommended to suppress its growth.

9.3.4.1 Manual methods

Dredging: This is probably the commonest way of cleaning weeds from drains and ditches. A dragline dredge may be equipped with a bucket or with a weed fork or other special tools.

Drying: The tops of under water weeds are exposed to sun by draining the water form ditches and ponds and allowed to dry. Drying may be repeated to control regrowth from roots or propagules in the bottom mud or sand.

Mowing: Mowing is a method of controlling weeds in the banks of the canal and ditches.

Hand cleaning: The men cut and remove the weeds with heavy knives and hooks.

Burning: It is used to control weeds in the banks above the water line. Best results could be obtained by first searing the green vegetation and following in 10 to 12 days with complete burning. A hot flame is passed over the vegetation at such a rate that the plants wilt but are not charred. Burning can be combined with chemical or other mechanical methods. Mowing followed by burning the dried weeds may increase the effectiveness of mowing.

Chaining: A heavy chain is attached between two teams or tractors on opposite banks of the ditch. As they move, the chain drags over the weeds and breaks them off.

Cutting: A mechanical weed cutter is used to cut the aquatic weeds at 1 to 1.5 m deep in the water. It consists of a sharp cutter bar operated hydraulically from a boat. The harvested weeds float to the water surface and are removed manually or by sieve buckets. The beach groomer is a portable and free standing weed control device fitted with a handle that can take care of every undesired water weeds.

9.3.4.2 Biological Methods

In the biological control of aquatic weeds, grass carp fish is considered as an excellent bio-agent directly fed on Hydrillla. A grass carp weighing 1.20 kg was found to consume daily about 1.4 times its own weight of Hydrilla. This fish stays as a major bio-agent of this weed. Reports emphasize that grass carp is a proven bio control agent of pond weeds.

Fig: 9.7 GRASS CARP

9.4 Catchment area treatment of Mined out land in NLC

NLC is adopting a holistic approach to the environmental management relating to its mining and thermal power production operations.

Mine Spoil Reclamation

Continuous Mine Closure and Reclamation of Mined-out Lands and mine spoil slopes are concurrently planned and executed with the respective Mine plans. So far, 2500 hectares of mined out lands have been reclaimed by nourishing the backfilled soil. Paddy, coconut trees, fruit bearing trees and vegetables are grown on the reclaimed land.

Land Reclamation

Fig 9.8 Paddy Crops and coconut trees in Reclaimed land

Fig 9.9 Slope Stabilization by Afforestation

Ash Pond Reclamation

Abandoned ash ponds of Thermal Power Stations are being reclaimed and variety of field crops, vegetables, fruits and 3500 trees of different species are now growing in the reclaimed area of 11.50 acres.

Biodiversity in afforestation

The integrated farming system developed in reclaimed and afforested area include flowering and fruit bearing trees, various agricultural and horticultural plants and crops, animal component, aquaculture and biogas.

9.5 Sea Water Intrusion

Introduction

Sea water intrusion is a major concern commonly found in coastal aquifers around the world. Seawater intrusion is induced due to flow of seawater into freshwater aquifers primarily caused by abnormal extraction of groundwater near the coast where groundwater is being pumped from aquifers that are having hydraulic connection with the sea. Generally, extraction of groundwater for agriculture, aquaculture, small & large scale industries, coastal habitations/resorts etc; induce reverse gradient on the coastal aquifer and thus sea water intrusion takes place.

Location

The study area is situated in between Cuddalore to Thachchanchavadi (Ayyampettai) village of coastal area in Cuddalore block and Kurinjipadi block of Cuddalore district. The area between the Longitude of 79° 46’ 33” E & 79° 45’ 27” E and between Latitude of 11° 42’ 05” N &11° 34’ 36” N is the study area. The study area is 13.9 Kilometers long and 5 Kilometers wide i.e. 69 Square kilometers. This area falls in the toposheets of 58M / 10 &14

Methodology

The State Ground and Surface water Resources Data Centre, under Water resources Department / PWD is undertaking sea water intrusion study systematically along the Coast of Tamil Nadu for its entire coastal length of 1076 Kilometer since 2007. In Paravanar basin, 7 open wells are being monitored by SG & SWRDC exclusively for sea water intrusion study and water samples are collected for chemical analysis (The above well locations map enclosed in **Plate No: PAR 46**). Such data were collected from the above department and analysed for water quality, both for pre monsoon and post monsoon, from 2011 to 2014. The results from the analysis are enclosed as Annexure SWI-1 and SWI-2.

The higher values of Electrical conductivity, total dissolved solids and ratio of chloride with carbonate and Bicarbonate Cl /(CO_3 + HCO_3) are the main factors indicating sea water intrusion, and the temporal variation of the ratio is shown in graph 1. The temporal variation in Electrical conductivity and Total dissolved solids are drawn as graph for premonsoon and Postmonsoon for better understanding, vide, graph 2 and 3, respectively.

In this study area, all observation wells are shallow open wells. The observation wells in Cuddalore OT, Capper Quarry and Thiruchopuram show high values of Cl / (CO_3 + HCO_3) due to marine conditions, where as the remaining wells shows no remarkable changes. Since the confluence point of Uppanar is low lying, sea water enters the river Uppanar easily and runs up to more than one kilometer (approximately). In this area the surface water is not suitable for irrigation and construction purposes. Even though some wells show high values of Cl / (CO_3 + HCO_3), the prevailing backwater conditions and the marine formations along the coast only contributes the salinity in this part. Otherwise the basin is free from sea water intrusion.

However, precautions need to be taken for preventing seawater intrusion in future by regulating unscrupulous extraction of groundwater along the coast. The salinity can be prevented by constructing a tail end regulator for arresting backwater flow into the Uppanar river. The monitoring well network needs to be strengthened and the geological condition along the coast is to be studied in depth. A master plan may be formulated by taking up a detailed study on the possibility of seawater intrusion along the coast of this basin.

9.6 Salinity

Salinity is an important land degradation problem. The saline degradation is due to natural causes and poor irrigation, which disturb the water cycle. Expansion of canal irrigation is also responsible for widespread water logging and salinity problems. A continual supply of water in excess of that required by growing crop and without adequate drainage results in rising of the water table to levels from which salts can be drawn by capillary water movement and evapo-transpiration by crops. When the water dries up, the salts are left on the upper surface as a crust or layer.

Salinity in ground water can be of broadly categorised into two types, i.e. Inland Salinity and Coastal salinity.

9.6.1 Inland Salinity

Inland salinity is also caused due to practice of surface water irrigation without consideration of ground water status. The gradual rise of ground water levels with time has resulted in water logging and heavy evaporation in semi arid regions lead to salinity problem in command areas.

9.6.2 Coastal Salinity

Ground water in coastal areas occurs under unconfined to confined conditions in a wide range of unconsolidated and consolidated formations. Normally, saline water bodies owe their origin to entrapped sea water (connate water), sea water ingress, leachates from navigation canals constructed along the coast, leachates from salt pans etc. In general, the following situations are encountered in coastal areas.

- Saline water overlying fresh water aquifer
- Fresh water overlying saline water
- Alternating sequence of fresh water and saline water aquifers

The most prevalent type of salinity is those caused by chlorides and sulphates of sodium and calcium. Higher content of soluble salts in soil results in salinity problems. Under conditions of high evaporation, the depth to which rain penetrates is limited and salts become concentrated in the root zone.

Salinity directly affects the productivity by making the soil unsuitable for crop growth. Indirectly, it lowers productivity through its adverse effects on the availability of nutrients.

Impact on Environment

- Ground water rendered unfit for human consumption.
- Damage to infrastructure (roads, bricks, corrosion of pipes and cables)
- Land subsidence due to sea water ingress.
- Salinity affects production in crops, pastures and trees by interfering with nitrogen uptake, reducing growth, stopping plant reproduction and ultimately results in soil infertility.
- Increases repair and maintenance costs for a range of services provided for public use as there is a need to replace infrastructure earlier than normal.

The water quality criteria for Irrigation in respect of salinity(total salt concentration) are given in **Table 9.7.**

Table 9.7 Water quality criteria for Irrigation in respect of salinity (total salt concentration)

Salinity	**Range of EC (micro mhos/cm)**
Low	Below 1500
Medium	1500-3000
High	3000-6000
Excessive	Above 6000

Source: IS 11624-1986

Generally in the Paravanar Basin, the EC value is within the limits and the water is well suited for Irrigation except in villages Odaiyur, Kiliyanur and Kullanchavadi. (Table 6.10). The salt tolerant crops like sunflower, sugar beets etc can be grown where EC value is high.

Mitigation

- It is essential to enhance sustainable land use and water management.
- Proper irrigation management can prevent salt accumulation by providing adequate drainage water to leach added salts from the soil.
- Rainwater Harvesting structures should be made mandatory.
- Additional costs may include surface leveling, lining drainage channels, sub soil drainage schemes, pumping to lower water tables and mixing saline water with water of better quality.
- Drainages should be de-silted once a year before rainy season.
- Garbage should not be dumped in ponds and channels.

Artificial recharge structures such as sub surface dyke, check dams may be constructed at vulnerable points to prevent seawater intrusion.

9.7 Fisheries

Tamil Nadu is one of the leading States in India in fisheries development having a coastal length of 1076 km (13% of the country's coast line). The different types of aquatic resources like marine, freshwater, brackish water, riverine stretches, and cold water streams in upland area are bestowed with rich biodiversity of aquatic fauna and flora. There are about 2500 species of fishes found in different aquatic environment.

Paravanar River basin has a coastal length of 13.90 kilometers. The fisheries sector has been broadly categorized as Inland fisheries and Marine fisheries.

Out of 591 marine fishermen villages in Tamil Nadu, 49 marine fishermen villages in are in Cuddalore district.

9.7.1 Inland Fisheries

Tamil Nadu ranks eighth place in inland fisheries production in the Country. The inland fishery resources comprise reservoirs, major irrigation and long seasonal tanks, short seasonal tanks and ponds which are amenable to both capture and culture fisheries. There are 22 Inland Fishermen Co-operative Societies and 6 Inland Fisher women Co-operative Societies in the district.

9.7.2 Marine Fisheries:

There are 325 Mechanized fishing boats, 1723 FRP boats and 3000 FRP and wooden catamarans operating in this district. There are 35 Fishermen Coop Societies and 40 Fisherwomen Co-op societies are functioning in Cuddalore district. Various welfare schemes are implementing through the Co-op societies. Fishing boats are berthing at Cuddalore Fishing Harbour, Mudasalodai Fishing Landing Centre and Annankoil Fish Landing Centers, Year wise Inland Fish production in Paravanar River basin is depicted below in **Table 9.9** and Year wise Marine Fish production in Paravanar River basin is depicted below in **Table 9.10**

Table 9.9 Year wise Inland Fish production

(in Tonnes)

Sl.No	Districts	2009-10	2010-11	2011-12	2012-13	2013-14
1	Cuddalore	15641.84	15548.13	16656.03	16848.07	17382.35

Source: Statistical Handbook of Tamil Nadu

Table 9.10 Year wise Marine Fish production

(in Tonnes)

Sl.No	Districts	2009-10	2010-11	2011-12	2012-13	2013-14
1	Cuddalore	22086.13	25531.73	25646.62	25820.68	25978.19

Source: Statistical Handbook of Tamil Nadu

The annual inland fish production in Cuddalore district amounts to nine percent of overall inland fish production of Tamil Nadu.

Mitigation Measures

- Expansion in area of fish culture through stocking of all culturable water bodies by leasing, licensing, share fishing and introduction of fish culture in Multi Purpose farm ponds/water recharge ponds.
- Expansion by increasing stocking density & improving survival through improved aeration, supply of quality feed material, water quality management and disease prevention programme.
- Practicing of improved culture methods with low cost models to increase unit productivity by cage culture, closed & semi closed recirculation culture method, sewage fed fish culture, integrated fish farming with poultry, piggery & cattle and biomass based fish culture.
- Development of farm made fish feeds to reduce input cost as feed form 60-70% of input cost – use of organic manure to improve plankton & feeding.
- Development of hatcheries / seed rearing centres with proper technology through brood stock development programme, development of improved strains of established fish species, establishment of multi species breeding centers and backyard hatcheries, establishment of earthen fish seed rearing units and fish seed rearing in cages/pens.
- Promoting ornamental fish culture as a commercial activity.

9.8 Public Health

Urbanization in India has been taking place at a rapid pace at an average rate of around two percent per annum. In Paravanar river basin the total population is 849360. Due to Urbanization and drastic increase in population, the water demands in domestic, agricultural and industrial sectors have gone very high. The water used by these sectors is highly polluted due to biological and chemical means. This enters into the water bodies and deteriorates the water quality and thereby affects the human health also. Water-borne diseases are caused by pathogenic microorganisms which is present in human or animal waste. Unawareness of the hygienic practices and poverty are also the main causes of many diseases among the people. Some of the common water borne diseases includes typhoid, cholera, malaria, diarrhoea, leptospirosis, chikungunya etc. The cause for the disease is shown in **Table 9.11.** The Block wise prevalent diseases in the Paravanar basin are depicted in **Table 9.12.**

Table 9.11 Water borne diseases and the cause for the disease

Sl.No	Water Borne Diseases	Cause for Disease
1	Diarrhoea	Discharge of water faeces from the intestines containing blood and mucus.
2	Cholera	Caused due to the infection of the small intestine by bacterium Vibrio cholera. This disease happens when cholera bacterium present in drinking water or in the food that we eat.
3	Japanese Encephalitis	Mosquito borne zoonotic viral disease
4	Leptospirosis	A bacterial disease spread through the urine of infected animals.
5	Malaria	This is a parasitic disease transmitted from one person to another. It happens from the bite of female Anopheles mosquitoes.
6	Dengue Fever	An outbreak prone viral disease is transmitted by Aedes mosquitoes.
7	Chikungunya	Caused by a virus and is transmitted to humans by two species of mosquito (Aedes and Aegypti).

Table 9.12 Blockwise prevalence diseases
Malaria

Block	2009		2010		2011		2012		2013		2014	
	C	D	C	D	C	D	C	D	C	D	C	D
Cuddalore	63	0	50	0	56	0	31	0	34	0	17	0
Panruti	2	0	1	0	7	0	1	0		0	0	0
Kurinjipadi	1	0	0	0	3	0	5	0	2	0	2	0
Parangipettai	1	0	0	0	28	0	17	0	7	0	3	0
Bhuvanagiri	0	0	0	0	2	0	1	0	3	0	2	0
Kammapuram	0	0	0	0	1	0	4	0	0	0	0	0
Virudhachalam	0	0	0	0	1	0	1	0	0	0	0	0
Total	67	0	51	0	98	0	60	0	46	0	24	0

ADD (Acute Diarrhea Disease)

Block	2011		2012		2013		2014	
	C	D	C	D	C	D	C	D
Cuddalore	4144	0	4842	0	3867	0	3994	0
Panruti	3373	0	3811	0	2789	0	4413	0
Kurinjipadi	951	0	1807	0	1497	0	1924	0
Parangipettai	1174	0	1744	0	1809	0	1788	0
Bhuvanagiri	1128	0	2220	0	1893	0	1968	0
Kammapuram	1190	0	1790	0	1790	0	2352	0
Virudhachalam	1738	0	2437	0	1489	0	2324	0
Total	13698	0	18651	0	15134	0	18763	0

Japanese Encephalitis

Block	2009		2010		2011		2012		2013		2014	
	C	D	C	D	C	D	C	D	C	D	C	D
Cuddalore	0	0	0	0	0	0	0	0	0	0	0	0
Panruti	0	0	0	0	0	0	0	0	0	0	0	0
Kurinjipadi	0	0	0	0	1	0	0	0	0	0	0	0
Parangipettai	0	0	0	0	0	0	0	0	0	0	0	0
Bhuvanagiri	0	0	0	0	0	0	0	0	0	0	0	0
Kammapuram	0	0	0	0	0	0	1	0	0	0	0	0
Virudhachalam	0	0	0	0	0	0	1	0	0	0	0	0
Total	0	0	0	0	1	0	2	0	0	0	0	0

Leptospirosis

Block	2009		2010		*2011*		2012		2013		2014	
	C	D	C	D	*C*	*D*	C	D	C	D	C	D
Cuddalore	0	0	2	0	*3*	*0*	1	0	1	0	1	0
Panruti	0	0	0	0	*0*	*0*	1	0	0	0	1	0

Kurinjipadi	0	0	1	0	*2*	*0*	0	0	2	0	0	0
Parangipettai	2	0	0	0	*0*	*0*	2	0	0	0	0	0
Bhuvanagiri	0	0	0	0	*0*	*0*	0	0	0	0	0	0
Kammapuram	1	0	1	0	*1*	*0*	0	0	1	0	0	0
Virudhachalam	0	0	0	0	*0*	*0*	0	0	0	0	0	0
Total	3	0	4	0	*6*	*0*	4	0	4	0	2	0

Chikungunya

Block	**2009**		**2010**		**2011**		**2012**		**2013**		**2014**	
	C	D	C	D	C	D	C	D	C	D	C	D
Cuddalore	1	0	2	0	0	0	1	0	3	0	1	0
Panruti	0	0	0	0	4	0	1	0	1	0	0	0
Kurinjipadi	1	0	1	0	0	0	2	0	3	0	1	0
Parangipettai	2	0	1	0	0	0	0	0	0	0	0	0
Bhuvanagiri	0	0	0	0	0	0	0	0	0	0	0	0
Kammapuram	0	0	0	0	0	0	0	0	1	0	0	0
Virudhachalam	0	0	0	0	0	0	0	0	0	0	3	0
Total	4	0		0	4	0	4	0	8	0	5	0

Dengue

Block	**2009**		**2010**		**2011**		**2012**		**2013**		**2014**	
	C	D	C	D	C	D	C	D	C	D	C	D
Cuddalore	3	0	0	0	484	0	208	0	151	0	263	0
Panruti	7	0	4	0	162	0	78	0	76	0	31	0
Kurinjipadi	1	0	0	0	183	0	86	0	102	0	52	0
Parangipettai	1	0	1	0	67	0	55	0	21	0	23	0
Bhuvanagiri	0	0	0	0	33	0	44	0	12	0	17	0
Kammapuram	5	0	3	0	66	0	23	0	15	0	12	0
Virudhachalam	1	0	0	0	91	0	33	0	14	0	25	0
Total	18	0	8	0	1086	0	527	0	391	0	423	0

Source: The Director of Public Health and Preventive Medicine

C: Cases reported. D: Deaths reported.

It is observed that the number of cases reported to be higher and the death rate has become almost Nil. The main cause for all these diseases are the polluted water. Clean water is most important to reduce the spread of these diseases. People should consider these three tips to reduce the spread of bacteria through water.

1. Never drink untreated water.
2. Avoid eating raw foods.
3. Practice good hygiene.

Mitigation measures

- The domestic and Trade effluents have to be treated properly to acceptable standards before letting into any sources after ascertaining the permissible limits.
- Agriculture pollution due to agricultural run- off has to be analysed periodically.
- The drinking water should be consumed only after boiling or chlorination or by using any electrical purifier.
- Anti larval measures may be undertaken frequently by source reduction of vector breeding places like artificial containers such as broken utensils, discarded tyres, plastic waste cups and broken bottles for the control of Aedes mosquitoes which spread dengue fever
- Daily surveillance can be carried out to control the diseases.
- The water containers should be washed and cleaned every day.
- The pipes and tanks that supply water should be maintained properly.
- Education and awareness creation as a cost effective way in improving health and better life.

9.9 Background Information about the City

Cuddalore town is the headquarters of the Cuddalore taluk and the Cuddalore district. It is located at the estuary of rivers Gadilam and Pennaiyar on Bay of Bengal. The town is at a distance of 200 Km from South of Chennai, 23 Km South of Puducherry and 44 Km North of Chidambaram. The Cuddalore town covers a total area of 27.69 Km^2 and is divided in to 8 sanitary division and 45 political wards. The urbanization and industrialization has made rapid changes and expanding residential areas. The lack of adequate collection and treatment of MSW by Cuddalore Municipality Corporation

(CMC) has created greater challenges for waste management in the rapidly expanding town. The MSW problem has become very acute in Cuddalore town, where the disposal facilities available are inadequate in comparison to the generated quantity of MSW, which is typical to any expanding city.

Municipal Solid Waste Generation

Managing Municipal Solid waste in Cuddalore is handled by Cuddalore Municipal Corporation. The major sources of waste include waste from Residence, Commercial establishments, Institutions, Markets and health care centers. The majority of daily waste is produced from the residential sector and the rest of the sources like Institutional, Industrial, Commercial, Construction, demolition and Street cleaning.

The quantity of the MSW generation in Cuddalore municipality rapidly increased in last few decades. For the past ten years the total municipal solid waste generated has increased by 50% whereas the population growth is approximate 9.28% in the same period.

Secondary Collection and Transportation

Transportation and secondary collection of MSW from the various collection points to disposal sites is commonly done by Municipal workers using tri-cycles, mini lorry, lorry, Hydraulic Dumper Plaza, tractor and trailer, depending on their availability and the nature/quantity of the MSW.

Disposal of Waste

At present open dumping is only disposal practice in Cuddalore. There are three disposal sites in the Cuddalore area - Kammiyampettai, Semmandalam and Pachankuppam of which Semmandalam landfill is not operated as open dumping or composting at present due to its very close proximity to government employees residential area in Semmandalam. Since Cuddalore does not have proper sanitary landfill or any other controlled waste disposal facility, all collected waste reach the two dumping sites without any kind of segregation and processing. The majority of waste is dumped in Kammiyampettai landfill located approximately 3 Km from Cuddalore bus stand. It is the largest landfill site in Cuddalore Municipality and it is operating since 1985. The landfill

has 6.10 acres and still receives majority of municipal waste. Another dumpsite is located in Pachankuppam area on the South Cuddalore, the landfill covers 1.90 acre and is operating for nearly 15 years. This dumping site receives waste from Cuddalore old town market. There is no systematic environmental monitoring to prevent possible pollution sources like emission, leachate migration and leachate gas from landfill operations.
Source: World Applied Sciences Journal 31(6):1096-1103, 2014

Mitigation Measures

- The municipality should create awareness among the public to encourage waste segregation and recycling behavior at source and the local authorities should involve and get support from various resident welfare associations and non-governmental organizations on waste management program.
- Waste to energy potential: Waste to energy consider as one of the suitable resource recovery option, the MSW landfills are major sources of Green House Gases (GHGs) which are contributor for global warming, if the methane recovered from landfill, unpleasant odour and environmental impacts will be minimized. In addition, clean energy will be produced that will offset the polluting fossil fuel. Since the amount of organic waste is highest in Cuddalore, energy could be recovered by thermal process. The thermal treatment process of MSW results energy recovery of 500 to 600 Kwh electricity from one ton of combusted MSW, similar project implemented by several local authorities with support of Ministry of New and Renewable Energy (MNRE) Govt.of India. Hence, this kind of energy recovery plan needs a proper technical and feasibility study for sustainable energy recovery from Cuddalore municipal landfill.
- Waste reduction at source: The households are the major source of MSW generation; it may useful to focusing on improving household waste management behavior and segregation at household level can help to reduce volume of waste being generated. The municipal authority have to provide separate waste collection bins to collecting bio and non bio-degradable waste to each residents, it can be distribute through the NGO and Resident’s Associations. The municipality also should allot particular day and time to each zone for door to door collection.
- Community Based Management: Another important point drawn from this study is lack of community participation on waste management, that community

organizations, municipal administration should focus their attention on developing grass root enterprises for waste collection, segregation and composting. The community groups can get Payment for the service may be direct from the household in the case of household waste collection and through the association for street sweeping.

- Composting: Composting is tradition practice rural areas and considering environmentally sound option to reduce organic waste going to landfill, the composted fertilizer and other products has good economic and environmental values and composting with involvement of community is one of the best sustainable way to manage local waste .
- Sanitary Landfilling: The existing open dumping causes contamination of water, air and soil quality and it creating unhygienic health condition to the public. Municipal authority need to setup sanitary Landfills / modern scientific landfill with leachate and gas collecting facility.

9.10 Wild Life

There are no wildlife or bird sanctuaries located in this basin. However in the Neyvlei Lignite Corporation campus in the integrated farming system developed in reclaimed and afforested area and a beautiful deer park is established and also a beautiful artificial lake has been created which become a bird sanctuary now attracting hundreds of species round the year.

Fig. 9.10 Deer Park in Mine I **Fig. 9.11 Lake in Afforestation Area**

9.11 Tourism

Tourism is a major growth engine for economic development in terms of providing employment and eradication of poverty. Tourism is a travel for recreational or Leisure purposes which is a mere service industry, has transformed into a major revenue generating industry. Tourists are attracted by its visitor-friendly traditions, varied life styles and cultural heritage and colorful fairs and festivals.

There are many tourist attractions in Paravanar basin and district wise most popular tourist spots are as follows:

9.11.1 Places of Interest

1. Lignite Mines at Neyveli

It is 45 Km from Cuddalore. They are biggest open mines. The Lignite mines here supply the fuel required for Thermal Power Stations here at Neyveli. Apart from coal, there are units manufacturing bye-products from the Lignite

2. Silver – Beach Devanampattinam

It is situated on the east of Cuddalore town. Horse Riding, Boating and Children's play area attracts large number of tourists to this Beach. It is the second longest beach on the Coromandel Coast and considered to be one of the longest Beaches in Asia.

3. Port Novo

It is also called as Parangipettai and it is 23 Km from Cuddalore. This is famous for the battle between the forces of the Mysore Maharaja and Britain during the pre-independence war. It was ruled by the Portuguese first and then followed by the Dutch and British. Remains of the Portuguese fort is located here.

4. Bhuvanagiri

It is on the banks of River Vellar. This is the birth place of Sri Raghavendra-theertha as Venkatanatha [called as Mantralaya Mahan] in 1595. Bhuvanagiri Silk Textiles have their own brand equity all over the world.

5. Padaleswarar Temple

Padaleswarar- Aunthuva Nayaki Temple dedicated to Lord Siva is located within the city of Cuddalore.

6. Thiruvanthipuram

Lord Vishnu is called as Devanatha Swami and Achuthan in this temple and it is located on the banks of Gadilam River, at Thiruvanthipuram.

7. Virudhachalam

Ancient Siva Temple called as Viruthagiriswarar Temple [Periyamalainathar] is located here.

8. Chidambaram Natarajar Temple

Tall and towering temples mark the landscape of Tamil Nadu. They remain as preserves of cultural heritage and protectors and promoters of inner urge of people for ethereal bliss and blessings of the Almighty. Not only that the temples inspired promotion of art and culture, and, infact, human life revolved around these centers of worship in ancient period. Chidambaram is one such sacred place with Lord Nataraja temple.

Here in Chidambaram, one of the holy cities in Tamil Nadu, Lord Nataraja, otherwise known as Lord Siva, the benign and the fiery dancer, expounds the myth and mythology of Hinduism and the rhythm of human life through His Cosmic dance.

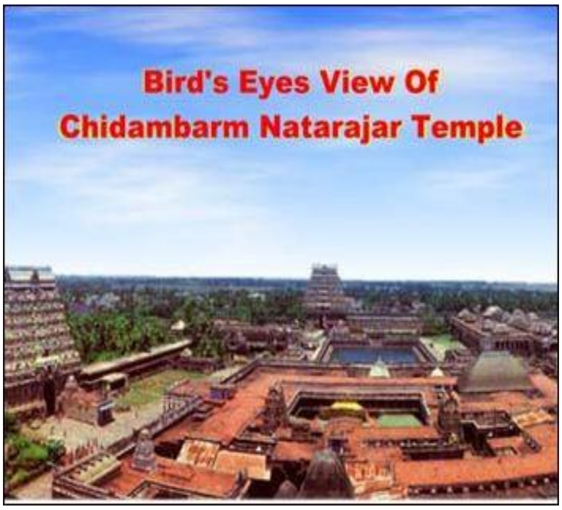


Fig 9.12 Chidambaram Natarajar Temple

The Nataraja Temple built during the eleventh century is the most celebrated of the south India saivite Temple. Lord Nataraja is the family deity of Vikrama Chola(1128) and his successors. The temple located in the middle of the municipal town sprawls in an area of 40 acres. Inside the walls are four Gopurams(Towers) embellished with numerous sculptures. They represent various religious scenes and parables. The East Gopuram, being the main entrance is the oldest and the West Gopuram is more attractive and outstanding. The tallest is 42.4 meter above sea level and 140 feet above the ground level. The light at top the gopurams here and the Gopurams are visible from the sea and they are the landmarks for the marines. The inner enclosure is the most sacred and has four of five Sabahs. The Nrithya Sabha (Kanaka sabha /Swarna sabha(golden Hall of Dance)) is the most beautiful and interesting part of the temple. The Sivakami temple, the sivagami tank and the hall of thousand pillars are important features of temple. The presiding deity of the temple is represented by sky/universe, one of five elements and is known as Akasa Lingam.

9. Vadalur

Ramalinga Swamigal popularly called as Vallalar had established Sathyagnana Sabai. The "Thai Poosam" function in December-January is a festival of this place. He sung thousands of songs called "Thiru Arutppa". This district named after his, for some time. Vallalar started the Jyoti Darshan (Lamp darshan) on Thai Poosam (January-February) in the year 1872. This festival is very devotionally celebrated since that day. The Jyoti darshan can be had by the devotees on this day only, after removing all the seven curtains in the Gnana Sabha – Wisdom Hall. The seven curtains will be removed that day at 6.30 a.m., 10.00 a.m., 1.00 p.m., 7.00 p.m. 10.00 p.m. and 5.30 a.m. in the next day. During the Poosam star days, three such darshans are shown at 8.00 p.m. removing only six curtains.

Fig 9.13 Vadalur Vallalar Ashram

Statistical Data of the tourist arrivals in the Cuddalore district from the year 2009 to 2015 is given in **Table 9.15**

Table 9.15 Tourist arrivals during the year 2009 to 2014

Years	2009	2010	2011	2012	2013	2014
Cuddalore	858067	1947901	4282740	6055275	7391184	7818888

Source: Department of Tourism

From the above table, it is inferred that the tourist population increases every year. Tourism's relationship with the environment is complex. It involves many activities that can have adverse environmental effects. Negative impacts from tourism occur when the level of visitor use is greater than the environment's ability to cope with this use within the acceptable limits of change.

9.11.2 Impact of Tourism

The following are tourism's three main impact areas:-

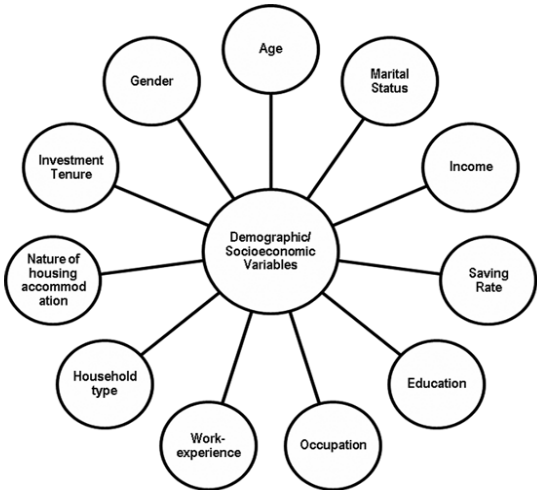
- Depletion of Natural Resources : These include Water resources, Local resources and Land degradation
- Pollution : The pollution includes Air pollution, Noise pollution , Waste disposal, sewage pollution, etc.,
- Physical Impacts includes degradation of ecosystems, continuing tourist activities, etc.,

Mitigation measures

- Revenue from park-entrance fees and similar sources may be allocated specifically to pay for identifying environmental related issues and for the protection and management of environmentally sensitive areas.
- Sound environmental management of tourism facilities can increase the benefits to natural areas by careful planning for controlled development.
- Cleaner production techniques may be used as tools for planning and operating tourism facilities in a way that minimizes their environmental impacts. For example, green building (using energy-efficient and non-polluting construction materials, sewage systems and energy sources)
- Tourists and tourism-related businesses consume an enormous quantity of goods and services; moving them toward using those that are produced and provided in an environmentally sustainable way, may have an enormous positive impact on the planet's environment.
- Providing environmental information and raising awareness among tourists about the environmental consequences and their remedial actions.
- Regulatory measures help offset negative impacts; for instance, controls on the number of tourist activities and movement of visitors within protected areas can limit impacts on the ecosystem and help maintain the integrity and vitality of the site. Limits should be established after an in-depth analysis of the maximum sustainable visitor capacity.

9.12 Socio Economic Aspects & Legal Issues

The socio economic aspects of the people depend on the factors which have been depicted in the diagram as below:



In Paravanar basin total population is 0.85 million which includes urban population of 0.36 million and Rural population of 0.49 million. Agriculture is practicing in through out the entire basin where paddy is the main crop.

The educational levels of farmers are favourable to adopt modern water management practices, cropping pattern etc. The Water Users Association (WUA) is vested with more powers and they actively participate in the developmental activities. The alternative options such as brick works, small engineering works are major off-farm occupations of the people. Marine and Inland Fishing are mainly carried out in Cuddalore district.

The overall literacy rate of Paravanar Basin is found to be 66 percent.

9.12.1. Legal Issues :-Conservation laws:

Human activities are progressively reducing the nature and the nature continue to deteriorate. Hence the nature is to be protected for survival and well being of the people. Hence laws are enacted to protect the environment. There is a constitutional provision under the

Article 48-A.: The state shall endeavor to protect and improve the environment and to safe guard the forests and wildlife of the country.

Article 51-A (g) : It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers & wild life and to have compassion for living creatures.

9.12.2. Acts related to Water resources & Environment & Encroachment.

Table 9.16 - Acts related to Water resources & Environment & Encroachment.

Sl. No.	Name of Act
1	The Tamil Nadu forest Act, 1882
2	Tamil Nadu Land Encroachment Act, 1905
3	Environment protection Act 1986
4	Tamil Nadu Farmers Management of Irrigation Systems Act of 2000
5	The Manufacture, Storage and Import of Hazardous Chemical Rules, 1989 as amended in 2000.
6	The Municipal Solid Wastes (Management and Handling) Rules, 2000.
7	The Noise Pollution (Regulation and Control) Rules, 2000.
8	Biological Diversity Act 2002
9	The Water Cess Act, 1977 as amended in 2003.
10	The Bio-Medical Wastes Rules, 1998 as amended in 2003.
11	The Environment Impact Assessment Notification, 2006 as amended.
12	Tamil Nadu Protection of tanks and Eviction of Encroachment Act No 8 of 2007
13	The Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 as amended in 2009 and 2010.
14	The Plastic Waste (Management and Handling) Rules, 2011.
15	The Coastal Regulation Zone Notification, 2011.

9.12.3 The Government Orders related to Environmental aspects

Table 9.17 - The Government Orders related to Environmental aspects

Sl. No	G.O.Ms. No	Content
1	G.O.Ms. No. 957 PWD dt 29.5.72	The poromboke lands within radius of 500 m both on the upstream and downstream side of water supply head works located on river banks are prohibited lands for removal of sand by private parties.
2	G.O. Ms. No. 938 PWD dt 07.06.88.	Condition of removal of earth from tank beds was stipulated.
3	G.O. Ms. No. 1210 PWD dt 26.07.88	The collector should grant permission in consultation with PWD officers concerned, for sand mining. It is also stated that the PWD will identify the sites for quarrying sand and the prohibited areas.
4	G.O.Ms.No.95 Industries (MMC.1) Department dt 01.10.03	Quarrying of sand in Government poramboke lands and private patta lands by private agencies will cease to be effective with immediate effect and sand quarrying was entrusted to a single agency viz., Public Works Department.
5	G.O.Ms.No.19 Industries (MMC1) dt 19.4.04	No machinery shall be used for quarrying sand from river beds, except with the permission of the Secretary to Government, Industries Department or any other authority or Officer, as may be authorized by him in this behalf, who may grant such permission if use of such machinery will not be detrimental to ecology.

Table 9.18 The GO's related to Industries, Environment and Forest

1	TNPCB BP Ms.No. 30 dt 21.02.84.	The TNPCB has prescribed the effluent standards
2	G.O. Ms. No. 213 Environment and Forest EC - I dept dt 30.03.89	No new industry is to be sited within 1 km from water resources. The TNPCB will examine the case and obtain the approval of the Government for setting up highly polluting industries from water sources.

9.13 **Public Awareness and Participation**:

It is essential to create awareness among public about environmental aspects and the action to be taken by them to remove or reduce the impact due to the environmental problems. In Paravanar River Basin, Awareness programmes have been conducted for the public, school students, farmers and local bodies by the Environmental Cell Divisions of Water Resources Department, NGO's and Neyveli Lignite Corporation under their corporate social responsibility scheme and the topics covered in the awareness programmes are given below.

- **Awareness Programme for Public and School Students:**

Rainwater harvesting and water conservative method, tree planting, growing and caring of plants, sand mining, effluent discharged by industries, solid waste management, organic farming, global warming, Impact analysis on tobacco consumption, Recycling of aquatic weeds into manure, plastics and its causes, river pollution and air pollution.

- **Awareness Meeting for Motivating the Local Bodies:**

Solid waste management system including source, segregation, recycle of dry waste and linkage with user agencies. effluent discharged by sewage treatment plant, Organic farming, global warming.

- **Demonstration of Vermi Compost to farmers /WUA members:**

Demonstration to farmers /WUA members/ women self help groups about the preparation of vermi compost manure in vermi compost pit.

- **Conducting Fair/Exhibition in School and Institutions:**

Tree Planting, growing and caring of plants, conservation of Forest and wild animals, water pollution, river basin and it's status problem like effluent discharged by industries, etc

- **Field Visit to the farmers:**

Herbal Garden, Organic Farm, etc.

Training programme on Sustainable Development for women

This Project resolves to educate the womenfolk on Sustainable Development and aims at disseminating information about environment, environmental protection, the ability to cope with the problems and stressing the importance of a sustainable approach.
The main message of this Project is effectively transferred to the women employees and through them to other members of their families and to the society by engaging an Green Path expert faculty in this field.

Women employees were taught about the concept of

- Green home,
- **Zero waste,**
- water conservation
- Rain water harvesting,
- Energy conservation, green house effect and efforts needed to mitigate global warming etc
- Organic farming
- Vermi composting etc.,

Wherein they learnt how to collect waste and prepare composts, about noise pollution, and Citizen's social responsibility towards environment protection, conservation of bio diversity and cultural values and heritage. The training was imparted through utilising the services of expert consultant.

Fig 9.14 Awareness Programme Photos

Celebration of World Forest day at Kendriya Vidhyalaya, Neyveli on March 21,2016 where “ Mass Tree Plantation” programme was started

9.14 Summary

1. The Polluter Pays Principle (PPP) is an environmental policy principle which requires that the costs of pollution be borne by those who cause it. In its original emergence the Polluter Pays Principle aims at determining how the costs of pollution prevention and control must be allocated: the polluter must pay.
2. The storm water drainage should be kept clean, tidy and maintained properly for free flow of the water so that no stagnation of water occurs and thereby minimizing backing effects of storm water drains.
3. The Industrial and Domestic effluent water to be treated properly and separate lines to be designed for carrying all the effluents and the same should not be let into the river courses untreated. The treated water can be used for landscaping, gardening and other industrial purposes; this practice will reduce the water scarcity and also improve the environmental status of the region.
4. Necessary steps may be taken to plant tree saplings on the banks of water bodies so as to curtail the effects of climatic changes or global warming.
5. The Domestic and Industrial waste should not be dumped in the river bank or river course or drainage course. It leads to contamination of surface water and ground water.
6. The domestic waste has to be segregated as bio-degradable and non bio-degradable and bio-degradable wastes to be converted as compost which will reduce the environmental degradation.
7. The metals and plastics should be recycled for further use and also awareness programmes have to be conducted on the ill effects of plastics.
8. Water weeds in water bodies may be controlled by introducing fish species like grass carp which destroys the water weeds.
9. Waterweeds as well as domestic waste can be effectively used as Protein source, as fertilizer, as Biogas source, as Soil additive and also as a source of income generation.
10. Environmental protection information has to be given to the people through viable media and other sources.

11. Silt sedimentation studies should be carried out periodically for tanks etc., and remove the silt to restore the original/designed capacity. Catchment area treatment in the upper reaches of the tanks should be carried out to minimize the rate of sedimentation. Desilting of tanks can be taken up after detailed investigation.
12. Environmental management of facilities to tourism spots can boost the revenue to Government and increase the benefits by careful planning for controlled development.
13. Rainwater harvesting projects have to be carried out effectively, to increase the ground water potential.
14. Plantation program to regenerate the degraded forests.
15. Drainages and water bodies should be de-silted before rainy season.
16. The garbage should not be dumped in pond and channels.
17. The waste generator should be responsible for collection, segregation, storage and disposal of Construction and Demolition waste. The construction waste shall be recycled wherever possible and the use of these wastes shall be utilized in modern landfill for solid waste management.
18. Farmers may resort to control the soil erosion in their fields.
19. Chemical fertilizers should be replaced with organic fertilizers in a phased manner.
20. Alternative materials for sand in construction practices have to be introduced by conducting active research programme.

    By adopting suitable mitigation measures, environmental sustainability can be achieved.

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin - Pre Monsoon (2011-2014)

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin (2011 - Pre Monsoon)

Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/L	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8.2	2400	1356	365	104	26	327	42	390	137	48	519	22	1.088365288
Pachayankuppam	11 42 21	79 45 46	8.5	990	574	235	64	18	63	72	121	62	60	165	31	0.725466009
Capper Quary	11 41 01	79 44 49	8.4	910	583	230	68	15	99	26	291	28	18	49	13	5.849689572
Poondiyankuppam	11 37 55	79 43 36	8.6	620	466	220	38	30	61	65	92	2	24	220	44	0.5889415
Kayalpattu	11 35 15	79 43 31	8.5	780	457	215	54	19	46	47	71	44	24	207	49	0.477607793
Puduchatram	11 32 11	79 43 12	8.2	910	647	300	70	30	82	72	60	2	12	390	124	0.24914094
Thiruchopuram	11 37 00	79 44 49	8.4	440	252	170	26	26	31	20	57	25	12	110	0	0.729775337

Chemical Analysis of Water Samples for Ssea Water Intrusion study in Paravanar basin (Cuddalore Dt-2012 Pre Monsoon)

Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/L	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8	2710	1502	610	88	95	293	85	532	67	0	634	25	1.443896188
Pachayankuppam	11 42 21	79 45 46	7.8	1220	699	365	52	57	73	68	142	12	0	427	81	0.572234536
Capper Quary	11 41 01	79 44 49	8.1	1040	563	345	44	57	76	7	255	60	0	122	3	3.596614951
Poondiyankuppam	11 37 55	79 43 36	8.5	650	394	233	46	29	32	48	78	39	18	146	31	0.735033994
Kayalpattu	11 35 15	79 43 31	8.6	1200	694	375	100	30	78	45	124	55	36	390	31	0.460645391
Puduchatram	11 32 11	79 43 12	8.5	810	526	250	62	23	53	49	57	45	24	293	66	0.286956716
Thiruchopuram	11 37 00	79 44 49	8.5	260	161	185	14	36	7	3	32	19	6	79	4	0.603766115

Chemical Analysis of Wwater Samples for Sea Water Intrusion study in Paravanar basin (Cuddalore Dt-2013 Pre Monsoon))

Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/L	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8	2890	1619	660	152	68	300	103	532	22	0	787	49	1.16318956
Pachayankuppam	11 42 21	79 45 46	8	1140	636	325	90	24	76	62	106	12	0	372	80	0.490316514
Capper Quary	11 41 01	79 44 49	7.9	1030	532	350	86	33	76	0	230	33	0	133	13	2.975704423
Poondiyankuppam	11 37 55	79 43 36	8	910	533	200	64	29	47	56	131	22	0	244	62	0.923836389
Kayalpattu	11 35 15	79 43 31	8.2	980	537	315	40	52	61	34	892	46	0	354	35	4.335859371
Puduchatram	11 32 11	79 43 12	8.1	910	552	285	36	47	23	95	64	15	0	329	107	0.334732338
Thiruchopuram	11 37 00	79 44 49	8.2	400	218	180	26	28	8	3	74	35	0	73	7	1.744305118

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin (Cuddalore Dt-2014 Pre Monsoon)

Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/L	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	7.7	1950	1099	395	128	18	189	113	291	93	0	525	4	0.953777957
Pachayankuppam	11 42 21	79 45 46	7.8	1460	823	395	94	39	115	59	184	96	0	366	53	0.865068171
Capper Quary	11 41 01	79 44 49	7.9	870	436	280	70	26	51	6	184	23	0	134	9	2.362798139
Poondiyankuppam	11 37 55	79 43 36	8.2	730	409	196	52	10	48	41	96	39	0	189	22	0.874023328
Kayalpattu	11 35 15	79 43 31	7.9	1480	873	389	80	46	116	76	167	103	0	287	142	1.001263005
Puduchatram	11 32 11	79 43 12	8.6	800	447	223	68	13	57	41	71	70	42	116	27	0.606614068
Thiruchopuram	11 37 00	79 44 49	7.9	250	113	121	14	21	2	0	35	21	0	31	4	1.942763547

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin - Post Monsoon (2011-2014)

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin (Cuddalore Dt-2011 Post Monsoon)

Name of the location	Latitude	Longitutude	PH	Ec/mho/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl/mg/L	so4 mg/l	co3	HCO3	No3	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	7.9	1970	1191	295	104	9	288	39	411	51	0	543	18	1.302433589
Pachayankuppam	11 42 21	79 45 46	7.9	930	683	245	68	18	143	21	177	47	0	293	62	1.039487429
Capper Quary	11 41 01	79 44 49	7.7	710	443	215	66	12	58	4	199	30	0	104	22	3.292557231
Poondiyankuppam	11 37 55	79 43 36	8	490	393	150	26	21	81	19	106	8	0	201	31	0.907451459
Kayalpattu	11 35 15	79 43 31	8.1	1000	607	240	74	13	122	24	174	47	0	305	0	0.981664316
Puduchatram	11 32 11	79 43 12	8	530	422	240	44	32	81	18	131	4	0	207	9	1.088966565
Thiruchopuram	11 37 00	79 44 49	7.7	1000	260	180	115	20	16	37	1	53	17	0	73	0.049780138

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin of Cuddalore Dt-2012-Post Monsoon)

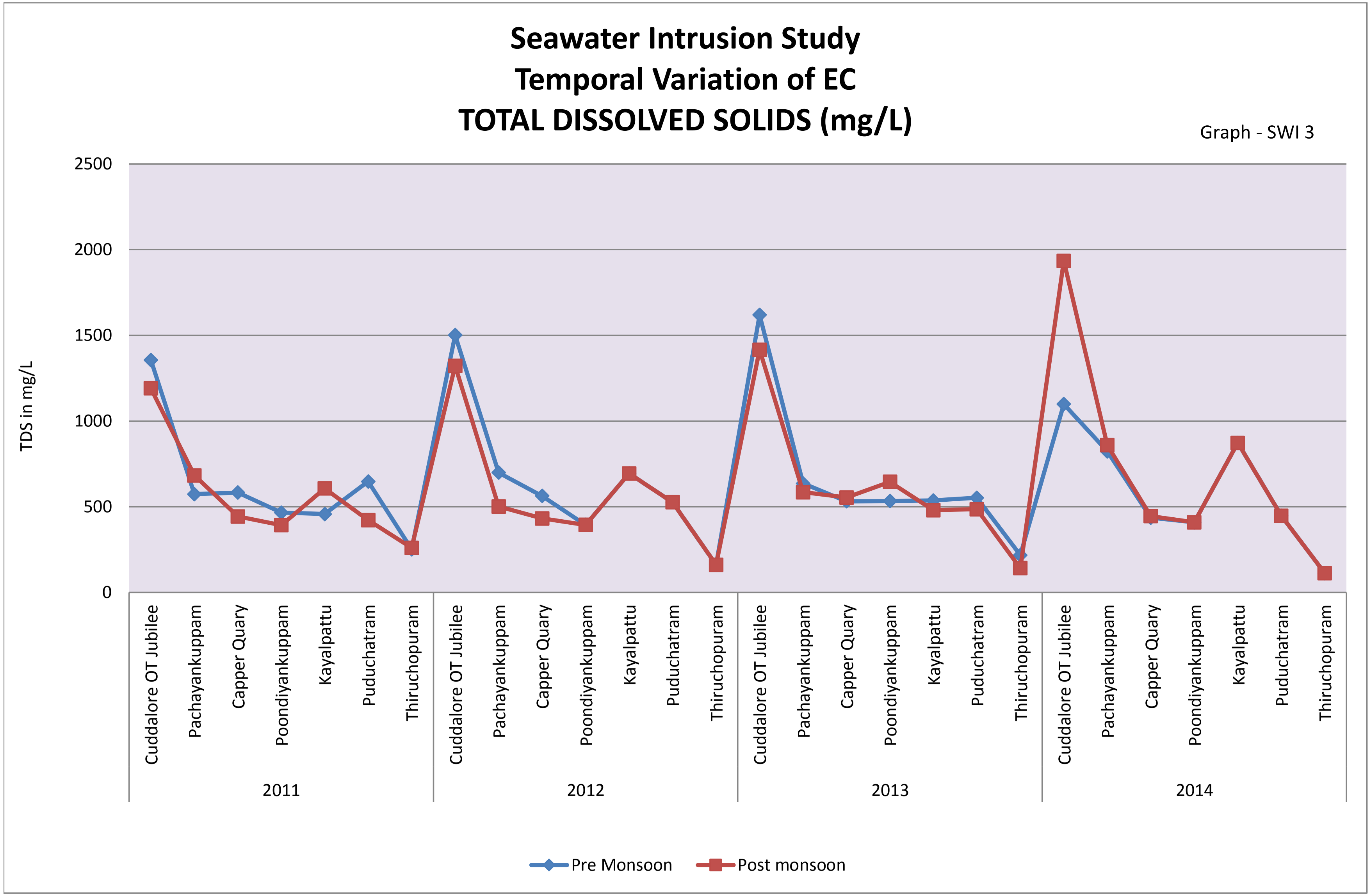
Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8.7	2250	1322	470	156	19	265	63	347	110	48	549	40	0.923437209
Pachayankuppam	11 42 21	79 45 46	8.6	910	501	275	78	19	71	36	99	3	18	275	40	0.546702854
Capper Quary	11 41 01	79 44 49	8.4	810	432	285	78	22	35	9	184	34	6	110	9	2.590957043
Poondiyankuppam	11 37 55	79 43 36	8.5	650	394	233	46	29	32	48	78	39	18	146	31	0.735033994
Kayalpattu	11 35 15	79 43 31	8.6	1200	694	375	100	30	78	45	124	55	36	390	66	0.460645391
Puduchatram	11 32 11	79 43 12	8.5	810	526	250	62	23	53	49	57	45	24	293	66	0.286956716
Thiruchopuram	11 37 00	79 44 49	8.5	260	161	185	14	36	7	3	32	19	6	79	4	0.603766115

Chemical Analysis of Water Samples for Sea Water Intrusion study in Paravanar basin (Cuddalore Dt JULY-2013 Post Monsoon)

Name of the location	Latitude	Longitutude	Ph	Ec Micro	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8	2520	1416	520	72	83	274	113	489	34	0	641	30	1.312696796
Pachayankuppam	11 42 21	79 45 46	7.8	1040	585	315	36	55	69	43	124	12	0	366	63	0.582980724
Capper Quary	11 41 01	79 44 49	8	1020	554	325	52	47	83	4	238	38	0	165	9	2.48202761
Poondiyankuppam	11 37 55	79 43 36	8.1	1040	645	225	40	30	108	47	113	110	0	238	78	0.816986879
Kayalpattu	11 35 15	79 43 31	8.1	890	480	270	34	45	58	39	64	6	0	403	32	0.27326784
Puduchatram	11 32 11	79 43 12	8.2	830	486	230	34	35	48	63	67	8	0	317	72	0.363688138
Thiruchopuram	11 37 00	79 44 49	8.1	270	142	100	20	12	15	2	46	6	0	79	1	1.001946046

Chemical Analysis of Water Samples for Sea Water Intrusion Study in Paravanar basin (Cuddalore Dt-2014 Post Monsoon)

Name of the location	Latitude	Longitutude	Ph	Ec mhos/cm	TDS	TH	Ca/mg/l	Mg mg/L	Na mgl	K mg/l	Cl mg/L	so4 mg/l	co3	HCO3	No3 mg/	Cl/co3+Hco3
Cuddalore OT Jubilee	11 47 07	79 46 02	8	3490	1935	599	136	63	487	66	666	50	0	842	44	1.361055181
Pachayankuppam	11 42 21	79 45 46	8.3	1450	859	441	86	55	101	48	209	106	0	207	151	1.737358871
Capper Quary	11 41 01	79 44 49	8	840	445	264	58	29	69	3	170	28	0	140	18	2.089462019
Poondiyankuppam	11 37 55	79 43 36	8.2	730	409	106	52	16	48	41	96	39	0	189	22	0.874023328
Kayalpattu	11 35 15	79 43 31	7.9	1480	873	389	80	46	116	76	167	103	0	287	142	1.001263005
Puduchatram	11 32 11	79 43 12	8.6	800	447	223	68	13	57	41	71	70	42	116	27	0.606614068
Thiruchopuram	11 37 00	79 44 49	7.9	250	113	121	14	21	2	0	35	21	0	31	4	1.942763547



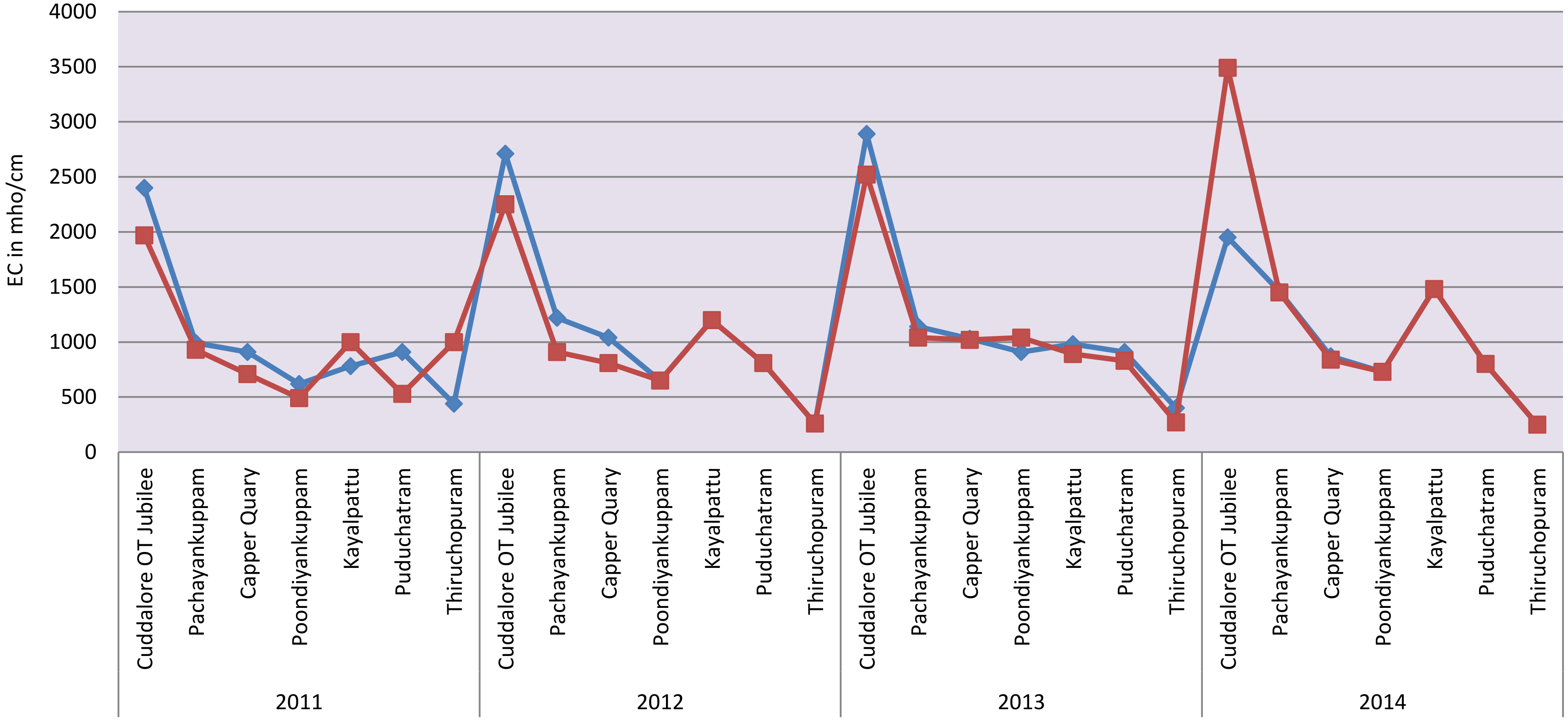
Seawater Intrusion Study
Temporal Variation of EC
TOTAL DISSOLVED SOLIDS (mg/L)
Graph - SWI 3
TDS in mg/L
2500
2000
1500
1000
500
0
Cuddalore OT Jubilee
Pachayankuppam
Capper Quary
Poondiyankuppam
Kayalpattu
Puduchatram
Thiruchopuram
2011
2012
2013
2014
Pre Monsoon
Post monsoon

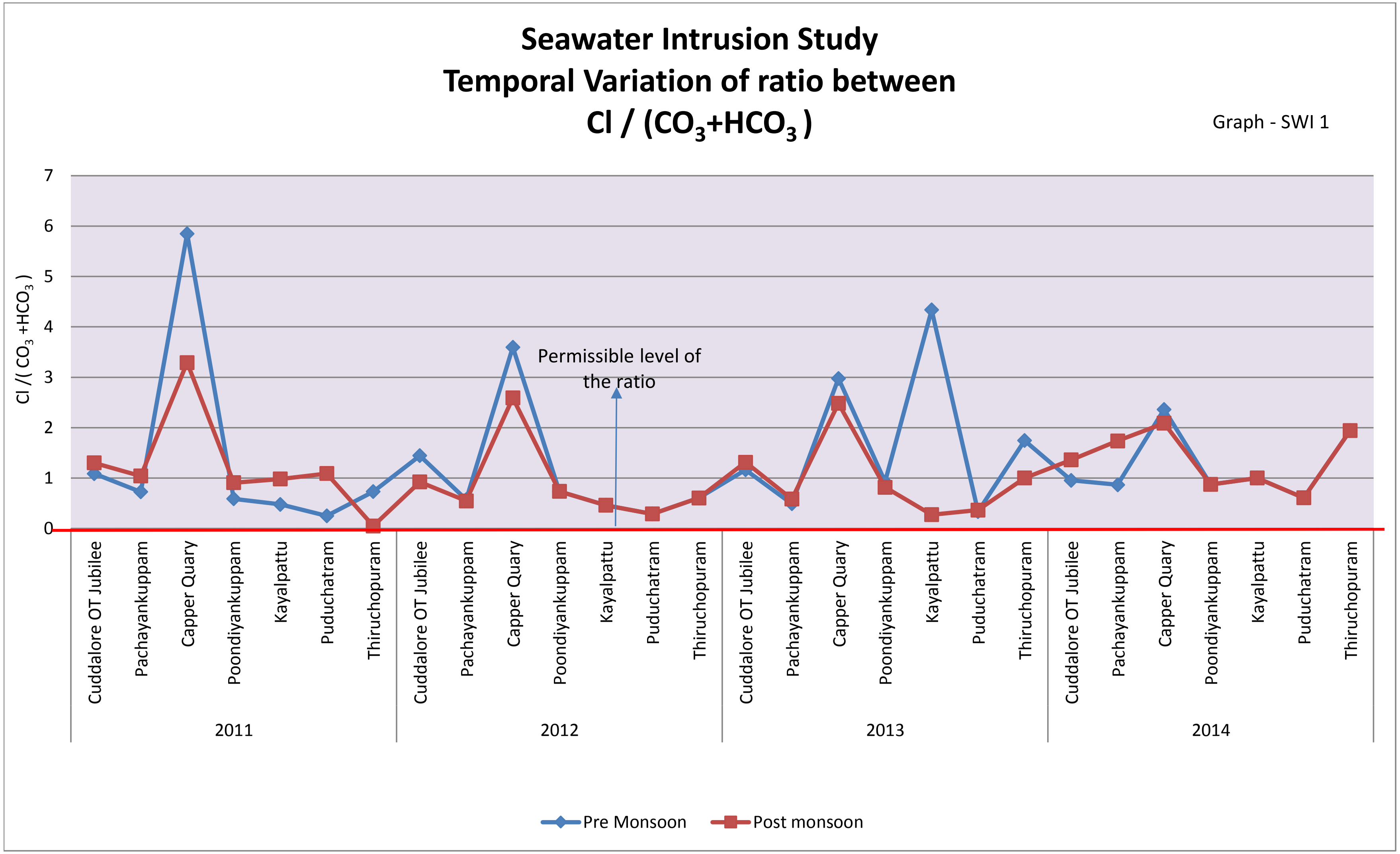
Seawater intrusion study

Temporal Variation of EC

Ec (mho/cm)

Graph - SWI 2




Seawater Intrusion Study
Temporal Variation of ratio between
Cl / (CO_3+HCO_3)
Graph - SWI 1
Cl /(CO_3 +HCO_3)
7
6
5
4
3
2
1
0
Permissible level of the ratio
Cuddalore OT Jubilee
Pachayankuppam
Capper Quary
Poondiyankuppam
Kayalpattu
Puduchatram
Thiruchopuram
2011
2012
2013
2014
Pre Monsoon
Post monsoon

CHAPTER 10

PRESENT INSTITUTIONAL SETUP

CHAPTER10

PRESENT INSTITUTIONAL SETUP

Institutional arrangements with sets of working rules that are used to determine who is eligible to make decisions in some arena, and what actions are allowed or constrained in management of water resources in a river basin. Suitable institutional arrangements are necessary to enable effective water management in river basins.

As an initiative for this integrated approach in Tamil Nadu, the Tamil Nadu Water Resources Consolidation Project (WRCP) is a State-wide program implemented during 1995 - 2004 in selective sub basins to improve the productivity and sustainability of State'sIrrigation sector, to introduce multi-sectoral water planning, to integrate farmers in irrigation management, and to strengthen the state's institutional and technical capacity in water development, management and planning.

As a multi-disciplinary approach on modernization of Irrigation and Agriculture, Tamil Nadu Irrigated Agriculture Modernization and Water bodies Restoration and Management **(TN IAMWARM)** project is being implemented by eight departments dealing with water viz., Water Resources Department, Agriculture Department, Agriculture Engineering Department, Horticulture Department, Tamil Nadu Agricultural University, Agricultural Marketing & Business, Animal Husbandry & Dairy Department and Fisheries Department. The IAMWARM project is implemented through the above stake holding agencies with Water Resources Department playing a leading role in a sub basin frame work, in four phases over a period of 8 years including the extended period upto 2015 in selected 61 sub basins of Tamil Nadu. The project aims at Modernization of Irrigation Systems, Agricultural Intensification and Diversification, Institutional modernization for Irrigated Agriculture., etc to improve benefits to farmers, farm labourers, landholders, fishermen and livestock owners.The IAMWARM project was completed by June-2015.

10.1 Present Institutional set up

The variousDepartments / Institutions of the Government of Tamil Nadu / Government of Indiavested with different categories of responsibilities in water resources management and supply in Paravanar River basin are detailed as below:

10.1.1 Water Resources Department (WRD)

The Water Resources Department is a part of the Public Works Department.The Water Resources Department is responsible for the maintenance & rehabilitation of all the Irrigation Structures and improving the irrigation infrastructure in the Tamil Nadu as well as monitoring floods. One of the main objectives of the Water Resources Department is to ensure effective management and distribution of surface and ground water to achieve optimum utilization in a rational and scientific way for maximizing the production and productivity of all the sectors requiring water in the State of Tamil Nadu.

The Engineer-in-Chief, WRD and Chief Engineer (General) PWD is the head of the Water Resources Department. The Engineer-in-Chief, WRD and Chief Engineer (General), PWD assists the Government as the technical and administrative head of the department, monitors and co-ordinates the functions of all the four Regional Chief Engineers and five functional Chief Engineers who are specialized in overall planning and execution of irrigation projects.

In Water Resources Department(WRD), the water management in the State has been decentralized along river basin lines and for effective control, the entire State has been divided into four Regions functioning under the control of Regional Chief Engineers viz., Chennai Region, Madurai Region, Trichy Region & Coimbatore Region. The Regional Chief Engineers are the Basin Managers of all the Basins falling in their Region. The Regional Chief Engineers develops goals and objectives for the Basin, co-ordinates all the Basin activities and responsible for the Infrastructure Development of the Basins. In addition to the above Regional Chief Engineers, there are five functional Chief Engineers viz., Chief Engineer, Plan Formulation, Chief Engineer, Design Research and Construction Support (DR&CS), Chief Engineer, Operation & Maintenance (O&M) , Chief Engineer, State Ground and Surface Water Resources Data Centre (SG & SWRDC) and the Chief Engineer & Director, Institute for Water Studies (IWS) are functioning in Chennai.

Details regarding in-flow & out-flow of reservoirs and anicuts, surplus flow particulars at gauging sites maintained by WRD and tank hydraulic particulars are collected from the territorial WRD offices and these details are used to arrive the surface water potential. Report on Sedimentation studies of tanks are collected from the Design Research and Construction Support (DR&CS) office and documented. Rain fall and climatic data, Artificial Recharge Schemes, sea water intrusion and salinity details are collected from the State Ground and Surface Water Resources Data Centre (SG & SWRDC) office and documented. Details recording activities of Environmental Cell Divisions such as collection of water samples, pollution points, Environmental awareness meetings & workshops, etc., are collected and documented.

10.1.2 Institute for Water Studies (IWS)

The Government of Tamil Nadu in G.O.Ms.No.457/PWD dated 08.04.1974, established the Institute for Water Studies to plan, assess and manage the Water Resources in Tamil Nadu in a scientific manner. It is a multi-disciplinary organization headed by a Director in the rank of Chief Engineer, WRD with a team of Engineers, Hydro-geologists, Geo-chemists, Geophysicists, Environmental Engineers, Photo-geologists, Remote Sensing Scientists, Agro-Economist and Administrative Staff. The main objectives of Institute for Water Studies (IWS) are to develop broad principles for planning and management of water resources, to assist in the formulation of water management policies, to undertake research works related to water planning and policy making, to develop training programmes and to advice the Government, on specific policy matters related to it.

Tamil Nadu State Remote Sensing Centre at Institute for Water Studies is responsible for the delineation of River Basin and Sub Basin boundaries of all the rivers in Tamil Nadu and updating it, then and there. The Institute for Water Studies has grouped the 34 rivers in Tamil Nadu into 17 major river basins. "Unique codification" for all PWD/WRD tanks have been assigned using GIS, which enables easy access to the details of tanks viz., location, hydraulic particulars etc., taluk wise and district wise. The preparation of GIS based unique coding for all reservoirs and anicuts are in progress.

So far, Micro level studies have been completed for 16 river basins except Cauvery river basin. These Micro level study reports have been sent to all the Regional Chief Engineers of Water Resources Department and other line departments. To update the above reports with present data, Reappraisal studies were initiated. Accordingly, Reappraisal studies for Kodaiyar, Vaippar, Vaigai, Vellar, Palar, Tamiraparani and Pennaiyar River Basins have been taken up and completed during 2010 to 2015.This Micro level Reappraisal study of Paravanar river basin is taken for the year 2015 – 2016. Necessary Study reports are prepared for further use in the Water Resource Department and respective user departments.

The Paravanar River basin falls under the jurisdiction of the Chief Engineer, WRD, Chennai Region, Chennai. The Superintending Engineer, Vellar Basin Circle, Cuddalore coordinates the management of water resources in Paravanar River basin along with the Executive Engineer, Coleroon Basin Division, Chidambaram and Executive Engineer, Vellar Basin Division, Virudhachalam. The Executive Engineer along with the Sub Division and section officers is responsible for execution of all the works viz., maintenance and improvements to irrigation structures, water regulation for irrigation from dams/reservoirs/ tanks in their jurisdiction as well as mitigation of floods, construction of new irrigation structures etc,.

Details regarding in-flow & out-flow of reservoirs and anicuts, surplus flow particulars at gauging sites maintained by WRD, tank hydraulic particulars and hydro-meteorological data are collected from the territorial WRD offices and these details are used to arrive the surface water potential and Ground water potential of River Basins. The various sectoral water demands are being found out and future water demand for river basins are forecasted. For effective management of water resources and basin planning, Water Balance Studies are being carried out to access the surplus or deficit status of the river basin and giving suggestion on developmental action required in the river basin.

10.1.3 Central Water Commission

The Central Water Commission is a Central Government organization functioning under the Ministry of Water Resources, Government of India. Paravanar River basin falls under the jurisdiction of Cauvery & Southern Rivers Organization (C&SRO) of Central Water Commission. The organization is headed by a Chief Engineer head quartered at Coimbatore and the above functions are discharged through Superintending Engineer / District level officers in various offices such as Cauvery & Southern Rivers Circle, Bangalore, Monitoring Directorate, Coimbatore, Beach Erosion Section, Cochin. The Executive Engineer / Deputy Director level officers and his team of Assistant Executive Engineer, Sub Division Engineer, Assistant Director, Assistant Director – II level officers and Junior Engineers stationed across the Region execute the works under their jurisdiction.

10.1.4 Tamil Nadu Water Supply and Drainage Board (TWAD)

Tamil Nadu Water Supply and Drainage Board is responsible for implementation of Water Supply and Sewerage facilities to the public of the entire State of Tamil Nadu except for Chennai Metropolitan city. Paravanar river basin falls under the jurisdiction of the Chief Engineer, Chennai. The Engineering Director, Chennai; Superintending Engineer, Cuddalore-Villupuram under the control of Chief Engineer, Chennai implements the various schemes in Paravanar River Basin, with the assistance of their Executive Engineers. Details of water supply schemes implemented in urban and rural areas of Paravanar river basin are collected from the territorial TWAD offices. These details are used to arrive the domestic demand at present and in future.

10.1.5 Forest Department

Forest Department conserves the forest wealth, undertakes control measures in watersheds and is in charge of social forestry works. The Principal Chief Conservator of Forest, the Chief Wild Life Warden, Chief Conservator of Forest (Social Forestry) are at Chennai who has control in their respective fields. The Conservator of Forests at Vellore Circle, Divisional office at Vellore and Assistant Conservator of Forests, Villupuram territorial division that forms the part of Villupuram and Cuddalore districts, Regional

Manager ,Tamil Nadu Forest Plantation Corporation Limited, Cuddalore; Regional Manager, Tamil Nadu Forest Plantation Corporation, Tirukovilur are the Various forest offices operating in the Paravanar river basin. Details regarding forest cover, bio-diversity and wild life are collected from the forest department. These details are used to know the wealth of forest and suggestions are given for the protection and sustainable development of the bio-diversity.

10.1.6 Agriculture Department

Agriculture Department is headed by the Commissioner of Agriculture, located at Chennai. The Joint Directors, Agriculture at Cuddalore along with their team of officers implement and execute the schemes of this department in Paravanar River basin. This department coordinates with Water Resources Department to increase the productivity for agriculture. The various development schemes and introduction of relevant technologies to step up the production are Intensive Integrated farming system, massive Wasteland Development Programme, comprehensive watershed development activities, water management through Micro irrigation systems, Organic farming, Soil health improvement through Bio-fertilizer including Green Manuring, adoption of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) technologies are given priority through various programmes, besides crop diversification and introduction of modern advanced agricultural practices (SRI) to fetch better return to improve the economic status of the farming community.

Details regarding consumption of fertilizers and Pesticides in Paravanar river basin area are collected from the territorial Agriculture offices. These details are used to know the quantity of fertilizers & pesticides used at present and suggestions are given to encourage organic farming in future. Details about Crop area irrigation demand, Organic farming development, water saving techniques, cropping pattern, use of bio-fertilizers in Paravanar river basin are collected and documented.

10.1.7 Agricultural Engineering Department

This department has been engaged in the conservation, development and management of the agricultural land and water resources of the State thereby contributing to the sustainable increase in agricultural production. The main focus of the department is on watershed development, water management and agricultural mechanization. Under Command Area Development and Water Management Programmes the field channels and supply channels are renovated so as to improve the utilization of created irrigation potential and also to achieve optimum agricultural production.

The Agricultural Engineering Department is headed by Chief Engineer, located at Chennai. The Agricultural Engineering division offices are functioning at Cuddalore, Chidambaram and Virudhachalam. The Executive Engineer is responsible for the implementation and management of the Agricultural Engineering activities in their division under the guidance of the respective regional Superintending Engineer. The Executive Engineer is assisted by Assistant Executive Engineers for implementation of all the scheme activities. Agricultural Engineering Department is implementing various schemes for soil & water conservation, water management through micro sprinkler irrigation and agricultural mechanization apart from hiring of Land Development & Minor Irrigation machinery to farmers. Details of Catchment area treatment in the basin are collected from the territorial Agricultural Engineering Department and documented.

10.1.8 Public Health and Preventive Medicines Department

This department takes care of preventive and control measures in the event of outbreak of epidemics, undertakes the testing of water samples, educate the public on measures on water borne and water related diseases. This department is headed by a Director (Public Health & Preventive Medicines) at Chennai. The Deputy Director of Health services at Cuddalore and Villupuram covers Paravanar river basin area. Details of vector-borne diseases and water borne diseases are collected from the territorial Public Health offices. These details are used to document the prevailing health conditions in Paravanar river basin.

10.1.9 Animal Husbandry & Veterinary Science Department

Animal Husbandry Department is headed and governed by the Director, Animal Husbandry & Veterinary Sciences, Chennai. The Regional Joint Director at Cuddalore along with their Additional Directors are responsible for all the activities of this Department in Paravanar river basin area.

The Livestock sector provides livestock based food products such as milk, egg, meat, raw materials like wool for industries, manure etc,. The Animal Husbandry Department provides comprehensive veterinary assistance and health cover to all livestock and poultry across the State of Tamil Nadu through a network of 2,579 Veterinary Institutions and 850 Veterinary sub centers. With the implementation of cross breeding programme and various other schemes by the department, livestock farming has become economically viable and remunerative to large number of rural households. Details of animal census and schemes implemented in Paravanar river basin are collected from the territorial Animal Husbandry & Verterinary Science Department offices. These details are used to arrive the Livestock Water demand at present and in future.

10.1.10 Fisheries Department

This department is concerned with the Marine and inland fish production in the State and implements fisherman welfare schemes and look after the infrastructure facilities like fishing harbour and jetties, aquaculture activities and training of fishermen.

Fisheries Department is headed by the Director of Fisheries, stationed at Chennai. As far as Paravanar River Basin is concerned, there is a Joint Director of Fisheries (Regional)at Chennai and under his control an Assistant Director, Fisheries (Inland Fisheries), Villupuram; Assistant Director Fisheries(Marine), Cuddalore.

The fisheries sector of Paravanar River Basin may be categorized as Inland fishing and Marine fishing. Inland fishing is the main activity within the Basin. The different component of work executed under this are promoting fresh water aquaculture, reservoir fisheries, infrastructure development for fish seed production, promoting fish farming and cold water fisheries development. Details about fish production in Paravanar river Basin is collected and documented.

10.1.11 Tamil Nadu Pollution Control Board (TNPCB)

Tamil Nadu Pollution Control Board is functioning with Chairman as its head, member secretary, 2 Additional Chief Environmental Engineers, 10 Joint Chief Environmental Engineers, 32 District Environmental Engineers and 2 Assistant Environmental Engineers. The Chief Environmental Engineers are implementing the Pollution Control Legislations and Rules and Notifications framed therein, collects and disseminates data relating to water, air and land pollution, lays down standards for sewage/trade effluent and emissions. This Board monitors the industrial effluents discharges into water bodies from pollution point of view. The Board has established 5 Advanced Environmental Laboratories, 10 District Environmental Laboratories to assist in the analytical and scientific side by experimental analysis and conducting research in abating pollutants. The District offices of Tamil Nadu Pollution Control Board functioning with the District Environmental Engineer as its head, is located at Cuddalore. The District Environmental Engineer monitors and controls the Industrial Pollution in Paravanar river Basin. The District Environmental Engineers handles the issues regarding pollution in the District, issue / renew the consent to orange & green industries, renews consent to red small industries, issues show cause notice to the erring industries.etc.

List of industries, type of industries, water requirement, treatment method adopted and waste generated are collected from the territorial TNPCB office. These details are used to arrive the industrial demand at present and in future. Quantity of industrial effluent generated and pollution status of river basin are also arrived.

10.2. Water Utilization Committee

The Government constituted Water Utilization Committee and Technical sub Committee to Water Utilization Committee in order to take final decision on the proposals seeking permission for surface/ ground water drawal, by various organizations /institutions. The various proposals seeking requisition for water drawal from surface/ ground water are scrutinized based on the assessment of the available surface and ground water potential and existing scenario of water demand at which drawal is requested.

A **Technical Sub-Committee to Water Utilization Committee** was constituted with the Engineer-in-Chief WRD& Chief Engineer (General), PWD, as the Convener and the Chief Engineer, WRD, Plan Formulation; the Chief Engineer ,WRD, State Ground &Surface Water Resources Data Centre; the Chief Engineer, WRD, Design Research &Construction Support; the Chief Engineer, WRD, Operation &Maintenance; the Chief Engineer, WRD, Chennai Region; the Chief Engineer, WRD, Trichy Region; the Chief Engineer, WRD, Madurai Region; the Chief Engineer, WRD, Coimbatore Region; the Chief Engineer & Director, Institute for Water Studies; the Chief Engineer, Agriculture Engineering and the Chief Engineer, TWAD Board are as members.The water supply schemes involving drawal of water of more than one MGD should be placed before the said committee for consideration and clearance.

10.3 Participatory Irrigation Management (PIM)/Water User's Association

Under the Water Resources Consolidation Project & IAMWARM project, farmer's organizations are formed in the project implementation areas, to regulate the use of water among the various users, to manage the operation and maintenance of the irrigation systems. The farmer's organization comprises of Water User Association, Distributory Committee, Project Committee and Apex Committee with each having various functions.

Water Users Associations are delineated based on the command area of the major / medium irrigation system. Water Users Association at the primary level consists of all the water users in such association area as members. A Water User Association can be called by its local distinct name. Every Water User Association shall be divided into Territorial Constituencies (TC) which should not be less than four and not greater than ten. A Territorial Constituency means a contiguous block of command area of one or more sluices under a Water Users Association area. There is a Management Committee for every Water User Association and a President of the Management Committee is elected by the members of the Water Users Association.

Project Committee's are formed at project level to comprising two or more Distributory Committee's to manage the Distributory Committee. Project areas are delineated on the basis of command area or part of a major irrigation system. The President of every Distributory Committee is the members of the Project Committee.

The Chairman of the Project Committee is elected by its members. The main function of the Project Committee is to approve an operational plan, based on its entitlement, area, soil, cropping pattern, as prepared by the competent authority, in respect of the entire project area at the beginning of each irrigation season.

A competent authority, an officer of the Water Resources Department is appointed to the farmer's organization by the Government to implement and execute the decisions taken by the farmer's organization. The farmer's organization shall extend its assistance and co-operation to the competent authority.

The farmer's organization may, for carrying out the purposes of this Act, and or achieving the objects of such organization and performing its functions, levy and collect such fees not exceeding five hundred rupees per hectare per year from every water user, as prescribed, from time to time. The other sources of funds to the farmers organization are grants received from Government as a share of water charges, Central / State Government fund for development of that area, resources raised from any financial agency for undertaking any economical development activities, income from properties and assets attached to the irrigation system as granted by the Government.

Functions of **WUA** are

1. To prepare and implement an operational plan and a rotational water supply for each irrigation season. consistent with the operational plan, prepared by the distributor committee and the project committee and based upon the entitlement area soil and cropping pattern as approved by the managing committee or as the case may be of the project committee.

2. To prepare a plan for the maintenance of irrigation system in the area of its operation at the end of each crop season and carry out the maintenance works of both distributary system. Water courses and field drains in its area of operation with the funds of the water users association from time to time.

3. To regulate the use of water among the various sluices under its area of operation according to the rotational water supply.

4. To assist the authorities of the revenue department of the government in the preparation of demand and collection of water charges.

5. To prepare and maintain an inventory of the irrigation system within the area of operation.

6. To resolve the disputes if any between the members of the water users association in its area of operation.

7. To conduct general body meeting in such a manner as may be prescribed.

8. To encourage avenue plantation on canal and tank poremboke and to protect and maintain such plantations.

78 WUAs and 430 TCs are formed in Cuddalore district during WRCP. WUAs are not formed during IAMWARM Project, since the sub basins of Paravanar basin are not taken under IAMWARM Project.

10.3.1. Single Window Information Centre (SWIC)

As a measure to improve the service delivery of field officials of the implementing departments, an innovative initiative was taken to facilitate convergence and collaboration between the departments and farmers. Single Window Information Centre (SWIC) was conceived to act as a common platform for the officials and farmers to meet and discuss issues and find solutions. This free space was provided in IAMWARM project implementation villages by the community to facilitate this convergence. A board showing the name, date, time of visit, mobile numbers of the officers who regularly visit the centre are displayed outside the SWIC, so farmers can contact the officers over phone any time. Technical experts from Agriculture, PWD (Water Resource Department), Horticulture, Animal Husbandry, Agricultural Engineering and Agricultural Marketing departments are visited farmers and provided technical guidance through the SWIC.

10.3.2.Model Village

Under IAMWARM project , Model village program was piloted and it focused on strong multi departmental team work at village level; System of regular and combined field visit for sharing information at pre designated dates; Holistic water vision approach towards water management cropping husbandry and community participation; and Overall improved income per unit of water.

400 model villages spread over 17 districts of Tamil Nadu has been established with strategic converged developmental plans, departmental interventions along with increased capacity building activities of WUAs and service providers. In Cuddalore district 20 model villages are selected for this project.

In model village, focus will be on entire village to create appreciable outcome and not on the Demo area only. The target outcomes are:

- Up to 50% reduction in gap area in the ayacut in the village.
- 25% increase in the conveyance efficiency.
- WUAs well trained and effective.
- 30% reduction in area under horticulture crop in each village.
- 10 % increase in diversification.
- 25 % increase in horticulture crop productivity.
- 20% increase in cropping intensification.
- 25% increase in average crop productivity.
- Yield improvement in Tonne / Ha.
- Modern irrigation for 25 % of area under technically feasible crops.
- 10 % increase in marketable income.
- Villagers will be trained to assess the water availability, undertake water Budgeting, Decision Support System for selection of crops and cropping extent. They will be empowered to maintain the irrigation system below the Sluice, themselves.

Implementation Strategy:

The Centre of Excellence for change unit in MDPU- IAMWARM Project will provide detailed operational guidelines on the Strategies for implementation of Model village programme. The key component of model village program would include WUA participation through Community mobilization, Single Window Information Knowledge

Centre, pre scheduled combined field visits, a well documented grievance and Problem Solving Mechanism , holistic Water Vision, Water Budgeting, Water Conservation and Productive Water Use, Crop Decision Support System associated with Water Management / Conservation interventions and Cropping Technologies, E- velanmai and Livestock Interventions, increase return on farm produce etc.,

10.4 Agencies Responsible for Various activities in Paravanar River basin

The agencies responsible for the various main activities related to Water Resources Management in the Paravanar River basin are given in **Table 10.4**

Table 10.4 - Main Activities for Basin Management and Agencies Responsible

Sl. No	Main Activity	Department / Agency Responsible	Key functions
1	Water Resources Management.	Water Resources Department	✓ Planning, Designing and Execution of New Irrigation Projects. ✓ Operation and Maintenance of Irrigation systems including tanks. ✓ Collection of Surface and Ground Water Data for effective Water Resources Management.
		Central Water Commission	✓ Planning, Designing and Execution of New Irrigation Projects sanctioned by Central Government. ✓ Collection of Surface and Ground Water Data for effective Water Resources Management.
		Ministry of Water Resources (MoWR) & Ministry of	✓ Clearance for New Irrigation Projects.
		Environment and Forest (MoEF), Government of India.	
		Institute for Water Studies,	✓ Develop broad principles for planning and management of water

		WRD.	resources. ✓ Assist in the formulation of water management policies. ✓ Fostering or undertaking research, relating to water planning and policy making. ✓ Develop training programmes. ✓ Advice the Government, on specific policy matters referred to it.
		State Water Resources Management Agency (SWaRMA)	✓ Advise the Government of Tamil Nadu in water policies. ✓ Advise in regulating water allocation for bulk users. ✓ Review and approve state and River Basin master plans and to appraise all surface water resources in the hydrological boundaries. ✓ Develop a State water allocation data base. ✓ Prepare an annual Water Audit for each river basin in the state and to publish the same. ✓ Support and aid the enhancement and preservation of water quality within the State.
2	Ground Water Level and Quality monitoring.	State Ground and Surface Water Resources Data Centre, WRD.	✓ Installation & Maintenance of Observation wells and Piezometers. ✓ Collection and Testing of water samples from Observation wells and Piezometers. ✓ Construction of Artificial Recharge Structures. ✓ Observation, Documentation and Supply of Ground Water Data. ✓ Accords Ground Water clearance for environmental, Institutional and financial point of view
		Central Ground Water Board	✓ Monitors Ground Water Level and Quality

3	Surface Water and Hydrological data collection.	State Ground and Surface Water Resources Data Centre, WRD.	✓ Installation & Maintenance of Rain gauge Station, Climatic Stations, Automatic Weather stations and Gauge discharge station. ✓ Observation, Documentation and supply of Rainfall and Hydrometeorological data. ✓ Collection and testing of water samples from rivers at selected locations.
		Indian Meteorological Department (IMD)	✓ Observation of Rainfall& Hydrometeorological data.
4	Providing Drinking Water and Sanitation facilities.	Tamil Nadu Water Supply and Drainage Board	✓ Planning, Designing and Execution of New Drinking Water Schemes. ✓ Planning, Designing and Execution of New Under Ground Sewerage Schemes. ✓ Providing water supply for Rural, Urban and industrial needs.
5	Protecting the forest cover, according clearance for forest area, protecting the flora and fauna, Environmental protection.	Forest Department	✓ Conserving the forest wealth. ✓ Undertaking control measures in watersheds. ✓ In charge of social forestry works.
6	Agricultural Development.	Agriculture Department	✓ Providing facilities to the farmers including supply of subsidies like fertilizers, pesticides, seeds etc and suggests for suitable crop pattern. ✓ Monitors the Agricultural activities.
7	Command area development including On Farm Development (OFD) works.	Agricultural Engineering Department	✓ Executes watershed management works and control measures on soil conservation. ✓ Water Management through micro and sprinkler irrigation.

8	Pollution Prevention.	Tamil Nadu Pollution Control Board	✓ Monitoring the proper functioning of Industrial Effluent Treatment Plant. ✓ Monitoring the quality of treated effluents released by industries. ✓ Collection and Testing Water Sample from rivers at selected locations. ✓ Issue / Renewal of consent to different categories of industries. ✓ Effecting standards for Safe disposal of effluents to land and water bodies.
9	Assessment of cultivated area and collection of water charges.	Revenue department.	✓ Monitoring the natural calamities of Flood & Drought Management.
10	Preventive and control measures of epidemics, testing of water samples and educate the public on water borne diseases.	Public Health Department	✓ Providing infrastructure facilities to health services. ✓ Monitoring the health status. ✓ Collection of statistics on disease prevalence ✓ Conducting special medical camp at the time of outbreak of epidemics.
11	Comprehensive Veterinary assistance and health cover to all livestock.	Animal Husbandry & Veterinary Sciences	✓ Providing infrastructure facilities to Veterinary health services. ✓ Planning for development of livestock and livestock based products. ✓ Conducting special medical camp for livestock.
12	Development of inland and marine fish farming, fish seeding and other activities	Fisheries Department	✓ Implementation of fishermen welfare schemes. ✓ Development of Aquaculture activities, reservoir fishing and fishermen training.

CHAPTER 11

CONCLUSION AND ACTION PLAN

CHAPTER 11

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11.1 Conclusion

Paravanar river basin is one of the major river basins in Tamil Nadu. It originates in the marginally high lands, Northwest of Neyveli Lignite Corporation in the Semakottai Reserve Forest area at an altitude of about 100 metres above MSL and passes through Mathurai and Ammeri villages. The slope of the river course is not steep till it empties into Bay of Bengal. As it traverses in a flat terrain, the water that it carries spreads on either side of its course for a wider distance and hence it has derived the name Paravanar which means ‘Spreading river’ in Tamil.

The Paravanar river basin has two sub basins namely Paravanar sub basin in the west of the basin and Uppanar sub basin in the east of the basin. Entire basin lies in the Cuddalore district only.

This basin is made up of sedimentary formations which is highly suitable for groundwater exploration and for artificial recharge of groundwater. Due to the overburden thickness, the lineaments picked up in this basin are vague and need field verification. The lineament ascertained in the field in any of the formations of Paravanar basin can be considered as more productive and promisable. Geomorphically, this basin comprises land forms of sedimentary origin. These landforms indicate that the basin is subjected to the denudational, fluvial and marine actions. The coastal area indicates the progradation of delta and is undergoing severe erosion.

13 raingauge stations are considered for the study. Out of 13 stations only, one station is falling within the basin area (i.e) in the Uppanar sub basin, and the remaining 12 stations are falling adjacent to the basin area. There is no raingauge station in the Paravanar sub basin. The average annual rainfall of Paravanar River basin is 1197.70 mm which is well above the State average of 920 mm (**Source: Statistical Handbook of Tamil Nadu 2015**). When compared to the previous study done by IWS in 2007 (1214.15 mm), meager change in the average annual rainfall of Paravanar River Basin (1.35%)is noticed.

There is no climatic station falling within the basin area. The climatic station falling adjacent to the basin area is considered for the analysis of climatic parameters.On viewing the climatic pattern, it isobserved that there is increase in number of rainy days, marginal increase in summer & winter maximum temperature and reasonable increase in summer & winter minimum temperature.

The Gross irrigated area of crops in Paravanar Basin is 51887 Ha. Paddy is the main crop cultivated in the basin. Other crops are Sugarcane, Pulses, Coconut and Cashew. Irrigated area in Paravanar sub basin is 24686 Ha and in Uppanar sub basin is 27201 Ha. Net Irrigation demand of this basin at 75% dependable rainfall is 361.49 MCM and at 50% dependable rainfall is 374.16 MCM.

Using modern irrigation techniques, viz., drip irrigation, using coir as mulch and latest cultivation practices like SRI, water can be saved. Irrigation demand is the major demand (90%) among the other sectoral demands, like, Domestic, industrial, livestock. During less precipitation period, less water consuming crops like millets, Green Manure, Fodder, Gingelly may be cultivated.

There are no major reservoirs in the basin. Walajah and Perumal tanks are the two major irrigation tanks in the basin. Perumal tank is the last gauging location in the course, there is no gauging site near the tail end to measure the surplus flow to sea.

The main source of feed to Walajah tank is the water pumped from NLC Mine I &II, which carries lots of ash and coal particles in it.The same water is used for irrigation purpose, which in turn may affect the soil quality in future.

The source of supply to Perumal tank is Paravanar river. As the Paravanar course is a drainage cum irrigation course, it will irrigate its command area during normal irrigation supply from Walajah tank. But during the flood period, as a flood carrier course, it has its own drawback of submerging its command area and it requires proper remedial measures and maintenance.

In Paravanar basin, the surface system is sick and inefficient. The real problem is with the main distribution system. Drains carrying silt into the irrigation canals causes heavy siltation. The damaged and deteriorated conveyance systems including masonry structures are to be rehabilitated for their proper functioning. There is almost no control of water since most of the outlets are neither gated nor operated. The control structures are not easily approachable for regulation, measurement and monitoring the flows at various points for the system management.

The original course of Paravanar has been diverted by excavating a new channel by the Neyveli Lignite Corporation (NLC) at its own cost to discharge the pumped water generated due to the mining as well as to extend the mining activity. Due to this diversion of existing course from its original course, the ayacut of Kathalai tank, Karivetti, M. Chozhagan, Sathapadi, U.Adhanur tank, Valayamadevi tank have been affected. A case has been filed under National Green Tribunal (SZ), Chennai for restraining them from altering or diverting or changing the old Paravanar course videO.A.No. 203/2015 and M.A.No.313/2015.

In Paravanar basin, there is no sampling location identified for the assessment of Surface water quality.

Groundwater recharge works are to be given top priority in Kammapuram (E), Kammapuram(W) and Umangalam firka in Paravanar sub basin and Thiruvanthipuram firka in Uppanar sub basins to improve the level of Groundwater, where the extraction is more.

Generally groundwater quality is good in Paravanar sub basin, while in Uppanar sub basin the quality ranges from good to moderate quality. pH and Nitrate values are within the Permissible limit in the basin. Higher TDS is observed in Kullanchavadi village of Kurinjipadi taluk, due to local pollution. Higher value of Nitrate is observed in Neyveli village due to the excessive use of fertilizers.

To recharge the ground water in future, 17 Artificial Recharge Structures like Check dams, Vertical shafts and Percolation ponds, are suggested in Over Exploited, Semi critical and Critical in the Paravanar basin.

The sub-basin wise population projection for the Paravanar river basin for the present year 2016 and the target years 2020, 2023, 2030 & 2040 are arrived as 0.849 million, 0.905 million, 0.949 million, 1.061 million & 1.246 million respectively. Accordingly, the domestic water demand for the present year 2016 and the target years 2020, 2023, 2030 & 2040 are obtained as 34.597 Mcum, 37.027 Mcum, 38.965 Mucm, 43.909 Mcum & 52.129 Mcum respectively. The population density is higher in Uppanar sub basin (1181 persons per sq.km) and lower in Paravanar sub basin (765 Person per Sq.km).

The Uppanar Sub Basin has a high sex ratio of 997 females to every 1000 males and Paravanar Sub basin has a low sex ratio of 975 females to every 1000 males. The overall literacy rate of Paravanar River basin is found to be 66 %.

The total Industrial water demand of Paravanar River basin for the years 2016, 2020, 2023, 2030 & 2040 is estimated as73.195 Mcum, 96.617 Mcum, 119.806 Mcum, 148.656 Mcum & 184.600 Mcum respectively.

The livestock water demand during 2016, 2020, 2023, 2030 & 2040 is worked out as 4.666 Mcum, 4.733 Mcum, 4.797 Mcum, 4.992 Mcum &5.421 Mcum respectively.

Heavy rainfall, which occurs during cyclonic storms / low pressure, causes flood in the basin. The size of waterways and water bodies of Paravanar basin are reduced due to weeds, plantation and siltation thereby the run off is obstructed, causing flood. In addition NLC is also pumping very large quantity of water into water bodies in Paravanar basin, which also aggravates flooding phenomena in the basin.

78 WUAs and 430 TCs were formed in Cuddalore district during WRCP. WUAs were not formed during IAMWARM Project, since both the sub basins of Paravanar basin were not taken up under IAMWARM Project.

Paravanar river basin is found to be a deficit basin both at 75% and 50% dependable rainfall. But the pumped water from NLC mines and Industrial waste water reuse contributes a major portion to the Surface Water Potential of the basin making the basin as a Surplus one.

From the total water requirement value, it is found that the irrigation demand value accounts for about 90% of the total water demand. Hence steps may be taken to improve the percentage of water use efficiency by means of lining of canals, proper maintenance of irrigation structures, and adopting micro irrigation techniques. Also more artificial recharge structures such as check dams, recharge shafts and percolation ponds may be provided in suitable locations in the basin for effective utilization of the available balance water. Also water can be diverted from surplus sub basins to nearby deficit sub basins.

TABLE 11.1 STRATEGIC OBJECTIVES AND ACTION PLAN

Sl. No	Issues	Strategies Recommended	Action to be Taken
1	No raingauge station is installed in Paravanar sub basin. Area of Paravanar Sub basin is 435.016 Sq.km	• A minimum of one raingauge station has to be installed for an area of about 500 Sq.Km.	The Chief Engineer, SG&SWRDC
2	No gauging sites at the tail end point for assessing the Surplus outflow to sea	• Automatic flow measuring devices to be installed at all tail end. • Proposals for utilizing the surpluses of Paravanar suggested in Vision 2023 (list furnished separately) may be implemented. • Steps to utilize the surplus water in the upper reaches may be analyzed.	The Chief Engineer, Chennai Region and Chief Engineer Plan Formulation. The Chief Engineer, SG&SWRDC
3	The surface system is sick and inefficient. The real problem is with the main distribution system. Drains carrying silt into the irrigation canals causes heavy siltation.	• The damaged and deteriorated conveyance systems including masonry structures are to be rehabilitated for their proper functioning	The Chief Engineer, Chennai Region
4	No sampling location identified for the assessment of Surface water quality and its monitoring.	• Necessary steps to be taken for identifying the surface water sampling location.	The Chief Engineer, Chennai Region and The Chief Engineer, SG&SWRDC
5	Managing future water need for irrigation.	Change of cropping pattern during normal rain year and during drought rain year • SRI method cultivation for paddy and SSI method for Sugarcane may be implemented.	Agriculture Dept., Horticulture Dept. and Agricultural Engg. Dept.

		• Soil – moisture conservation techniques like coir pith, Contour bunding, downward terrace cultivation, alternative furrow irrigation, and alternative day irrigation. • Equitable distribution of irrigation water by better management. • Adopting micro irrigation techniques	
6	The size of waterways and water bodies of Paravanar basin are reduced due to weeds, plantation and siltation thereby the run off is get obstructed and causing flood. Also, NLC is pumping very large quantity of water and letting into water bodies in Paravanar basin	• Necessary actions to be taken for clear up the waterways of Paravanar course.	The Chief Engineer, Chennai Region
7	No WUAs have been formed in Paravanar basin under IAMWARM project.	• Necessary action to be taken for setting up of WUAs in Paravanar basin	The Chief Engineer, Chennai Region

The issues in the strategic objectives and the developments required in various aspects as discussed above are recommended to be implemented by the Water Resources Department in co-ordination with the Tamil Nadu Water Supply and Drainage Board, Tamil Nadu Pollution Control Board, Agriculture Department and Agricultural Engineering Department for effective Water Resources Management of the Paravanar River basin.

11.2 Action Plan

The recharge zones were identified in Paravanar basin with the help of GIS software by weighted overlay analysis of relevant thematic layers which were given appropriate ranks and weightages based on their relevance. The recharge zone map (Plate:PRA.53) shows that very good zones are available in the western part of Bhuvanagiri block, Parts of Virudhachalam block, northern part of Kammapuram block of the basin. Good recharge zones are identified in some parts of Panruti, Kurinjipadi and Cuddalore blocks. Moderate recharge zones are noticed in the lower parts of Kurinjipadi, eastern part of Bhuvanagiri and western part of Parangipettai blocks. Poor and very poor category of recharge zones are noticed in western part of Kurinjipadi and southern part of Kammapuram blocks.

The recharge zones were overlaid with drainages and water bodies for ascertaining the location of new artificial recharge structures in the basin. Existing artificial recharge structures obtained from line departments were also plotted on the recharge zone map so as to plan the new structures in suitable locations. New structures are recommended in the very good, good and moderate category of recharge zones by considering the groundwater status (categorization of blocks) in the basin. The selected locations were corroborated with the lithological details to ascertain the feasibility of the structures.

Based on the analysis, 7 check dams. 4 percolation ponds and 14 vertical shafts were recommended in various locations. The recommended structures percolation ponds, vertical shafts and check dams in the favourable recharge zones are given in **Table 11.2.** These structures may be constructed after detailed field verification in the recommended locations.

Table 11.2 Recommended Structures

Structure	Location/Village	Block	In tank / Across river / Stream	Sub Basin	Lat (N)	Long (E)
Vertical Shaft	Ammeri RF	Kammapuram	Ammeri Tank (PU)	Paravanar	11.5813	79.4184
Vertical Shaft	Tandavankuppam	Kammapuram	Valayamadevi Big Tank (WRD)	Paravanar	11.5853	79.4744
Vertical Shaft	Kammapuram Big Tank	Kammapuram	Kammapuram Big Tank(WRD)	Paravanar	11.4873	79.4295
Vertical Shaft	Kammapuram Small Tank	Kammapuram	Kammapuram Small Tank (PU)	Paravanar	11.4807	79.4256
Vertical	VadakkuVellur	Kammapuram	VadakkuVellur	Paravanar	11.5547	79.466

Shaft	Tank		Tank (PU)			
Vertical Shaft	Agaram	Kammapuram	Agaram Tank (PU)	Paravanar	11.5402	79.4002
Vertical Shaft	Sorattur	Panruti	Sorattur Tank (PU)	Paravanar	11.6403	79.505
Vertical Shaft	Kallal	Panruti	Kallal Tank (PU)	Paravanar	11.6481	79.5433
Vertical Shaft	Terkiruppu Big Tank	Kammapuram	Terkiruppu Big Tank (PU)	Paravanar	11.6228	79.4286
Vertical Shaft	Sattankuppam	Cuddalore	Sattankuppam Tank (PU)	Uppanar	11.7017	79.6918
Vertical Shaft	Ramapuram	Cuddalore	Ramapuram Tank (PU)	Uppanar	11.686	79.6956
Vertical Shaft	Dharamanallur	Mel Bhuvanagiri	Dharamanallur Tank (WRD)	Paravanar	11.4791	79.4837
Vertical Shaft	Nellikollai tank	Mel Bhuvanagiri	Nellikollai Tank (WRD)	Paravanar	11.4789	79.5199
Vertical Shaft	Manaveli	Mel Bhuvanagiri	Manaveli Tank (PU)	Uppanar	11.4649	79.6345
Check Dam	Tandaivelpettai	Kurinjipadi	Confluence point of KanyakoilOdai and stream	Paravanar	11.5852	79.5573
Check Dam	Mudanai	Kammapuram	Stream flowing through Mudanai Village	Paravanar	11.5692	79.4121
Check Dam	Tambipettai	Kurinjipadi	Stream flowing through Anandampettai Village	Uppanar	11.6065	79.628
Check Dam	Amalyampettai	Kurinjipadi	Across the river Uppanar	Uppanar	11.5956	79.7214
Check Dam	Sangalikuppam	Kurinjipadi	Across the river Uppanar	Uppanar	11.6565	79.7487
Check Dam	Kattalai	Kammapuram	Stream flowing through Karaimedu Village	Paravanar	11.4999	79.4777
Check Dam	Tiruvennainallur	Kurinjipadi	Stream flowing through Tiruvennainallur Village	Paravanar	11.5079	79.5716
Percolation Pond	Uttangal Mangalam RS	Kammapuram	Poramboke land	Paravanar	11.5448	79.4226
Percolation Pond	Virudhagiri-kuppam	Kammapuram	Poramboke land	Paravanar	11.558	79.3884
Percolation Pond	Mel Kuppam	Kammapuram	Poramboke land	Paravanar	11.5689	79.4464
Percolation Pond	Chona-kanchavadi	Cuddalore	Poramboke land	Uppanar	11.6388	79.7339

(These locations are subject to ground truthing)

Table7.3New Schemes proposed in Paravanar River Basin

Sl.No.	Description of the Schemes	Cost Rs. in lakhs
1	Improving water retention capacity of Perumal tank in Kurinjipadi taluk of Cuddalore district.	**4500.00**
2	Construction of a check dam across Therkuveliodai near Ayikuppam Village in Kurinjipadi taluk of Cuddalore district in Paravanar sub basin.	**121.00**
3	Construction of a check dam across Sengalodai near Rajakuppam Village in Kurinjipadi taluk of Cuddalore district in Paravanar sub basin.	**176.00**
4	Construction of a check dam across Kattuodai in Peyiganattam Village near Thambipettai in Kurinjipadi taluk of Cuddalore district in Uppanar sub basin.	**143.00**
	TOTAL	**4940.00**

WATER IS PRECIOUS. LET US ALL STRIVE TO PRESERVE IT.