CHAPTER – 1

INTRODUCTION

AND

DESCRIPTION OF THE BASIN

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1.1. River Basins as Units of Planning

There are 34 major rivers in Tamil Nadu. For hydrological studies, they are grouped into 17 river basins.

The complex problem of planning the Water Resources of the entire State of Tamilnadu can only be solved if it is broken down into independent problems, which can be dealt with effectively. In that respect, river basins are suitable units of planning as they form cohesive entities in terms of water resources. However, river basins are not self contained. For example groundwater flows may cross the boundaries of the river basins, inter-basin transfer may be possible and part of a river basin may come under the jurisdiction of adjoining State. Inspite of such links, river basins still form the best possible breakdown for water resources planning, i.e. as far as the flow and supply of water is concerned.

The rationale for choosing a river basin as the unit for the planning is to optimize the use of water resources in that basin, considering the water potential & water demand. An analysis of water balance, water utilisation & allocation plan for different competing water users form the core of a river basin planning is utmost important.

1.2 Objectives of present report & its updates

This report deals with assessment of Water Resources (Surface water & Groundwater) scientifically using the latest technology available related to water resources, computing the sectoral demands for various sectors like domestic, irrigation, industries, livestock, power generation and public purposes governed by socio-economic and agricultural factors such as present and future population size, income level, urbanization, markets, prices, cropping patterns, environment and other uses and future planning of water resources in the State for the benefit of the society.

The development of water resources in a river basin is not a goal in itself, but a means to reach the socio-economic objectives of production, income, employment and quality of life. Therefore, water resources development should be programmed on the wider context of regional planning. Regional planning integrates all resources economic and social sectors, strategies and projects will be designed for an optimal use of space and resources.

Prioritization of projects is carried out by considering other criteria also in addition to the leading Irrigation Net Benefit to investment ratio criteria. These are: contribution to domestic and industrial water supply, level of exploitation of the water resource, level of pollution and quality degradation and the need for water (such as fraction of area under rain fed cultivation).

The prioritisation process with these criteria was programmed to obtain an action plan phased over time.

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 of their prioritisation; (2) institutional and legal deficiencies revealed in the basin with their proposed modifications. The feedback is schematically presented in Fig. 1.1

The planning process is considered as a continuous effort. The present report is a snap-shot of the state-of-the-art for the year 2015-16. The planning process as demonstrated in this report is based on tools and data base such as GIS and Simulation which have to be continuously updated.

The process of the present planning study which is proposed also for its updates is presented concisely in Fig.1.2

Pennaiyar River systems, especially those closer to human settlements and industrial developments suffer from acute levels of pollution. River that flow through densely populated areas including towns and housing areas are often polluted with solid wastes.

Soil erosion caused by land development in the surrounding areas and untreated waste discharges from nearby factories further contribute to the high pollution levels. These toxic wastes not only destroy aquatic life but also the surrounding vegetation, flora and fauna due to its highly acidic levels.

Pennaiyar River which gives drinking water to Krishnagiri, Tiruvannamalai, Cuddalore and part of Villupuram districts is facing pollution problem, owing to dumping of Industrial and medical wastes, plastics and city garbage indiscriminate letting of domestic sewage water into the river.

Industries around Bellandur Lake in Karnataka and in Hosur areas release effluents directly into the water body. Fertilizers used by farmers of Karnataka as well as Tamilnadu have made things worse. This may result in eutrophication.

Many of the open wells in the adjacent villages of river banks are dried because of uncertain rainfall and drought as a result they are used as dumping pits.

The planning process is considered as a continuous effort. In this way, the first report on Pennaiyar river basin by the Institute for Water Studies was prepared and published in the year 1984 under the United Nations Development Programme (UNDP) project – Strengthening the Water Institute. The second report on Pennaiyar river basin was brought out under the project named Water Resources Management Studies – (WRMS) funded by World Bank. Subsequently, the comprehensive system study of Pennaiyar river basin was entrusted to WAPCOS by PWD, Govt. of Tamil Nadu in the year 1993 under agreement No. 29/SE/PI/93-94/dt.02.09.93. Simulation model study for Pennaiyar river basin was done by M/s. Krishna Associates and the final report was submitted in February 2003. Micro level report of Pennaiyar basin was prepared during the year 2004 based on tools and data base such as GIS and Simulation models.

According to variations in results, for the future planning horizons, the recommended action plan will also be revised and updated. The various models and data base have been devised accordingly for an adjustable scientific assessment of water resources and of sectoral water demands at present and in the future under different socio economic development scenarios.

1.3. Basin – Specific Data

Water Resources planning is people oriented and resources based. Data relating to Geology, Geo-morphology, Hydrogeology, Hydrology, Climatology, Water quality, Environment, Socio-economic, Agricultural, Population, Livestock, Industries, were collected for analysis. For the sake of consistency, other types of data were treated in the same way. 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 basins. For units situated in two or more river basins, the values of the variables were split between those basins, for example, in proportion to the area contained in the respective river basins.

In this aspect, a complete assessment of inter-basin linkages is the only possible when all basin plans are ready and can be put together in a State Frame Work Water Resources plan. Until then each basin can be treated as a closed system.

1.4 Location and Extent

As per the Central Water Commission's Basin Report, Pennaiyar Basin is the second largest interstate East flowing river basin among the 12 basins lying between Pennar and Cauvery basins. It covers a large area in the State of Tamil Nadu besides the areas covered in the states of Karnataka and Andhra Pradesh

The basin is located between the geographical co-ordinates Latitude 11^0 38'30" N & 12^0 54'00" N and Longitude 77^0 39'30" E & 79^0 54".15" E. The total area of the basin in Tamil Nadu is 11,375.55sq.km and that of Union Territory of Pondicherry is 90 sq.km.

Necessity of Micro level study in Pennaiyar basin

Public of Vellore district has urged the state Government to provide a link canal from the Krishnagiri dam (Nedungal Anicut) to the Palar river near Vaniyambadi, so that the excess water from the dam could be diverted to replenish the ground water table of the Palar river bed. The excess flood water from Pennaiyar river could be diverted through open canal system as an alternative means to give a new lease of life to Palar river and along the canal route which get groundwater potential. Pennaiyar (Krishnagiri)-Palar Intra State Link envisages transfer of 3.5 TMC of water, annually available at Krishnagiri dam as flood flows to the Kallar, a tributary of Palar River in the adjacent basin through 55.7 km-long canal by gravity during the months of October to December at 2,700 cusecs discharge for 15 days ie. five days in each month. The diverted water is proposed to be utilised for recharging the groundwater potential of Palar basin and thereby to stabilise the existing command area of about 1,186 hectares being irrigated through the existing wells and bore well in Vaniyambadi Taluk of Vellore District.

In Pennaiyar (Sathanur dam)-Palar link, water would be conveyed from Sathanur dam to Cheyyar river, another tributary of Palar, through a new head regulator and a canal of 23.55km length with discharging capacity of 3,400 cusecs for 20 days (5.87TMC). A feeder canal of 38.72 km length would be formed to feed the Nandan Channel. About 18,651 acres of ayacut would be benefitted.

A proposal in this regard had already been considered by National Water Development Agency (NWDA) under Ministry of Water Resources which is one of the 36 proposals received for intra-state links from seven States of Maharashtra, Gujarat, Jharkhand, Orissa, Bihar, Rajasthan and Tamil Nadu so far. Tamilnadu Government has already submitted a proposal in 2009 for diversion of excess water of Pennaiyar river below Krishnagiri reservoir to the water shortage Palar basin through a Pennaiyar-Palar link project (Nedungal Anicut to Palar river), which is under examination by NWDA.

Whenever it rains, the first people to be affected are those settled on the banks of Pennaiyar River. Villagers have to cross over the river to reach Hosur or any other major towns. As only low level bridges were constructed, people suffer a lot, as and when it rains, water overflows the bridges and keeps them not able to cross the bridge (affected are those living in Gopachandiram village and its surroundings).

Consequences of floods in Pennaiyar River Basin

Heavy rain in Bangalore and its surroundings is flooding Kelavarapalli dam in Tamilnadu which has a full storage capacity of 13.62 MCM at FTL-44.2 feet. Hence, on considering the safety of the dam and to avoid any major flood situation, the surplus water is let out into Pennaiyar of Tamil Nadu and the water level was maintained at 2 feet below FTL. The flood has put the people living in villages of Hosur in great trouble. The water has submerged the low bridges and hence villagers were forced to take up a long route to reach Hosur.

Recent Flash floods on Nov 2015 & Dec 2015

The flood situation in Cuddalore district due to heavy rain during November and December 2015 turned grim on recent flood, with all the five rivers including Gadilam running through the district and other water sources were overflowing, following incessant heavy rains and further, flood occurred due to the discharge from the Sathanur and Gomukhi dams. According to a conservative estimate, one lakh people have been marooned and thousands stranded. Road traffic and train movement were affected, compounding commuters' misery. The strong current flowing across the road at Pallapattu between Panruti and Koliyanur snapped the road link with Villupuram.As a result of the discharge of water from the Sathanur dam, the swollen Pennaiyar had submerged the A.K.Kuchipalayam causeway, affecting the Chennai-Thanjavur traffic.

The Pennaiyar breached at Melkumaramangalam near Panruti, inundating three villages, and farm land. At Vriddhachalam, the Manimuktha had inundated Manavalanallur.

Water transfer from water surplus areas to deficit areas; inter-basin/sub-basin transfer after taking care of local riparian obligations; river interlinking on the basis of diversion of flood water and resorting to pumping schemes on the basis of terrain requirements of utilising the available water potential. Ground water resources would also be developed through recharging and augmenting of the resource through measures such as construction of check dams and recharge wells.

In the above circumstances it is the time to study the basin in micro level using scientific tools for water availability, demand and balance. This micro level study is also helpful for identifying flood source areas in the watershed are considered to be important in order to reduce the impact of floods. In this study, the flood source area (watershed) can be identified. The micro level study of this report includes the exploration of urbanization tends to increase peak discharge, reduce infiltration and increase the runoff volume. Due to increasing population and encroachments, the channels have lost their ability to carry flood water. Therefore, efforts should be made to prevent the destruction of the channels. Human settlements and encroachments must not be allowed in the flood prone areas. Existing storm water drains and water bodies must be maintained properly. On the whole, the encroachment seen on the river banks, sewage disposal and solid waste dumping in the river must be prohibited to reduce flood vulnerability & pollution. The effect of flooding on downstream can be minimized by adopting suitable techniques for recharging the aquifers identified as “potential recharge zones” in Pennaiyar basin.

FIG 1.1 FLOW CHART OF WATER PLANNING AND RIVER BASIN PLANS

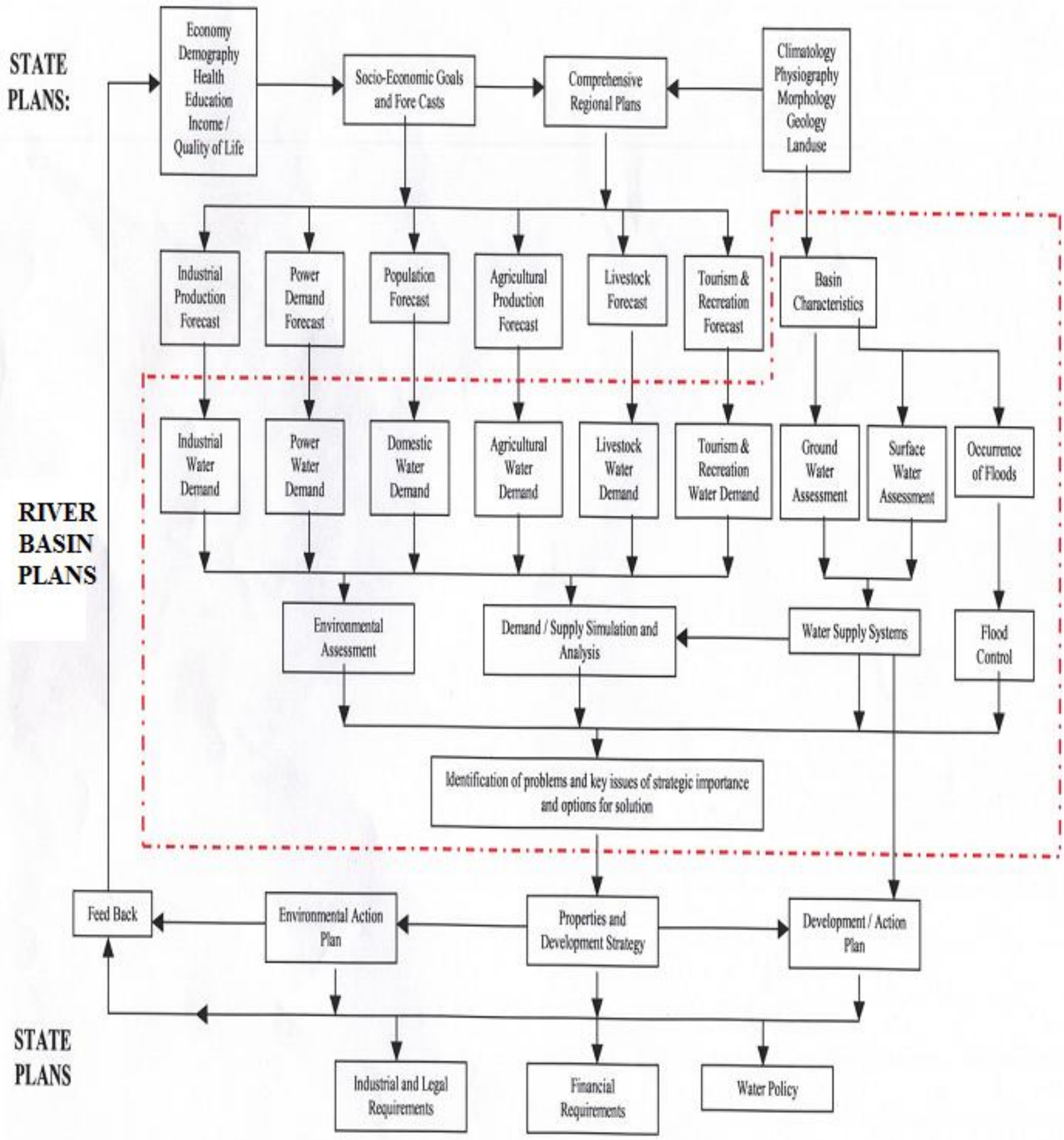
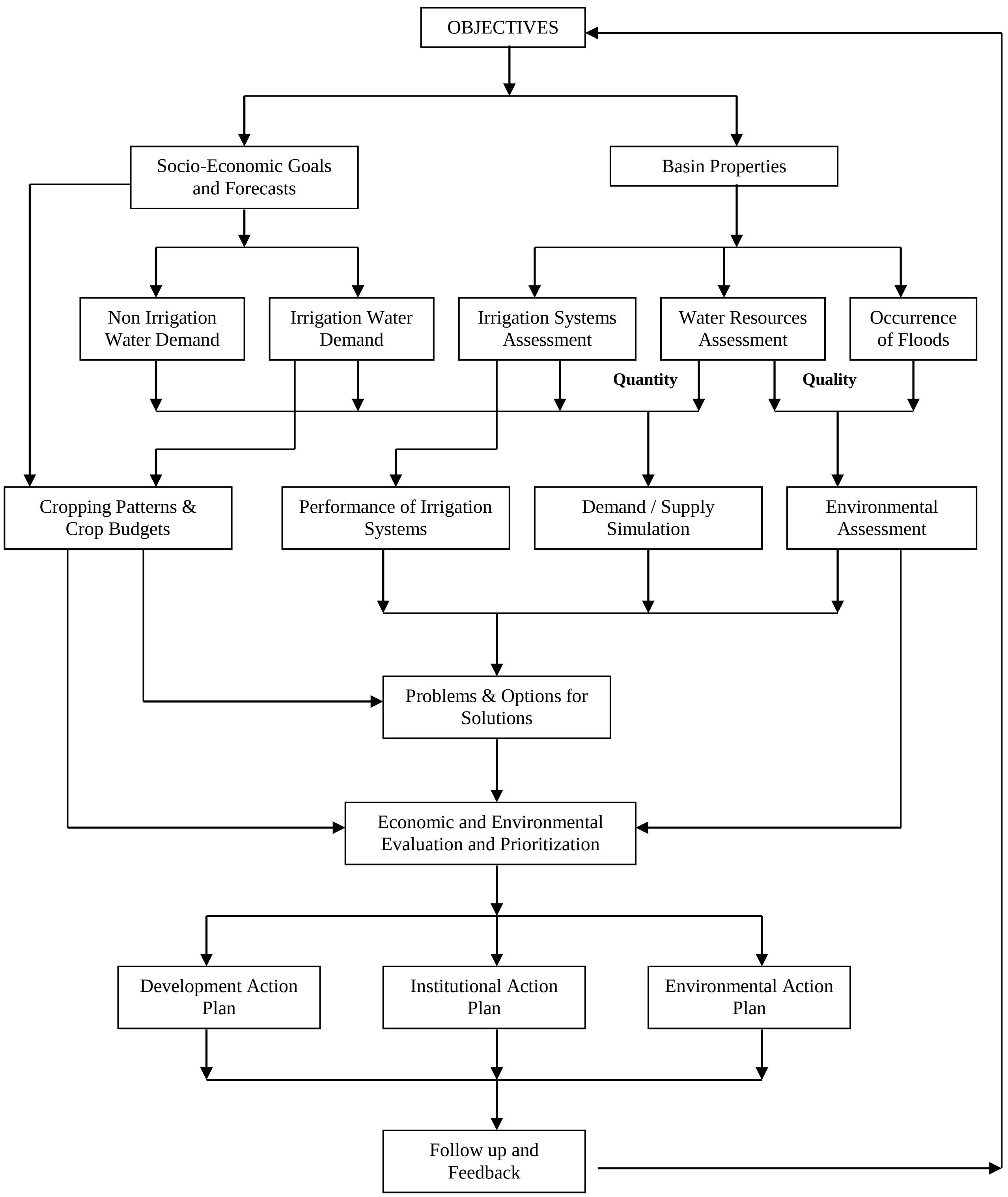


Fig. 1.2 SUMMARY FLOWCHART OF RIVER BASIN PLANNING



CHAPTER – 2

BASIN FEATURES

AND

SCOPE OF THE STUDY

CHAPTER 2

BASIN FEATURES AND SCOPE OF THE STUDY

2.1 General

Pennaiyar River originates on the south eastern slopes of Chennakesava Hills, North west of Nandidurg in Karnataka State at an altitude of 1000 m. above MSL. The river is called Dakshina pinakine in Karnataka state. After flowing through Karnataka, the river enters Tamil Nadu near Bagalur village of Hosur taluk and takes the name of Pennaiyar. Pennaiyar river basin is sandwiched between Cauvery river basin at its west and south and Palar and Varahanadhi basins at its east and north.

The details of the districts, taluks and blocks covered by the basin are given in **Table 2.1**. The details of the district area and block area falling in each sub basin are given in **Table 2.2.**

The main tributaries of Pennaiyar River are Chinnar West, Chinnar East, Markandanadhi, Kambainallur, Mathurar, Pambar, Vaniyar, Kottapatti-kallar, Vayalar Odai, Ramakal Odai, Pambanar, Aliyar, Musukundanadhi and Thurinjilar.

The Reservoirs in Pennaiyar River Basin are Pambar, Thumbalahalli, Vaniyar, Shoolagiri Chinnar ,VarattarvalliMadurai, Andiyappanur Odai, Krishnagiri, Kelavarapalli and Sathanur.

The major anicuts are Nedungal Anaicut, Kumarapatti Anaicut, Ichambadi Anaicut, Sathanur Anaicut, Tirukoilur Anaicut, Ellis Choultry Anaicut and Sornavur Anaicut. In addition to this 152 minor anaicuts and about 66 open off take channels are also available in this basin.

The total length of Pennaiyar River is 432 kms. It spreads over 112 kms. in Karnataka state, 180 kms. in Dharmapuri, Krishnagiri & Salem districts, 34 kms. in Thiruvannamalai and Vellore districts and 106 kms. in Cuddalore and Villupuram districts of Tamil Nadu.

There is no flow in the river normally except during monsoon seasons. The maximum discharge of the river so far measured is 3,00,000 cusecs. Total actual dependable run off is 45 TMC.

Table 2.1 District, Talk and Blocks in Pennaiyar River Basin

District	Taluk	Block
Krishnagiri	Krishnagiri	Krishnagiri
		Veppanapalli
	Hosur	Hosur
		Shoolagiri
	Denkanikottai	Kelamangalam
		Thali
	Uttangarai	Mathur
		Uthangarai
	Pochampalli	Bargur
		Kaveripatinam
Dharamapuri	Dharmapuri	Dharmapuri
		Nallampalli
	Pennagaram	Pennagaram
	Harur	Harur
	Pappireddipatti	Morappur
		Pappireddipatti
	Palacode	Palacode
		Karimangalam
Salem	Valapadi	Ayodyapattnam
	Attur	Peddanaikanpalayam
	Yercaud	Yercaud
Vellore	Tirupattur	Alangayam
		Kandili
		Jolarpettai
		Natrampalli
		Tirupattur
Tiruvannamalai	Chengam	Chengam
		Pudupalayam
		Thandarampattu
	Tiruvannamalai	Tiruvannamalai
		Kilpennathur
		Thurinjalapuram
Villupuram	Gingee	Gingee
	Sankarapuram	Kalrayan Hills
		Rishivandiyam
		Sankarapurm
	Villupuram	Kanai
		Kandamangalam
		Kolianur
	Kallakurichi	Theyagadurgam
	Ulundurpettai	Tirunavalur
		Ulundurpettai
	Tirukoilur	Tirukoilur
		Tiruvennainallur
		Mugaiyur

Cuddalore	Cuddalore	Cuddalore
	Viruthachalam	Kammapuram
		Annagramam
	Panrutti	Panrutti
Pondicherry State	Pondichery	Pondichery

Table 2.2: SUB BASIN WISE ADMINISTRATIVE DETAILS (ACCORDING TO FLOW PATTERN)

Sl. No.	Sub Basin Name	Sub Basin Area Sq.Km.	District Name	District Area in Sq.Km.	Taluk Name	Taluk Area in Sq.Km.	Block Name	Block Area in Sq.Km.
1	Chinnar - West	125.315	KRISHNAGIRI	125.315	HOSUR	99.470	SHOOLAGIRI	6.403
							HOSUR	93.066
					DENKANIKOTTAI	25.846	THALLY	25.846
		Total				**125.315**		125.315
2	Chinnar - East	307.959	KRISHNAGIRI	307.959	HOSUR	307.952	SHOOLAGIRI	298.805
							HOSUR	9.147
					DENKANIKOTTAI	0.008	KELAMANGALAM	0.008
		Total				**307.959**		307.959
3	Markandanadhi	368.210	KRISHNAGIRI	368.210	HOSUR	110.967	SHOOLAGIRI	110.967
					KRISHNAGIRI	257.242	KRISHNAGIRI	4.724
							VEPPANAPALLI	252.518
		Total				**368.210**		368.210
4	Kambainallur	919.279	DHARMAPURI	891.804	HARUR	77.794	MORAPPUR	77.794
					PAPPIREDDIPATTI	11.761	MORAPPUR	11.761
					PENNAGARAM	41.640	PENNAGARAM	41.640
					DHARMAPURI	305.451	DHARMAPURI	253.127
							NALLAMPALLI	52.324
					PALAKKODU	455.158	KARIMANGALAM	287.350
							PALACODE	167.808
						891.804		891.804
			KRISHNAGIRI	27.475	KRISHNAGIRI	18.173	KAVERIPATTINAM	17.835
							KRISHNAGIRI	0.338
					DENKANIKOTTAI	9.044	KELAMANGALAM	9.044
					POCHAMPALLI	0.258	KAVERIPATTINAM	0.258
						27.475		27.475
		Total		919.279		**919.279**		919.279
5	Pambar	1757.418	DHARMAPURI	4.834	HARUR	4.834	HARUR	4.834

			KRISHNAGIRI	902.857	KRISHNAGIRI	413.861955	BARGUR	363.718955
							KAVERIPATTINAM	1.486
							KRISHNAGIRI	48.657
					POCHAMPALLI	236.888	BARGUR	97.601
							KAVERIPATTINAM	10.744
							MATHUR	128.542
					UTTANGARI	252.108	MATHUR	70.424
							UTHANGARAI	181.684
						902.857		902.857
			VELLORE	849.727	VANIYAMBADI	195.564	ALANGAYAM	101.136
							THIRUPATHUR	94.428
					TIRUPATTUR	654.162857	ALANGAYAM	79.859
							JOLARPET	146.982677
							KANDHILI	262.404422
							NATRAMPALLI	20.480
							THIRUPATHUR	144.437
						849.727		849.727
		Total		1757.418		**1757.418**		1757.418
6	Vaniyar	998.385	DHARMAPURI	817.580	HARUR	216.606	HARUR	202.953
							MORAPPUR	13.653
					PAPPIREDDIPATTI	598.890	HARUR	83.080
							MORAPPUR	232.632
							PAPPIREDDIPATTI	283.178
					DHARMAPURI	2.084	DHARMAPURI	2.084
			KRISHNAGIRI	3.131	UTTANGARI	3.131	UTHANGARAI	3.131
			SALEM	177.674	YERCAUD	177.544	YERCAUD	177.544
					VAZHAPADI	0.130	VALAPADY	0.130
		Total		998.385		**998.385**		998.385
7	Matturar	58.498	DHARMAPURI	0.002	HARUR	0.002	HARUR	0.002
			KRISHNAGIRI	18.441	UTTANGARI	18.441	UTHANGARAI	18.441
			THIRUVANNA MALAI	35.547	CHENGAM	35.547	CHENGAM	35.547
			VELLORE	4.508	TIRUPATTUR	4.508	ALANGAYAM	4.508
		Total		58.498		**58.498**		58.498
8	Kottapattikallar	410.229	DHARMAPURI	353.120	HARUR	257.224	HARUR	257.224
					PAPPIREDDIPATTI	95.895	PAPPIREDDIPATTI	95.895
			SALEM	13.429	ATTUR	13.429	PETHANAICKEN PALAYAM	13.429
			THIRUVANNA MALAI	3.947	CHENGAM	0.039	CHENGAM	0.039
					THANDARAMPATTU	3.908	THANDRAMPET	3.908
			VILLUPURAM	39.733	SANKARAPURAM	39.733	KALRAYANHILLS	39.733
		Total		410.229		**410.229**		410.229

9	Valayar Odai	85.394	THIRUVANNA MALAI	85.394	CHENGAM	**85.394**	CHENGAM	85.394
10	Ramakal Odai	14.415	THIRUVANNA MALAI	14.415	THANDARAMPATTU	**14.415**	THANDARAMPATTU	14.415
11	Pambanar and Varattar	292.092	DHARMAPURI	18.785	HARUR	18.785	HARUR	18.785
			THIRUVANNA MALAI	244.648	THANDARAMPATTU	244.648	THANDARAMPATTU	244.648
			VILLUPURAM	28.659	SANKARAPURAM	28.659	KALRAYANHILLS	28.659
		Total		292.092		**292.092**		292.092
12	Aliyar	211.070	THIRUVANNA MALAI	211.070	CHENGAM	95.598	CHENGAM	75.325
							PUDUPALAYAM	20.273
					THANDARAMPATTU	115.472	THANDRAMPET	115.472
		Total				**211.070**		211.070
13	Musukundanadhi	179.255	THIRUVANNA MALAI	13.441	THANDARAMPATTU	13.441	THANDRAMPET	13.441
				165.814	SANKARAPURAM	165.814	KALRAYANHILLS	51.124
							RISHIVANDIYAM	27.510
							SANKARAPURAM	87.180
		Total		179.255		**179.255**		179.255
14	Thurinjalar	853.623	THIRUVANNA MALAI	742.772	CHENGAM	62.645	CHENGAM	32.105
							PUDUPALAYAM	30.540
					THIRUVANNAMALAI	655.841	KILPENNATHUR	184.094
							THURINJAPURAM	124.930
							TIRUVANNAMALAI	346.817
						24.286	THANDRAMPET	24.286
						742.772		742.772
			VILLUPURAM	110.851	GINGEE	11.879	GINGEE	11.879
					TIRUKKOVILUR	98.972	MUGAIYUR	98.972
						110.851		110.851
		Total		853.623		**853.623**		853.623
15	Gadilam	1562.903	CUDDALORE	503.475	CUDDALORE	125.370	CUDDALORE	125.353
							KURINJIPADI	0.017
					PANRUTI	351.089	ANNAGRAMAM	93.980
							KURINJIPADI	0.286
							PANRUTI	256.823
					VIRUTHACHALAM	27.015	KAMMAPURAM	27.015
						503.475		503.475
			VILLUPURAM	1059.428	SANKARAPURAM	131.050	RISHIVANDIYAM	131.050
					THIRUKOILUR	257.807	MUGAIYUR	4.337
							THIRUKOILUR	173.359
							THIRUVENNAI NALLUR	80.111

	Gadilam		VILLUPURAM		ULUNDURPETTAI	653.088	THIRUNAVALUR	281.506
							THIRUVENNAI NALLUR	94.199
							ULUNDURPET	277.383
					KALLAKKURICHI	17.483	THIAGADURUGAM	17.483
						1059.428		1059.428
		Total		1562.903		**1562.903**		1562.903
16	Upto Krishnagiri Reservoir	772.638	DHARMAPURI	14.749	PALAKKODU	14.749	KARIMANGALAM	14.749
			KRISHNAGIRI	757.889	HOSUR	395.706	SHOOLAGIRI	187.969
							HOSUR	207.737
					KRISHNAGIRI	254.535	KAVERIPATTINAM	0.943
							KRISHNAGIRI	207.332
							VEPPANAPALLI	46.261
					DENKANIKOTTAI	107.647	KELAMANGALAM	107.647
		Total		772.638		**772.638**		772.638
17	Krishnagiri to Pambar	894.518	DHARMAPURI	208.888	HARUR	186.251	HARUR	56.141
							MORAPPUR	130.110
					PAPPIREDDIPATTI	6.663	MORAPPUR	6.663
					PALAKKODU	15.973	KARIMANGALAM	15.973
						208.888		208.888
			KRISHNAGIRI	685.630	KRISHNAGIRI	341.819	BARGUR	1.678
							KAVERIPATTINAM	191.398
							KRISHNAGIRI	143.839
							VEPPANAPALLI	4.904
					POCHAMPALLI	142.282	BARGUR	30.704
							KAVERIPATTINAM	110.367
							MATHUR	1.210
					UTTANGARI	201.529	MATHUR	50.981
							UTHANGARAI	150.548
						685.630		685.630
		Total		894.518		**894.518**		894.518
18	Pambar to Thirukovilur	1002.393	DHARMAPURI	196.521	HARUR	196.521	HARUR	196.521
			KRISHNAGIRI	49.211	UTTANGARI	49.211	UTHANGARAI	49.211
			THIRUVANNA MALAI	370.600	CHENGAM	105.135	CHENGAM	105.135
					THIRUVANNAMALAI	33.497	TIRUVANNAMALAI	33.497
					THANDARAMPATTU	231.967	THANDRAMPET	231.967
			VELLORE	48.804	TIRUPATTUR	48.804	ALANGAYAM	48.804
			VILLUPURAM	337.257	SANKARAPURAM	197.614	KALRAYANHILLS	1.832

			VILLUPURAM		SANKARAPURAM		RISHIVANDIYAM	150.339
							SANKARAPURAM	45.444
					TIRUKKOVILUR	139.643	MUGAIYUR	74.077
							THIRUKOILUR	65.566
		Total		1002.393		**1002.393**		1002.393
19	Lower Pennaiyar	561.963	CUDDALORE	162.015	CUDDALORE	81.962	CUDDALORE	81.962
					PANRUTI	80.053	ANNAGRAMAM	80.053
			VILLUPURAM	399.948	VILLUPURAM	198.877	KANAI	19.200
							KANDAMAN GALAM	85.053
							KOLIANUR	94.624
					TIRUKKOVILUR	175.692	MUGAIYUR	122.828
							THIRUKOILUR	26.129
							THIRUVENNAI NALLUR	26.735
					ULUNDURPETTAI	25.379	THIRUVENNAI NALLUR	25.379
		Total		561.963		**561.963**		561.963

2.2 Physiographic features

Pennaiyar River Basin area from Tamil Nadu State boundary to Krishnagiri reservoir site has an undulating and hilly terrain. This terrain slopes from an altitude of about 880mt in a distance of about 50kms. Average topographical gradient is 8 metres per Kilometre. The basin area from Krishnagiri Reservoir to Sathanur Reservoir has an undulating terrain with many hills and valleys along the eastern and western boundaries. Average topographical gradients are 2.27 meters per km.

The basin area from Sathanur Reservoir to Tirukoilur anicut has a plain terrain moderately sloping from an altitude of about 222metres at Sathanur reservoir to 81.25metres at Tirukoilur anicut. The average topographical gradient is 2.5metres per km. The basin area from Tirukoilur anicut to sea is a plain terrain and slopes gently from an altitude of about 81.25metres at Tirukoilur to the mean sea level at the terrain and slopes gently an altitude of about 81.25metres at Tirukoilur to the mean sea level at the eastern and joins at Bay of Bengal. Average topographical gradient is 0.70 meters per km.

2.3 Drainage

Pennaiyar river, an inter-state river is one of the largest river of the State of Tamil Nadu. Pennaiyar river from it rises as the Southern Pinakini on the eastern slope of Nandidrug Mountain, in the Chennakaseva Hills of eastern Karnataka at an altitude of about 1000m above mean sea level. The river enters Tamil Nadu after traversing 110kms from its origin. A number of large and small tributaries such as Chinar, Markanda, Mathurar, Vaniaru, Pambaru, Kallaru join the river during its way before it confluences in the Bay of Bengal. The river, flow for a major portion through wooded country deep ravines and narrow gorges with the country at the sides rising steeply to a height of about 90m above the river bed. It then flows southward for 110 km through Karnataka to northwestern Tamil Nadu, where it turns southeastward and flows 322 km to enter the Bay of Bengal at Cuddalore. Heavy rains at the river's source cause sudden, but short-lived, floods. The river is extensively dammed for irrigation, especially in Tamil Nadu.

En route, its main tributaries are Chinnar West , Chinnar East, Markanda nadhi, Vaniyar and Pambar rivers. It is the sole water source in Krishnagiri, Tiruvannamalai, Villupuram and Cuddalore districts. Chinnar and Markandanadhi flows towards south from the Mysuru Plateau through the valley of Tirtham and Veppanapalli and joins Pennaiyar river. The river Vaniyar originates and run completely in Shervaroyan Hills close to Yercaud in Tamil Nadu. It joins the Pennaiyar river in Boongarrampatty Reserved Forest area. The river Pambar rises on the hill of Javadhu near Alangayam and from Thirupathur southwards it flows a course of remarkable straightness through Uthangarai and joins the Pennaiyar. Gadilam river, which starts in eastern part of Thirukoilur Taluk of Villupuram district flows through Cuddalore Taluk. In Cuddalore Taluk, Malattar joins with it on the right and then it flows into the Bay of Bengal at a point, just north of Cuddalore.

2.4 Geology

2.4.1 General:

The surface geology and the structures prevalent in this basin area were done using Landsat, MSS data, Geological Survey of India publications and district manuals. A Geological map on 1: 50,000 scale was prepared based on the above study incorporating the various rock types such as crystallines and sedimentary formations.

2.4.2 Surface Geology:

The surface Geology of Pennaiyar basin is covered by the Archaean rocks such as Pyroxene granulites, Quartzite, Ferruginous Quartzite, Amphibolites, Gneiss and Hornblende biotite gneiss with younger intrusive of Pegmatite and Dolerite in the central and western parts and the overlying sedimentaries of uppercretaceous, tertiary and quarternary formations of the eastern part. The contact between the crystallines and sedimentaries are sharp and are separated by boundary fault. The tentative geological succession of the basin area is given below:

Stratigraphic succession of rock types:

Quarternary	Recent of Sub recent	Soils Alluvium Laterite
	--------------Unconformity----------------	
Tertiary	Cuddalore Sandstone (Mio-Pliocene)	Cal. Sandstone
	--------------Unconformity----------------	
Upper Cretaceous	Ariyalur stage	Clay, Marl and Shell Limestone, Sandstone
	--------------Unconformity----------------	
Younger Intrusives		Dolerite, Pegmatite, Granites, Syenites, Carboratites.
Dharwars		Granite gneiss, Charnockite, Hybrid Gneiss, Migmatites, Dunites, Pyroxinites etc Magnetite quartzite, Amphibolites and Unclassified Crystallines.

2.4.3 Archaean Rock Types:

Archaean rocks of the basin include unclassified crystallines, amphibolites, magnetite quartzites, pyroxinites, dunites, migmatites, mixed gneisses, hybrid gneisses, charnockites and granite gneisses and belonged to Dharwar System. The younger intrusives, which cut across and occur as huge massifs, include syenite, granite, dolerite and pegmatites. The older rock types form a distinct representation along with charnockite type of rocks and peninsular granite gneisses. The various rock types reflect that they are polymetamorpic and migmatised and the bands of the metasediments and peninsular gneisses are concordant with foldings of synforms and antiforms. The bands of phroxene granulite, amphibolite and magnetite quartzite serve as marker horizons in this area. The various rock types that occur in this area are briefly described below:

Magnetite Quartzite:

Magnetite quartzites occur as prominent linear bands with concordant disposition parallel to the foliation of charnockites. The bands are fine and are alternating with magnetite and quartzite. In zones of intensive foldings, these bands exhibit pronounced contortions, and drag folds with fractures and joints. The rocks are massive, dark coloured, medium to coarse granied and belonged to metasediments. Prominent occurrences of these bands are located north of Veppenahalli near Krishnagiri trending almost, N-S as a plunging synclinal fold. Several bands are cutting across the peninsular gneisses near Kaveripattinam, Kavuthimalai near Thiruvannamalai, Radhapuram and Elarempadi. The trend is N 10º to N55ºE to S10º W with steep vertical dips. The magnetites are poor in grade.

Amphibolites:

Amphibolites occur as small Xenolithic patches within migmatites and are dark green, coarse grained and locally foliated. The foliation is alternated by layers of amphiboles and quartzo felspathic material.

Pyroxene Granulites:

Pyroxene granulites and associated rocks occur as unclassified crystallines in several locations as conformable bands in charnockites, parallel to sub parallel to the foliation. It is dark coloured and weathered into angular blocks. Hornblende granulite with minor garnet also occur as bands or lenses and xenoliths in peninsular gneisses.

Dunites and Pyroxinites:

These rocks form the ultra basic ground in this area and are found associated with Carbonatites. The dunite in Kanjanur is found to have altered to magnesite. The pyroxinites occurs in Koratti and Kanjanur and are altered to vermiculite. Pyroxinites are dark colored, massive and coarse grained.

Hybrid Gneisses, Mixed Gneisses and Migmatites:

Hybrid gneisses have developed around shear zones or at the contact between charnockite and granite or around ultrabasics and carbonatite complexes. The composition of these rocks varies according to the type of the older basic, ultrabasic or by the younger intrusives. Hybrid gneisses enclose the ultrabasic, alkalisilicates and carbonatite rocks.

Mixed gneisses are found along the Thirukoilur granite and Kalrayan charnockites with more basic bands and lenses.

Migmatites or migmatic gneiss of this area comprises a group of quartzo – feldspathic gneisses derived from different rock types such as Charnockites, Pyroxene Granulites, Phroxinites and Amphibolites and are associated with the rock types. These are leucocratic, coarse grained and are well developed in the central part of the basin. The rocks are ptygmatically folded with quartzo –feldspathic layers. Migmatic ampibole gneiss is more common along with biotite gneiss. The composition of minerals indicates that they are of amphibole facies.

Charnockites:

Charnockites form the major rock type in this area and are widely distributed in Krishnagiri and Dharmapuri Districts. The rocks are associated with biotite gneiss, migmatites and Pyroxene granulites. Acidic to basin varieties are encountered in this area. At places, the aspersthene in charnockites altered to biotite resulting in the development of biotite gneiss. The typical charnockites are bluish grey, fine to medium grained, massive rocks. Carnets are occasionally developed. Pegmatites, quartz veins and colerite dykes cut across these rocks. Weathering and jointing are also prevalent in charnockites.

Granite Gneisses:

Granite gneisses equivalent to peninsular gneisses are extensively seen in between Hosur and Krishnagiri areas and also in some part of the central basin area. The gneisses are hornblende bearing or biotite bearing gneisses conforming to the regional foliation of the basin area. Both banded and granite types are well developed trending NNE-SSW direction xenoliths of biotite granulite of small dimensions are common. The composition of these rocks are quartzo feldspathic, light grey in colour, medium to coarse grained and also massive. Occasionally, the rocks are porphyrithic with grey plagioclase felspar as porphyroblast generally arranged parallel to the foliatin. Ptygmatic folding is common.5

sets of jointing are developed in these rocks. Epidote occurs as this vein around Kaveripattinam and Harandahalli.

Hornblends gneisses, are also seen in certain parts of the area with more garnet along the contact of charnockites conforming with regional foliation. The rocks are grayish white, medium to coarse grained with lesser amount of biotite.

Carbonatites:

It is a compact, massive and finegrained rock with calcitic and dolomitic in composition. Pyrochlore, magnetite, apatite occur as main accessories. The major occurrences are found in Koratti, Kanjanur, Sevathur near Tirupatthur and are associated with pyroxinite and sysnites. The weathered rock is dark brown or black in colour, porous, ribbed and slaggy. The band at Koratti forms a belt and lies in ENE-WSW to EW direction with southern dip.

Syenites:

Syenites are found associated with carbonatites in Koratti and also occur as plug in Elagiri hills. It is a quartz free felsic rock with alkali feldspar and medium grained and light coloured. In Koratti and Elagiri, these are associated with folding activity and occur in the central portion of the fold. The syenite rocks contain numerous inclusions or xenoliths of amphibole variety.

Granites:

Pink to grey granites grading into pegmatites occur in several parts of the basin. The prominent occurrences are noticed around Hosur and Krihsnagiri and the extension of Gingee granite in Thirukoilur Taluk. The granites are light coloured, massive, medium to coarse grained and are of biotite or hornblende variety. In places the granites develop banding to the grade of granite gneiss.

Dolerite:

Dykes of doleritic nature occurs throughout the crystalline area of the basin as narrow ridges on the hills, traversing charnockites, gneisses and also granites and are concentrated around Krishnagiri, Hosur, Thirukoilur and Sathanur. The dykes occur NNW-SSE and EW directions as linear bands. Dolerite dykes are dark in colour, fine grained, massive and show spheroidal weathering.

Pegmatites and Quarz Veins:

Veins of pegmatites and quartz are extensively seen in gneisses charnockites and also in granites with E.W. orientation in parts of Dharmapuri District and are controlled by the prominent joint patterns developed in the hard rock. The length and width is greatly variable.

Sedimentary Formations:

In the lower Pennaiyar Basin, Sedimentary formations are exposed and are belonging to upper cretaceous, tertiary (Cuddalore Sandstone) and quarternary age. The formations include fossiliferous limestone, calcareous sandstone, shell limestone, clay, marl alluvium laterite and soils.

Upper Cretaceous Formations:

Upper cretaceous formations are exposed near Sirumangalam in a nallah cutting and lie unconformably over the archean. The arenaceous limestone is yellowish brown and consists of broken fragments of coarals and lamellibranch shells in calcareous matrix and grade into shell limestone calcareous sandstone intercalated with clay and marl is brownish to yellowish in colour and unfossiliferous. The lithological and fossil assemblages indicate that these beds are equivalent to Ariyalur stage.

Teritary Formatins (Cuddalore Sandstone)

Cuddalore sandstone and associated clay overlie the cretaceous formations, south of Patti, and are also exposed south of Pennaiyar near Panrutti as conspicuous low elevated uplands. The cuddalore sandstone is gritty consisting of quartz cemented in clay matrix and is interbedded with thin, lenticular bodies of white clay. The sandstone is characterized by ferrugeneous materials and is of yellowish red, pink, and purple in colours. The formations of sandstone and clay alternate and dip towards east with low angle creating a artesian conditions in the tertiary.

Alluvium:

The river Pennaiyar and Gadilam have built up extensive alluvium consisting of admixtures of sand, clay and silt in the delta portions in and around Cuddalore. The extent of alluvium and depth varies greatly as there are number of exposures in the river almost its eastern part of basin area. The thickness varies from 10 to 15 m below ground level. Several abandoned channel and buried courses are also indicated in the coastal portions that consist of medium to coarse grained sand and silt with appreciable porosity and permeability.

2.5 Geological Structure

Physiographic bridge between the Karnataka, part of the Deccan Plateau and upland plains of Tamil Nadu which incorporates a part of the district between north of Pennayanam and south of Denkanikottai are occupied by the hill ranges of Deccan Plateau trending North North East (NNE) - South South West (SSW). It has a general elevation of 823m to 914m with occasional inselbergs of 1026m, 1219, 1042m and 1034m height. Deccan Plateau is bounded on the southeast by the Eastern Ghats trending North East (NE) – South West (SW) with peaks attaining height of 1395m 1306m. These are mostly structural hills drained by Chinnar and Pennaiyar river courses. Eastern Ghats are followed in the east by pediplained upland. The upland is an extensive plain studded with a few inselbergs and regions of isolated block mountains such as Shevroy, the Chtteri and the Kalrayan hills. The upland of Dharmapuri has a general elevation of 518 m in the west and 457m in the east and forms a major gap trending NE-SW.

Western part of Tiruvannamalai district in the basin is a hilly terrain (structural hills & denudation hills & plateaus) with an undulating rugged topography. Rocks of the hornblende-biotite gneiss and epidote-hornblende gneiss occur as concordant bands within the charnockite country. These bands are involved in sympathetic folding within the charnockite rocks. Landslide prone areas are demarcated near Polur of Tiruvannamalai district.

A greater part of the Villupuram district in the basin is covered by rocks belonging to Archaean age comprising the charnockite group and the migmatite complex. The terrain displays much-structural complexity due to the multiple deformations it has suffered. A number of prominent shear zones have been recognized viz., N-S shear zone, east of Gingee town and NNW-SSW near the eastern foot of the Kalayan hill SW of Kallakkurichchi and is the most striking. The rock of Mio-Pliocene age i.e. Cuddalore sandstone and laterite were from low plateaus in the northeastern part of the district. The south-central part is marked by depositional regime of Pennaiyar and Gadilam rivers. These are manifested in the form of flood plains occurring at the lowest elevation in the areas. The coastal plain represents Cretaceous- Eocene formation. Some of the Palaeo shorelines are recognizable inland suggesting periods of marine transgression and regression. The Quaternary sediments are of the two types that are deposited under fluvial environment and Marine environment. They comprise flood plain / back swamp deposit(lagoon) tidal flat, mudflat deposits (black clays and muds.) The ongoing geodynamic process is generally progradation along the coast which is modified at several places by erosion and deposition by aeolian and fluvial sediments.

2.6 Geomorphology

Geomorphology and its scope as a basic and applied science in general and as a tool for searching groundwater resources in different Geomorphological land forms in sedimentary and basement rocks plays an important role in the water resources study. The basic principle in understanding geomorphology being that the surface forms of the earth are a result of a set of processing taking place at the boundary of lithosphere, atmosphere and biosphere. The genetic classes to which various land forms can be grouped are described. The study related to land forms and basement rocks the formation of pediment-inselberg topography in these rocks and the need to have a Geomorphological approach in addition to structural mapping (structure & lineament) will help in identifying the deep groundwater zones.

Geomorphological studies form one of the most important aspects in the evaluation of water resources both surface and groundwater. In this Pennaiyar basin study more attention is focused on the evaluation of groundwater potential qualitatively taking into account the geomorphological landforms. These geomorphological landforms are synthesized with related components like soil, lithology, structure and lineament and other hydrological information available for the Pennaiyar basin area. Remote sensing and GIS techniques are employed in the Pennaiyar basin area, formed in the semi arid region. Remote sensing techniques adopted to delineate the geomorphological land forms and the processes that have developed by marine, fluvial, fluvio-marine and denudational action which developed, modified and shaped the rugged terrain to the coastal plain area in the Pennaiyar basin are elucidated and discussed to bring out the groundwater potential map to a vivid qualitative appraisal. The Pennaiyar basin area is mostly covered by structural hills and pediplain areas, in the west and rest of the area is covered by the alluvial plain in the east. Groundwater occurrence and potential zones have been identified by delineating the geomorphic units. The study of geomorphology exercises a significant control over the groundwater region, relief, slope and depth of weathering, thickness of deposition, nature of the deposited materials and the assemblage of different landforms.

IRS-1D satellite data –LISS III false colour composite have been used to demarcate the different geomorphic units. These different geomorphic units given in

Table 2.8 are giving vital information about the groundwater occurrence in the heterogenic hard rock and sedimentary regions The description of landforms and groundwater occurrence are furnished in the **Table 2.9**. Further the groundwater potential thematic map (PLATE PEN-14) is prepared taking into consideration the hydro geological, hydro geomorphological and structural lineament data information derived from Satellite images and during the field check study. Lineament intersections are potential groundwater zones. These lineament zones are influencing geomorphic units like buried pediment deep, uplands, old river courses and valley fills to enrich more groundwater occurrence and distribution.

2.7 Land use

Land use Remote sensing technology finds extensive applications in the fields of natural resources including water resources, land use, agriculture management etc. The repetitive coverage of the satellite over the same region on different dates offers an excellent opportunity to monitor the changes that have occurred over a period of time. Remote sensing helps in analyzing the land use patterns of the past and in comparing the changes with present trends. Land use and land cover study is important for planning, development and land management activities of agricultural sector. The high-resolution satellite data of IRS 1D and P6 provide a new dimension to the mapping of land use or land cover details on various levels. The Pan and LISS III type sensors provide very good resolution facility to classify data with better details.

Landuse map of Pennaiyar river basin was prepared using the recent IRS P6 LISS III February 2015 on 1: 50,000 scale by visual interpretation and also by digital image processing and classification methods. [Vide Landuse Map PLATE PEN-15]

The information derived from the existing landuse and spatial distribution is the basis for this landuse classification. The present land use pattern has been assessed in relation to the groundwater development which is taking place during the non monsoon period in this basin.

The detailed land use classification of Pennaiyar river basin is given **Table 2.**

Table 2.3 Land use Classification – Pennaiyar River Basin

Landuse Category		2015	
Ist Level	**IInd Level**	**Area in sqkm**	**Percentage %**
Crop Land	Paddy and Sugarcane	3213.94	28.25
	Groundnut, Cholam, Etc.	1264.28	11.11
	Cashew and Jack fruit plantation	199.33	1.75
		4677.55	**41.12**
Waste Land	Land affected by Alkalinity/ Salinity	45.58	0.40
	Barren Land	1360.45	11.95
	Barren Land- Out Crop	126.93	1.12
	Barren Land –Gullies	7.41	0.07
	Barren Land Covered by Shrub	22.78	0.20
	Out Crop	14.47	0.13
	Rocky Out Crop	1601.54	14.08
		3179.16	**27.95**
Forest Land	Reserve Forest	125.56	1.10
	Structural Hill/Medium Dense Forest	2882.64	25.34
		3008.20	**26.44**
Water Bodies	**Tank/ Reservoir River**	**408.32**	**3.59**
Settlement		**102.32**	**0.90**
TOTAL		**11,375.55**	**100**

2.7.1 Classification and Description

2.7.1.1 Built-up land

This category is composed of areas under intensive use with much of the land covered by settlements, villages and towns.

2.7.1.2 Agricultural land

Agricultural lands are primarily lands put into use for production of food and fiber. Most of the lands falling under this category are found in Pennaiyar river valley, along the drainages and streams. Most of the area is falling under river, channel and tank command. The main Pennaiyar river course is supporting cropland, which is mainly sugarcane and paddy.

It is found from Krishnagiri Reservoir down on either side of river upto Nedungal. The Sathanur Dam canal supply the water for irrigation in the downstream upto Tirukoilur. From Tirukoilur, the irrigated area is widening gradually up to Villupuram. After Villupuram the whole flood plain area is cultivated intensively with sugarcane and paddy upto the Cuddalore coast.

The Groundnut is the predominant dry crop cultivated in Pennaiyar basin around Villupuram and further east upto the Cuddalore coast. Around the Cuddalore high ground area cashew plantation and Jackfruit trees are cultivated in large area.

Vegetables are cultivated in Panruti and Villupuram taluks in selected areas. Orchards are grown in the major portion of dry crop area in parts of Dharmapuri, Krishnagiri and Hosur taluks as they are fetching cash immediately at the market.

2.7.1.3 Forest Land

Forest land category includes dense, medium dense, deciduous, semi deciduous forest areas which are covering the Kalrayan Hills (Part), Chitteri Hills (Part) and Jawadi Hills(Part). Medium dense and dense forests, shrubs and scrubs are seen in the hills and hillocks covering the rest of the pediplain areas in the Pennaiyar river basin.

2.7.1.4 Water Bodies

The area covered by the water bodies such as rivers/tanks/reservoirs is about 408.32sq.km, representing 3.59% of the total area. The details of rivers/tanks/reservoirs are presented in Chapter 5.

2.7.2 Wasteland

Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently under utilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. Wastelands can result from inherent/ imposed disabilities such as by location, environment, chemical and physical properties of the soil or financial or management constraints”.

Now the wasteland in the Pennaiyar river basin is studied using the IRS imagery following the Technical Task force group, National Remote Sensing Agency, Department of Space, Hyderabad.

Barren Rocky/ Rocky out crops /Stony waste

In Pennaiyar river basin it is an area of rock exposures of varying lithology often barren and devoid of soil cover and vegetation. Most of the gently slopping elevated upper slopes on either side of water divides of minor basins are sometimes covered by scrub/shrub. Especially the barren rocky area is located in and around Thurinjalar subbasin. Barren rocky land is partially devoid of vegetation has also been included in this category. The rocky outcrop covers an area of 1601.54sq.km in the basin. This is almost 14.08% of the total basin area.

Land affected by Salinity/alkalinity (Coastal or inland)

Salt affected land is generally characterized as land that has adverse effects on the growth of most plants due to the action or presence of excessive soluable salts (saline) or high exchangeable sodium. A linear stretch of this salinity zone is occupying the Uppanar River Uppodai southeast of cuddalore old town.

Alkali land has an Exchangeable Sodium Percentage (ESP) of about 15, which is generally considered as the limit between normal and alkali soils. The predominant salts are carbonates and bicarbonates of sodium.

Coastal saline soils may be with or without ingress or inundation by seawater. This may be due to coastal alluvium rich in sodium and also calcium. The area of coverage is 45.58sq.km and 0.40% of the total basin area.

Sands-Coastal

Sandy areas are barren and these areas have accumulation of beach ridges and sand dunes. These are developed along the coast and shallow depressions area in between ridges from the shallow water table. Paddy is cultivated in the shallow water table linear zone.

Wasteland Mapping

Wasteland mapping was done by interpreting the IRS-1D image LISS III FCC data for the entire Pennaiyar river basin [vide Wasteland Map PLATE PEN-16]. This wasteland map was prepared by using visual interpretation techniques. A considerable portion of the wasteland in this basin is falling under barren land area, which is blanketing the hard rock terrain (Area 8196.39sqkm, covering 72.05of total area **11375.55**sqkm).

The wasteland classification analysis using remotely sensed data shows the total wasteland as **3179.16**sqkm.

Total area of the basin **11375.55**sqkm

Wasteland category **3179.16**sqkm

Other than wasteland category 8196.39sqkm

(Forest land **3008.20**sqkm,Land under cultivation **4677.55**sqkm)

Table 2.4 Wasteland – Classification

Sl. No.	Wasteland Category	Area in sqkm	Percentage %
1.	Land affected by Alkalinity/ Salinity	45.58	0.40
2.	Barren Land	1360.45	11.95
3.	Barren Land- Out Crop	126.93	1.12
4.	Barren Land –Gullies	7.41	0.07
5.	Barren Land Covered by Shrub	22.78	0.20
6.	Out Crop	14.47	0.13
7.	Rocky Out Crop	1601.54	14.08
8.	Other than wasteland category	8196.39	72.05
	Total	**11375.55**	**100**

Barren Land –Gullies:

Barren gullies are deeply developed in the western end of Cuddalore sand stone near Malayampattu, Iruppu and Naduvirappattu village area. It covers an area of 7.41sq.km and the percentage is 0.07% .

Barren land is distributed as linear patches from Hosur to Singarapettai in the east and from Tirupattur to Pappireddippatti in the south. It is covering vast area in these parts. Further east it occurs as small patches in the southern part i.e, Thirukoilur, Elavanur Nuralai, Uludurpettai and Tirupalapandal areas. Totally it occurs over an area of 1360.45sq.km and the percentage is 11.96%.

Barren land covered by outcrop is seen in the area around Nukkuambadi, Kolakkaravadi, Mugaiyur and Appanandal villages, over an area of 126.93sq.km and percentage is 1.12%.

Wasteland covered by outcrop is noted around Kariyandal village and covers an area of 14.47 sq.km and the percentage is 0.13 %.

Barren land covered by shrubs is seen around Aladi, Palakkolai and Madiyanur villages. Total area is 22.78sq.km and the percentage is 0.20%.

The pie chart showing the distribution wasteland types is shown in Fig B.

Wasteland and Lineament study:

The wasteland and lineament themes are merged and integrated with the field hydrogeological data to prepare a wasteland action plan map (PLATE PEN-17).

NE-SW, NW-SE and NNW-SSE trending lineaments are the major lineaments mapped in the Pennaiyar river basin. These lineaments are traversing the barren land areas in between the Singarapatti –Hosur and Tirupattur – Pappireddippatti. Some of the selected lineament and lineament intersection points are shown in map (PLATE PEN-17) for further development of wastelands in Pennaiyar river basin. Most of the barren land is falling in hornblende gneisses and granitoid gneiss.

2.8 Geophysics

Introduction

Geophysics is a subject for the study of subsurface lithology of earth using physics principles. Geophysical survey takes main roll to study the sub surface lithology. By conducting geophysical survey we can determine aquifer for groundwater resources. Some of the important geophysical methods are the electrical, seismic, gravity and magnetic method. Of these electrical resistivity method have been widely used for the practical application in detecting the groundwater.

Electrical Resistivity Methods

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 ▲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's of geological formations are depends on the porosity, density and quality of water in the aquifer. The resistivity's 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. Massive rocks with little interconnected pore spaces have high resistivity. Saturated clayey sediments have low resistivity, Clayey sand and gravel deposits that are saturated with groundwater of high ionic strength have very low resistivity (Gilkeson et.al 1983). The electrical resistivity study can also be tried to

a) locate high or low resistivity subsurface materials
b) locate fault zones which serve as channels for groundwater movement
c) locate areas of weathered rocks and thickness of such rocks
d) estimate the depth of occurrence of fresh rocks
e) demarcate fresh and salt water contact, and
f) Determine the sequence of high and low resistivity zones with depth and thereby determine the different zones saturated with ground water.

Therefore, it is clear, that a geological formation would give a lower 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 area favourable for prospecting. Further as this study can indicate the depth, thickness and nature of aquifer, the type of drill that could be used, also can be determined and the study could be done with instruments like Terrameter, Aquameter, D.C. Resistivity meter etc. One of the most commonly used electrode arrangement in the field is Wenner arrangement, the other being Schlumberger method.

Identification of aquifer, especially the deep aquifer, present in hard rock area is rather a challenging work for hydro geological specialists. This is basically due to the high level of inhomogenity present in the hard rock terrain as well as sedimentary rock.In sedimentary rocks the area occupied by thick layer of clay at the top causes high noise to signal ratio, while exploring the possible aquifer depth through geophysical techniques. Interpreting the different lithological units, by applying an integrated approach of geophysical survey and correlating hydro geological data already collected, has given acceptable results with adequate accuracy. Borehole drilling and subsequent litholog data are of immense use in delineating the thickness of aquifer, particularly in a regional scale. The difficulty in the identification of deep water bearing fractured horizons below 80 – 100 m is attributed to the heterogeneous nature of fracture present in hard rock. Similarly in sedimentary terrain, the presence of thick clay layer at top / at shallow depth causing skin effect that makes difficult to explore the presence of aquifer at depths. Thus, the

Vertical Electrical Sounding (VES) data interpretation as well as the determination of subsurface hydrogeological conditions in the deeper horizon still remain uncertain especially in the over exploited and poor quality groundwater area.

Methodology

Pennaiyar river basin, approximately **11,375.55**sqkm in extent is comparatively a large river basin. The details of aquifer viz. its depth, thickness and areal extent are determined as sub basin wise for entire basin area based on the hydrogeological information available. it was decided to analyse high-density electrical resistivity data (where soundings are close to each other) in order to understand the relationship between geoelectrical parameters and hydrogeological characteristics of the formations. In general, lithological and hydrological data from some existing boreholes are necessary to calibrate the geophysical results. Four hundred and thirtyone Vertical Electrical Soundings (VES) were analysed**.** Also borehole lithology data of two hundred and twenty four were considered as benchmarks. Both VES and borehole lithology data forms the database in the simulation of aquifer geometry of this basin. The VES had been conducted up to a spread of 100 metres 'a' separation (spacing between any two electrodes) in Wenner electrode configuration in general, however some VES were conducted with an electrode separation of 'a' = 70 to 80 m only. Geo electrical parameters such as formation resistivity, total longitudinal conductance and depth to bedrock are useful guides in evaluating the groundwater potential of a site. These parameters are derived from the apparent resistivity data by theoretical interpretation of the sounding curves with the help of computer codes for reducing geoelectrical sounding curves into values of thickness and resistivity of individual layers. A majority of the VES curves indicate a four-layered sub-surface in the area, corresponding to the topsoil, weathered rock, fractured rock and massive rock. The information thus obtained along with that of the borehole lithology were used as attributes in the GIS environment for the creation of thematic maps depicted as surface plots/contours showing the spatial and/or vertical distribution pattern of topsoil, weathered rock, fractured rock and fresh rock of the basin. There exist close correspondence between the pattern of drainage and the aquifer dimension. Along the rivers and parts of the foot hills region, deep weathering and/or fracturing is noticed. Theme map of topsoil, weathered rock and fractured rock are integrated digitally in order to obtain the places where thicknesses of all the three are more, thus suitable for artificial recharge (RWH). The results generated from this research will be of great help in administration of this basin though various numerical solutions and GIS analysis pertaining to this basin.

Around 431 **Vertical Electrical Soundings (VES)** data have been collected in the Pennaiyar basin area. These VES had been conducted up to a spread of 60 to 100 metres 'a' separation (spacing between any two electrodes) in wenner electrode configuration. The details of aquifer viz. its depth and thickness are determined for entire basin area based on the hydrogeological information available. In general, lithological and hydrological data from existing 60 boreholes are utilized in this analysis. However geophysical data such as electrical resistivity (Vertical Electrical Sounding - VES) are appropriately used in order to have better interpolation. The database used in the simulation of aquifer geometry of this basin consists of 224 borehole lithology .The 431 verified VES data have been analyzed with the help of **"Resist 87"** computer software in order to understand the details of aquifer.

Three or four layers have been identified based on the difference in resistivity values/pattern of curve for each layer and also due to the lithology. The VES data have been analyzed with Arc map software.

Based on these, the following maps are generated with interpolation techniques.

1) Depth of Unconsolidation Map (Plate No PEN-19)
2) Depth to Weathered rock (Plate No PEN-20) and
3) Depth to bed rock (Plate No PEN-21) representing the depth to bottom of aquifer in metre below ground level has been drawn.

Depth of unconsolidation map is used to analyse the foundation structures in construction industry. Depth of weathered rock map is showing the actual dynamic ground water column and water level below this indicates the over extraction status of the area. Hence in general the depth to bedrock map is used in assessing groundwater quantum.

After analyzing the data where they were correlated and integrated with GIS, and the findings are reported for each Sub basin.

i) Chinnar west sub basin

Chinnar West river, a tributary of Pennaiyar originates in Karnataka state and enters into Tamilnadu near Begepalli and joins with Pennaiyar at its right flank near Peddakulla village. Chinnar west sub basin is having a drainage area of about 125.315sq.km falling in Shoolagiri , Hosur, and Kelamanagalam blocks. Achaean Crystalline formations such as cordierite bearing Garnetiferous Gneisses, Calc Gneisses, Quartzite and Charnokites are found in most of the sub basin area. Lithology data of eight bore wells in different locations reveals the depth to bed rock ranges from 15 meter to 40 meters below ground level.

ii) Chinnar East sub basin.

Chinnar East river, a tributary of Pennaiyar originates near Athimugam and joins with Pennaiyar at its left flank near Bikkanapalle village. Chinnar east sub basin is having a drainage area of about 307.95 sq.km falling in Shoolagiri, Hosur and Thally blocks. Most of the area comprises of Archaean metamorphic varieties like Calc gneisses, Charnokite, Quartzite, Pink granites and Garnetiferous gneisses. The valley fill sediments and alluvial formations encounter the remaining area. Lithology data of ten bore wells in different locations reveals the depth to bed rock ranges from 20 meter to 45 meters below ground level.

iii) **Markandanadhi sub basin**

Markandanadhi river, a tributary of Pennaiyar originates from Veppanapalli and flows through Shoolagiri and joins with Pennaiyar at its right flank near Ragimakanapalli village. The sub basin is having a drainage area of about 368.209sq km, falling in Shoolagiri, Krishnagiri & Veppanapalli block. The depth to bed rock ranges from 20 meter to 60meters below ground level..

iv) Kambainallur sub basin

Poollapatti river, a tributary of Pennaiyar originates near Erudukuttapatti and joins with Pennaiyar at its left flank near Kuduturaipatti. Kambainallur sub basin is having a drainage area of about 919.278sq.km falling in Morappur, Pennagaram, Dharmapuri, Nallampalli, Karimangalam and Palacode blocks. The entire sub basin is made up of crystalline rock of archaen age consisting of Charnokites, Garnetiferous Gneiss, Biotite Gneiss, Calc Gneiss, Quartzites and Pegmatite. Charnokite is the predominant in majorarea. The Depth to bed rock ranges from 15 to 30 meters below ground level.

v) Pambar sub basin

Pambar river, a tributary of Pennaiyar originates near Pungulam and joins with Pennaiyar at its left flank near Karukkanpatti. Pambar sub basin is having a drainage area of about 1757.42sq km falling in Bargur, Kaveripattinam and Thirupathur blocks. The entire sub basin is comprises of Archaeon Charnokite and Garneteferous Gneiss. The depth to bedrock range of this sub basin is 15 meter to 30 meters below ground level

vi)Vaniyar sub basin

Vaniyar river, a tributary of Pennaiyar originates from Pottukadu and joins with Pennaiyar at kallapuram. This sub basin is having a drainage area of about 998.385sqkm falling in Karuru, Morappur, Pappireddypatti, Dharmapuri, Uthangarai,Yercaud and Valapady blocks. Geologically rocks like Garentiferous Gneiss, Charnokites and Quartzite are well exposed in this area. The depth to bed rock range of this sub basin is 20 meters to 40 meters.

vii)Matturar sub basin

Matturar sub basin is having a drainage area of about 58.50 sq km falling in Harur, Uthangarai, Chengam and Alangayam blocks. Granitic Gneiss, Quartz and Charnokite are encountered in this sub basin. Alluvial sand of considerable thickness is present in this sub basin. The depth to bed rock range of this sub basin is 20 -40 meters.

Viii)Kottapatti kallar

Kallar river, a tributary of Pennaiyar originates near Mullikadu and joins with Kovilar at Tanippady. Kovilar originates at Tolikattimalai and joins at the right side of Pennaiyar. This sub basin is having a drainage area of about 410.229sq.km falling in Kalrayanhills, Thandrampattu ,Chengam, Attur and Papireddipatti blocks. Charnokite is the major formation encountered in this sub basin and Granitic Gneiss is the other predominant formation. The depth to bed rock range of this sub basin is 20 -40 meters.

ix)Valayar odai sub basin

Valayar Odai river, a tributary of Pennaiyar originates near Anandavadi reserve forest and joins in Sathanur reservoir. This sub basin is having a drainage area of about 85.39sq.km falling in Chengam block. This sub basin comprises of Granitic Gneiss and Alluvial formations. The depth to bed rock range of this sub basin is from 20 meter to 35 meter.

x)Ramakkal Odai sub basin

Ramakkal odai river, a tributary of Pennaiyar originates near Pennaiyar reserve forest and joins in Sathanur reservoir. This sub basin is having a drainage area of about 14.41sq.km. The geological formation comprises of sand stones, grey sandy shales and subsequent to recent quarternary sediments in the form of alluvium and aeolian sands are encountered in this sub basin. The depth to bed rock ranges of this sub basin is 10m to 20 meter.

xi) Pambanar and Varattar sub basin

Varattar river, a tributary of Pennaiyar originates near Nattampalli and joins with Pambanar and Pambanar joining with Pennaiyar at Puthurchekkadi. This sub basin is having a drainage area of about 292.09sq.km falling in Haruru, Thandrampattu and Kalrayanhills blocks. Charnokite is the major formation encountered in this sub basin and

Granitic Gneiss is the other predominant geological formation. The depth to bed rock range of this sub basin is from 15 meters to 35 meters basin. Alluvial sand of considerable thickness is present in this sub basin. The depth to bed rock range of this sub basin is 20 - 40 meter below ground level

xii)Aliyar subbasin

Aliyar river, a tributary of Pennaiyar originates from Uchchimalai reserve forest and joins with Pennaiyar at its right flank near Karampallipattu. This sub basin is having a drainage area of about 211.07sq.km falling in Chengam, Pudupalayam and Thandarampattu blocks. The entire sub basin is made up of crystalline rock of Archaen age consisting of Charnokites, Garnetiferous Gneiss, Biotite, Calc Gneiss and Quartzites. The depth to bed rock range of this sub basin is from 10 to 60 meters below ground level.

xiii)Musukundanadhi subbasin

Musukundanadhi river, a tributary of Pennaiyar originates near Erapatti and joins with Pennaiyar at its left flank near Sripadanallur. This sub basin is having a drainage area of about 179.25sq.km falling in Thandarampattu , Kalrayan hills ,Rishivandiyam and Sankarapuram blocks.. The area is comprises of Archaean metamorphic varieties like Calc Gneisses, Charnokite, Quartzite, Pink Granites and Garnetiferous Gneisses. The depth to bed rock range of this sub basin is from 15 to 60 meters below ground level.

xiv)Thurinjalar subbasin

Thurinjalar river, a tributary of Pennaiyar river orginates near from Kavuttimalai reserve forest and joins with Pennaiyar at its left flank near Manampunai. Drainage area of this sub basin is 853.623sqkm falling in Chengam Pudupalayam, Kilpennathur, Thurinjalapuram, Thiuvannamali and Thandrampattu blocks. The sub basin is made up of Charnokite, Garneteferous gneiss rock types. The depth to bed rock range of this sub basin is from 10 meter to 30 meter below ground level.

xv)Gadilam sub basin

Gadilam river originates near Melpalangur reserve forest and passes through Thirunavalur, Panruti,and Ulundurpet area of the southern part of Pennaiyar river basin and confluence with Bay of Bengal in Cuddalore town. The sub basin is having a drainage area of about 1562.903sqkm falling in Kurinjipadi, Annagramam,Kammpuram, Rishivandhiyam, Mugaiyur and Cuddalore blocks. Geologically the crystalline Archeaon rocks of age like Garentiferous gneiss, Charnokites are encounted. The depth to bed rock range of this sub basin is 30 to 100 meters

xvi)Upto Krishnagiri Reservoir subbasin

This sub basin is having a drainage area of about 772.63sqkm falling in Karimangalam, Shoolagiri, Hosur, Kaveripatinam and Krishnagiri blocks. Geologically the crystalline rocks of Archeaon age, Charnokite formation encountered in this sub basin and Granitic gneiss is also present in this basin. The depth to bed rock range of this sub basin is from 20 meters to 50 meter.

xvii) Krishnagiri to Pambar subbasin

This sub basin is having a drainage area of about 894.52sqkm falling in Kaveripattinam, Krishnagiri, Mathur, Morappur and Uthangarai blocks. The sub basin is made up of Archaean Charnokite and Garneteferous Gneiss type of rocks. The depth to bed rock range of this sub basin is from 20 meters to 60 meters.

xviii)Pambar to Tirukovilur subbasin

This sub basin is having a drainage area of about 1002.393sqkm falling in Harur, Uthangarai, Chengam, Tiruvannamalai, Thandarampattu, Alangayam, Kalrayanhills, Risivandiyam, Sankarapuram, Mugaiyur and Thirukoilur blocks. The geological formation of this sub basin comprises of rocks like garentiferous gneiss, Charnokites and quartzite. The depth to bed rock range of this sub basin is from 20 meters 40 m

xix) Lower Pennaiyar subbasin

This sub basin is having a drainage area of about 561.963sqkm falling in Kandamangalam, Kanai, Koliyanur, Mugaiyur, Thirukoilur, Thiruvennainallur, Cuddallore, Annagramam blocks. The crystalline rocks of archaean and Charnokite formation are encountered in this sub basin. The depth to bed rock range of this sub basin is from 30 meters to100 meters.

2.9 Soil and its characteristics

Soil is one of the natural resources, which has the most direct impact on agricultural development. In an agrarian country like India, it becomes necessary to take steps for its proper conservation and management. Soil survey provides nature of soils, their extent and physico chemical characteristics etc.

The soils of the Pennaiyar Basin have been shown in Plate PEN-22. The predominant soil types found in this river basin is Inceptisols, Alfisols, Entisols and Vertisols. Due to different stages 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.

Entisols:

These soil shows a little or no evidence of development of pedogenic(diagnostic) horizons. Horizons have not been formed in these soils due to shortness of time for pedogenesis. Surface material is removed from the site as fast as or faster than most diagnostic horizons can form. They are found distributed on steep, actively eroding slopes and on flood plains which receive new deposits of alluvium. Erosion is active in these soils. Resistant nature of the parent material like quartzite, bed rock etc prolongs the period of undistinguished horizonation. Larger part of the Dharmapuri and Krishnagiri district is covered by Entisols and a little extent is occurring in Villupuram and Vellore districts.

The following are the four sub groups identified under Entisols.

1) Typic Ustorthentic:

a) Typic Ustorthents:

These are reddish brown to red, light to medium textured and mostly non calcarious soils. They are well drained externally and the permeability is moderate to rapid. Soil erosion is the major concern in these soils. Dry cultivation with millets, pulses and groundnut is quite common.

b) Lithic Ustorthents:

These soils resemble Typic Ustorthents but their depth is within 50 cm followed by bedrock.

c) Typic Ustifluvents:

These soils are dark brown to dark grey soils of fluvial (alluvial) origin with rapid permeability and are well drained. Stratification of layers on account of fluvial deposition with irregular decrease in organic matter with depth is common. These are confined to river systems. Intensive agriculture is being followed on these soils both as irrigated and rain fed.

d) Typic Ustipsamments:

These soils are very deep, freely drained sands and have low water holding capacity.

2) Inceptisols:

This comprises of immature soils having profile features more weakly expressed. All the pedogenic processes are active to some extent but none predominates in these soils. They are poorly drained to well drained with moderate to rapid permeability. Most of them are cultivated under irrigated or rainfed conditions.

3) Vertisols:

This order includes dark brownish grey, very deep, calcareous, heavy clayey and self-churning soils that have deep wide cracks. The surface shows a complex microtopography of mounds and depressions. Slickenside feature is common in the sub surface and the mineralogy is dominantly montmorillonitic which is expanding type of clay. They are moderately well drained with slow permiability except in the cracks.

The following two sub groups are identified under Vertisols.

a) Typic Chromusterts:

These have a Chroma, moist of 1.50 or more and colour value, moist less than 3.50 and a value dry less than 5.50 throughout the 30 cm of the pedon i.e surface soils are gray in colour. The cracks remain open more than 150 cumulative days in most years.

b) Udorthentic Chromusterts:

The cracks of these soils remain open from 90 to 150 cumulative days in most years with higher colour values.

4) Alfisols:

This consists of deep to very deep, matured soils with alluvial concentration of clay in the sub horizon. The surface horizon is massive and hard. Cultivation is extensive on these soils. They have moderate to high base saturation. 9 sub groups belonging to this category is described below.

a) Typic Haplustalfs:

This consists of reddish to brownish, deep to very deep, Moderately drained to well drained, and medium to heavy textured, moderately rapid to rapid permeability. Calcareousness in the form of calcic horizon or powdery lime is present, at moderate depth.

c) Udic Haplustalfs:

These soils are similar to Typical Haplustalfs except that they do not have calcic origin.

d) Ultic Haplustalfs:

These resemble typical Haplustalfs except that they have base saturation is less than 75 % in the textural horizon.

e) Vertic Haplustalfs:

These are also like Typical Haplustalfs but are heavy textured and develop cracks.

f) Typical Rhodustalfs:

These are comparatively dark red soils than Typic Halplustalfs and have secondary carbonates at moderate depth.

g) Udic Rhodustalfs:

These are like typical Rhodustalfs but do not have secondary lime in the sub orizon and are non-calcareous.

h) Udic Paleustalfs:

The texterual B horizon has a colour hue of 5 YR or Yellower in some part or has a value moist of 4 or more. They do not have secondary carbonates in the sub surface.

i) Vertic Natrudal

This consists of dark grayish brown, very deep, medium textured, calcareous and imperfectly drained soils. They are alkaline in nature and have sodium accumulation in the diagnestic horizon with Exchangeable Sodium Percentage of 1.50 % .

j) Plinthustalfs:

Soils of this group are reddish, deep to very deep and well drained soils but have plinthite, humus, poor mixture of clay) within 1.25 m of the soil surface.

5.Ultisols:

These soils are very deep to reddish and are distributed mostly in higher elevation and are humus rich but extensively leached soils resulting in low base status(less than 35 %). They are thoroughly weathered, well drained and occur in humid moist areas. The following 3 sub groups of this order are described as under.

a) Typic Haplohumults:

They have 0.90 % more organic carbon in the upper portion of the diagnostic horizon or 12 kg or more organic carbon in the soil per square metre in the sub surface. The moisture control section of these soils is dry for less than 90 days cumulatively.

b) Typic Palehumults

These are freely drained soils, very deep and reddish. The diagnostic horizon has few weatherable minerals.

c) Humic Palcudults:

These soils have a colour value, moist less than 4 in the diagnostic horizon, weatherable minerals are usually absent in these soils.

Soil Classifications maps have been prepared in 1996 by National Bureau of Soil Survey (NBSS) and Land use Planning, Bangalore in co-operation with the Department of Agriculture, Tamil Nadu. The Classification of Soils in Pennaiyar River Basin are given in **Table 2.5**

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 1997) and the corresponding soil classification, the irrigable soils of the Pennaiyar River Basin were identified. The irrigable soils main properties are summarized in **Table 2.6** and their interpretative classifications for land capability for crop production; irrigability and suitability for rice, sugarcane, groundnuts and cotton are given in **Table 2.7**

Based on the soil properties and their classification the Basin soils were grouped for irrigation planning purposes, into 5 major groups denoted Type-I to 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, groundnuts – 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 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, groundnuts – S3 and cotton – mainly S1 and some S3. The soils are irrigable and suitable for field crops relatively tolerant to imperfect drainage such as cotton, sorghum and some fodder crops. 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 soil. 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, groundnuts – mainly S3 and cotton – mainly S2.

Type-III soils are irrigable and suitable to 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 and sodicity problems those soils could be sustainably irrigated if corrective measures to those problems would be taken.
- Type-V soils. Those 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 the Pennaiyar Basin were identified. The soils were classified for crop suitability purposes into four types:

Type 1 : Irrigable, fruits, vegetables and field crop soils

Type 2 : Irrigable crop soils

Type 3 : Irrigable rice soils

Type 4 : Non-Irrigable soils

The soils main properties for this classifications are summarized in **Table 2.4** and the interpretative classifications for land capability for crop production, irrigability and suitability for rice, sugarcane, groundnuts and cotton are given in **Table 2.5** . 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-1, Type-2 and Type-3 and Type-4.

- Type I Soils are coarse and medium texture; well-drained, medium depth and 1-3 % Slope and are suitable for crops like groundnuts, cotton, pulses, millets, maize, sorghum, and vegetables.
- Type II Soils are mostly of medium texture, well to moderately well drained,deep andflat and are suitable to various degree to all kind of crops.
- Type III Soils are mostly of fine texture; some of them are imperfectly drained, deep and flat and are suitable mainly for crops such as rice, sugarcane and some fodder crops.

- Type IV The rest non-irrigable soils

Table 2.5 Classification of Soils in Pennaiyar River Basin

Mapping Unit	Description	**Classification**
2	Moderately deep, well drained, gravelly clay soils on gently slopping footslopes, Moderately eroded associated with; Moderately shallow, well drained, clayey soils.	Clayey skeletal, mixed, Rhodic Paleustalfs. Fine, mixed, Typic Paleustalfs.
3	Moderately shallow, well drained, gravelly clay soils on undulating lands, Moderately eroded; Associated with; Moderately shallow, well drained, clayey soils.	Clayey skeletal, mixed, Rhodic Paleustalfs. Fine, mixed, Rhodic Paleustalfs.
4	Moderately shallow, well drained, gravelly clay soils on gently sloping lands, Moderately eroded; associated with; shallow, well drained; gravelly clayey soils with slight erosion.	Clayey skeletal, mixed, Rhodic Paleustalfs. Fine, mixed, Rhodic Paleustalfs.
5	Moderately shallow, well drained, gravelly clay soils on undulating lands, Moderately eroded; Associated with; Moderately shallow, well drained, clayey soils.	Clayey skeletal, mixed, Rhodic Paleustalfs. Fine, mixed, Rhodic Paleustalfs.
8	Shallow, well drained, gravelly clay soils on gently sloping lands, Moderately eroded; Associated with; Moderately shallow, well drained, gravelly clay soils.	Clayey skeletal, mixed, Rhodic Paleustalfs. Fine, mixed, Rhodic Paleustalfs.
10	Shallow, well drained, gravelly clay soils on undulating lands, Moderately eroded; Associated with; shallow, well drained, gravelly loam soils with severe erosion..	Clayey skeletal, mixed, Rhodic Paleustalfs. Loamy-skeletal, mixed Typic Haplustalfs.
12	Very deep, well drained, clayey soils on gently sloping lands, Moderately eroded.	Fine, mixed, Rhodic Paleustalfs. Fine, mixed, Typic Rhodustalfs.
26	Moderately shallow, well drained, gravelly clay soils on gently sloping lands, Moderately eroded; associated with; Moderately shallow, well drained, gravelly loamy soils.	Clayey skeletal, mixed, Typic Rhodustalfs. Loamy-skeletal, mixed Typic Rhodustalfs.
29	Moderately deep, somewhat excessively drained, gravelly clay soils on Moderately sloping, high hills, severely eroded; associated with; Moderately shallow, somewhat excessively drained; gravelly clay soils.	Clayey skeletal, mixed, Typic Rhodustalfs. Clayey-skeletal, mixed, Typic Ustropepts.
30	Moderately shallow, well drained, gravelly	Clayey skeletal, mixed,

	clay soils on gently sloping lands. Moderately eroded; associated with; Moderately deep, well drained; loamy soils.	Typic Rhodustalfs. Fine loamy, mixed, Typic Ustropepts.
36	Moderately shallow, well drained, clayey soils on gently sloping lands. Moderately eroded; associated with; Moderately shallow, well drained; gravelly clay soils.	Clayey skeletal, mixed, Typic Rhodustalfs. Clayey skeletal, mixed, Typic Rhodustalfs.
37	Moderately shallow, well drained, clayey soils on gently sloping lands. Slightly eroded; associated with; Moderately shallow, well drained; gravelly clay soils.	Fine, mixed, Typic Rhodustalfs. Clayey skeletal, mixed, Typic Rhodustalfs.
41	Deep, well drained, clayey soils on Moderately sloping , high hills and hill ranges, very severely eroded; associated with; very deep well drained clayey soils on Moderately sloping hills with moderate erosion.	Fine, mixed, Typic Rhodustalfs. Fine , mixed, Typic Haplustalfs.
43	Moderately shallow, somewhat excessively drained, clayey soils on undulating lands. Slightly eroded; associated with; shallow, well drained; loamy soils.	Fine, mixed, Typic Rhodustalfs. Fine loamy, mixed, Typic Ustropepts.
46	Moderately shallow, well drained, gravelly loamy soils on gently sloping lands. Moderately eroded; associated with; very deep, well drained; gravelly clay soils.	Loamy skeletal, mixed, Typic Haplustalfs. Clayey skeletal, mixed, Rhodic Paleustalfs.
48	Moderately shallow, somewhat excessively drained, clayey soils on undulating lands. Slightly eroded; associated with; shallow, well drained; loamy soils.	Fine, mixed, Typic Rhodustalfs. Fine loamy, mixed, Typic Ustropepts.
59	Very shallow, well drained, loamy soils on gently sloping summits of high hills, Moderately eroded; associated with; very deep well drained loamy soils.	Loamy, mixed, Typic Ustorthents. Fine loamy, mixed, Typic Haplustalfs.
75	Shallow, somewhat excessively drained, gravelly loam soils on Moderately sloping footslopes. Severly eroded; associated with; Moderately deep, well drained clayey soils on undulating lands.	Loamy –skeletal, mixed, Typic Ustorthents. Fine, mixed, Typic Haplustalfs.
78	Moderately deep, somewhat excessively drained, gravelly loam soils on high hills, Moderately eroded; associated with; rock outcrops.	Loamy –skeletal, mixed, Typic Ustorthents. Rock Outcrops.
79	Deep, well drained clay soils on Moderately sloping, low hills, severly eroded; associated with; Moderately shallow, well drained, gravelly loam soils on undulating low hills,	Clayey –skeletal, mixed, Typic Ustorthents. Loamy-skeletal, mixed, Lithic Ustropepts.
86	Moderately deep, well drained loamy soils of gentle sloping, interhill basins/valleys, Moderately eroded; associated with; Moderately shallow, well drained, clayeys	Fine loamy, mixed, Typic Ustorthents. Fine, mixed, Typic Rhodustalfs.

	soils.	
89	Very deep, well drained calcarious, clayey soils on nearly level low lands, slightly eroded; associated with; deep, well drained, calcarious gravelly clay soils.	Fine, mixed, Typic Ustorthents. Clayey-skeletal, mixed, Typic Ustropepts.
91	Deep, Moderately well drained clayey soils on gently sloping low lands, slightly eroded; associated with; very deep, Moderately well drained, calcarious loamy soils.	Fine, mixed, Typic Ustorthents. Fine -loamy, mixed, Typic Ustropepts.
98	Very deep, well drained clay soils on gently sloping lands, slightly eroded; associated with; very deep, well drained, loamy soils.	Fine, mixed, Typic Ustorthents. Fine loamy, mixed, Typic Haplustalfs.
100	Deep, moderatel well drained clayey soils on nearly level low lands, slightly eroded.	Fine, mixed, Typic Ustorthents. Fine, Fine, mixed, Typic Ustorthents.
104	Shallow, well drained calcarious, clayey soils of geltly sloping valleys, slightly eroded; associated with; Moderately deep, well drained, calcarious, stratified loamy soils.	Clayey –skeletal, mixed, Typic Ustorthents. Fine loamy, mixed, Typic Ustropepts.
112	Very shallow somewhat excessively drained gravelly loamy soils on Moderately steep land.	Loamy –skeletal, mixed, Typic Ustorthents. Fine loamy, mixed, Typic Ustropepts.
114	Shallow, well drained, gravelly loam soils on steep hill slopes, severely eroded; associated with; very shallow, well drained, loamy soils.	Loamy–skeletal, mixed, Typic Ustorthents. Loamy, mixed, Lithic Ustrothents.
118	Deep, Moderately well drained calcarious clayey soils on gently sloping low lands, slightly eroded; associated with; deep, well drained, calcarious gravelly clayey soils.	Fine, mixed, Typic Ustorthents. Fine loamy, mixed, Typic Haplustalfs.
124	Deep, well drained clayey soils on steeply sloping, high hills and hill ranges, severely eroded; associated with; Moderately shallow, well drained, loamy soils.	Fine, mixed, Typic Argiustolls. Fine loamy, mixed, Typic Haplustalfs.
132	Moderately deep, Moderately well drained, calcarious, cracking clay soils on nearly level lands, slightly eroded; associated with; Moderately shallow, well drained, calcarious, clayey soils on gently sloping lands.	Fine, montmorilonitic, Udic Chromusterts. Fine, mixed, Typic Ustropelpts.
133	Rock Outcrops.	Rock Lands.
134	Rock outcrops, associated with, Moderately shallow, well drained, clayey soils on undulating lands, Moderately eroded.	Rock land fine, mixed, Rhodic Paleustalfs.
137	Rock outcrops, associated with shallow, well drained, gravelly loam soils on undulating lands, severely eroded.	Rock land. Loamy-Skeletal Fixed, Typic Ustorthents.
138	Rock outcrops, associated with shallow, well	Rock land.

	drained, loamy soils on Moderately steeply sloping low hills, severely eroded.	Loamy-Skeletal mixed, Typic Ustorthents.
141	Rock outcrops, associated with shallow, well drained, gravelly loamy soils on Moderately sloping lands, Moderately eroded.	Rock land. Loamy-Skeletal mixed, Typic Ustorthents.
144	Rock outcrops, associated with Moderately deep, well drained, loamy soils on gently sloping hills, Moderately eroded.	Rock land. Fine loamy, mixed, Typic Ustorthents.
146	Rock outcrops, associated with shallow somewhat excessively drained, loamy soils on gently sloping hills, Moderately eroded.	Rock land. Fine loamy, mixed, Typic Ustorthents.
147	Rock outcrops, associated with shallow well drained, loamy soils on undulating lands, Moderately eroded.	Rock land. Fine loamy, mixed, Typic Ustorthents.
149	Rock outcrops, associated with Moderately deep, well drained, clayey soils on Moderately sloping hills, severely eroded.	Rock land fine, mixed Typic Ustropepts.
152	Very deep, well drained, clayey soils on gently sloping lands, slightly eroded; associated with; deep, well drained, clayey soils.	Very –fine, kaolinitic, kandic Paleustalfs. Fine-loamy, mixed, Typic Ustifluvents. Fine, mixed, Typic Ustropepts.
153	Moderately deep, well drained, stratified, loamy soils on nearly levels, tank irrigated lowlands, slightly eroded; associated with; deep, well drained, clayey soils.	Fine-loamy, mixed, Typic Ustifluvents. Fine, mixed, Typic Ustropepts.
158	Very deep, well drained, clayey soils on gently sloping lands, Moderately and severly eroded; associated with; Moderately deep, well dained, loamy soils on nearly level lands with slight erosion.	Fine-kaikubutuc, kandic Paleustalfs. Fine-loamy , mixed, kanhaplicaplustalfs.
168	Moderately shallow, well drained, clayey soils on gently sloping lands, severely eroded, associated with; Moderately deep, well drained loamy soil.	Fine, mixed, Rhodic Paleustalfs Coarse loamy, mixed, Typic Ustropepts.
169	Moderately deep, well drained, clayey soils on undulating lands, Moderately eroded, associated with; rock outcrops.	Fine, mixed, Rhodic Paleustalfs Rock outcrops.
174	Moderately deep, well drained, gravelly clay soils on gently sloping lands, Moderately eroded, associated with; Moderately shallow, well drained gravelly loam soils.	Clayey skeletal, mixed, Typic Rhodustalfs. Loamy-skeletal, mixed Typic Ustropepts.
183	Deep, well drained, loamy soils on gently sloping lands, Moderately eroded; associated with; deep, well drained, clayey soils.	Fine-loamy, mixed, Typic Haplustalfs. Fine, mixed, Typic Rhodustals.
186	Deep, well drained, clayey soils on gently sloping lands, Moderately eroded; associated with; rock outcrops.	Fine, mixed, Typic Haplustalfs. Rockoutcrops.
199	Very deep, imperfectly drained, sandy soils	Mixed, Aquic

	on nearly level lands, Moderately eroded, associated with; very deep, excessively drained, sandy soils.	Ustipsamments. Mixed, Typic Ustipsamments.
213	Very deep, Moderately well drained, calcarious, clayey soils on nearly level, tank irrigated lands, slightly eroded, associated with; very deep, Moderately well drained, calcarious, cracking clay soils.	Fine, mixed, Typic Haplustalfs. Rock outcrops.
220	Deep, imperfectly drained, calcarious, clayey soils on nearly level low lands, slightly eroded.	Fine, mixed, Typic Ustropepts.
229	Very deep, Moderately well drained, calcarious,clayey soils on nearly level, tank irrigated lands, slightly eroded, associated with; very deep, Moderately well drained , calcarious, cracking clay soils.	Fine, mixed, Typic Ustropepts. Fine, mixed, Typic Ustropepts.
251	Very deep, well drained, loamy soils on gently sloping lands, Moderately eroded, associated with; deep, well drained, loamy soils.	Fine-loamy, mixed, Typic Ustropepts. Fine, loamy mixed, Typic Ustropepts.
258	Very deep, Moderately well drained, calcarious cracking clay soils on nearly level low lands, slightly eroded, associated with; deep, Moderately well drained, clayey soils.	Fine, montmorillonitic, Vertic Ustropepts. Fine, mixed, Typic Ustropepts.
267	Very deep, imperfectly drained, cracking clay soils of nearly level valleys, Moderately eroded, associated with; very deep, Moderately well drained, calcarious, loamy soils.	Fine, montmorillonitic , Typic Chromusterts. Fine - loamy, mixed, Fluventic Ustropepts.

Table 2.6 Major Properties of Soil

Type	Unit (*)	Drainage	Ground water Depth (m)	Surface texture	Available water (mm/m) (**)	Depth (cm)	Slope (%)
I	30	Well	>5	Cl	50-150	100-150	1-3
	43	Well	>5	Cl	50-150	100-150	
	46	Well	>5	Scl	50-150	100-150	
	59	S.W. Excess	>5	Sl	50-100	50-150	
	78	well	>5	Ls	50-150	100-150	
	86	Well	>5	C	50-150	100-150	
	98	S.W. Excess	>5	Sl	50-100	50-150	
	112	Well	>5	Ls	50-B 150	100-150	
	114	Well	>5	Ls	50-150	100-150	
	153	Well	>5	Ls	50-150	100-150	
	183	Well	>5	C	50-150	100-150	
	199	Well	>5	S	50-150	100-150	
	251	Well	>5	Ls	50-150	100-150	
II	2	Well	>5	C	150-200	100-150	1-3
	3	Well	>5	C	150-200	100-150	
	4	Well	>5	C	150-200	100-150	
	8	Well	>5	C	150-200	100-150	
	10	Well	>5	C	150-200	100-150	
	12	Well	>5	C	150-200	100-150	
	26	Well	>5	C	150-200	100-150	
	29	s.w. Excess	>5	C	150-200	50-150	
	36	Well	>5	C	150-200	100-150	
	37	Well	>5	C	150-200	100-150	
	41	Well	>5	C	150-200	100-150	
	48	s.w. Excess	>5	C	150-200	100-150	
	79	Well	>5	C	150-200	100-150	
	91	Well	>5	C	150-200	100-150	
	100	Well	>5	C	150-200	100-150	
	124	Well	>5	C	150-200	100-150	
	152	Well	>5	C	150-200	100-150	
	158	Well	>5	C	150-200	100-150	
	168	Well	>5	C	150-200	100-150	
	169	Well	>5	C	150-200	100-150	
	174	Well	>5	C	150-200	100-150	
	186	Well	>5	C	150-200	100-150	
	267	Imperfect	2-5	C	>150	100-150	
III	89	Well	2-5	C	<50-150	100->150	1-3
	104	Well	>5	C	<50-150	100-150	
	118	Mod. Well	>5	C	<50-150	>150	
	132	Mod. Well	>5	C	<50-150	>150	
	213	Mod. Well	>5	C	<50-150	>150	
	220	Imperfect.	2-5	C	<50-150	100-150	
	229	Mod. Well	2-5	C	<50-150	>150	
	258	Mod. Well	2-5	C	<50-150	>150	
IV	133	Well	2-5	c l	150-200	>150	

Type	Unit (*)	Drainage	Ground water Depth (m)	Surface texture	Available water (mm/m) (**)	Depth (cm)	Slope (%)
	134	Well	>5	Rocky	150-200	>150	1-3
	137	Well	>5	Rocky	150-200	>150	
	138	Well	>5	Rocky	150-200	>150	
	141	Well	>5	Rocky	150-200	>150	
	144	Well	>5	Rocky	150-200	>150	
	146	S.W.excess	>5	Rocky	150-200	>150	
	147	Well	>5	Rocky	150-200	>150	
	149	Well	>5	Rocky	150-200	>150	

<u>Drainage</u>

Mod. = Moderately
S.w.exc = Somewhat excessive
Impr = Imperfect

<u>Texture</u>

s = sandy
scl = sandy-clay-loam
ls = loamy-sand
sl = sandy-loam
c = clay
cl = clay loam

(*) Soil association according to NBSS Publication No.46 1997
(**) Per 1 m of soil depth if the soil is shallower.

Table 2.7 Classifications for land capability

Type	Unit (*)	Capability	Irrigability	Rice	Groundnuts	Cotton	Sugarcane
I	30	IIIs	3s	NR	S3	S3	NR
	43	IIIs	3s	NR	S2	S3	NR
	46	II s	3s	NR	S2	S3	NR
	59	II s	3s	NR	S3	S3	NR
	78	II s	3s	NR	S2	S3	NR
	86	IIIs	3s	NR	S2	S3	NR
	98	IIIs	3s	NR	S2	S3	NR
	112	IIIs	3s	NR	S2	S3	NR
	114	IIIs	3s	NR	S2	S3	NR
	153	IIIs	3s	NR	S2	S3	NR
	183	IIIs	3s	NR	S2	S3	NR
	251						
	2	II s	2s	S2	S3	S3	NR
II	3	II s	2s	S2	S2-S3	S1	S2
	4	II s	3s	S2	S2-S3	S1	S2
	8	II s	3d	S1-S2	S2-S3	S2	S2
	10	II s	2d	S1-S2	S1-S2	S3	S2
	12	II s	3d	S1-S2	S1-S2	S3	S2
	26	II s- II w	2s	S1-S2	S1-S2	S1-S2	S2
	29	II s- II w	2s	S1-S2	S1-S2	S1-S2	S2
	36	II s- II w	2s	S1-S2	S1-S2	S1-S2	S2
	37	II s- II w	2s	S1-S2	S1-S2	S3	S2
	41	II s- II w	2s	S1-S2	S1-S2	S3	S2
	48	II s- II w	2s	S1-S2	S1-S2	S3	S2

	79	II s- II w	2s	S1-S2	S1-S2	S3	S2
	91	II s- II w	2s	S1-S2	S1-S2	S3	S2
	100	II s	2s	S1-S2	S1-S2	S3	S2
	124	II s	2s	S1-S2	S2-S3	S3	S2
	152	II s	2s	S1-S2	S2-S3	S3	S2
	158	II s	2s	S1-S2	S2-S3	S1-S2	S2
	168	II s	2s	S1-S2	S2-S3	S1-S2	S2
	169	II s	2s	S1-S2	S2-S3	S3	S2
	174	II s	2s	S1-S2	S2-S3	S3	S2
	186						
	267						
III	89	IIIs-IIs	3s-2d	S1	NR	NR	S1-S2
	104	IIIw	2s-2d	S1	NR	NR	S2
	118	IIIw	2d	S1	NR	NR	S1-S2
	132	IIIw	2d	S1	NR	NR	S2
	213	II e	2d	S2	NR	NR	S2-S3
	220	IIIe	2d	S2	NR	NR	S2-S3
	229	II s	2s-2d	S2	NR	NR	S2
	258						
IV	133	IIIw	2d	S3	NR	NR	S2-S3
	134	IIIw	2d	S3	NR	NR	S2-S3
	137	IIIw	2d	S3	NR	NR	S2-S3
	138	IIIw	2d	S3	NR	NR	S2-S3
	141	IIIw	2d	S3	NR	NR	S2-S3
	144	IIIw	2d	S3	NR	NR	S2-S3
	146	IIIw	2d	S3	NR	NR	S2-S3
	147	IIIw	2d	S3	NR	NR	S2-S3
	149						

Table 2.8 – Geomorphology

Sl. No.	Geomorphic Unit	Area in Sq. Km	Percentage %
1.	Estuary	5.90	0.05
2.	Alluvial plain (Flood plain & interfluvials plain)	487.04	4.26
3.	River island	13.54	0.12
4.	Sand dune	12.69	0.11
5.	Old river course	67.05	0.58
6.	Bazada	34.19	0.30
7.	Valley fill	214.63	1.88
8.	Duri crust	47.67	0.42
9.	Upland (Teritary)	295.45	2.58
10.	Gullied and Ravines	62.93	0.55
11.	Pediment	654.53	5.72
12.	Pediment covered by outcrop	3082.53	26.94
13.	Pediment covered by outcrop/RF	43.98	0.38
14.	Shallow buried pediment	684.90	5.99

15.	Shallow buried pediment moderate	1272.53	11.12
16.	Shallow buried pediment deep	637.66	5.57
17.	Deep buried pediment	429.15	3.75
18.	Hill top valleys	181.78	1.59
19.	Low structure hill	249.18	2.18
20.	Structure hill/ RF	16.86	0.15
21.	Structural hill	2473.11	21.62
22.	Settlement	71.83	0.63
23.	Tank/River/Reservoir	426.43	3.73
	Total	**11465.558**	**100.00**

Table: 2.9 Description of Land Forms and Groundwater Occurrence

Geomorphic Units	Characteristics	Hydrogeology	Groundwater Potential
Estuary	It is usually defined as that part of lower river coast	It is affected by the mixing of fresh water and salt water.	**Saline**
Beach ridges	It is adjacent to the coastal area. Parallel to sub parallel ridges developed. Parallel to the coastline. Running several kilometers length.	Comprised of wind blown sand and shell directly rain fed. Good recharge. High infiltration	**Moderate**
Swales	Forms in the coastal zone in between ridges and sand dunes. It is forming a low-lying depression.	Infiltration moderate recharge is good. Shallow water table.	**Good**
Alluvial Plain **(Flood plain & Interfluvials plain)**	Comprised of flat surface of the flood plains and the fluvials carried in between the streams are forming an unconsolidated sediment like, sand silt, gravels sand particles dominates.	In filtration good recharge in very good from flood water discharge by two or three stream comprehending of several old river course show the of river.	**Good to Very good**
River island	Comprised of coarse to fine alluvium. It remain as island in the river course. Having a thick vegetation cover.	Infiltration and recharge is good	**Good**

Sand dune (Active)	Active sand dunes change the forms constantly migrating under influence of prevailing wind such dunes are common and area devoid of vegetative cover. Observed in between rivers.	Infiltration is high. Recharge is mostly from the rainfall and run of water.	**Poor to moderate**
Old river course	Comprised of sand grains of various sizes with clay forming a narrow uniformly widened course. And in between the rivers.	Infiltration is higher in this unit. Recharge is goods and mainly from the rivers.	**Very good**
Bazada	Coalescence of alluvial cones and fans formed at the break of composite slopes at the foothills boundary	More infiltration. Recharge zone is comprised of colluviofluvial materials	**Good**
Geomorphic Units	**Characteristics**	**Hydrogeology**	**Groundwater Potential**
Valley fill	Comprised of cobbles, pebbles and detridal materials of varying grains, sizes, lithology like sarel, silt, kankar and friable clay. Formed in linear depression along the stream /drainage	Infiltration is good recharge is from stream and rivers	Good
Duricrust	Poor drainage facility. Induced evaporation and percolation cause thin salt incrustation. Very fine silty clay	Less Infiltration	**Very Poor**
Upland (Teritary)	Occupying elevated land plain terrain-medium to coarse textured less drainage density. Infiltration and permeability is good. Prone to erosion and deterioration.	Direct recharge from rainfall. Infiltration	**Good Deeper aquifers**
Gullies and Ravines	Formation of perceptible unconsolidated materials removed in gullies. Comprises fine grained alluvium semi consolidated. Dissection of land network developed in gullies. Drainage flowing from upland developed along the river course	Run off zone filled with alluvials at the bottom of gullies and ravines.	**Poor**
Pediment	Rock cut surface with thin veneer of soil cover. Under going deterioration and erosional processes.	Run off zone	**Poor**

Pediment (Out crop Complex)	Forming more outcrops area with the without soil cover.	Run off zone	**Poor**
Pediment covered by out crop (Reserve Forest)	Outcrops area covered by the reserve forest.	Direct recharge from rainfall	**Run off zone**
Buried pediment Shallow	Intermediate zone Between pediment and buried pediment moderate weathering thickness is less.	Moderate infiltration recharge by influenced by hydrogeolgical feature	**Less to Moderate**
Geomorphic Units	**Characteristics**	**Hydrogeology**	**Groundwater Potential**
Buried pediment Shallow (moderate)	Intermediate zone Between buried pediment shallow and shallow buried pediment deep. Weathering thickness is moderate.	Poor infiltration recharge by influenced by hydrological feature	**Moderate**
Buried pediment Shallow (Deep)	Intermediate zone between buried pediment moderate and deep buried pediment. Weathering thickness is appreciably more.	Moderate infiltration recharge, influenced by hydrogeological features	**Moderate**
Buried Pediment Deep	Occupying low-lying topography. Weathered thickness more connected by good drainage network and hydrological bodies. Less drainage density. Infiltration and permeability is good.	Infiltration is high. Recharge from tanks and streams. Moderate infiltration recharge by influenced by hydrological feature	**Good**
Hill top valleys (Erosional Surface)	Developed in the vegetation in the low lying topograph on the hills. Comprised of colluvium and fluvium with less to moderate thickness of weathered rock	Soil moisture high. Good recharge from rain water infiltration good	**Good to Moderate**
Structural Hill	Composed of composite ridges and hill top valleys traversed by structural features	Run off zone Little Infiltration moderate on the hill top valleys and super imposed secondary fractures	**Moderate and poor**

2.10 Demographic and Social Characteristics

Population trend and population dynamics are important indicators of future water requirement. 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. Land utilization pattern, size of land holdings, nature of agricultural employment and industrial employment also would reflect on the water requirement of the population. An analysis of all these parameters in Pennaiyar River Basin is described hereunder.

2.10.1 Population in Pennaiyar River Basin

63 % of total area of Krishnagiri District (3246.12 sq.km out of 5143 sq.km), 56 % of total area of Dharmapuri District (2506.28 sq.km out of 4498 sq.km), 4 % of total area of Salem District (191.1 sq.km out of 5245 sq.km) ,15 % of total area of Vellore District (903.04 sq.km out of 6077 sq.km), 28 % of total area of Thiruvannamalai District (1721.84 sq.km out of 6190 sq.km), 30 % of total area of Villupuram District (2141.69 sq.km out of 7191 sq.km), and 18% of total area of Cuddalore District (665.49 sq.km out of 3706 sq.km) falls in Pennaiyar River Basin. The total population in Dharmapuri ,Krishnagiri, Villupuram, Thiruvannamalai, Vellore, Salem and Cuddalore districts and population of those districts in Pennaiyar River Basin as per census 2011 is given below in **Table 2.10**

Table 2.10 Population in Pennaiyar River Basin

S. No	Name of the District	Population as per census 2011			Population as projected to 2015		
		Rural (in Million)	Urban (in Million)	Total (in Million)	Rural (in Million)	Urban (in Million)	Total (in Million)
1.	Krishnagiri	1.299	0.524	1.823	1.368	0.568	1.936
2.	Dharmapuri	0.423	0.046	0.469	0.445	0.050	0.495
3	Salem	0.021	0.00	0.021	0.023	0.000	0.023
4	Vellore	0.364	0.097	0.461	0.382	0.105	0.487
5	Thiruvannamalai	0.557	0.178	0.735	0.586	0.192	0.778
6	Villupuram	0.962	0.095	1.057	1.013	0.103	1.116
7	Cuddalore	0.395	0.316	0.711	0.416	0.343	0.759
	Total	**4.021**	**1.256**	**5.277**	**4.233**	**1.361**	**5.594**

Source: *Census 2011*

There are 19 sub Basins in Pennaiyar 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 2.1 to 2.19.** The Sub Basin wise Population of Pennaiyar River Basin is given in the **Table 2.11**.

The population of Pennaiyar River Basin is projected for the years 2015, 2020, 2023, 2030 and 2040 which is detailed in Chapter 7.

Table 2.11 Sub Basin wise Population in Pennaiyar River Basin

S. No	Name of Sub basin	As per census 2011 (in million)			As projected to 2015 (in million)		
		Rural	Urban	Total	Rural	Urban	Total
1.	Chinnar West	0.049	0.219	0.268	0.052	0.237	0.289
2.	Chinnar East	0.089	0.000	0.089	0.094	0.000	0.094
3.	Markandanathi	0.101	0.000	0.101	0.106	0.000	0.106
4.	Kambainallur	0.366	0.086	0.452	0.385	0.093	0.478
5.	Pambar	0.611	0.132	0.743	0.643	0.143	0.786
6.	Vaniyar	0.247	0.046	0.293	0.260	0.050	0.310
7.	Maturar	0.016	0.000	0.016	0.017	0.000	0.017
8	Kottapattikallar	0.039	0.000	0.039	0.041	0.000	0.041
9	Valayar Odai	0.021	0.000	0.021	0.022	0.000	0.022
10	Ramakkal Odai	0.000	0.000	0	0.000	0.000	0.000
11	Pambanar and Varattar	0.069	0.000	0.069	0.073	0.000	0.073
12	Aliyar	0.063	0.000	0.063	0.066	0.000	0.066
13	Muskundanadhi	0.058	0.000	0.058	0.061	0.000	0.061
14	Thurinjalar	0.347	0.181	0.528	0.365	0.196	0.561
15	Gadilam	0.768	0.334	1.102	0.809	0.362	1.171
16	Upto Krishnagiri Reservoir	0.233	0.021	0.254	0.245	0.023	0.268
17	Krishnagiri to Pambar	0.301	0.164	0.465	0.317	0.178	0.495
18	Pambar to Thirukovilur	0.300	0.013	0.313	0.316	0.014	0.330
19	Lower Pennaiyar	0.343	0.06	0.403	0.361	0.065	0.426
	Total	**4.201**	**1.256**	**5.277**	**4.233**	**1.361**	**5.594**

Source: Census 2011

2.10.2 Population Growth Rate

The average Growth Rate of Rural and Urban Population in Pennaiyar River Basin is taken as 1.3% and 2% respectively. The Sub Basin wise population is projected for the present year 2014 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 projected population in Pennaiyar River Basin for 2014 is given below in **Table 2.12.**

Table 2.12 Projected population in Pennaiyar River Basin for 2015

S. No	Name of Sub basin	Area in Sq.km	Total Urban Population in million		Total Rural Population in million	
			2011	2015	2011	2015
1	Chinnar West	125.32	0.000	0.000	0.089	0.094
2	Chinnar East	307.96	0.219	0.237	0.049	0.052
3.	Markandanathi	368.21	0.000	0.000	0.101	0.106
4.	Kambainallur	919.28	0.086	0.093	0.366	0.385
5.	Pambar	1757.42	0.132	0.143	0.611	0.643
6.	Vaniyar	998.39	0.046	0.050	0.247	0.260
7.	Maturar	58.50	0.000	0.000	0.016	0.017
8	Kottapattikallar	410.23	0.000	0.000	0.039	0.041
9	Valayar Odai	85.39	0.000	0.000	0.021	0.022
10	Ramakkal Odai	14.41	0.000	0.000	0.000	0.000
11	Pambanar and Varattar	292.09	0.000	0.000	0.069	0.073
12	Aliyar	211.07	0.000	0.000	0.063	0.066
13	Muskundanadhi	179.26	0.000	0.000	0.058	0.061
14	Thurinjalar	853.62	0.181	0.196	0.347	0.365
15	Gadilam	1562.90	0.334	0.362	0.768	0.809
16	Upto Krishnagiri Reservoir	772.64	0.021	0.023	0.233	0.245
17	Krishnagiri to Pambar	894.52	0.164	0.178	0.301	0.317
18	Pambar to Thirukovilur	1002.39	0.013	0.014	0.300	0.316
19	Lower Pennaiyar	561.96	0.06	0.065	0.343	0.361
	Total	**11375.56**	**1.256**	**1.361**	**4.021**	**4.233**
Average Annual growth rate			**1.3%**		**2%**	

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 Pennaiyar River Basin is given in **Table 2.13.** The population density is higher in Chinnar West sub Basin (2149 persons per sq.km) and lower in Kottapattikallar sub Basin (95 Persons per sq.km).

Table 2.13 Sub Basin wise population density in the Pennaiyar River Basin

Sl. No	Name of the sub Basin	Area (Sq.km)	Total population 2015	Density (Person/Sq.km)
1.	Chinnar West	125.32	269291	2149
2.	Chinnar East	307.96	89169	290
3.	Markandanathi	368.21	100511	273
4.	Kambainallur	919.28	451616	491
5.	Pambar	1757.42	742856	423
6.	Vaniyar	998.39	293049	294
7.	Maturar	58.50	16388	280
8	Kottapattikallar	410.23	38846	95
9	Valayar Odai	85.39	20777	243
10	Ramakkal Odai	14.41	0	0
11	Pambanar and Varattar	292.09	69445	238
12	Aliyar	211.07	62955	298
13	Muskundanadhi	179.26	57854	323
14	Thurinjalar	853.62	527497	618
15	Gadilam	1562.90	1101439	705
16	Upto Krishnagiri Reservoir	772.64	254107	329
17	Krishnagiri to Pambar	894.52	465348	520
18	Pamabar to Thirukovilur	1002.39	313719	313
19	Lower Pennaiyar	561.96	403571	718
Total		**11375.56**	**5278438**	
Average population Density				**453**

2.10.4 Population by Sex

The sex wise distribution of population in Pennaiyar River Basin in 2015 is given in **Table 2.14,**

Table 2.14 District wise population by Sex in Pennaiyar River Basin

Sl. No	Name of the District	Area in Sq.km	Total Population 2015	Population of Male	% Male	Population of Female	% Female
1	Krishnagiri	3246.12	1948848	1008091	52%	940757	48%
2	Dharmapuri	2506.28	501000	259094	52%	241906	48%
3	Salem	191.1	23663	12142	51%	11521	49%
4	Vellore	903.04	498523	251732	50%	246791	50%
5	Thiruvannamalai	1721.84	795135	399736	50%	395399	50%
6	Villupuram	2141.69	1143871	578108	51%	565763	49%
7	Cuddalore	665.49	758717	384895	51%	373822	49%
	Total	**11375.56**	**5669757**	**2893798**	**51%**	**2775959**	**49%**

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 Lower Pennaiyar Sub Basin has a high sex ratio of 991 females to every 1000 males and Chinnar west Sub Basin has a low sex ratio of 938 females to every 1000 males The sex wise distribution of population in all the sub basins of Pennaiyar River Basin is given below in **Table 2.15.**

Table 2.15 Sexwise population distribution in the Pennaiyar River Basin

Sl. No	Name of the Sub Basin	Population			Male %	Female %	Total %	Sex Ratio
		Male	Female	Total				
1	Chinnar West	0.150	0.140	0.290	52%	48%	100%	933 females / 1000 males
2	Chinnar East	0.048	0.046	0.094	51%	49%	100%	958 females / 1000 males
3	Markandanathi	0.054	0.052	0.106	51%	49%	100%	963 females / 1000 males
4	Kambainallur	0.246	0.232	0.478	51%	49%	100%	943 females / 1000 males
5	Pambar	0.399	0.387	0.786	51%	49%	100%	970 females / 1000 males
6	Vaniyar	0.157	0.153	0.310	51%	49%	100%	975 females / 1000 males
7	Maturar	0.009	0.009	0.017	53%	53%	100%	1000 females / 1000 males
8	Kottapattikallar	0.021	0.020	0.041	51%	49%	100%	952 females / 1000 males
9	Valayar Odai	0.011	0.011	0.022	50%	50%	100%	1000 females / 1000 males
10	Ramakkal Odai	0.000	0.000	0.000	-	-	-	-
11	Pambanar and Varattar	0.037	0.036	0.073	51%	49%	100%	973 females / 1000 males
12	Aliyar	0.033	0.033	0.066	50%	50%	100%	1000 females / 1000 males
13	Muskundanadhi	0.031	0.030	0.061	51%	49%	100%	968 females / 1000 males
14	Thurinjalar	0.282	0.279	0.561	50%	50%	100%	989 females / 1000 males
15	Gadilam	0.589	0.581	1.170	50%	50%	100%	986 females / 1000 males
16	Upto Krishnagiri Resrevoir	0.136	0.132	0.268	51%	49%	100%	971 females / 1000 males

17	Krishnagiri to Pambar	0.250	0.245	0.495	51%	49%	100%	980 females / 1000 males
18	Pamabar to Thirukovilur	0.167	0.164	0.331	50%	50%	100%	982 females / 1000 males
19	Lower Pennaiyar	0.214	0.212	0.427	50%	50%	100%	991 females / 1000 males
	Total	**2.834**	**2.762**	**5.596**	**51%**	**49%**	**100%**	**975 females / 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 department status. The literacy rate of the Pennaiyar River Basin is worked out sub basin wise and is given in **Table 2.16**. The overall literacy rate of Pennaiyar River Basin is found to be 64 %.

Table 2.16 Details of Literacy level in Pennaiyar 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	Chinnar West	0.108	0.091	0.200	0.139	0.130	0.269	78%	70%	74%
2	Chinnar East	0.028	0.020	0.049	0.046	0.043	0.089	61%	47%	55%
3	Markandanathi	0.032	0.024	0.056	0.051	0.049	0.101	62%	48%	56%
4	Kambainallur	0.160	0.118	0.277	0.232	0.219	0.452	69%	54%	61%
5	Pambar	0.271	0.211	0.482	0.377	0.366	0.743	72%	58%	65%
6	Vaniyar	0.104	0.080	0.184	0.149	0.144	0.293	70%	55%	63%
7	Maturar	0.006	0.002	0.008	0.008	0.008	0.016	69%	23%	46%
8	Kottapattikallar	0.011	0.008	0.020	0.020	0.019	0.039	57%	43%	50%

9	Valayar Odai	0.007	0.005	0.012	0.011	0.010	0.021	64%	49%	57%
10	Ramakkal Odai	0.000	0.000	0.000	0.000	0.000	0.000	0%	0%	0%
11	Pambanar and Varattar	0.021	0.016	0.037	0.035	0.034	0.069	60%	46%	53%
12	Aliyar	0.021	0.016	0.037	0.032	0.031	0.063	67%	51%	59%
13	Muskundanadhi	0.019	0.015	0.034	0.029	0.028	0.058	66%	52%	59%
14	Thurinjalar	0.200	0.164	0.364	0.265	0.263	0.527	76%	62%	69%
15	Gadilam	0.397	0.315	0.712	0.554	0.547	1.101	72%	58%	65%
16	Upto Krishnagiri Reservoir	0.088	0.069	0.156	0.129	0.125	0.254	68%	55%	62%
17	Krishnagiri to Pambar	0.174	0.141	0.314	0.235	0.230	0.465	74%	61%	68%
18	Pamabar to Thirukovilur	0.107	0.081	0.189	0.158	0.155	0.314	68%	52%	60%
19	Lower Pennaiyar	0.148	0.118	0.266	0.203	0.201	0.404	73%	59%	66%
	Total	**1.902**	**1.494**	**3.396**	**2.673**	**2.605**	**5.278**	**71%**	**57%**	**64%**

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, Dharmapuri, Krishnagiri, Salem, Thiruvannamalai, Vellore and Villupuram Districts is given in **Table 2.17.**

Table 2.17 Details of Births and Deaths Registered in Districts covered in Pennaiyar River Basin

Sl. No.	Name of the District	Mid – Year Estimated Population	Births	Deaths	Infant Deaths	Still Births	Maternal Deaths
1.	Krishnagiri	1785000	31703	2521	140	492	2
2.	Dharmapuri	1451000	25727	8559	838	252	24
3	Salem	3445000	45560	21271	525	233	0
4	Vellore	3912000	66232	26596	515	865	3
5	Thiruvannamalai	2322000	43672	14301	30	27	0
6	Villupuram	3155000	36104	15278	206	118	33
7	Cuddalore	2440000	41424	13071	217	161	7

2.10.8 Family Welfare & Impact of Family Planning

Tamil Nadu is a 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 favoured method, followed by the use of IUD (Intra – Uterine Device).

Family welfare Programme details for the districts covered by Pennaiyar Basin for the period of 2013-14 is given in **Table 2.18.**

Table 2.18 District wise details of Family Welfare Programme

Name of the District	Sterilization	Intra – Uterine Device (IUD)	Oral Pill Users	Users of Conventional Contraceptives
Krishnagiri	8968	13688	816	3083
Dharmapuri	7969	15760	682	2409
Salem	13386	14608	755	3526
Vellore	21549	22198	765	3867
Thiruvannamalai	9504	10496	875	2547
Villupuram	11779	16182	1710	3517
Cuddalore	9605	17028	1894	5117

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 Pennaiyar River Basin is given in **Table 2.19**

Table No 2.19 Number of Households in Pennaiyar River Basin

Sl.No.	Name of the Sub Basin	Number of House Holds
1	Chinnar West	79139
2	Chinnar East	28882
3	Markandanathi	31353
4	Kambainallur	139899
5	Pambar	208767
6	Vaniyar	86049
7	Maturar	6084
8	Kottapattikallar	14549
9	Valayar Odai	8187

10	Ramakkal Odai	0
11	Pambanar and Varattar	19324
12	Aliyar	21648
13	Muskundanadhi	18947
14	Thurinjalar	140765
15	Gadilam	293751
16	Upto Krishnagiri Reservoir	92053
17	Krishnagiri to Pamabr	138018
18	Pamabar to Thirukovilur	109306
19	Lower Pennaiyar	123964
	Total	**1560685**

Source: Census of India 2011

2.11 General Problem

Some of the important problems that hamper the water availability in the River Basin are water logging, salinity, pollution, environmental degradation, inefficient use of water, seawater intrusion in coastal regions, natural calamities like floods and droughts, etc and health related problems. These problems are locally assessed and possible solutions are evaluated in the planning process for decision making at higher levels.

2.12 Economic Analysis and Prioritization

The economic analysis carried out for the prioritisation of the development plan is focused on estimating the Benefit Cost (BC) Ratio. This factor, if greater than one indicates that the project under consideration is economically feasible. This value also indicates a descending ranking order for prioritisation. This reflects the objective of receiving maximum economic returns for public investments.

The benefits in the net benefit estimate reflect the economic value of using the water for irrigation. For projects evaluation, it is assumed that there will be a gradual transition of agro-technology and efficiency from the present state situation to a future improved and upgraded state.

For projects which are not related (directly or indirectly) to the increase of agricultural product value, the benefits are in the domain of increasing other human well being services (drinking water, public health) or enhancing environmental sustainability.

Prioritization of projects is carried out by considering other criteria also in addition to the leading Irrigation Net Benefit to the investment ratio criterion. There are contribution to domestic and industrial water supply, level of exploitation of the water resource, level of population and quality degradation and the need for water (such as fraction of area under rainfed cultivation).

The prioritization process with these criteria was programmed to obtain an action plan phased over time.

2.12.1 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 Pennaiyar River Basin are discussed.

Service sector industry has been playing a vital role in the economy in Thiruvannamalai district. The mineral base is found to be spread across the Thiruvannamalai district which is the most important factors for the industrial development of the area. Tiruvannamalai district is enriched in with minerals deposit like Black Granite, Multi colored Granite, Blue metal, Earth and Brick Clay. Maximum units have been established in Agro & Food Processing category followed by Readymade Garments & Embroidery units. Agro & Food Processing units have also taken the maximum share of investment and employment. Food processing and Silk Saree based units are turning out to be major growing sectors for the Thiruvannamalai district.

Agro based industries, readymade garment & embroidery , metal based steel fabrication industries are some of the most common industry in Krishnagiri District. The major export materials from this districts are auto Components/tools, vehicles, watches,jewellery, polished granite slabs, mango pulp , cut flowers etc.,.In Krishnagiri district, mango pulp extraction is the most popular segment in the belt which is growing over 10%, granite slab mining, cutting and polishing is another important activity in the area. Hosur is a hub for auto-component sector which is growing fast.

In Thiruvannamalai district cottage and rural industries are more common. Fruit, vegetable and floriculture are the major thrust sectors that are considered as sleeping giants in the Thiruvannamalai district. Certain regions of the Thiruvannamalai district have great potential for promoting agro-based industries.

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 (DIC) 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 Pennaiyar River Basin, the District Industrial Centers are functioning at Salem, Vellore, Villupuram, Hosur, Thiruvannamalai.

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, Dharmapuri, Krishnagiri, Salem, Vellore, Villupuram, Thiruvannamalai,

Table No 2.20 District wise list of Backward Blocks

Sl. No.	Name of District	Backward Blocks in the District	Backward Blocks in the Pennaiyar River Basin
1	Krishnagiri	1.Bargur 2.Sulagiri 3.Kaveripattinam 4.Thally 5.Kelamangalam 6.Uthangarai 7.Mathur 8.Veppanapalli	1.Bargur 2.Sulagiri 3.Kaveripattinam 4.Thally 5.Kelamangalam 6.Mathur 7.Veppanapalli

2	Dharmapuri	1.Harur 2.Palacode 3. Karimangalam 4.Pappireddipatti 5. Morappur 6. Pennagaram 7.Nallampalli	1.Harur 2.Palacode 3. Karimangalam 4.Pappireddipatti
3	Salem	1.Ayothiapatnam 2.Pethanaickenpalayam 3.Kadayampatti 4.Thalaivasal 5.Konganapuram 6.Tharamangalam 7.Mechery 8.Yercaud 9.Omalur	1.Pethanaickenpalayam
4	Vellore	1.Anaicut 2.Natrampalli 3.Arcot 4.Nemili 5.Jolarpet 6.Pernambut 7.K.V.Kuppam 8.Sholingur 9.Kandhili 10.Thimiri 11.Kaveripakkam 12.Tirupattur	1.Jolarpet 2.Kandhili 3.Natrampalli 4.Tirupattur
5	Thiruvannamalai	1.Annakkavoor 2.Polur 3.Arni 4.Pudupalayam 5.Chengam 6.Thandrampat 7.Chetpat 8.Thellar 9.Cheyyar 10.Thurinjapuram 11.Jawathumalai 12.Vandavasi 13.Kalasapakkam 14.Vembakkam 15.Kilpennathur 16.West Arni 17.Peranamallur	1.Chengam 2.Kilpennathur 3.Pudupalayam 4.Thandrampat 5.Thurinjapuram
6	Villupuram	1.Chinnaselam 2.Rishivandiyam 3.Gingee 4.Sankarapuram	1.Gingee 2.Kalvarayanmalai 3.Kanai 4.Kandamangalam

		5.Kallakurichi 6.Thirukoilur 7. Kalvarayanmalai 8.Thirunavalur 9.Kanai 10.Thiruvennainallur 11.Kandamangalam 12.Thiyagadurgam 13. Mailam 14.Ulundurpet 15. Marakkanam 16.Vallam 17.Melmalaiyanur 18.Vanur 19.Mugaiyur 20.Vikkiravandi 21.Olakkur	5.Mugaiyur 6.Rishivandiyam 7.Sankarapuram 8.Thiyagadurgam 9.Thirukoilur 10.Thiruvennainallur 11.Ulundurpet
7	Cuddalore	1.Annagramam 2.Mangalore 3. Kammapuram 4. Melbhuvanagiri 5. Kattumannarkoil 6. Nallur 7. Kumaratchi 8. Parangipettai (Portonovo) 9. Kurinjipadi	1.Annagramam 2.Kammapuram 3. Kurinjipadi

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).

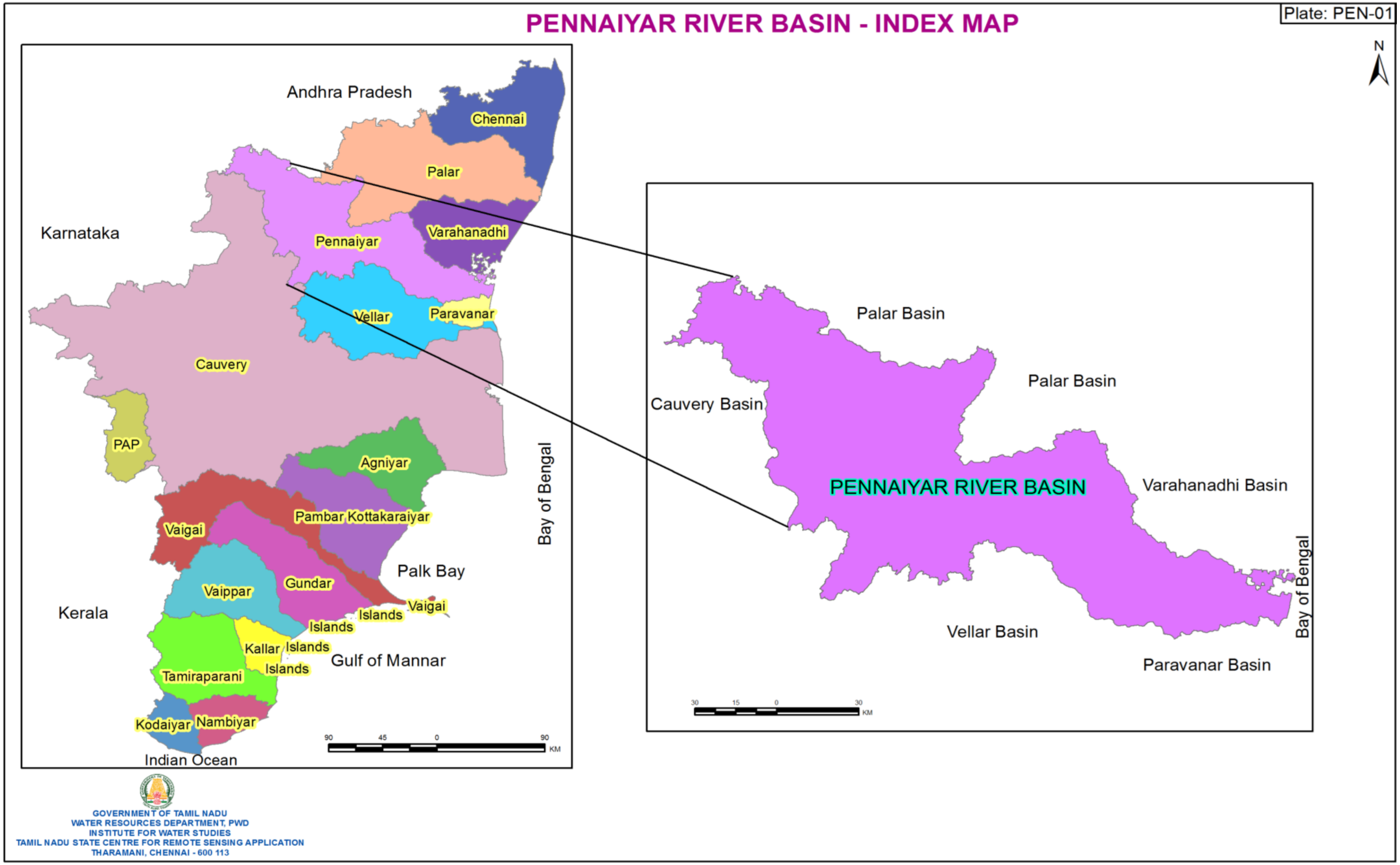
For this purpose, a thrust has been given to establish, promote and develop the rural industries and the Government also in active move in promoting Self-Employment opportunity in Urban and Rural areas by extending financial assistance through banking sector for the establishment and development of small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

Since Agricultural sector has been fairly saturated, it is necessary to develop secondary sector of economic activity in order to improve the overall economy of the district, as well as to solve the mounting unemployment problem towards this objective. Hence a new scheme namely, NEW ANNA MARUMALARCHI THITTAM has been introduced with a very purpose of imparting thrust to the Agro based industries in each Block of this state.

The **Mahatma Gandhi National Rural Employment Guarantee Act** (MGNREGA) is an **Indian law** that aims to guarantee the **'right to work'** and ensure livelihood security in rural areas by providing at least 100 days of guaranteed wage employment in a financial year to every household whose adult members volunteer to do unskilled manual work. This work guarantee can also serve other objects, generating productive assets, protecting the environments ,empowering rual women, reducing rual - ubran migration and fostering social equity among others.

MGNREGA is a right-based, demand-driven public employment programme that is principally based on decentralized, participatory planning at the **gram panchayat** level with adequate transparency and accountability safeguards for effective implementation.

The MGNREGA is notified on 7 September 2005. At minimum wage rate and within 5 km radius of the village, the employment under MGNREGA is an entitlement that creates an obligation on the government failing which an unemployment allowance is to be paid within 15 days. Along with community participation, the MGNREGA is to be implemented mainly by the **gram panchayats (**GPs). The involvement of contractors is banned. Labour-intensive tasks like creating infrastructure for water harvesting, drought relief and flood control are preferred. Starting from 200 districts in 2 February 2006, the MGNREGA covered all the districts of India from 1 April 2008.


PENNAIYAR RIVER BASIN - INDEX MAP
Plate: PEN-01
N
Andhra Pradesh
Chennai
Palar
Karnataka
Pennaiyar
Varahanadhi
Vellar
Paravanar
Cauvery
PAP
Agniyar
Bay of Bengal
Pambar Kottakaraiyar
Vaigai
Palk Bay
Vaippar
Gundar
Vaigai
Islands
Islands
Kerala
Kallar
Islands
Islands
Gulf of Mannar
Tamiraparani
Kodaiyar
Nambiyar
Indian Ocean
90 45 0 90 KM
Palar Basin
Palar Basin
Cauvery Basin
PENNAIYAR RIVER BASIN
Varahanadhi Basin
Bay of Bengal
Vellar Basin
Paravanar Basin
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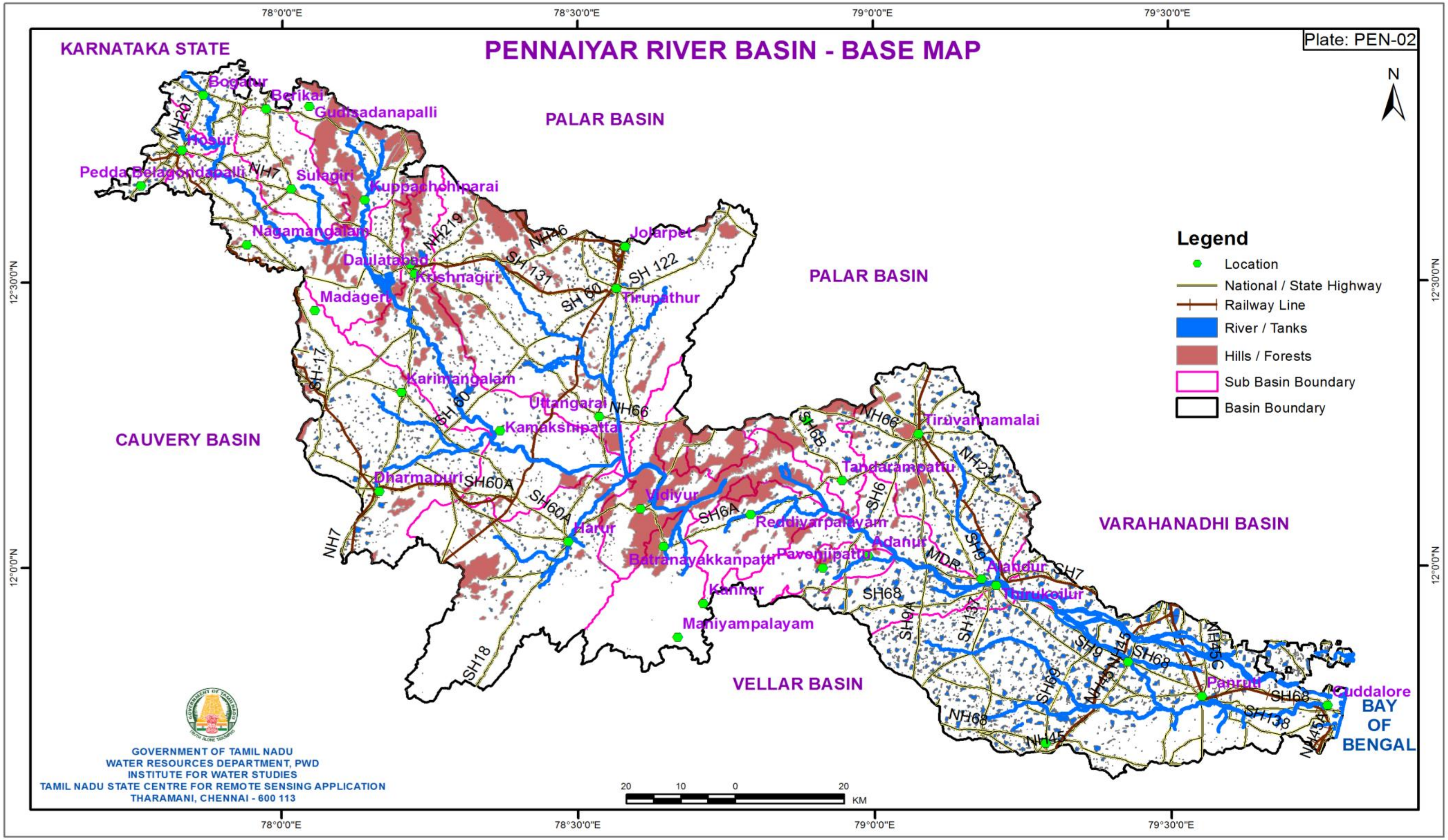
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113



PENNAIYAR RIVER BASIN - BASE MAP
Plate: PEN-02
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Location
National / State Highway
Railway Line
River / Tanks
Hills / Forests
Sub Basin Boundary
Basin Boundary
Bagalur
Berikai
Gudisadanapalli
Hosur
Pedda Belagondapalli
Sulagiri
Kuppachchiparai
Nagamangalam
Jolarpet
Daulatabad
Krishnagiri
Tirupathur
Madageri
Karimangalam
Uttangarai
Kamakshipattai
Dharmapuri
Vidiyur
Harur
Batranayakkanpatti
Reddiyarpalayam
Pavanjipattu
Kannur
Maniyampalayam
Tiruvannamalai
Tandarampattu
Adanur
Alandur
Thirukoilur
Panruti
Cuddalore
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
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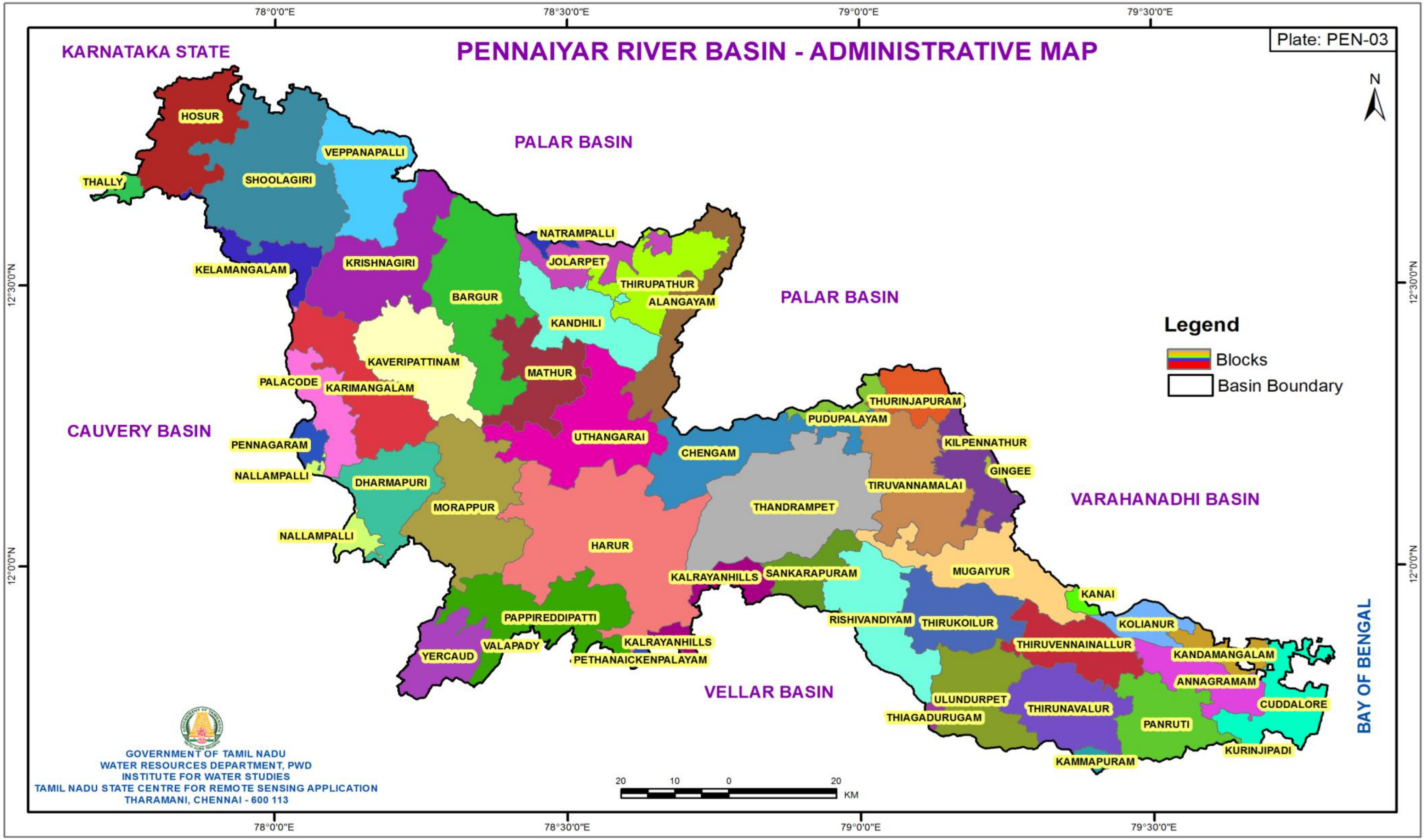
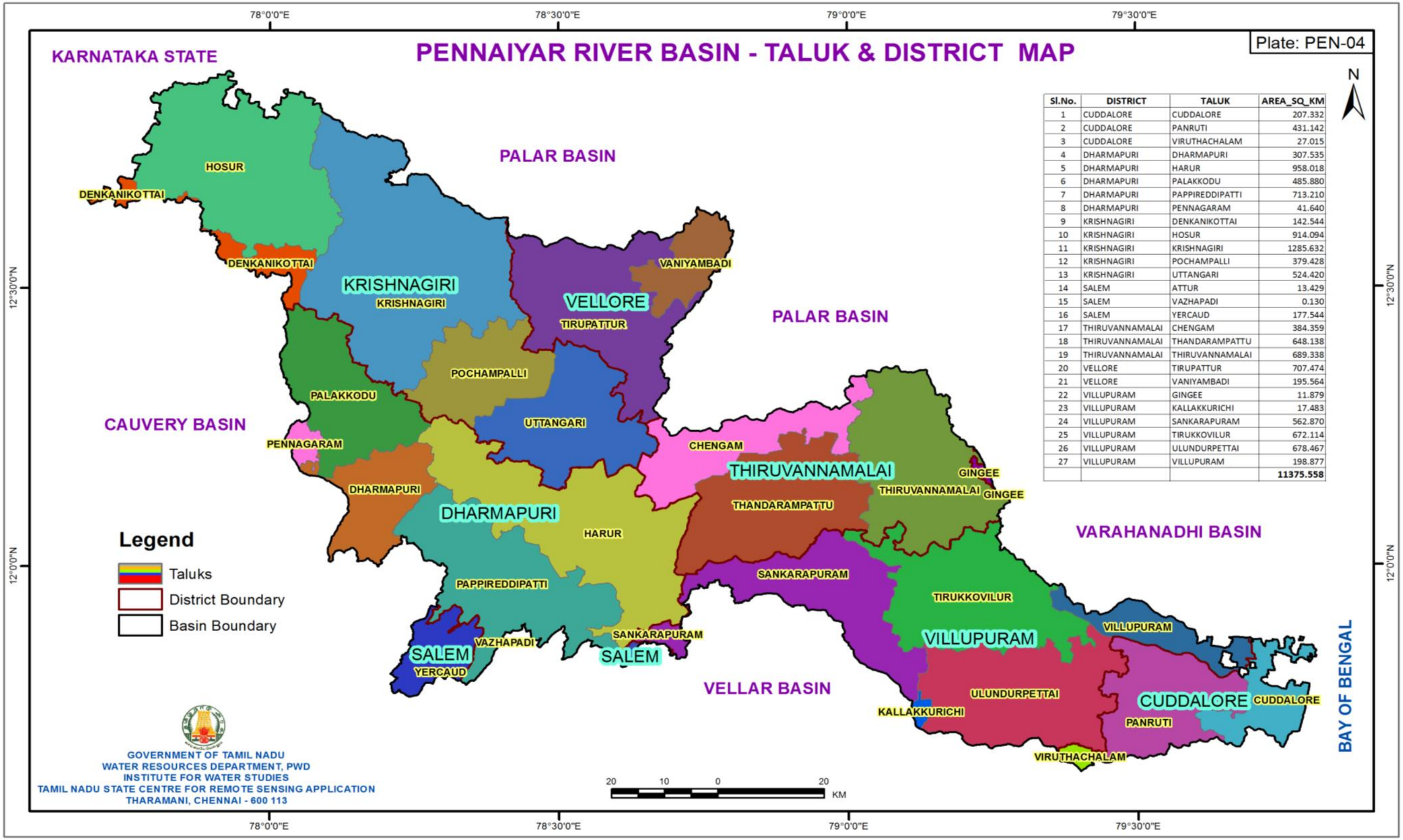
20 10 0 20 KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113



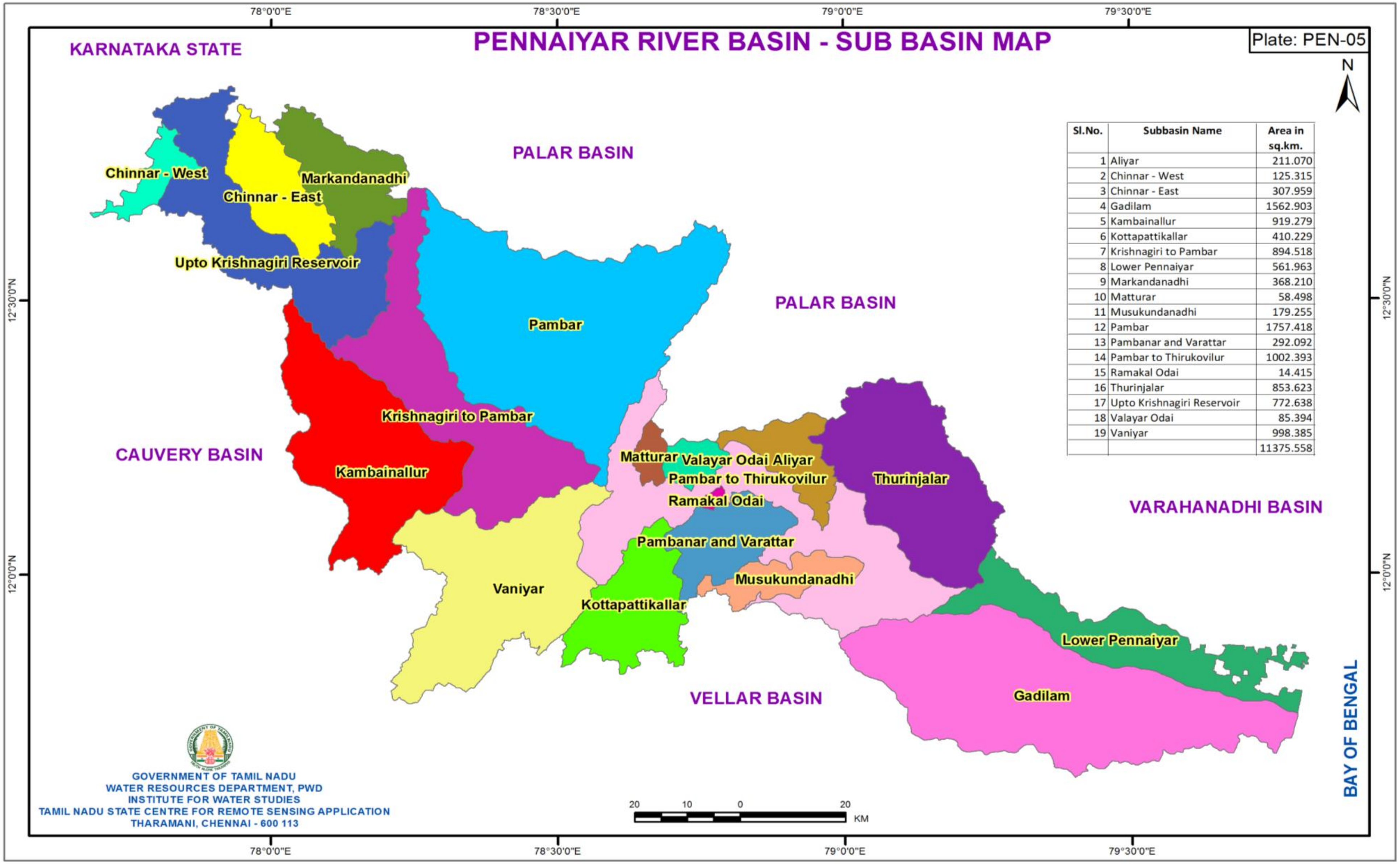
PENNAIYAR RIVER BASIN - ADMINISTRATIVE MAP
Plate: PEN-03
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Blocks
Basin Boundary
HOSUR
THALLY
SHOOLAGIRI
VEPPANAPALLI
KELAMANGALAM
KRISHNAGIRI
BARGUR
NATRAMPALLI
JOLARPET
THIRUPATHUR
ALANGAYAM
KANDHILI
MATHUR
KAVERIPATTINAM
PALACODE
KARIMANGALAM
UTHANGARAI
CHENGAM
PENNAGARAM
NALLAMPALLI
DHARMAPURI
MORAPPUR
NALLAMPALLI
HARUR
THANDRAMPET
THURINJAPURAM
PUDUPALAYAM
KILPENNATHUR
GINGEE
TIRUVANNAMALAI
MUGAIYUR
KANAI
KALRAYANHILLS
SANKARAPURAM
RISHIVANDIYAM
THIRUKOILUR
KOLIANUR
THIRUVENNAINALLUR
KANDAMANGALAM
ANNAGRAMAM
CUDDALORE
PAPPIREDDIPATTI
VALAPADY
YERCAUD
KALRAYANHILLS
PETHANAICKENPALAYAM
ULUNDURPET
THIAGADURUGAM
THIRUNAVALUR
PANRUTI
KURINJIPADI
KAMMAPURAM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
20 10 0 20
KM
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N

PENNAIYAR RIVER BASIN - TALUK & DISTRICT MAP

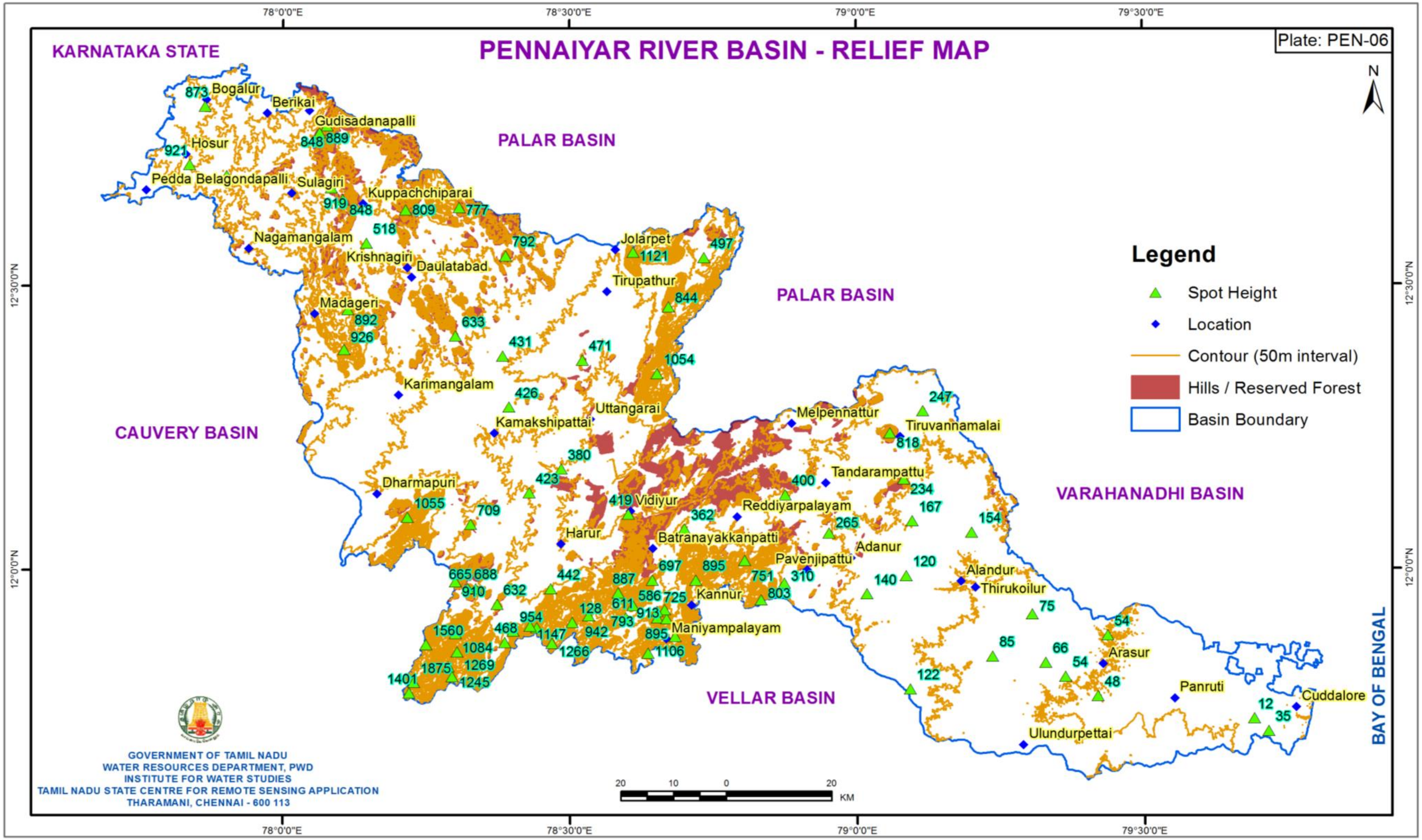
Plate: PEN-04

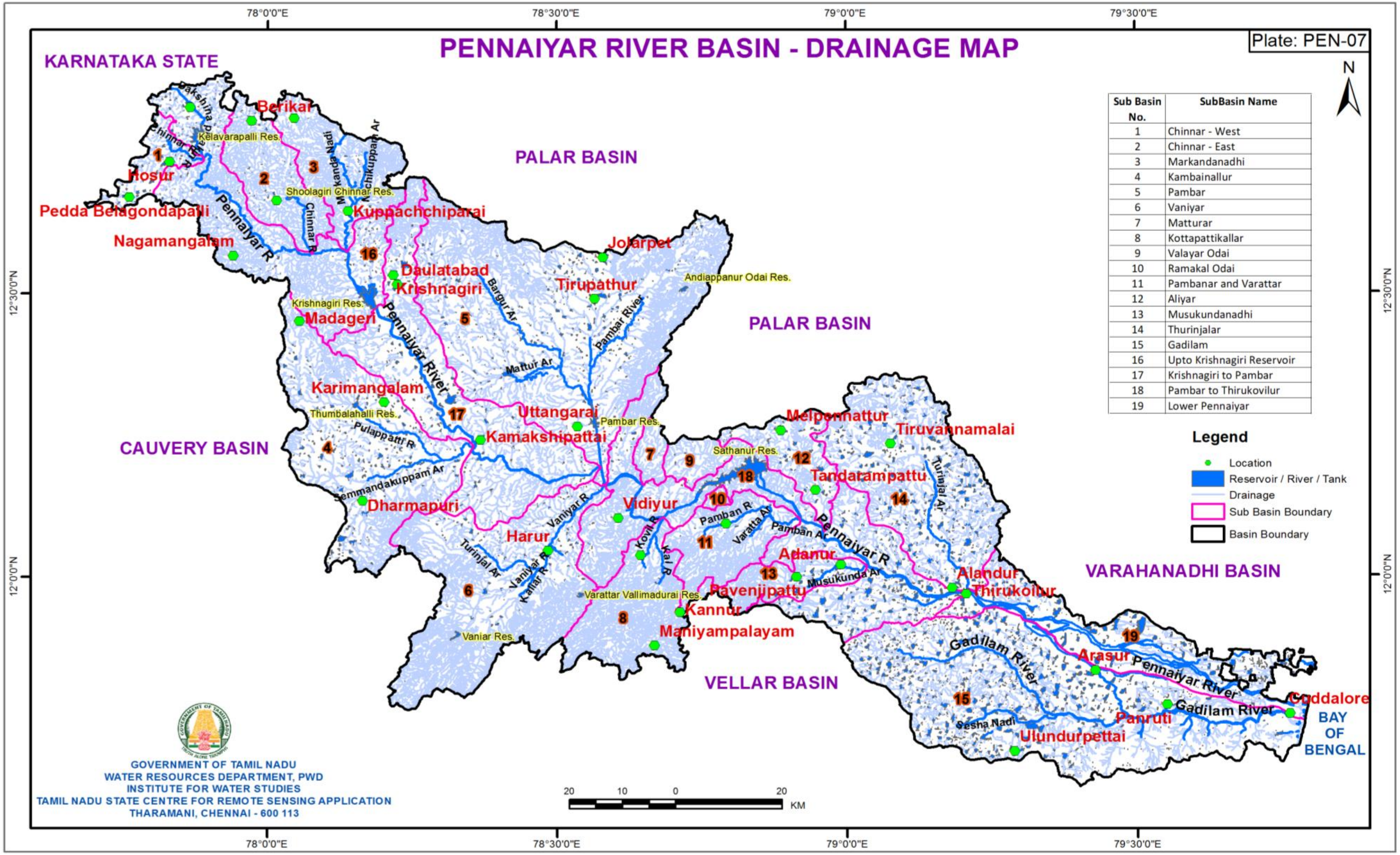


Sl.No.	DISTRICT	TALUK	AREA_SQ_KM
1	CUDDALORE	CUDDALORE	207.332
2	CUDDALORE	PANRUTI	431.142
3	CUDDALORE	VIRUTHACHALAM	27.015
4	DHARMAPURI	DHARMAPURI	307.535
5	DHARMAPURI	HARUR	958.018
6	DHARMAPURI	PALAKKODU	485.880
7	DHARMAPURI	PAPPIREDDIPATTI	713.210
8	DHARMAPURI	PENNAGARAM	41.640
9	KRISHNAGIRI	DENKANIKOTTAI	142.544
10	KRISHNAGIRI	HOSUR	914.094
11	KRISHNAGIRI	KRISHNAGIRI	1285.632
12	KRISHNAGIRI	POCHAMPALLI	379.428
13	KRISHNAGIRI	UTTANGARI	524.420
14	SALEM	ATTUR	13.429
15	SALEM	VAZHAPADI	0.130
16	SALEM	YERCAUD	177.544
17	THIRUVANNAMALAI	CHENGAM	384.359
18	THIRUVANNAMALAI	THANDARAMPATTU	648.138
19	THIRUVANNAMALAI	THIRUVANNAMALAI	689.338
20	VELLORE	TIRUPATTUR	707.474
21	VELLORE	VANIYAMBADI	195.564
22	VILLUPURAM	GINGEE	11.879
23	VILLUPURAM	KALLAKKURICHI	17.483
24	VILLUPURAM	SANKARAPURAM	562.870
25	VILLUPURAM	TIRUKKOVILUR	672.114
26	VILLUPURAM	ULUNDURPETTAI	678.467
27	VILLUPURAM	VILLUPURAM	198.877
			11375.558

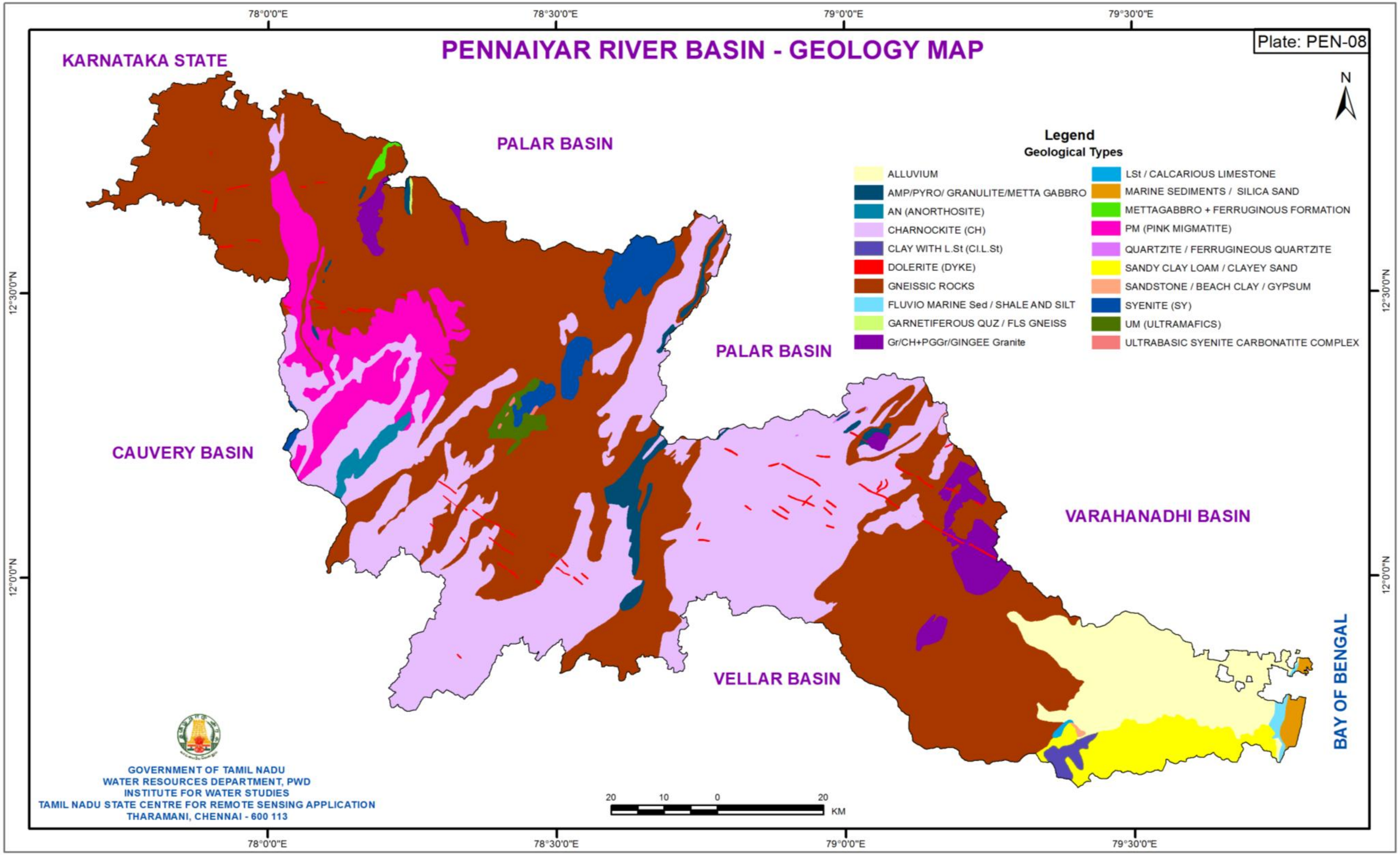


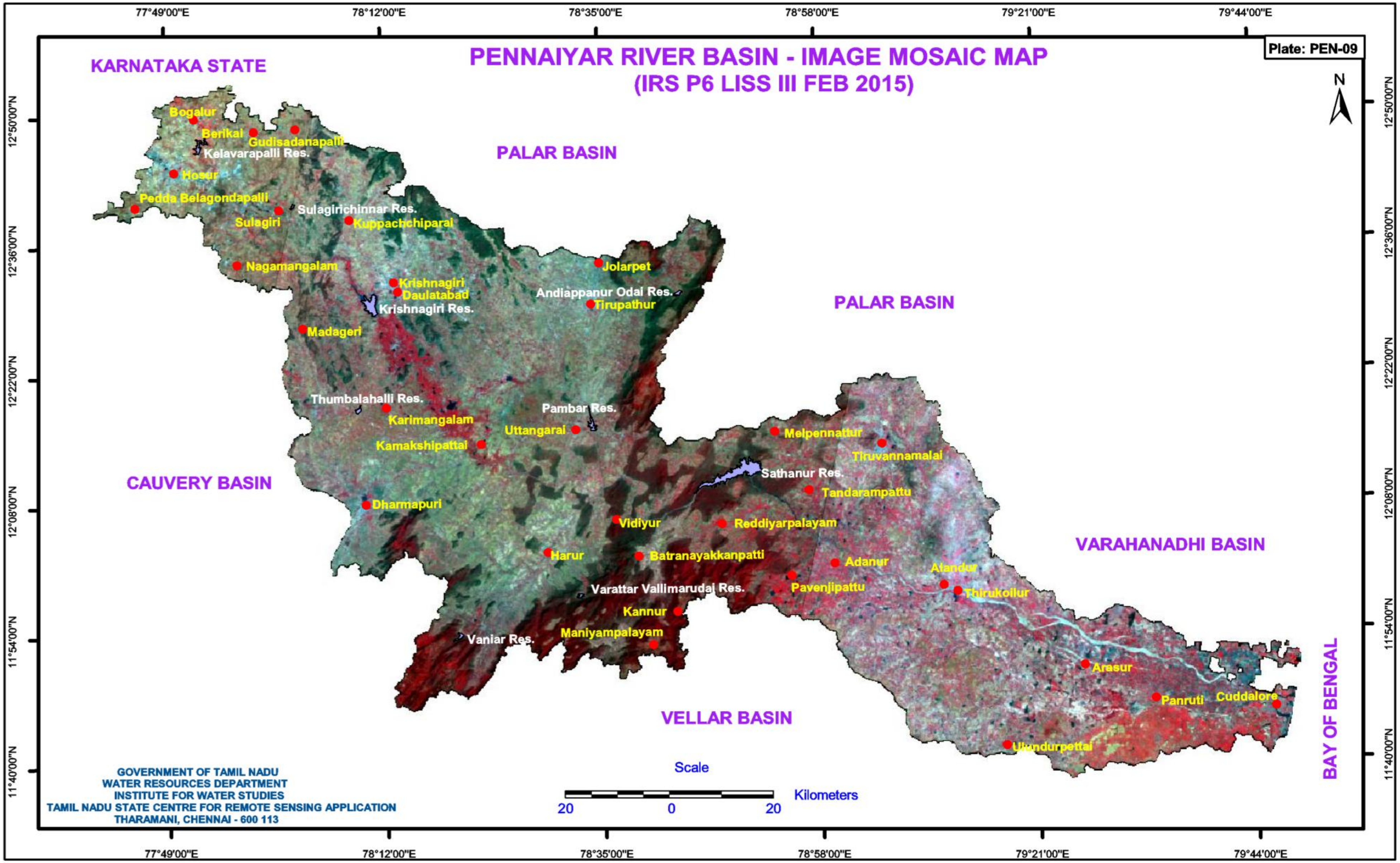
Sl.No.	Subbasin Name	Area in sq.km.
1	Aliyar	211.070
2	Chinnar - West	125.315
3	Chinnar - East	307.959
4	Gadilam	1562.903
5	Kambainallur	919.279
6	Kottapattikallar	410.229
7	Krishnagiri to Pambar	894.518
8	Lower Pennaiyar	561.963
9	Markandanadhi	368.210
10	Matturar	58.498
11	Musukundanadhi	179.255
12	Pambar	1757.418
13	Pambanar and Varattar	292.092
14	Pambar to Thirukovilur	1002.393
15	Ramakal Odai	14.415
16	Thurinjalar	853.623
17	Upto Krishnagiri Reservoir	772.638
18	Valayar Odai	85.394
19	Vaniyar	998.385
		11375.558

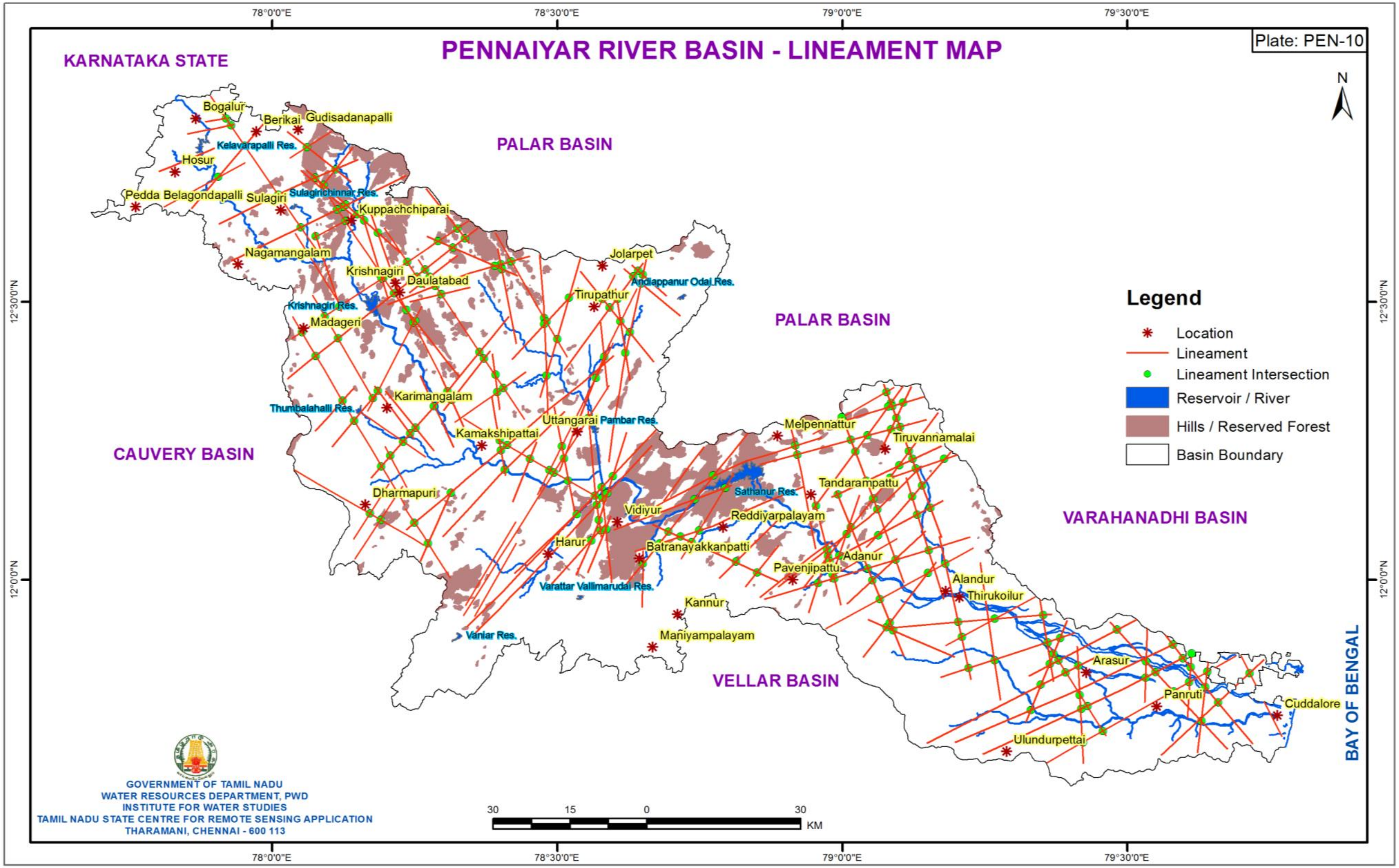

PENNAIYAR RIVER BASIN - RELIEF MAP
Plate: PEN-06
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Spot Height
Location
Contour (50m interval)
Hills / Reserved Forest
Basin Boundary
Bogalur
Berikai
Gudisadanapalli
Hosur
Pedda Belagondapalli
Sulagiri
Kuppachchiparai
Nagamangalam
Krishnagiri
Daulatabad
Madageri
Karimangalam
Kamakshipattai
Uttangarai
Jolarpet
Tirupathur
Dharmapuri
Harur
Vidiyur
Reddiyarpalayam
Batranayakkanpatti
Pavenjipattu
Kannur
Maniyampalayam
Melpennattur
Tiruvannamalai
Tandarampattu
Adanur
Alandur
Thirukoilur
Arasur
Panruti
Cuddalore
Ulundurpettai
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
N
20 10 0 20
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



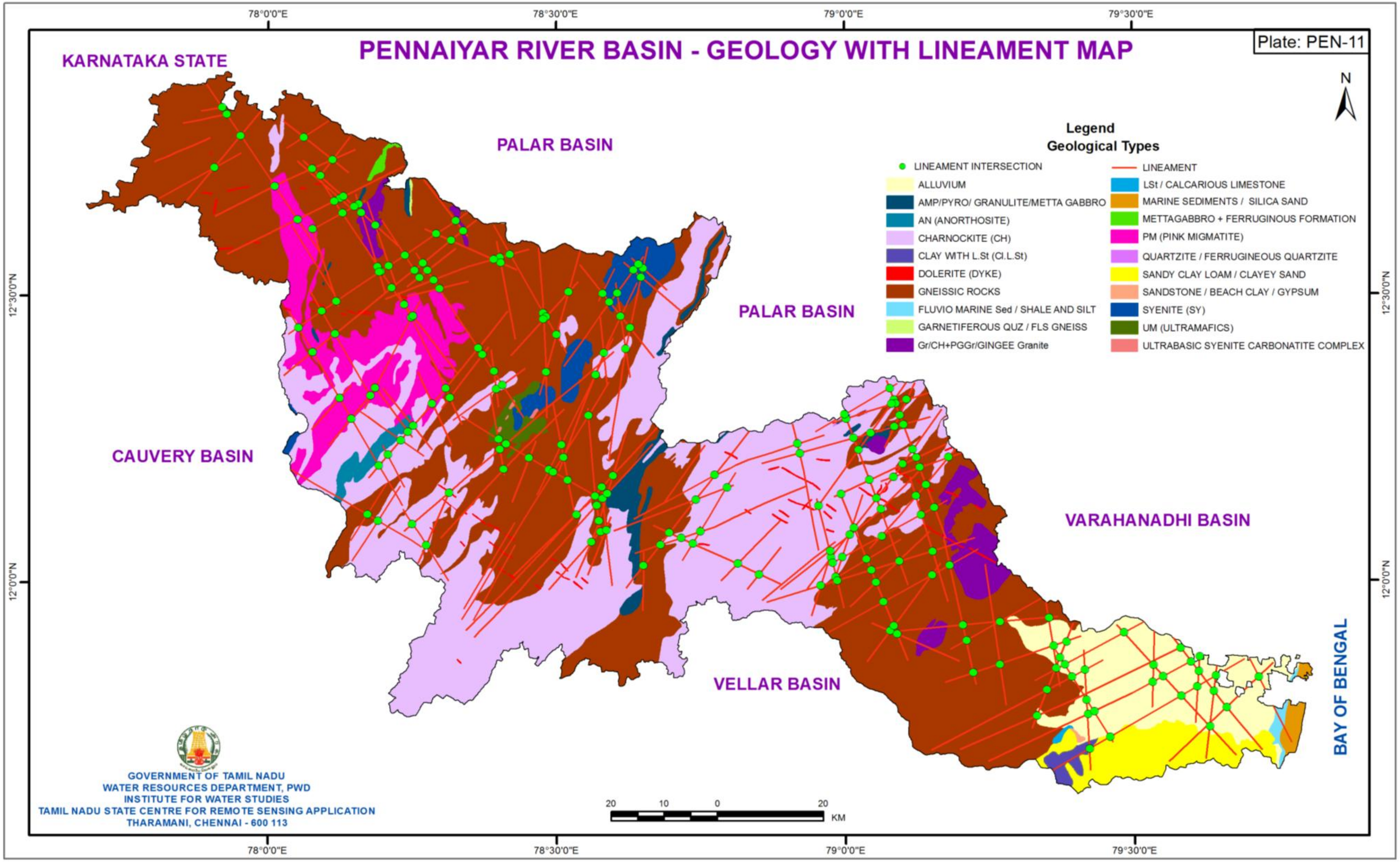
PENNAIYAR RIVER BASIN - DRAINAGE MAP
Plate: PEN-07
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VELLAR BASIN
VARAHANADHI BASIN
BAY OF BENGAL
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
Hosur
Berikai
Pedda Belagondapalli
Nagamangalam
Kuppachchiparai
Daulatabad
Krishnagiri
Madageri
Karimangalam
Kamakshipattai
Dharmapuri
Harur
Uttangarai
Jolarpet
Tirupathur
Vidiyur
Kannur
Maniyampalayam
Melpennattur
Tiruvannamalai
Tandarampattu
Adanur
Pavenjipattu
Alandur
Thirukoilur
Arasur
Panruti
Ulundurpettai
Cuddalore
Kelavarapalli Res.
Shoolagiri Chinnar Res.
Krishnagiri Res.
Thumbalahalli Res.
Pambar Res.
Sathanur Res.
Andiappanur Odai Res.
Varattar Vallimadurai Res.
Vaniar Res.
Pennaiyar R
Pennaiyar River
Chinnar R
Markanda Nadi
Mathur Ar
Pambar River
Pulappatti R
Semmandakuppam Ar
Turinjal Ar
Vaniyar R
Kal R
Pamban R
Varatta Ar
Musukunda Ar
Gadilam River
Sesha Nadi
Sub Basin No. | SubBasin Name
1 Chinnar - West
2 Chinnar - East
3 Markandanadhi
4 Kambainallur
5 Pambar
6 Vaniyar
7 Matturar
8 Kottapattikallar
9 Valayar Odai
10 Ramakal Odai
11 Pambanar and Varattar
12 Aliyar
13 Musukundanadhi
14 Thurinjalar
15 Gadilam
16 Upto Krishnagiri Reservoir
17 Krishnagiri to Pambar
18 Pambar to Thirukovilur
19 Lower Pennaiyar
Legend
Location
Reservoir / River / Tank
Drainage
Sub Basin Boundary
Basin Boundary
20 10 0 20
KM
N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

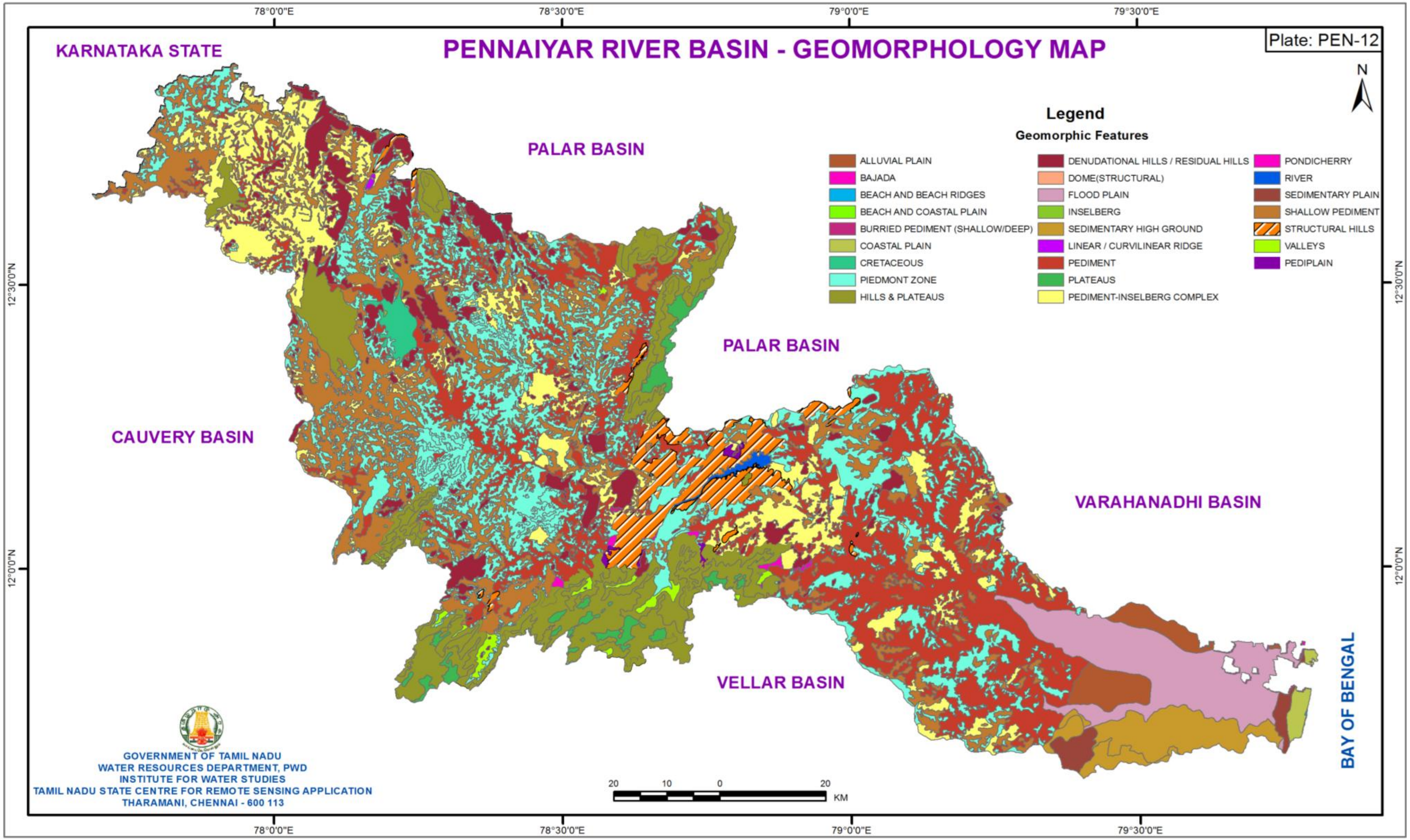

PENNAIYAR RIVER BASIN - GEOLOGY MAP
Plate: PEN-08
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Geological Types
ALLUVIUM
AMP/PYRO/ GRANULITE/METTA GABBRO
AN (ANORTHOSITE)
CHARNOCKITE (CH)
CLAY WITH L.St (Cl.L.St)
DOLERITE (DYKE)
GNEISSIC ROCKS
FLUVIO MARINE Sed / SHALE AND SILT
GARNETIFEROUS QUZ / FLS GNEISS
Gr/CH+PGGr/GINGEE Granite
LSt / CALCARIOUS LIMESTONE
MARINE SEDIMENTS / SILICA SAND
METTAGABBRO + FERRUGINOUS FORMATION
PM (PINK MIGMATITE)
QUARTZITE / FERRUGINEOUS QUARTZITE
SANDY CLAY LOAM / CLAYEY SAND
SANDSTONE / BEACH CLAY / GYPSUM
SYENITE (SY)
UM (ULTRAMAFICS)
ULTRABASIC SYENITE CARBONATITE COMPLEX
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
20 10 0 20
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

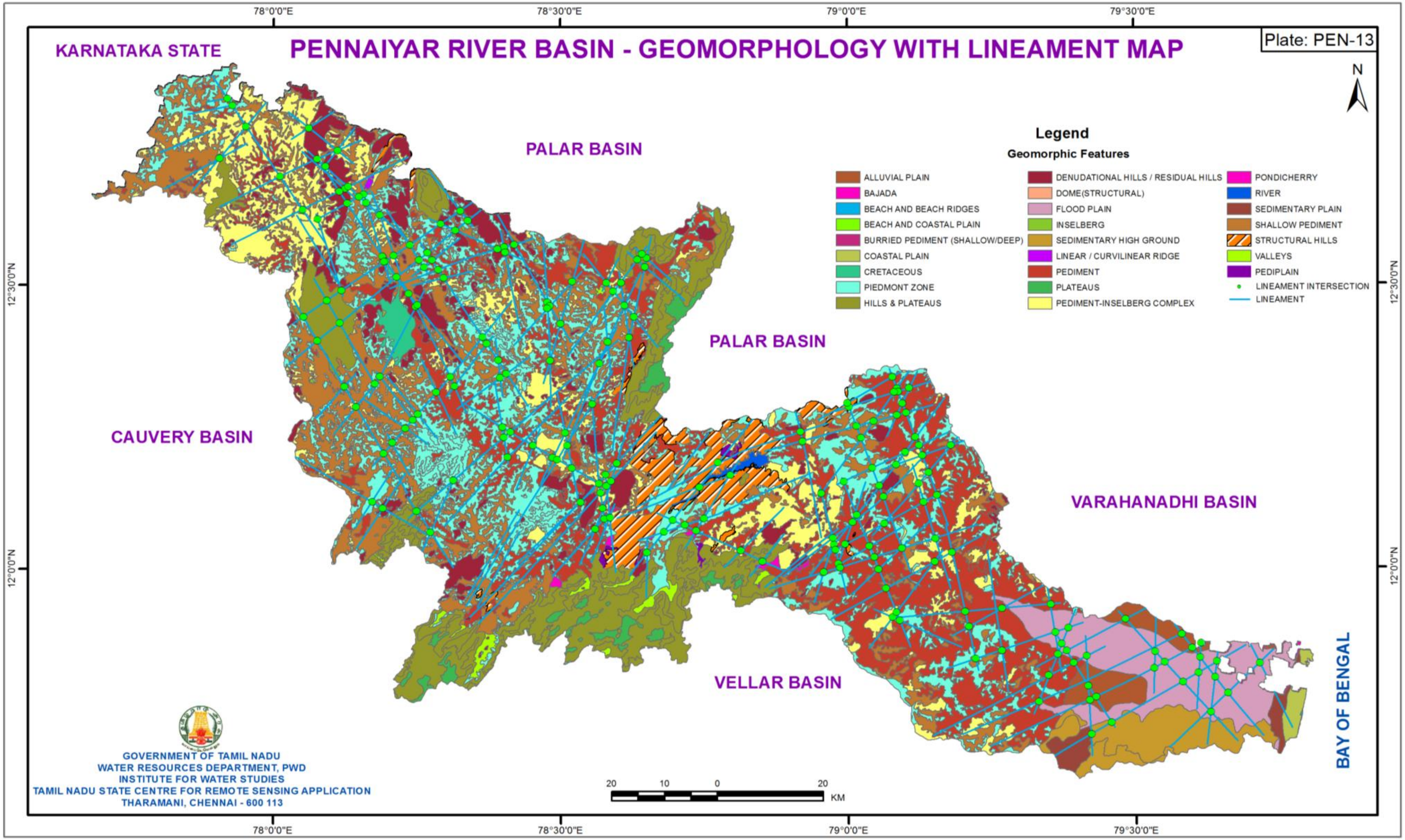

PENNAIYAR RIVER BASIN - IMAGE MOSAIC MAP
(IRS P6 LISS III FEB 2015)
Plate: PEN-09
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Bogalur
Berikai
Gudisadanapalli
Kelavarapalli Res.
Hosur
Pedda Belagondapalli
Sulagiri
Sulagirichinnar Res.
Kuppachchiparai
Nagamangalam
Jolarpet
Krishnagiri
Daulatabad
Krishnagiri Res.
Andiappanur Odai Res.
Tirupathur
Madageri
Thumbalahalli Res.
Karimangalam
Kamakshipattai
Pambar Res.
Uttangarai
Melpennattur
Tiruvannamalai
Sathanur Res.
Tandarampattu
Dharmapuri
Vidiyur
Reddiyarpalayam
Harur
Batranayakkanpatti
Adanur
Atandur
Thirukoilur
Pavenjipattu
Varattar Vallimarudai Res.
Kannur
Maniyampalayam
Vaniar Res.
Arasur
Panruti
Cuddalore
Ulundurpettai
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
Scale
20 0 20
Kilometers
N
77°49'00"E
78°12'00"E
78°35'00"E
78°58'00"E
79°21'00"E
79°44'00"E
12°50'00"N
12°36'00"N
12°22'00"N
12°08'00"N
11°54'00"N
11°40'00"N

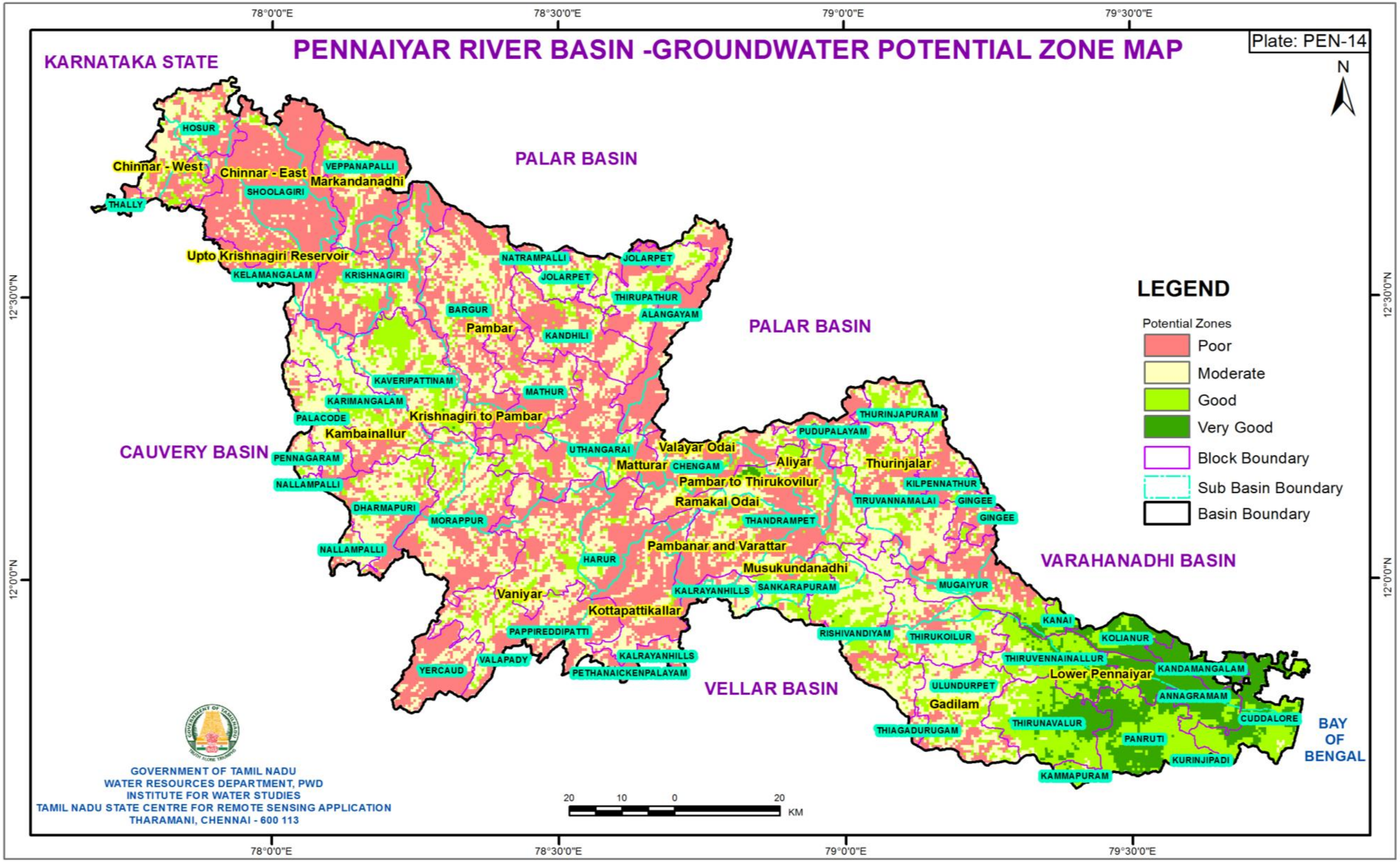


PENNAIYAR RIVER BASIN - LINEAMENT MAP
Plate: PEN-10
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Bogalur
Berikai
Gudisadanapalli
Kelavarapalli Res.
Hosur
Pedda Belagondapalli
Sulagiri
Sulagirichinnar Res.
Kuppachchiparai
Nagamangalam
Krishnagiri
Daulatabad
Krishnagiri Res.
Madageri
Jolarpet
Andiappanur Odai Res.
Tirupathur
Thumbalahalli Res.
Karimangalam
Kamakshipattai
Uttangarai
Pambar Res.
Melpennattur
Tiruvannamalai
Tandarampattu
Sathanur Res.
Dharmapuri
Vidiyur
Reddiyarpalayam
Harur
Batranayakkanpatti
Adanur
Pavenjipattu
Varattar Vallimarudai Res.
Alandur
Thirukoilur
Kannur
Maniyampalayam
Vaniar Res.
Arasur
Panruti
Cuddalore
Ulundurpettai
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
N
Legend
Location
Lineament
Lineament Intersection
Reservoir / River
Hills / Reserved Forest
Basin Boundary
30 15 0 30
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


PENNAIYAR RIVER BASIN - GEOLOGY WITH LINEAMENT MAP
Plate: PEN-11
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Geological Types
LINEAMENT INTERSECTION
LINEAMENT
ALLUVIUM
AMP/PYRO/ GRANULITE/METTA GABBRO
AN (ANORTHOSITE)
CHARNOCKITE (CH)
CLAY WITH L.St (Cl.L.St)
DOLERITE (DYKE)
GNEISSIC ROCKS
FLUVIO MARINE Sed / SHALE AND SILT
GARNETIFEROUS QUZ / FLS GNEISS
Gr/CH+PGGr/GINGEE Granite
LSt / CALCARIOUS LIMESTONE
MARINE SEDIMENTS / SILICA SAND
METTAGABBRO + FERRUGINOUS FORMATION
PM (PINK MIGMATITE)
QUARTZITE / FERRUGINEOUS QUARTZITE
SANDY CLAY LOAM / CLAYEY SAND
SANDSTONE / BEACH CLAY / GYPSUM
SYENITE (SY)
UM (ULTRAMAFICS)
ULTRABASIC SYENITE CARBONATITE COMPLEX
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
20 10 0 20
KM


PENNAIYAR RIVER BASIN - GEOMORPHOLOGY MAP
Plate: PEN-12
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Geomorphic Features
ALLUVIAL PLAIN
BAJADA
BEACH AND BEACH RIDGES
BEACH AND COASTAL PLAIN
BURRIED PEDIMENT (SHALLOW/DEEP)
COASTAL PLAIN
CRETACEOUS
PIEDMONT ZONE
HILLS & PLATEAUS
DENUDATIONAL HILLS / RESIDUAL HILLS
DOME(STRUCTURAL)
FLOOD PLAIN
INSELBERG
SEDIMENTARY HIGH GROUND
LINEAR / CURVILINEAR RIDGE
PEDIMENT
PLATEAUS
PEDIMENT-INSELBERG COMPLEX
PONDICHERRY
RIVER
SEDIMENTARY PLAIN
SHALLOW PEDIMENT
STRUCTURAL HILLS
VALLEYS
PEDIPLAIN
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
20 10 0 20
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


PENNAIYAR RIVER BASIN - GEOMORPHOLOGY WITH LINEAMENT MAP
Plate: PEN-13
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
Legend
Geomorphic Features
ALLUVIAL PLAIN
BAJADA
BEACH AND BEACH RIDGES
BEACH AND COASTAL PLAIN
BURRIED PEDIMENT (SHALLOW/DEEP)
COASTAL PLAIN
CRETACEOUS
PIEDMONT ZONE
HILLS & PLATEAUS
DENUDATIONAL HILLS / RESIDUAL HILLS
DOME(STRUCTURAL)
FLOOD PLAIN
INSELBERG
SEDIMENTARY HIGH GROUND
LINEAR / CURVILINEAR RIDGE
PEDIMENT
PLATEAUS
PEDIMENT-INSELBERG COMPLEX
PONDICHERRY
RIVER
SEDIMENTARY PLAIN
SHALLOW PEDIMENT
STRUCTURAL HILLS
VALLEYS
PEDIPLAIN
LINEAMENT INTERSECTION
LINEAMENT
20 10 0 20
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



PENNAIYAR RIVER BASIN -GROUNDWATER POTENTIAL ZONE MAP
Plate: PEN-14
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
LEGEND
Potential Zones
Poor
Moderate
Good
Very Good
Block Boundary
Sub Basin Boundary
Basin Boundary
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Valayar Odai
Matturar
Aliyar
Thurinjalar
Pambar to Thirukovilur
Ramakal Odai
Pambanar and Varattar
Musukundanadhi
Vaniyar
Kottapattikallar
Lower Pennaiyar
Gadilam
HOSUR
VEPPANAPALLI
SHOOLAGIRI
THALLY
KELAMANGALAM
KRISHNAGIRI
NATRAMPALLI
JOLARPET
JOLARPET
THIRUPATHUR
ALANGAYAM
BARGUR
KANDHILI
KAVERIPATTINAM
MATHUR
KARIMANGALAM
PALACODE
UTHANGARAI
CHENGAM
PENNAGARAM
NALLAMPALLI
DHARMAPURI
MORAPPUR
NALLAMPALLI
HARUR
THURINJAPURAM
PUDUPALAYAM
KILPENNATHUR
TIRUVANNAMALAI
GINGEE
GINGEE
THANDRAMPET
KALRAYANHILLS
SANKARAPURAM
MUGAIYUR
PAPPIREDDIPATTI
KALRAYANHILLS
PETHANAICKENPALAYAM
YERCAUD
VALAPADY
RISHIVANDIYAM
THIRUKOILUR
KANAI
KOLIANUR
THIRUVENNAINALLUR
KANDAMANGALAM
ULUNDURPET
ANNAGRAMAM
THIAGADURUGAM
THIRUNAVALUR
CUDDALORE
PANRUTI
KURINJIPADI
KAMMAPURAM
N
20 10 0 20 KM
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

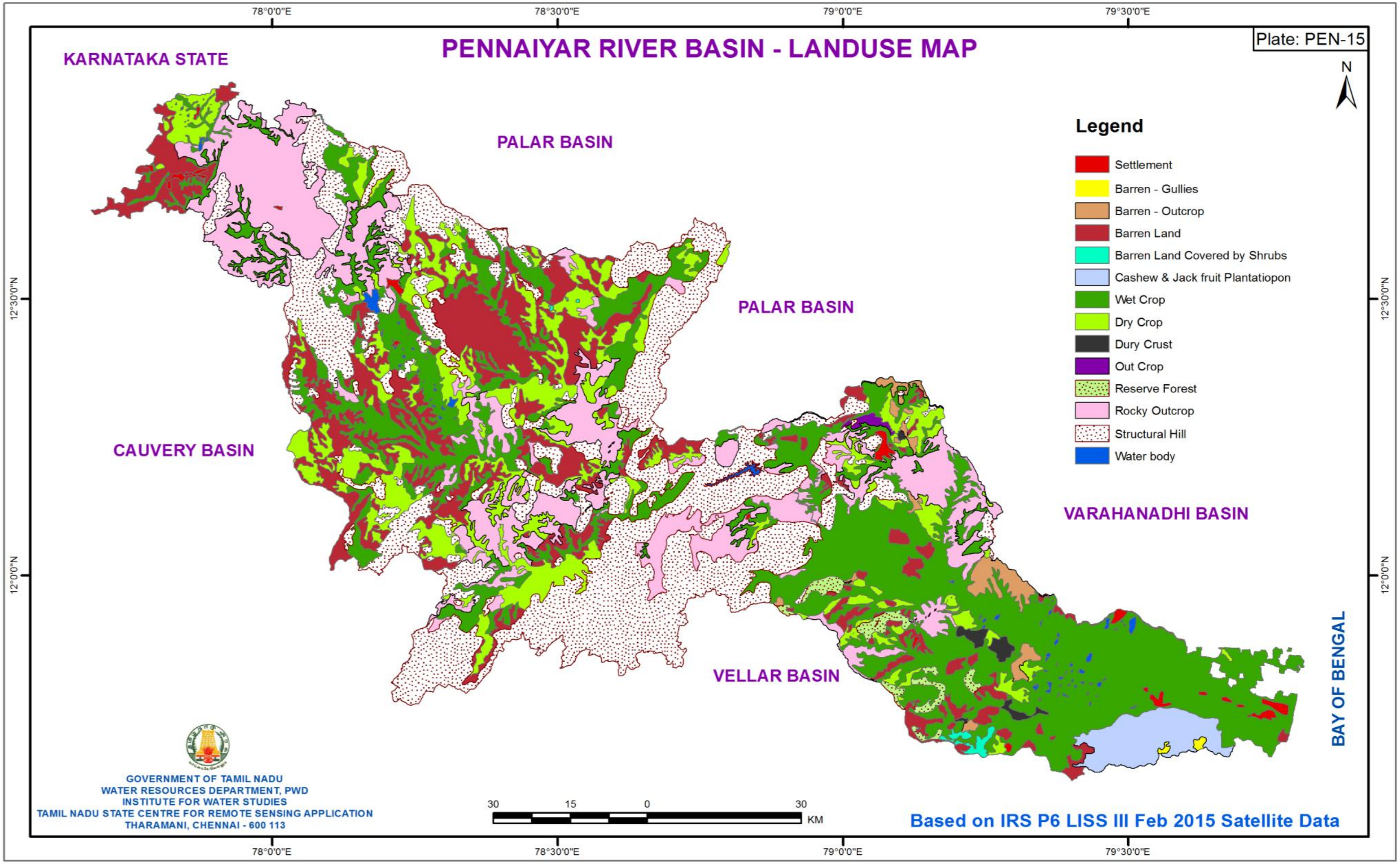
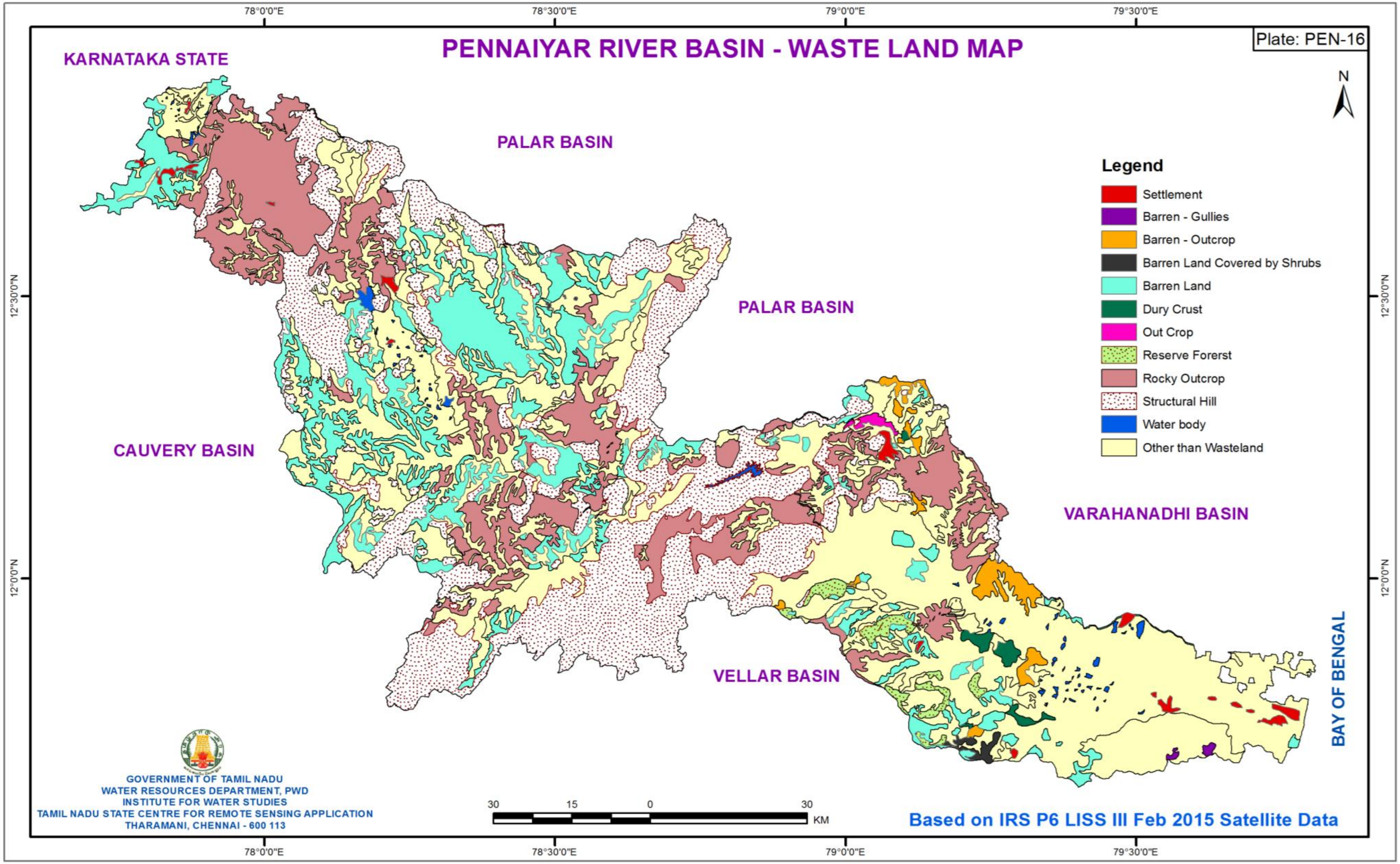
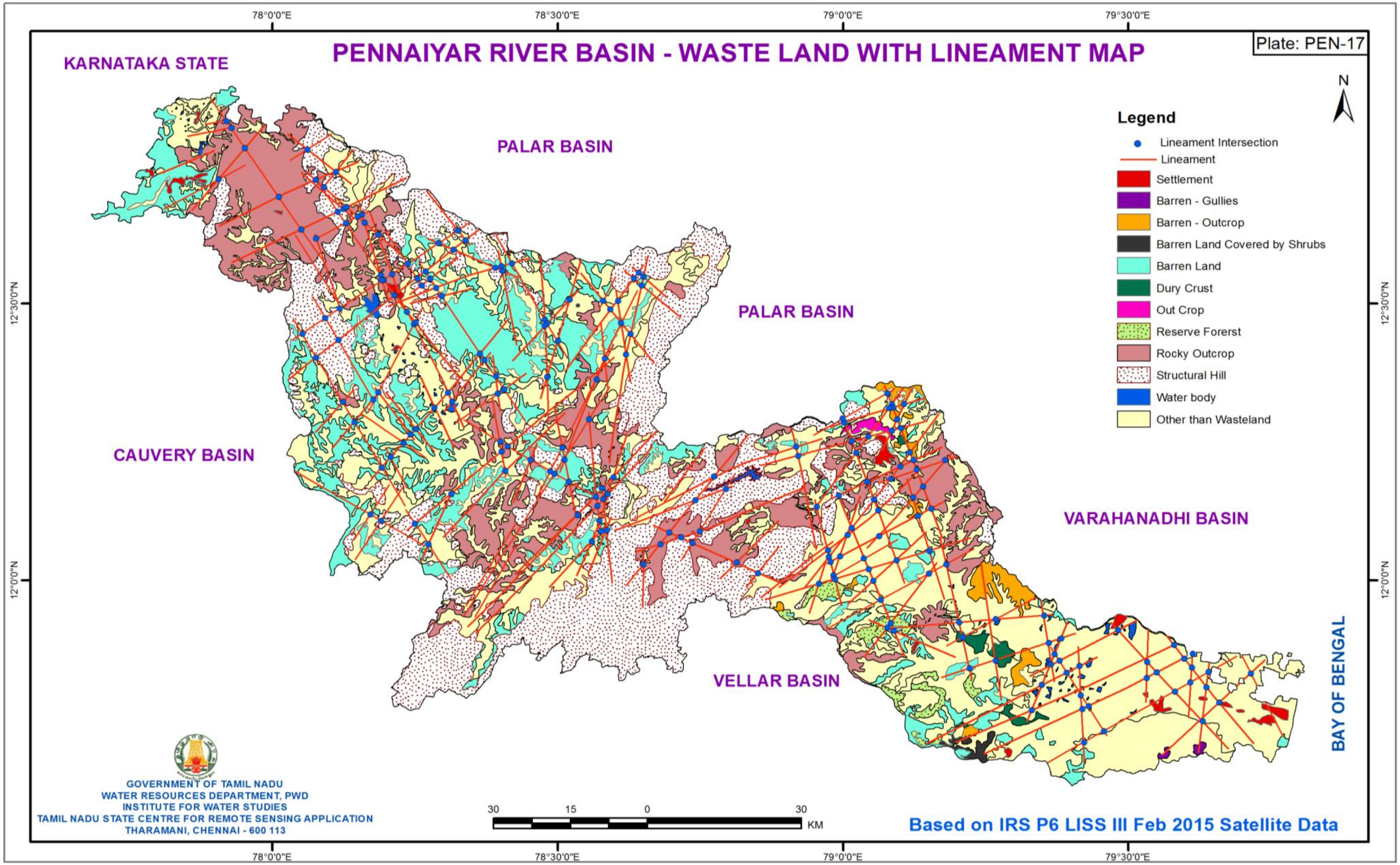
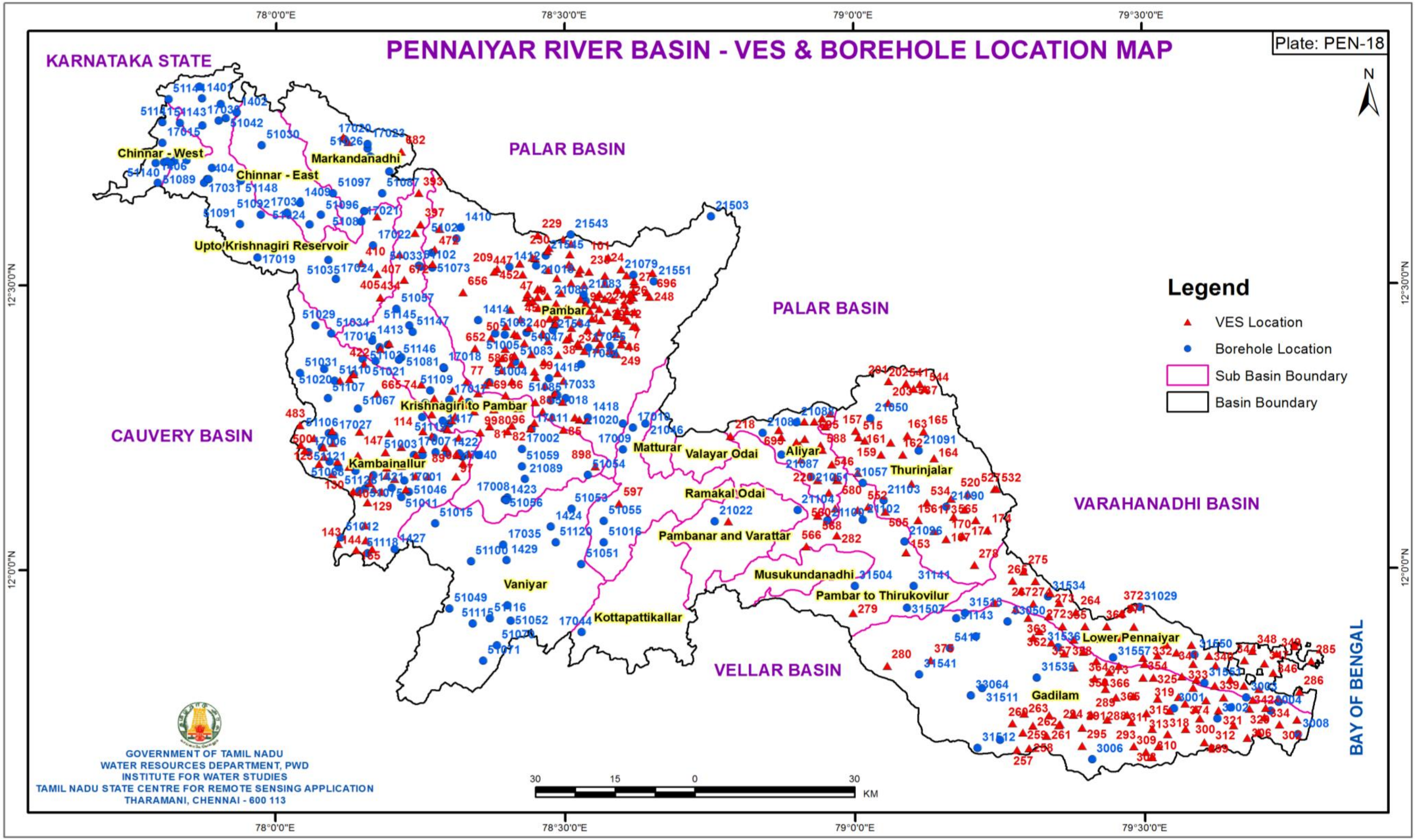
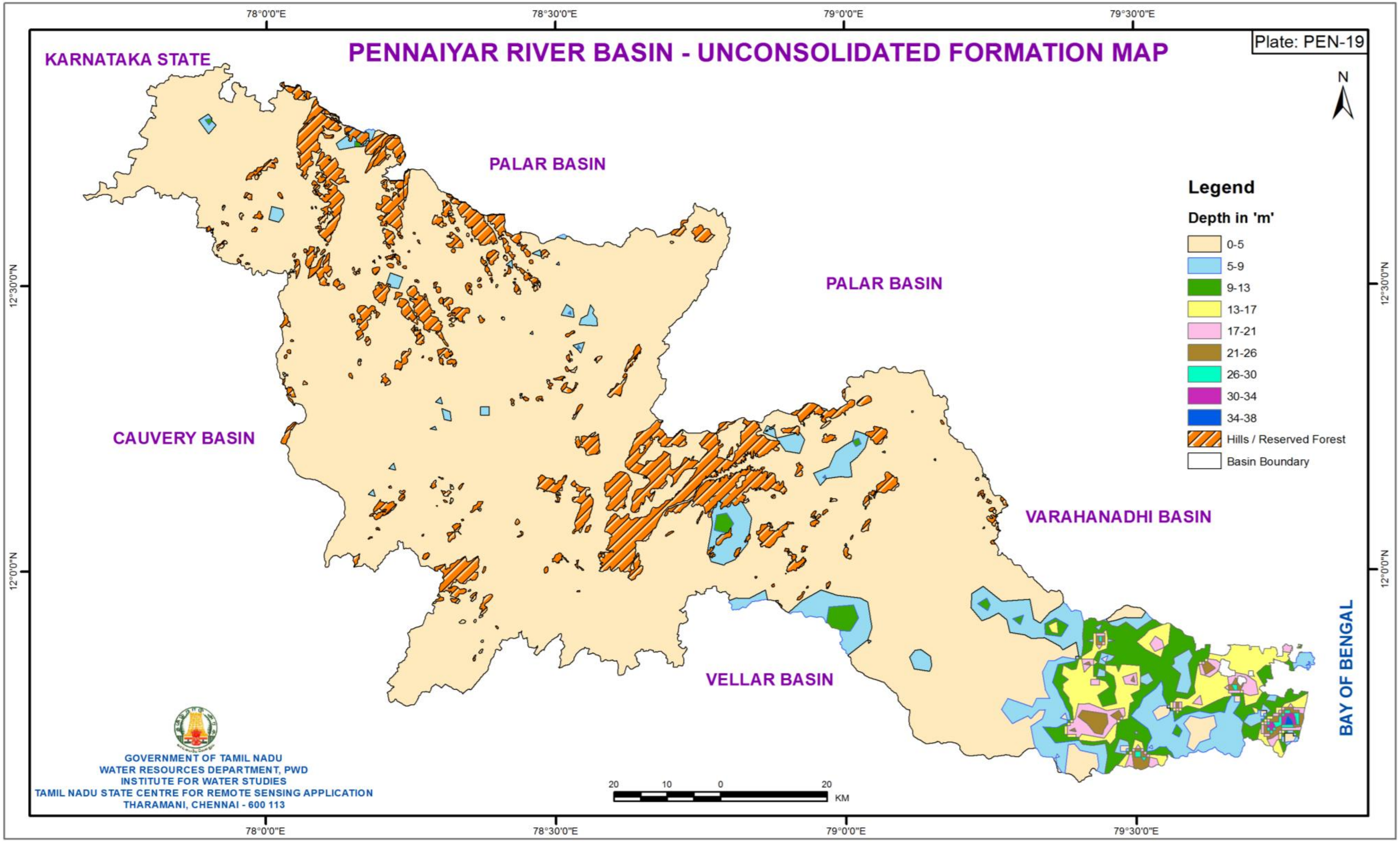


Plate: PEN-15
PENNAIYAR RIVER BASIN - LANDUSE MAP
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Settlement
Barren - Gullies
Barren - Outcrop
Barren Land
Barren Land Covered by Shrubs
Cashew & Jack fruit Plantatiopon
Wet Crop
Dry Crop
Dury Crust
Out Crop
Reserve Forest
Rocky Outcrop
Structural Hill
Water body
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
30 15 0 30
KM
Based on IRS P6 LISS III Feb 2015 Satellite Data

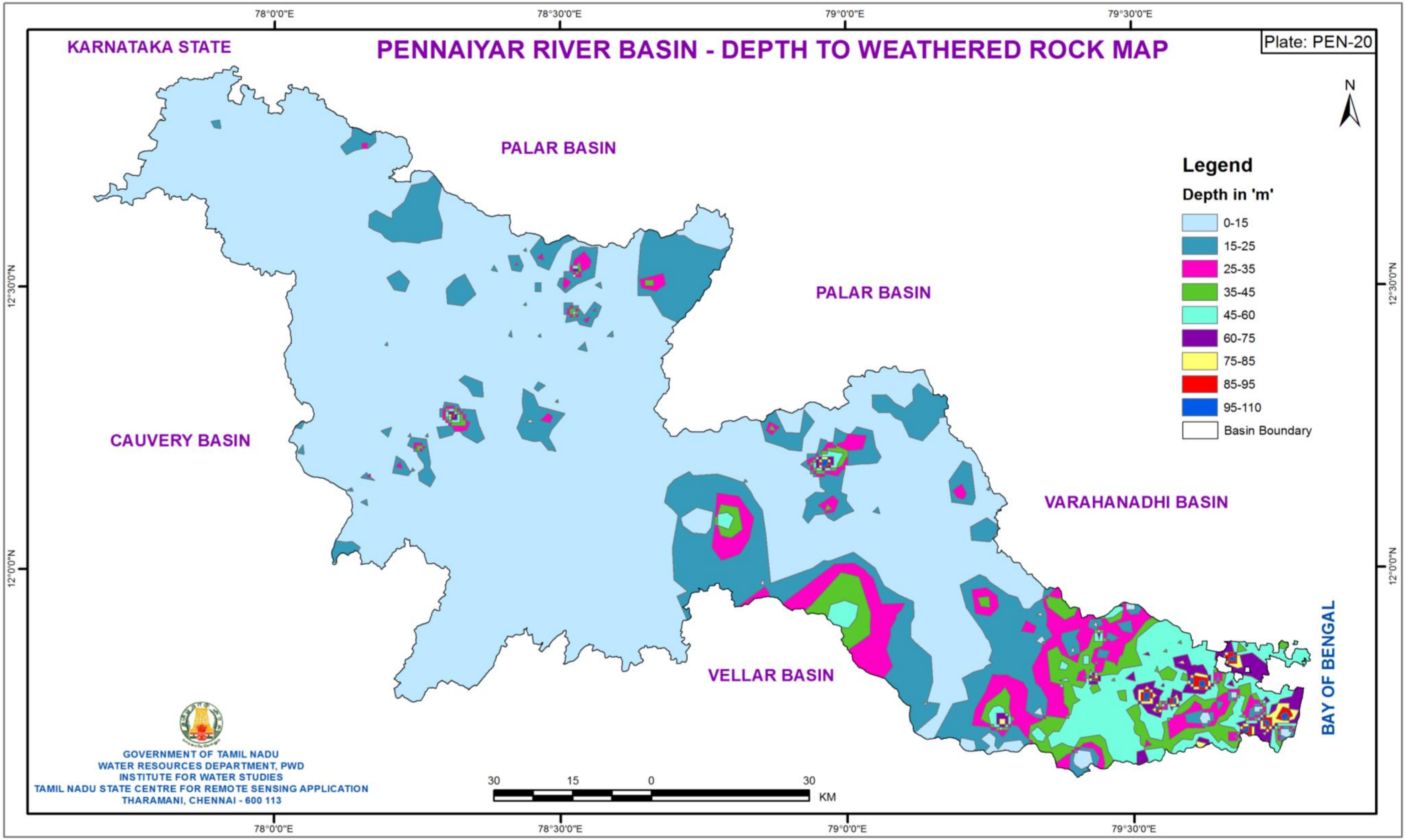

PENNAIYAR RIVER BASIN - WASTE LAND MAP
Plate: PEN-16
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Settlement
Barren - Gullies
Barren - Outcrop
Barren Land Covered by Shrubs
Barren Land
Dury Crust
Out Crop
Reserve Forerst
Rocky Outcrop
Structural Hill
Water body
Other than Wasteland
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30 15 0 30
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
Based on IRS P6 LISS III Feb 2015 Satellite Data

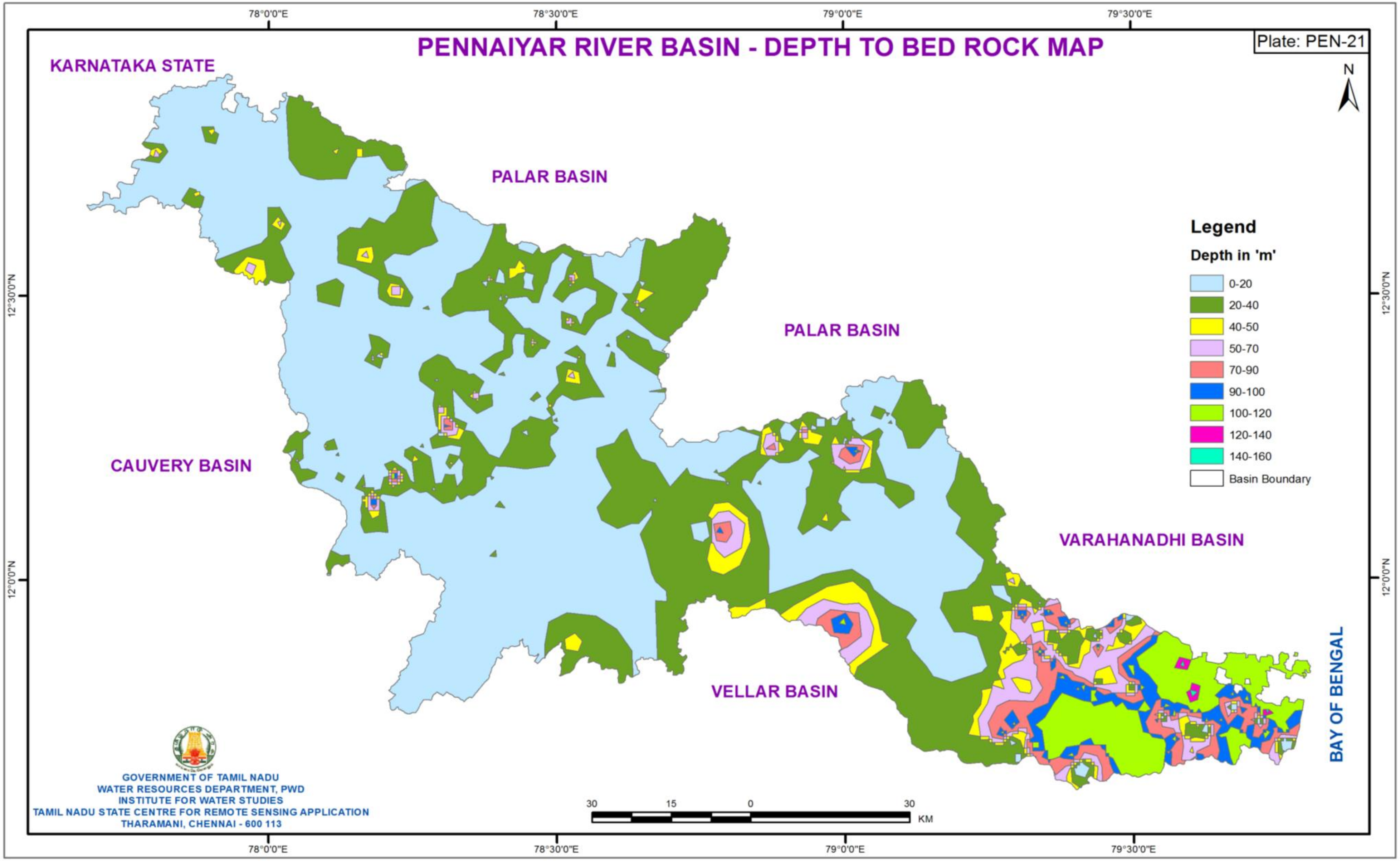

PENNAIYAR RIVER BASIN - WASTE LAND WITH LINEAMENT MAP
Plate: PEN-17
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Lineament Intersection
Lineament
Settlement
Barren - Gullies
Barren - Outcrop
Barren Land Covered by Shrubs
Barren Land
Dury Crust
Out Crop
Reserve Forerst
Rocky Outcrop
Structural Hill
Water body
Other than Wasteland
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
30 15 0 30
KM
Based on IRS P6 LISS III Feb 2015 Satellite Data

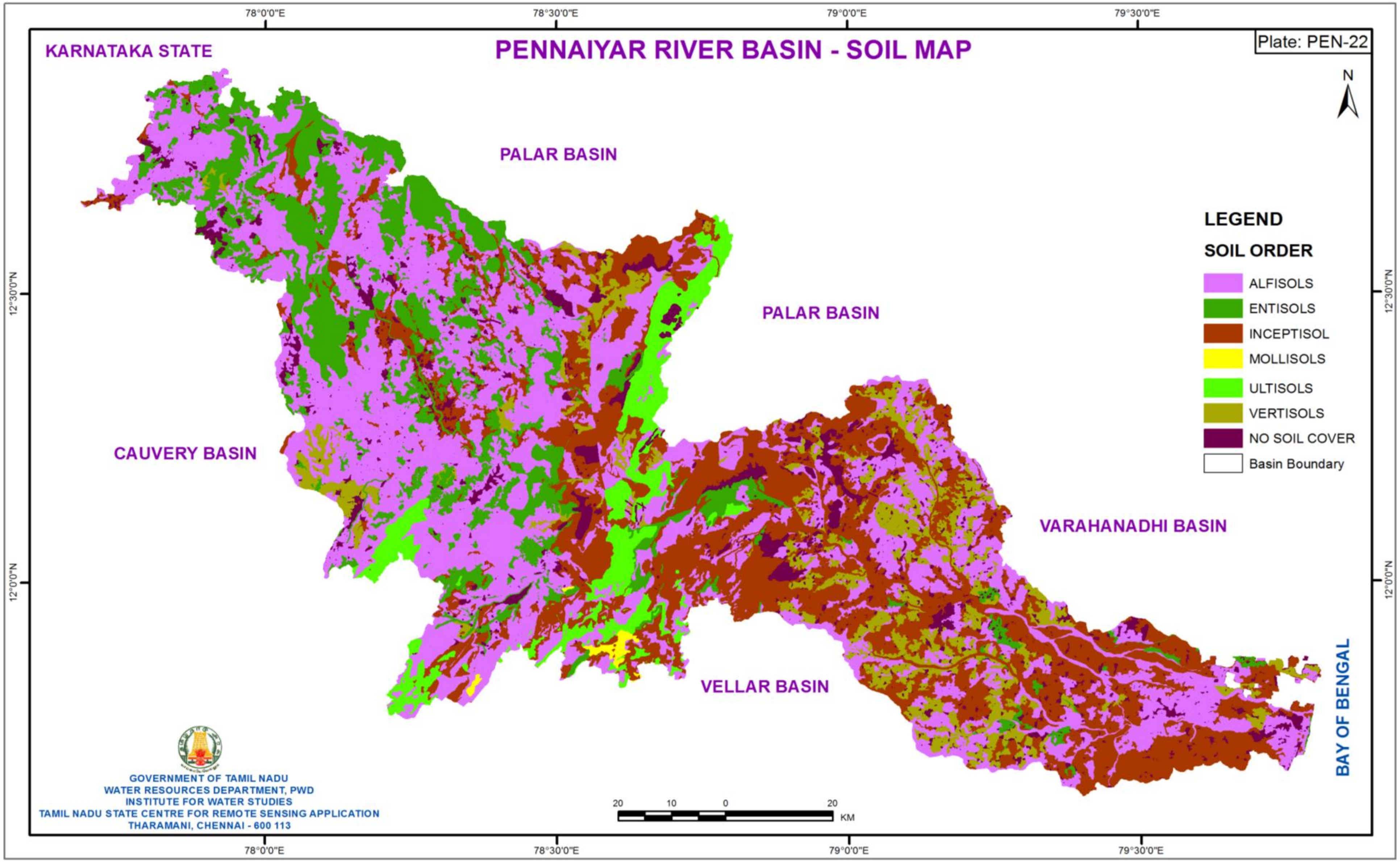

PENNAIYAR RIVER BASIN - VES & BOREHOLE LOCATION MAP
Plate: PEN-18
N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Matturar
Valayar Odai
Aliyar
Thurinjalar
Ramakal Odai
Pambanar and Varattar
Musukundanadhi
Pambar to Thirukovilur
Vaniyar
Kottapattikallar
Lower Pennaiyar
Gadilam
Legend
VES Location
Borehole Location
Sub Basin Boundary
Basin Boundary
30 15 0 30
KM
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113



PENNAIYAR RIVER BASIN - UNCONSOLIDATED FORMATION MAP
Plate: PEN-19
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Depth in 'm'
0-5
5-9
9-13
13-17
17-21
21-26
26-30
30-34
34-38
Hills / Reserved Forest
Basin Boundary
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
20 10 0 20
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


PENNAIYAR RIVER BASIN - DEPTH TO WEATHERED ROCK MAP
Plate: PEN-20
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Depth in 'm'
0-15
15-25
25-35
35-45
45-60
60-75
75-85
85-95
95-110
Basin Boundary
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30 15 0 30
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


PENNAIYAR RIVER BASIN - DEPTH TO BED ROCK MAP
Plate: PEN-21
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Depth in 'm'
0-20
20-40
40-50
50-70
70-90
90-100
100-120
120-140
140-160
Basin Boundary
30 15 0 30
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


PENNAIYAR RIVER BASIN - SOIL MAP
Plate: PEN-22
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
LEGEND
SOIL ORDER
ALFISOLS
ENTISOLS
INCEPTISOL
MOLLISOLS
ULTISOLS
VERTISOLS
NO SOIL COVER
Basin Boundary
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
20 10 0 20
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

CHAPTER – 3

HYDROMETEOROLOGICAL CHARACTERISTICS

CHAPTER - 3

HYDROMETEOROLOGICAL CHARACTERISTICS

3.1 General

Hydrometeorology is the scientific study of the interaction between meteorological and hydrologic phenomena, including the occurrence, motion, and changes of state of atmospheric water, and the land surface and subsurface phases of the hydrologic cycle. Various climatic variables such as rainfall, temperature, wind direction and evapo-transpiration together with physiographic factors such as drainage pattern, slope and aspect factors play significant role in the Hydrometeorology of a river basin. These factors are guided by geographical position and topography of the basin, which in turn controls the vegetation, rock and soil covers. These hydro-meteorological parameters represent and exhibit the nature of the environment of a river basin. Additionally, it also determines the setting up and viability of any development project and its management in such river basins.

The study made on the hydro-meteorological characteristics of the Pennaiyar 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.

Pennaiyar River Basin has an area of 11,375.55Sq.Km. and the entire basin lies in Cuddalore, Dharmapuri, Krishnagiri, Salem, Thiruvannamalai, Vellore & Villupuram districts. 44 Rain gauge stations and six climatic stations lie in this Basin. Rain gauge stations are maintained by Public Works Department, Revenue Department, and all the climatic stations are maintained by PWD.

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

3.2 Rainfall

3.2.1 Rain gauge Stations

In Pennaiyar basin, 44 no. of rain gauge stations and 6 weather stations (full climate stations) are available. Considering the distribution of rain gauge station and the availability of data for the period of 44 years only 33 stations are considered for obtaining average annual rainfall of this basin. The details of influencing and non-influencing rain gauge stations and district wise abstract of rain gauge stations in Pennaiyar basin is given in the **Table 3.1 (a), (b) and (c)**. For the purpose of rainfall analysis, month is taken as a time step.

3.2.2 Monsoon and Non-monsoon periods

Pennaiyar 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 rainfalls for 33 rain gauge stations are given in the **Appendix 3.1**. The Thiesson Polygon Map is given in **(Plate No: PEN – 20)** 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 3.20**. The season wise Isohyets maps (**Plate No: PEN –21 to 25)** are presented.

Table 3.1 (a)
Influencing Raingauge Stations of Pennaiyar River Basin

Sl. no	Name of Raingauge Station	Block	Taluk	District	Source	Lat	Long	Data Availability Period
1	Anaimaduvu Reservoir	Valapadi	Valapadi	Salem	PWD	11°46'27"	78°25'36"	1984-2015
2	Barur	kaveripattinam	Vellore	Krishnagiri	PWD	12°18'19"	78°18'25"	1971-2015
3	Chengam	Chengam	Thiruvannamalai	Thiruvannamalai	PWD	12°18'36"	78°47'35"	1971-2015
4	Cuddalore	Cuddalore	Cuddalore	Cuddalore	PWD	11°45'23"	79°45'57"	1971-2015
5	Dharmapuri	Dharmapuri	Dharmapuri	Dharmapuri	PWD	12°07'52"	78°09'43"	1971-2015
6	Gomukhi Reservoir	Kallakurichi	Kallakurichi	Villupuram	PWD	11°46'43"	78°49'49"	1971-2015
7	Harur	Harur	Harur	Dharmapuri	PWD	12°03'06"	78°28'30"	1971-2015
8	Hosur	Hosur	Hosur	Krishnagiri	PWD	12°43'38"	77°49'39"	1971-2015
9	Jolarpettai	Jolarpettai	Thiruppathur	Vellore	PWD	12°33'57"	78°34'37"	1971-2015
10	Kilnachipattu	Thiruvannamalai	Thiruvannamalai	Thiruvannamalai	PWD	12°14'21"	79°06'24"	1973-2015
11	Krishnagiri	Krishnagiri	Krishnagiri	Krishnagiri	PWD	12°31'32"	78°13'02"	1971-2015
12	Manimuthar Reservoir	Rishivanthiyam	Sankarapuram	Villupuram	PWD	11°48'36"	78°59'28"	1971-2015
13	Marandahalli	Palacode	Palacode	Dharmapuri	PWD	12°23'27"	77°59'28"	1978-2015
14	Melumalai	Soolagiri	Hosur	Krishnagiri	PWD	12°36'58"	78°05'14"	1975-2015
15	Nedungal	kaveripattinam	Pochampalli	Krishnagiri	PWD	12°22'26"	78°16'08"	1971-2015
16	Palacode	Palacode	Palacode	Krishnagiri	PWD	12°18'08"	78°04'24"	1971-2015
17	Panruti	Panruti	Cuddalore	Cuddalore	PWD	11°45'51"	79°33'01"	1971-2015
18	Pappireddypatty	Pappireddypatty	Pappireddypatty	Dharmapuri	PWD	11°55'04"	78°21'56"	1986-2015
19	Perugondapuram	Mathur	Pochampalli	Krishnagiri	PWD	12°21'50"	78°25'22"	1971-2015
20	PickupAnicut - Sathanur	Thandrampet	Chengam	Thiruvannamalai	PWD	12°08'22"	78°53'38"	1971-2015
21	Rayakotta	Kelamangalam	Denkanikottai	Krishnagiri	PWD	12°30'40"	78°01'52"	1971-2015
22	Sathanur Dam	Thandrampet	Thiruvannamalai	Thiruvannamalai	PWD	12°10'49"	78°51'05"	1971-2015
23	Thalli	Thalli	Hosur	Krishnagiri	PWD	12°35'03"	77°39'13"	1974-2015

Sl. no	Name of Raingauge Station	Block	Taluk	District	Source	Lat	Long	Data Availability Period
24	Thanipadi	Thandrampet	Thiruvannamalai	Thiruvannamalai	PWD	12°06'27"	78°50'06"	1971-2015
25	Thirukovilur	Thirukovilur	Thirukoilur	Villupuram	PWD	11°56'30"	79°11'32"	1971-2015
26	Thirupathur	Thirupathur	Thirukoilur	Villupuram	PWD	12°29'35"	78°33'57"	1971-2015
27	Thiruvannamalai	Thiruvannamalai	Chengam	Thiruvannamalai	PWD	12°14'04"	79°04'34"	1971-2015
28	Thoppaiyar Dam	Nallampalli	Dharmapuri	Dharmapuri	PWD	11°57'33"	78°06'24"	1988-2015
29	Ulundurpet	Ulundurpet	Ulundurpet	Villupuram	PWD	11°41'28"	79°17'23"	1971-2015
30	Uthangarai	Uthangarai	Uthangarai	Krishnagiri	PWD	12°15'52"	78°31'60"	1971-2015
31	Vanapuram	Thandrampet	Thiruvannamalai	Thiruvannamalai	PWD	12°06'16"	79°01'05"	1971-2015
32	Vaniambadi	Vaniampadi	Vaniampadi	Vellore	PWD	12°41'13"	78°37'07"	1973-2015
33	Villupuram	Kolianur	Villupuram	Villupuram	PWD	11°55'56"	79°28'52"	1971-2015

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

Sl. No	Name of Raingauge Station	Block	Taluk	District	Source	Latitutde	Longitude	Data Avilability Period
1	Bargur	Bargur	Krishnagiri	Krishnagiri	PWD	12°32'22"	78°21'55"	1999-2015
2	Ellis Anicut SRG	Thiruvennainallur	Villupuram	Villupuram	PWD	11°54'13"	79°23'54"	1988-2015
3	Krishnagiri Reservoir	Krishnagiri	Krishnagiri	Krishnagiri	PWD	12°28'20"	78°11'15"	1970-1981,1999-2014
4	Palur	Annagramam	Panruti	Cuddalore	PWD	11°44'49"	79°38'10"	2000-2015
5	Pambar Reservoir	Uthangarai	Uthangarai	Krishnagiri	PWD	12°15'45"	78°34'00"	1996-2015
6	Sitteri	Pappireddypatty	Pappireddypatty	Dharmapuri	PWD	11°53'24"	78°30'34"	1986-2015
7	Soolagiri	Soolagiri	Hosur	Krishnagiri	PWD	12°39'47"	78°00'43"	1996-2015

Sl. No	Name of Raingauge Station	Block	Taluk	District	Source	Latitutde	Longitude	Data availability Period
8	Thurinjapuram	Thurinjapuram	Thiruvannam alai	Thiruvannamal ai	PWD	12°18'30"	79°05'45"	1998-2015
9	Vanamadevi.	Cuddalore	Cuddalore	Cuddalore	PWD	11°44'31"	79°38'35"	1981-2015
10	Vaniyar reservoir	Pappireddypatty	Vaniyar	Dharmapuri	PWD	11°54'18"	78°19'30"	1999-2015
11	Yelagiri Hills	Jolarpettai	Thiruppathur	Vellore	PWD	12°35'02"	78°38'53"	2000-2015

Table 3.1 (c) District wise Raingauge Stations in Pennaiyar River Basin

Sl. No	District	No. of influencing Raingauge stations	No. of non-influencing Raingauge stations
1	Krishnagiri	10	4
2	Dharmapuri	5	2
3	Salem	1	-
4	Vellore	2	1
5	Thiruvannamalai	7	1
6	Villupuram	6	1
7	Cuddalore	2	2
	Total	**33**	**11**

Table 3.2 – Chinnar - West Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Chinnar - West				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	406.82	333.31	218.04	177.16	360.39
NE	300.26	205.98	117.06	91.95	243.05
Winter	3.75	0.00	0.00	0.00	5.36
Summer	217.53	138.44	106.98	68.46	159.10
Annual	955.21	655.66	500.94	455.81	767.90

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

Name of the Sub basin	Chinnar - East				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	477.72	343.78	260.84	211.79	371.80
NE	285.80	230.86	183.59	105.99	257.02
Winter	10.34	1.53	0.00	0.00	9.56
Summer	216.19	157.91	117.31	77.67	166.09
Annual	1007.00	809.25	630.78	542.76	804.47

Table 3.4 - Markandanadhi Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Markandanadhi				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	513.60	376.06	268.19	199.03	417.72
NE	369.82	245.92	186.40	108.55	284.59
Winter	9.49	1.74	0.00	0.00	11.61
Summer	220.40	182.49	113.33	58.51	181.30
Annual	1051.53	881.31	641.17	545.57	895.22

Table 3.5 - Kambainallur Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Kambainallur				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	507.80	434.78	322.77	272.13	425.49
NE	361.40	315.76	232.76	162.95	328.61
Winter	7.89	0.12	0.00	0.00	9.33
Summer	221.71	167.87	119.83	92.98	175.79
Annual	1137.01	894.80	720.00	631.13	939.21

Table 3.6 – Pambar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Pambar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	494.96	413.79	295.92	243.80	413.38
NE	332.22	263.23	203.43	162.09	280.43
Winter	6.28	1.30	0.00	0.00	7.49
Summer	178.71	135.09	82.59	60.10	135.72
Annual	958.36	824.56	657.40	605.93	837.02

Table 3.7 – Vaniyar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Vaniyar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	482.50	368.73	284.10	233.17	383.21
NE	425.06	332.55	262.51	190.40	346.38
Winter	10.90	1.54	0.00	0.00	11.75
Summer	179.79	147.02	109.41	84.80	146.71
Annual	1028.89	877.13	738.91	646.99	888.05

Table 3.8 – Matturar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Matturar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	475.04	369.79	294.67	205.02	380.25
NE	372.64	293.46	229.75	189.28	304.12
Winter	11.99	1.43	0.00	0.00	11.56
Summer	144.07	100.67	66.75	46.79	109.28
Annual	961.59	804.82	684.02	527.26	805.21

Table 3.9 – Kottapattikallar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Kottapattikallar				
Season	25%	50%	75%	90%	Average
SW	416.22	335.29	259.03	222.38	342.04
NE	351.22	267.32	159.41	121.38	274.17
Winter	5.15	0.00	0.00	0.00	7.21
Summer	175.30	132.28	94.88	64.42	133.76
Annual	912.34	749.33	582.59	508.09	757.17

Table 3.10 – Valayar Odai Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Valayar Odai				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	479.21	419.59	269.97	205.46	390.01
NE	468.53	361.39	236.56	197.56	369.15
Winter	15.18	4.36	0.00	0.00	15.18
Summer	123.74	94.24	69.71	35.48	101.39
Annual	1031.96	914.52	674.13	521.70	875.73

Table 3.11 – Ramakal Odai Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Ramakal Odai				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	474.24	360.82	249.45	182.41	368.77
NE	514.25	378.28	237.48	178.79	404.23
Winter	24.58	2.33	0.00	0.00	21.65
Summer	126.31	85.91	51.23	14.27	88.67
Annual	1026.82	844.10	698.49	614.16	883.31

Table 3.12 – Pambanar and Varattar Sub Basin- Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Pambanar and Varattar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	480.83	363.27	261.34	192.33	369.51
NE	522.76	381.16	245.92	187.42	406.41
Winter	23.47	3.68	0.00	0.00	21.71
Summer	121.80	83.31	51.58	14.84	89.05
Annual	1027.67	853.57	700.08	603.88	886.67

Table 3.13 – Aliyar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Aliyar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	462.6	372.9	271.8	214.7	377.5
NE	496.6	414.1	266.2	222.7	393.3
Winter	17.1	6.6	0.0	0.0	17.1
Summer	119.7	92.4	63.4	30.9	95.6
Annual	1020.8	888.2	713.6	558.0	883.4

Table 3.14 – Musukundanadhi Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Musukundanadhi				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
W	472.39	398.77	294.8	224.23	393.69
NE	556.34	401.18	229.05	176.69	410.61
Winter	30.16	7.71	0	0	20.1
Summer	132.4	79.35	47.54	31.61	93.24
Annual	1057.34	922.17	711.35	590.13	917.64

Table 3.15 – Thurinjalar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Thurinjalar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	507.02	430.17	328.72	300.71	437.27
NE	586.76	399.44	274.12	226.98	423.83
Winter	18.07	5.83	0.00	0.00	15.80
Summer	106.50	79.54	47.90	27.90	85.12
Annual	1186.49	963.63	762.39	574.38	962.02

Table 3.16 – Gadilam Sub Basin - Season wise – Dependable Rainfall (in mm)

Name of the Sub basin	Gadilam				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	470.30	405.54	336.36	281.05	403.87
NE	713.18	558.34	421.80	309.41	572.03
Winter	19.71	4.87	0.71	0.05	22.80
Summer	112.77	68.57	27.53	15.59	80.95
Annual	1284.59	1038.19	916.49	808.71	1079.64

Table 3.17 – Upto Krishnagiri Reservoir Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Upto Krishnagiri Reservoir				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	423.12	336.55	241.34	191.35	345.75
NE	309.02	246.58	164.27	100.95	250.59
Winter	6.83	0.54	0.00	0.00	6.66
Summer	192.73	134.02	93.67	85.66	145.17
Annual	953.41	713.55	565.90	468.74	748.16

Table 3.18 – Krishnagiri to Pambar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Krishnagiri to Pambar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	478.74	376.80	329.74	270.86	396.30
NE	400.45	289.62	216.56	173.59	313.50
Winter	10.50	2.20	0.00	0.00	9.05
Summer	182.65	147.93	92.42	82.57	144.22
Annual	985.36	853.33	714.11	651.01	863.07

Table 3.19 – Pambar to Thirukovilur Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Pambar to Thirukovilur				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	447.92	414.07	310.16	265.24	395.94
NE	474.72	391.73	280.52	221.70	387.33
Winter	18.17	5.87	0.95	0.00	16.11
Summer	120.42	93.95	62.25	49.46	100.66
Annual	1013.64	893.14	773.81	655.47	900.05

Table 3.20 – Lower Pennaiyar Sub Basin - Season wise - Dependable Rainfall (in mm)

Name of the Sub basin	Lower Pennaiyar				
Season	**25%**	**50%**	**75%**	**90%**	**Average**
SW	466.66	388.72	315.27	250.82	408.99
NE	714.73	601.74	383.70	330.37	565.52
Winter	29.08	6.94	0.67	0.04	24.91
Summer	101.62	55.59	28.61	9.24	72.84
Annual	1251.26	1068.12	890.63	726.30	1072.26

3.2.3 Dependable Rainfall

The 25%, 50%, 75% and 90% dependable rainfall for Pennaiyar River Basin are tabulated below in **Table 3.21**:

Table 3.21 - Dependable Rainfall in mm – Pennaiyar River Basin

Name of the basin	Pennaiyar Basin			
Season	**Dependability**			
	25%	**50%**	**75%**	**90%**
SW	470.4	381.2	284.9	228.6
NE	450.3	346.2	238.5	182.0
Annual	1044.8	865.8	698.8	591.4

3.2.4 Frequency Analysis

The range of annual precipitation and their frequency have been analysed and furnished in **Table 3.22**. From the table it is noticed that rainfall exceeding 1000mm occurred 50% of the study period (1971-2015) in Gomukhi Reservoir, Manimuthar Reservoir, Panruti and Vanapuram. Cuddalore out of 44 years rainfall exceeded 1000mm in 36 years. Rainfall in the range of 900-1000mm occurred nearly 30% of the study period in Barur. Rainfall in the range of 800-900mm occurred in nearly 30% of the study period in Dharmapuri. 600 to 800mm rainfall occurred nearly 40% of the study period in Anaimaduvu Reservoir, barur,harur, Jolarpet, Krishnagiri, Melumalai, Nedungal, Palacode, Pickup Anicut, Royakotta, Thali, Thanipadi, Thirupathur and Uthangarai. 400 to

600mm rainfall occurred nearly 40% of the study period in Hosur. 200 to 400mm rainfall occurred nearly 20% of the study period in Rayakotta.

Table 3.22 - 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	Anaimaduvu Reservoir	44	4	2	4	16	4	1	13
2	Barur	44	8	12	4	16	4	0	0
3	Chengam	44	18	6	7	9	4	0	0
4	Cuddalore	44	36	2	3	3	0	0	0
5	Dharmapuri	44	15	4	12	11	1	1	0
6	Gomukhi Reservoir	44	24	5	7	4	4	0	0
7	Harur	44	10	4	8	12	7	3	0
8	Hosur	44	7	5	3	9	16	4	0
9	Jolarpettai	44	14	6	6	12	6	0	0
10	Kilnachipattu	44	15	9	7	4	7	0	2
11	Krishnagiri	44	17	6	5	13	3	0	0
12	Manimuthar Reservoir	44	22	3	7	9	3	0	0
13	Marandahalli	44	5	7	9	11	3	2	7
14	Melumalai	44	10	6	5	12	6	1	4
15	Nedungal	44	14	6	5	12	7	0	0
16	Palacode	44	13	3	6	14	6	2	0
17	Panruti	44	27	3	4	6	1	3	0
18	Pappireddypatty	44	10	2	4	10	3	0	15
19	Perugondapuram	44	8	1	3	11	12	6	3
20	PickupAnicut - Sathanur	44	17	5	4	14	4	0	0
21	Rayakotta	44	3	4	1	14	10	8	4
22	Sathanur Dam	44	15	4	5	5	11	4	0

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
23	Thalli	44	11	10	4	12	4	0	3
24	Thanipadi	44	11	8	8	13	3	1	0
25	Thirukovilur	44	18	10	5	9	2	0	0
26	Thirupathur	44	12	7	3	12	10	0	0
27	Thiruvannamalai	44	17	6	5	11	5	0	0
28	Thoppaiyar Dam	44	1	1	3	5	8	4	22
29	Ulundurpet	44	18	7	8	10	1	0	0
30	Uthangarai	44	7	4	9	12	10	2	0
31	Vanapuram	44	22	6	2	7	6	1	0
32	Vaniambadi	44	10	5	6	11	8	2	2
33	Villupuram	44	21	7	7	6	3	0	0

3.2.5 Moving Average

The 5 years moving average graph for the annual rainfall has been drawn for the Nineteen sub basins. A linear fit has also been shown along with moving average curve. The details are given in **Appendix 3.2** and **Appendix 3.3** respectively.

All the sub basins are showing no remarkable change in trend line, except Chinnar East, Chinnar west, Markandanadhi, Valayar Odai, Vaniyar which are showing the decreasing trend.

3.2.6 Rainfall in different regions

Pennaiyar River Basin area from Tamil Nadu State boundary to Krishnagiri reservoir site has an undulating and hilly terrain. This terrain slopes from an altitude of about 880mt in a distance of about 50kms. Average topographical gradient is 8metres per Kilometre. The basin area from Krishnagiri Reservoir to Sathanur Reservoir has an undulating terrain with many hills and valleys along the eastern and western boundaries. Average topographical gradients are 2.27 meters per km.

The basin area from Sathanur Reservoir to Tirukoilur anicut has a plain terrain moderately sloping from an altitude of about 222metres at Sathanur reservoir to 81.25metres at Tirukoilur anicut. The average topographical gradient is 2.5metres per km.

The basin area from Tirukoilur anicut to sea is a plain terrain and slopes gently from an altitude of about 81.25metres at Tirukoilur to the mean sea level at the eastern and joins at Bay of Bengal. Average topographical gradient is 0.70 meters per km

Physiographically, this basin area can be broadly divided into three units, namely.

a) Western undulating and hilly terrain.
b) Central undulating terrain with hills and valleys.
c) Eastern plain terrain.

A. Western undulating and hilly terrain

The sub basins covered in this region are Chinnar East, Chinnar west, Markandanadhi & upto Krishnagiri Reservoir. The annual rainfall in this region ranges between 895.2 mm (Markandanadhi) to 767.9 mm (Chinnar west). Average topographical gradient is 8 metre per kilometer.

B. Central undulating terrain with hills and valleys

The sub basins covered in this Terrain are Pambar, Krishnagiri to Pambar, Kambainallur, Vaniyar, Matturar, Valayar Odai, Pambar to Thirukoilur, Aliyar, Ramakal Odai, Pambanar & Varattar and Kottapattikallar. The slope of the surface is generally towards southeast. The Average topographical gradient is 2.27 metre per kilometer. The annual average rainfall in this region ranges between 935.29mm (Kambainallur) to 757.17mm (Kottapattikallar).

C. Eastern plain terrain

The sub basins covered in this plain are Thurinjalar, Muskundanadhi, Gadilam and Lower Pennaiyar. In this plain area, the slope is towards East. The Average topographical gradient is 2.5 metre per kilometer upto Thirukoilur Anicut and 0.7 metre per kilometer from Thirukoilur to sea. The annual average rainfall in this region ranges between 1063.41mm (Lower Pennaiyar) to 917.64mm (Muskundanadhi).

3.2.7 Maximum, minimum and average rainfall

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

- Maximum Rainfall of this basin is 1079.64 mm [Gadilam]
- Minimum Rainfall of this basin is 748.16 mm [Upto Krishnagiri Reservoir]
- Average annual rainfall of the Pennaiyar River Basin is 882.43 mm

And each sub basin rainfall details are tabulated below **in Table 3.23**

Table 3.23 - Rainfall Details of the Pennaiyar Basin

Sl. No.	Name of the Sub-basin	No. of influencing Raingauage Staions	Rainfall range in mm (1971 - 72)-(2014-15)					Annual Average Rainfall in mm
			Annual	NE	SW	Winter	Summer	
1	Chinnar - West	2	1947.10 To 366.40	713.10 To 43.20	1033.60 To 116.30	63.0 To 0.0	425.10 To 20.4	767.90
2	Chinnar - East	2	1345.5 To 402.6	644.9 To 81.9	714.2 To 135.9	57.3 To 0.0	418.5 To 39.2	804.47
3	Markanda nadhi	3	1973.80 To 369.60	722.10 To 71.90	1050.60 To 151.40	74.0 To 0.0	413.0 To 40.70	895.22
4	Kambainallur	6	1621.90 To 486.40	847.60 To 85.90	797.80 To 85.90	70.60 To 0.0	412.40 To 63.90	939.21
5	Pambar	8	1336.70 To 465.0	641.20 To 66.80	744.90 To 141.0	85.5 To 0.0	257.80 To 48.80	837.02
6	Vaniyar	5	1582.8 To 602.60	616.90 To 99.40	882.30 To 112.70	94.60 To 0.0	241.10 To 38.90	888.05
7	Matturar	3	1182.60 To 439.60	595.40 To 53.30	646.20 To 150.10	119.10 To 0.0	271.40 To 26.90	805.21
8	Kottapatti kallar	4	1223.60 To 353.0	642.30 To 71.0	665.20 To 111.10	77.60 To 0.0	226.0 To 54.90	757.17
9	Valayar Odai	3	1337.20 To 424.50	787.90 To 68.30	704.10 To 110.30	104.90 To 0.0	197.0 To 10.0	875.73
10	Ramakal Odai	2	1688.70 To 359.20	1060.30 To 80.20	876.20 To 17.70	260.40 To 0.0	251.10 To 0.4	883.31
11	Pambanar and Varattar	2	1697.70 To 371.30	1038.50 To 90.0	881.10 To 25.40	245.10 To 0.0	250.70 To 1.50	886.67

Sl. No.	Name of the Sub-basin	No. of influencing Raingauage Staions	Rainfall range in mm (1971 - 72)-(2014-15)					Annual Average Rainfall in mm
			Annual	**NE**	**SW**	**Winter**	**Summer**	
12	Aliyar	5	1390.6 To 411.0	873.2 To 115.1	691.5 To 104.1	131.7 To 0.0	224.8 To 7.9	883.40
13	Musukunda nadhi	3	1748.90 To 413.90	903.50 To 77.70	880.90 To 95.40	165.10 To 0.0	263.20 To 1.20	917.64
14	Thurinjalar	4	1867.40 To 499.40	954.30 To 82.50	929.80 To 160.80	135.30 To 0.0	308.10 To 6.30	962.02
15	Gadilam	6	1837.6 To 658.2	1096.50 To 198.30	773.50 To 171.60	212.9 To 0.0	373.30 To 3.0	1079.64
16	Upto Krishnagiri Reservoir	4	1219.70 To 352.10	616.50 To 60.70	659.80 To 125.40	63.10 To 0.0	293.20 To 58.20	748.16
17	Krishnagiri to Pambar	8	1471.90 To 555.70	629.40 To 76.80	772.80 To 119.60	100.90 To 0.0	265.30 To 62.40	863.07
18	Pambar to Thirukovilur	9	1600.10 to 536.50	711.0 To 122.40	836.40 To 156.40	116.0 To 0.0	269.20 To 23.20	900.05
19	Lower Pennaiyar	4	1896.80 To 648.30	990.30 To 223.70	866.0 To 216.10	194.30 To 0.0	354.10 To 0.30	1072.26

3.2.8 Statistical Analysis

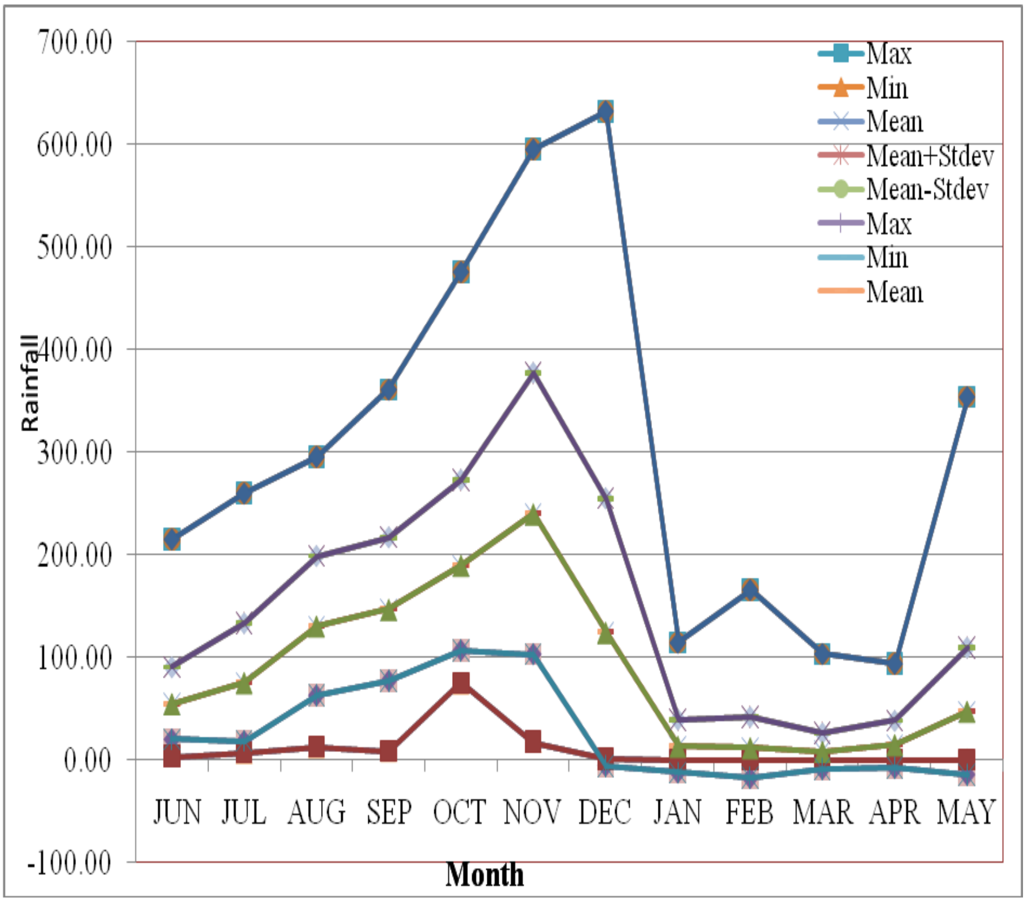
The statistical analysis for the rainfall data has been done for all the sub basins for the various seasons namely southwest, northeast, winter, summer and annual. The statistical results namely, Standard Deviation, Coefficient of variation, Skewness and Kurtosis have been analysed and tabulated in **Appendix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

The average value of the Pennaiyar River Basin statistical Parameters are

- Standard Deviation - 244.95
- Coefficient of variation - 0.28
- Skewness - 0.60
- Kurtosis - 0.75

The Statistical Parameters represents 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 Pennaiyar Sub-basin is given below in **Fig 3.1**:

Fig.3.1 Statistical Parameters of Lower Pennaiyar Sub-basin (1971-72 to 2014-15)



3.2.9 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 **3.24**

Table3.24 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 evapotranspiration (i.e. PET) of the following weather Stations are taken for calculating moisture Index is shown in **the Table 3.25**. The Moisture index (Im) for all the 33 rain gauge stations and for all the sub basins has been worked out in **Table 3.26**.

Table3.25 Annual Evapo Transpiration

Sl.No	**Station**	**Evapotranspiration (mm/year)**
1	Kilinachipattu	1658.75
2	Melumalai	1527.6
3	Palur	1644.99
4	Thirukoilur FCS	1563.77
5	Vaniyar reservoir	1479.94
6	Lekkur	1909.58

The Moisture index (Im) for all the sub basins are worked out in **Table 3.27** and the abstract is shown in **Table 3.28**

Table 3.26 - Moisture Index (Im) for Climatic Classification

Sl. No	Station Name	Annual Ave. Percipitation (P) mm	PET mm	Difference between P&PET mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
1	Anaimaduvu Reservoir	752.5	1480	727.5	0	49.2	-49.2	Semi-arid
2	Barur	848.0	1528	679.6	0	44.5	-44.5	Semi-arid
3	Chengam	940.2	1659	718.5	0	43.3	-43.3	Semi-arid
4	Cuddalore	1344.6	1645	300.4	0	18.3	-18.3	Dry Sub-humid
5	Dharmapuri	962.7	1480	517.3	0	35.0	-35.0	Semi-arid
6	Gomukhi Reservoir	1139.4	1564	424.4	0	27.1	-27.1	Dry Sub-humid
7	Harur	819.2	1480	660.8	0	44.6	-44.6	Semi-arid
8	Hosur	697.1	1528	830.5	0	54.4	-54.4	Semi-arid
9	Jolarpettai	895.5	1659	763.2	0	46.0	-46.0	Semi-arid
10	Kilnachipattu	924.3	1528	603.3	0	39.5	-39.5	Semi-arid
11	Krishnagiri	990.6	1528	537.0	0	35.2	-35.2	Semi-arid
12	Manimuthar Reservoir	977.2	1564	586.6	0	37.5	-37.5	Semi-arid
13	Marandahalli	810.6	1528	717.0	0	46.9	-46.9	Semi-arid
14	Melumalai	817.7	1528	709.9	0	46.5	-46	Semi-arid
15	Nedungal	886.4	1528	641.2	0	42.0	-42.0	Semi-arid
16	Palacode	892.0	1528	635.6	0	41.6	-41.6	Semi-arid

Sl. No	Station Name	Annual Ave. Percripitation P mm	PET mm	Difference between P&PET mm	Humidity Index (Ih in %)	Aridity Index (Ia in %)	Moisture Index (Im=Ih-Ia) (%)	Classification
17	Panruti	1208.7	1645	513.4	0	31.2	-31.2	Dry Sub-humid
18	Pappireddypatty	875.2	1480	604.7	0	40.9	-40.9	Semi-arid
19	Perugondapuram	665.7	1528	861.9	0	56.4	-56.4	Semi-arid
20	PickupAnicut - Sathanur	939.5	1659	719.3	0	43.4	-43.4	Semi-arid
21	Rayakotta	596.4	1528	931.2	0	61.0	-61.0	Semi-arid
22	Sathanur Dam	805.1	1659	853.7	0	51.5	-51.5	Semi-arid
23	Thalli	876.0	1528	651.6	0	42.7	-42.7	Semi-arid
24	Thanipadi	882.1	1659	776.7	0	46.8	-46.8	Semi-arid
25	Thirukovilur	984.8	1564	578.9	0	37.0	-37.0	Semi-arid
26	Thirupathur	851.3	1528	676.3	0	44.3	-44.3	Semi-arid
27	Thiruvannamalai	925.8	1659	733.0	0	44.2	-44.2	Semi-arid
28	Thoppaiyar Dam	509.0	1480	970.9	0	65.6	-65.6	Semi-arid
29	Ulundurpet	997.1	1645	647.8	0	39.4	-39.4	Semi-arid
30	Uthangarai	764.4	1659	894.3	0	53.9	-53.9	Semi-arid
31	Vanapuram	978.0	1564	585.7	0	37.5	-37.5	Semi-arid
32	Vaniambadi	807.4	1528	720.2	0	47.1	-47.1	Semi-arid
33	Villupuram	1000.3	1564	563.5	0	36.0	-36.0	Semi-arid

Table 3.27 - 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	Chinnar - West	767.9	1527.6	759.7	0	49.7	-49.7	Semi-arid
2	Chinnar - East	804.5	1527.6	723.1	0	47.3	-47.3	Semi-arid
3	Markandanadhi	895.2	1527.6	632.4	2	41.4	-39.4	Semi-arid
4	Kambainallur	939.2	1527.6	588.4	0	38.5	-38.5	Semi-arid
5	Pambar	837.0	1527.6	690.6	6	45.2	-39.2	Semi-arid
6	Vaniyar	888.0	1479.94	591.9	12	40.0	-28.0	Dry Sub-humid
7	Matturar	805.2	1658.75	853.5	3	51.5	-48.5	Semi-arid
8	Kottapattikallar	757.2	1479.94	722.8	0	48.8	-48.8	Semi-arid
9	Valayar Odai	875.7	1658.75	783.0	11	47.2	-36.2	Semi-arid
10	Ramakal Odai	883.3	1658.75	775.4	8	46.7	-38.7	Semi-arid
11	Pambanar and Varattar	886.7	1563.77	677.1	5	43.3	-38.3	Semi-arid
12	Aliyar	883.4	1658.75	775.3	0	46.7	-46.7	Semi-arid
13	Musukundanadhi	917.6	1563.77	646.1	4	41.3	-37.3	Semi-arid
14	Thurinjalar	962.0	1658.75	696.7	9	42.0	-33.0	Dry Sub-humid
15	Gadilam	1076.64	1563.77	509.8	0	32.6	-32.6	Dry Sub-humid
16	Upto Krishnagiri Reservoir	748.2	1527.6	779.4	10	51.0	-41.0	Semi-arid
17	Krishnagiri to Pambar	863.1	1527.6	664.5	0	43.5	-43.5	Semi-arid
18	Pambar to Thirukovilur	900.0	1479.94	579.9	7	39.2	-32.2	Dry Sub-humid
19	Lower Pennaiyar	1072.3	1644.99	581.6	1	35.4	-34.4	Semi-arid

Table 3.28 Sub Basin wise Climatic Classification

Sl.No	Sub Basin Name	Classification
1	Chinnar - West	Semi-arid
2	Chinnar - East	Semi-arid
3	Markandanadhi	Semi-arid
4	Kambainallur	Semi-arid
5	Pambar	Semi-arid
6	Vaniyar	Dry Sub-humid
7	Matturar	Semi-arid
8	Kottapattikallar	Semi-arid
9	Valayar Odai	Semi-arid
10	Ramakal Odai	Semi-arid
11	Pambanar and Varattar	Semi-arid
12	Aliyar	Semi-arid
13	Musukundanadhi	Semi-arid
14	Thurinjalar	Dry Sub-humid
15	Gadilam	Dry Sub-humid
16	Upto Krishnagiri Reservoir	Semi-arid
17	Krishnagiri to Pambar	Semi-arid
18	Pambar to Thirukovilur	Dry Sub-humid
19	Lower Pennaiyar	Semi-arid

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.

There are six climatic stations falling in this basin. Considering stations having long term records, only five stations are considered for analysis. The Location details of weather stations considered for analysis are furnished in **Table 3.29**

Table-3.29-Weather Stations

SI.No	Name of the weather station	Block	Sub-basin	Maintained by
1	Kilinachipattu	Thiruvannamalai	Thurinjalar	PWD
2	Melumalai	Soolagiri	Chinnar east	PWD
3	Palur	Annagramam	Gadilam	PWD
4	Thirukoilur FCS	Thirukovilur	Lower Pennaiyar	PWD
5	Vaniyar reservoir	Pappireddypatty	Vaniyar	PWD

The climatological values of this river basin are given in **Table 3.30**

Table-3.30-Climatological Parameters

SI. No	Climatological Parameter (Annual Average)	Kilinachi pattu	Melu malai	Palur	Thirukoilur FCS	Vaniyar reservoir
1	Average monthly temperature Maximum in ^{0} Celsius	36.21	35.4	36.11	36.17	33.90
2	Average monthly temperature Minimum in ^{0} Celsius	28.47	13.30	19.98	20.33	20.50
3	Average mean temperature in ^{0} Celsius	28.00	24.30	28.04	28.25	27.90
4	Average relative humidity in %	65.30	70.30	73.73	83.47	74.7
5	Average wind velocity in km/hour	5.50	3.30	4.89	6.16	3.90
6	Average Sunshine hours / day	5.20	6.80	6.55	6.04	5.80
7	Average Pan Evaporation in mm/month	172.30	271.30	163.59	161.70	142.40

3.4 Climate Change and its Impacts

3.4.1 Temperature

The meteorological features of the basin have been studied from the data collected from weather stations. Temperature is one of the basic factors under climatological features and it is one of the main parameters to calculate the crop water requirement (i.e. reference crop evapo-transpiration). The maximum and minimum monthly average temperature observed in the climatological station is given below.

Table-3.31-Temperature

Sl. No	Temperature	Name of the Weather Station				
		Kilinachi pattu	Melu malai	Palur	Thirukoi lur FCS	Vaniyar reservoir
1	Monthly average Maximum Temperature	43.00 (May-2001)	40.0 (May-2003)	43.00 (Jun-2003)	43.50 (May-2003)	41.00 (May-2003
2	Monthly average Minimum Temperature	15.00 (Jan-2012)	9.00 (Dec-1998)	14.00 (Jan-2002)	17.00 (Dec-2007)	13.00 (Dec-2002)

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

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 observed in the climatological stations is given in **Table-3.32** and **Appendix-3.4.**

Table-3.32- Relative Humidity

Sl. No	**Relative Humidity**	**Name of the Weather Station**				
		Kilinachi pattu	**Melu malai**	**Palur**	**Thirukoilu r FCS**	**Vaniyar reservoir**
1	Monthly average Relative Humidity varies	From 89.55% Nov1993 to 46.40% May1996	From 95.25% Nov2013 to 53.35% Apr2010	From 89.73% Nov2010 to 51.23% May 2002	From 99.35% Aug2000 to 51.18% May-2002	From 91.6% Dec2006 to49.81% Mar2004

3.4.2 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 observed in the climatologically stations is given in **Table-3.33** & **Appendix-3.4.**

Table-3.33-Wind Speed

Sl. No	Wind Speed	Name of the Weather Station				
		Kilinachi pattu	**Melu malai**	**Palur**	**Thirukoilur FCS**	**Vaniyar reservoir**
1	Monthly average Wind velocity varies	From 14.59 Km/hr (Dec1995) to 0.89 Km/hr (Mar1995)	From 16.36 Km/hr (Jan2010) to 0.30 Km/hr (Apr2013)	From 9.50 Km/hr (June2003) to 1.77Km/hr (Oct 2013)	From 14.23 Km/hr (May2006) to 0.81 Km/hr (Dec-2014)	From 8.20Km/hr (Jul2002) to0.90 (Nov2008)

3.4.3. Sunshine

The monthly average sunshine hours of the climatological station is given in **Table-3.34** & **Appendix-3.4.**

Table-3.34-Sunshine

Sl. No	Sun shine	Name of the Weather Station				
		Kilinachi pattu	**Melu malai**	**Palur**	**Thirukoilur FCS**	**Vaniyar reservoir**
1	Monthly average Sunshine varies.	From 8.37 hrs/day (Mar2005) to 1.95 hrs/day (Nov2014)	From 10.39 hrs/day (Apr2002) to 2.43 hrs/day (Jul2013)	From 10.05 hrs/day (Apr2002) to 3.32 hrs/day (Jul2013)	From 11.70 hrs/day (Aug2008) to 2.39 hrs/day (Dec-2010)	From 10.05 hrs/day (Apr2002) to3.0 hrs/day (Nov2010)

3.4.4 Evaporation

Evaporation is one of the main factors causing hydrologic cycle, particularly in arid and semi arid region. The loss of water is caused due to evaporation, particularly in arid and semi arid region. 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 stations, are tabulated and given in **Appendix-3.4.**

Evapotranspiration

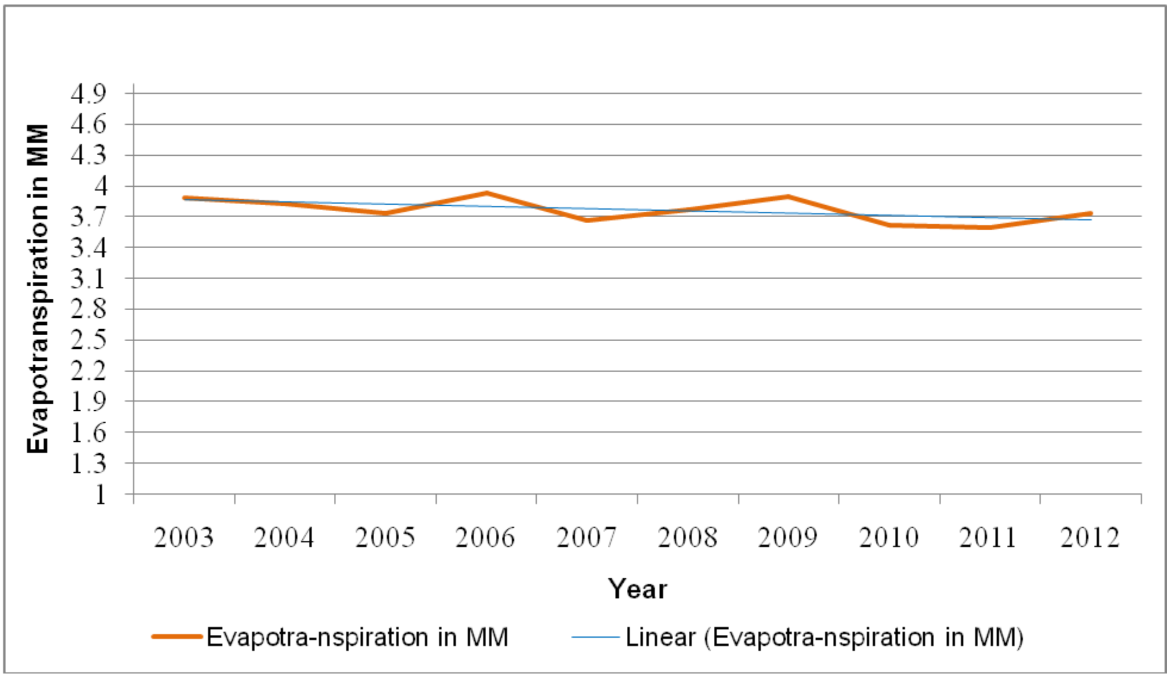
The monthly average ETo in mm for the Weather stations are estimated using Penman Montieth Method. The estimated ETo values for the stations are given in Appendix-3.4.

Potential Evapotranspiration (PET)

PET arrived for Palur station is 1644.99mm. The potential Evapotranspiration (PET) for each month for the entire basin has been arrived and tabulated in Appendix-3.4.

There is not much change in the trend of Potential Evapotranspiration for Palur (2003 to 2012) and is shown in **Fig 3.2.**

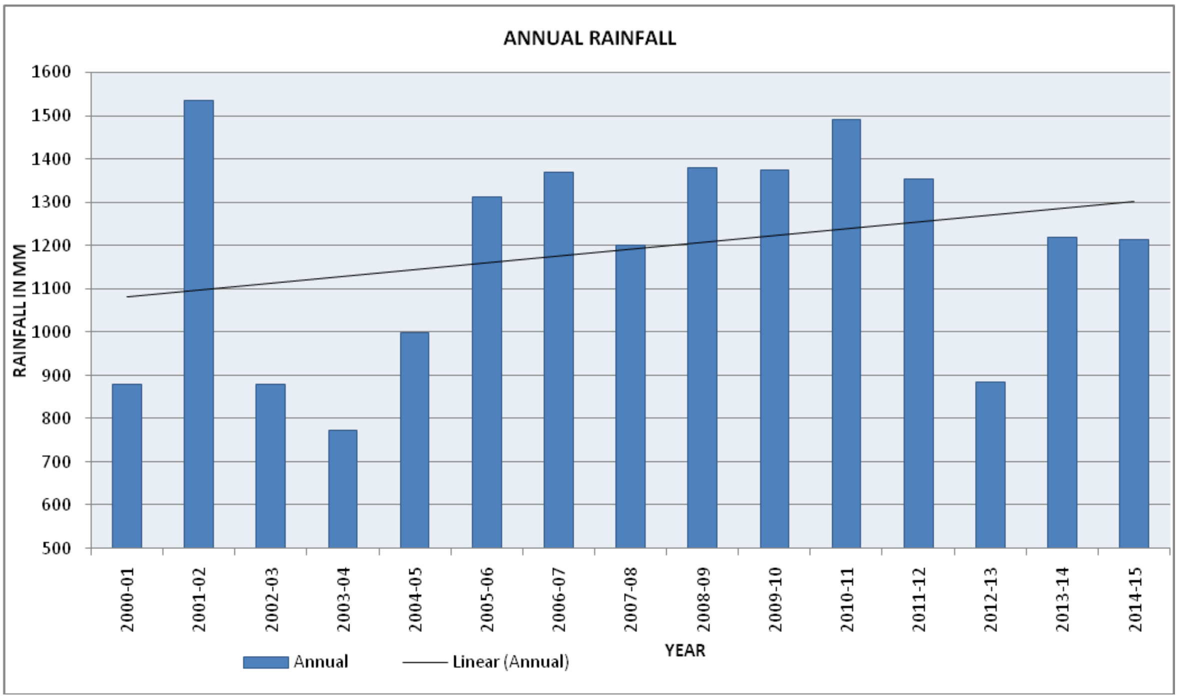
Fig.3.2 Evapotranspiration of weather Station in Palur (2003 to 2012)

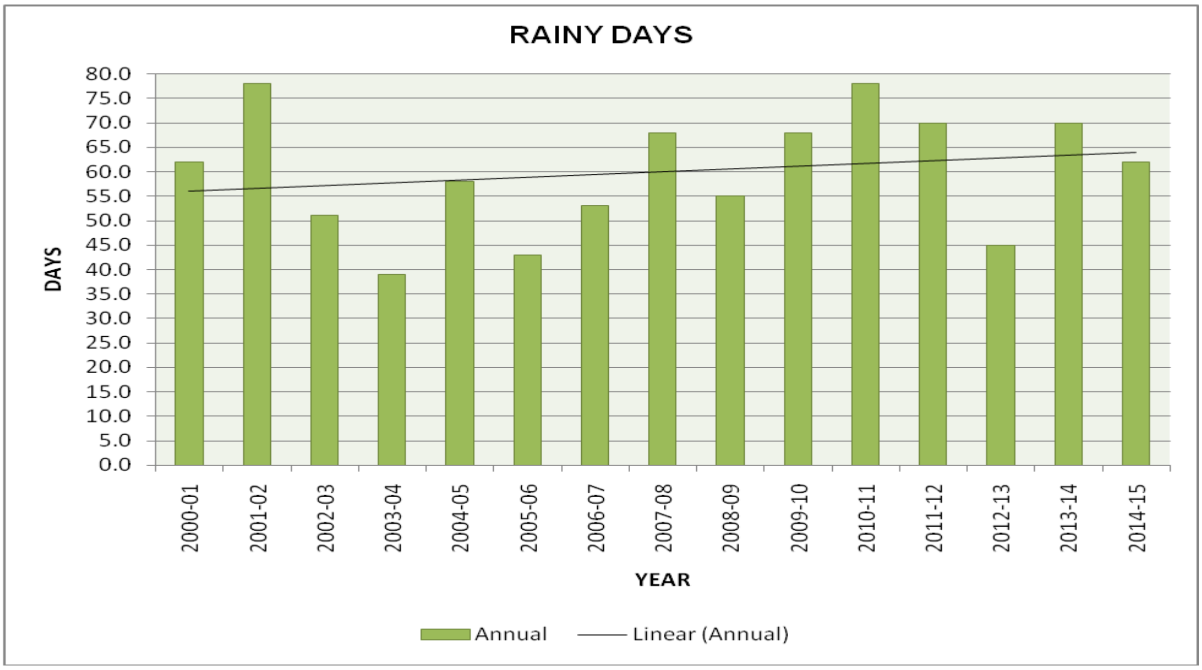


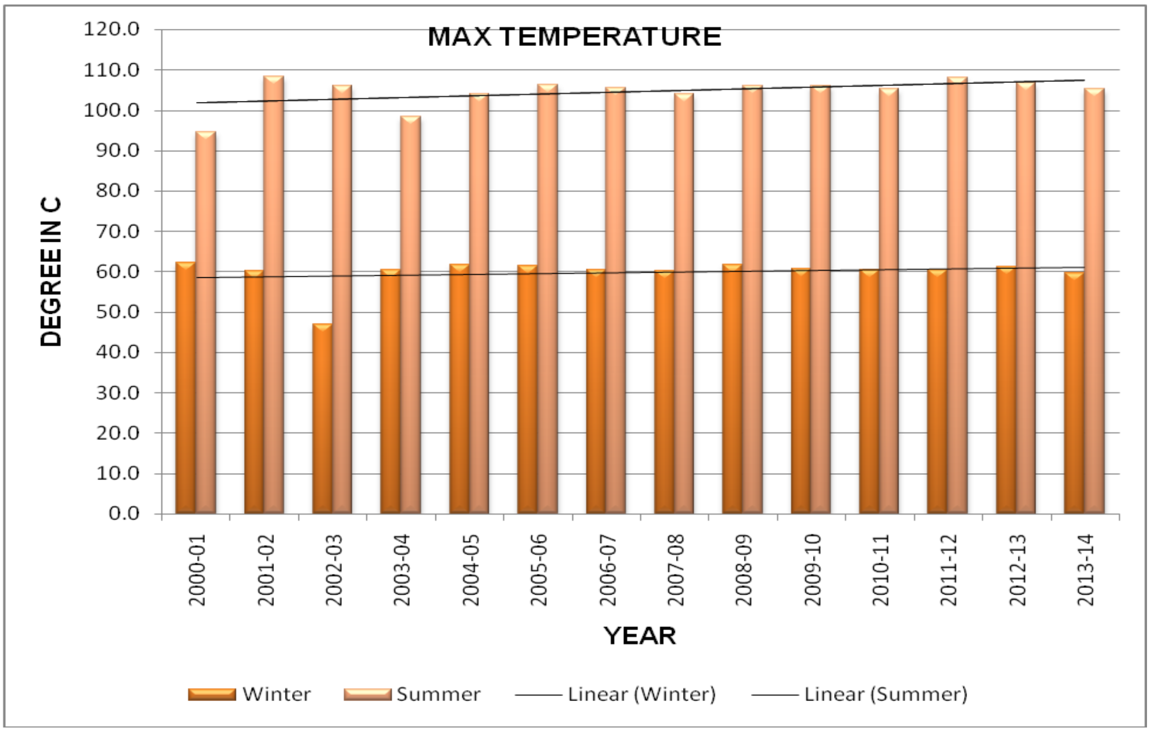
To study the climatic pattern of Pennaiyar river Basin climatic data (2000-2015) of the weather station **in Palur is taken for analysis** and its results are given below:

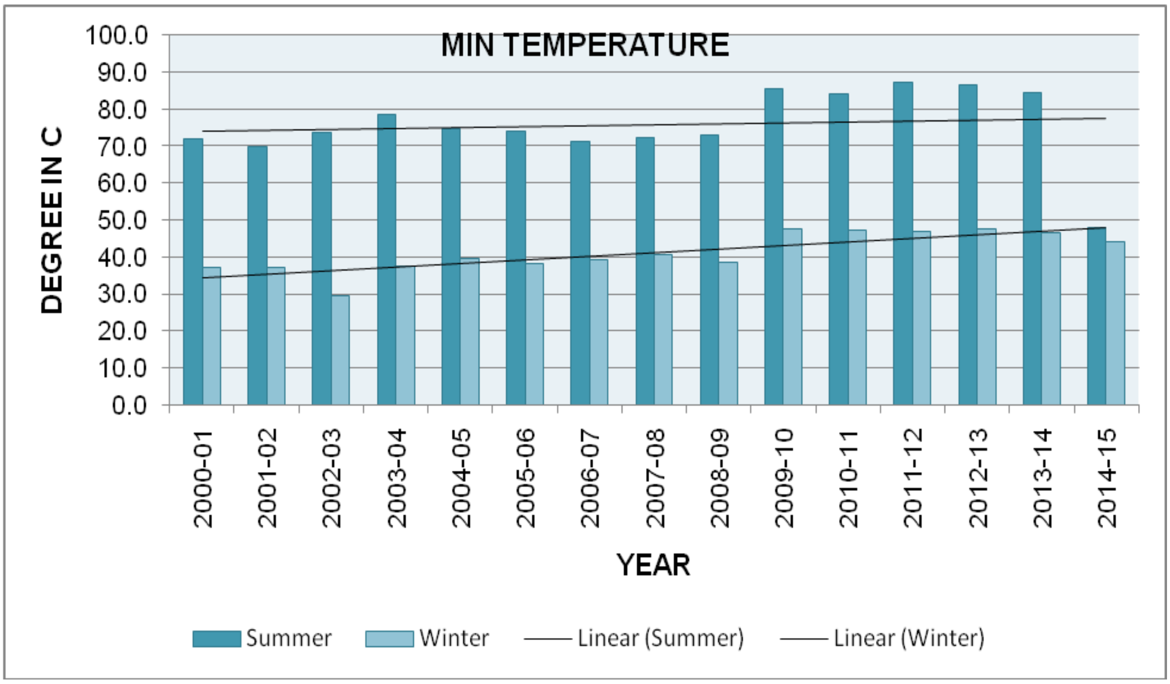
- The trend of annual rainfall increases
- The trend of number of rainy days also increases
- There is very marginal increase in summer & winter maximum temperature.
- Increase Trend line of summer and winter minimum temperature

Fig 3.3 Results of climatic data – Palur (2000-2015)









3.4.5 Drought Assessment

India 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

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

Where Pi is the annual rainfall in the year i and 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 3.35**

Table-3.35 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 ten years for all the thirty three rain gauge stations. The drought severity such as no, mild, moderate and severe drought for thirty three stations from the available data were found out and presented in **Table 3.36** and an abstract is also given in **Table 3.37**. It is observed from the **Table 3.36 & 3.37** that Mo (No Drought) is more than the M1, M2 & M3 (Mild, Moderate and Severe Drought). This basin is not frequently drought prone. Some of the years have been moderately drought years. Severe drought conditions was felt only in a few Stations like Harur – (2003-04,2007-08,2008-09,2009-10) – Vaniyar Sub basin, Thirupathur - (2013-14, 2014-15) - Pambar Sub basin,

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

- Harur area comes under the grip of **moderate to severe drought** more frequently i.e 4 times out of 15 years.
- In Thirupathur of Vellore district, severe drought occurred in 2 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 - 3.36 Meteorological Drought in Palar River Basin using IMD Method Drought

(MO - No Drought-M1 - Mild Drought, M2 - Moderate Drought, M3 - Severe Drought)

(2001-02 to 2014-15)

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
1	Anaimaduvu Reservoir	M1	M2	M2	M0	M0	M0	M1	M0	M1	M0	M0	M1	M1	M0
2	Barur	M0	M2	M0	M1	M0	M2	M0	M1	M0	M0	M2	M1	M1	M2
3	Chengam	M0	M1	M0	M1	M0	M1	M0	M1	M0	M0	M1	M0	M2	M1
4	Cuddalore	M1	M2	M1	M0	M0	M0	M0	M0	M0	M0	M0	M1	M1	M0
5	Dharmapuri	M0	M1	M0	M0	M0	M3	M1	M1	M1	M0	M2	M0	M1	M1
6	Gomukhi Reservoir	M0	M1	M0	M0	M0	M1	M0	M0	M0	M0	M1	M1	M2	M1
7	Harur	M1	M2	M3	M1	M2	M2	M3	M3	M3	M2	M1	M0	M1	M1
8	Hosur	M0	M1	M0	M0	M0	M2	M0	M0	M0	M0	M2	M2	M1	M2
9	Jolarpettai	M0	M2	M1	M2	M0	M1	M1	M0	M0	M0	M0	M1	M1	M2
10	Kilnachipattu	M0	M2	M1	M1	M0	M2	M0	M1	M1	M0	M0	M1	M1	M0
11	Krishnagiri	M0	M2	M0	M1	M0	M2	M0	M0	M0	M0	M3	M2	M1	M1
12	Manimuthar Reservoir	M0	M1	M0	M0	M0	M0	M0	M0	M0	M0	M0	M1	M0	M1
13	Marandahalli	M0	M2	M0	M0	M0	M1	M1	M0	M1	M0	M2	M1	M0	M1
14	Melumalai	M1	M2	M0	M2	M0	M1	M0	M0	M0	M0	M3	M1	M1	M1
15	Nedungal	M2	M2	M0	M2	M0	M0	M0	M2	M0	M0	M2	M2	M1	M1
16	Palacode	M0	M1	M0	M0	M0	M2	M1	M0	M1	M0	M2	M1	M2	M1

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
17	Panruti	M1	M1	M0	M0	M0	M0	M0	M0	M1	M0	M3	M3	M3	M3
18	Pappireddypatty	M1	M2	M1	M1	M0	M1	M0	M0	M1	M0	M2	M1	M2	M2
19	Perugondapuram	M0	M1	M0	M0	M0	M1	M0	M1	M2	M1	M2	M1	M0	M1
20	PickupAnicut - Sathanur	M1	M1	M0	M1	M0	M1	M0	M2	M0	M0	M0	M1	M1	M1
21	Rayakotta	M0	M0	M0	M1	M0	M3	M0	M0	M0	M0	M2	M1	M0	M1
22	Sathanur Dam	M2	M2	M2	M0	M0	M0	M0	M0	M0	M0	M0	M0	M1	M0
23	Thalli	M0	M2	M1	M0	M0	M2	M0	M0	M0	M0	M0	M1	M1	M0
24	Thanipadi	M1	M1	M0	M1	M0	M1	M0	M0	M0	M0	M0	M1	M1	M1
25	Thirukovilur	M1	M2	M0	M0	M0	M0	M0	M0	M1	M0	M2	M0	M1	M1
26	Thirupathur	M0	M0	M0	M0	M0	M1	M0	M0	M0	M0	M1	M2	M3	M3
27	Thiruvannamalai	M0	M2	M0	M0	M0	M1	M0	M0	M0	M0	M0	M0	M0	M1
28	Thoppaiyar Dam	M0	M3	M0	M0	M0	M0	M0	M0	M1	M0	M1	M1	M0	M1
29	Ulundurpet	M0	M1	M1	M0	M1	M1	M0	M2	M1	M0	M1	M2	M1	M1
30	Uthangarai	M2	M3	M0	M0	M0	M1	M0	M1	M1	M0	M1	M1	M0	M0
31	Vanapuram	M0	M1	M0	M0	M0	M2	M0	M0	M0	M0	M0	M0	M0	M0
32	Vaniambadi	M0	M2	M0	M1	M0	M1	M0	M0	M0	M0	M0	M1	M2	M2
33	Villupuram	M2	M2	M0	M1	M0	M0	M0	M1	M0	M0	M0	M1	M1	M1

Table 3.37 - Abstract of Drought Assessment (From 2001-02 to 2014-15)

Sl.No.	STATION CODE	M0	M1	M2	M3
1	Anaimaduvu Reservoir	7	6	2	0
2	Barur	7	4	4	0
3	Chengam	7	7	1	0
4	Cuddalore	9	4	2	0
5	Dharmapuri	7	6	1	1
6	Gomukhi Reservoir	9	5	1	0
7	Harur	2	5	4	4
8	Hosur	9	2	4	0
9	Jolarpettai	6	6	3	0
10	Kilnachipattu	7	6	2	0
11	Krishnagiri	8	3	3	1
12	Manimuthar Reservoir	11	4	0	0
13	Marandahalli	8	5	2	0
14	Melumalai	7	5	2	1
15	Nedungal	7	2	6	0
16	Palacode	7	5	3	0
17	Panruti	8	3	0	0
18	Pappireddypatty	4	7	4	0
19	Perugondapuram	7	6	2	0
20	PickupAnicut - Sathanur	7	7	1	0
21	Rayakotta	10	3	1	1
22	Sathanur Dam	10	1	4	0
23	Thalli	10	3	2	0
24	Thanipadi	8	7	0	0
25	Thirukovilur	8	5	2	0
26	Thirupathur	10	2	1	2
27	Thiruvannamalai	12	2	1	0
28	Thoppaiyar Dam	10	4	0	1
29	Ulundurpet	4	9	2	0
30	Uthangarai	8	5	1	1
31	Vanapuram	12	1	2	0
32	Vaniambadi	9	3	3	0
33	Villupuram	8	5	2	0

North east Monsoon 2015

The Three month long season has given excess rain over Tamil Nadu. For the overall season from October 1st to December 31st Tamil Nadu has recorded 673.3mm of rain against the normal rain of 439.5 mm.

The rainfall recorded in some of the station falling in Pennaiyar Basin is tabulated below.

North east Monsoon 2015									
District	**Station**	**Oct**	**Nov**	**Dec**	**Total NE**	**44 Yrs avg (LPA)**	**% of Deviation**	**Highest RF in MM**	**Year of occurrence**
Krishnagiri	Barur	191.80	144.40	55.80	392.00	319.98	22.51	706.60	2005-06
	Hosur	156.00	180.00	15.00	351.00	223.69	56.91	672.80	2005-06
	Melumalai Fcs	174.00	98.00	9.00	281.00	265.61	5.79	630.60	2005-06
	Royakkottai	112.00	161.00	7.00	280.00	219.37	27.64	678.60	1999-2000
	Thalli	100.00	117.00	0.00	217.00	245.30	-11.54	982.00	2005-06
	Uthangarai	63.40	180.30	46.50	290.20	279.42	3.86	979.60	1991-92
Dharma-puri	Harur	68.20	330.30	114.80	513.30	321.52	59.65	759.10	1996-97
	Pappireddipatti	82.80	336.40	75.40	494.60	366.79	34.85	1035.50	2005-06
Vellore	Vaniyambadi	89.60	434.40	22.80	546.80	263.44	107.56	676.00	2005-06
Thiruvanna malai	Chengam	110.90	311.55	42.70	465.15	378.65	22.85	744.10	1997-98
	Kilnatchipattu Fcs	75.70	413.70	71.50	560.90	403.63	38.96	1086.50	1973-74
	Sathanur Anaicut	111.60	402.00	61.40	575.00	356.03	61.50	943.70	2005-06
	Thiruvannamalai	74.65	398.30	42.80	515.75	395.43	30.43	808.00	1996-97
Villupuram	Thirukoilur Fcs	104.30	530.90	163.50	798.70	444.82	79.56	830.70	2005-06
	Ulundurpet	46.00	351.00	238.00	635.00	509.09	24.73	1072.00	2007-08
	Villupuram	80.00	790.30	341.00	1211.30	525.34	130.57	1167.50	1997-98
Cuddalore	Cuddalore	151.00	822.20	654.70	1627.90	850.86	91.32	1370.00	1997-98
	Panruti	14.20	755.80	494.60	1264.60	663.06	90.72	1893.80	2005-06

* **LPA- Long Period Average**.

From the Table is seen that Cuddalore recorded 1627.90mm rainfall which is highest in this basin whereas its LPA is 850.86mm following Panruti and Villupuram stations.

The highest percentage of deviation recorded in Villupuram as 130.57 following Vaniyambadi 107.56. Cuddalore and Panruti stations recorded 91.32 and 90.72 percentage respectively. Unprecedented rainfall recorded only at Cuddalore station of this basin.

3.5 Summary

Pennaiyar River Basin is divided into Nineteen 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 3.38.** The 44 years annual average rainfall of the basin is 882.43 mm which is lower than the Tamil Nadu normal rainfall which is equal to 921.0 mm. (Statistical hand book of Tamil Nadu 2014)

The previous water plan study of Pennaiyar River Basin was carried out in the year 2004 by IWS. The data period considered in IWS study was from 1935-2003 and the average annual rainfall of the basin was reported as 874.89 mm. When compared to the previous study, the average annual rainfall of Pennaiyar River Basinis found to be on more or less equal (882.43mm).

In general, Pennaiyar basin, receives slightly more rainfall in South west monsoon than North East monsoon.

With respect to adequacy of rain gauge Stations, Sub basins like Kottapattikallar (410.23 Sq.Km), Mushkundanadhi(179.26 Sq.km), Markandanadhi (368.21 Sq.Km) sub basin does not have any rain gauge stations.

Most of the sub basins in this basin having average annual rainfall of 800 to 1000mm.Coastal sub basins average annual rainfall of more than 1000mm.The highest rainfall of 1079.64mm was received in Gadilam sub basin. Similarly lowest rainfall of 748.16mm was received in Upto Krishnagiri Reservoir sub basin.

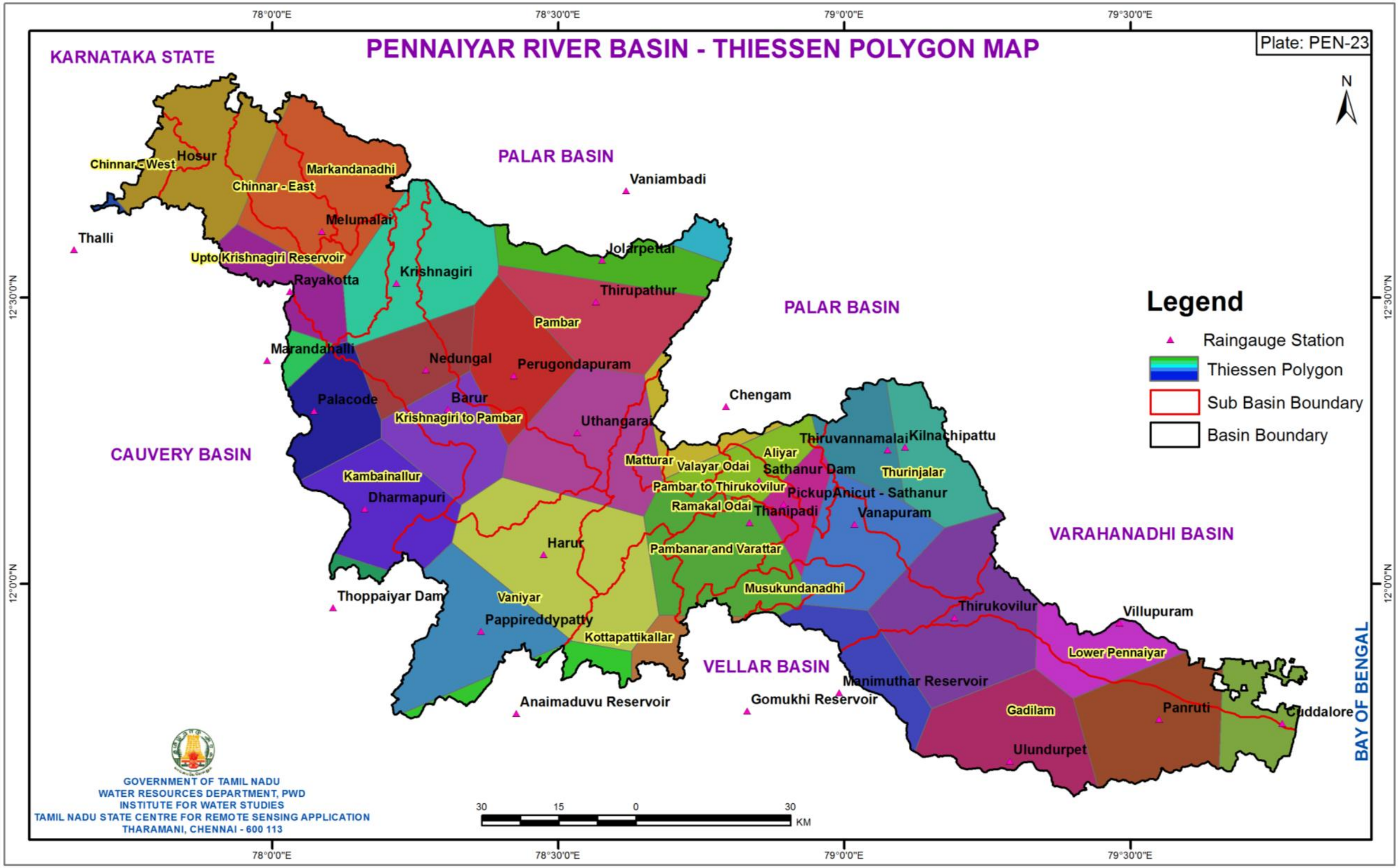
Table 3.38 - Influencing Rainguage Stations of each sub-basin

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	Chinnar - West	1	Thalli	7.72	125.32	0.06	922.20	767.90
		2	Hosur	117.60		0.94	449.70	
2	Chinnar - East	1	Melumalai	203.41	307.96	0.66	619.50	804.47
		2	Hosur	104.55		0.34	449.70	
3	Markandanadhi	1	Krishnagiri	6.67	368.21	0.02	772.90	895.22
		2	Melumalai	355.49		0.97	619.50	
		3	Hosur	6.04		0.02	449.70	
4	Kambainallur	1	Rayakotta	25.50	919.28	0.03	554.70	939.21
		2	Dharmapuri	386.18		0.42	791.00	
		3	Nedungal	31.35		0.03	743.60	
		4	Barur	137.03		0.15	622.70	
		5	Palacode	284.77		0.31	741.60	
		6	Marandahalli	54.44		0.06	750.00	
5	Pambar	1	Thirupathur	454.27	1757.42	0.26	421.20	837.02
		2	Vaniambadi	58.10		0.03	590.30	
		3	Uthangarai	258.71		0.15	811.60	
		4	Perugondapuram	340.19		0.19	640.40	

		5	Nedungal	71.01		0.04	743.60	
		6	Krishnagiri	271.72		0.15	772.90	
		7	Jolarpettai	270.41		0.15	710.34	
		8	Barur	33.03		0.02	622.70	
6	Vaniyar	1	Harur	397.41	998.39	0.40	617.00	888.05
		2	Dharmapuri	75.51		0.08	791.00	
		3	Pappireddypatty	474.24		0.48	620.60	
		4	Anaimaduvu Reservoir	34.65		0.03	810.00	
		5	Uthangarai	16.58		0.02	811.60	
7	Matturar	1	Chengam	12.42	58.50	0.21	813.40	805.21
		2	Thanipadi	1.71		0.03	744.60	
		3	Uthangarai	44.37		0.76	811.60	
8	Kottapattikallar	1	Harur	188.94	410.23	0.46	617.00	757.17
		2	Anaimaduvu Reservoir	65.54		0.16	810.00	
		3	Thanipadi	72.05		0.18	744.60	
		4	Gomukhi Reservoir	83.69		0.20	1100.40	
9	Valayar Odai	1	Chengam	42.82	85.39	0.50	813.40	875.73
		2	Thanipadi	3.20		0.04	744.60	
		3	Sathanur Dam	39.37		0.46	814.00	
10	Ramakal Odai	1	Thanipadi	14.10	14.41	0.98	744.60	883.31
		2	Sathanur Dam	0.32		0.02	814.00	
11	Pambanar and Varattar	1	Thanipadi	268.58	292.09	0.92	744.60	886.67
		2	PickupAnicut - Sathanur	23.51		0.08	795.00	
12	Aliyar	`	Vanapuram	21.10	211.07	0.10	995.00	883.40

		2	Chengam	21.05		0.10	813.40	
		3	Thiruvannamalai	7.97		0.04	814.00	
		4	Sathanur Dam	93.43		0.44	814.00	
		5	PickupAnicut - Sathanur	67.52		0.32	795.00	
13	Musukundanadhi	1	Vanapuram	62.63	179.26	0.35	995.00	917.64
		2	Thanipadi	110.22		0.61	744.60	
		3	PickupAnicut - Sathanur	6.40		0.04	795.00	
14	Thurinjalar	1	Vanapuram	133.27	853.62	0.16	995.00	962.02
		2	Thiruvannamalai	227.89		0.27	814.00	
		3	Thirukovilur	176.92		0.21	960.60	
		4	Kilnachipattu	315.54		0.37	953.20	
15	Gadilam	1	Villupuram	63.96	1562.90	0.04	873.50	1079.64
		2	Ulundurpet	483.54		0.31	0.00	
		3	Thirukovilur	323.19		0.21	960.60	
		4	Manimuthar Reservoir	160.83		0.10	803.10	
		5	Panruti	417.28		0.27	432.80	
		6	Cuddalore	114.12		0.07	1652.20	
16	Upto Krishnagiri Reservoir	1	Rayakotta	223.92	772.64	0.29	554.70	748.16
		2	Krishnagiri	130.37		0.17	772.90	
		3	Melumalai	108.98		0.14	619.50	
		4	Hosur	309.36		0.40	449.70	
17	Krishnagiri to Pambar	1	Harur	114.50	894.52	0.13	617.00	863.07
		2	Dharmapuri	8.46		0.01	791.00	
		3	Uthangarai	150.82		0.17	811.60	

		4	Perugondapuram	30.26		0.03	640.40	
		5	Nedungal	187.19		0.21	743.60	
		6	Krishnagiri	182.63		0.20	772.90	
		7	Barur	204.63		0.23	622.70	
		8	Palacode	16.02		0.02	741.60	
18	Pambar to Thirukovilur	1	Harur	144.09	1002.39	0.14	617.00	900.05
		2	Vanapuram	230.33		0.23	995.00	
		3	Chengam	23.23		0.02	813.40	
		4	Thirukovilur	115.61		0.12	960.60	
		5	Thanipadi	119.91		0.12	744.60	
		6	Sathanur Dam	88.39		0.09	814.00	
		7	PickupAnicut - Sathanur	68.02		0.07	795.00	
		8	Manimuthar Reservoir	92.53		0.09	803.10	
		9	Uthangarai	120.28		0.12	811.60	
19	Lower Pennaiyar	1	Villupuram	213.78	561.96	0.38	873.50	1072.26
		2	Thirukovilur	130.84		0.23	960.60	
		3	Panruti	103.79		0.18	432.80	
		4	Cuddalore	113.55		0.20	1652.20	
Basin Total Area				**11375.557**	**11375.559**			**882.43**


PENNAIYAR RIVER BASIN - THIESSEN POLYGON MAP
Plate: PEN-23
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Raingauge Station
Thiessen Polygon
Sub Basin Boundary
Basin Boundary
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
Chinnar - West
Hosur
Markandanadhi
Chinnar - East
Melumalai
Thalli
Upto Krishnagiri Reservoir
Rayakotta
Krishnagiri
Vaniambadi
Jolarpettai
Thirupathur
Pambar
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Krishnagiri to Pambar
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Aliyar
Matturar
Valayar Odai
Sathanur Dam
Thurinjalar
Pambar to Thirukovilur
PickupAnicut - Sathanur
Ramakal Odai
Thanipadi
Vanapuram
Kambainallur
Dharmapuri
Harur
Pambanar and Varattar
Musukundanadhi
Thoppaiyar Dam
Vaniyar
Pappireddypatty
Kottapattikallar
Thirukovilur
Villupuram
Lower Pennaiyar
Manimuthar Reservoir
Anaimaduvu Reservoir
Gomukhi Reservoir
Gadilam
Panruti
Cuddalore
Ulundurpet
30 15 0 30
KM
GOVERNMENT OF TAMIL NADU
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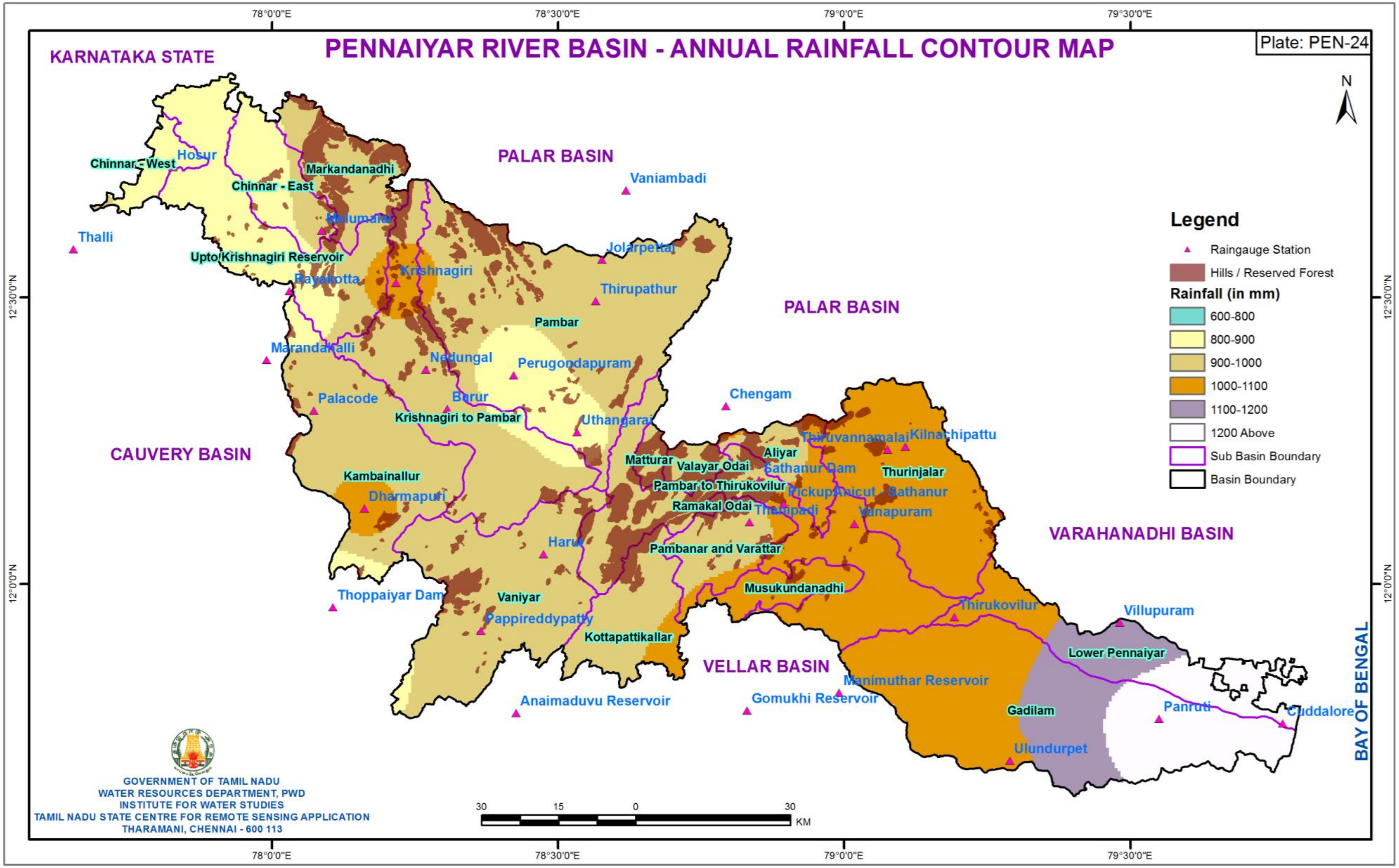
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


PENNAIYAR RIVER BASIN - ANNUAL RAINFALL CONTOUR MAP
Plate: PEN-24
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VELLAR BASIN
VARAHANADHI BASIN
BAY OF BENGAL
Chinnar - West
Hosur
Markandanadhi
Chinnar - East
Melumalai
Thalli
Upto Krishnagiri Reservoir
Rayakotta
Krishnagiri
Vaniambadi
Jolarpettai
Thirupathur
Pambar
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Krishnagiri to Pambar
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Matturar
Valayar Odai
Aliyar
Sathanur Dam
Thurinjalar
Pambar to Thirukovilur
Pickup Anicut
Sathanur
Kambainallur
Dharmapuri
Ramakal Odai
Thandipadi
Vanapuram
Harur
Pambanar and Varattar
Musukundanadhi
Thoppaiyar Dam
Vaniyar
Pappireddypatty
Thirukovilur
Villupuram
Kottapattikallar
Lower Pennaiyar
Manimuthar Reservoir
Anaimaduvu Reservoir
Gomukhi Reservoir
Gadilam
Panruti
Cuddalore
Ulundurpet
N
Legend
Raingauge Station
Hills / Reserved Forest
Rainfall (in mm)
600-800
800-900
900-1000
1000-1100
1100-1200
1200 Above
Sub Basin Boundary
Basin Boundary
30 15 0 30
KM
GOVERNMENT OF TAMIL NADU
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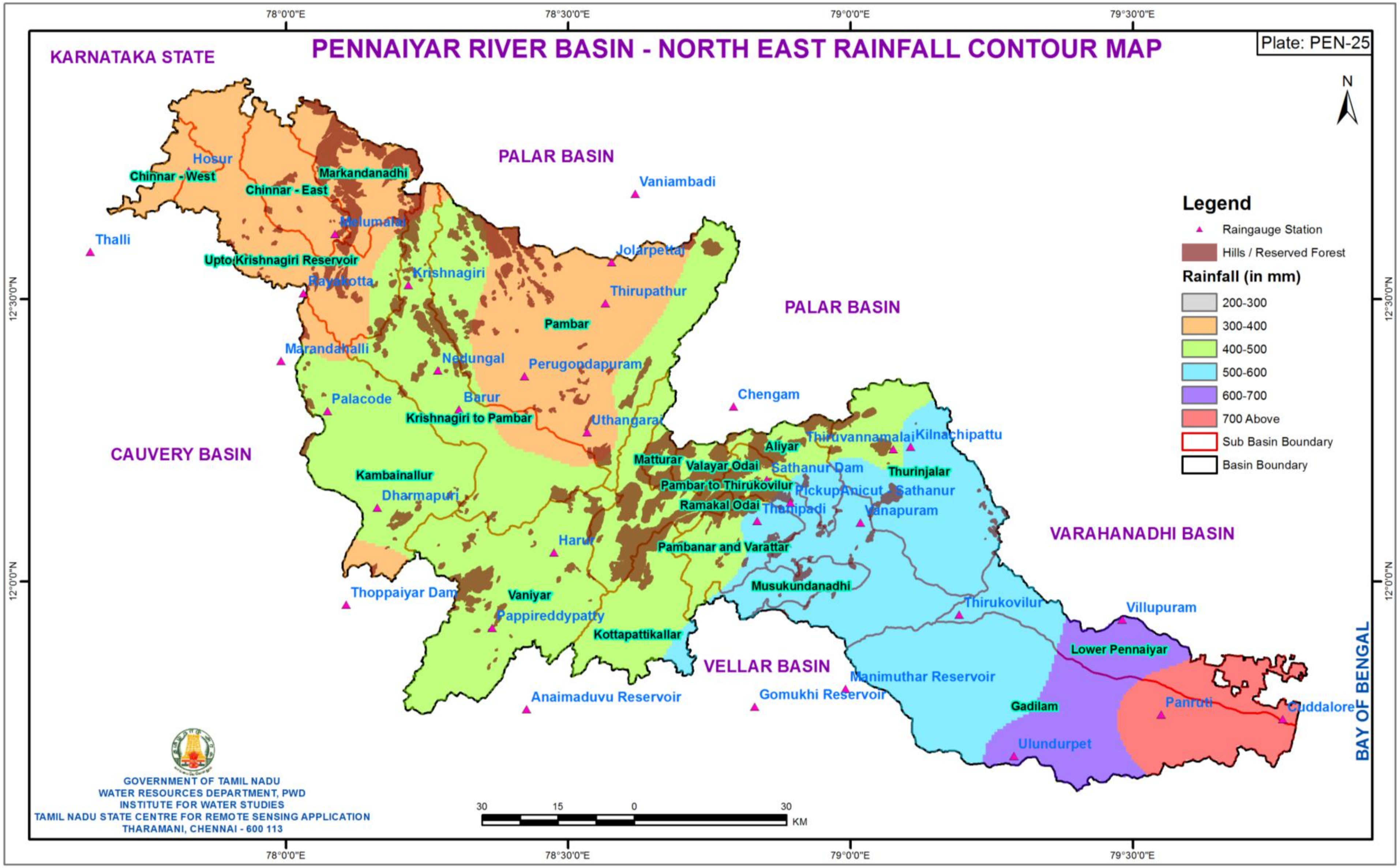
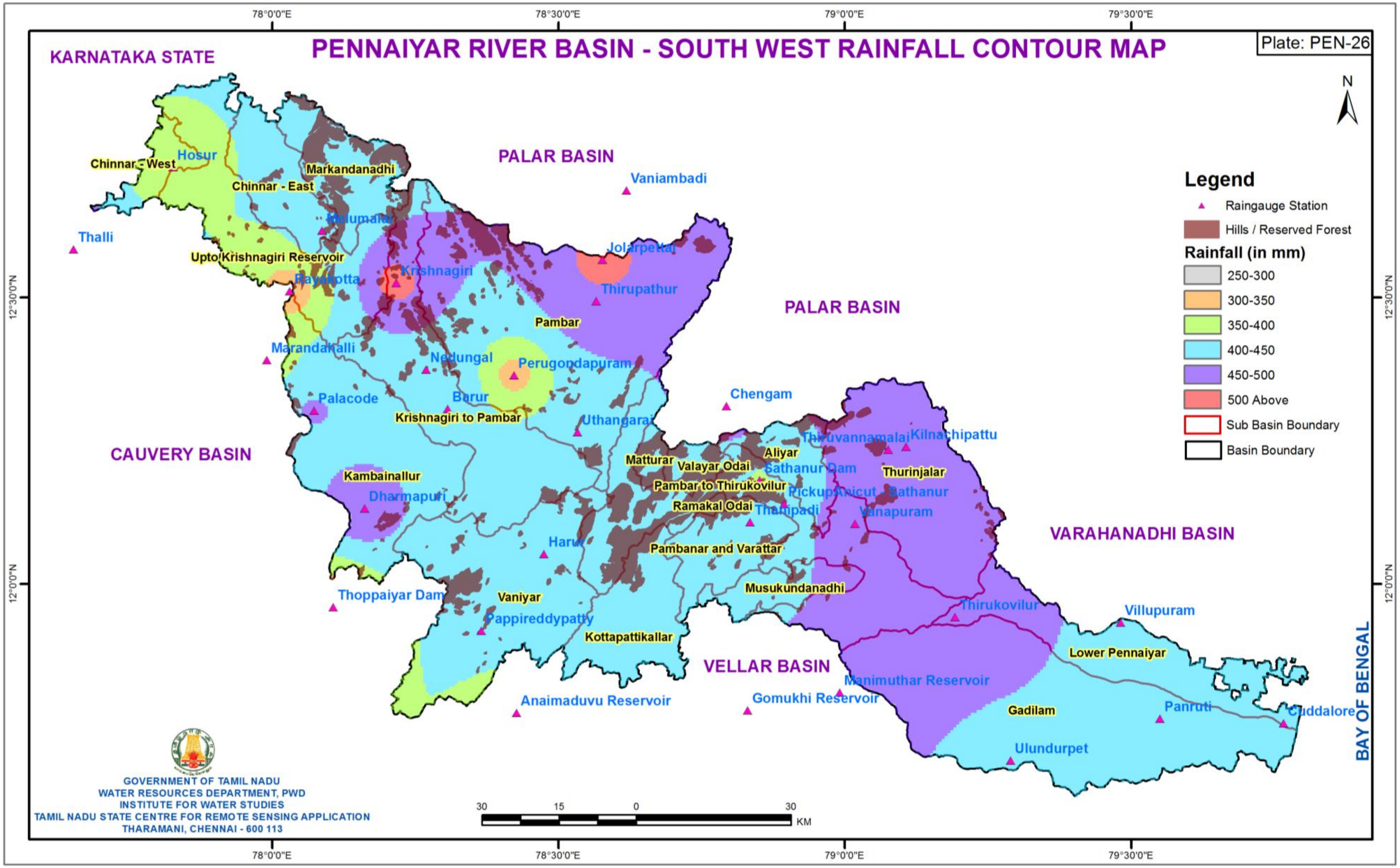
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


PENNAIYAR RIVER BASIN - NORTH EAST RAINFALL CONTOUR MAP
Plate: PEN-25
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VELLAR BASIN
VARAHANADHI BASIN
BAY OF BENGAL
Legend
Raingauge Station
Hills / Reserved Forest
Rainfall (in mm)
200-300
300-400
400-500
500-600
600-700
700 Above
Sub Basin Boundary
Basin Boundary
Hosur
Chinnar - West
Chinnar - East
Markandanadhi
Melumalai
Thalli
Upto Krishnagiri Reservoir
Rayakotta
Krishnagiri
Vaniambadi
Jolarpettai
Thirupathur
Pambar
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Krishnagiri to Pambar
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Aliyar
Matturar
Valayar Odai
Sathanur Dam
Thurinjalar
Pambar to Thirukovilur
Pickup Anicut
Sathanur
Ramakal Odai
Thandipadi
Vanapuram
Kambainallur
Dharmapuri
Harur
Pambanar and Varattar
Musukundanadhi
Thoppaiyar Dam
Vaniyar
Pappireddypatty
Kottapattikallar
Thirukovilur
Villupuram
Lower Pennaiyar
Manimuthar Reservoir
Anaimaduvu Reservoir
Gomukhi Reservoir
Gadilam
Panruti
Cuddalore
Ulundurpet
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
30 15 0 30
KM
N
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N


PENNAIYAR RIVER BASIN - SOUTH WEST RAINFALL CONTOUR MAP
Plate: PEN-26
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VELLAR BASIN
VARAHANADHI BASIN
BAY OF BENGAL
Chinnar - West
Hosur
Markandanadhi
Chinnar - East
Thalli
Melumalai
Upto Krishnagiri Reservoir
Rayakotta
Krishnagiri
Vaniambadi
Jolarpettai
Thirupathur
Pambar
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Krishnagiri to Pambar
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Matturar
Valayar Odai
Aliyar
Sathanur Dam
Thurinjalar
Pambar to Thirukovilur
Pickup Anicut
Sathanur
Ramakal Odai
Thanipadi
Vanapuram
Kambainallur
Dharmapuri
Harur
Pambanar and Varattar
Musukundanadhi
Thoppaiyar Dam
Vaniyar
Pappireddypatty
Kottapattikallar
Thirukovilur
Villupuram
Lower Pennaiyar
Manimuthar Reservoir
Anaimaduvu Reservoir
Gomukhi Reservoir
Gadilam
Panruti
Cuddalore
Ulundurpet
N
Legend
Raingauge Station
Hills / Reserved Forest
Rainfall (in mm)
250-300
300-350
350-400
400-450
450-500
500 Above
Sub Basin Boundary
Basin Boundary
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
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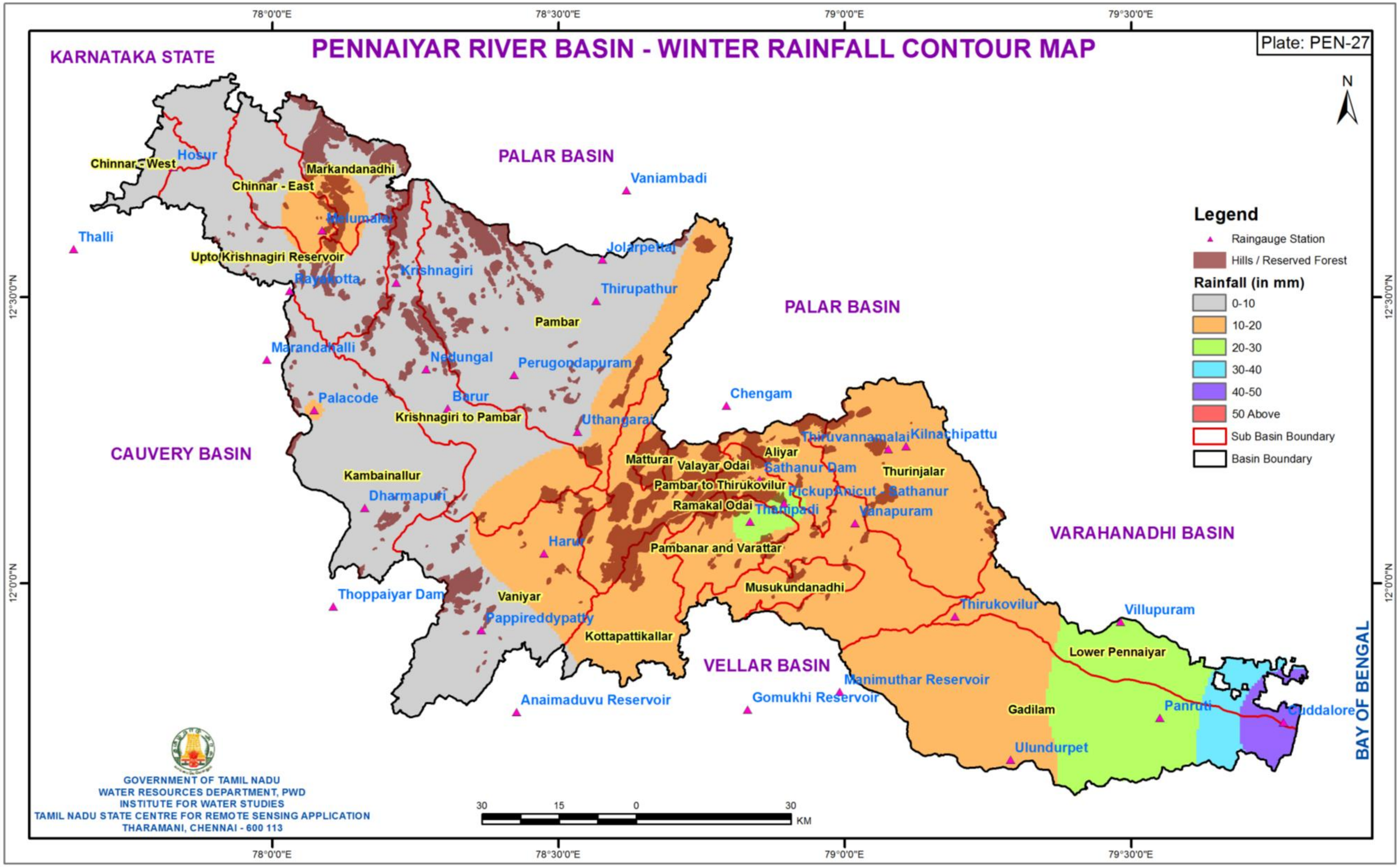
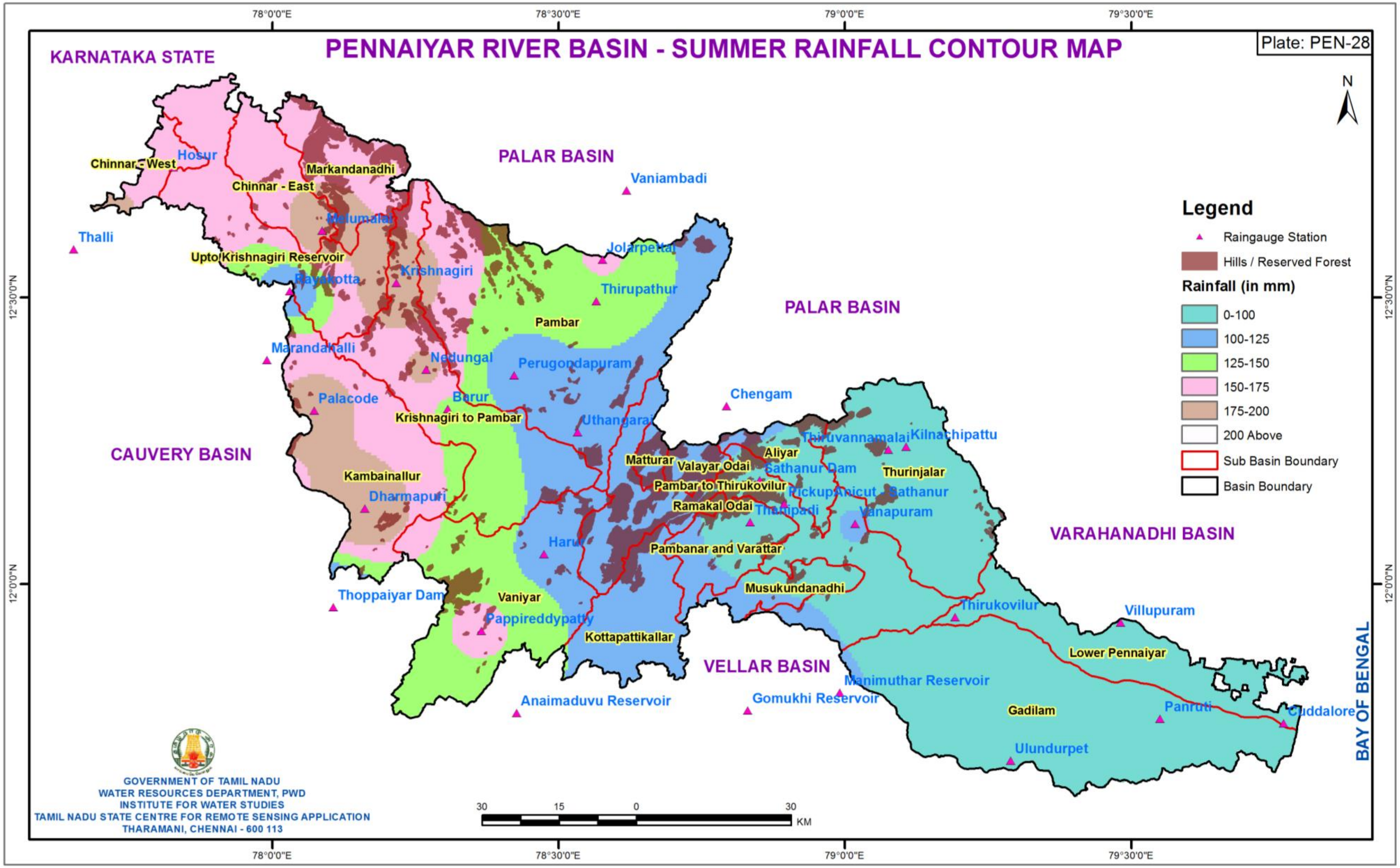
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
30
15
0
30
KM


PENNAIYAR RIVER BASIN - WINTER RAINFALL CONTOUR MAP
Plate: PEN-27
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
N
Legend
Raingauge Station
Hills / Reserved Forest
Rainfall (in mm)
0-10
10-20
20-30
30-40
40-50
50 Above
Sub Basin Boundary
Basin Boundary
Chinnar - West
Hosur
Markandanadhi
Chinnar - East
Melumalai
Thalli
Upto Krishnagiri Reservoir
Rayakotta
Krishnagiri
Vaniambadi
Jolarpettai
Thirupathur
Pambar
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Krishnagiri to Pambar
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Matturar
Valayar Odai
Aliyar
Sathanur Dam
Thurinjalar
Kambainallur
Dharmapuri
Pambar to Thirukovilur
Pickup Anicut - Sathanur
Ramakal Odai
Thanipadi
Vanapuram
Harur
Pambanar and Varattar
Musukundanadhi
Thoppaiyar Dam
Vaniyar
Pappireddypatty
Kottapattikallar
Thirukovilur
Villupuram
Lower Pennaiyar
Manimuthar Reservoir
Gomukhi Reservoir
Anaimaduvu Reservoir
Gadilam
Panruti
Cuddalore
Ulundurpet
30 15 0 30
KM
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113



PENNAIYAR RIVER BASIN - SUMMER RAINFALL CONTOUR MAP
Plate: PEN-28
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VELLAR BASIN
VARAHANADHI BASIN
BAY OF BENGAL
Legend
Raingauge Station
Hills / Reserved Forest
Rainfall (in mm)
0-100
100-125
125-150
150-175
175-200
200 Above
Sub Basin Boundary
Basin Boundary
Hosur
Thalli
Vaniambadi
Jolarpettai
Thirupathur
Melumalai
Krishnagiri
Rayakotta
Marandahalli
Nedungal
Perugondapuram
Palacode
Barur
Uthangarai
Chengam
Thiruvannamalai
Kilnachipattu
Sathanur Dam
Pickup Anicut
Sathanur
Thanipadi
Vanapuram
Dharmapuri
Harur
Thoppaiyar Dam
Pappireddypatty
Thirukovilur
Villupuram
Manimuthar Reservoir
Gomukhi Reservoir
Anaimaduvu Reservoir
Panruti
Cuddalore
Ulundurpet
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Matturar
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thirukovilur
Ramakal Odai
Pambanar and Varattar
Musukundanadhi
Vaniyar
Kottapattikallar
Lower Pennaiyar
Gadilam
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30
15
0
30
KM
N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

CHAPTER – 4

IRRIGATION AND AGRICULTURE

CHAPTER – 4

IRRIGATION AND AGRICULTURE

4.1 Classification and Properties of Soil

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 lakh hectares. It is the second largest in economy and the most urbanized state in the country.

The Gross State Domestic Product (GSDP) of 2013-14 at constant price stood at Rs.480618.05 crores with a growth rate of 7.29% where as the GSDP on Agriculture and allied sector at constant prices showed a passive growth rate of 8.22%. (Source: Season and Crop Report Tamil Nadu 2013-14). 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 cultivation of land depends mainly on the irrigation water. Medium & minor irrigation schemes are implemented in the state for augmenting the irrigation for agriculture. The various sources of irrigation for this basin are tanks, canals, wells and tube wells.

The ayacut area of Pennaiyar river basin is 204128ha (ayacut of tanks and reservoirs). In the year 2013-14, gross area irrigated is 3.54 L Ha and gross area sown is 7.098 L Ha. The main crops cultivated are paddy, Ground nut, Maize, Ragi, Coconut and Sugarcane.

Soil is an unconsolidated mineral or organic material that is on the surface of the earth in which crops grow. Every soil is a mixture of three main components: sand, clay and silt. Loam is the most fertile type of soil and has a mixture of these components.

Sub-basin wise Soils found in this basin are as follows. Chinnar west, Chinnar east, Kambainallur, Krishnagiri to Pambar, Markandanadhi, Up to krishnagiri reservoir and vaniyar sub basin has Non Calcareous red & brown and calcareous black soil. Aliyar, Gadilam, Kottapattikallar, Lower Pennaiyar, Matturar, Muskundanadhi, Pambar, Pambanar&Varattar,

Table -4.1 SUB BASINWISE NUMBER OF OPERATIONAL HOLDING

Social Group	Chinnar - West	Chinnar - East	Markandanadhi	Kambainallur	Pambar	Vaniyar	Matturar	Kotapatikallar	Valayar Odai	Ramakal Odai	Pambanar and Varattar	Aliyar	Musukundanad hi	Thurinjalar	Gadilam	Upto Krishnagiri Reservoir	Krishnagiri to Pambar	Pambar to Thirukovilur	Lower Pennaiyar	Total	% of Total
Marginal (less than 1 Ha)	4385	11053	17154	59155	106790	29548	2675	11192	4292	497	9343	8696	7091	57296	118469	30561	57356	47855	41476	624884	73.85
Small (1 to 2 Ha)	1488	4096	4466	14219	25616	10577	772	4598	1060	161	3170	2510	2122	13767	20842	8363	12638	12779	7495	150739	17.81
Semi medium (2 to 4 Ha)	543	1548	1387	4374	8046	3479	229	1468	286	45	913	686	683	3706	7067	2969	4101	3822	2434	47788	5.65
Medium (2 to 5 Ha)	117	328	254	732	1437	648	35	254	31	8	157	99	99	484	1477	595	768	629	525	8678	1.03
Larger (5 Ha & above)	8444	231	186	433	952	463	24	160	29	4	84	65	57	275	1009	403	521	391	375	14105	1.67
	17042	**17255**	**23447**	**78913**	**142841**	**44715**	**3736**	**17672**	**5699**	**715**	**13667**	**12057**	**10053**	**75527**	**148864**	**42890**	**75383**	**65476**	**52305**	846194	

Pambar to Thirukovilur, Ramakkalodai, Thurinjalar, Valayar odai has Red sandy loam and clay loam. Some part of Lower Pennaiyar and Gadilam sub basin has got coastal alluvium soil.

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% operated 5.4% of total area. Average size of holding in the state was 0.80ha. 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 Pennaiyar Basin on the land holding size is given in **Table 4.1**. Marginal farmers accounts for 72.81% in Pennaiyar Basin.

4.3 Crop Water Requirement

4.3.1 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 sprinkler method, less water is required as it just moist the soils like rainwater, where as in flooding 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.

4.3.2 Crop Water Requirement Calculation

Water budgeting at field level helps to allocate the available water to crops based on water requirements. At system level, it helps the irrigation engineers to distribute the required quantity of water to be given based on the water supply.

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

ETc = Kc x Eto, Where Eto is the reference evapo-transpiration and Kc is the crop coefficient.

The ET_0 values as discussed in Chapter 3 are taken for calculating Crop Water Requirement. The ET_0 is estimated by using Penmann Monteith method. The normal Reference Crop Evapo-transpiration values are tabulated in **Appendix 3.4.**

4.3.3 Crop Parameters

The Kc stages and coefficients are taken from Food and Agriculture Organization (FAO) irrigation Paper No. 56. The growth stage of a crop as in **Fig. 4.1** 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.**

Figure 4.1 Growth Stage of a Crop

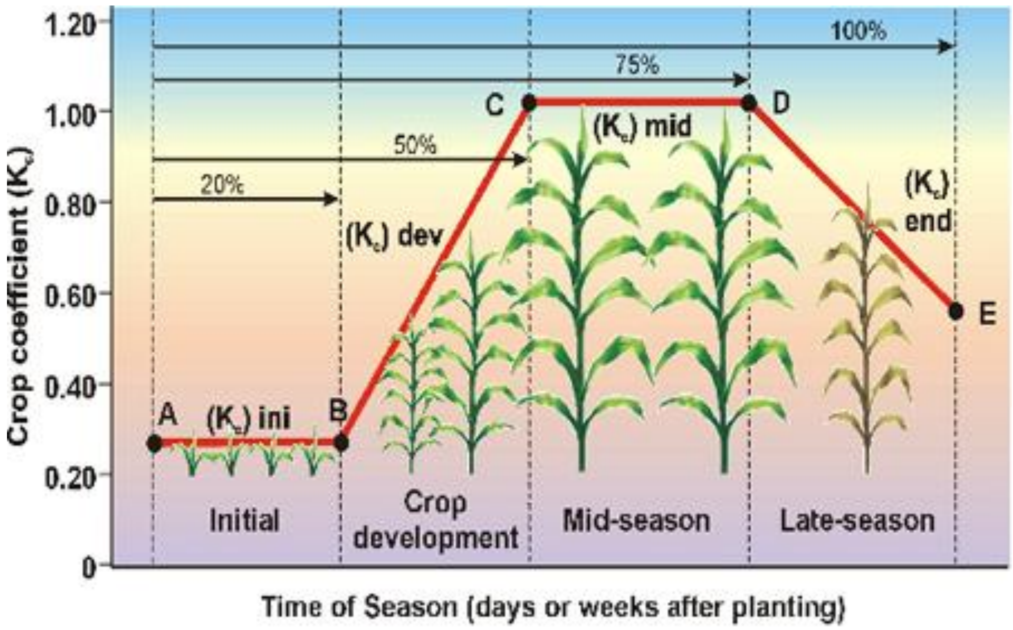


Table 4.2 Important physiological and critical growth stages of crops for irrigation

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

4.3.4 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 Pennaiyar basin is given in **Table 4.3**. **Fig 4.2** shows sub basin wise distribution of average irrigated area of crops in this basin &**Fig 4.3** 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 technical irrigation for crops considered for calculating crop water requirement of this basin are tabulated in **Table 4.4** and **Table 4.5** respectively.

Fig.4.4 explains about the methodology adopted in the calculation of Irrigation Demand. **Table 4.6** gives the Irrigation water requirement at 75% rainfall dependability in Aliyar sub basin and Irrigation Water Demand for 25%, 50%, 75%, 90%. Rainfall Dependability of entire basin are tabulated in **Tables 4.7, 4.8, 4.9, 4.10** respectively.

Figure 4.2 Sub basin wise irrigated area of crops in Pennaiyar Basin

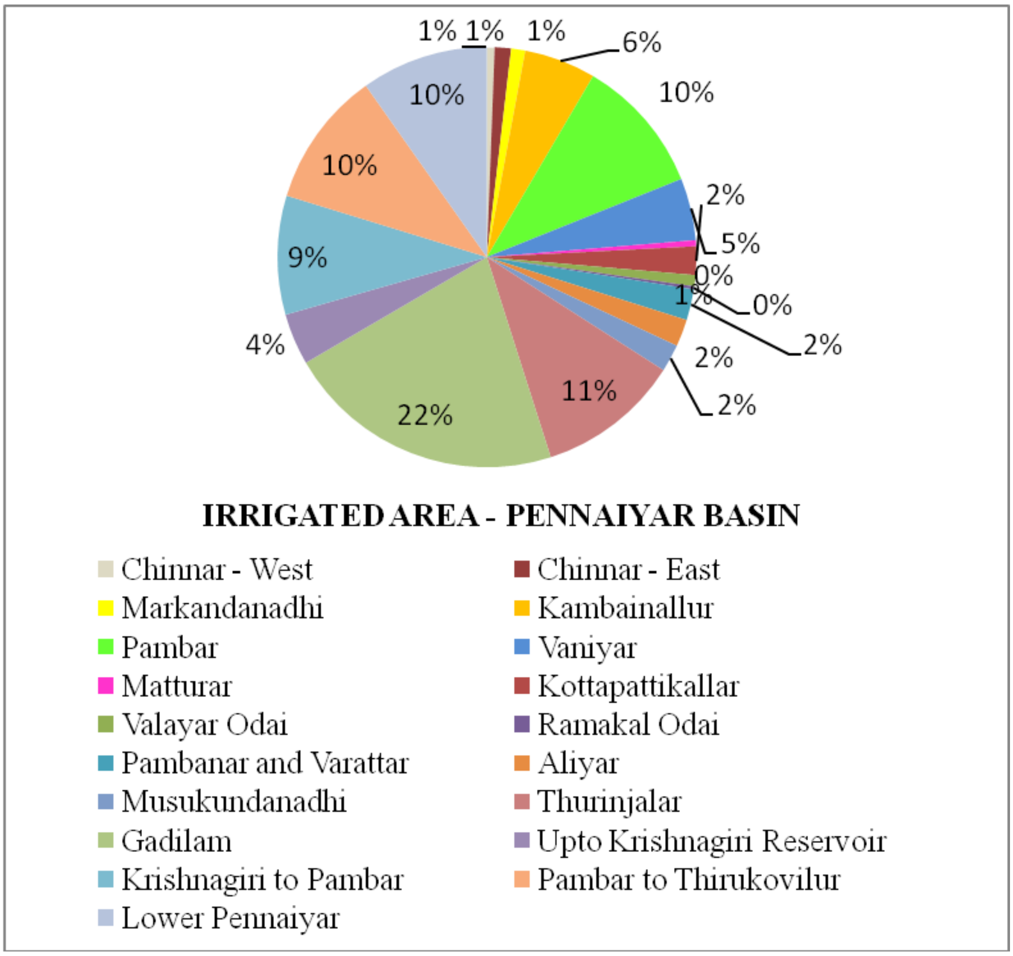


Figure 4.3 Irrigated area of Major crops in PennaiyarBasin

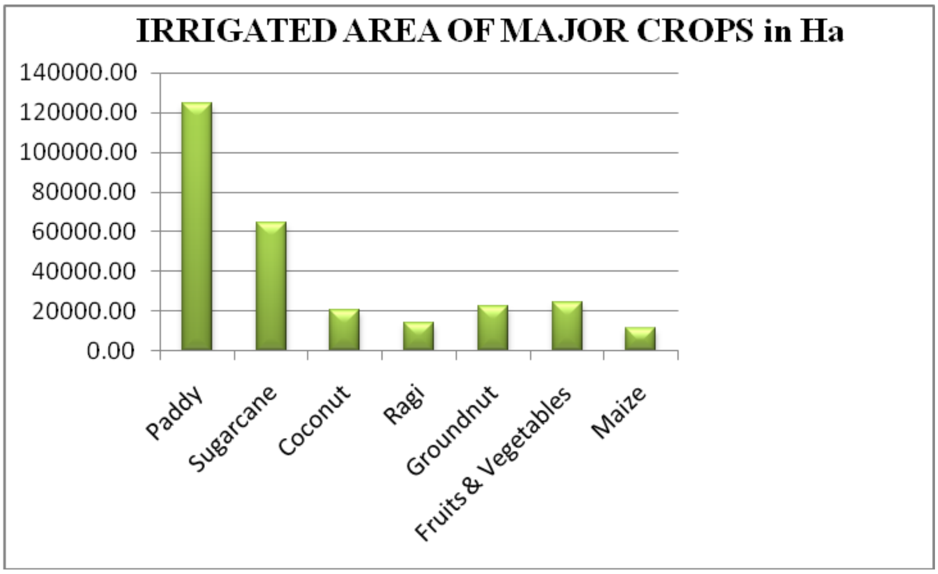


FIGURE 4.4 METHODOLOGY FOR CALCULATING IRRIGATION DEMAND - PENNAIYAR BASIN

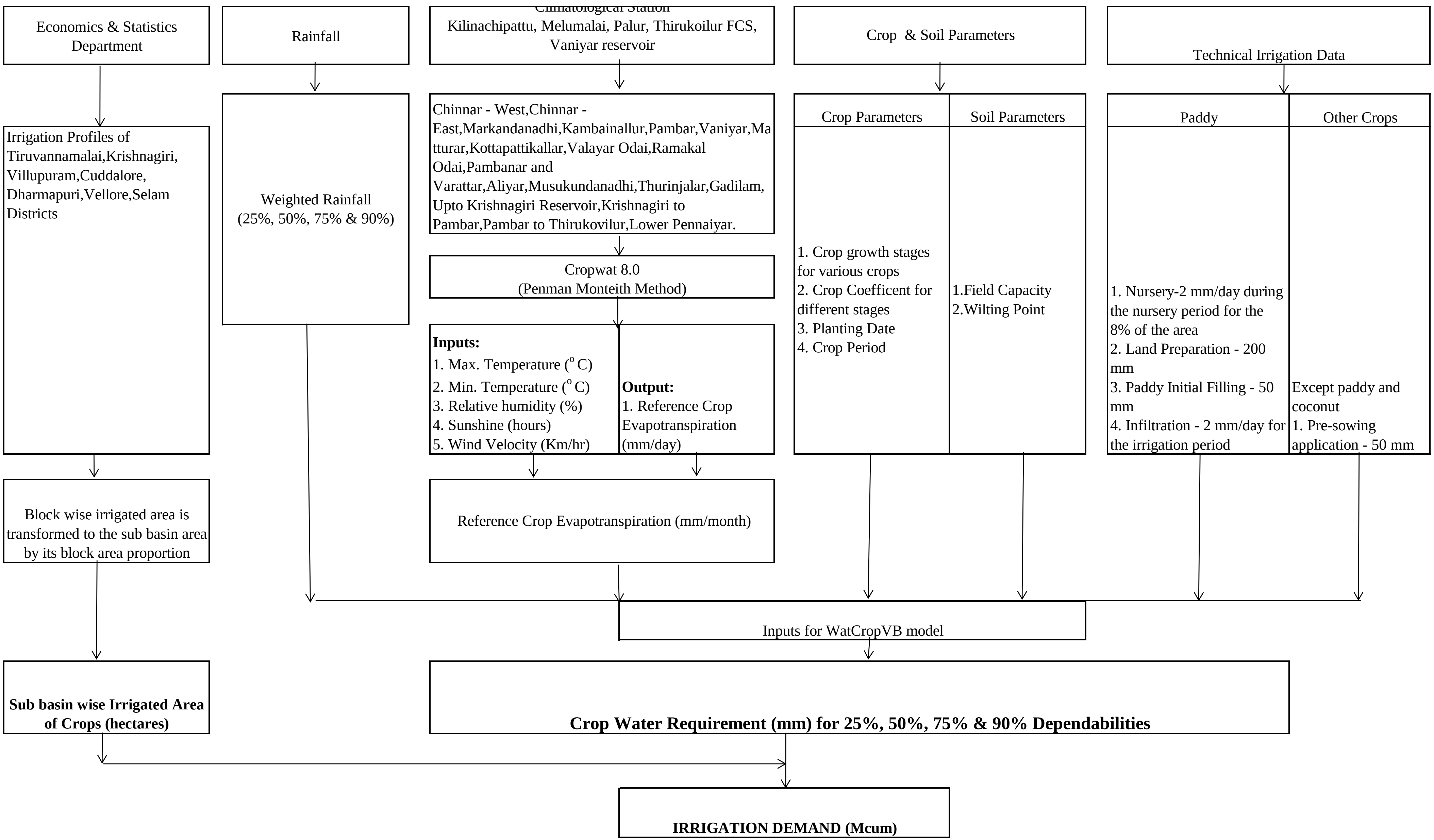


TABLE - 4.3

SUB BASINWISE IRRIGATED AREA OF CROPS (Ha.) -PENNAIYAR BASIN

Crop	Chinnar - West	Chinnar - East	Markanda nadhi	Kambai nallur	Pambar	Vaniyar	Matturar	Kottapatti kallar	Valayar Odai	Ramakal Odai	Pambanar and Varattar	Aliyar	Musukund anadhi	Thuri njalar	Gadilam	Upto Krishnagiri Reservoir	Krishnagi ri to Pambar	Pambar to Thiruko vilur	Lower Pennaiyar	Total
Coconut - Per - Jan	73	379	164	1300	9975	675	82	331	39	0	31	44	17	47	321	823	5380	453	285	**20416**
Paddy - First Crop - Aug	278	867	805	5049	5269	3977	328	1847	576	0	1572	1577	1864	9009	8716	3798	10324	9029	10890	**75775**
Paddy - Second Crop - Oct	93	289	268	1683	1756	1326	109	616	192	0	524	526	621	3003	26148	1266	3441	3010	3630	**48501**
Cholam - Apr	0	0	24	48	47	55	22	46	53	0	1	50	1	61	8	4	10	77	22	**530**
Cumbu - Mar	0	0	6	38	565	58	28	10	64	0	142	137	17	349	359	11	125	484	281	**2672**
Ragi - Jan	98	321	397	2037	2929	1662	43	527	65	0	165	139	67	426	259	1038	3255	763	108	**14299**
Maize - May	175	315	117	1033	1586	1238	35	198	0	0	14	0	976	225	1563	604	947	1756	461	**11244**
Red Gram - June	0	0	6	155	1	258	29	76	68	0	44	79	13	51	103	4	99	233	46	**1264**
Black Gram - Sep	0	0	5	204	204	28	84	19	201	0	174	283	36	1121	1858	32	64	826	963	**6102**
Green Gram - Sep	0	0	0	43	55	2	17	0	40	0	5	38	0	51	55	17	13	69	14	**421**
Other Cereals - July	55	110	39	17	1	178	1	109	2	0	305	144	16	32	109	182	18	360	79	**1758**
Chillies - Jan	29	10	66	119	200	12	6	5	7	0	9	12	3	70	37	109	148	31	30	**904**
Onion-June	16	4	2	79	18	16	4	10	8	0	1	8	0	11	3	38	10	17	3	**248**
Fodder - Mar	0	0	201	261	538	330	13	181	31	0	18	32	1	99	16	127	520	138	8	**2514**
Condiments -Sep	182	358	127	98	214	127	13	88	31	0	4	3	1	85	4	630	32	76	34	**2107**
Sugarcane - Apr	8	16	25	1452	1792	2128	143	1011	307	0	1878	1346	2454	11284	21023	155	716	9454	9464	**64655**
Banana - Apr	7	11	123	143	1191	93	35	34	64	0	16	65	1	79	1106	109	179	150	919	**4325**
Groundnut - Nov	2	0	102	716	1219	487	277	396	631	0	1796	1463	171	6998	2841	128	502	3590	1301	**22618**
Cotton - Sep	0	0	47	481	498	387	30	300	28	0	40	35	95	21	337	24	298	462	41	**3123**
Gingelly - Feb	0	0	0	0	15	39	6	37	15	0	273	141	178	629	1076	0	7	686	349	**3453**
Fruits & Vegetables - June	811	1259	869	1248	4550	851	125	598	167	0	582	401	192	1086	2386	3216	1857	1646	2243	**24086**
Flowers - Per - Oct	51	62	63	316	271	99	51	21	118	0	11	124	1	373	74	249	550	186	44	**2665**
Turmeric - June	2	0	11	1078	495	1226	18	528	21	0	41	24	26	11	224	73	754	640	3	**5175**
	1879	**4001**	**3467**	**17598**	**33391**	**15252**	**1499**	**6988**	**2729**	**0**	**7647**	**6668**	**6750**	**35120**	**68626**	**12636**	**29249**	**34136**	**31218**	**318855**

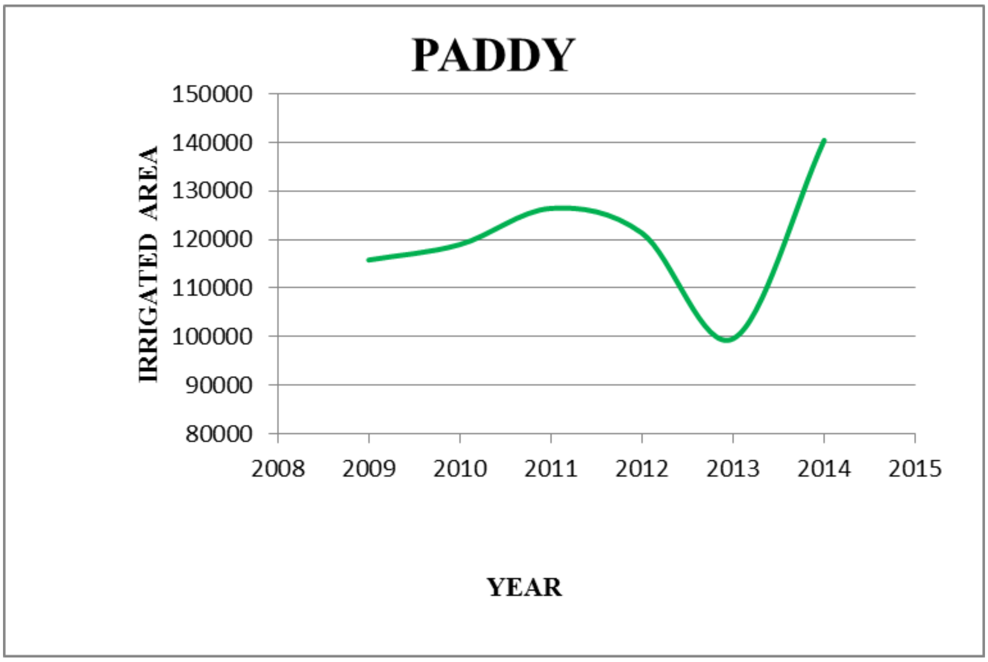
4.3.5 Future Irrigation Water Demand – Lower Limit Scenario

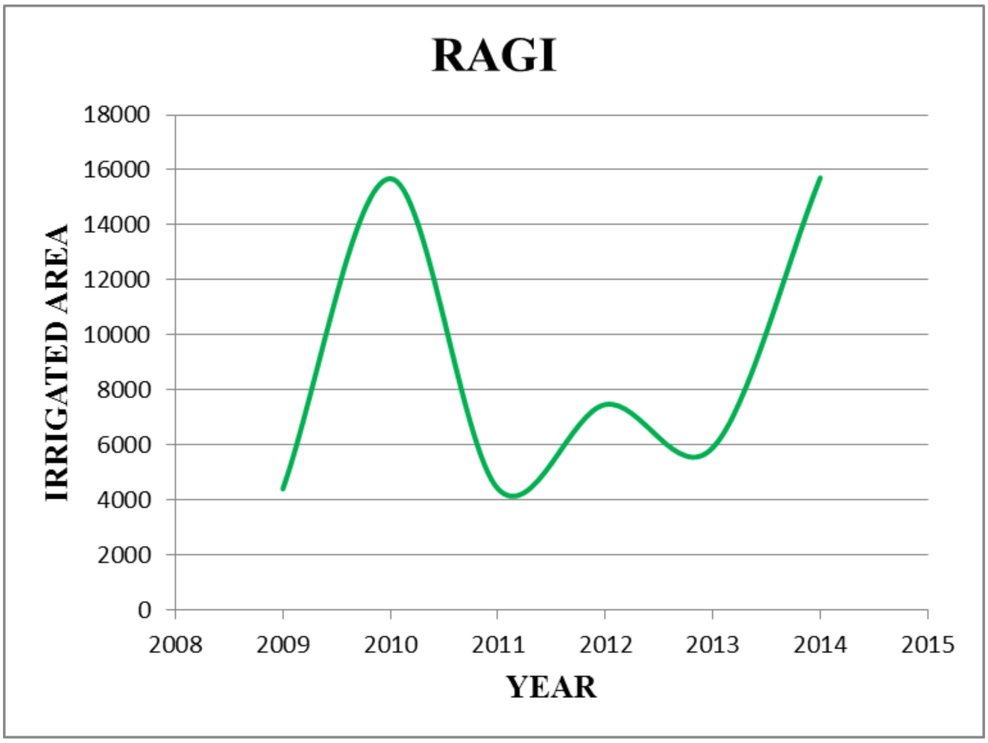
This scenario is based on the identification of changes in the present cropping or cultivation pattern, which would result in, some reasonable lower limit for the future demand of irrigation water in the basin. This limit will define a quantitative range of the future irrigation demand for the simulation analysis of the river basin water resources model.

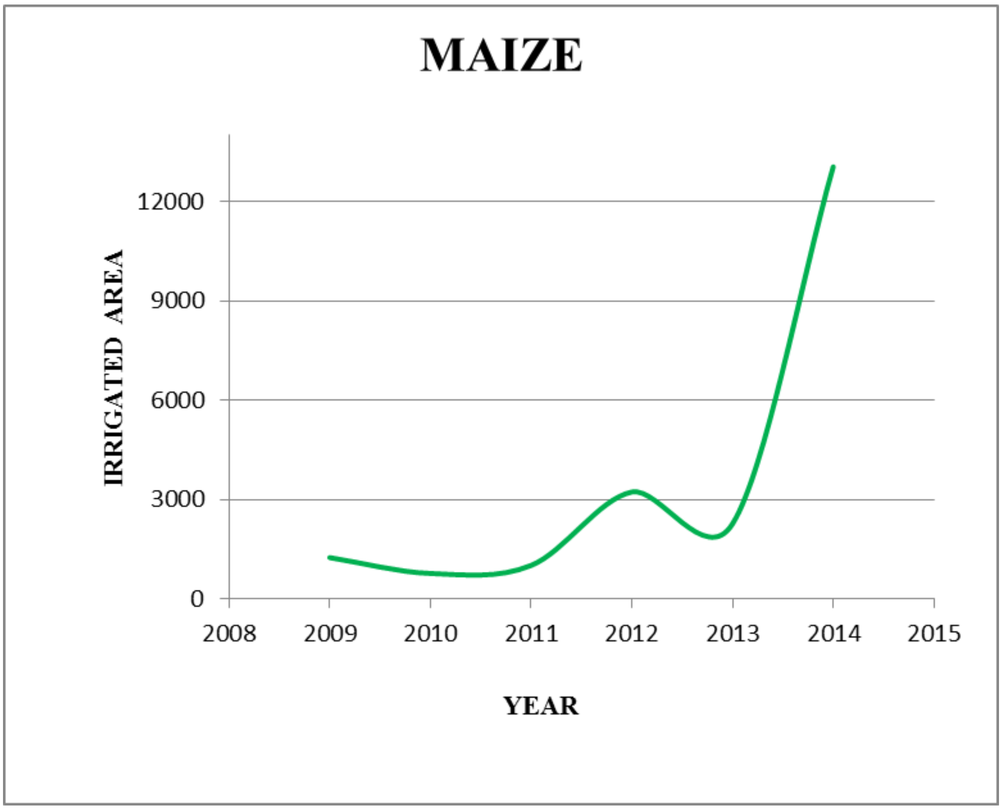
The lower limit for the future irrigation demand is determined taking into consideration the cultivation of SRI (System of Rice Intensification) paddy (70% paddy cultivation area) as recommended by agricultural department. Currently paddy cultivation area under SRI method is being emphasized by the agricultural 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 Pennaiyar 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 Pennaiyar River Basin is listed in **Table 4.16**

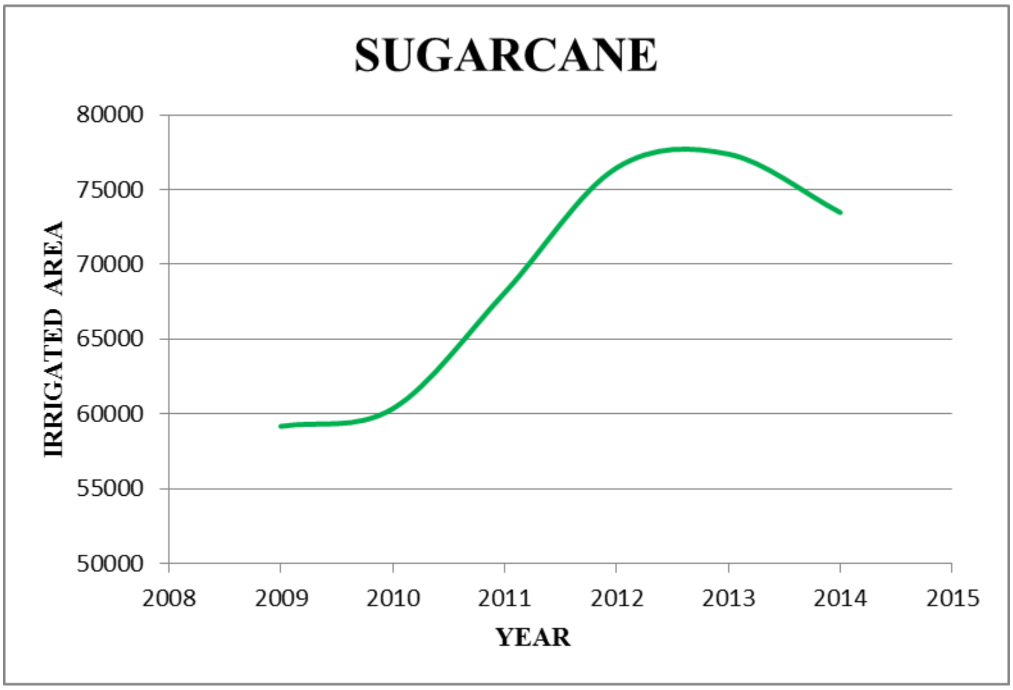
4.4 Cropping Pattern

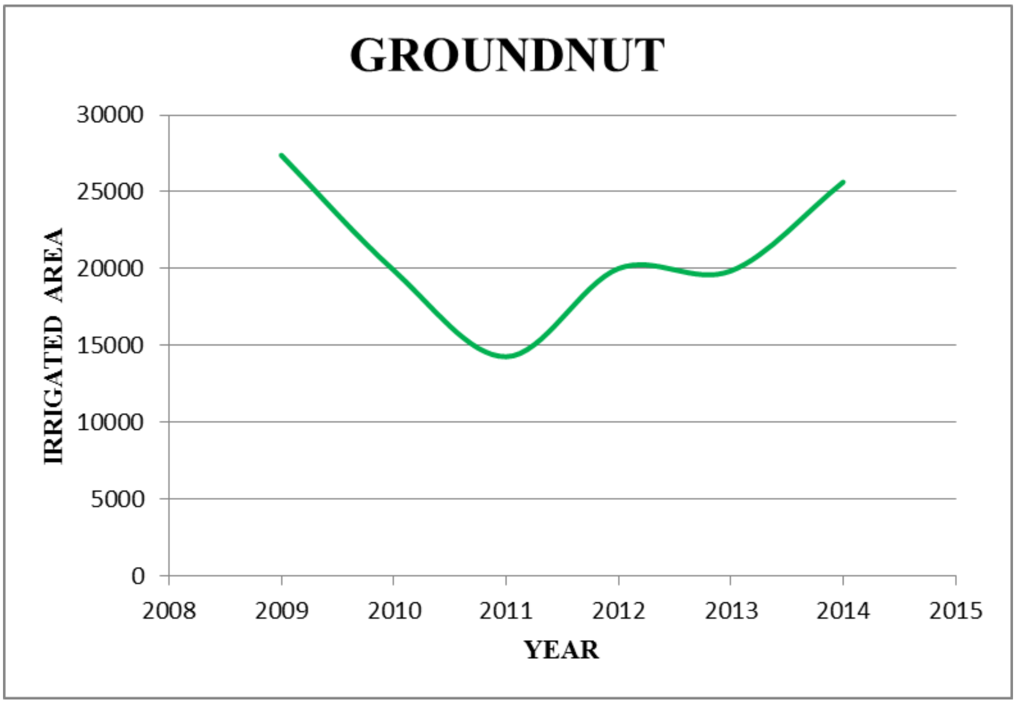
From time immemorial due to the good soil health and plentiful water availability, farmers have a set cropping pattern in command areas, tank-fed areas and well irrigated areas, which predominantly paddy, banana, sugarcane, coconut and other hydrophilic crops. Due to the changing rainfall pattern over the years, ground water depletion, lack of flows in the perennial rivers, 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. The Irrigated area (in Ha) of various major crops for past five years in this basin is given in graph.

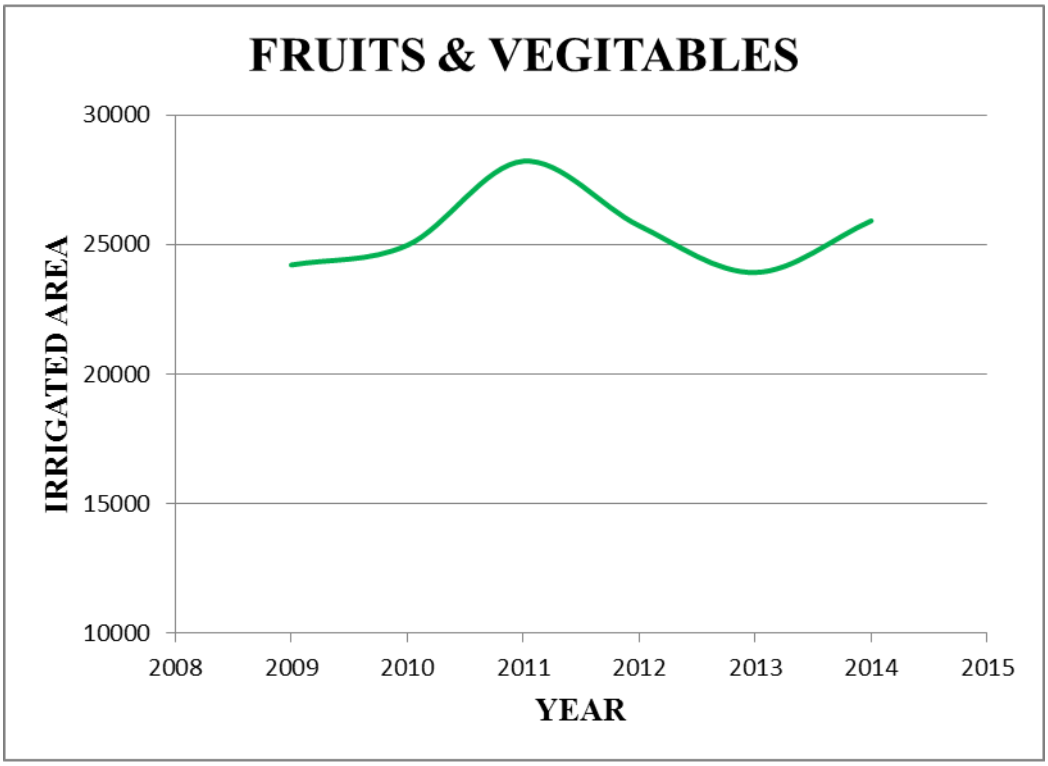

PADDY
IRRIGATED AREA
150000
140000
130000
120000
110000
100000
90000
80000
2008
2009
2010
2011
2012
2013
2014
2015
YEAR

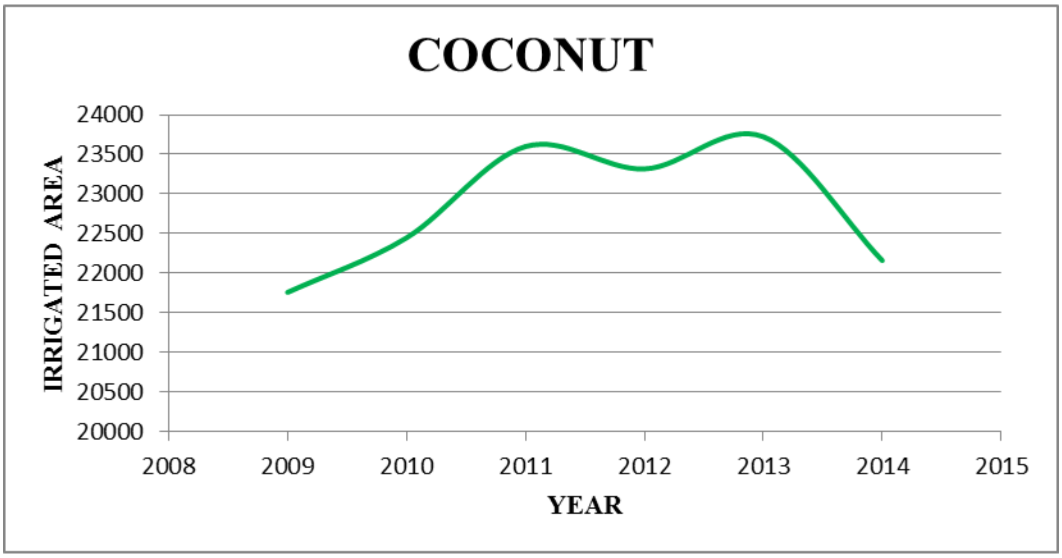

RAGI
IRRIGATED AREA
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2008
2009
2010
2011
2012
2013
2014
2015
YEAR


MAIZE
IRRIGATED AREA
12000
9000
6000
3000
0
2008
2009
2010
2011
2012
2013
2014
2015
YEAR

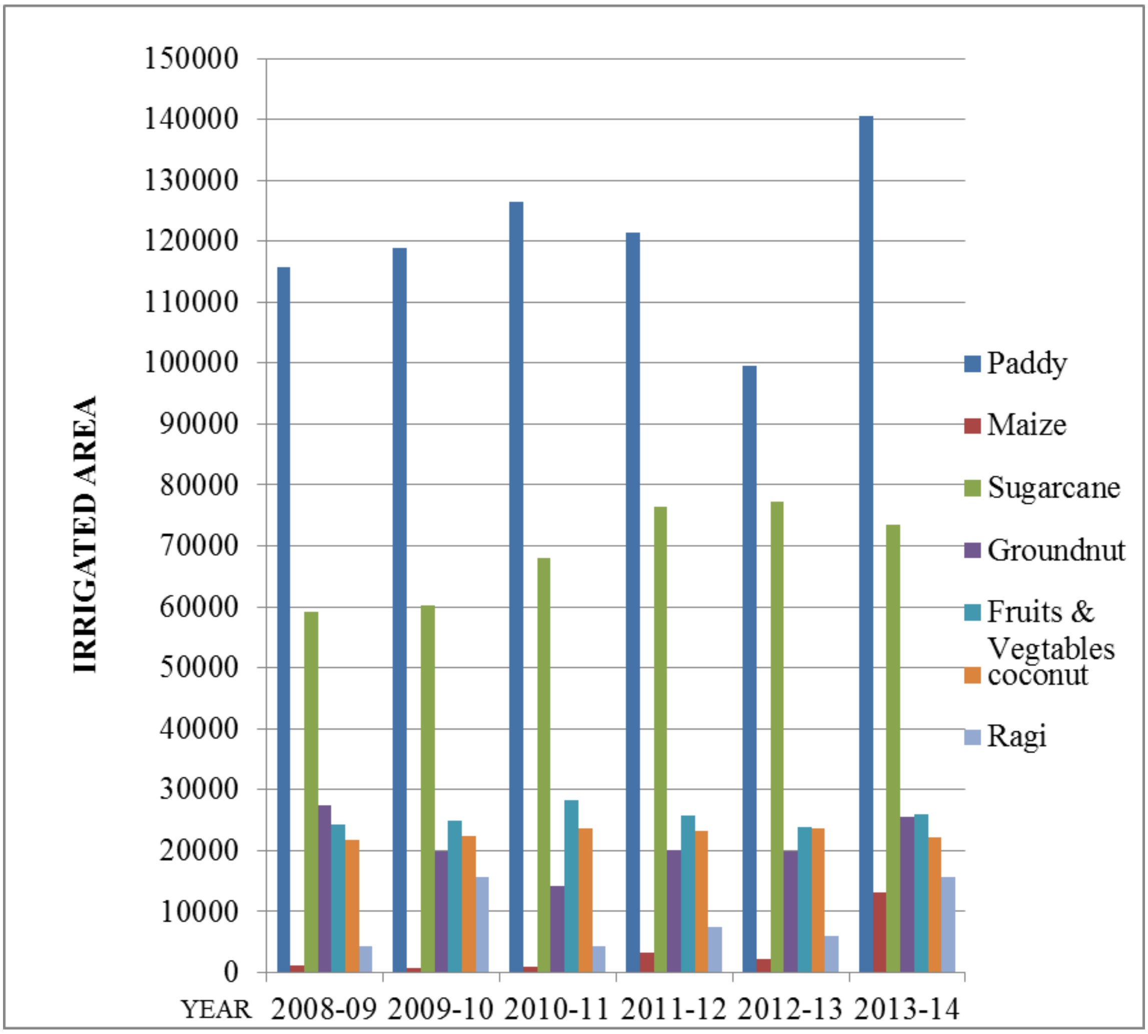

SUGARCANE
IRRIGATED AREA
80000
75000
70000
65000
60000
55000
50000
2008
2009
2010
2011
2012
2013
2014
2015
YEAR


GROUNDNUT
30000
25000
20000
15000
10000
5000
0
IRRIGATED AREA
2008
2009
2010
2011
2012
2013
2014
2015
YEAR


FRUITS & VEGITABLES
30000
25000
20000
15000
10000
IRRIGATED AREA
2008
2009
2010
2011
2012
2013
2014
2015
YEAR



IRRIGATED AREA OF VARIOUS MAJOR CROPS



4.4.1 Existing & Suggested Cropping Pattern in Pennaiyar Basin

The major crops cultivated in Pennaiyar Basin are Paddy, Maize, Ragi, Sugarcane, Ground nut, Coconut and Fruits & Vegetables. The irrigated area for the year 2013-14 in Pennaiyar Basin under different crops is 354703.23ha with paddy the main crop of the basin cultivated in 124276.01ha.In the remaining area, other crops are cultivated. Sub basin wise irrigated area of crops in Pennaiyar river basin in given in **Fig 4.5**

The forecast for normal rainfall is +19 to -19, moderate is –19 to –59 and below -59 indicates severe drought. These figures are the deviation from average rainfall. The distribution of rain also plays a vital role in crop productivity. Existing cropping pattern during normal rain year and suggested cropping pattern for Poor rain year for the Districts covered in this basin are given in the**Table4.18**.

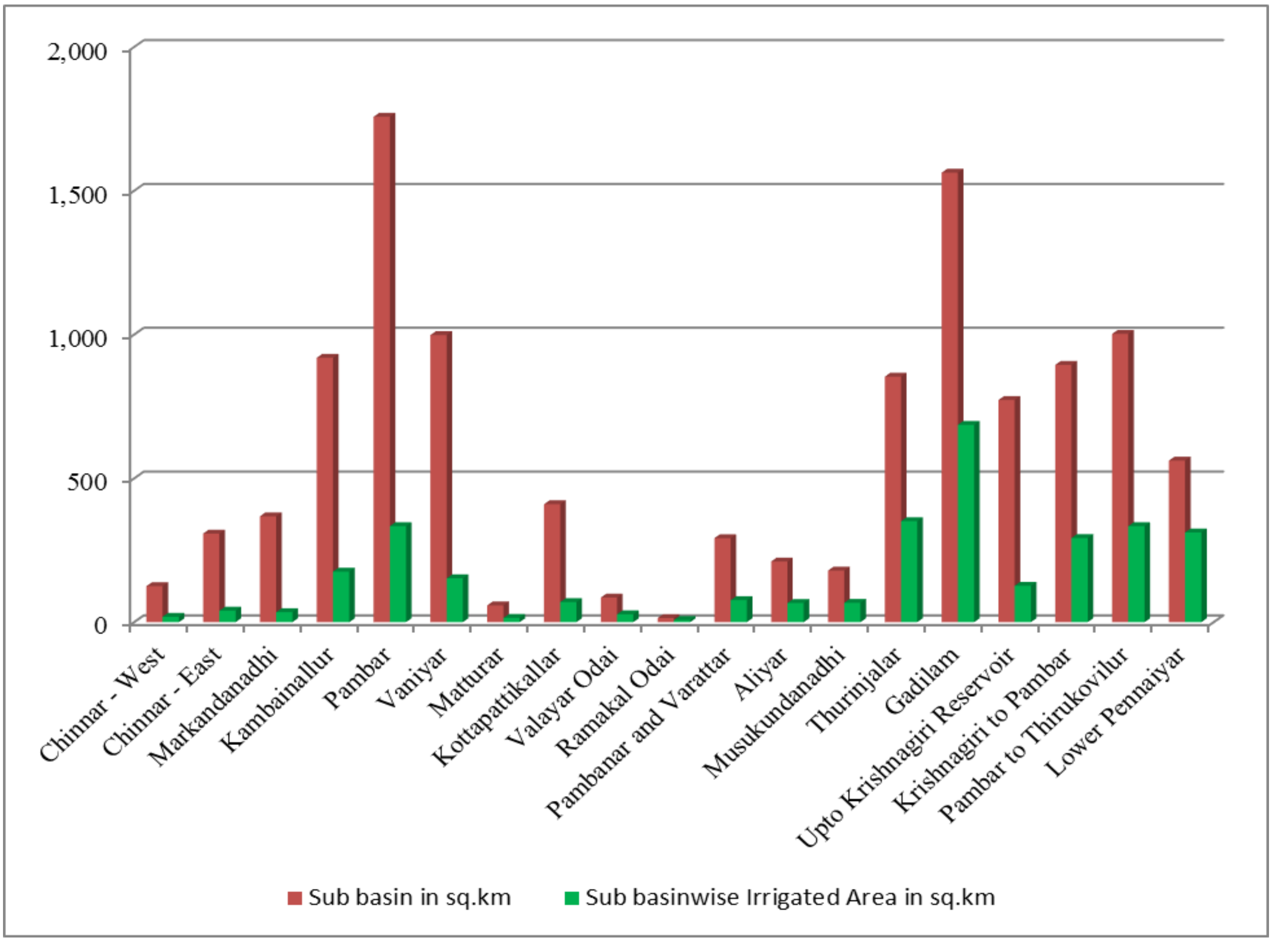


Figure 4.5 Sub basin area vs Irrigated area of crops in Pennaiyar River Basin

Table 4.17 District wise Cropping Pattern in Pennaiyar River Basin

Sl. No.	District	Existing cropping pattern during normal rain year	Suggested Contingency measures during Poor Rainfall Year	
			Change in crop/cropping system	Agronomic measures
1	Krishnagiri	1.Rice – Rice 2.Rice – Ragi / Vegetables	1.Change of varieties from Medium duration to short Duration 2.Change from MD to SD varieties transplanting 45-60 day old seedlings	SRI techniques Adopt Drum seeding in canal irrigated situation
2	Dharmapuri	1.Paddy 2.Sugarcane 3.Tapioca	Finger millet /groundnut Tapioca / Maize Finger millet / Pulses	Deep ploughing
3	Salem	1.Rice – Rice 2.Sugarcane	Gingelly / Sorghum / Maize Fodder sorghum /	1.Mulching 2. Adopting moisture
4	Vellore	1. Rice/ Vegetables (Aug. – Jan.)- Pulses (Dec- Jan.) 2. Groundnut (June-Sept) Maize (June-Sept) Vegetables (June-Oct)	1.Fodder (Nov – Feb)Pulses/Ragi/maize (Feb-May) 2. Sorghum / Pearl Millet / Ragi (July-Oct)-fodder (Nov-Feb)-Vegetables (Feb-Mar)	Mulching and Inter cultivation
5	Thiruvannamalai	Rice/Maize (Aug-Jan) – Pulses/Gingelly (Jan – Apr)	1.Groundnut/Maize (Aug –Dec) – Pulses (Jan- Apr)Pearl/Sorghum /fodder /Millets(Oct.-Jan.) 2.Cluster bean/Vegetable beans (Oct.-Jan.) in heavy oils	Rice-Use of short duration drought resistant varieties Pulses Groundnut- Irrigation at pegging, flowering and pod development stage Maize- Skip irrigation at seedling, knee high and dough stages under water scarce situation Gingelly- Irrigation at critical stages of moisture requirement - flowering stage (35-45DAS)

6	Villupuram	Paddy-Pulses, Banana -ratoon banana (2 yrs rotation)	1) Short duration Paddy Variety ADT 42 & ADT 39 2) Raising Pulses particularly Black gram –VBN 4 & VBN 5 3) Sugarcane – Decline in Area of cultivation and raising pulses particularly Black gram– VBN4 & VBN 5	**Paddy:** 1. Raise Rice crop in semi dry condition 2. Spray Cycocel @ 1000 ppm 3. Foliar spray of Kaolin 3 % or KCl1 %. 4. Split application of K ie. 50 % at basal and 25 % each at tillering and panicle initiation stage. **Sugarcane:** 1. Soaks setts in ethereal 200 ppm or lime solution for an hour 2. Spray Potash and Urea each at 2.5 % during stress period at 15 days interval
7	Cuddalore	1. Rice (June-Sep) - rice (Oct-Jan) - pulses/gingelly(Feb-May) 2.Maize /vegetables /pulses/sesame/green manure (June-Sep) - rice (Aug-Feb)-pulses(Feb-May) 3.Groundnut (June-Sep/Oct)- 3 years rotation	Rice Sesame Fodder legumes	Improved management techniques such as SRI, Direct sown crop for Paddy Short duration crops for fodder purpose Adopt moisture conservation practices

4.5 Development of Organic Farming

Organic Farming is a method of farming system which 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 (bio fertilizers) to release nutrients to crops for increased sustainable production in an ecofriendly pollution free environment. It is a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives ,etc) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection".

The total consumption of NPK fertilizers in the state is 14.11 Lakh MT and Pesticides 3210 MT in the form of Dust, 4.85 Lakh litre in the form of liquid(Source: Department of Agriculture, Chennai 600 005. Year 2012-13).In the present era, a natural balance needs to be maintained at all cost for existence of life and property by means of organic farming.

Organic Farming Area, Certified by Tamil Nadu Organic Farming Certification Department in the districts covered under Pennaiyar Basin as follows.

Sl.No	District	Area in Acre	Crops Covered
1	Krishnagiri	53.93	Mango , Amla , Ragi , Mulberry ,Banana , Drumstick , Guva , Jamun , Sappota,
2	Dharmapuri	555.54	Minor Millets
3	Salem	88.54	Vegetables, Sugarcane , Turmeric , Chillies , Brinjal.
4	Vellore	5511.64	Paddy , Sugarcane , Coconut , Banana ,Mango
5	Thiruvannamalai	924.03	Vegetables , Millets , Pulses , Paddy , Groundnut , Mangoes , Sappota
6	Villupuram	1616.82	Paddy , Sugarcane , Coconut , pulses , Millets
7	Cuddalore	9515	Cashew, Gingelly , Groundnut ,black Gram, Vegetables.

Though the yield of crops 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. The quality of produce from organic farming are monitored and certified by the Department of organic certification, Tamilnadu.

Yet another benefit of using organic farming is seen during the heavy flood. Heavy rain lashed over in the four districts of Tamilnadu 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. But using organic farming one farmer in Kancheepuram district sighed relief from damage to his crop due to inundation. Given below the news appeared in the newspaper "THE HINDU" dated 21st December 2015, where in the farmer says that his paddy plant gained momentum after inundation since he practiced organic fertilizer.

CHENNAI

THE HINDU • MONDAY, DECEMBER 21, 2015

Crops raised with organic manure survive inundation

V. VENKATASUBRAMANIAN

KANCHEEPURAM: For the second year in succession, Velu, a farmer in Morappakkam, near Madurantakam, has become the envy of other farmers as the crop raised by him managed to survive the inundation caused by the recent rains.

Enquiries reveal that the unexpected downpour during February last resulted in the damage of paddy crop raised in several acres in this village.

But, one variety — ADT 49 paddy crop — raised by Mr. Velu in about two acres of land owned by his landlord using high-nutrient fermented organic manure survived the inundation thanks to strong roots and firm stalks bearing the rice-corns. He harvested 30 bags, each weighing around 75 kilograms, of paddy per acre last year.

Encouraged by the result and help from M.J. Narasimhan, his landlord, Mr. Velu raised 150-day paddy varieties — 'ponni' and 'kichili samba' — this year in about three acres using the same organic manure, manufactured by Subashree Bio Energies, Tiruchengodu.

When the crop was about to blossom, the paddy fields were flooded and remained under three feet of water for two or three days due to the rain. However, when the water receded, the crops remained firmly rooted and paddy-corns started sprouting much to the delight of Mr. Velu and other farmers.

Talking to reporters at the field at Morapakkam on Sunday, Mr. Velu said he was elated to witness the crop withstand flooding at the time of sprouting.

Stating that he had not used pesticides since there were no situations warranting pesticide use, Mr. Velu said he had not encountered rat menace too. "The crop will be ready for harvest by January," he added.

Despite the paddy fields being waterlogged for three days, the crop was not damaged — PHOTO: D. GOPALAKRISHNAN.

4.6 Water Saving Techniques in Crop Production

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

Paddy: Especially for dominant crop like paddy, the effective and successful **System of Rice Intensification (SRI)** method of cultivation is suggested. Alternate wetting and drying practiced in this method of cultivation improve water use efficiency by 40% over the conventional method of cultivation and also the farmers of this basin have accepted this technology. Under 12th Five year plan (2012-2017) Agricultural Department is taking measures to cover 100% paddy area under SRI.

Benefits of the methodology:

- Drastic reduction in seed rate
- Synergistic root development and tillering of more than 70 tillers per hill with greater grain filling, greater pest and disease resistance and no lodging
- Good response both with traditional and high yielding varieties. However best response with high yielding variety.
- No requirement of herbicide.
- Multiple advantages of using weeder (weed incorporation, less labour for weeding, incorporation of top dressed fertilizer, disturbance to the soil system, increased tillering)
- More accessible to poor farmers as it is less dependent on external inputs
- Labour and water saving (40-50 percent)
- Environmental friendly – reduction in greenhouse gases
- Increase in number of panicles/m^{2}per grains panicle, grain and straw yield
- Higher net return

System of Rice Intensification (SRI) method of Paddy cultivation

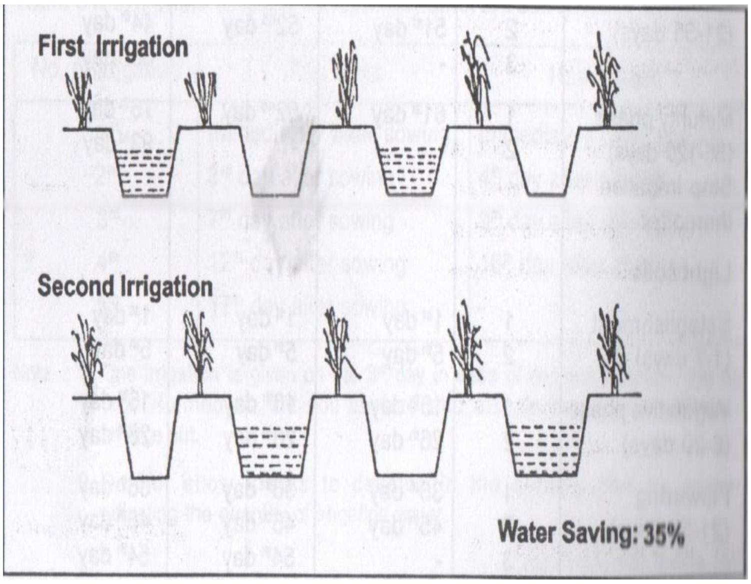
Sugarcane: Sustainable Sugarcane Initiative (SSI) is a method of sugarcane cultivation which involves using less seeds, less water and effective utilization of fertilizers and land to achieve more yields.

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) with single row planted above the lateral

Using Skip furrow Irrigation, Water saving is 50%. Using Alternate furrow Irrigation Water saving is 34.2 % when compared to the conventional furrows.



Alternate Furrow Irrigation

Sustainable Sugarcane Initiative (SSI) method of Sugarcane Cultivation

Maize: Maize crop requires irrigation at, immediately after sowing, life irrigation on 4th day, irrigation at Irrigation water / Cumulative Pan Evaporation ratio of 0.9 up to 15 days prior to harvest.

Application of water at 50 percent and 25 percent depletion levels at pre and post-flowering phases, respectively in maize utilized 305 mm of water with higher grain yield of 3359 kg/Ha. This is comparable term of yield to irrigating the crop at 25, 75, 25 and 100 percent depletion levels during pre and post flowering phases. In maize crop, higher water use efficiency was obtained when irrigation was scheduled at 75 percent available soil moisture depletion.

Groundnut: The infiltration rate of water is considerably improved by the application of coir waste which also gives highest yield of groundnut. For Groundnut crop, irrigating 50 mm depth at irrigation water / cumulative pan evaporation of 0.6 recorded higher yield. More number of irrigations in pre-flowering and maturity phases has no substantial increase in the pod yield.

In ground nut crop, among 4, 5 and 6 m width plots, plot of 5 m width, four irrigations with eight splashes per irrigation was found to be the best proposition for higher yield of groundnut pods, which consumed 202 mm of water against flood irrigation (500mm). It resulted in a saving of 247 mm of water.

Micro irrigation at 80% pan evaporation with 50% recommended fertilizer through fertigation would fetch Benefit/Cost ratio as 2.18.

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.

By adopting above mentioned water saving techniques on cultivation water saving in MCM is given below:

Sl.No.	Crop	Cultivated area in Ha	Water requirement- conventional method (MCM)	% of saving by adopting saving technique	Saving (MCM)
1	SRI-Paddy	90325	826.4	40	330.56
2	SSI-Sugarcane	64655	328.45	40	131.38

3	Banana	4325	21.9	33.33	7.23
4	Coconut	20416	165.2	63	102
5	Groundnut	22618	57.27	49.4	28.29
6	Vegetables	24086	43.4	29	13.46
				Total	**612.92**

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 Pennaiyar Basin. The cost of cultivation of crops in Tamilnadu is also appended in **Appendix 4.1 to 4.4 of Volume-II.**

4.7.1 Precision Farming.

Tamil Nadu has a wide range of diverse agro climatic conditions. These conditions greatly favour the cultivation of wide range of crops. TN IAMWARM project scheme is implemented in 61 sub-basins of Tamil Nadu which created lot of awareness among the stakeholders about importance of irrigation water and need of water saving technologies. Under IAMWARM project, in Kambainallur sub basin of Pennaiyar Basin, water savings are achieved in cultivation of following crops using drip fertigation system.

Banana - 23%, Tomato – 84%, Brinjal – 42%, Bhendi – 32.4%, Ribbed gourd – 34%, Watermelon- 69% , muskmelon – 58.6%

The cost of the system depends on the type of crops grown, spacing adopted, water requirements, location of water sources etc. It varies from Rs 30,000/- per ha for coconut/mango (wide spaced crops) to Rs 1, 60,000/- per ha for sugarcane / vegetables (closely spaced row crops) including fertigation equipment

In the last seven years, precision farming has been demonstrated by TNAU over in an area of 5800 ha over a wide range of crops. In many of the districts of the state, introduction was done through the project by TNAU and the sustainability proved is a daunting task and stand alone example of achievement.

Precision farming, a cultivation protocol which results in high yield with high quality first grade marketable produce, is being promoted by following cluster development approach. Farmers are being provided with critical input such as seeds, water soluble fertilizes, Bio fertilizers, Micro nutrient mixture & weed cide at 50% subsidy and drip irrigation equipments a up to Rs.97000 per Ha subsidy besides conducting adequate training under National Agricultural Development programme (NADP).

Micro irrigation system should be viewed as part of precision farming and it is important that all the inputs including water and fertilizer should be applied precisely at the right time and in right quantity. It is considered as the key activity that has the potential to improve the performance of the crop productivity.

Precision farming activities taken place under NADP in the districts covered Pennaiyar basin is given below. Crops mostly covered are sugar cane, Red gram, cotton, Maize and sunflower.

Sl.No.	District	Area in Ha					
		2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
1	Krishnagiri	500	0	0	0	100	60
2	Dharmapuri	470	0	100	300	100	40
3	Salem	450	40	660	500	320	80
4	Vellore	90	350	80	0	100	120
5	Tiruvannamalai	100	400	60	100	100	120
6	Villupuram	450	0	520	100	200	120
7	Cuddalore	90	350	40	380	200	120

Benefits of precision farming are

1. 90-95 % water application efficiency. Fixed network of pipes, ensures accurate and application at known rates
2. High matrix potential and osmotic potential of soil water which minimize osmotic stress. Low water pressure, low flow rate, high frequency irrigation resulting in continuously high soil water potential resulting possible benefit to plant
3. 40-80% water saving. Water applied to root zone in droplets. Soil moisture is kept at constant optimum level. Application rate matching the consumptive use of crop
4. 30 -130 % increased yield. Optimum plant performance resulting in higher yield and better quality produce
5. Avoids direct contact between water and leaves. Avoid salt accumulation in root zone (best method of irrigation to use saline water)
6. 40-60 %. Less opportunity of transporting fewer weeds and germination weeds
7. Easy and require less man power. System operation is continued through day and night regardless of wind, daylight and other hindrances
8. Saving 30-60% of electricity. Less operating time

9. 40-70%. Adequate and need based supply of water and nutrient to the root zone could be achieved by synchronizing the supply of both.
10. 70-40%. Labour required only for switching on or off.

4.8 Summary

4.8.1 Conclusion

- The Average Gross irrigated area of crops in Pennaiyar Basin is reported to be 3,18,855 Ha
- Out of the total area irrigated, about 44% is under paddy cultivation and 23% is under Sugarcane cultivation
- Gadilam sub basin has the maximum irrigated area 68626 Ha which accounts for about 22% of the total irrigated area.
- Maturar sub basin has the lowest irrigated area 1499 Ha which accounts for about 0.5% of the total irrigated area.
- Net Irrigation demand of this basin at 75% dependable rainfall is 1561.15 MCM
- Net Irrigation demand of this basin at 50% dependable rainfall is 1468.19 MCM
- Gadilam sub basin has the maximum irrigation demand of about 325.78MCM and Maturar sub basin has the minimum irrigation demand of about 6 MCM at 75% dependable rainfall.
- Organic farming practice is in tender stage in this basin.
- As per 2004 Pennaiyar study report, irrigation demand was given as 1330.02 MCM at 75% rainfall dependability with then crop area of 296233 Ha.

4.8.2 Recommendation

- If entire paddy cultivation practice is changed to SRI cultivation 40% of water could be saved. About 330.56 MCM of water can be saved.
- Using drip irrigation for the cultivation of Banana and Sugarcane water saving to the tune of 33.33% (7.23 MCM) and 40 %(131.238 MCM) respectively could be achieved.
- Using coir pith as soil mulch for coconut trees, 63% of Irrigation water could be saved. About 102 MCM of water can be saved.
- Using micro irrigation method for the cultivation of Groundnut, 49.4 %(28.29 MCM) water can be saved.

- Using drip irrigation for the cultivation of Vegetables water saving to the tune of 29% (13.46 MCM) could be achieved.
- During poor precipitation, suitable cropping pattern may be adopted with crops that require lesser irrigation like Millets, tapioca, Maize, Fodder legumes, Groundnut, Sorghum, Pulses etc.
- By adopting water saving technique, irrigation demand which consumes 90% of total demand can be brought down, and that can be used for other sectoral demands.
- Frequency/intensity of irrigation can be improved.
- 100% crop production can be achieved when un irrigated area is converted to irrigated. Hence Un irrigated area of 354800 Ha of this basin may be irrigated with available water potential. 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 River System

Pennaiyar River originates on the southeastern slopes of Chennakesava Hills, Northwest of Nandidurgam in Karnataka State at an altitude of 1000m above MSL. The river is known as Dakshina Pinakini in Karnataka State. After flowing through Karnataka, the river enters Tamil Nadu near Begalur village of Hosur Taluk. Pennaiyar river basin is bounded by Cauvery basin at its West, Vellar basin at South and Palar and Varahanadhi river basins at its North. The basin is located between the geographical co-ordinates Latitude 11^0 38’30” N & 12^0 54’00” N and Longitude 77^0 39’30” E & 79^0 54”.15” E. The total area of the basin in Tamil Nadu is 11,375.55sqkm and that of in Union Territory of Pondicherry is 90sq.km. The total drainage area of the river including the area in Karnataka is 15,101 sqkm. The total length of Pennaiyar River is 432 kms. It spreads over 112 kms. in Karnataka state, 180 kms. in Dharmapuri, Krishnagiri & Salem districts, 34 kms. in Thiruvannamalai and Vellore districts and 106 kms. in Cuddalore and Villupuram districts of Tamil Nadu. The river flows through Hosur, Krishnagiri, Sathanur, Tirukovilur, Sornavur and falls into Bay of Bengal at Cuddalore. It runs through Karnataka State and Dharmapuri, Krishnagiri, Thiruvannamalai, Vellore, Salem, Villupuram and Cuddalore districts in Tamil Nadu.

Pennaiyar river is not a perennial river and it has flows only during the monsoon season alone.

Pennaiyar river starts with a first order stream in Karnataka State and when it touches Tamil Nadu boundary it attains sixth order. As Markandanadhi joins it becomes seventh order. Vaniyar which has seventh order at its mouth makes the order of Pennaiyar from 7 to 8. Pennaiyar has eighth order till it confluences with the sea. Among the sub basins Vaniyar has the highest order (i.e) 7^{th} order, Valayar Odai, Ramakkal Odai and Thurinjalar have the lowest stream order of 4. The stream orders are generally proportional to the size of the basin.

The basin has a moderate drainage density and except in Kottaipattikallar, Valayar Odai and Pambanar and Varattar sub basins where the drainage density is more and for the other sub basins the drainage density is less, which indicates that the basin generally has hard resistant ground strata in the upper reaches upto Sathanur.

The Pennaiyar river is having 14 tributaries, namely, 1.Chinnar West, 2.Chinnar East, 3.Markandanadhi, 4.Kambainallur, 5.Pambar, 6.Vaniyar, 7.Kottaipatti, 8.Kallar, 9.Valayar Odai, 10.Ramakkal, 11.Pambanar, 12.Aliyar, 13.Musukundanadhi and 14.Turinjalar.

There are also 7 major Anicuts namely Nedungal Anicut, Kumarapatti Anicut, Ichembadi Anicut, Sathanur pick up Anicut, Tirukkoilur Anicut, Ellis Choultry Anicut and Sornavur Anicut.

In addition to this, there are 152 Minor Anicuts and about 66 open offtake channels in this river basin. A pick up anicut is located below 7km from the Sathanur reservoir to divert water to canals and river. Tirukovilur, Ellis Choultry, Sornavur anicuts are the major anicuts located below the Sathanur reservoir. There are 19 open off takes to feed the tanks above Tirukovilur Anicut and 47 open off takes to feed the tanks below Tirukovilur Anicut.

5.1.1 Tributaries of River Pennaiyar

Kelavarapalli reservoir is constructed across Pennaiyar at about 16 Km downstream of Tamil Nadu border of the river.

Just 3 Km downstream of the Kelavarapalli reservoir site, Chinnar West after travels a length of 40 Km and drains an area of 120 sq.km, it confluences with Pennaiyar on its right flank. About 10 Km from this point another tributary by name Chinnar East confluences with Pennaiyar on the left flank and having a length of 30 Km and drainage area of 300 sq.km. Shoolagiri Chinnar Reservoir is constructed across the river Chinnar East. About 12 Km downstream of the confluence point, a major tributary Markandanadhi joins Pennaiyar on the left flank. This river has its source from Berikai reserve forest and has two tributaries.

Below the confluence of Markandanadhi, many jungle streams join the main river on the right flank draining the Alapathy and Jakkasamudram reserve forest.

About 14 km below the confluence of Markandanadhi, Krishnagiri reservoir is constructed having a capacity of 47.18 Mcum.

About 40 Km downstream of Krishnagiri reservoir another tributary Kambainallur also called Semmandakuppam river joins Pennaiyar on the right flank. Kambainallur river has two tributaries namely Pullapatty river and Solakuttai river. Below the confluence point, Pennaiyar takes almost easterly course till the river Pambar, another major tributary joins the main river 30 km downstream on the left flank near Pavakkal in Uthangarai taluk. Pambar has two tributaries by name Bargur river and Mottur river. Both these tributaries join Pambar on its right flank Mottur river originates from Varattampatti hills and joins Bargur river near Kunnathur. Pambar has got another tributary also by name Kunnathur river which is only a jungle stream.

A little above the confluence of Pambar with Pennaiyar, Pambar Reservoir has been formed across Pambar river. On the right side of the river Pennaiyar a reservoir across Pullampattiyar a tributary has been formed namely Thumbalahalli reservoir.

About 10 Km downstream of confluence point of Pennaiyar with Pambar, another tributary Vaniyar joins the main river. This point is about 150 km from the Tamil Nadu boundary. Vaniyar has four tributaries namely Meenar, Peeniar, Kallar and Varattar. Across the river Vaniyar, Vaniyar reservoir has been formed.

Below the confluence point of Vaniyar, the main river flows to the north and east of Thirumalai hills with a number of bends in its course. In this reach many small jungle streams drains into Pennaiyar and the important of them are Kallar and Kovilar on its right flank. The river thus enters Chengam taluk and flows through Pennaiyar reserved forest.

Sathanur reservoir has been formed across Pennaiyar at this point. Downstream of the reservoir, the river takes a bend and follows the south easterly direction. About 7 Km below the reservoir a pick up anicut has been constructed from where Sathanur right bank and left bank and right bank canals are taking off.

A few Km below the pick up anicut another tributary Pambanar joins with Pennaiyar on its right flank. This river originates from Valasamalai R.F. Pambanar has two tributaries namely Varattar and Nettapalli Ar. About 16 km below the confluence of Pambanar river, another tributary namely Aliyar joins with the Pennaiyar. From the confluence of Pambanar with Pennaiyar, another tributary by name Musukandanadhi joins Pennaiyar. Musukandanadhi originates from Kalrayan hills in Kallakurichi taluk and runs for about a length of 40 km before falling into Pennaiyar. Below this the last tributary Thurinjalar joins Pennaiyar near Thirukoilur.

Just below the confluence of Thurinjalar, Thirukoilur anicut has been constructed and irrigates through five head sluices. Below this anicut the river splits into Pennaiyar and Malattar. Below Thirukoilur at about 20 km Ellis Choultry anicut has been constructed. And irrigates through five head sluices. Sornavur anicut is the last anicut across Pennaiyar. This was constructed in 1969. Thiruvendipuram anicut is the last anicut across Gadilam river.

S. No.	River	Source	Sub-Tributaries	Length of Main Tributaries km	Drainage sqkm.
1	Chinnar West	Karnataka		40	120
2	Chinnar East	Berigai		30	300
3	Markandanathi	Karnataka	Natchikuppam, Veppanapatti R	30	450
4	Kambainallur	Thoppur Hills MSL 2950 Dharmapuri Taluk	Palapathi Solakuttai	50	900
5	Pambar	Alangayam Hills MSL 3200	Mottur river Bargur river Kunnathur R	70	1900
6	Vaniyar	Vaniyambadi Taluk Yercaud Shevoray Hills	Meenar Peeniar Kallar Varattar	55	1100
7	Kottapatti	Kalvarayan Hills	-	40	450
8	Kallar	Harur Taluk			
9	Valayar Odai	Chengam Taluk	Kodi Odai Para-yarpalayam odai	15	70
10	Ramakkal	Ponnaiyar R.F. MSL 1500		5	16
11	Pambanar	Valasamalai Varattar R.F. 3400 MSL	Varattar Nettapalli Ar.	35	280
12	Aliyar	Chengam Taluk		30	220
13	Musukundanadhi	Alamur MSL 3900		40	200
14	Thurinjalar	Kavuthamalai R.F. MSL 1900		55	820

The flow diagram of Pennaiyar and Gadilam river is given in Fig. 5.1 and Fig 5.2. The irrigation System Map showing the locations of Reservoirs and Anicuts are given in Plate: PEN-29.

5.2 The Existing Surface Water Supply System

5.2.1. Existing Storage Reservoirs

There are following Nine reservoirs on the river Pennaiyar and its tributaries.

1. Kelavarapalli
2. Shoolagiri Chinnar
3. Krishnagiri
4. Andiappanoor Odai
5. Pambar
6. Thumbalahalli
7. Vaniyar
8. Varattar Vallimadurai
9. Sathanur

5.2.2. Anicuts

There have been ancient traditions of constructing anicuts across rivers and tributaries for diversion of water for irrigation purposes. These anicuts create a sort of temporary storage during lean periods when inflows are minimal at the sites, which were found suitable for water diversion.

i. **Nedungal Anicut**

The Nedungal Anicut is located at 16 km down stream of Krishnagiri Dam irrigates an area of 1760 ha.

ii. **Kumarapatti Anicut**

Kumarapatti Anicut has been constructed below Nedungal Anicut. It irrigates about 1011 ha by supply channels.

iii. **Ichembadi Anicut**

Ichembadi Anicut has been constructed across Kambainallur below Kumarapatti Anicut. Pullapatty river is the main tributary of Kambainallur. It irrigates an area of 2529 ha.

iv. **Sathanur pick up Anicut**

Sathanur pick up Anicut is located at 7 km down stream of Sathanur Dam from which canals take off to feed 18211ha. The length of the anicut is 122m with maximum flood discharge of 5664 Cumecs.

a) Left Canal:

Length of main canal	-	36 km
Full supply discharge	-	11.32 Mcum
Total area irrigated	-	9717 ha
Under tanks alone	-	130 ha

b) Right Canal:

Length of main canal	-	28.64 km
Full supply discharge	-	7.08 Mcum
Total area irrigated	-	8505 ha
Under tanks alone	-	1890 ha

v. Tirukovilur Anicut

Just below the confluence of Thurinjalar, Tirukovilur Anicut has been constructed. An irrigation of 8910 ha is carried out through five head sluices. Below this point the river splits into Pennaiyar and Malattar. The total yield for Tirukkoilur Anicut is worked out as 1244 Mcum.

vi. Ellis Choultry Anicut

Ellis Choultry Anicut was constructed below Tirukkoilur Anicut at the distance of about 20 km. This anicut irrigates about 5065 ha through five head sluices. The combined catchment area of this anicut is 13470 sqkm.

vii. Sornavur Anicut

Sornavur Anicut is the last anicut across Ponnaiyar. This anicut was constructed in 1969. This anicut stabilizes the irrigation for about 2509 ha, which includes 1932 ha in the Union territory of Pondicherry.

The hydraulic particulars of Sornavur Anicut and flow particulars of all anicuts are given in Appendix 4.4 of Volume II.

Anicuts and Channels details are given in Appendix 5.2 and 5.3 of Vol- II.

5.2.3.Tanks

Water harvesting when available in plenty and storing them in reservoir, convey, distribute and apply to field economically and manage them is a part of irrigation. Old village tanks created by our ancestors are one such rain water harvesting indigenous structure which had stood the test of time and even today are serving the community for its multifarious needs.

There are 206 system and 403 Non-system tanks in this basin. The total storage capacity of these 609 tanks is around 2176.50 MCM i.e. under system tanks 1209.18 MCM and under non-system tanks 967.32 MCM..

In Pennaiyar system, nearly 80% of the area is being irrigated through tanks only. Most of the tanks are lying in series with the result that more water stress is being felt in the commands of the downstream tanks. The tanks of higher capacities exist under the lower reach of the basin. The total command area under tank is 167920.40ha. Sub basin wise Tank Details are given in Appendix 1.1 of Volume II.

Table 5.1 Tank Details of Pennaiyar River Basin

S.NO	Name of Sub basin	No of Tanks		Capacity in Mcum		Ayacut Benifitted	
		System	Non-System	System	Non-System	System	Non-System
1	Chinnar West	---	4		2.28		268
2	Chinnar East	---	2		0.72		122.5
3	Markandanadhi	---	4		1.58		292.22
4	Kambainallur	---	36		14.01		115238.4
5	Pambar	9	37	2.11	33.33	416.85	3198.24
6	Vaniyar	5	4	2.39	1.05	6086	3255
7	Matturar	---	---	---	---	---	---
8	Kottaipattikallar	---	1		0.51		708
9	Valayar Odai	---	---	---	---	---	---
10	Ramakkal Odai	---	---	---	---	---	---
11	Pambanar and Varattar	---	1		0.88		82.98
12	Aliyar	3	11	0.27	7.22	58.07	655.79
13	Musukandanadhi	10	8	66.42	194.95	195.99	590.89
14	Thurinjalar	21	47	98.8735	23.66	1067.57	2489.245
15	Gadilam	69	109	460.29	56.59	5610.21	8294.48
16	Upto Krishnagiri Reservoir	---	9		4.56		1007.48
17	Krishnagiri to Pambar	26	21	3.497635	28.03	941.6	2261.35
18	Pambar to Thirukoilur	54	11	477.47	67.08	2294.245	921.09
19	Lower Pennaiyar	9	98	97.8591	530.875	1367.04	10497.145
	TOTAL	**206**	**403**	**1,209.18**	**967.320**	**18,037.58**	**1,49,882.81**

5.2.4. Operation and Maintenance of Water Bodies

In Pennaiyar basin, most of the big tanks are provided with shutters on the surplus weir, which are manually controlled. 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.

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 its capacity.

The Ministry of Water Resources, River Development & Ganga Rejuvenation has launched a State Sector Scheme with domestic Support for RRR scheme covering 10000 water bodies having Culturable Command Area (CCA) of 6.235 ha at a cost of Rs. 10000 Crore during XII Plan period. These include

1. Desilting and Improvements to Supply Channel
2. Desilting and Tank Bund Strengthening
3. Repairs / Improvements to Sluices and Weir
4. Lining of field Channel
5. Ground Water Recharge Shafts.

The objective of the scheme is comprehensive improvement of selected water bodies including Catchment Treatment and Command Area Development (CCA), increase in storage capacity of water bodies, Improvement in agricultural productivity, increased availability of drinking water and capacity building of communities in better water management.

The Project Proposals under Repair Renovation Restoration (RRR) schemes for all the river basins are prepared in a phased manner. For Pennaiyar basin the details are as given below

Sl.No.	Name of the Tank	Name of the Sub Basin	CCA / Ayacut in Ha	Estimate Amount in Lakh
Phase I – 7 Nos.				
1.	Chinnasamudram	Pambar	41.00	26.80
2.	Kakkankarai	Pambar	111.73	58.30
3.	Kurumberi	Pambar	58.93	23.48
4.	Rachamangalam	Pambar	55.320	30.75

5	Simmanapudur Tank	Pambar	93.670	44.09
6	Marimanikuppam Tank	Pambar	47.690	33.60
7	Kudapattu Tank	Pambar	47.780	47.16
Phase III – 2 Nos.				
1	Papparapatti Big Tank	Kambainallur	90.63	55.78
2	Adiyur Tank	Pambar	65.13	43.00
Phase IV – 12 Nos.				
1	Anandur	Krishnagiri upto Pambar	55.630	43.40
2	Thiruvanapatti Tank	Krishnagiri upto Pambar	55.190	39.00
3	Ettipalli Tank	Markendayanadhi	44.070	40.00
4	Mavathur	Krishnagiri upto Pambar	27.920	22.14
5	Thimmammacheruvu Tank	Markendayanadhi	76.760	58.20
6	Nagendran Tank	Chinnar West	83.770	31.70
7	Polayampalli Tank	Kambainallur	44.050	23.17
8	Konepallam Tank	Kambainallur	23.52	13.68
9	Mahendramangalam Tank	Kambainallur	76.050	47.40
10	Vetharampatti Tank	Kambainallur	45.750	29.24
11	Sinthalpadi Tank	Vaniyar	57.890	35.41
12	Bikkanahalli Tank	Kambainallur	91.660	29.83

The safety of the dams is maintained by the Dam Safety Directorate since 1991 which follows the dam safety procedures laid down by the Central Water Commission. Dams due to aging may develop some short comings in operation and monitoring facilities.

Under Dam Rehabilitation and Improvement Project (DRIP), a World Bank loan assistance project, it is proposed to rehabilitate the dams in Pennaiyar basin. Some of the rehabilitation measures proposed are:

Standardisation of Earthen bund

Repairs to road

Repairs / Renovation to Chute / Toe drain

Repairs / Renovation to Spillway

Repairs / Renovation to hoisting arrangements

Reaming and Grouting works to Gallery etc.

Repairs / Renovation to Spillway gates, sluice shutter, emergency gate etc.,

Sl.No.	Name of the Reservoir	Estimate Cost Rs.in Lakhs
1.	Kelavarapalli	291.45
2.	Shoolagiri Chinnar	17.00
3.	Krishnagiri	600
4.	Thumbalahalli	8.50
5.	Pambar	71.20
6.	Vaniyar	93.10
7.	Sathanur	445

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.

Central Water Commission (CWC) is having gauge stations at three places in the basin namely, 1.Gummanur, 2.Vazhavachanur and 3.Villupuram.

There are 16 Gauging sites in Pennaiyar river basin maintained by PWD as detailed below.

S. No.	Station Name	District	Latitude	Longitude
1	Kelavarapalli Reservoir	Krishnagiri	12^o 52' 42"	77^o 46' 06"
2	Shoolagiri Chinnar Reservoir	Dharmapuri	12^o 40' 05"	78^o 02' 20"
3	Krishnagiri Reservoir	Krishnagiri	12^o 28' 00"	78^o 11' 15"
4	Nedungal Anicut	Dharmapuri	12^o 22' 15"	78^o 16' 15"
5	Thumbalahalli Reservoir	Krishnagiri	12^o 18' 42"	78^o 09' 22"
6	Pambar Reservoir	Krishnagiri	12^o 16' 25"	78^o 34' 15"

7	Ichambadi Anicut	Dharmapuri	12° 09' 10"	78° 24' 00"
8	Vaniyar Reservoir	Dharmapuri	12° 54' 38"	78° 20' 15"
9	Sathanur Reservoir	Thiruvannamalai	12° 11' 00"	78° 50' 40"
10	Sathanur pick up Anicut	Thiruvannamalai	12° 08' 30"	78° 54' 00"
11	Tirukovilur Anicut	Villupuram	11° 56' 30"	79° 15' 00"
12	Ellis Choultry Anicut	Villupuram	11° 53' 30"	79° 25' 30"
13	Sornavur Anicut	Cuddalore	11° 41' 17"	79° 33' 05"
14	Thiruvathigai Anicut	Cuddalore	11° 46' 00"	79° 34' 30"
15	Thiruvanthipuram Anicut	Cuddalore	11° 44' 50"	79° 42' 40"
16	Gadilam Anicut	Cuddalore	11° 45' 00"	79° 44' 30"

There are nine reservoirs in this basin, their names, storage capacity, command area and Water Spread Area etc. are given below in **Table 5.2**

Table 5.2 Details of reservoir in Pennaiyar River Basin

S. No.	Name of the Reservoir	Capacity in Mcum	Water Spread Area in sq.Km	Catchment in sqkm.	Ayacut in ha.
1	Kelavarapalli	13.22	4.332	2442	3240
2	Shoolagiri Chinnar	2.3	0.445	144	871
3	Krishnagiri	66.1	12.48	5428	3647
4	Andiappanur Odai	3.177	0.866	5281	2034
5	Thumbalahalli	3.68	1.94	233	1059
6	Pambar	7.02	2.43	1736	1619
7	Vaniyar	11.78	1.093	102	3460
8	Varattar Vallimadurai	3.12	0.596	61.46	2067
9	Sathanur	228.91	18.21	10826	18211

The Inflow & Outflow particulars of the above nine Reservoirs are given in Appendix 5.6 of Volume II.

5.4 Surface water quality

Surface water is water on the surface of the planet such as in a stream, river, lake, wetland or ocean. It can be contrasted with groundwater and atmospheric water. It is mainly accumulated due to rainfall and runoff.

Non-saline surface water is replenished by precipitation and by recruitment from ground-water. It is lost through evaporation, seepage into the ground where it becomes ground-water, used by plants for transpiration, extracted by mankind for agriculture, living, industry etc. or discharged to the sea where it becomes saline.

The Nation's surface-water resources—the water in the nation's rivers, streams, creeks, lakes, and reservoirs are vitally important to our everyday life. The main uses of surface water include drinking-water and other public uses, irrigation uses, and for use by the thermoelectric-power industry to cool electricity-generating equipment. The majority of water used for thermoelectric power, public supply, irrigation, mining, and industrial purposes came from surface-water sources.

5.4.1 Surface Water Resources of Pennaiyar River Basin

The Pennaiyar river is a non – Perennial river and depends mainly on the North East and South West monsoon. During the monsoon period heavy flow is contemplated.

The total utilizable water potential of the state is 45818 Mcum / 1618 TMC. There are 17 major river basins in the State with 89 reservoirs and about 40,000 tanks (Water Resources Department and Panchayat Union). Most of the surface water has already been tapped, primarily for irrigation which is the largest user. The utilization of surface water for irrigation is about 90 percent.

Water resource potential of the Pennaiyar Basin @ 75% dependability is as follows:

Water resource potential during the South West Monsoon is 534.31 Mcum.

Water resource potential during the North East Monsoon is 639.85 Mcum

Water resource potential during the Non Monsoon is 145.42 Mcum

Total Water resource potential of Pennaiyar basin is **1319.58** Mcum.

Regarding surface water quality of Pennaiyar Basin, surface water samples collected from four places monitored by the State Ground and Surface Water Resources data Center, Tharamani, Chennai -113 were considered for this study.

They are

1. Krishnagiri Reservoir (G.D)
2. Sathanur at pick up anicut
3. Sornavur anicut (G.D)
4. Thiruvathigai anicut (G.D)

PON 01, PON 02, PON 03 and PON 04 are the ID number given to the above surface water sampling locations.

Regarding the **water quality of Pennaiyar River Basin,** all the values of the major ions falls within good quality range (TDS < 500mg/l) and the water can be used for domestic as well as agricultural purposes.

5.4.2 Daily Threats to Surface Water Quality

- Deforestation and poor land use practices in the catchment area which disturb topsoil and vegetative cover resulting in decreased infiltration rates, increased runoff, sediment transport and deposition in rivers and storage reservoirs.
- Over abstraction of surface water sources at the upstream reduces the minimum flow required in the downstream sections for the sustenance of ecosystems and mangroves.
- Use of lawn fertilizers and pesticides.
- Disposal of effluents and industrial wastes into water bodies.
- Leaky septic tanks.
- Improper disposal of household hazardous wastes (Medicines, cleaning products and electronics).
- Storm sewer contamination (Detergents used for car washing, animal wastes).

Monitoring surface water quality of our water bodies has to be seriously looked into, so as to ascertain portable drinking water and to be free from hazardous health problems arising due to contaminated water.

5.4.3 Measures to be Taken to Maintain the Quality of surface Water

1. Avoid contamination of surface water from agriculture fertilizers and pesticides.
2. Prevent disposal of effluents and industrial wastes into the water bodies without proper treatment.
3. To evict encroachments on the banks of river and streams so as to prevent contamination due to human wastes and sewages being let, into the water.
4. To encourage growth of fishes in water bodies.
5. Arrest the spreading of water hyacinth and water weeds which affects the quality and quantity of surface water.
6. Necessary steps may be taken to prevent the flow of excess surface water into

the sea by diverting the excess water to the affected surface water bodies.

7. Monitoring surface water quality of our water bodies has to be seriously looked into, so as to ascertain portable drinking water and to be free from hazardous health problems arising due to contaminated water.

8. Storm water management means, to manage surface run off. It is essential to prevent erosion of agricultural land and flooding of inhabited urban or rural areas. Both cases can cause severe damage and contamination of the environment if sanitation facilities are flooded. This results in high costs and notably massive suffering for the local communities.

5.5 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, climate and precipitation, intensity, duration, size and shape of the catchment, the direction of storm, orientation of the catchment, slope, soil, land use, etc. Monthly Runoff Simulation (MRS) Model assesses the surface water potential for 75% dependable yield for southwest, northeast and non monsoon periods. The influential rainfall stations having long term records are considered for Run-off analysis and the sub basin wise rainfall stations considered for analysis are given

Table 5.3 Raingauge stations considered for Run-off analysis

Sl. No.	Name of sub basins	Subbasin area (Sq.Km.)	Raingauge stations
1.	Chinnar West	125.315	Thali, Hosur
2.	Chinnar East	307.959	Melumalai, Hosur
3.	Markandanadhi	368.210	Krishnagiri, Melumalai, Hosur
4.	Kambainallur	919.279	Rayakotta, Dharmapuri, Nedungal, Barur, Palacode, Marandahalli.
5.	Pambar	1757.418	Thirupathur, Vaniyambadi, Uthangarai, Perugondapuram, Nedungal, Krishnagiri, Jolarpettai, Barur
6.	Vaniyar	998.385	Harur, Dharmapuri, Pappireddipatti, Anaimaduvu Rservoir, Uthangarai
7.	Matturar	58.498	Chengam, Thanipadi, Uthangarai

8.	Kottaipattikallar	410.229	Harur, Anaimaduvu Reservoir, Thanipadi, Gomukhi
9.	Valayar Odai	85.394	Chengam, Thanipadi, Sathanur Dam
10.	Ramakkal Odai	14.415	Thanipadi, Sathanur Dam
11.	Pambanar and Varattar	292.092	Thanipadi, Sathanur Pickup Anicut
12.	Aliyar	211.070	Vanapuram, Chengam, Thiruvannamalai, Sathanur dam, Sathanur Pickup Anicut
13.	Musukandanadhi	179.255	Vanapuram, Thanipadi, Sathanur Pickup Anicut
14.	Thurinjalar	853.623	Vanapuram, Thiruvannamalai, Thirukovilur, Kilnachipattu
15.	Gadilam	1562.903	Villupuram, Ulundurpet, Thirukovilur, Manimuthar, Panruti, Cuddalore
16.	Upto Krishnagiri Reservoir	772.638	Rayakotta, Krishnagiri, Melumalai, Hosur
17.	Krishnagiri to Pambar	894.518	Harur, Dharmapuri, Uthangarai, Perugondapuram, Nedungal, Krishnagiri, Barur, Palacode
18.	Pambar to Thirukoilur	1002.393	Harur, Vanapuram, Chengam, Thirukoilur, Thanipadi, Sathanur dam, Sathanur Pickup Anicut, Manimuthar, Uthangarai
19.	Lower Pennaiyar	561.963	Villupuram, Thirukoilur, Panruti, Cuddalore
	TOTAL	**11375.558**	

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

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

I. Surface Water Potential by Rainfall – Run-off Co-efficient Method

Pennaiyar River Basin has a drainage area of 11,375.558 Sq.Km. A rational approach to obtain the Run-off of a catchment is by assuming a suitable Run-off Co-efficient.

For arriving the yield the formula yield = C x A x P is used, where,

A - area of catchment in Sq.Km

P - weighted rainfall arrived from Theisson Polygon

C - Run-off Co-efficient

It is a very difficult process to decide the rainfall runoff factor. However, as adopted in the earlier reports prepared by IWS, it has been finally decided that a runoff coefficient of 0.15 for the plains and 0.20 for hilly would be more appropriate for 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 1263.38 MCM and is given below.

Table 5.4 Surface Water Potential in Pennaiyar River Basin

Sl. No.	Name of the Sub basin	Total Area in Sq.Km	Hilly Area in Sq.Km	Plain Area in Sq.Km	75% dependable Rainfall in mm	SW Potential for Hilly Area in MCM	SW Potential for Plain Area in MCM	Total SW Potential in MCM
1.	Chinnar West	125.32	0	125.32	500.94	0.00	9.42	9.42
2.	Chinnar East	307.96	17.11	290.85	630.78	2.16	27.52	29.68
3.	Markandanadhi	368.21	146.37	221.84	641.17	18.77	21.34	40.11
4.	Kambainallur	919.28	27.78	891.50	720.00	4.00	96.28	100.28
5.	Pambar	1757.42	160.08	1597.34	657.40	21.05	157.51	178.56
6.	Vaniyar	998.39	69.93	928.46	738.91	10.33	102.91	113.24
7.	Matturar	58.50	36.07	22.43	684.02	4.93	2.30	7.24
8.	Kottapattikallar	410.23	34.35	375.88	582.59	4.00	32.85	36.85
9.	Valayar Odai	85.39	44.35	41.04	674.13	5.98	4.15	10.13
10.	Ramakkal Odai	14.41	14.37	0.04	698.49	2.01	0.00	2.01
11.	Pambanar & Varattar	292.09	36.92	255.17	700.08	5.17	26.80	31.97
12.	Aliyar	211.07	43.03	168.04	713.60	6.14	17.99	24.13
13.	Musukandanadhi	179.26	7.11	172.15	711.35	1.01	18.37	19.38
14.	Thurinjalar	853.62	44.44	809.18	762.39	6.78	92.54	99.31
15.	Gadilam	1562.90	0	1562.90	837.43	0.00	196.32	196.32
16.	Upto Krishnagiri Reservoir	772.64	56.61	716.03	565.90	6.41	60.78	67.19

17.	Krishnagiri to Pambar	894.52	92.23	802.29	714.11	13.17	85.94	99.11
18.	Pambar to Thirukovilur	1002.39	219.67	782.72	773.81	34.00	90.85	124.85
19.	Lower Pennaiyar	561.96	0.03	561.93	873.29	0.01	73.61	73.61
Total		**11375.56**	**1050.45**	**10325.11**	**13180.39**	**145.91**	**1117.47**	**1263.38**

Annual Surface Water Potential of Pennaiyar River Basin calculated using Rainfall – Run-off Co-efficient Method is 1263.38 MCM at 75% dependability.

II. Surface Water Potential by NWDA Approach

Methodology adopted for working out Surface water potential:

(i) Krishnagiri to Pambar basin is the sub basin in the Middle reach of Pennaiyar River. There are 8 rain gauge stations in and around Lower Pennaiyar sub basin. Monthly rainfall data is available for the period between 1971-72 and 2014-15. Weighted rainfall for the sub basin is computed by Thiesson polygon method using Ars GIS software.

(ii) Utilisations in Lower Pennaiyar sub basin during monsoon period has been estimated considering the data on yearly irrigated area (Collected from the Department of Economics and Statistics).

(iii) Available observed monsoon flow data in Ichambadi anicut for the period from 1999-2000 to 2014-15 is tabulated. By adding this value with the upstream utilization, 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 2014-15, rainfall-runoff relationships are worked out based on regression analysis for the sub basin. The equation is $y = 0.108x+59.28$.

(v) The gross monsoon yield series of the sub basin for the period from 1999-2000 to 2014-15 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 109.67 Mcum for Krishnagiri to Pambar sub basin is obtained.

(vi) For the remaining sub basins namely, Chinnar West, Chinnar East, Markandanadhi, Kambainallur, Pambar, Vaniyar, Matturar, Kottaipattikallar, Valayar Odai, Ramakkal Odai, Pambanar and Varattar, Aliyar, Musukandanadhi, Thurinjalar, Gadilam, Upto Krishnagiri reservoir, Pambar to Thirukoilar and Lower Pennaiyar the above procedure is adopted and the gross monsoon yields are evaluated. The details are given in **Appendix 5.4.1 to 5.4.7of Vol II**. **75% dependable Monsoon yield (June to December) for the whole Pennaiyar river basin using NWDA approach works out to 1334.61 Mcum**

III. Surface Water Potential by MRS Model

(i) About the MRS Model

The Monthly Runoff Simulation (MRS) model and the related computer program were developed and prepared by Dr. Moshe Negev of TAHAL Consulting Engineers Ltd., Tel-Aviv, Israel ("TAHAL"). The 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, evapotranspiration 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 water shed model is that developed by Stanford University, U.S.A., in the nineteen-sixties, to which the author of the MRS model had the honour to contribute. 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 evapo transpiration 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. Detailed MRS Model descriptions are given in **Appendix 5.5 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 evapo transpiration 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 Potential Evapo Transpiration (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 evapo transpiration.

The following model parameters are required for 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.

The surface water potential arrived from MRS Model is given below.

Table 5.5 75% Dependable Surface Water Potential using MRS Model for Pennaiyar River Basin

Sl. No.	Subbasin Name	75% Dependable Surface Water Potential in Mcum			
		SW	NE	NM	Annual
1	Chinnar West	3.28	3.92	1.97	**9.17**
2	Chinnar East	15.25	11.38	2.81	**29.44**
3	Markandanadhi	13.96	13.58	12.80	**40.34**
4	Kambainallur	46.82	46.23	9.70	**102.75**
5	Pambar	114.42	56.92	17.66	**189.01**
6	Vaniyar	38.96	58.36	17.68	**115.01**
7	Matturar	4.17	2.11	0.76	**7.05**
8	Kottapattikallar	10.29	15.74	11.36	**37.40**
9	Valayar Odai	4.51	3.36	1.64	**9.51**
10	Ramakkal Odai	1.11	0.76	0.08	**1.96**

11	Pambanar and Varattar	17.54	12.41	1.78	**31.74**
12	Aliyar	10.66	11.16	2.77	**24.60**
13	Musukandanadhi	13.80	4.87	1.69	**20.25**
14	Thurinjalar	17.09	79.98	1.42	**98.51**
15	Gadilam	69.39	131.04	7.78	**208.21**
16	Upto Krishnagiri Reservoir	19.51	31.60	17.58	**68.69**
17	Krishnagiri to Pambar	44.15	42.08	14.61	**100.85**
18	Pambar to Thirukovilur	54.57	40.53	20.04	**115.15**
19	Lower Pennaiyar	34.83	73.82	1.29	**109.96**
Total		**534.31**	**639.85**	**145.42**	**1319.58**

South West Monsoon Potential	**534.31 (or) 534 Mcum**
North East Monsoon Potential	**639.85 (or) 640 Mcum**
Non Monsoon Potential	**145.42 (or) 145 Mcum**
Annual Potential	**1319.58 Mcum or 1320 Mcum**

Annual Surface Water Potential of Pennaiyar river basin calculated using MRS model is 1319.58 Mcum at 75% dependability.

Sub basin wise simulated monthly runoff is given in **Appendix 5.6.1 to 5.6.7 of Vol - II**.

The yield values worked out using MRS Model, Surface runoff Coefficient method and by NWDA approach is given in the table below:

Table 5.6 Surface Water Potential by NWDA approach

S. No.	Name of Sub basins	75% dependable Monsoon yield in Mcum		
		MRS Model	NWDA Approach	Surface Runoff Co efficient method
1	Chinnar West	9.17	7.14	9.42
2	Chinnar East	29.44	22.89	29.68
3	Markandanadhi	40.34	32.48	40.11
4	Kambainallur	102.75	91.52	100.28

5	Pambar	189.01	175.73	178.56
6	Vaniyar	115.01	117.55	113.24
7	Matturar	7.05	6.94	7.24
8	Kottaipattikallar	37.40	40.76	36.85
9	Valayar Odai	9.51	8.38	10.13
10	Ramakkal Odai	1.96	2.22	2.01
11	Pambanar and Varattar	31.74	31.88	31.97
12	Aliyar	24.60	22.43	24.13
13	Musukandanadhi	20.25	21.76	19.38
14	Thurinjalar	98.51	118.78	99.31
15	Gadilam	208.21	187.36	196.32
16	Upto Krishnagiri Reservoir	68.69	96.27	67.19
17	Krishnagiri to Pambar	100.85	109.76	99.11
18	Pambar to Thirukoilur	115.15	110.19	124.85
19	Lower Pennaiyar	109.96	164.93	73.61
Total		**1319.58**	**1368.97**	**1263.38**

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 1319.60 Mcum, calculated using MRS model is taken for Water Balance calculations, given in Chapter 8.

5.6 Out Flow to Sea

Sornavur anicut is the last anicut constructed across Pennaiyar river in Melpathy village of Villupuram taluk. Puducherry Union Territory border starts at 10 Km below Sornavur anicut and then pass through Cuddalore district and confluence in Bay of Bengal. Surplus flow details of this anicut are available from 1973 to 2015.

The analysis reveals that there was no surplus flow in 11years, the quantity exceeding 2000 Mcum is for 2 years, the quantity exceeding 1000 Mcum and above are for 2 years. The quantity between 400 – 1000 Mcum in 6 years, 100 – 400 Mcum in 7 years and less than 100 Mcum in 15 years. The analysis of the surplus flow details reveals that the flow to sea at 75% dependability is Nil Mcum. The surplus seems to occur in the lower reaches. The details are given below:

S. No.	Year	Discharge in Mcft	Descending order of discharge in Mcft	Descending order of discharge in Mcum	Relative frequency
1	1973	4906	90899	2574	0.02
2	1974	515	83468	2364	0.05
3	1975	4177	55670	1576	0.07
4	1976	45	35330	1000	0.09
5	1977	35329	33027	935	0.11
6	1978	3486	32817	929	0.14
7	1979	33026	24270	687	0.16
8	1980	0	21405	606	0.18
9	1981	16313	16313	462	0.2
10	1982	0	16201	459	0.23
11	1983	1643	**8758**	248	**0.25**
12	1984	1721	7016	199	0.27
13	1985	125	6908	196	0.3
14	1986	102	5447	154	0.32
15	1987	375	4968	141	0.34
16	1988	0	4906	139	0.36
17	1989	0	4177	118	0.39
18	1990	0	3486	99	0.41
19	1991	24269	2573	73	0.43
20	1992	6908	2346	66	0.45
21	1993	7016	1720.82	49	0.48
22	1994	1320	1643.24	47	0.50
23	1995	0	1493.34	42	0.52
24	1996	55670	1319.93	37	0.55
25	1997	32817	1201.22	34	0.57
26	1998	21405	1050.09	30	0.59

27	1999	1050	515.46	15	0.61
28	2000	2346	375.14	11	0.64
29	2001	2573	124.84	4	0.66
30	2002	0	101.95	3	0.68
31	2003	0	44.5	1	0.7
32	2004	5447	24.62	1	0.73
33	2005	83468	**0**	**0**	**0.75**
34	2006	1201	0	0	0.77
35	2007	4968	0	0	0.8
36	2008	8758	0	0	0.82
37	2009	25	0	0	0.84
38	2010	16201	0	0	0.86
39	2011	1493	0	0	0.89
40	2012	0	0	0	0.91
41	2013	0	0	0	0.93
42	2014	0	0	0	0.95
43	2015	90899***	0	0	0.98

*** 50% Dependability 1643.24 Mcft /47 Mcum**

**** 75% Dependability Nil**

*****Due to Flash Floods during November and December 2015**

5.6.1 Issues in the Management of Surface Water Resources

In a modernised agrarian context, as witnessed in several parts of Tamil Nadu the surface sources of irrigation are becoming scarcer year by year. Choosing crops, date of sowing / harvesting and so on, under tank / canal irrigation, ultimately depends upon the availability and the timing of the release of water from reservoir.

Tank irrigation, which is one of the most ancient systems in India, has a glorious history of extremely well organised governance and execution of all critical functions of water management such as maintenance, water sharing and arbitrating the conflicts that arise among users from time to time.

Tank irrigation system plays a major role in Tamil Nadu Agriculture and about 30% of the irrigated command area comes under tank irrigation system. Hence, possibility of rehabilitating the tanks in a phased manner has to be explored and executed by getting assistance from internal as well as external financial agencies.

1) Problems in Tanks Irrigation and the need for restoration

Much of south India lies in rain shadow regions, receiving a rainfall of less than 1,000 mm for most of the year. However, south India has had a long history of rainwater harvesting using tanks, which had helped support vibrancy in agriculture in this semi-arid region. If we look at the statistics then, the largest concentration of tanks in the country is found in the three southern states of Andhra Pradesh, Karnataka and Tamil Nadu and also in the union territory of Pondicherry, which account for nearly 60 percent of the tank-irrigated area. Together, these three states and the union territory have nearly 120,000 tanks (out of the 208,000 tanks in the country as a whole), irrigating 1.8 million hectares.

With the turn of the last century, there has been widespread recognition that the tanks are on a decline. This decline can be seen both in the form of decrease in the relative importance of tanks vis other modes of irrigation, as well as a decline in the actual area irrigated by them. From 1900s onward, several programs have been started with the help of the government as well as multilateral donors to revive the usage of tanks, but they have been ineffectual in checking the decline of tank irrigation.

In a modernised agrarian context, as witnessed in several parts of Tamil Nadu the surface sources of irrigation are becoming scarcer year-by-year. Choosing crops, date of sowing / harvesting and so on, under tank / canal irrigation, ultimately depends upon the availability and the timing of the release of water from reservoir.

Tank irrigation which is one of the most ancient systems in India, has a glorious history of extremely well organised governance and execution of all critical functions of water management such as maintenance, water sharing and arbitrating the conflicts that arise among users from time to time. Most of these rules, though regarded as informal have been recorded and are treated as legal documents even today, for all matters concerning adjudication and arbitration in particular.

The tanks in Tamil Nadu suffered from neglect in recent years. The statistics relating to tanks has the same fate. There is only disparate information available for tanks and tank irrigation. The tank memoirs, which were prepared during British period, were attempted to be updated, but they were discontinued in the recent years. This resulted in the non-availability of essential data on tanks to the researchers and the practising Irrigation Engineers. Each tank is a distinct entity with characteristic features of its own. There is a vast diversity and variety that the tanks represent. There is no way by which we could get a representative sample tank in Tamil Nadu.

Management of any irrigation system also depends on proper maintenance of field channels carrying water from the tank to the ayacut. It requires the careful attention and cooperation of both users and administrators of the system. Under tank irrigation system all ayacutdars are not equally effective in maintenance of channels.

Whenever there is a group of tanks, the water harvesting is effectively done and reduces flood damages. The over flow of one tank is directed to another and so on up to the terminal tank, which disposes the surplus to the nearby stream. In exceptional cases where tank chain systems are long and delays in carrying water to the tanks waiting in queue are available, bypass channels should be considered, bearing in mind the legal implications of prescriptive or traditional rights.

Despite the failures of the past 100 years in reviving tank irrigation, the quest for finding a way to rehabilitate this method continues, now more actively than ever before. This is because incidents reported from over large parts of south India indicate that groundwater, the prominent source of irrigation, has started to become unsustainable due to declining water tables. With possibilities of canal irrigation having already reached closure, the revival of tank irrigation offers a significant supply side intervention to fill the gap left by declining groundwater irrigation.

2) 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. Qualification of daily inflows received, diverted and surpluses 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 in the irrigation sluice and over the surplussing weir. Revised capacity curves are required to be established from the contour survey of the tank bed where these 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.

5.6.2 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 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 play 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 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 taken to conduct silt surveys in reservoirs in this basin to find out the rate of siltation and to take suitable soil conservation measures including afforestation for all these reservoirs.
10. Effective measures may be taken to utilize the surplus flow of Sornavur Anicut.
11. Changing operational methods of reservoirs, 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 salinisation 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.

5.7 Inter Basin Transfer of Water

Pennaiyar (Sathanur) - Cheyyar link

It is proposed to excavate a off take channel for a length of 23.55 Km and then a feeder canal for a length of 38.720 Km at LS 12.88 Km from the main canal, to divert the surplus water of Pennaiyar Basin from Sathanur to Palar River through Cheyyar and augmenting the supply to Nandan Canal in Thiruvannamalai District. Ayacut benefitted through this scheme is 189651.26 ha. Total cost for the proposed scheme is Rs. 250 Crores. Quantity of water diverted 5.87 TMC (i.e.3400 c/s for 20 days) of water.

Pennaiyar (Nedungal Anicut) - Palar Link

It is proposed to divert 3.50TMC of surplus water from Nedungal anicut at 50% dependability (2700 Cusecs for 15 days). The length of the Channel proposed under this scheme is 55.7 Km for stabilising the existing command areas to an extent of 11,870 ha.

5.8 Summary

Pennaiyar river is not a perennial river and it has flows only during the monsoon season alone. The Water Potential of a basin comprises of both Surface Water Potential and Ground Water Potential. For Pennaiyar basin the total potential works out to **3459.67 Mcum.**

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

The Annual Surface Water Potential of Pennaiyar River Basin calculated using Rainfall – Run-off Co-efficient Method is 1263.38 Mcum at 75% dependability and that by using MRS Model is 1319.58 Mcum. Also the 75% dependable Monsoon yield (June to December) for the whole Pennaiyar river basin using NWDA approach works out to 1334.61 Mcum.

As the MRS model considers individual monthly rainfall values for analysis, the 75% dependable Annual Surface water potential value of **1319.58 Mcum**, calculated using MRS model is taken for Water Balance calculations, given in Chapter 8.

In Pennaiyar river basin flow is measured in 9 anicuts and in 7 Reservoirs only. In addition to the above there are three measuring stations maintained by Central Water Commission, at Gummanur, Vazhavachanur and Villupuram. Hence automatic flow measuring devices may be installed in other anicuts and reservoirs 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 reserviors, 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 to ground water.

The surplus flow from the Sornavur Anicut to sea is **47 Mcum** and **Nil** for **50%** and **75%** dependability respectively.

It is suggested that the following proposals may be implemented for better and effective water management in this basin.

North East Monsoon Committee 2012 in its report has recommended the following structures :

Sl.No	Description	Storage Capacity in Mcft
1.	Reservoir across Muskandanadhi a tributary of Pennaiyar river, near Kodiyanur hamlet of Lakkinaickanpatti village of Sankarapuram taluk of Villupuram district.	56
2.	Bed Dam across Seshanadhi river near Padur village in Ulunderpet taluk, Villupuram district.	-

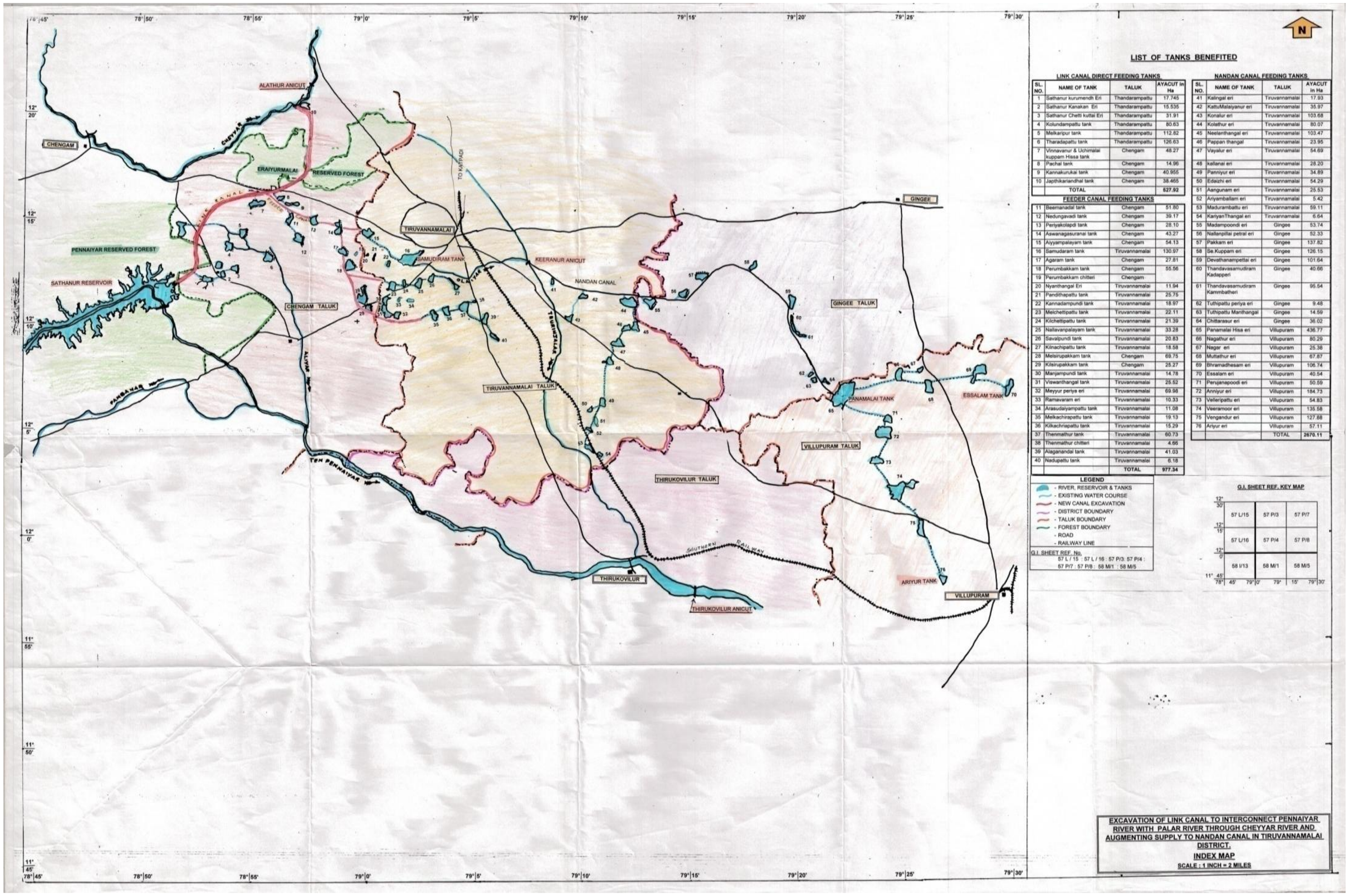
In addition to the above, The Chief Engineer, Chennai Region supported by Chief Engineer, Plan Formulation have also suggested the following new schemes in Pennaiyar Basin as shown in the given table **Table No:5.7**

Table No:5.7 New schemes in Pennaiyar River Basin

Sl.No	Description	Estimate Cost Rs in Crores
1	Construction of Check dam in Bellarapalli Village in Krishnagiri Taluk and District.	0.72
2	Construction of Check Dam across Pambar River in Singarapettai Village in Pambar Sub basin at Uthangarai taluk of Krishnagiri District	0.57
3	Construction of Check dam across Nachikuppam river in Markandeyanadhi Sub basin at Viruppasandriam Village of Krishnagiri Taluk and District.	0.84
4	Excavation of Supply Channel from Senganbasuvanthalav tank to divert flood surplus water of Chinnar river to feed Endapatti tank, Kondasamanahallu tank and 8 other inter –mediate tanks in Palacode Taluk of Dharmapuri District.	10.20
5	Construction of Check Dam across Kambainallur Village in Kambainallur Sub basin at Harur Taluk of Dharmapuri District.	1.16
6	Construction of Check dam across Kovilar river in Bairanaikampatti village in Kovilar Sub basin at Harur Taluk of Dharmapuri District.	0.83
7	Construction of new supply channel for Diversion of flood waters of Betamugaliampallam to Kesarigulihalla reservoir in Palacode Taluk of Dharmapuri District.	1.00
8	Excavation of New Supply Channel to feed Kagankarai tank in Thirupattur Taluk of Vellore District.	2.71
9	Formation of Earth Dam and Construction of Spillway and river Sluices across Malattar River at Bathallapalli village in Gudiyatham taluk of	29.55

	Vellore District	
10	Construction of Check dam across Pambanar river near Narayanakuppam village in Pambanar Sub basin at Thandarampattu Taluk of Thiruvannamalai District.	2.18
11	Construction of Artificial Recharge well Structures in Thurinjalar Sub basin in Thiruvannamalai District (7 Tanks-Aradapattu,Su.Andapattu,Pavithram,Mallavadi,Mathulampadi,Nookampadi and Somasipadi)	3.54
12	Construction of Sea Wall from LS from Ls 1850 m to 2470 m and Ls 2710 m to LS 3090 m (1000 m) in Chinnamudaliyar Chavadi Village in Vanur Taluk in Villupuram District.	2.80
13	Construction of series of 2 Groynes (5 and 6) in Mudaliyar Chavadi in Vanur Taluk in Villupuram District.	9.65
14	Construction of series of 3 Groynes in Bommaiyarpalayam in Vanur Taluk in Villupuram District.	6.90
15	Construction of series of 5 Groynes in Sodhanaikuppam in in Vanur Taluk in Villupuram District.	4.72
16	Construction of Diaphragm wall across Pennaiyar river between Perandaiyur village in Ulundurpet Taluk and Pidagam village in Villupuram Taluk of Villupuram District.	12.63
17	Construction of Check dam across Gadilam river near Koothambakkam village in Gadilam Sub basin at Cuddalore Taluk and District.	16.24
18	Construction RMS wall at Devanampattinam (LS 800m-LS 1220m) in Cuddalore Taluk of Cuddalore District.	1.80
19	Construction RMS wall for a length of 650 m from right bank of Pennaiyar mouth to Thazhanguda Village in Cuddalore Taluk of Cuddalore District.	2.54
20	Construction RMS wall for a length of 210 m from left bank of Pennaiyar mouth to Subauppalavadi village in Cuddalore Taluk of Cuddalore District.	0.84
21	Construction RMS wall at Devanampattinam (LS 1220 m – LS 2140 m)in Cuddalore Taluk of Cuddalore District.	3.90

FIG 5.1 PENNAIYAR (SATHANUR) - CHEYYAR LINK



LINK CANAL DIRECT FEEDING TANKS

SL. NO.	NAME OF TANK	TALUK	AYACUT in Ha
1	Sathanur kurumendh Eri	Thandarampattu	17.745
2	Sathanur Kanakan Eri	Thandarampattu	15.535
3	Sathanur Chetti kuttai Eri	Thandarampattu	31.91
4	Kolundampattu tank	Thandarampattu	80.63
5	Melkaripur tank	Thandarampattu	112.82
6	Tharadapattu tank	Thandarampattu	126.63
7	Vinnavanur & Uchimalai kuppam Hissa tank	Chengam	48.27
8	Pachai tank	Chengam	14.96
9	Kannakurukai tank	Chengam	40.955
10	Japthikariandhal tank	Chengam	38.465
	TOTAL		527.92

FEEDER CANAL FEEDING TANKS

SL. NO.	NAME OF TANK	TALUK	AYACUT in Ha
11	Beemanadal tank	Chengam	51.80
12	Nedungavadi tank	Chengam	39.17
13	Periyakolapdi tank	Chengam	28.10
14	Aswanagasuranai tank	Chengam	43.27
15	Aiyyampalayam tank	Chengam	54.13
16	Samudaram tank	Tiruvannamalai	130.97
17	Agaram tank	Chengam	27.81
18	Perumbakkam tank	Chengam	55.56
19	Perumbakkam chitteri	Chengam	
20	Nyanthangal Eri	Tiruvannamalai	11.94
21	Pandithapattu tank	Tiruvannamalai	25.75
22	Kannadampundi tank	Tiruvannamalai	18.97
23	Melchettipattu tank	Tiruvannamalai	22.11
24	Kilchettipattu tank	Tiruvannamalai	21.39
25	Nallavanpalayam tank	Tiruvannamalai	33.28
26	Savalpundi tank	Tiruvannamalai	20.83
27	Kilnachipattu tank	Tiruvannamalai	18.58
28	Melsirupakkam tank	Chengam	69.75
29	Kilsirupakkam tank	Chengam	25.27
30	Manjampundi tank	Tiruvannamalai	14.78
31	Viswanthangal tank	Tiruvannamalai	25.52
32	Meyyur periya eri	Tiruvannamalai	69.98
33	Ramavaram eri	Tiruvannamalai	10.33
34	Arasudaiyampattu tank	Tiruvannamalai	11.08
35	Melkachirapattu tank	Tiruvannamalai	19.13
36	Kilkachriapattu tank	Tiruvannamalai	15.29
37	Thenmathur tank	Tiruvannamalai	60.73
38	Thenmathur chitteri	Tiruvannamalai	4.66
39	Alaganandal tank	Tiruvannamalai	41.03
40	Nadupattu tank	Tiruvannamalai	6.18
		TOTAL	977.34

NANDAN CANAL FEEDING TANKS

SL. NO.	NAME OF TANK	TALUK	AYACUT in Ha
41	Kalingal eri	Tiruvannamalai	17.93
42	KattuMalaiyanur eri	Tiruvannamalai	35.97
43	Konalur eri	Tiruvannamalai	103.68
44	Kolathur eri	Tiruvannamalai	80.07
45	Neelanthangal eri	Tiruvannamalai	103.47
46	Pappan thangal	Tiruvannamalai	23.95
47	Vayalur eri	Tiruvannamalai	54.69
48	kallanai eri	Tiruvannamalai	28.20
49	Panniyur eri	Tiruvannamalai	34.89
50	Edaizhi eri	Tiruvannamalai	54.29
51	Aangunam eri	Tiruvannamalai	25.53
52	Ariyamballam eri	Tiruvannamalai	5.42
53	Madurambattu eri	Tiruvannamalai	59.11
54	KariyanThangal eri	Tiruvannamalai	6.64
55	Madampoondi eri	Gingee	53.74
56	Nallanpillai petral eri	Gingee	52.33
57	Pakkam eri	Gingee	137.82
58	Se.Kuppam eri	Gingee	126.15
59	Devathanampettai eri	Gingee	101.64
60	Thandavasamudiram Kadapperi	Gingee	40.66
61	Thandavasamudiram Kammbatheri	Gingee	95.54
62	Tuthipattu periya eri	Gingee	9.48
63	Tuthipattu Manthangal	Gingee	14.59
64	Chittarasur eri	Gingee	36.02
65	Panamalai Hisa eri	Villupuram	436.77
66	Nagathur eri	Villupuram	80.29
67	Nagar eri	Villupuram	25.38
68	Muttathur eri	Villupuram	67.87
69	Bhramadhesam eri	Villupuram	106.74
70	Essalam eri	Villupuram	40.54
71	Perujanapoodi eri	Villupuram	50.59
72	Anniyur eri	Villupuram	184.73
73	Velleripattu eri	Villupuram	54.83
74	Veeramoor eri	Villupuram	135.58
75	Vengandur eri	Villupuram	127.88
76	Ariyur eri	Villupuram	57.11
		TOTAL	2670.11

FIG 5.2 PENNAIYAR (NEDUNGAL ANICUT) - PALAR LINK

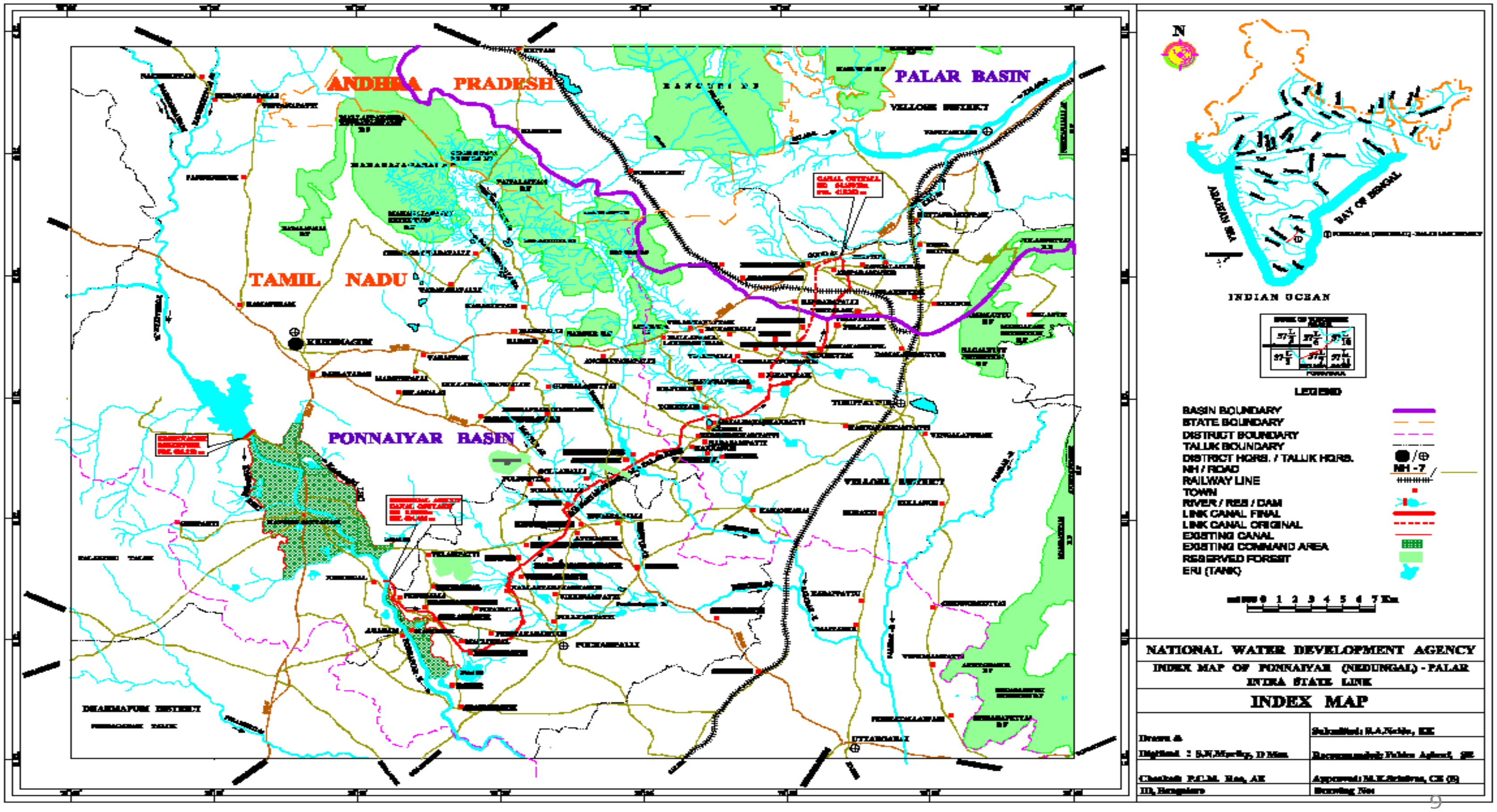
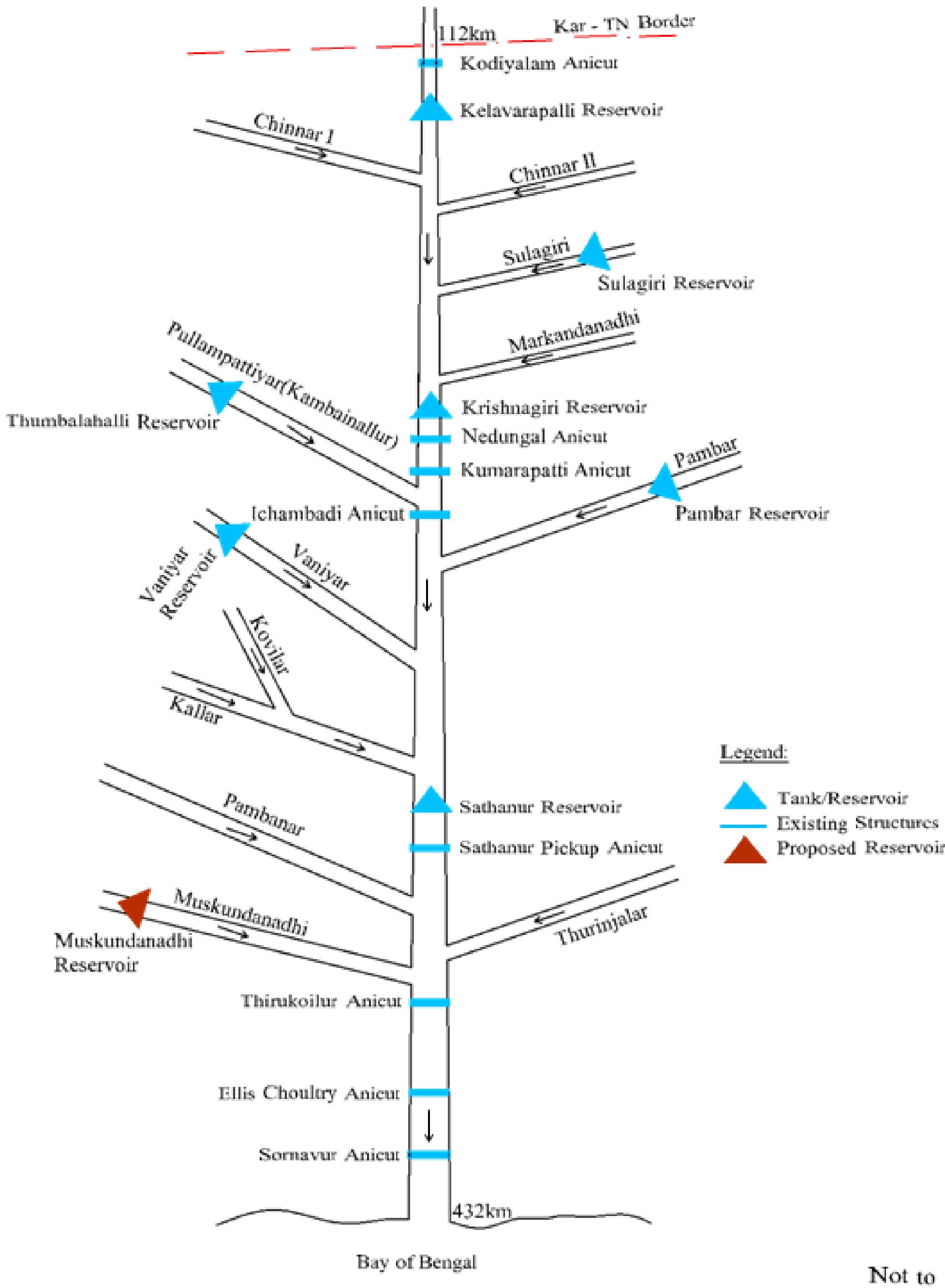
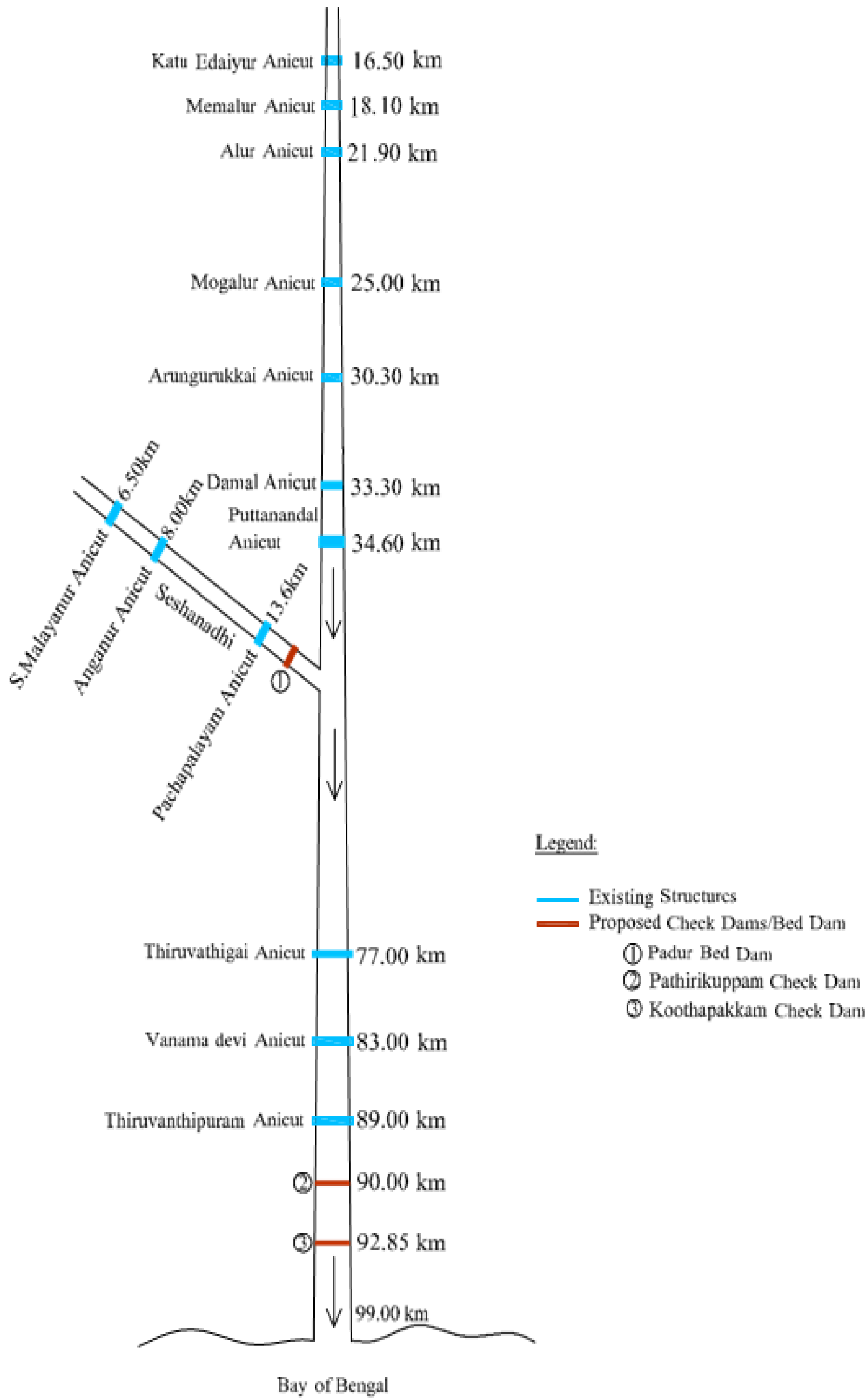


FIG 5.3 PENNAIYAR RIVER



Not to Scale

FIG 5.4 GADILAM RIVER



Not to Scale

SATHANUR RESERVOIR

1.	Location	:	12º11’0.51 ” N	**Spill Way**		:	
		:	78º51’1.41 ” E	18.	Vents	:	9 Nos 12.19 x 6.10 m
General				19.	Crest	:	+216.100 m
2.	River	:	Pennaiyar	20.	Type	:	Ogee
3.	Basin	:	Pennaiyar	**River Sluice**			
4.	Sub Basin		Pambar to Thirukoilar				
5.	Nearest Town	:	Thiruvannamalai	21.	Vent	:	5 Nos 1.52 x 1.83 m
6.	District	:	Thiruvannamalai	22.	Sill	:	+185.930 m
7.	Construction Period	:	1954 -1958	23.	Discharge	:	240.49 cumecs
8.	Cost	:	Rs.318.00 lakh	**L.B.Canal**			
Reservoir				24.	Length	:	35.40 km
9.	Catchment Area	:	10825.78 Sq.km	25.	Discharge	:	11.3 cumecs
10.	Design Flood	:	Original 5664 cumecs Revised as per DRIP 21181 cumecs	**R.B.Canal**			
11.	F. R.L/M.W.L	:	+222.200 m	26.	Length	:	28.64 km
12.	Water Spread Area	:	18.21 Sq.km	27.	Discharge	:	7.08 cumecs
13.	Capacity at F.R.L	:	207.30 M.cum	**Ayacut**			
Dam				28.	L.B.C	:	9712.5 ha
14.	Type	:	Masonry-cum-Earth Dam	29.	R.B.C	:	8498.4 ha
15.	Top of Road Way	:	+224.785 m	30.	District Benefitted	:	Thiruvannamali and Villupuram
16.	Maximum Height	:	44.81 m				
17.	Length of Earth Dam Masonry	:	 361 m 419 m				

KELAVARAPALLI RESERVOIR

1.	Location	:	12º46’12 ” N	20.	Type	:	Ogee
		:	77º52’30 ” E	**River Sluice**			
General				21.	Vent	:	1 No 1.20 x 1.82 m
2.	River	:	Pennaiyar	22.	Sill	:	+818.000 m
3.	Basin	:	Pennaiyar	23.	Discharge	:	0.40 cumecs
4.	Sub basin		Upto Krishnagiri Reservoir				
5.	Nearest Town	:	Hosur	**Canal Sluice**			
6.	District	:	Krishnagiri	24.	Left Side Vent	:	1 No 0.80 X 1.50 m
7.	Construction Period	:	1977 - 95	25.	Sill	:	+823.000 m
8.	Cost	:	Rs.1250 lakh	26.	Discharge	:	1.92 cumecs
Reservoir				27.	Right Side Vent	:	1 No 0.90 x1.50 m
9.	Catchment Area	:	2442 Sq.km	28.	Sill	:	+823.000 m
10.	Design Flood	:	Original 2490 cumecs Revised as per Drip 2641 cumecs	29.	Discharge	:	0.697 cumecs
11.	F. R.L/M.W.L	:	+831.50m	**Canal**			
12.	Area at F.R.L	:	4.332 Sq.km	**Left Side**			
13.	Capacity at F.R.L	:	13.61 Mcum	30.	Length	:	25.50 km
Dam				31.	F.S.Discharge	:	1.92 cumecs
14.	Type	:	Earth cum Masonry Dam	**Right Side**			
15.	Top of Road Way	:	+833.900 m	32.	Length	:	21.99 km
16.	Maximum Height	:	13.5 m	33.	F.S.Discharge	:	0.697 cumecs
17.	Length of Earth Dam Masonry	:	 546.80 m 118.20 m	34.	**Ayacut**	:	4380 ha
Spill Way				35.	District	:	Krishnagiri
18.	Vents	:	7 Nos	36.	Taluk	:	Hosur
19.	Crest	:	+825.400 m				

PAMBAR RESERVOIR

1.	Location	:	12°16’ N	16.	Maximum Height	:	16.50 m
		:	78°34’ E	17.	Length of	:	
General					Earth Dam		652.00 m
					Masonry Dam		73.00 m
2.	River	:	Pambar	**Spill Way**			
3.	Basin	:	Pennaiyar	18.	Vents	:	5 Nos 12.19 x 4.57m
4.	Sub basin	:	Pambar	19.	Crest	:	+316.500 m
5.	Nearest Town	:	Uthangarai				
6.	District	:	Krishnagiri	20.	Type	:	Free overflow with radial Gates
7.	Construction Period	:	1977-1983				
8.	Cost	:	Rs.248 lakh	**River Sluice**			
	Reservoir			21.	Vent	:	1 No 0.91x 1.52 m
9.	Catchment Area	:	1736.00 Sq.km	22.	Sill	:	+315.000 m
10.	Design Flood	:	Original 1513.39 cumecs Revised per Drip 1928 cumecs	23.	Discharge	:	1.42 cumecs
11.	F. R.L	:	+321.000 m	**Canal**			
12.	Area at F.R.L	:	2.43 Sq.km	24.	Length	:	29.50Km
13.	Capacity at F.R.L	:	7.93 Mcum	25.	F.S.Discharge	:	1.42 cumecs
	Dam			26.	**Ayacut**		1618.78 ha
14.	Type	:	Earth cum Masonry	27.	District Benefitted	:	Krishnagiri
15.	Top of Road Way	:	+ 323.500 m	28.	Taluk Benefitted	:	Uthangarai and Harur

KRISHNAGIRI RESERVOIR

1.	Location	:	12°28' N	20	Type	:	Lift gates
		:	78°11' E	**River Sluice**			
General				21.	Vent	:	3 Nos 1.52 X 1.82m
2.	River	:	Pennaiyar	22.	Sill	:	+ 467.26 m
3.	Basin	:	Pennaiyar	23.	Discharge	:	172.75 cumecs
4.	Sub Basin	:	Upto Krishnagiri Reservoir				
5.	Nearest Town	:	Krishnagiri	**Canal Sluice**			
6.	District	:	Krishnagiri	24.	**Left Side Vent**	:	1 No 1.52 X 1.83 m
7.	Construction Period	:	1955-1958	25.	Sill	:	+473.730 m
8.	Cost	:	Rs.202 lakh	26.	Discharge		2.83 cumecs
Reservoir				27.	**Right Side Vent**	:	1 No 1.22 X 1.22 m
9.	Catchment Area	:	5366 Sq.km	28.	Sill	:	+473.730 m
10.	Design Flood	:	Original 4061 cumecs Revised as per Drip 5103 cumecs	29.	Discharge Discharge	:	2.83 cumecs
11.	F. R.L	:	+483.110 m	**Canal**			
12.	Area at F.R.L	:	12.48 Sq.km				
13.	Capacity at F.R.L	:	47.18 M.cum	**Left Side**			
Dam				30.	Length	:	18.5 km with 9
14.	Type	:	Earth cum masonry dam	31.	F.S.Discharge	:	2.83 cumecs
15.	Top of Road Way	:	+ 487.370 m	**Right Side**			
16.	Maximum Height	:	29.26 m	32.	Length	:	14 km with 9
17.	Length of Earth Dam Masonry dam	:	 713 m 290 m	33.	F.S.Discharge	:	2.83 cumecs
Spill Way				34.	**Ayacut**		3642.25 Ha
18.	Vents	:	8 Nos 12.20 X 6.10 m	35.	District Benefitted		Krishnagiri
19.	Crest	:	+477.100 m	36.	Taluk Benefitted		Krishnagiri

Note : The total ayacut localized under this project is 9012 acres inclusive of 2329 acres irrigated by two P.W.D. tanks and 24 Minor Irrigation tanks, which are fed, by KRP. The Barur tank is fed by this reservoir, which has an ayacut of about 2800 acres

SHOOLAGIRICHINNAR RESERVOIR

1.	Location	:	12º40’50 ” N	**Spill Way – High co- efficient weir**			
		:	78º02’31 ” E	18.	Vents	:	-
General				19.	Crest	:	+664.00 m
				20.	Type	:	High Coefficient
2.	River	:	Chinnar East	21.	Vent	:	1 No 0.9 X 1.50 m
3.	Basin	:	Pennaiyar	22.	Sill	:	+ 654.000 m
4.	Sub Basin	:	Chinnar East				
5.	Nearest Town	:	Shoolagiri	23.	Discharge	:	0.48 cumec
6.	District	:	Krishnagiri		**Canal Sluice**		
7.	Construction Period	:	1981-85	24.	Right Side Vent	:	1 No 0.9 X 1.50 m
8.	Cost	:	Rs.176 lakh	25.	Sill	:	+654.000 m
Reservoir				26.	Discharge	:	0.113 Cumecs
9.	Catchment Area	:	143.62 Sq.km		**Canal**		
10.	Design Flood	:	Original 547.10 cumecs Revised as per Drip 689 cumecs		**Left Side**		
11.	F. R.L	:	+664.00 m	27.	Length	:	2600 m
12.	Area at F.R.L	:	0.445 Sq.km	28.	F.S.D	:	0.35 m
13.	Capacity at F.R.L	:	2.30 M.cum		**Right Side**		
Dam				29.	Length	:	8650 m
14.	Type	:	Earthen dam	30.	F.S.D	:	0.75 m
15.	Top of Road Way	:	+ 667.500 m	31.	**Ayacut**	:	871 Ha
16.	Maximum Height	:	25.30 m	32.	District	:	Dharmapuri
17.	Length of Earth Dam	:	415 m	33.	Taluk Benefitted	:	Hosur

THUMBALAHALLI RESERVOIR

1.	Location	:	$12^o18'$ N	19.	Crest	:	+467.00 m
		:	$78^o09'22''$ E	20.	Type	:	Ogee with radial
General				**River Sluice**			
2.	River	:	Poollapatti	21.	Vent	:	1 No 1.52 X 1.83 m
3.	Basin	:	Pennaiyar	22.	Sill	:	+462.000 m
4.	Sub Basin	:	Kambainallur	23.	Discharge	:	16.82 cumecs
5.	Nearest Town	:	Palakode	**Canal Sluice**			
6.	District	:	Dharmapuri	24.	Left Side Vent	:	1 No 0.90 X 1.52 m
7.	Construction Period	:	1979-83	25.	Sill	:	+467.000 m
8.	Cost	:	Rs. 205 lakh	26.	Discharge		0.42 cumecs
Reservoir				27.	Right Side Vent	:	1 No 0.90 X 1.52 m
9.	Catchment Area	:	232.50 Sq.km	28.	Sill	:	+467.000 m
10.	Design Flood	:	Original 689 cumecs Revised as per Drip 1111 cumecs	29.	Discharge Discharge	:	0.42 cumecs
11.	F. R.L/M.W.L	:	+471.50 m	**Canal**			
12.	Area at F.R.L	:	1.94 Sq.Km	**Left Side**			
13.	Capacity at F.R.L	:	3.71 Mcum	30.	Length	:	8.39 km
Dam				31.	F.S.Discharge	:	0.868 cumecs
14.	Type	:	Earth cum masonry dam	**Right Side**			
15.	Top of Road Way	:	+473.60 m	32.	Length	:	4.55 km
16.	Maximum Height	:	12.30 m	33.	F.S.Discharge	:	0.236 cumecs
17.	Length of Earth Dam Masonry dam	:	 1043.50 m 58.90 m	34.	**Ayacut**	:	883.85 Ha
Spill Way				35.	District Benefitted	:	Krishnagiri
18.	Vents	:	3 Nos 12.5 X 4.50 m	36.	Taluk Benefitted	:	Palacode

VANIYAR RESERVOIR

1.	Location	:	11°54’18 ” N	20.	Type	:	Free overflow with Radial Gates
		:	78° 19’30 ”E				
General				River Sluice			
2.	River	:	Vaniyar	21.	Vent	:	1 No, 1.50x 1.83 m
3.	Basin	:	Pennaiyar	22.	Sill	:	+455.000 m
4.	Sub Basin	:	Vaniyar				
5.	Nearest Town	:	Pappireddipatti	23.	Discharge	:	1.573 cumecs
6.	District	:	Dharmapuri	**Canal Sluice**			
7.	Construction Period	:	1981-85	24	Left Side Vent	:	1 No. 1.50 x 1.80m
8.	Cost	:	Rs. 1203.10 lakh	25.	Sill	:	+451.100 m
Reservoir				26.	Discharge		0.93 cumecs
9.	Catchment Area	:	101.76 Sq.km	27.	Right Side Vent	:	1 No. 1.50 x 1.80 m
10.	Design Flood	:	Original 654.90 cumecs Revised as per DRIP 857 cumecs	28.	Sill	:	+451.10 m
11.	F. R.L/M.W.L	:	+471.000 m	29.	Discharge	:	1.48 cumecs
12.	Area at F.R.L	:	1.093 Sq.Km	**Canal**			
13.	Capacity at F.R.L	:	11.80 Mcum	**Left Side**			
Dam				30.	Length	:	11.40 km
14.	Type	:	Earth dam	31.	F.S.Discharge	:	0.93 cumecs
15.	Top of Road Way	:	+ 474.000 m	**Right Side**			
16.	Maximum Height	:	31.17 m	32.	Length	:	12.40 km
17.	Length of Earth Dam	:	1360 m	33.	F.S.Discharge	:	1.48 cumecs
Spill Way				34.	**Ayacut**	:	3460 ha
18.	Vents	:	3 Nos, 11.3x 4.50m	35.	District Benefitted	:	Dharmapuri
19.	Crest	:	+466.500 m	36.	Taluk Benefitted	:	Harur

VARATTAR RESERVOIR

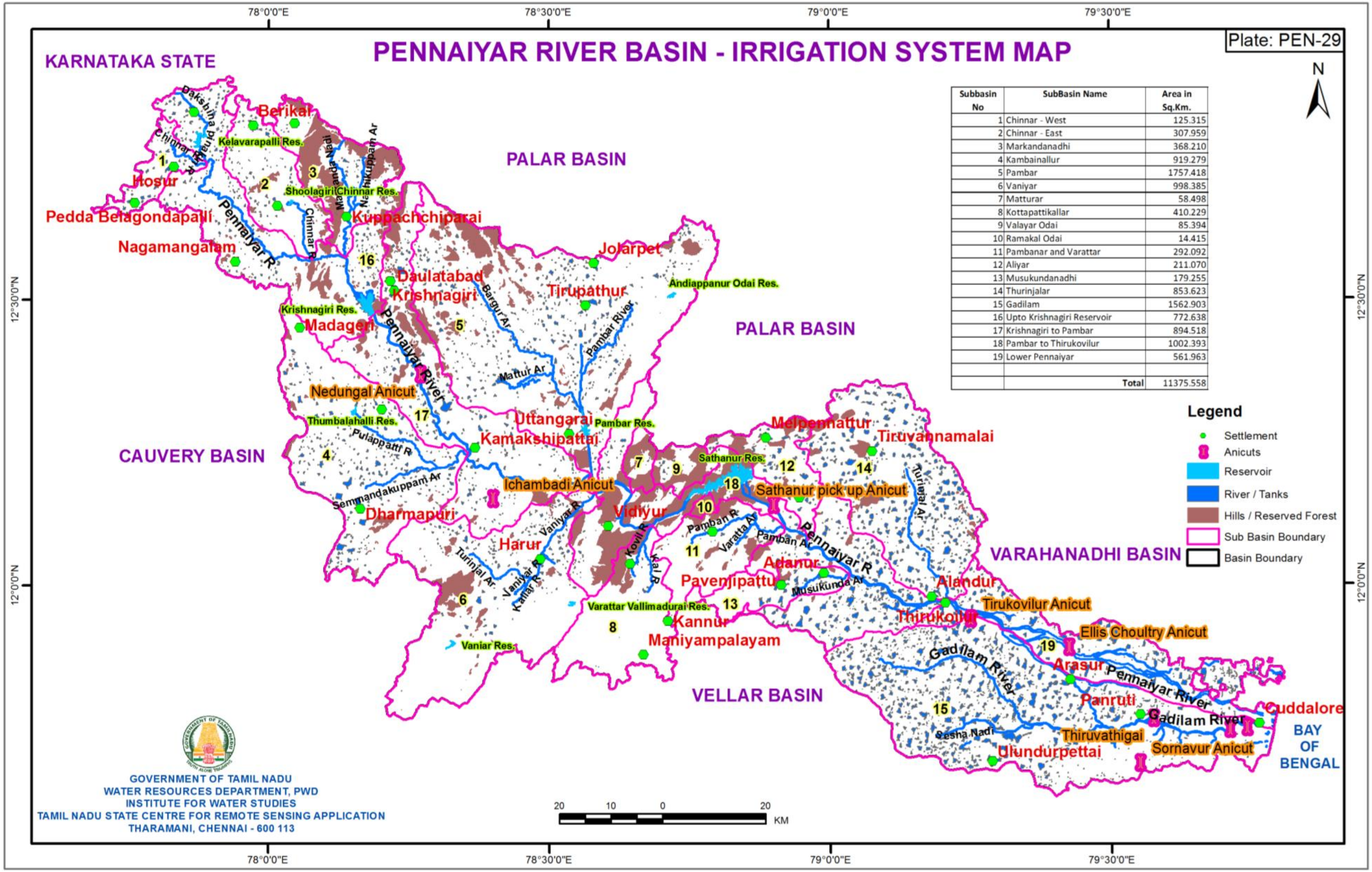
1.	Location	:	11°58’00 ” N	16.	Maximum Height	:	21 m
		:	78° 32’00 ”E	17.	Length of Earth Dam Masonry Dam	:	 1200 m 160 m
General							
2.	River	:	Varattar	**Spill Way – Uncontrolled Surplus Weir**			
3.	Basin	:	Pennaiyar	18.	Vents	:	--
4.	Sub Basin	:	Vaniyar	19.	Crest	:	+466.50 m
5.	Nearest Town	:	Harur				
6.	District	:	Dharmapuri	20.	Type	:	Uncontrolled
7.	Construction Period	:	2001-07	**Canal**			
8.	Cost	:	Rs. 3595 lakh	**Left Side**			
Reservoir				21.	Length of Main canal Branch canal	:	 9 km 6x12.45 km
9.	Catchment Area	:	:	22.	F.S.Discharge	:	1.65 cumecs
10.	Design Flood	:	439 cumecs	**Right Side**			
11.	F. R.L M.W.L	:	+434.50 m +435.70 m	23.	F.S.Discharge	:	0.27 cumecs
12.	Area at F.R.L	:	54.62 Sq.Km	24.	**Ayacut**	:	2067 ha
13.	Capacity at F.R.L	:	110.33 Mcum	25.	District Benefitted	:	Dharmapuri
Dam				26.	Taluk Benefitted	:	Harur
14.	Type	:	Earth dam cum Masonry				
15.	Top of Road Way	:	+ 437.700 m				

ANDIAPPANUR ODAI RESERVOIR

1.	Location	:	12 ^{0}43 ' N	15.	Top of Road Way	:	+502.50 m
		:	78 ^{0} 41 ' E	16.	Maximum Height	:	8 m
General				17.	Length of	:	
2.	River	:	Pambar		Earth Dam		1077 m
3.	Basin	:	Pennaiyar		Masonry dam		108 m
4.	Sub Basin	:	Pambar	**Spill Way - Uncontrolled Surplus Weir**			
5.	Nearest Town	:	Vaniyambadi	18.	Vents	:	-
6.	District	:	Vellore	19.	Crest	:	+467.00 m
7.	Construction Period	:	2001-07	20.	Type	:	Uncontrolled
8.	Cost	:	-	**River Sluice**			
Reservoir				21.	Vent	:	1 No 1.50 X 0.90 m
9.	Catchment Area	:	20.39 Sq.Km	22.	Sill	:	+491.00 m
10.	Design Flood	:	422.68 cumecs	23.	Discharge	:	1.427 cumecs
11.	F. R.L M.W.L	:	+499.00 m +500.50 m	24.	**Ayacut**	:	2034.41 Ha
12.	Area at F.R.L	:	216.50 Sq.Km	25.	District Benefitted	:	Vaniyambadi
13.	Capacity at F.R.L	:	3.177 Mcum	26.	Taluk Benefitted	:	Thirupathur
Dam							
14.	Type	:	Earth cum masonry dam				

Tributaries of River Ponnaiyar

S. No.	River	Source	Sub-Tributaries	Length of Main Tributaries km	Drainage sqkm
1	Chinnar West	Karnataka		40	120
2	Chinnar East	Berigai		30	300
3	Markandanathi	Karnataka	Natchikuppam, Veppanapatti R	30	450
4	Kambainallur	Thoppur Hills	Palapathi	50	900
5	Pambar	Alangayam Hills	Mottur river	70	1900
6	Vaniyar	Vaniyambadi Taluk	Meenar	55	1100
7	Kottapatti	Kalvarayan Hills	-	40	450
8	Kallar	Harur Taluk			
9	Valayar Odai	Chengam Taluk	Kodi Odai	15	70
10	Ramakkal	Ponnaiyar		5	16
11	Pambanar	Valasamalai	Varattar	35	280
12	Aliyar	Chengam Taluk		30	220
13	Musukundanadhi	Alamur MSL 3900		40	200
14	Thurinjalar	Kavuthamalai		55	820



Subbasin No	SubBasin Name	Area in Sq.Km.
1	Chinnar - West	125.315
2	Chinnar - East	307.959
3	Markandanadhi	368.210
4	Kambainallur	919.279
5	Pambar	1757.418
6	Vaniyar	998.385
7	Matturar	58.498
8	Kottapattikallar	410.229
9	Valayar Odai	85.394
10	Ramakal Odai	14.415
11	Pambanar and Varattar	292.092
12	Aliyar	211.070
13	Musukundanadhi	179.255
14	Thurinjalar	853.623
15	Gadilam	1562.903
16	Upto Krishnagiri Reservoir	772.638
17	Krishnagiri to Pambar	894.518
18	Pambar to Thirukovilur	1002.393
19	Lower Pennaiyar	561.963
	Total	11375.558

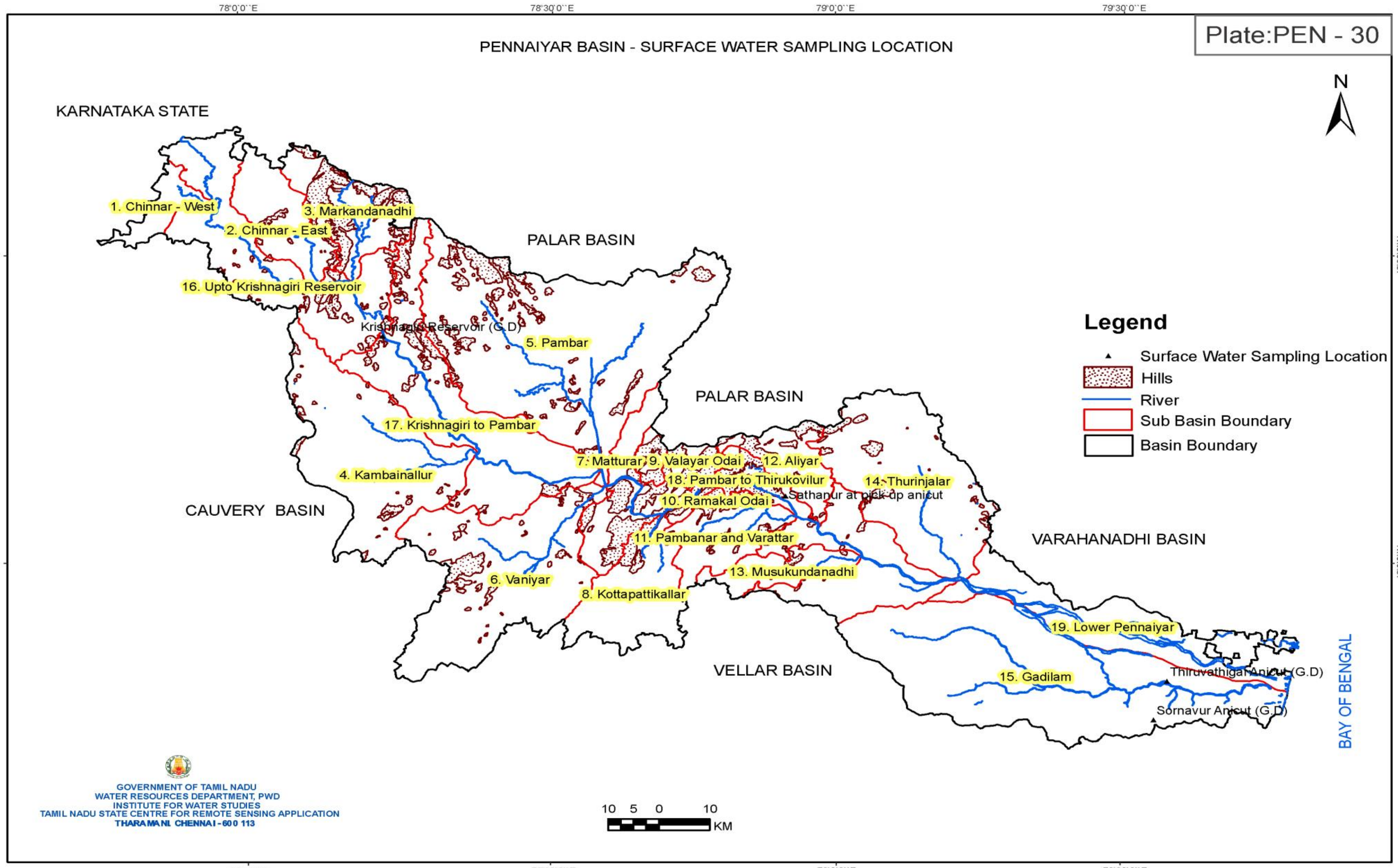


Plate:PEN - 30
PENNAIYAR BASIN - SURFACE WATER SAMPLING LOCATION
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
1. Chinnar - West
2. Chinnar - East
3. Markandanadhi
4. Kambainallur
5. Pambar
6. Vaniyar
7. Matturar
8. Kottapattikallar
9. Valayar Odai
10. Ramakal Odai
11. Pambanar and Varattar
12. Aliyar
13. Musukundanadhi
14. Thurinjalar
15. Gadilam
16. Upto Krishnagiri Reservoir
17. Krishnagiri to Pambar
18. Pambar to Thirukovilur
19. Lower Pennaiyar
Krishnagiri Reservoir (G.D)
Sathanur at pick up anicut
Thiruvathigai Anicut (G.D)
Sornavur Anicut (G.D)
Legend
Surface Water Sampling Location
Hills
River
Sub Basin Boundary
Basin Boundary
N
10 5 0 10
KM
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113

CHAPTER - 6

GROUND WATER RESOURCES
AND
WATER QUALITY

CHAPTER-6

GROUND WATER RESOURCES AND WATER QUALITY

6.1 Status of Ground water

The water resources of a country are mainly classified as surface water and ground water. Both these 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 percolates below the ground depending on the type of soil and this stored water is called ground water. The ground water is mostly tapped due to various reasons due to increasing 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 artificial recharge methods.

Ground water resources plays vital role in the Nation's most valuable natural resources. Its ubiquitous occurrence, reliability and availability in all seasons have made it the primary buffer against drought, playing pivotal role in ensuring the food security and livelihoods of many countries in the world. The total annual Replenishable Ground Water Resources of the country have been reassessed as 431 Billion cubic meters (BCM) and the net annual Ground Water availability is estimated as 396BCM. Annual Ground Water draft (extraction) on March, 2009 for all uses is 243 BCM. The stage of Ground Water Development is 61 % (Annual Report 2011-12, CGWB). It is the most preferred source of water in various user sectors in India. Nearly 80 percent of India’s domestic water needs and about 66.67 percent of its irrigation requirements are being met from ground water resources (Planning Commission 2012).

According to the dynamic groundwater resources estimation-March 2009 by State Ground & Surface Water Resources Data Centre, nearly 80% of the available groundwater resources are being utilized in our State, leaving a balance of only 20% for further development and availability of groundwater resources in the State is very uneven.

Unlike stream flows, groundwater is very dependable. Groundwater 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 summarize the groundwater availability and status prevailing in the 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 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

Pennaiyar river basin encountered with sedimentary formations includes grit, tertiary formations of sand stone and shale with recent to sub recent laterite and alluvium as the top layer in general and valley-fill sediments in the Valley portions of Kalrayanhills, Yercaud, and Gingee area of western part of basin.

The aquifer parameters of the formations in Pennaiyar River Basin are given in the following tables.

Table 6.1 Aquifer parameters in Hard Rock Area

S. No.	Parameter	Minimum value	Maximum value
1	Specific Capacity (lpm/m drawdown)	1.20	118
2	Transmissivity ‘T’ value (m^2/day)	0.45	338
3	Storativity ‘S’ value	2.6/ 1000000	3.6/100
4	Yield (lpm)	60	180

Table 6.2 Aquifer parameters in Sedimentary Area

S. No.	Parameter	Minimum value	Maximum value
1	Specific Capacity (lpm/m drawdown)	159	1892
2	Transmissivity 'T' value (m^2/day)	323	1937
3	Storativity 'S' value	1.13/ 100000	2.975/100000
4	Yield (lpm)	61	1273

Note:

lpm/m	=	litres per minute per metre
m^2/day	=	metre square /day
lpm/m	=	litres per minute

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.

Pennaiyar Basin commonly comprises of Alluvium Laterite, Calcium Sandstone, Caly, Marl, Shell Limestone, Sandstone, Dolerite, Pegmatite, Granites, Syenites, Carboratites, Granite gneiss, Charnockite, Hybrid Gneiss, Migmatites, Dunites, Pyroxinites, Magnetite quartzite, Amphibolites and Unclassified Crystallines. The geological background of the Pennaiyar Basin is detailed in Chapter 2.

All the observation wells exiting in Pennaiyar Basin area falling in the districts of Cuddalore, Dharmapuri, Krishnagiri, Salem, Tiruvannamalai, Vellore and Villupuram were plotted. It was found that 539 wells are lying in Pennaiyar Basin. An inventory of about 139 observation wells spread over the entire Pennaiyar Basin has been scrutinized based on the availability of data, period ranging from four years (4) 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 Pennaiyar River Basin are shown in **Plate: PEN-31.**

6.2.4 Occurrence of Groundwater in Nineteen (19) Sub-basins of Pennaiyar River Basin.

Table 6.3 Extent of hilly area and number of observation wells in geological formations

Sl. No	Sub Basin	Hilly Area (Sq.Km)	% of Hilly Area	Geological formations & no. of observation wells						
				ALV	CNK	GGN	GNS	GRT	HBG	SDM
1	Chinnar – West	0.000	0.00			3				
2	Chinnar – East	17.107	5.55			5				
3	Markandanadhi	146.369	39.75			5	1			
4	Kambainallur	27.784	3.02		11	5	1			
5	Pambar	160.083	9.11		4	7	2			
6	Vaniyar	69.935	7.00		11					
7	Matturar	36.065	61.65				1			
8	Kottapattikallar	34.352	8.37		2	1				
9	Valayar Odai	44.353	51.94		2					
10	Ramakal Odai	14.373	99.71							
11	Pambanar and Varattar	36.924	12.64		2					
12	Aliyar	43.027	20.39		3		1			
13	Musukundanadhi	7.111	3.97		3					
14	Thurinjalar	44.445	5.21		12	1	1			
15	Gadilam	0.000	0.00	2		5	1			4
16	Upto Krishnagiri Reservoir	56.606	7.33			10				
17	Krishnagiri to Pambar	92.234	10.31		6	6			2	
18	Pambar to Thirukovilur	219.673	21.91		5	6	1		1	
19	Lower Pennaiyar	0.028	0.00	2	1			1		1
	Total	**1,050.469**	**9.23**	**4**	**62**	**54**	**9**	**1**	**3**	**5**

Note:

ALV - Alluvium/Sand CNK - Charnockite GGN - Granitic Gneiss

GNS - Gneiss GRT - Granite HBG - Hornblende Biotite Geniss

SDM - Sedimentary Rocks

A brief description of each sub basin in Pennaiyar Basin and groundwater occurrence in the sub basins are given below:

1.Chinnar - West Sub Basin

Chinnar - West is having a drainage area of about 125.315sq.km. In this sub basin, Achaean Crystalline formations such as cordierite bearing Garnetiferous Gneisses, Calc Gneisses, Quartzite and Charnokites are found in most of the area. Three (3) observation wells data analyzed and the ground water level during post monsoon is varies from 3.67 to 70.80 m and during pre monsoon varies from 4.58 to 72.70 m below Ground Level.

2.Chinnar - East Sub Basin

Chinnar - East sub basin is having a drainage area of about 307.95sq.km. Most of the area is comprises of Archaean metamorphic varieties like Calc gneisses, Charnokite, Quartzite, Pink granites and Garnetiferous gneisses. The valley fill sediments and alluvial formations encounter the remaining area. Five (5) observation wells data analyzed and the ground water level during post monsoon is varies from 1.65 to 20.50m and during pre monsoon varies from 2.12 to 24.75 m below Ground Level.

3.Markandanadhi Sub Basin

Markandanadhi sub basin is having a drainage area of about 368.209sq km. Six (6) observation wells data analyzed and the ground water level during post monsoon is varies from 3.49 to 28.07m and during pre monsoon varies from 5.00 to 28.07m below Ground Level.

4.Kambainallur Sub Basin

Kambainallur sub basin s having a drainage area of about 919.278sq.km. The entire sub basin is formed with crystalline rock of archaeon age consisting of Charnokites, Garnetiferous Gneiss, Biotite Gneiss, Calc Gneiss, Quartzites and Pegmatite. Charnokite is the predominant formation and occupy a major area. Eighteen (18) observation wells data analyzed and the ground water level during post monsoon is varies from 0.30 to 15.80m and during pre monsoon varies from 1.25 to 18.15m below Ground Level.

5.Pambar Sub Basin

Pambar sub basin is having a drainage area of about 1757.42sq km. The entire sub basin is formed with Archaeon Charnokite and Garneteferous Gneiss. Thirteen (13) observation wells data analyzed and the ground water level during post monsoon is varies from 0.58 to 50.40 m and during pre monsoon varies from 1.35 to 54.65m below Ground Level.

6.Vaniyar Sub Basin

Vaniyar sub basin is having a drainage area of about 998.385sqkm. Geologically, rocks like Garentiferous Gneiss, Charnokites and Quartzite are well exposed in this area. Eleven (11) observation wells data analyzed and the ground water level during post monsoon is varies from 0.20 to 20.60m and during pre monsoon varies from 0.55 to 20.83m below Ground Level.

7.Matturar Sub Basin

Matturar sub basin is having a drainage area of about 58.50 sq km. Granitic Gneiss and Quartz and Charnokite are encountered in this sub basin. Alluvial sand of considerable thickness is also present in this sub basin. One (1) observation well data analyzed and the ground water level during post monsoon is varies from 0.10 to 5.20m and during pre monsoon varies from 1.10 to 10.95m below Ground Level.

8.Kottapattikallar Sub Basin

Kottapattikallar sub basin is having a drainage area of about 410.229sq.km. Charnokite is the major formation encountered in this sub basin and Granitic Gneiss is the other predominant geological formation. Three (3) observation wells data analyzed and the ground water level during post monsoon is varies from 1.00 to 17.25m and during pre monsoon varies from 2.55 to 16.57m below Ground Level.

9.Valayar Odai Sub Basin

Valayar Odai sub basin is having a drainage area of about 85.39sq.km. This sub basin is geologically formed with Granitic Gneiss and Alluvial formations. Two (2) observation wells data analyzed and the ground water level during post monsoon is varies from 0.34 to 11.62m and during pre monsoon varies from 1.89 to 11.74m below Ground Level.

10.Ramakal Odai Sub Basin

Ramakal Odai sub basin is having a drainage area of about 14.41sq.km. The geological formation comprising of sand stones, grey sandy shale and subsequent to recent quarternary sediments in the form of alluvium and aeolian sands are encountered in this sub basin. No observation well has sunken in this sub basin.

11.Pambanar and Varattar Sub Basin

Pambanar and Varattar sub basin is having a drainage area of about 292.09sq.km. The entire sub basin is made up of crystalline rocks of archaeon age consisting of Charnokites, Garnetiferous Gneiss, Calc Gneiss, Quartzites. Two (2) observation wells data analyzed and the ground water level during post monsoon is varies from 0.15 to 11.38m and during pre monsoon varies from 0.20 to 12.98m below Ground Level.

12.Aliyar Sub Basin

Aliyar sub basin is having a drainage area of about 211.07sq.km. The entire sub basin is formed with crystalline rock of Archaeon age consisting of Charnokites, Garnetiferous Gneiss, Biotite, Calc Gneiss and Quartzites are also present in this area. Four (4) observation wells data analyzed and the ground water level during post monsoon is varies from 0.30 to 14.45m and during pre monsoon varies from 1.80 to 14.95m below Ground Level.

13.Musukundanadhi Sub Basin

Musukundanadhi sub basin is having a drainage area of about 179.25sq.km. The area is formed with Archaean metamorphic varieties like Calc Gneisses, Charnokite, Quartzite, Pink Granites and Garnetiferous Gneisses. Three (3) observation wells data analyzed and the ground water level during post monsoon is varies from 0.90 to 22.30m and during pre monsoon varies from 2.65 to 22.20m below Ground Level.

14. Thurinjalar Sub Basin

Thurinjalar sub basin is having a drainage area of this sub basin is 853.623sqkm. The sub basin is formed with Charnokite, Garneteferous gneiss rock types. Fourteen (14) observation wells data analyzed and the ground water level during post monsoon is varies from 0.05 to 15.00m and during pre monsoon varies from 0.30 to 16.44m below Ground Level.

15.Gadilam Sub Basin

Gadilam sub basin is having a drainage area of about 1562.903sqkm. Geologically, Crystalline Archeaon rocks of age like Garentiferous gneiss, Charnokites and Quartzite are encountered in this area. Twelve (12) observation wells data analyzed and the ground water level during post monsoon is varies from 0.30 to 31.65m and during pre monsoon varies from 0.80 to 38.80m below Ground Level.

16.Upto Krishnagiri Reservoir Sub Basin

Upto Krishnagiri Reservoir sub basin is having a drainage area of about 772.63sqkm. Geologically, crystalline rocks of Archeaon age, Charnokite formation encountered in this sub basin and Granitic gneiss is also present in this basin. Ten (10) observation wells data analyzed and the ground water level during post monsoon is varies from 0.40 to 74.30m and during pre monsoon varies from 1.45 to 80.15m below Ground Level.

17.Krishnagiri to Pambar Sub Basin

Krishnagiri to Pambar sub basin is having a drainage area of about 894.52sqkm. The sub basin is formed with Archaeon Charnokite and Garneteferous Gneiss type of rocks. Fourteen (14) observation wells data analyzed and the ground water level during post monsoon is varies from 0.41 to 26.75m and during pre monsoon varies from 0.06 to 29.64m below Ground Level.

18.Pambar to Thirukovilur Sub Basin

Pambar to Thirukovilur sub basin is having a drainage area of about 1002.393sqkm. Rocks like garentiferous gneiss, Charnokites and quartzite are present in this area. Thirteen (13) observation wells data analyzed and the ground water level during post monsoon is varies from 0.60 to 12.60m and during pre monsoon varies from 1.45 to 12.60m below Ground Level.

19.Lower Pennaiyar Sub Basin

Lower Pennaiyar sub basin is having a drainage area of about 561.963sqkm. Geologically, crystalline rocks of archaean and Charnokite formation are encountered in this sub basin. Five (5) observation wells data analyzed and the ground water level during post monsoon is varies from 0.56 to 30.72m and during pre monsoon varies from 1.97 to 32.94m below Ground Level.

6.3 Groundwater Flow Regime and Water Level Fluctuations

Monitoring of ground water flow regime is an effort to obtain information on water levels. The ground water 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, where as anthropogenic influences include plumage 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. 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 needed to evaluate changes in the water resource over time, to develop groundwater models and forecast trends, and to design, implement, and monitor the effectiveness of ground-water management and protection programs.

It is imperative that water level measurements typically 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 trends over time. Five years is therefore a relatively short period for water level data collection, but it is at least sufficient to provide a record of several seasons of ground water level fluctuations.

Contour maps showing the depths of groundwater table for pre monsoon and post monsoon for Jul 1983, Jan 1984, Jul 1993, Jan 1994, Jul 2003, Jan 2004, Jul 2013 and Jan 2014 have been prepared and are shown in **Plate: PEN-32 to 39** respectively. Groundwater levels are displayed in the form of hydrographs for the wells listed in **Appendix 6.1**,vide **Appendix 6.8** for analysis of the long-term trends.

6.3.1 Water Level Fluctuations

Hydrographs (depending on available of well data from 1972 to 2015) of the groundwater levels for the 139 observation wells have been prepared. For this, observation wells with water level data for a period 4 years to 43 years were considered. Though some wells (MWS17053, MWS17070, MWS17078, MWS17080, MWS17081, HP17015, MWS17069, MWS17079, MWS17090, MWS17103, MW21620, HP21585 etc.) have data for short period, they were also considered to understand the recent trend in water 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 **(Appendix 6.1)** 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/rise as ascertained from the trend line, is greater than 3m, it is classified as high depletion/rise. If long term water level depletion/rise is in the range of 1-3 m, it is classified as moderate depletion/rise and if long term water level depletion/rise is in the range of 0-1 m, it is classified as slight depletion/rise.

It is observed from the 139 observation wells' Hydrograph that the long term linear trend lines of the 78 observation wells showed rise and 58 wells showed depletion in water level. Significantly, the long term linear trend line in three wells have showed as "0" (1.Well No:MWS17053 in Kambainallur sub-basin in Dharmapuri District, 2.Well No:MWS17096 in Krishnagiri To Pambar sub-basin in Krishnagiri District and 3.Well No:HP21551 in Pambar sub-basin in Vellore District).

i) Long-term Rise in Water Level:

- 78 observation wells data indicate rise in water level.
- High rise in water level (more than 3.00m)

Table 6.4 High rise Observation Wells

Sl.No	Well No	Sub-Basin	District
1	U33021	Gadilam	Cuddalore
2	53032	Musukundanadhi	Dharmapuri
3	53036	Vaniyar	Dharmapuri
4	53048	Kambainallur	Dharmapuri
5	53081	Vaniyar	Dharmapuri
6	MWS17081	Kambainallur	Dharmapuri
7	53044	Chinnar East	Dharmapuri
8	MWS17069	Krishnagiri to Pambar	Dharmapuri
9	MWS17095	Upto Krishnagiri	Dharmapuri

		Reservoir	
10	23003	Pambar to Thirukoilur	Tiruvannamalai
11	23039	Pambanar and Varattar	Tiruvannamalai
12	23110	Thrinjalar	Tiruvannamalai
13	23112	Thrinjalar	Tiruvannamalai
14	23118	Valayar Odai	Tiruvannamalai
15	MW21618	Thurinjalar	Tiruvannamalai
16	A23030	Pambar	Vellore
17	33062	Gadilam	Villupuram
18	HP31504	Pambar to Thirukovilur	Villupuram
19	HP31557	Gadilam	Villupuram
20	HP31562	Lower Pennaiyar	Villupuram

ii) Long-term Depletion in Water Level

- 58 observation wells data indicate depletion in water level.
- High depletion in water level (more than 3.00m)

Table 6.5 High Depletion Observation Wells

Sl.No	Well No	Sub-Basin	District
1	U33035	Gadilam	Cuddalore
2	53007	Krishnagiri to Pambar	Dharmapuri
3	53035	Krishnagiri to Pambar	Dharmapuri
4	HP17025	Kambainallur	Dharmapuri
5	MWS17078	Kambainallur	Dharmapuri
6	MWS17080	Kambainallur	Dharmapuri
7	53021	Pambar	Dharmapuri
8	53076	Upto Krishnagiri Reservoir	Dharmapuri
9	hp17015	Chinnar West	Dharmapuri
10	hp17016	Krishnagiri to Pambar	Dharmapuri
11	hp17021	Markandanadhi	Dharmapuri
12	hp17022	Upto Krishnagiri Reservoir	Dharmapuri
13	hp17023	Markandanadhi	Dharmapuri
14	MWS17079	Kambainallur	Dharmapuri
15	MWS17088	Chinnar West	Dharmapuri
16	MWS17090	Upto Krishnagiri Reservoir	Dharmapuri
17	MWS17091	Markandanadi	Dharmapuri
18	MWS17092	Chinnar East	Dharmapuri
19	MWS17093	Upto Krishnagiri Reservoir	Dharmapuri
20	MWS17097	Krishnagiri To Pambar	Dharmapuri
21	MWS17099	Krishnagiri To Pambar	Dharmapuri
22	MWS17102	Pambar	Dharmapuri
23	MWS17106	Markandanadi	Krishnagiri
24	23047A	Pambar	Vellore

iii) Seasonal Water Level Fluctuations

Minimum annual water level fluctuations vary from 0.00m (Gadilam, Vaniyar, Kambinalur, Thurinjalar & Pambar to Thirukovilur Sub-basins) to 22.40m (Chinnar West Sub-basin) and maximum annual water level fluctuations vary from 2.76m (Kambinallur Sub-basin) to 48.30m (Chinnar WestSub-basin). The minimum and maximum summer water level during post-monsoon and pre-monsoon of all wells are taken into for calculating seasonal fluctuation in a year and the seasonal fluctuation differs from well to well.

- Post-monsoon minimum water level varies from 0.00m (Well No. U33035 in Gadilam sub-basin) to 31.20m (Well No. MWS17088 in Chinnar West sub-basin).
- Post-monsoon maximum water level varies from 2.40m (Well No. MW21620 in Thurinjilar sub-basin) to 89.5m (Well No. MWS17106 in Markandanadhi sub-basin).
- Pre-monsoon minimum water level varies from 0.06m (Well No. 53018 in Krishnagiri to Pambar sub-basin) to 47.60m (Well No. MWS17088 in Chinnar West sub-basin).
- Pre-monsoon maximum water level varies from 4.27m (Well No. 53075 Chinnar East in sub-basin) to 95.75m (Well No. MWS17106 in Markandanadhi sub-basin).

Groundwater level fluctuations are significant in the sense that they indicate the level/degree of groundwater recharge. Sub basin-wise lowest and highest fluctuations are presented in **Table 6.6.**

Table 6.6 Sub basin-wise Fluctuations

Sl. No.	Name of Sub Basin	Seasonal Water Level Fluctuation in m			
		Minimum	During the year	Maximum	During the year
1	Chinnar - West	1.02	1976-77	48.30	2010-11
2	Chinnar - East	0.25	1985-86	12.79	1990-91
3	Markandanadhi	0.85	1987-88	31.20	2008-09
4	Kambainallur	0.00	1990-91	15.00	1991-92
5	Pambar	0.70	1987-88	45.60	2010-11
6	Vaniyar	0.00	1990-91	17.56	1977-78
7	Matturar	1.62	1995-96	9.83	1990-91
8	Kottapattikallar	0.60	1982-83	13.32	1992-93
9	Valayar Odai	0.95	1989-90	10.35	2000-01
10	Ramakal Odai	No Well			
11	Pambanar and Varattar	2.65	2002-03	11.95	2009-10

12	Aliyar	0.55	1989-90	15.55	1991-92
13	Musukundanadhi	0.80	1990-91	20.45	1993-94
14	Thurinjalar	0.00	1988-89	18.35	2012-13
15	Gadilam	0.00	2012-13	26.75	2003-04
16	Upto Krishnagiri Reservoir	0.20	1990-91	46.85	2012-13
17	Krishnagiri to Pambar	0.10	2003-04	30.15	2009-10
18	Pambar to Thirukovilur	0.00	2002-03	36.45	2005-06
19	Lower Pennaiyar	0.56	2008-09	16.19	2005-06

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 north to south in the upper region, west to east in the middle region and towards east in the tail end region of the Pennaiyar basin.

Comparison of pre-monsoon and post-monsoon contour maps (depth to water table maps) for four different years (one year for a decade: Jul-83 & Jan-84, Jul-93 & Jan-94and Jul-2003 & Jan-2004), Jul-2013& Jan-2014) have been prepared. The details of contour data are tabulated in **Appendix 6.2 of Vol-II**. Obviously, post-monsoon water level is at shall over depth than pre-monsoon water level.

6.3.3 Groundwater Level Scenario

i) Pre-Monsoon

In the upper region the water level is moderate (4 to 12m) during July 1983, July 1993 & July 2013 and little deeper (8 to 16m) during July 2003. In the middle region the water level varies moderate to deeper (8 to 20) during July 1983, July 1993, July 2003 & July 2013. In the tail end region the water level is moderate (4 to 12m) during July 1983 & July 1993 and the water is deeper (8 to 20m) during July 2003 & July 2013.

ii) Post-Monsoon:

In the upper region the water level varies shallow to moderate (0 to 12) during January 1984 & January 2004 and water level is shallow (0 to 8) during January 1994 & January 2014. In the middle region the water level varies shallow (0 to 8) during January 1984 & January 1994; the water level varies moderate to little deeper (4 to 12m) during January 2004 and the water level is moderate (4 to 8) during 2014. In the tail end region the water level is shallow (0 to 4) during January 1984 and January 1994; the water level is moderate to little deeper (4 to 12m) during January 2004 and the water level varies shallow to little deeper (0 to 12m) during January 2014.

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

Due to the very high rain fall precipitated during the recent monsoon (November & December 2015) the average ground water level of December 2015 has been raised very significantly whilst comparing with December 2014 in the districts falling in Pennaiyar basin as stated below:

Sl. No	Well Type	District	Water Level - December 2014 in m	Water Level - December 2015 in m	Rise in m
1	Observation Well	Krishnagiri	6.01	5.81	0.20
2	Observation Well	Dharmapuri	8.31	4.02	4.29
3	Observation Well	Salem	10.03	7.43	2.60
4	Observation Well	Vellore	8.29	3.35	4.94
5	Observation Well	Tiruvannamalai	6.93	2.62	4.31
6	Observation Well	Villupuram	5.66	1.73	3.93
7	Observation Well	Cuddalore	6.20	2.94	3.26

6.4 Categorization of Blocks

The Chief Engineer, SG&SWRDC has classified as of March 2009, all the 386 administrative blocks [including Chennai as a block (385+1=386)] in Tamil Nadu into Safe, Semi Critical, Critical and Over-exploited depending upon the present stage of groundwater development.

In general, the prime cause of over-exploitation is the rising demand for groundwater from agriculture. Cropping pattern and cropping intensity alter will increase 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 encouraged farmers in greater use of groundwater (Planning Commission 2007).

Pennaiyar basin encompass 50 blocks either fully or partially covered and among the 50 blocks 5 blocks come under Cuddalore district, 8 blocks comes under Dharmapuri district, 10 blocks come under Krishnagiri district, 3 blocks come under Salem District, 6 block come under Tiruvannamalai District, 5 block come under Vellore district and 13 blocks come under Villupuram district.

Whilst comparing the groundwater development in 2009 with 2003, the following observations were found.

- 26 blocks' categorization have not changed
  - 3 blocks (Thally, Yercaud & Kalrayanhills) maintain the "Safe" category, may be due to those are formed in hilly terrain
  - 2 blocks in the same "Semi Critical"
  - 21 blocks in the same "Over-exploited" category
- 3 blocks (Mugaiyur, Rishivandiyam & Thiruvennainallur) have impressively improved from "Over-exploited" to "Safe" category.
- 3 blocks (Krishnagiri, Kanai & Thiagadurugam) have extracted more groundwater and downgraded from "Semi Critical" to "Over-exploited" category.

A map **(Plate: PEN-40)** showing the category of blocks falling in Pennaiyar Basin is also prepared.

The Change in classification of blocks in Pennaiyar Basin based on the level of Ground Water Development from 2003 to 2009 is given in **Table 6.7**.

Table 6.7 Categorization of Blocks

Sl. No.	Block	District	Categorisation of Block (2003)	Categorisation of Block (2009)
1	Bargur	Krishnagiri	Over Exploited	Over Exploited
2	Hosur		Semi Critical	Safe
3	Kaveripattinam		Semi Critical	Semi Critical
4	Kelamangalam		Safe	Semi Critical
5	Krishnagiri		Semi Critical	Over Exploited
6	Mathur		Over Exploited	Over Exploited
7	Shoolagiri		Semi Critical	Critical
8	Thally		Safe	Safe
9	Uthangarai		Over Exploited	Over Exploited

10	Veppanapalli	Krishnagiri	Over Exploited	Over Exploited
11	Dharmapuri	Dharmapuri	Over Exploited	Over Exploited
12	Harur		Over Exploited	Over Exploited
13	Karimangalam		Over Exploited	Over Exploited
14	Morappur		Over Exploited	Over Exploited
15	Nallampalli		Over Exploited	Over Exploited
16	Palacode		Over Exploited	Over Exploited
17	Pappireddipatti		Over Exploited	Over Exploited
18	Pennagaram		Critical	Semi Critical
19	Pethanaickenpalayam	Salem	Over Exploited	Critical
20	Valapady		Over Exploited	Over Exploited
21	Yercaud		Safe	Safe
22	Alangayam	Vellore	Over Exploited	Critical
23	Jolarpet		Over Exploited	Over Exploited
24	Kandhili		Over Exploited	Over Exploited
25	Natrampalli		Over Exploited	Over Exploited
26	Thirupathur		Over Exploited	Over Exploited
27	Chengam	Tiruvannamalai	Over Exploited	Over Exploited
28	Kilpennathur		Over Exploited	Critical
29	Pudupalayam		Over Exploited	Critical
30	Thandrampet		Over Exploited	Over Exploited
31	Thurinjapuram		Over Exploited	Critical
32	Tiruvannamalai		Over Exploited	Over Exploited
33	Gingee	Villupuram	Over Exploited	Critical
34	Kalrayanhills		Safe	Safe
35	Kanai		Semi Critical	Over Exploited
36	Kandamangalam		Over Exploited	Critical
37	Kolianur		Over Exploited	Over Exploited
38	Mugaiyur		Over Exploited	Safe
39	Rishivandiyam		Over Exploited	Safe
40	Sankarapuram		Over Exploited	Semi Critical
41	Thiagadurugam		Semi Critical	Over Exploited

42	Thirukoilur	Villupuram	Semi Critical	Safe
43	Thirunavalur		Critical	Safe
44	Thiruvennainallur		Over Exploited	Safe
45	Ulundurpet		Over Exploited	Over Exploited
46	Annagramam	Cuddalore	Semi Critical	Safe
47	Cuddalore		Semi Critical	Over Exploited
48	Kammapuram		Semi Critical	Over Exploited
49	Kurinjipadi		Semi Critical	Safe
50	Panruti		Semi Critical	Semi Critical

Comparative Summary of Categorization

Sl.No	Category	2003	2009
1	Safe	4	11
2	Semi Critical	12	5
3	Critical	2	8
4	Over Exploited	32	26

6.5 Groundwater Potential

6.5.1 Groundwater Potential in the State

Based on the Groundwater Estimation Committee Methodology-1997 (GEC-97), the latest block wise groundwater potential was assessed as on March 2009 by State Ground & Surface Water Resources Data Center (SG & SWRDC). According to this assessment, the net annual groundwater availability (groundwater potential) of the State is 22,943 MCM and the annual groundwater extraction is 20,649 MCM. Thus, 80% of groundwater is being used. But this utilization is not uniform throughout the State. 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

The sub-basin wise groundwater potential and draft (extraction) were calculated on proportionate basis i.e based on the percentage of block area falling in the sub basin. The sub-basin wise balance groundwater potential available in that particular sub-basin for further development was arrived by deducting the total 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 wise groundwater potential, groundwater extraction and the balance groundwater potential and the stage of groundwater development are presented in **Table 6.8.**

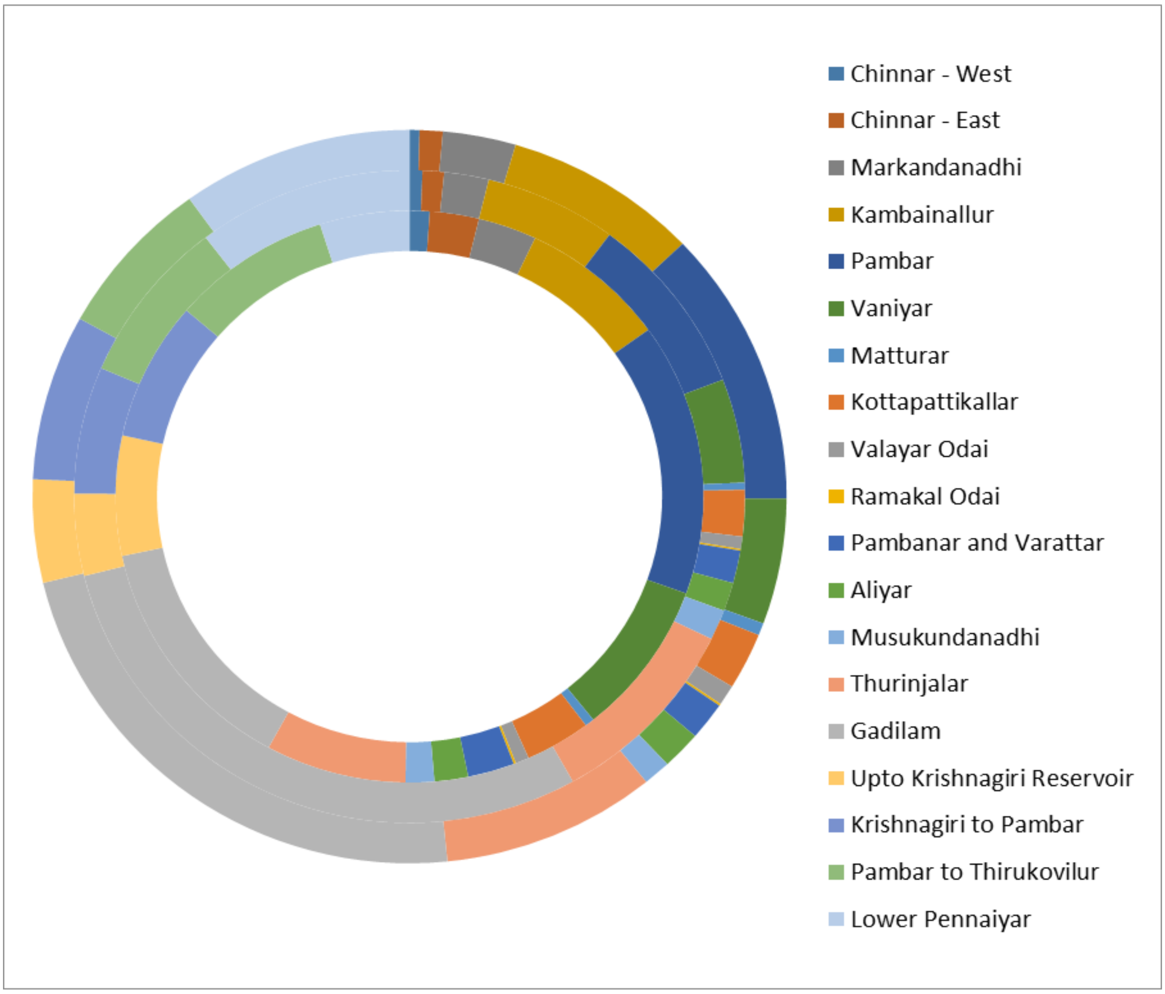
Table 6.8 Groundwater Potential, Extraction and balance potential (Based on 2009 Projection)

Sl. No.	Sub Basin	Net Groundwater Potential in sub basin (MCM)	Gross Groundwater Extraction in sub basin (MCM)	Balance Groundwater Potential (MCM)	Stage of Development (%)
1	Chinnar - West	13.14	8.91	4.23	67.81
2	Chinnar - East	22.24	20.72	1.52	93.17
3	Markandanadhi	43.26	61.63	0.44	142.46
4	Kambainallur	136.27	175.05	1.08	128.46
5	Pambar	201.58	250.16	0.45	124.10
6	Vaniyar	109.31	115.25	7.11	105.43
7	Matturar	8.10	11.22	0.00	138.52
8	Kottapattikallar	47.78	51.42	1.10	107.62
9	Valayar Odai	13.00	18.78	0.00	144.46
10	Ramakal Odai	11.67	1.72	0.00	102.99
11	Pambanar and Varattar	31.98	32.33	0.75	101.09
12	Aliyar	29.08	34.31	0.30	117.98
13	Musukundanadhi	31.98	24.52	7.51	76.67
14	Thurinjalar	206.81	191.68	19.94	92.68
15	Gadilam	598.56	449.30	207.02	75.06
16	Upto Krishnagiri Reservoir	85.94	93.70	9.84	109.03

17	Krishnagiri to Pambar	132.49	150.42	8.63	113.53
18	Pambar to Thirukovilur	170.96	143.65	39.56	84.03
19	Lower Pennaiyar	255.94	209.20	54.39	81.74
	TOTAL	**2,140.09**	**2,043.97**	**364.07**	**95.51**

The block-wise groundwater potential, extraction and balance potential available for future development are presented in Appendix 6.5, 6.6 and 6.7. The categorization of block is also presented in the Table 6.8. The groundwater potential of Pennaiyar basin was worked out as 2,140.09 MCM and the total extraction of groundwater was worked out as 2,043.97 MCM. Gadilam sub-basin has the highest groundwater potential while Ramakal Odai sub-basin has the lowest potential and extraction also high in Gadilam sub-basin and low in Ramakal Odai sub-basin. Thurinjalar, Gadilam and Lower Pennaiyar sub-basins combined together contribute nearly half of Pennaiyar basin's groundwater potential. The each 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 Basins in Groundwater Potential and Extraction



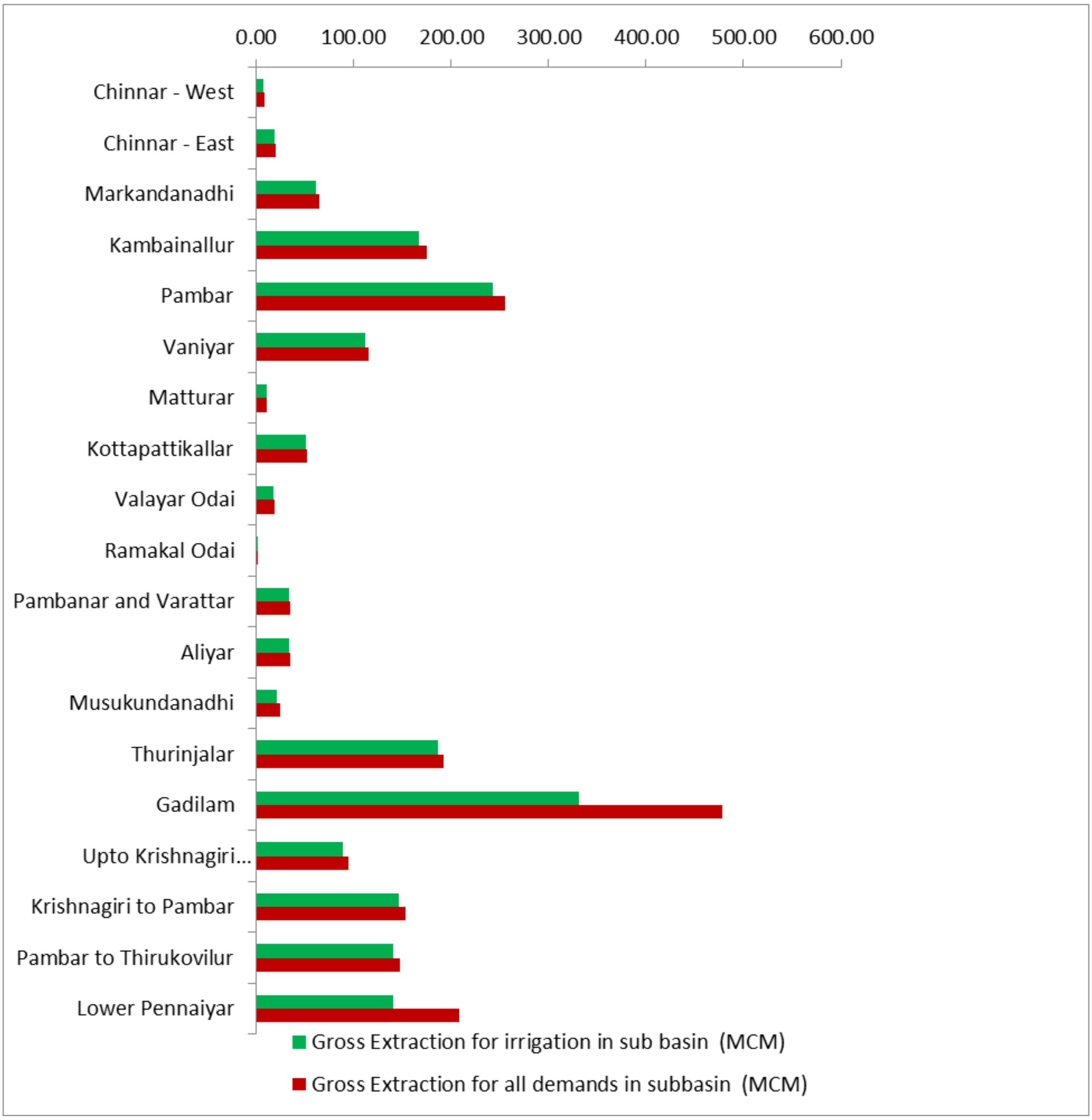
The entire Pennaiyar basin may be categorized as ‘Critical Basin’ based on the stage of groundwater development. From the **Appendix 6.7**, it is understood that further groundwater development is possible only in Chinnar West sub-basin.

Table 6.9 shows the comparison of groundwater extraction for irrigation and other purposes based on 2009 assessment.

Table: 6.9 Groundwater Gross Extraction for irrigation and Gross Extraction for all Demands

Sl. No	Sub Basin	Gross Extraction for irrigation in (MCM)	Gross Extraction for all demands (MCM)	Irrigation demand in total demand (%)
1	Chinnar - West	7.69	8.91	86.31
2	Chinnar - East	19.36	20.72	93.44
3	Markandanadhi	57.64	61.63	93.53
4	Kambainallur	167.59	175.05	95.74
5	Pambar	237.42	250.16	94.91
6	Vaniyar	111.90	115.25	97.09
7	Matturar	10.97	11.22	97.77
8	Kottapattikallar	50.55	51.42	98.31
9	Valayar Odai	18.44	18.78	98.19
10	Ramakal Odai	1.65	1.72	95.93
11	Pambanar and Varattar	31.02	32.33	95.98
12	Aliyar	33.27	34.31	96.97
13	Musukundanadhi	21.24	24.52	86.62
14	Thurinjalar	185.85	191.68	96.96
15	Gadilam	328.16	449.30	73.03
16	Upto Krishnagiri Reservoir	87.18	93.70	93.04
17	Krishnagiri to Pambar	144.09	150.42	95.79
18	Pambar to Thirukovilur	137.47	143.65	95.70
19	Lower Pennaiyar	141.89	209.20	67.83
	Total	**1,793.39**	**2,043.97**	**87.74**

Fig.6.2 Ground Water Extraction for irrigation & for All other purposes (Based on 2009 Assessment)



6.5.3 Status of Groundwater in Pennaiyar River Basin

Water level analysis indicates that out of 139 observation wells in this basin, 78 wells have shown a rising trend in ground water level. Even though 78 observation wells have shown rising trend, 21 bocks remain in “Over Exploited” category and 3 blocks have been down graded from “Semi Critical” to “Over Exploited” category. Only 3 bocks remain “Safe” category and 3 blocks have upgraded from “Over Exploited” to “Safe” category. By comparing 2003 and 2009 groundwater development 4 blocks moved upto 11 bocks in “Safe” category and 32 blocks got down to 26 blocks in “Over Exploited” category. This little improvement might be due to the result of rainwater harvesting by the way of constructed Artificial Recharge Structures.

6.6 Groundwater Quality

6.6.1 Introduction:

Water that falls to the earth in the form of rain, snow, sleet, or hail continues its journey in one of three ways: It might land on a water body and, essentially, go with the flow; it might runoff the land into a nearby water body or storm drain; or it might seep into the ground. Water that seeps into the ground moves in a downward direction because of gravity, passing through the pore spaces between the soil particles, until it reaches a soil depth where the pore spaces are already filled, or saturated, with water. When water enters the saturated zone, it becomes part of the ground water. The top of this saturated zone is called the water table.

The main source by which the groundwater gets replenished is precipitation due to rainfall. If the rainfall is very poor, the ground water potential will be affected.

The water table may be very close to the ground surface, which is often the case when it is adjacent to a water body. A water-bearing soil or rock formation that is capable of yielding enough water for human use is called an aquifer. In bedrock aquifers, water can move through cracks, or fractures. Some types of bedrock like sandstone can absorb water like a sponge; other types of bedrock like granite do not. How quickly water passes through, or infiltrates, the soil is a function of the size and shape of the soil particles, the amount of pore space between the particles, and whether or not the pore spaces interconnect.

For example, soils that consist primarily of larger sand and gravel particles tend to have larger, interconnected pore spaces that allow water to flow easily and relatively quickly. In contrast, some soils, such as silts and clays, have poorly connected pore spaces, a soil structure which tends to slow down infiltration. When infiltrating water reaches the water table, it begins to move along with the ground water flow, which tends to follow a downhill, or down slope, direction. Groundwater is very much a part of nature’s water cycle.

- Groundwater can be found almost everywhere. The water table may be deep or shallow; and may rise or fall depending on many factors. Heavy rains or melting snow will cause the water table to rise and heavy pumping of groundwater supplies may cause the water table to fall according to the use / drawal of groundwater in a particular block. The blocks are classified as safe, semi critical, critical and over exploited.

- Groundwater makes up about 1% of the water on earth, but groundwater makes up about 35 times the amount of water in lakes and streams.
- Most of the earth's fresh water is stored below the ground (besides ice). Approximately 15% of precipitation ends up as groundwater and groundwater is brought up to the surface by wells, springs and streams.
- Groundwater occurs everywhere beneath the earth's surface but is usually restricted to depths less than about 750 meters. Groundwater includes water in cracks, crevices, and pore spaces.
- Used as a resource for drinking and irrigation
- Groundwater flows, doesn't remain stagnant
- The surface below which all the rocks are saturated with groundwater is the water table.

We rely on groundwater - it's the water we drink, the water that grows our food, the water that helps recharge our lakes and rivers.

As far as Pennaiyar basin is concerned there are 50 blocks and the number of blocks in each district is as follows: 5 blocks in Cuddalore district, 8 blocks in Dharmapuri district, 10 blocks in Krishnagiri district, 3 blocks in Salem district, 6 blocks in Thiruvannamali district, 5 blocks in Vellore district and 13 blocks in Villupuram district. There are 26 over exploited blocks in Pennaiyar basin where the groundwater development is greater than 100%, 8 critical blocks where the groundwater development is between 90 and 100%, 5 semi critical blocks where the groundwater development is between 70 and 90% and there are 11 safe blocks where the groundwater development is less than 70%.

6.6.2 Potential Sources of Groundwater Contamination

- **Leaky 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 industries. When it rains, these chemicals seep into the ground and eventually affect the groundwater.

- **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. Mainly pollution in the air plays an important role in the contamination of groundwater.

- **Type of Rock or Soil**

The quality of groundwater also depends on the type of rock or soil beneath. For example if salt rock is encountered, the water will be automatically saline.

6.6.3 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 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.

Although the earth's surface is nearly 71% covered by water, most of this water is salty ocean water. The amount of fresh water available on the earth for drinking, bathing and agricultural is quite small; that is less than 1% of the total. In some areas, there may be plenty of water in one season of the year, but none at the other times.

Water from beneath the ground has been exploited for domestic use, livestock, industrial and irrigation activities since last few decades. Although the precise nature of its occurrence was not necessarily understood, successful methods of bringing the water to the surface have been developed and ground water use has grown consistently ever since. The overall goal of water quality assessment report is to obtain a comprehensive picture of the spatial distribution of ground water quality and of the changes that occur in time, either naturally, or under the influence of human activities.

. **The State Ground and Surface Water Resources Data Center,** PWD, Tharamani, Chennai – 113, is monitoring Groundwater level and water quality by collecting ground water samples from the observation wells in all the river basins in Tamilnadu during the pre monsoon period (July) and during 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 seven Districts, viz Cuddalore, Dharmapuri, Krishnagiri, Salem, Thiruvannamalai, Vellore and Villupuram districts were collected and the water quality assessment has been made for both the pre-monsoon and post monsoon periods for the year 2010 and 2013 and the results are shown in **PLATE:PEN-42-47**. Pre monsoon and Post monsoon data for the year 2010 and 2013 are given in the **Appendix 6.9.1 to 6.9.4**. Total Dissolved Solids, Chloride, Total Hardness, Alkalinity, Sulphate and Nitrate are considered as the deciding parameters for discussion. By using the Arc view and Arc info soft wares, the water quality contour of Total Dissolved Solids, Total Hardness and Chlorides are generated.

In this basin data from 43 numbers of observation wells were used to create the thematic maps for ascertaining the water quality status of this sub basin as shown in **PLATE: PEN-41**. In some season, the number of wells may vary, due to the dryness of the well during the pre monsoon period. The sub basin wise water quality status is analyzed and given below.

1 & 2. Chinnar west and Chinnar east Sub Basin:

No observation wells are observed in these sub basins.

3. Markandanadhi Sub Basin:

Only one observation well is observed in this basin.

The Total Dissolved Solids (TDS) value falls in moderate quality range (500 – 2000mg/l) in all the seasons in this well.

The chloride value is within the desirable limit of 250mg/l which is of good quality.

The Total Hardness value is within good to moderate quality range of 300 – 600mg/l in this well.

The nitrate value is within the desirable limit of 45 mg/l during all the periods. The nitrate value is 65 mg/l during the period January 2013. This may be due to some local pollution.

Generally the water quality is moderate in this sub basin.

4. Kambainallur Sub Basin:

No observation well is observed in this sub basin.

5. **Pambar Sub Basin:**

Six observation wells are available in this sub basin. From these wells, it is observed that the Total dissolved Solids value is found within the permissible limit of 2000mg/l in all the wells of this sub basin. Lower TDS value of 625mg/l is observed in Pavakkal village of Uthangarai block. Higher TDS value of 1723mg/l is observed in Alangayam village of Alangayam block in Vellore District.

The chloride value falls in good quality range of 250mg/l in almost all the wells in this sub basin except Alangayam village of Vellore district. Here the value observed is 659 mg/l. during the period july 2013 which falls under moderate quality.

The Total Hardness value is within the permissible limit of 600 mg/l in almost all the wells in this sub basin. Higher values above 600 mg/l is observed in Alangayam village of Vellore District. Here the value observed is 720 mg/l during the period july 2013.

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 2013 and 2010.

From the analysis it is revealed that, the quality of water is good to moderate in this sub basin.

6. Vaniyar Sub Basin:

There are three observation wells in this sub basin.

The Total Dissolved Solids value is found within the permissible limit of 2000mg/l in all the wells in this sub basin. The value of TDS ranges from 612 mg/l (Kombur village of Pappireddipatti block) to 1589 mg/l (Sunkarahalli village of Morappur block).

The chloride value is within good quality range of 250 mg/l in all the wells except K.Vetrapatti of Harur block. Here the value observed is 326 mg/l during January 2013 which is of moderate quality.

The Total Hardness value ranges from good to moderate quality in this sub basin. The value of TH varies from 165 mg/l (Kombur village of Pappireddipatti block) to 780 mg/l (K.Vetrapatti village of Harur block).

Nitrate value is within the permissible limit of 45 mg/l in all the wells in this sub basin.

Generally from the quality of water samples collected from wells in this sub basin, the quality is good for most of the wells, while for a few wells the quality is moderate.

7. Mathurar sub basin

No observation wells are observed in this sub basin.

8. Kottapattikallar Sub Basin:

There is only one observation well available in this sub basin.

Total Dissolved Solid test provides a qualitative measure of the amount of dissolved ions; therefore the TDS test is used as an indicator test to determine the general quality of water. The limit of TDS for good quality water is 500mg/l.

The TDS value observed in this sub basin is 3407 mg/l which is of poor quality.

The higher TDS value results in higher chloride (968 mg/l) and higher Total hardness (820 mg/l) value which is above the permissible limit.

Nitrate value observed is 61 mg/l in this sub basin which is above the permissible limit.

Generally the quality of water is not within the permissible limit in this sub basin.

9 & 10. Valayar odai and Ramakkal odai Sub Basin:

No observation well is observed in these sub basins as the basin area is surrounded by hilly areas on all sides.

11. Pambanar & Varattar Sub Basin:

Four observation wells are located in this sub basin.

The Total dissolved solids value ranges from good to moderate quality in all the wells in this sub basin.

The chloride value is good (<250 mg/l) in most of the wells while the value is higher than 250 mg/l for a few well in this sub basin.

The Total Hardness value ranges from good to moderate quality in all the wells in this sub basin.

Nitrate value is within the desirable limit of 45 mg/l in all the wells except Malaiyanur Chkkadi village of Thandrampet block of Thiruvannamalai District. Here the value observed is 80 mg/l which is above the desirable limit.

Generally the water quality is “good” in this sub basin.

12 & 13. Aliyar & Musukunda Sub Basin:

No observation well is found in this sub basin.

14. Thurinjalar Sub Basin:

Water quality data of eight observation wells are taken to ascertain the quality of this sub basin.

The Total Dissolved solids value ranges from good to moderate quality in all the wells in this sub basin.

The chloride value is less than 250 mg/l in almost all the wells in this sub basin which is of good quality.

The Total Hardness value ranges from good to moderate quality in this sub basin.

The nitrate value is within the desirable limit (<45 mg/l) in all the wells in this sub basin.

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

15. Gadilam sub basin:

Six observation wells are located in this sub basin.

The TDS, TH and chloride values vary from good to moderate quality in this sub basin.

The nitrate value ranges from 1 mg/l (Thiruvennainallur village of Villupuram District) to 34 mg/l (Rishivandhiyam village of Rishivandhiyam block) and it is within the desirable limit of 45 mg/l.

16. Upto Krishnagiri reservoir Sub Basin:

Only one observation well is found in this sub basin.

Total Dissolved Solids value is of moderate quality in this sub basin. The value observed is less than 1000 mg/l during all the seasons in this sub basin.

The chloride and TH value is of good quality in this well.

Generally the water quality is good in this sub basin.

17. **Krishnagiri to Pambar sub Basin**:

Water quality data of five observation wells are taken to ascertain the water quality in this sub basin.

Total Dissolved Solids value is of good to moderate quality in this sub basin.

Total Hardness value is of good to moderate quality in this sub basin.

Chloride value is of good quality in most of the wells while the value is moderate in some of the wells.

Nitrate value is within the desirable limit in all the wells in this sub basin.

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

18. Pambar to Thirukovilur Sub Basin:

Seven observation wells are located in this sub basin.

Total Dissolved Solids value ranges from good to moderate in all the wells in this sub basin. Lowest TDS value is observed in 557 mg/l (Jan 2010) in

Olagalapadi village of Thandrampet taluk. Highest TDS value of 2755 mg/l (Jul 2010) is observed in Neepathurai village of Chengam block.

The chloride value is within the desirable limit in most of the wells while in some wells the value is moderate.

Total Hardness value is less than 300 mg/l in most of the wells while in some wells the value is moderate (300 – 600 mg/l).

Nitrate value is within desirable limit in all the wells except Perungalathur village of Thandrampet block.

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

19. **Lower Pennaiyar Sub Basin**:

One observation well is observed in this sub basin.

Total Dissolved Solids is of moderate quality in this well.

TH, chloride, and nitrate value is of good quality in this well.

Apart from the above observation wells, water quality data of 42 bore wells as shown in **PLATE: PEN-48** were also taken to ascertain the water quality in this basin . The data reveals that the quality of water is “good to moderate” in all the wells. A separate graph is enclosed to reveal the water quality of the bore wells in the basin.

6.6.4 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.

6.6.5 Conclusion:

- ✓ In short there are 11 safe blocks, 5 semi critical, 8 critical and 26 over exploited blocks.
- ✓ The quality of ground water depends on the different types of rocks encountered. The basin consists mainly of red, black, sandy and mixed

soil. The important rock formations are hard or crystalline rocks of Archaean age Dharwar super group, Cuddapah series of rocks belonging to Proterozoic age.

- ✓ pH value lies within the permissible limit of 6.5 to 8.5 in all the wells of this basin.
- ✓ The chloride content is within the maximum acceptable limit of 1000 mg/l in almost all the wells except Gramam village of Thiruvennainallur block.
- ✓ The Total Hardness value ranges from good to moderate quality in this sub basin. Poor TH value greater than 600 mg/l is observed in Bairanaickanpatti village of Dharmapuri district, Alangayam of vellore district, Gramam and Rishivandhiyam of Villupuram district, Malayanur chakkadi, Neepathurai and Thatchampattu of Thiruvannamali district.
- ✓ The nitrate value is within the permissible limit of 45 mg/l in all the wells in this sub basin. Value higher than 45 mg/l is observed in Bairanaickanpatti and K.Vetrapatti villages of Dharmapuri district, Malayanur chakkadi and Thanipadi villages of Thiruvannamalai district.
- ✓ This basin is wide spread with good to moderate quality of Total Dissolved Solids whereas the Poor quality of TDS is observed in Bairanaickanpatti village of Dharmapuri district and Gramam village of Villupuram District.
- ✓ In general, the quality of groundwater is "good to moderate" in Pennaiyar 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.

6.6.6 Recommendations:

1. The components of groundwater vary from one place to another. Groundwater is of good to moderate quality in most of the wells in this basin. Poor quality of groundwater exist in some of the wells of this basin may be due to the composition of rocks and soils, which has direct influence on water quality.
2. Another reason may be due to local pollution, use of extensive fertilizers, and disposals of sludge and waste water effluents. Hence it is recommended that the Industrial effluents

are to be treated properly before allowing to flow in the river or water bodies. The organic manures can be substituted for chemical fertilizers.

3. The aquifers depleted due to excessive groundwater development can be recharged artificially through proper method.

4. Installation of water metering devices to control the tapping of groundwater may be encouraged so as to limit the excess exploitation of groundwater which in turn affects the quantity and quality of the groundwater of that area.

5. Check dams are small barriers that can be built across the direction of water flow in rivers and streams to recharge the groundwater. The small dams retain excess water flow during monsoon rains in a small catchments area behind the structure. Pressure created in the water spread area helps forces the impounded water into the ground. The major environmental benefit is the replenishment of nearby groundwater reserves and wells. The water entrapped by the dams, surface and subsurface is primarily intended for use in irrigation during the lean monsoons and also be used for livestock and domestic needs.

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 (Singh.R.D and Kumar.C.P, 2007). 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 food grains and cash crops have rapidly and indiscriminately increased. India's rapidly rising 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 measures 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, Agriculture Department, Agricultural Engineering Department, TWAD Board and Forest Department with and without Central Government assistance have taken up augmentation of the 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/tanks, 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, PWD, Tharamani, Chennai-113 and from the office of Chief Engineer, Chennai Region. About 587 ARS works were completed in this basin through WRD and other departments. The details of ARS constructed in Pennaiyar basin are given in **Table 6.10 & Table 6.11**.

Table 6.10 Artificial Recharge Structures constructed in Pennaiyar River Basin

Sl. No.	Sub Basin	Type of ARS	No. of ARSs	Blocks
1. ARS in Over Exploited Blocks (432 Nos.)				
1	Markandanadhi	Recharge Shaft	1	Veppanpalli
		Percolation Pond	2	Veppanpalli
		Village Tank	1	Veppanpalli
2	Kambainallur	Check Dam	17 5 28 4	Dharmapuri Morappur Karimangalam Palacode
		Recharge Shaft	1 3	Dharmapuri Palacode

		Percolation Pond	4 2 5	Dharmapuri Palacode Karimangalam
		Village Tank	2 3	Morappur Karimangalam
3	Pambar	Check Dam	6 12 13 13 12 6	Uthangarai Mathur Kandhili Thirupathur Bargur Jolarpet
		Recharge Shaft	11 8 5	Kandhili Thirupathur Jolarpet
		Percolation Pond	2 4 1 2 4 1	Uthangarai Mathur Kandhili Thirupathur Bargur Natrampalli
		Village Tank	4 3 1 1 1	Mathur Bargur Krishnagiri Kandhili Thirupathur
4	Vaniyar	Check Dam	19 8 14	Morapppur Pappireddipetti Harur

		Recharge Shaft	4 2	Morappur Harur
		Percolation Pond	2 2	Pappireddipetti Morappur
		Village Tank	6 2	Pappireddipetti Morappur
5	Kottapattikallar	Percolation Pond	2	Harur
		Village Tank	1 1	Pappireddipetti Harur
6	Aliyar	Check Dam	10 8 6	Thandrampet Chengam Tiruvannamalai
7	Thurinjalar	Check Dam	20 12	Tiruvannamalai Chengam
		Recharge Shaft	5 1 5	Chengam Thandrampet Tiruvannamalai
8	Gadilam	Check Dam	11 22	Cuddalore Ulundurpet
		Recharge Shaft	6	Ulundurpet
		Percolation Pond	4	Ulundurpet
		Village Tank	2	Ulundurpet
9	Upto Krishnagiri reservoir	Check Dam	6 9	Krishnagiri Veppanapalli
		Recharge Shaft	1	Veppanapalli
		Percolation Pond	1 1	Krishnagiri Veppanapalli
		Village Tank	3 4	Krishnagiri Veppanapalli
10	Krishnagiri to Pambar	Check Dam	15 1	Harur Krishnagiri

			3 1	Uthangarai Morappur
		Percolation Pond	1 1 2 2	Harur Morappur Krishnagiri Uthangarai
		Village Tank	2 1 1 2	Uthangarai Harur Karimangalam Krishnagiri
11	Pambar to Thirukovilur	Check Dam	2	Uthangarai
		Recharge Shaft	1 1	Thandrampet Harur
		Percolation Pond	3 2	Harur Thandrampet
		Village Tank	2 1	Harur Thandrampet
2. ARS in Critical Blocks (67 Nos.)				
1	Markandanadhi	Percolation pond	1	Shoolagiri
		Village Tank	3	Shoolagiri
2	Pambar	Recharge shaft	3	Alangayam
		Percolation pond	1	Alangayam
		Village tank	1	Alangayam
3	Kottapattikallar	Check Dam	2	Pethanaickan- palayam
4	Aliyar	Pudupalayam	6	Pudupalayam
		Recharge shaft	2	Pudupalayam
5	Thurinjalar	Check Dam	17 11 1	Kilpennathur Thurinjapuram Pudupalayam
		Recharge shaft	5	Kilpennathur
6	Upto krishnagiri	Check Dam Percolation	6 3	Shoolagiri Shoolagiri

		pond Village tank	5	Shoolagiri
3. ARS in Semi Critical Blocks (40 Nos.)				
1	Gadilam	Check dam	16	Panruti
2	Krishnagiri to Pambar	Check dam	13	Kaveripattnam
		Recharge shaft	1	Kaveripattnam
		Percolation pond	3	Kaveripattnam
		Village tank	3	Kaveripattnam
3	Pambar to Thirukovilur	Check dam Sankarapuram	3 1	Sankarapuram Sankarapuram
4. ARS in Safe Blocks (36 Nos.)				
1	Vaniyar	Check dam	2	Yercaud
		Percolation pond	1	Yercaud
2	Musukundanadhi	Check dam	1	Rishivandiyam
3	Thurinjalar	Percolation Pond	2	Mugaiyur
4	Gadilam	Check dam	11 2	Annagramam Thirunavalur
		Check Dam with Recharge Shaft	1	Annagramam
5	Pambar to Thirukovilur	Check dam	3	Rishivandiyam
		Recharge Shaft	4	Rishivandiyam
		Percolation Pond	2	Rishivandiyam
6	Lower Pennaiyar	Check dam	6	Annagramam
		Village tank	1	Mugaiyur

Table 6.11 List of Check Dams and ARS constructed by WRD in Pennaiyar 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 across Pambanar river near Malamanjanur Village in Thandarmpattu Taluk of Tiruvannamalai District	G O Ms No:224/PW (R2) Dept/dated 5.8.2008	12.50	Pambar and Varattar	Work Completed

2	Construction of Check Dam across Odai near Melmuthanur Village in Thandarampattur taluk of Tiruvannamalai District	G O Ms No;14 PW (R2) Dept/dated 13.1.2011	9.91	Pambar and Varattar	Work Completed
3	Construction of Check Dam across Odai near Puliyampatti Village in Thandarampattur taluk of Tiruvannamalai District	G O Ms No;14 PW (R2) Dept/dated 13.1.2011	9.67	Pambar and Varattar	Work Completed
4	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/ dated: 01.11.2011	42.25	Gadilam	Work Completed
5	Construction of Check Dam across Pambanar River near Narayanakuppam Village in Thandrampattu Taluk of Tiruvannamalai District	G O Ms No:216/PW (WR1) Dept/dated 06.09.2013	218.48	Pambanar and Varattar	Work completed. Funded through IAMWAR M
6	Construction of Check Dam across Pambanar River near Thanipadi Village in Thandrampattu Taluk of Tiruvannamalai District	G O Ms No:216/PW (WR1) Dept/dated 06.09.2013	55.00	Pambanar and Varattar	Work completed.
7	Drilling of Borewells for Artificial Recharge Structure at Billanakuppam Village of Veppanapalli Block Krishnagiri taluk in Krishnagiri District.	G.O.No.32 PW(R2)/ Dept. Date: 06.02.2012	1.05	Upto Krishnagiri Reservoir	Work Completed
8	Drilling of Borewells for Artificial Recharge Structure at Kilkuppam Village of Kaveripattinam Block Krishnagiri taluk in Krishnagiri District.	G.O.No.32 PW(R2)/ Dept. Date: 06.02.2012	1.05	Krishnagiri to Pambar	Work Completed
9	Drilling of Borewells for Artificial Recharge Structure at Sulamalai Village of Veppanapalli Block Krishnagiri taluk in Krishnagiri District.	G.O.No.32 PW(R2)/ Dept. Date: 06.02.2012	1.05	Markandanad hi	Work Completed

10	Drilling of Borewells for Artificial Recharge Structure at Velampatti Village of Harur Block Harur taluk in Dharmapuri District.	G.O.No.32 PW(R2)/ Dept. Date: 06.02.2012	1.05	Vaniyar	Work Completed
11	Drilling of Borewells for Artificial Recharge Structure at Marudhampatti Village of Harur Block Harur taluk in Dharmapuri District.	G.O.No.32 PW(R2)/ Dept.Date: 06.02.2012	1.05	Vaniyar	Work Completed
12	Drilling of Borewells for Artificial Recharge Structure at Sandhapatti Village of Morappur Block Harur taluk in Dharmapuri District.	G.O.No.32 PW(R2)/ Dept.Date: 06.02.2012	1.05	Vaniyar	Work Completed

Pennaiyar basin requires intensive groundwater augmentation to restore the ground water aquifer. Hence, promising groundwater recharge sites are identified with the application of GIS after giving appropriate weightage for spatial and non-spatial parameters like geo-morphology, geology ,lineament, depth to bed rock, soil, ground water, rainfall level. Check dams and recharge shafts are proposed in "Over Exploited", "Semi Critical" blocks to improve the potential. The details of the recommended Artificial Recharge Structures are given in **Table 6.12**

Table 6.12 ARS Recommended by IWS and their Details

Sl. No	Details of proposed ARS	Latitude	Longitude	Sub basin
	In Over Exploited Bocks			
1	Construction of Anicut in Nedusalai in Veppanapalli Bock in Krishnagiri District	12.6574	78.146	Markandanadhi
2	Construction of Check Dam in Olapatti in Morappur Bock in Dharmapuri District	12.2064	78.3023	Kambainallur
3	Construction of Check Dam in Gundalahalli in Dharmapuri Bock in Dharmapuri District	12.1709	78.172	Kambainallur
4	Construction of Percolation Pond in Oolakottai in Dharmapuri Bock in Dharmapuri District	12.1556	78.2206	Kambainallur
5	Construction of Check Dam in Olapatti in Morappur Bock in Dharmapuri District	12.2064	78.3023	Kambainallur
6	Construction of Vertical Shaft in Chinnampalli in Krishnagiri Bock in Krishnagiri District	12.5591	78.2676	Pambar
7	Construction of Vertical Shaft in Kalarpatti in	12.3946	78.6214	Pambar

	Kandhili Bock in Vellore District			
8	Construction of Vertical Shaft in Sandirapuram in Harur Bock in Dharmapuri District	12.1661	78.5787	Pambar
9	Construction of Check Dam in Koratti in Kandhili Bock in Vellore District	12.4225	78.5503	Pambar
10	Construction of Check Dam in Adilam in Bargur Bock in Krishnagiri District	12.4551	78.3564	Pambar
11	Construction of Percolation Pond in Timmanamuttur in Thirupathur Bock in Vellore District	12.4541	78.6111	Pambar
12	Construction of Anicut in Narankottai in Harur Bock in Dharmapuri District	12.0608	78.4881	Vaniyar
13	Construction of Percolation Pond in Periyapatti in Harur Bock in Dharmapuri District	12.0868	78.6955	Kottapatilkallar
14	Construction of Check Dam in Adichchanur in Tiruvannamalai Bock in Tiruvannamalai District	12.0345	79.1665	Thurinjalar
15	Construction of Percolation Pond in Endal in Tiruvannamalai Bock in Tiruvannamalai District	12.2052	79.1	Thurinjalar
16	Construction of Percolation Pond in Odalyandal in Tiruvannamalai Bock in Tiruvannamalai District	12.177	79.1133	Thurinjalar
17	Construction of Vertical Shaft in Kunnamangalam in Ulundurpet Bock in Villupuram District	11.6939	79.2574	Gadilam
18	Construction of Vertical Shaft in Attipakkam in Ulundurpet Bock in Villupuram District	11.842	79.2215	Gadilam
19	Construction of Vertical Shaft in Bampatti in Uthangarai Bock in Krishnagiri District	12.2401	78.5094	Krishnagiri to Pambar
20	Construction of Check Dam in Bajjakarundampudur in Krishnagiri Bock in Krishnagiri District	12.5677	78.2294	Krishnagiri to Pambar
21	Construction of Percolation Pond in Sengalanippatti in Uthangarai Bock in Krishnagiri District	12.2505	78.3983	Krishnagiri to Pambar
22	Construction of Percolation Pond in Palaiyam in Harur Bock in Dharmapuri District	12.089	78.576	Pambar to Thirukovilur
23	Construction of Check Dam in Vanlyampalaiyam in Kolianur Bock in Villupuram District	11.8922	79.5479	Lower Pennaiyar
24	Construction of Anicut in Kurichipalayam in Kolianur Bock in Villupuram District	11.8404	79.589	Lower Pennaiyar
	In Critical Blocks			
1	Construction of Vertical Shaft in Kalastambadi in Thurinjapuram Bock in Tiruvannamalai District	12.2938	79.1001	Thurinjalar

2	Construction of Vertical Shaft in Sorandai in Thurinjapuram Bock in Tiruvannamalai District	12.3366	79.0812	Thurinjalar
3	Construction of Check Dam in Sellankuppam in Thurinjapuram Bock in Tiruvannamalai District	12.1454	79.149	Thurinjalar
4	Construction of Vertical Shaft in Sirunandalur in Kandamangalam Bock in Villupuram District	11.8791	79.5805	Lower Pennaiyar
5	Construction of Vertical Shaft in Vaniyampadi in Kandamangalam Bock in Villupuram District	11.8354	79.64	Lower Pennaiyar

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

6.7.2 Demand-side Management of Groundwater

As irrigation sector gets a larger share in water consumption, water saving techniques in irrigation should be adopted. In Pennaiyar basin, groundwater extracted for irrigation is worked out as 1,819.59 MCM whereas total groundwater extraction is about 2,097.08 MCM. Obviously, reducing the largest water demand i.e irrigation water demand would bring down the stress on groundwater. In general the Pennaiyar basin is a water stressed basin pertaining to ground water resources. Out of 50 blocks encompass in this basin 8 blocks are categorized as “Critical” and 26 blocks are categorized as “Over Exploited”. Since the ground water extraction for irrigation in Pennaiyar basin is alarmingly high ie. 86.77%, latest modern water saving irrigation method may be adopted to reduce the supply-demand gap in Pennaiyar basin.

So, the latest water saving irrigation method, like “Precision Farming” and “Drip Irrigation” should be promoted in large scale to reduce the irrigation water demand in the Pennaiyar basin. Precision Farming has been adopted under National Agriculture Development Programme during 2012-13 in the districts covered in the Pennaiyar basin is as stated below:

- 120 Ha in each Cuddalore, Villupuram, Tiruvannamalai & Vellore districts.
- 80 Ha in Salem district

- 60 Ha in Krishnagiri district
- 40 Ha in Dharmapuri district

Paddy is the predominant crop in Tamil Nadu. Mr.Sivanappan.R.K, Former Dean, AEC&RI and founder Director, Water Technology Centre, Taminadu Agriculture University (TNAU) points out that more than 72% of irrigation water in our State is consumed exclusively by paddy. Therefore, adopting water saving techniques in paddy cultivation would be an effective strategy in irrigation water management.

The Agriculture Policy Note 2014-15 envisages adopting "System of Rice Intensification" (SRI) technique in an area of 13.65 Lakh Ha within paddy cultivating area and SRI technique in 3000 village covering an area of 2.61 Lakh Ha in Tamilnadu has been implemented. The SRI technique may be implemented in Pennaiyar basin also and change in cropping pattern i.e switching from paddy cultivation to dry crop cultivation like maize, sorghum, oil seeds, pulses, etc. is suggested for the 26 Over Exploited blocks of the Pennaiyar basin.

The irrigation demand is more than 90% in 15 out of the 19 sub basins in Pennaiayar basin.

Table: 6.13 Ground Water Potential and Demand as per 2009 Assessment

Sl. No	Sub Basin	Net Ground-water Potential in (MCM)	Gross Extract-ion for irrigation in (MCM)	Gross Extract-ion for other purposes in (MCM)	Gross Extract-ion for all demands (MCM)	Irrigation demand in total demand (%)
1	Chinnar - West	13.14	7.69	1.22	8.91	86.31
2	Chinnar - East	22.24	19.36	1.36	20.72	93.44
3	Markandanadhi	43.26	57.64	3.99	61.63	93.53
4	Kambainallur	136.27	167.59	7.46	175.05	95.74
5	Pambar	201.58	237.42	12.74	250.16	94.91
6	Vaniyar	109.31	111.90	3.35	115.25	97.09
7	Matturar	8.10	10.97	0.25	11.22	97.77
8	Kottapattikallar	47.78	50.55	0.87	51.42	98.31
9	Valayar Odai	13.00	18.44	0.34	18.78	98.19
10	Ramakal Odai	11.67	1.65	0.07	1.72	95.93
11	Pambanar and Varattar	31.98	31.02	1.31	32.33	95.98

12	Aliyar	29.08	33.27	1.04	34.31	96.97
13	Musukundanadhi	31.98	21.24	3.28	24.52	86.62
14	Thurinjalar	206.81	185.85	5.83	191.68	96.96
15	Gadilam	598.56	328.16	121.14	449.30	73.03
16	Upto Krishnagiri Reservoir	85.94	87.18	6.52	93.70	93.04
17	Krishnagiri to Pambar	132.49	144.09	6.42	150.42	95.79
18	Pambar to Thirukovilur	170.96	137.47	6.33	143.65	95.70
19	Lower Pennaiyar	255.94	141.89	67.31	209.20	67.83
	Total	**2,140.09**	**1,793.39**	**250.83**	**2,043.97**	**87.74**

6.8 Summary

Sub basin-wise groundwater potential, extraction and balance have been worked out from block-wise groundwater potential on proportionate basis. Based on the ground water level data of 139 observation wells scrutinized in Pennaiyar Basin, long-term trend in water level fluctuation has been analysed and pre-monsoon & post-monsoon contours maps of shallow aquifers are drawn.

Findings:

- It is found that 539 wells are lying in Pennaiyar Basin and an inventory of about 139 observation wells spread over the entire Pennaiyar Basin has been scrutinized for study purpose based on the availability of data period, ranging from four years (4) to forty three (43) years.
- Wells considered for scrutinisation based on availability of data in each sub-basin is as stated below:
    - Chinnar West – 3; Chinnar East – 5; Markandanadhi – 6; Kambinallur – 18; Pambar – 13; Vaniyar – 11; Mattur – 1; Kottapattikallar – 3; Valayar Odai – 2; Ramakal Odai – No observation well located; Pambanar and Varattar – 2; Aliyar – 4; Muskundanadhi – 3; Thurinjalar – 14; Gadilam – 12; Upto Krishnagiri Reservoir – 10; Krishnagiri to Pambar – 14; Pambar to Thirukovilur – 13; Lower Pennaiyar – 5.

- ❖ Hydrographs (depending on available of well data from 1972 to 2015) of the groundwater levels for the 139 observation wells have been prepared and the data available period ranging from 4 years to 43 years period.
- ❖ Long-tern water level rise found in 78 observation wells and high rise in water level (more than 3.00m) found in 20 wells.
- ❖ Long-tern water level depletion found in 58 observation wells and high depletion in water level (more than 3.00m) found in 24 wells.
- ❖ Out the 24 highly depleted water level wells the more depletion occurred during 202-13 in 1 well, during 2013-14 in 6 wells and during 2014-15 in 2 wells.
- ❖ Long-term water level is constant in three observation wells.
- ❖ Post-monsoon water level varies from 0.00m (Well No. U33035 in Gadilam sub-basin) to 89.5m (Well No. MWS17106 in Markandanadhi sub-basin).
- ❖ Pre-monsoon minimum water level varies from 0.06m (Well No. 53018 in Krishnagiri to Pambar sub-basin) to 95.75m (Well No. MWS17106 in Markandanadhi sub-basin).
- ❖ The water table contour map indicates that groundwater flows generally from north to south in the upper region, west to east in the middle region and towards east in the tail end region of the Pennaiyar basin.
- ❖ Pre-monsoon water level is moderate (4 to 12m) during July 1983 to deeper (8 to 20m) during July 2003 & July 2013.
- ❖ Post-monsoon water level is shallow to moderate (0 to 12) during January 1984 & January 2004 and is deeper (8 to 20m) during July 2003 & July 2013.
- ❖ Pannaiyar basin encompassed 50 blocks with the area either fully or partially covered and whilst comparing the water level assessment with 2003 and 2009, “Safe” category blocks has improved from 4 to 11 at the same time the “Over Exploited” category blocks has decreased from 32 to 26 which shows groundwater level improvement.
- ❖ Total groundwater potential of Pennaiyar Basin is **2,140.09** MCM and total groundwater extraction of the basin is **2,043.97** MCM. The balance groundwater potential available for further development is **364.07** MCM.

- By comparing 2003 and 2009 assessment, it is observed that the total groundwater potential of Pennaiyar Basin has been increased by 6.33% (from 2,012.70 MCM in 2003 to 2,140.09 MCM in 2009) and groundwater extraction in Pennaiyar basin has been decreased (from 2,412.12 MCM in 2003 to 2,043.97 MCM in 2009) by 15.26%, which is a positive trend.
- Based on the stage of groundwater development, Pennaiyar Basin is categorized as “Critical”.
- Only Chinnar West sub-basin is in “Safe” category, 3 sub-basins (Musukundanadhi, Gadiam & Pamber to Thirukovilur) sub-basins are in “Semi Critical”, 3 sub-basins are in “Critical” and the balance 12 sub-basins are in “Over Exploited” category.
- Gadilam sub-basin has the highest groundwater potential while Ramakal Odai sub-basin has the lowest potential and extraction also high in Gadilam sub-basin and low in Ramakal Odai sub-basin. Thurinjalar, Gadilam and Lower Pennaiyar sub-basins combined together contribute nearly half of Pennaiyar basin’s groundwater potential.
- The quality of ground water depends on the different types of rocks encountered. The basin consists mainly of red, black, sandy and mixed soil. The important rock formations are hard or crystalline rocks of Archaean age Dharwar super group, Cuddapah series of rocks belonging to Proterozoic age.
- pH value lies within the permissible limit of 6.5 to 8.5 in all the wells of this basin.
- The chloride content is within the maximum acceptable limit of 1000 mg/l in almost all the wells except Gramam village of Thiruvennainallur block.
- The Total Hardness value ranges from good to moderate quality in this sub basin. Poor TH value greater than 600 mg/l is observed in Bairanaickanpatti village of Dharmapuri district, Alangayam of vellore district, Gramam and Rishivandhiyam of Villupuram district, Malayanur chakkadi, Neepathurai and Thatchampattu of Thiruvannamali district.
- The nitrate value is within the permissible limit of 45 mg/l in all the wells in this sub basin. Value higher than 45 mg/l is observed in Bairanaickanpatti and K.Vetrapatti villages of Dharmapuri district, Malayanur chakkadi and Thanipadi villages of Thiruvannamalai district.

- ❖ This basin is wide spread with good to moderate quality of Total Dissolved Solids (TD) whereas the Poor quality of TDS is observed in Bairanaickanpatti village of Dharmapuri district and Gramam village of Villupuram District.
- ❖ In general, the quality of groundwater is “good to moderate” in Pennaiyar basin.
- ❖ Construction of Artificial Recharge Structures like check dams, percolation ponds, recharge pits, shafts or wells are considered to be the best option for recharging groundwater where soil condition is favourable.
- ❖ Various types of Artificial Recharge Structures (ARS) constructed: 432 structures in Over Exploited blocks, 67 structures in Critical blocks, 40 structures in Semi Critical blocks and 36 structures in Safe blocks.
- ❖ **Check Dams constructed across the rivers:** 5 check dams in Pambar and Varattar sub-basin, 1 check dam in Gadilam sub-basin, 2 check dams in Upto Krishnagiri Reservoir, 1 check dam in Markandanadhi sub-basin and 3 check dams in Vaniyar sub-basin.
- ❖ In Pennaiyar basin, groundwater extracted for irrigation is worked out as 1793.39 MCM which is alarmingly 87.74%, of the total groundwater extraction of 2,043.97 MCM.
- ❖ The irrigation demand is more than 90% in 15 out of the 19 sub basins in Pennaiayar basin.
- ❖ It has been found from the observation wells that the average ground water level has been increased very significantly during December 2015 whilst comparing with December 2014 due to very high monsoon precipitated during November & December 2015 in the 7 districts falling in the Pennaiyar basin.

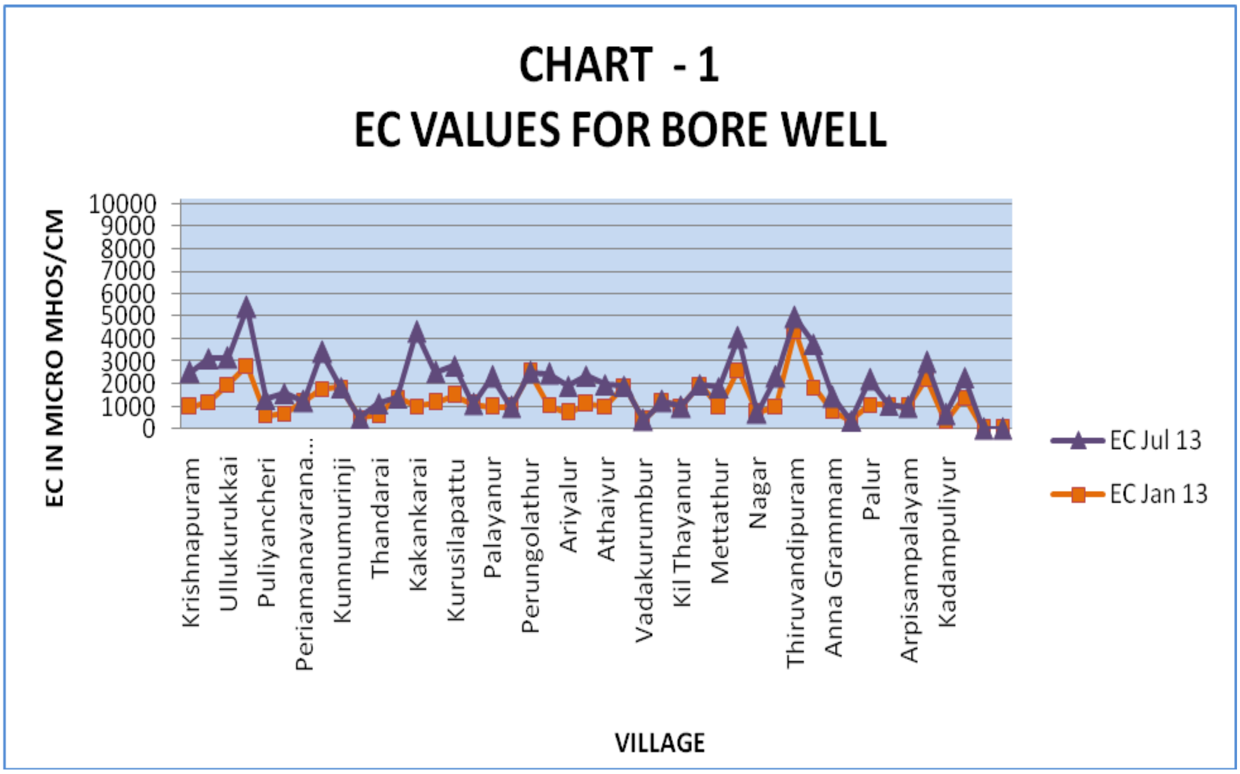
Recommendations:

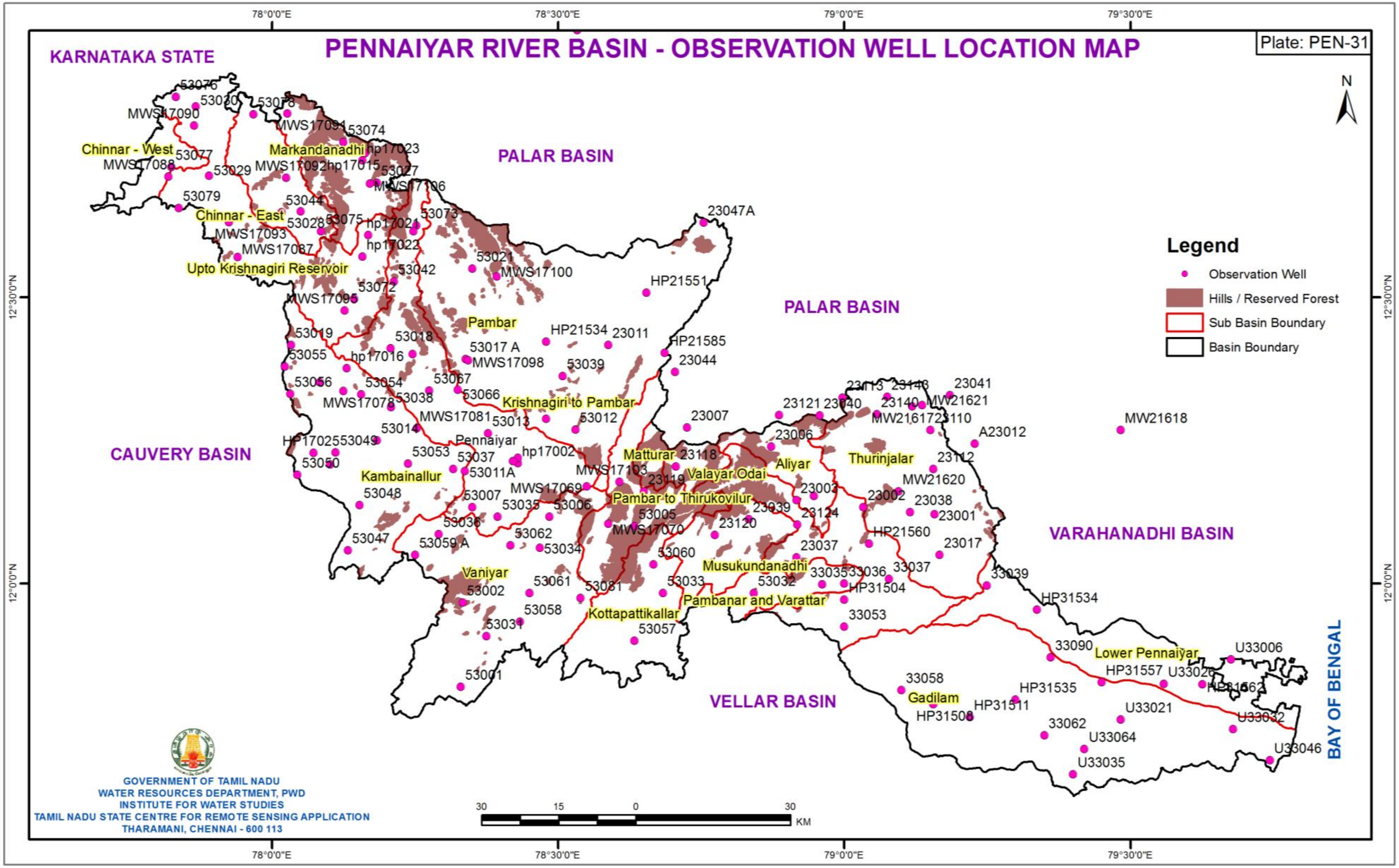
- ➢ Even though groundwater potential has increased and extraction decreased from 2003 to 2009, this basin comes under “Critical” category, so groundwater recharge is utmost priority in this basin.
- ➢ Small quantum of groundwater development is permissible in Chinnar West sub-basin.

- Groundwater development is to be maintain at present level in Musukundanadhi, Gadiam and Pambar to Thirukovilur sub-basins.
- The Groundwater quality is good to moderate in most of the wells in this basin and poor quality of groundwater exist in some of the wells of this basin and use of extensive fertilizers, and disposals of sludge and waste water effluents causing pollution. Hence it is recommended that the Industrial effluents are to be treated properly before allowing to flow in the river or water bodies. The organic manures can be substituted for chemical fertilizers.
- It is suggested to construct 24 various type of Artificial Recharge Structures like Vertical Shaft, Check Dams, Percolation Ponds and Anicut in Over Exploited Blocks and 5 various type of Artificial Recharge Structures like Vertical Shaft, and Check Dams in Critical blocks to recharge the ground water in future.
- Since latest modern water saving irrigation method like "Precision Farming" is implemented in very small area in this basin (120 Ha in each Cuddalore, Villupuram, Tiruvannamalai & Vellore districts, 80 Ha in Salem district, 60 Ha in Krishnagiri district and 40 Ha in Dharmapuri district), so the "Precision Farming" in large area spreading across the basin has to be implemented to reduce the ground water extraction for irrigation demand.
- The SRI technique has to be implemented in more dynamic approach in Pennaiyar basin and change in cropping pattern i.e switching from paddy cultivation to dry crop cultivation like maize, sorghum, oil seeds, pulses, etc. is suggested for the 26 Over Exploited blocks covered in the Pennaiyar basin.

Fig. 6.3 Pennaiyar River Bain Ground Water Quality Chart

(EC: Electrical Conductivity)




PENNAIYAR RIVER BASIN - OBSERVATION WELL LOCATION MAP
Plate: PEN-31
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
N
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30
15
0
30
KM
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Matturar
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thirukovilur
Musukundanadhi
Vaniyar
Kottapattikallar
Pambanar and Varattar
Lower Pennaiyar
Gadilam
Pennaiyar
53076
53030
53078
MWS17090
MWS17091
53074
53077
MWS17088
53029
MWS17092
hp17023
hp17015
53027
MWS17106
53079
53044
53028
53075
hp17021
53073
MWS17093
MWS17087
hp17022
53021
MWS17100
53042
53072
MWS17095
23047A
HP21551
53019
53018
53055
hp17016
53017 A
MWS17098
HP21534
23011
HP21585
23044
53039
53056
53054
53067
MWS17078
53038
53066
MWS17081
53013
53012
53014
23007
HP17025
53049
Pennaiyar
53053
53037
hp17002
53050
53011A
MWS17103
23118
23119
53048
53007
MWS17069
53035
53006
53005
MWS17070
53036
53062
53047
53059 A
53034
53060
23120
23039
23124
23003
23037
53061
53002
53081
53033
53032
33035
33036
33037
HP31504
53058
53031
53057
33053
53001
23121
23040
23113
23143
23140
MW21621
23041
MW21617
23110
23006
A23012
MW21618
23112
MW21620
23002
23038
23001
HP21560
23017
33039
HP31534
33090
HP31557
U33026
U33006
HP31562
33058
HP31535
HP31508
HP31511
U33021
U33032
33062
U33064
U33035
U33046
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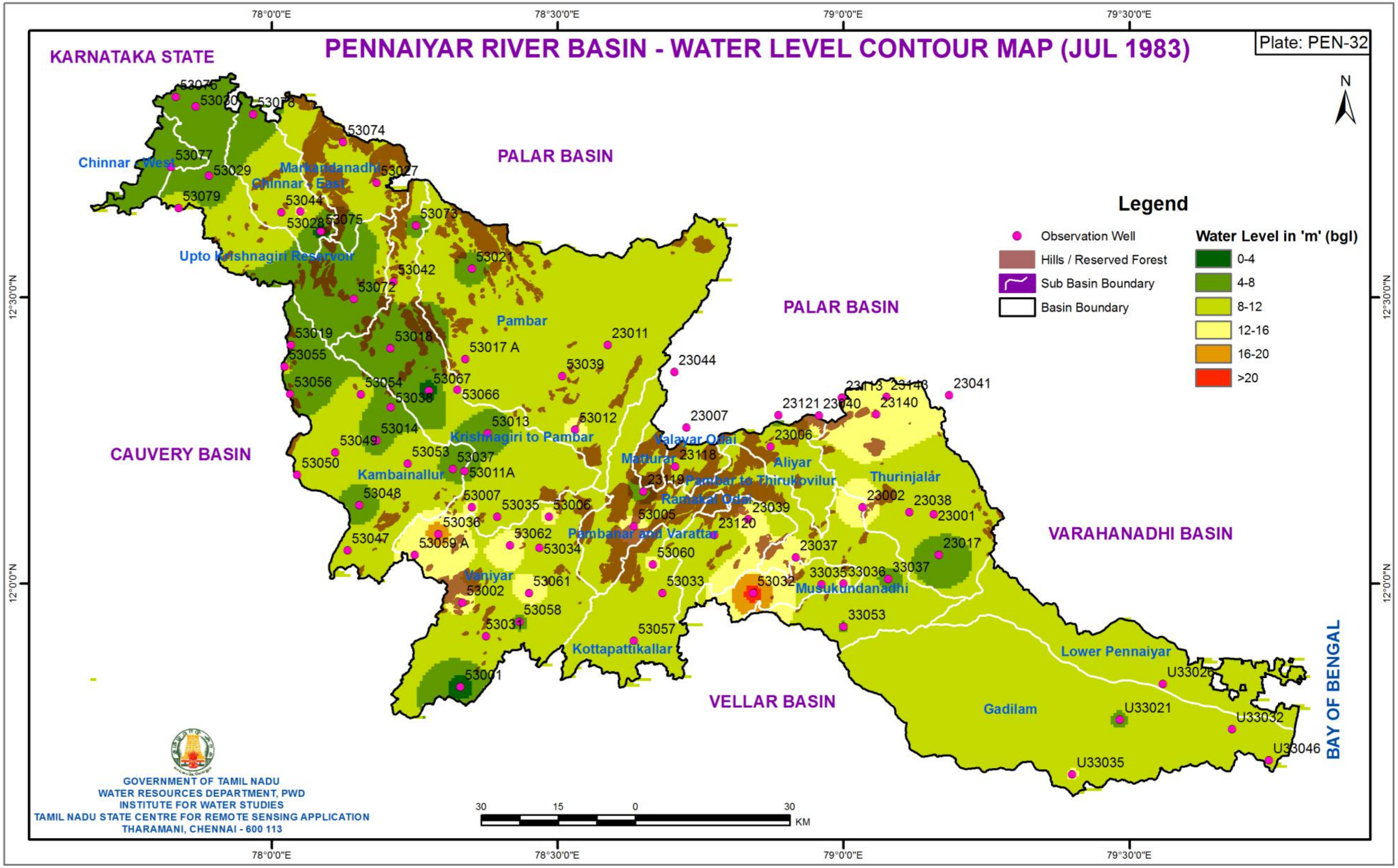
PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JUL 1983)
Plate: PEN-32
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
>20
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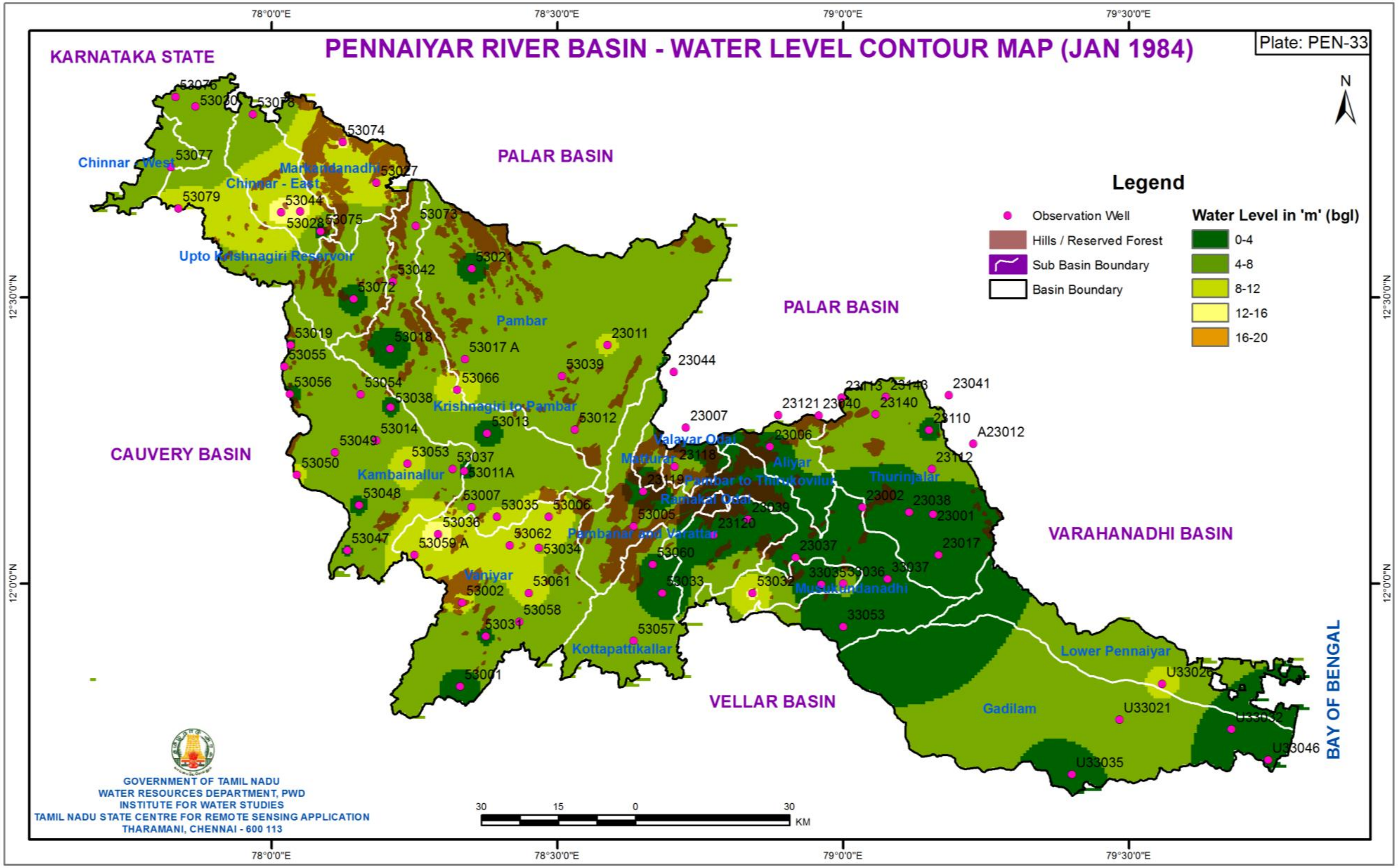
PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JAN 1984)
Plate: PEN-33
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Vaniyar
Kottapattikallar
Pambanar and Varattar
Valayar Odai
Mathurar
Aliyar
Pambar to Thirukovilur
Ramakal Odai
Thurinjalar
Musukundanadhi
Lower Pennaiyar
Gadilam
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INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
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KM
78°0'0"E
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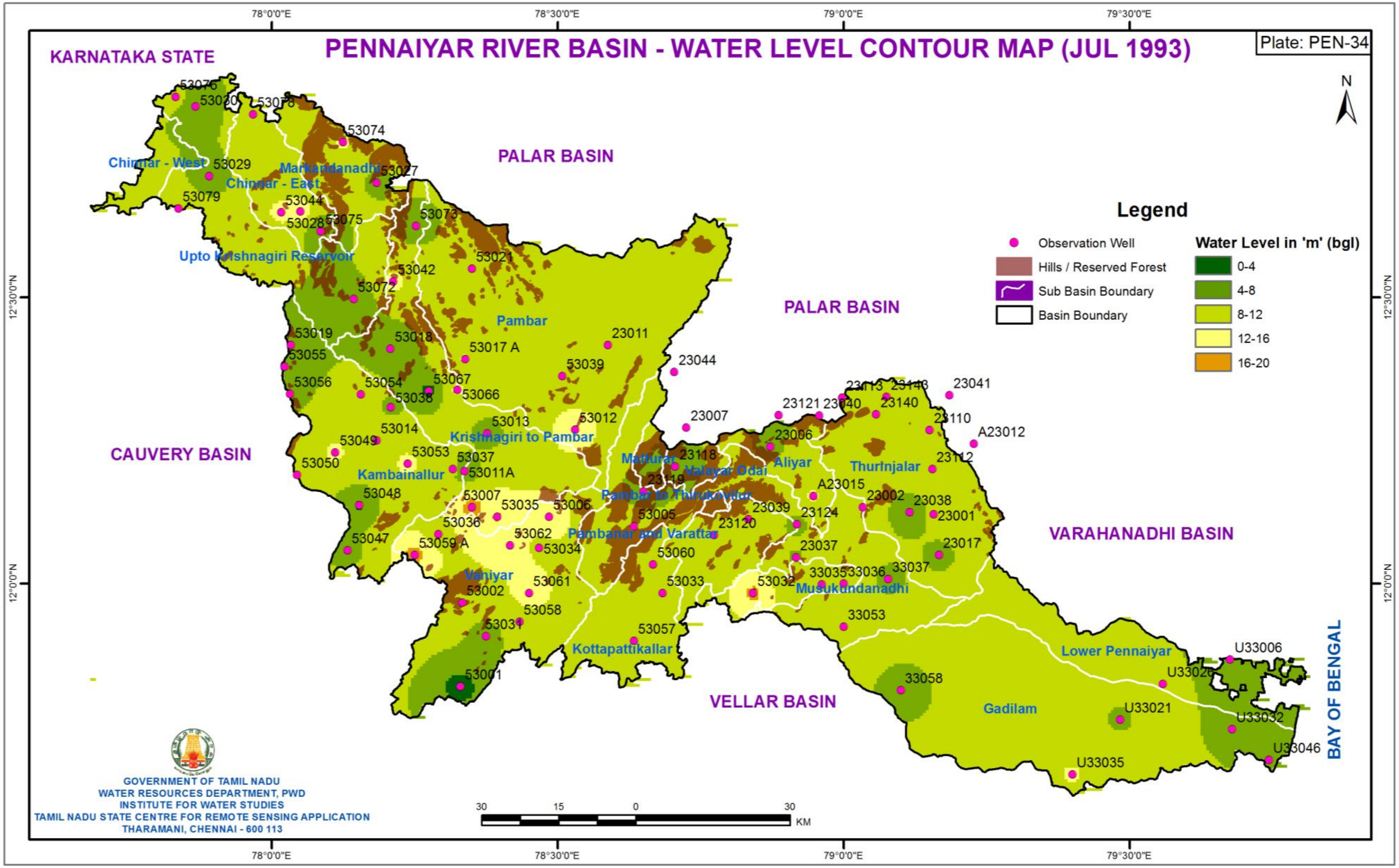
12°30'0"N
12°0'0"N
N


PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JUL 1993)
Plate: PEN-34
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Mattur
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thirukovilur
Pambanar and Varattar
Vaniyar
Musukundanadhi
Kottapattikallar
Lower Pennaiyar
Gadilam
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30 15 0 30 KM
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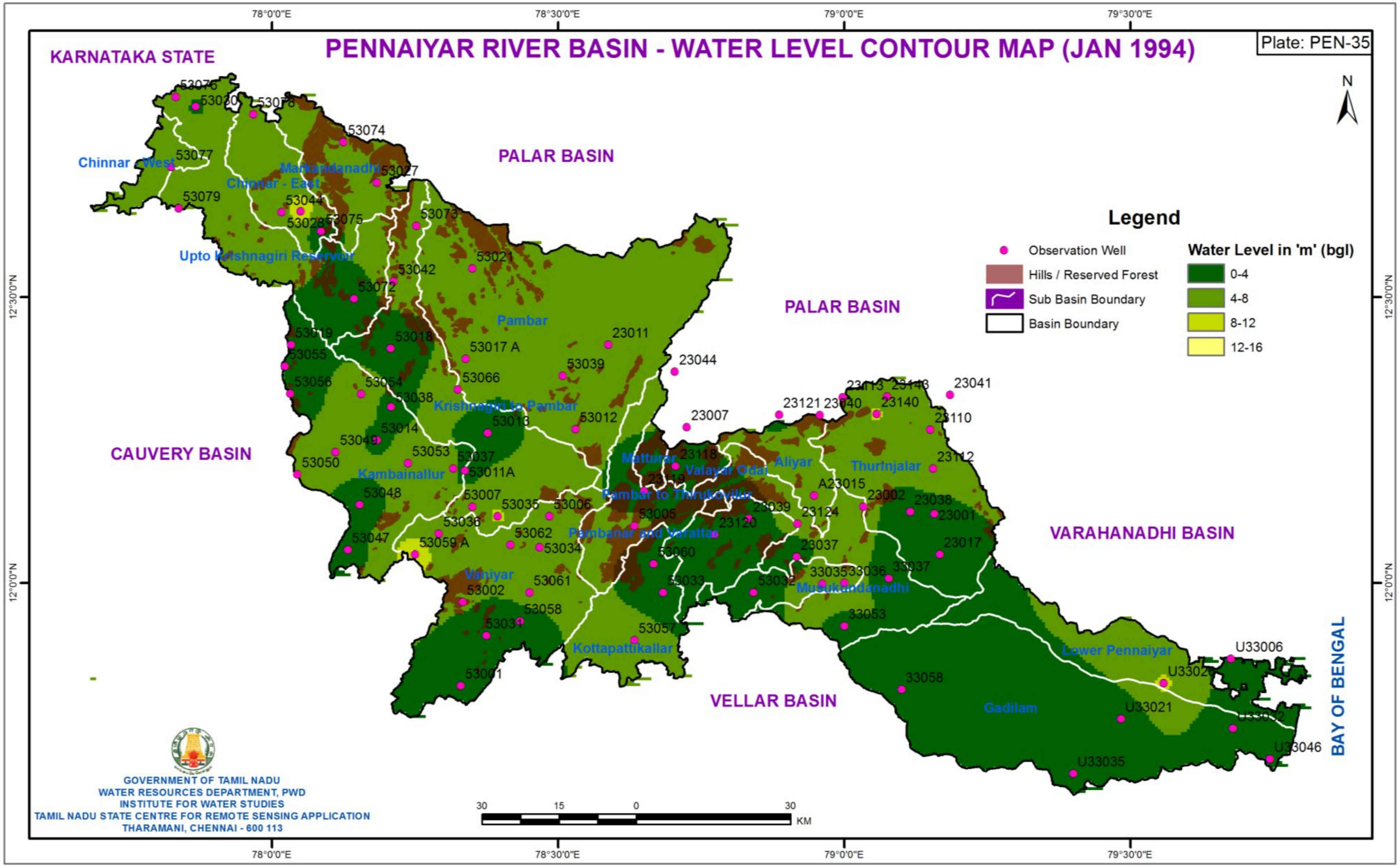
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JAN 1994)
Plate: PEN-35
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Mattur
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thurukovilur
Pambanar and Varattar
Vaniyar
Kottapattikallar
Musukundanadhi
Lower Pennaiyar
Gadilam
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
N
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30 15 0 30
KM
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INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
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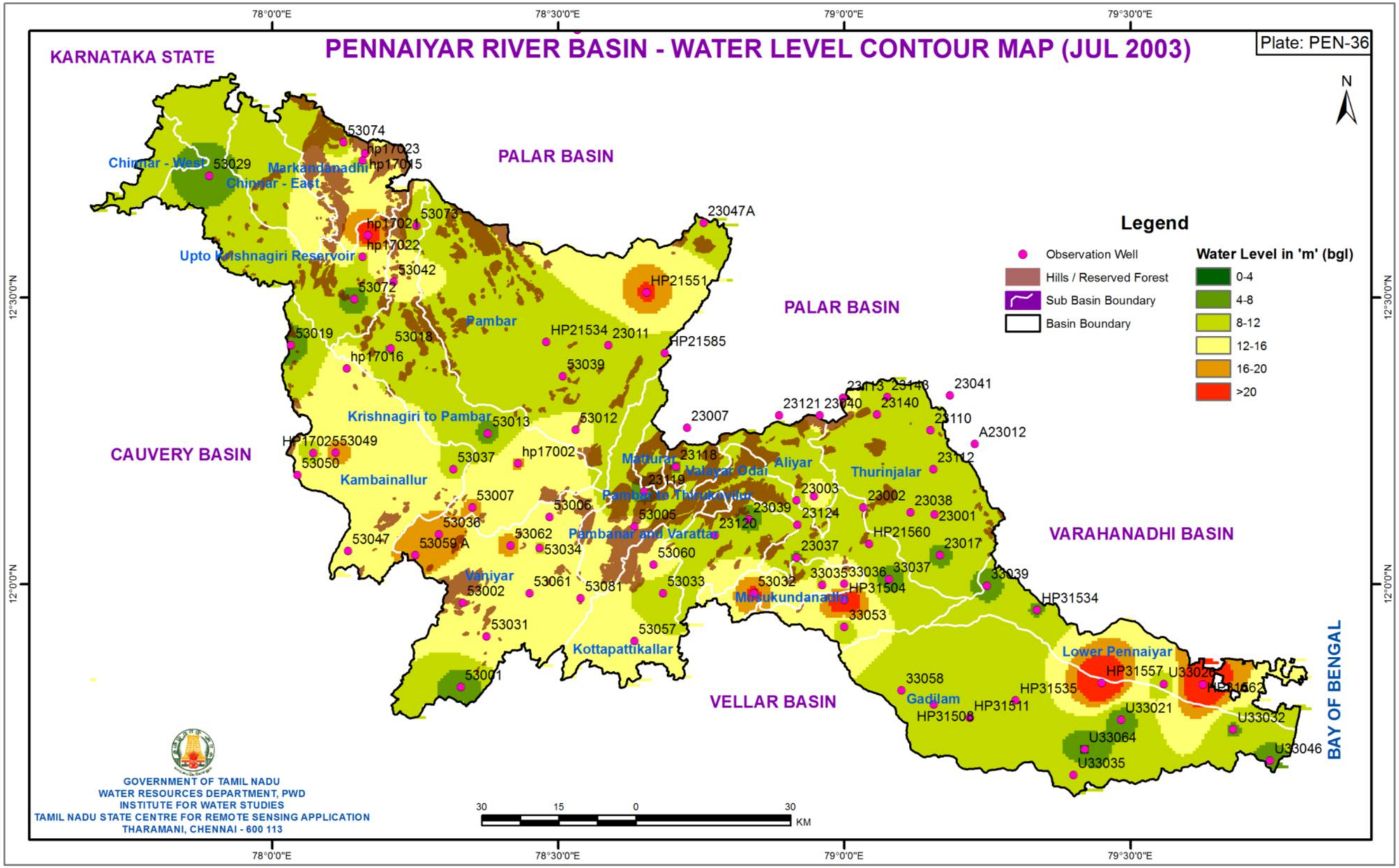
PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JUL 2003)
Plate: PEN-36
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
>20
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Vaniyar
Kottapattikallar
Pambanar and Varattar
Pambar to Thurukovilur
Mathurar
Valayar Odai
Aliyar
Thurinjalar
Musukundanadhi
Lower Pennaiyar
Gadilam
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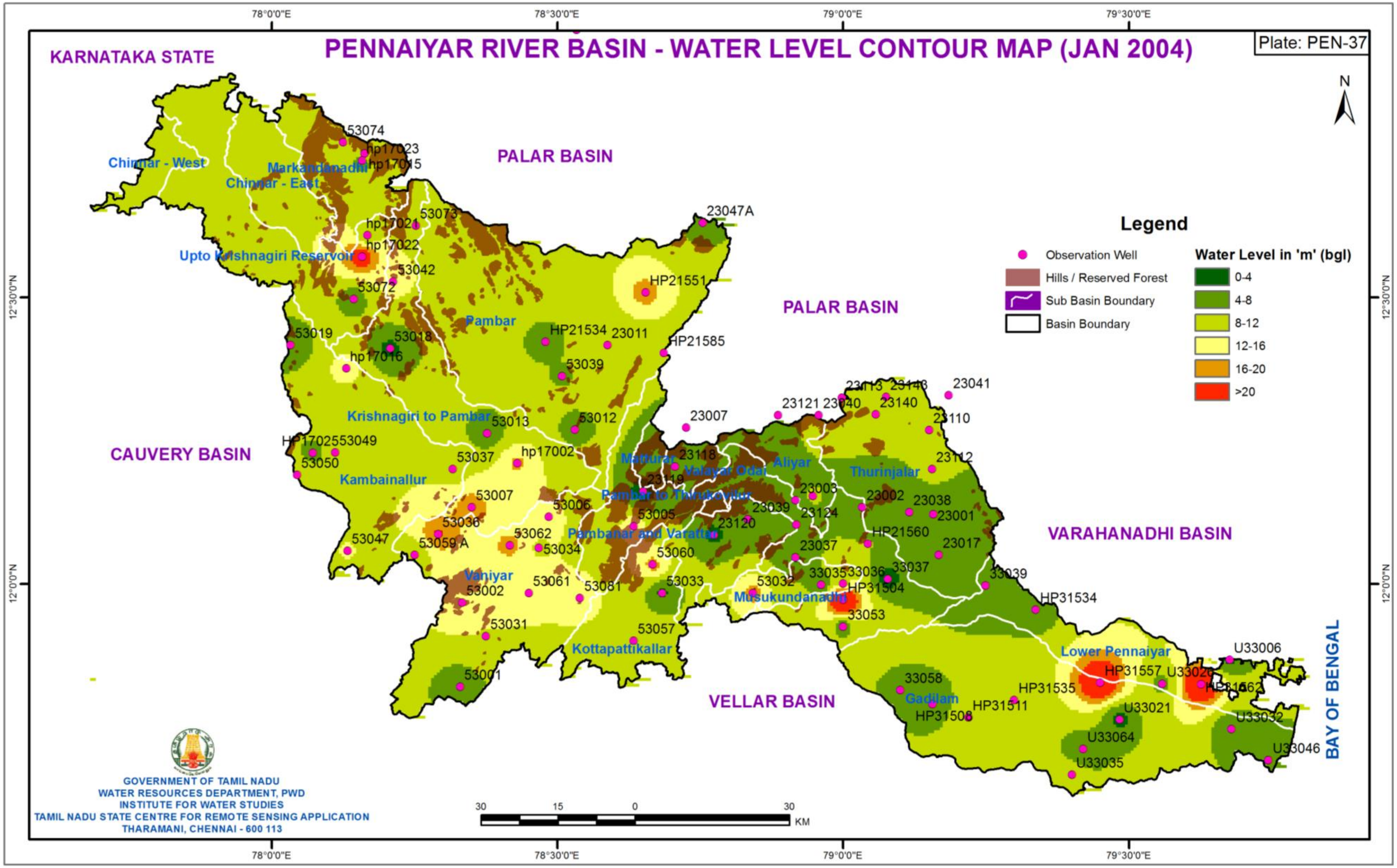
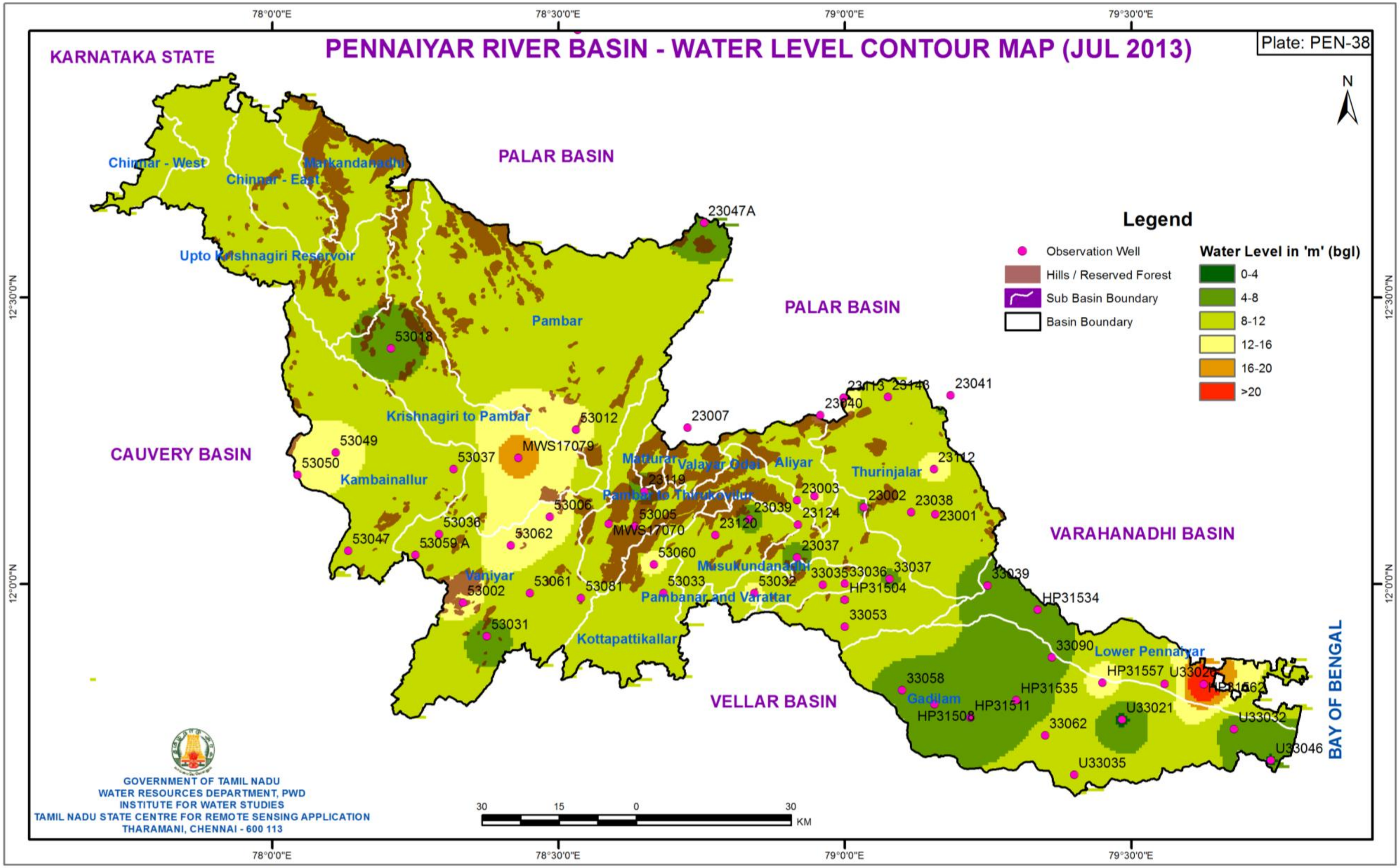
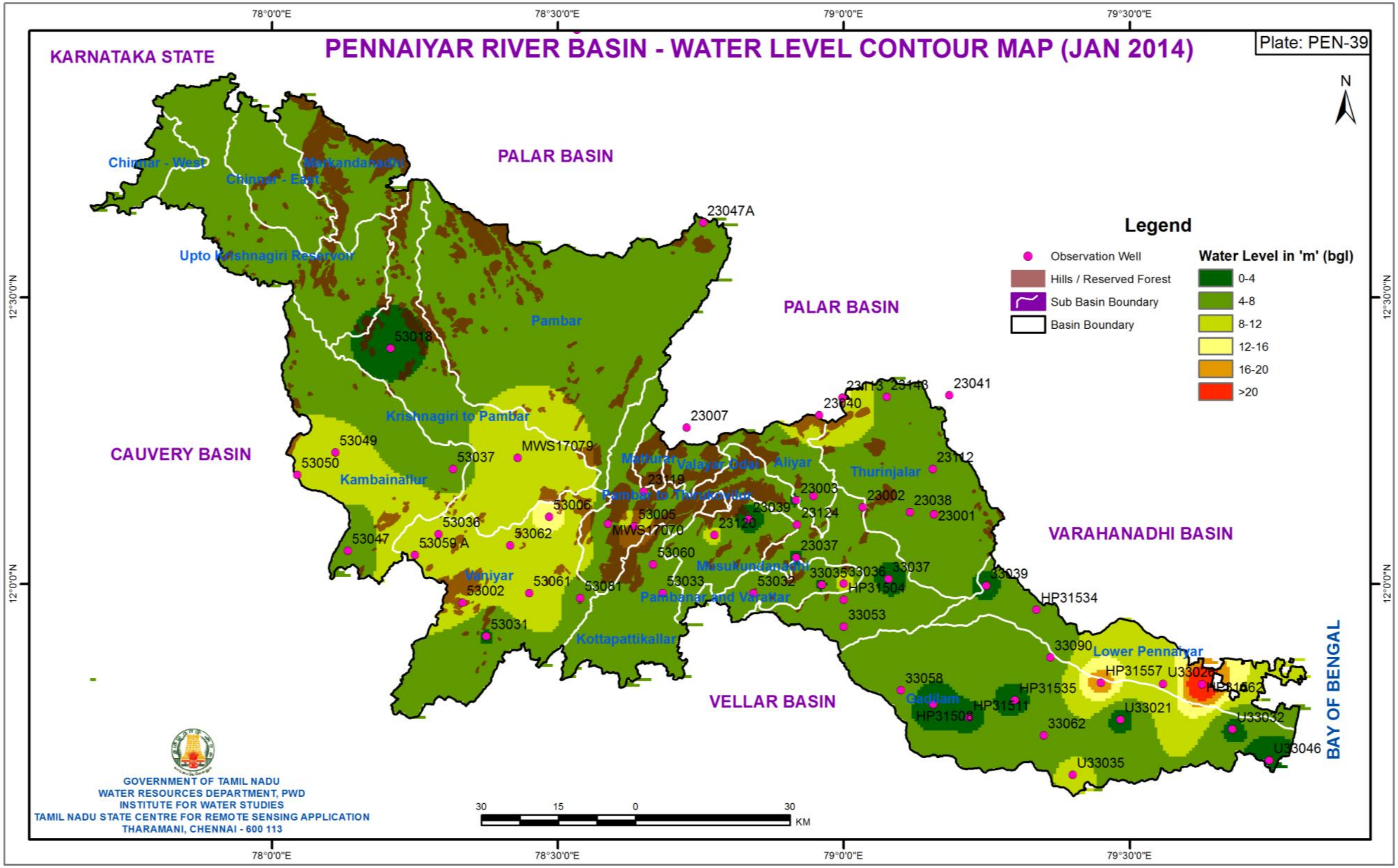
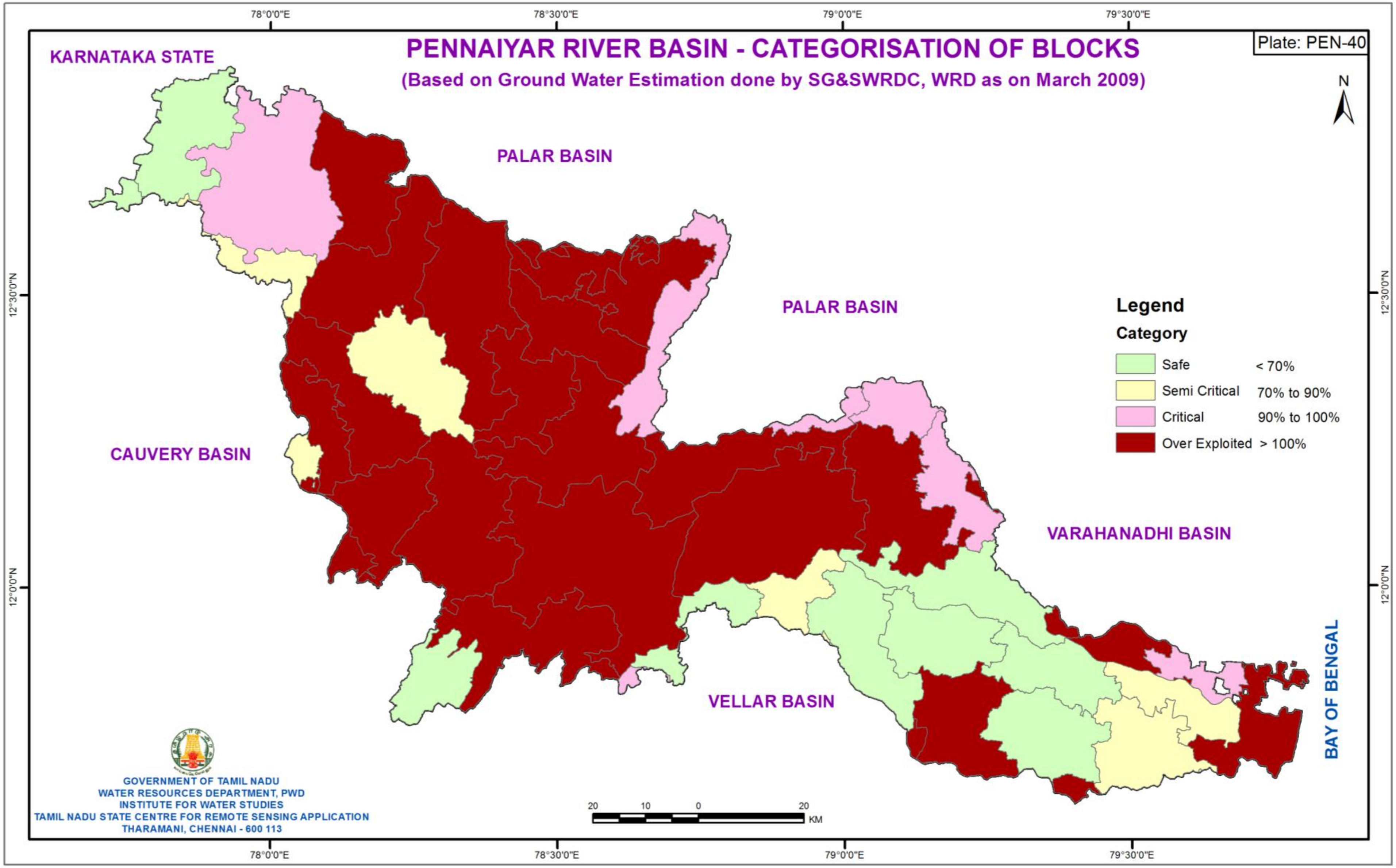
79°30'0"E
12°30'0"N
12°0'0"N


PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JAN 2004)
Plate: PEN-37
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
>20
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Vaniyar
Kottapattikallar
Pambanar and Varattar
Pambar to Thirukovilur
Malattar
Valayar Odai
Aliyar
Thurinjalar
Musukundanadhi
Lower Pennaiyar
Gadilam
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
30 15 0 30
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


PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JUL 2013)
Plate: PEN-38
KARNATAKA STATE
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
>20
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Vaniyar
Kottapattikallar
Matturar
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thirukovilur
Musukundanadhi
Pambanar and Varattar
Lower Pennaiyar
Gadilam
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
KM



PENNAIYAR RIVER BASIN - WATER LEVEL CONTOUR MAP (JAN 2014)
Plate: PEN-39
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Observation Well
Hills / Reserved Forest
Sub Basin Boundary
Basin Boundary
Water Level in 'm' (bgl)
0-4
4-8
8-12
12-16
16-20
>20
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Pambar
Krishnagiri to Pambar
Kambainallur
Vaniyar
Kottapattikallar
Mathurar
Valayar Odai
Aliyar
Thurinjalar
Pambar to Thirukovilur
Musukundanadhi
Pambanar and Varattar
Lower Pennaiyar
Gadilam
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
KM



78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
PENNAIYAR RIVER BASIN - CATEGORISATION OF BLOCKS
(Based on Ground Water Estimation done by SG&SWRDC, WRD as on March 2009)
Plate: PEN-40
N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Category
Safe < 70%
Semi Critical 70% to 90%
Critical 90% to 100%
Over Exploited > 100%
20 10 0 20
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

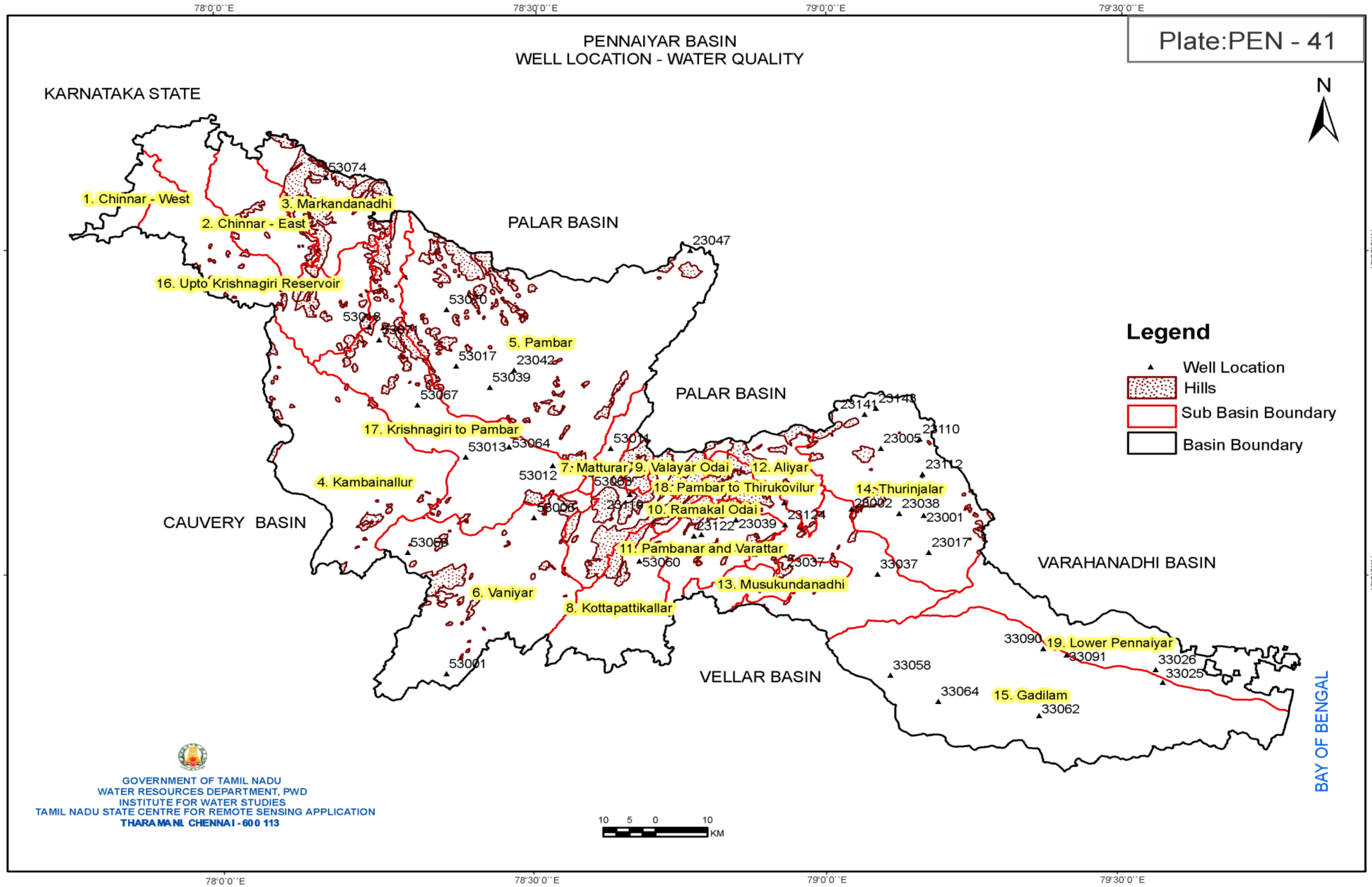
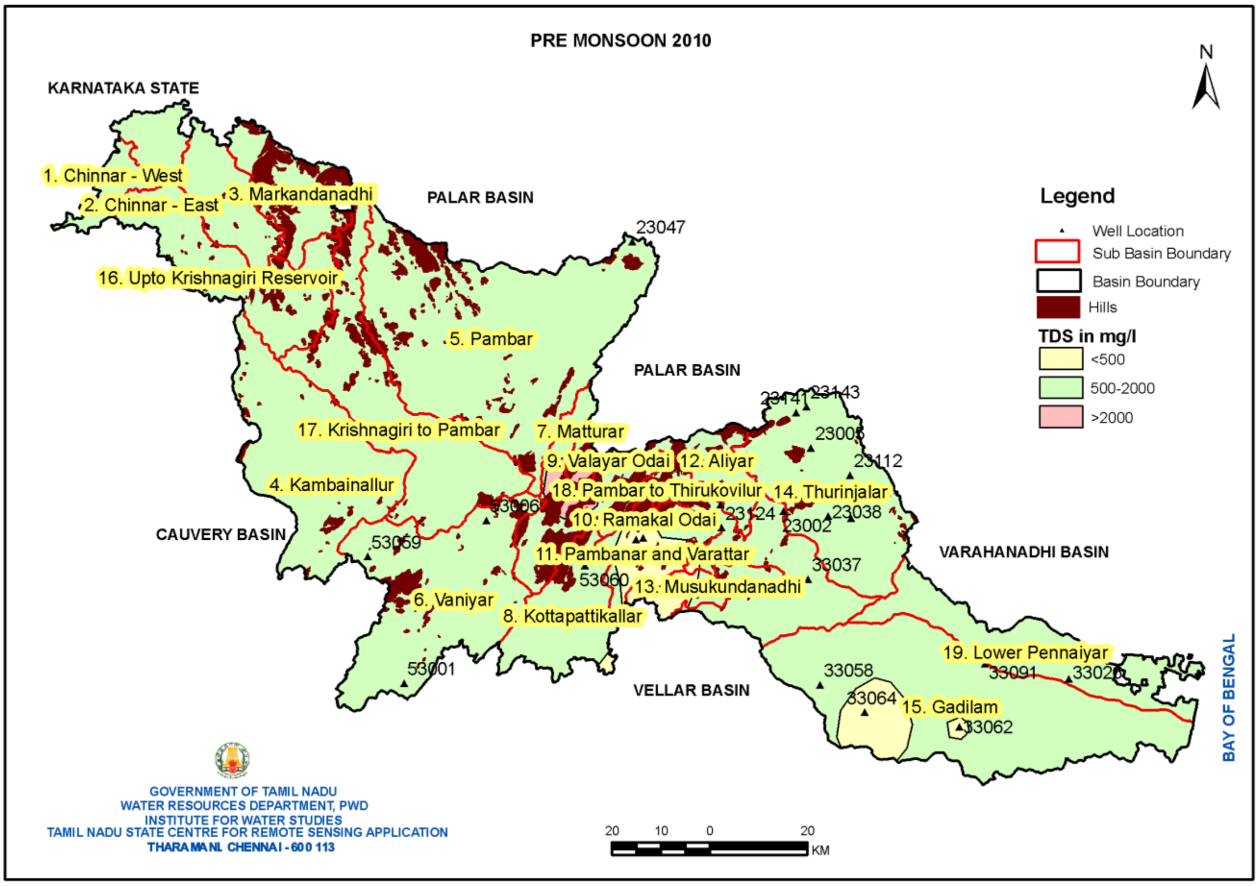


Plate:PEN - 41
PENNAIYAR BASIN
WELL LOCATION - WATER QUALITY
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
1. Chinnar - West
2. Chinnar - East
3. Markandanadhi
4. Kambainallur
5. Pambar
6. Vaniyar
7. Matturar
8. Kottapattikallar
9. Valayar Odai
10. Ramakal Odai
11. Pambanar and Varattar
12. Aliyar
13. Musukundanadhi
14. Thurinjalar
15. Gadilam
16. Upto Krishnagiri Reservoir
17. Krishnagiri to Pambar
18. Pambar to Thirukovilur
19. Lower Pennaiyar
Legend
Well Location
Hills
Sub Basin Boundary
Basin Boundary
N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
10 5 0 10
KM

Plate:PEN - 42

PENNAIYAR RIVER BASIN - WATER QUALITY MAP
TOTAL DISSOLVED SOLIDS



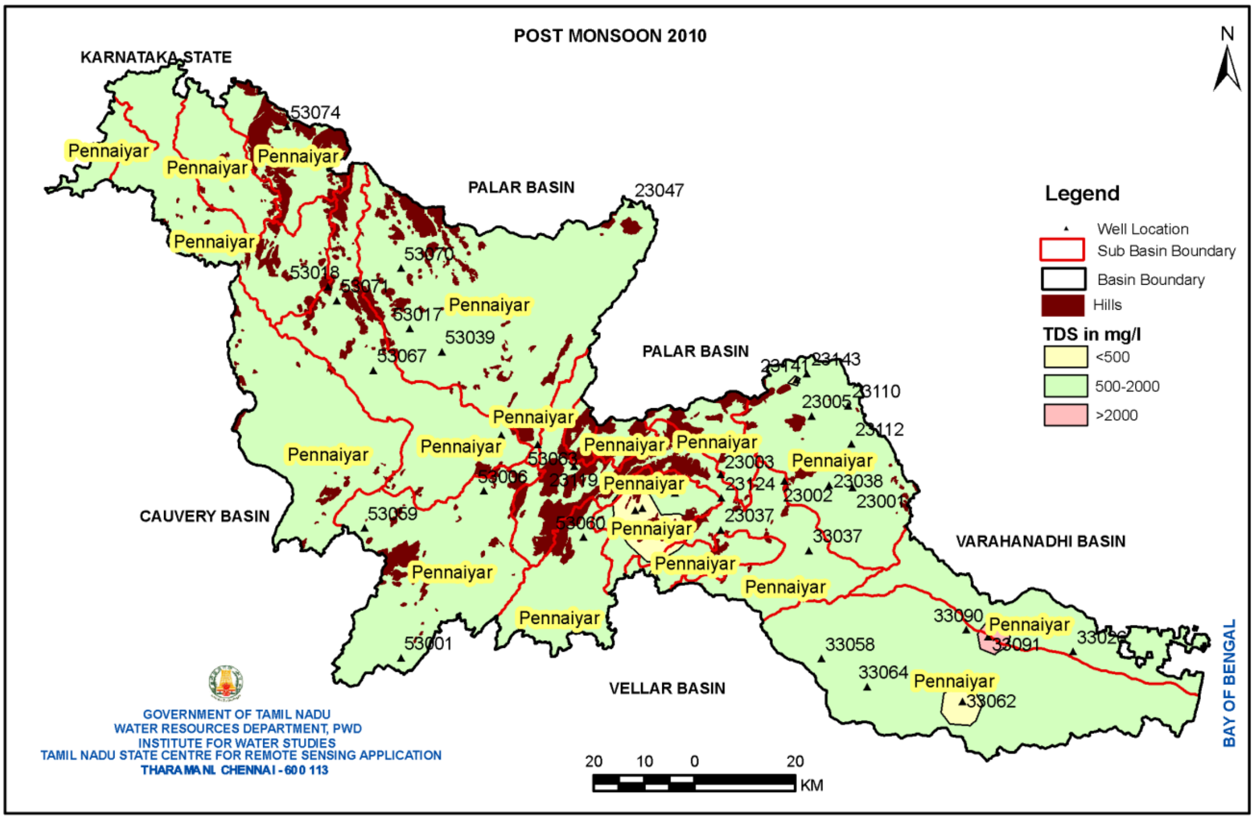
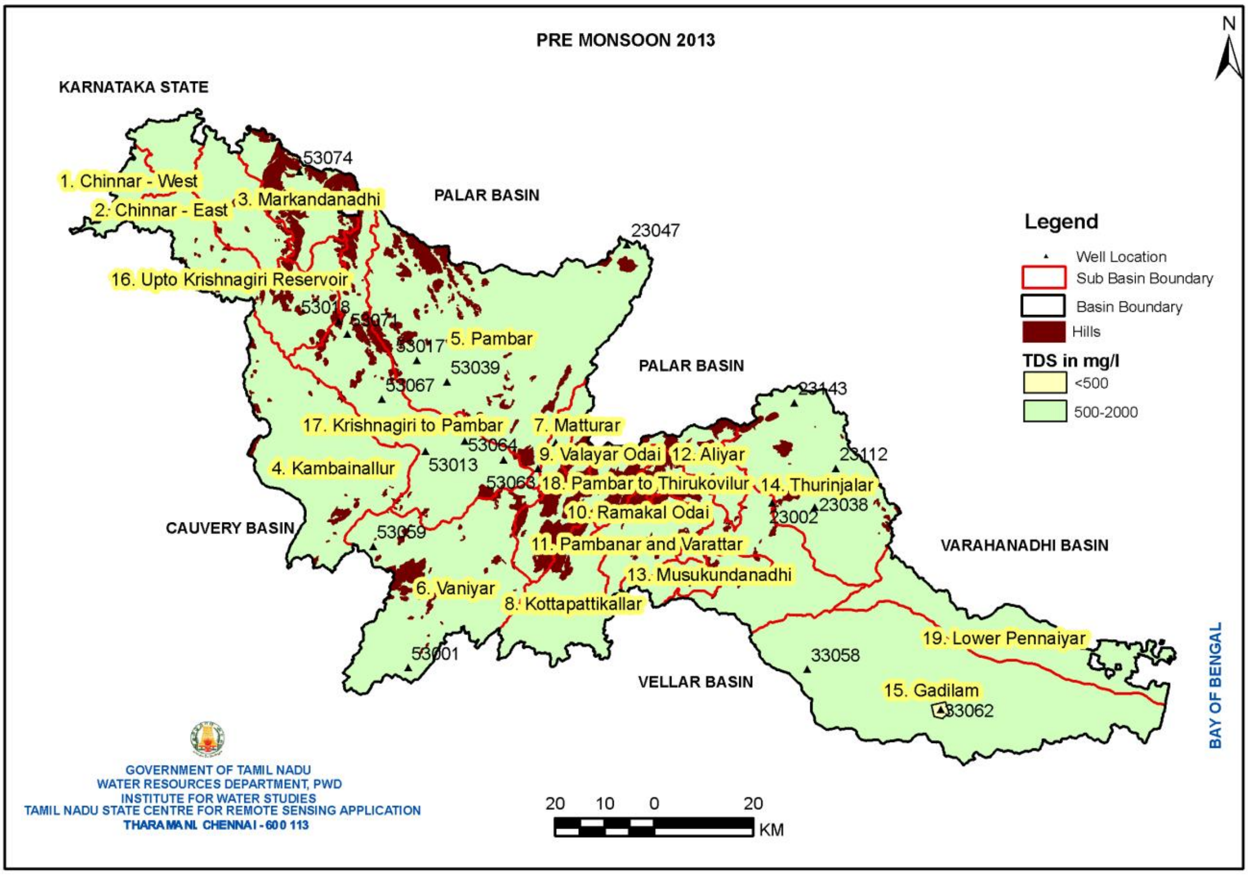


Plate:PEN - 43

PENNAIYAR RIVER BASIN - WATER QUALITY MAP
TOTAL DISSOLVED SOLIDS



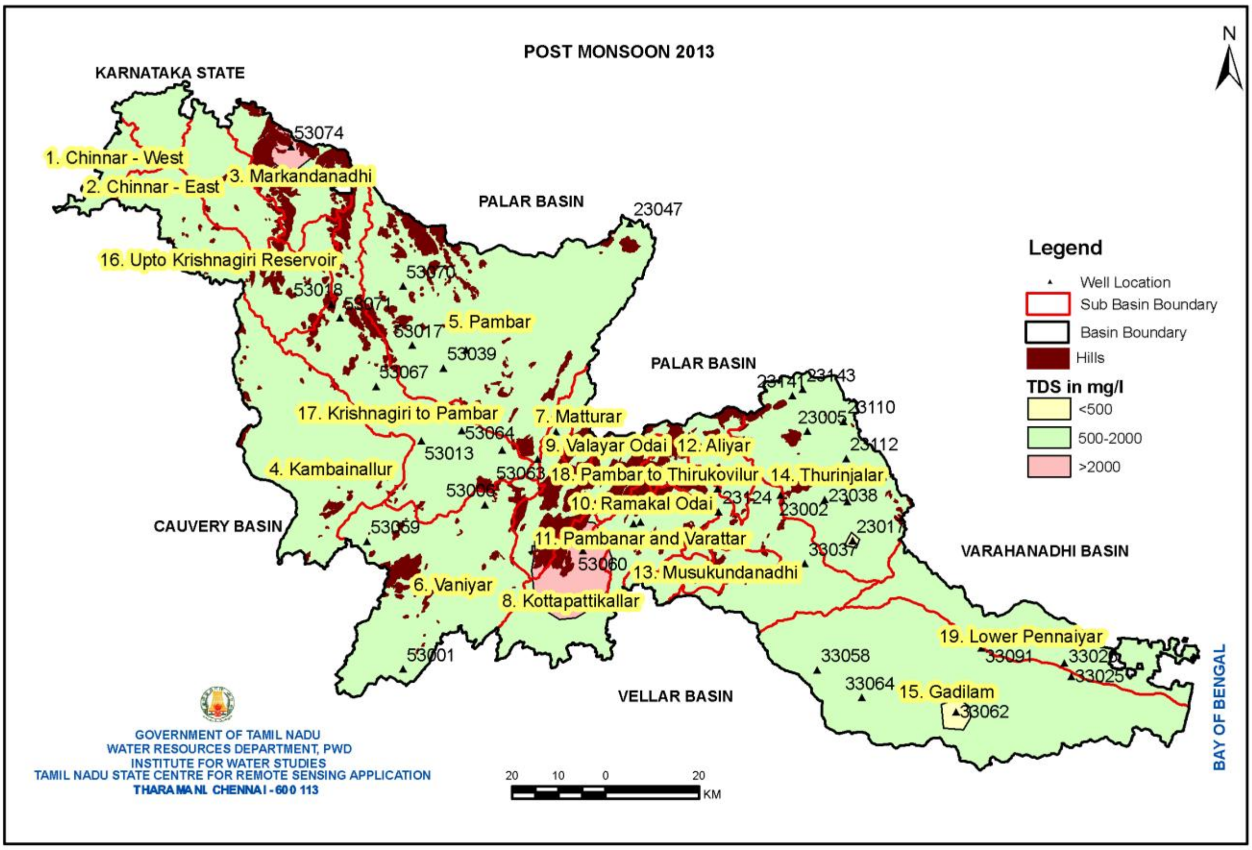
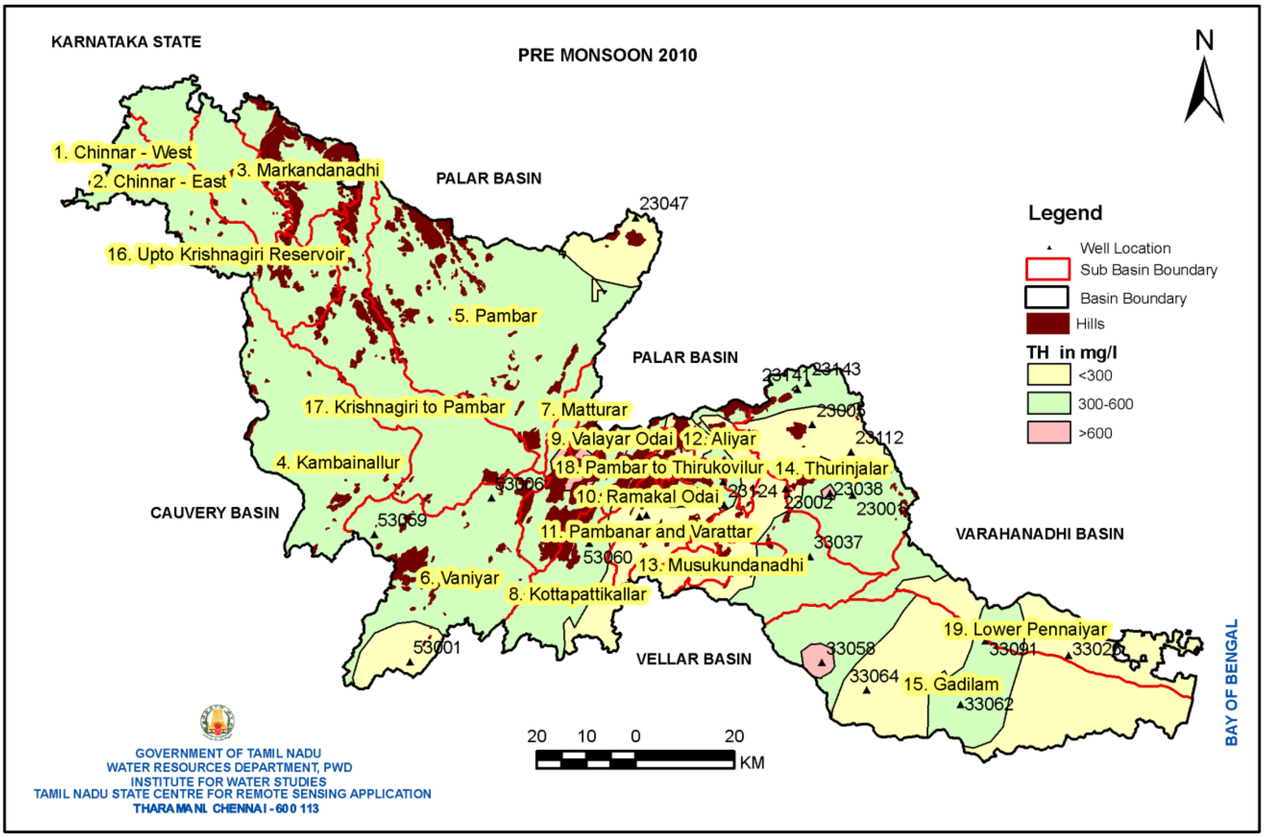


Plate:PEN - 44

PENNAIYAR RIVER BASIN - WATER QUALITY MAP

TOTAL HARDNESS



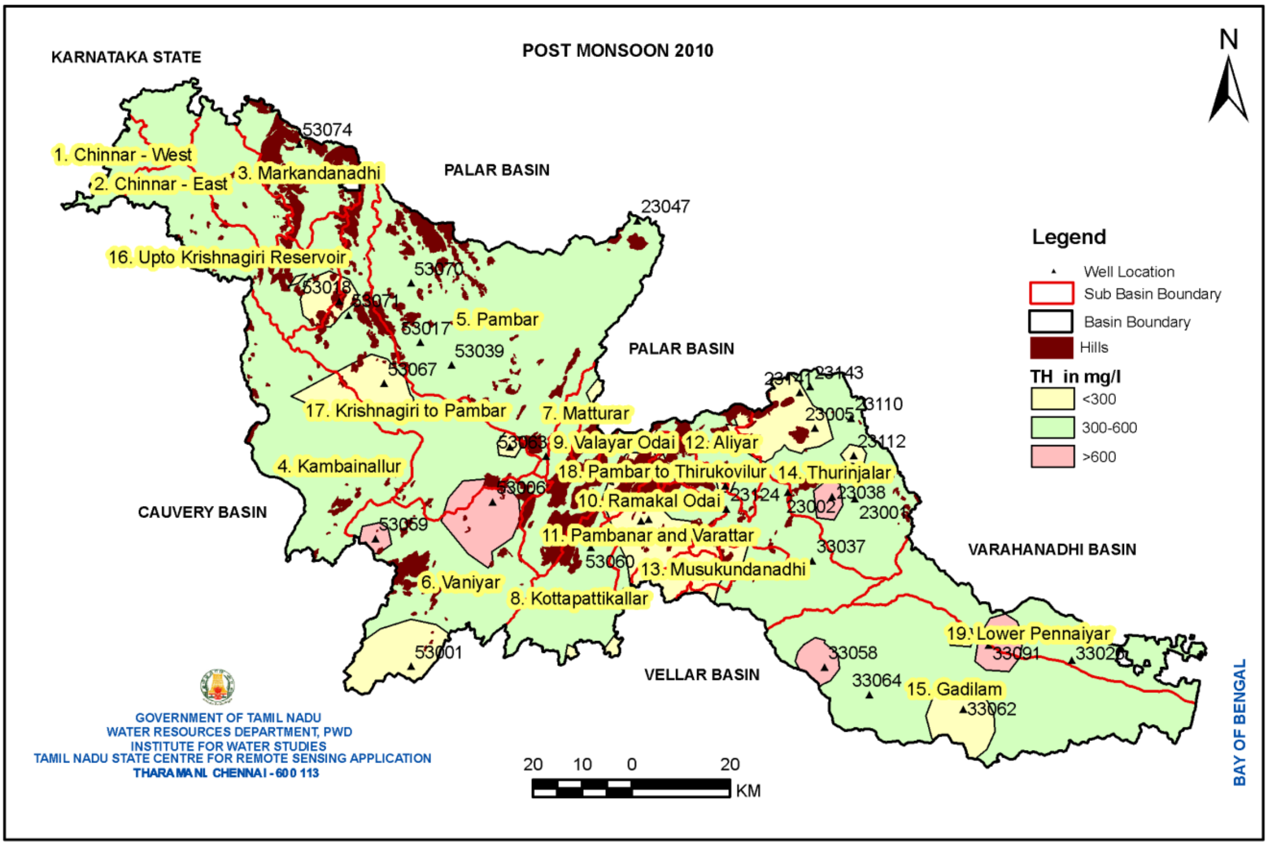
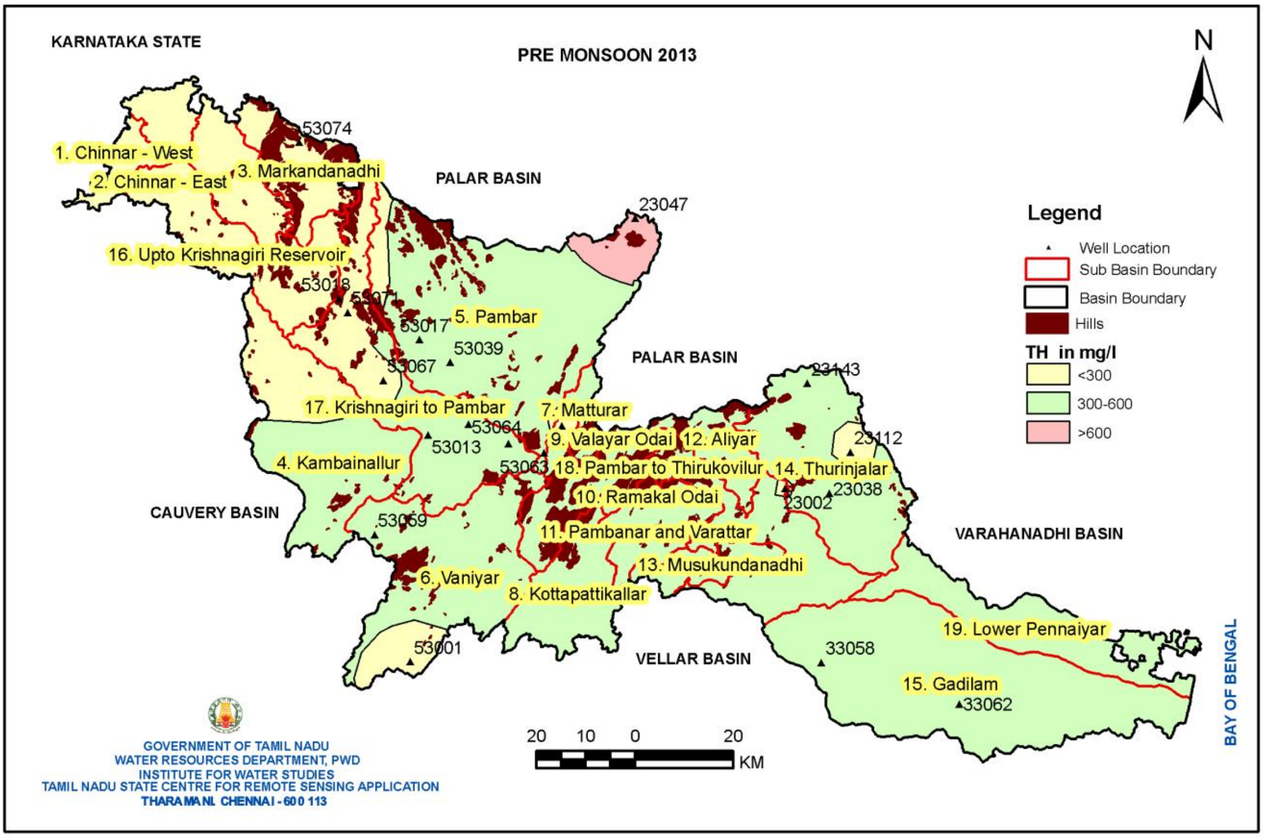


Plate:PEN - 45

PENNAIYAR RIVER BASIN - WATER QUALITY MAP

TOTAL HARDNESS



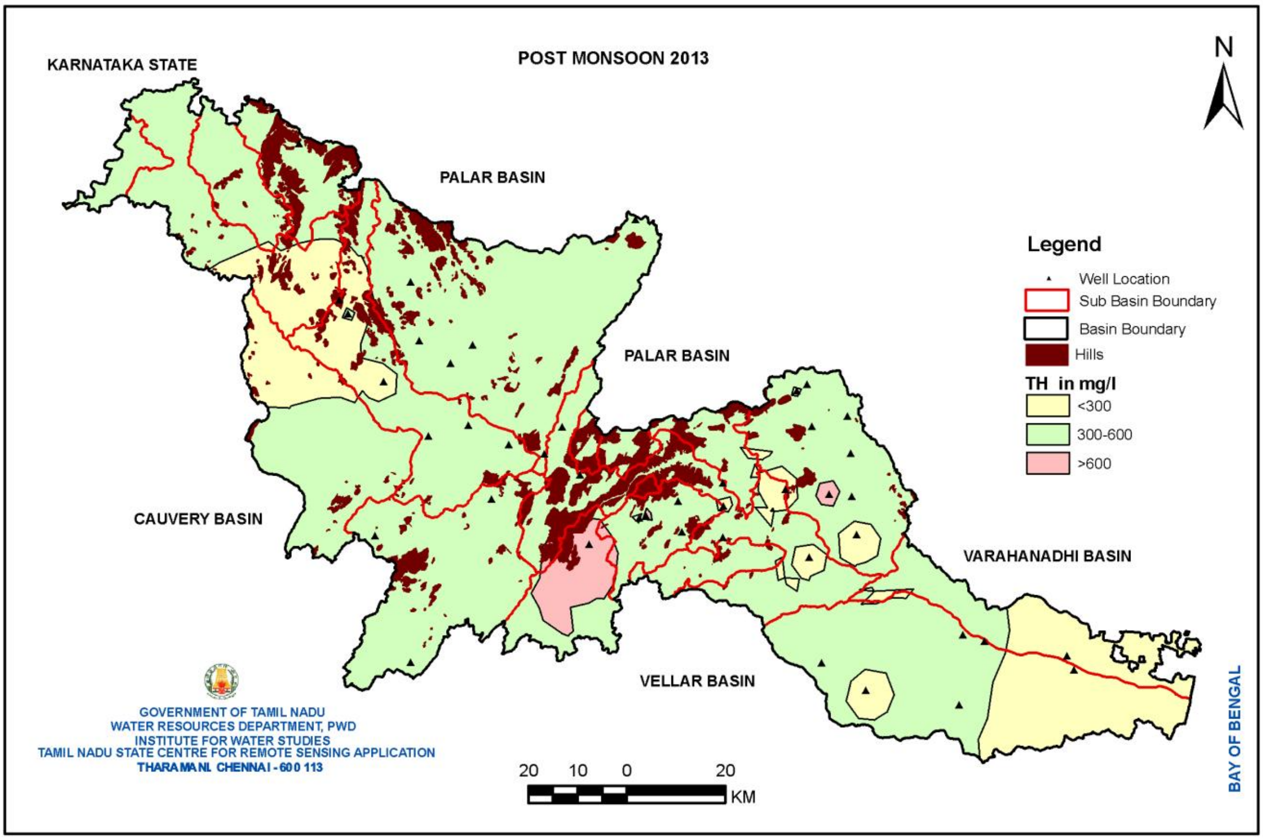
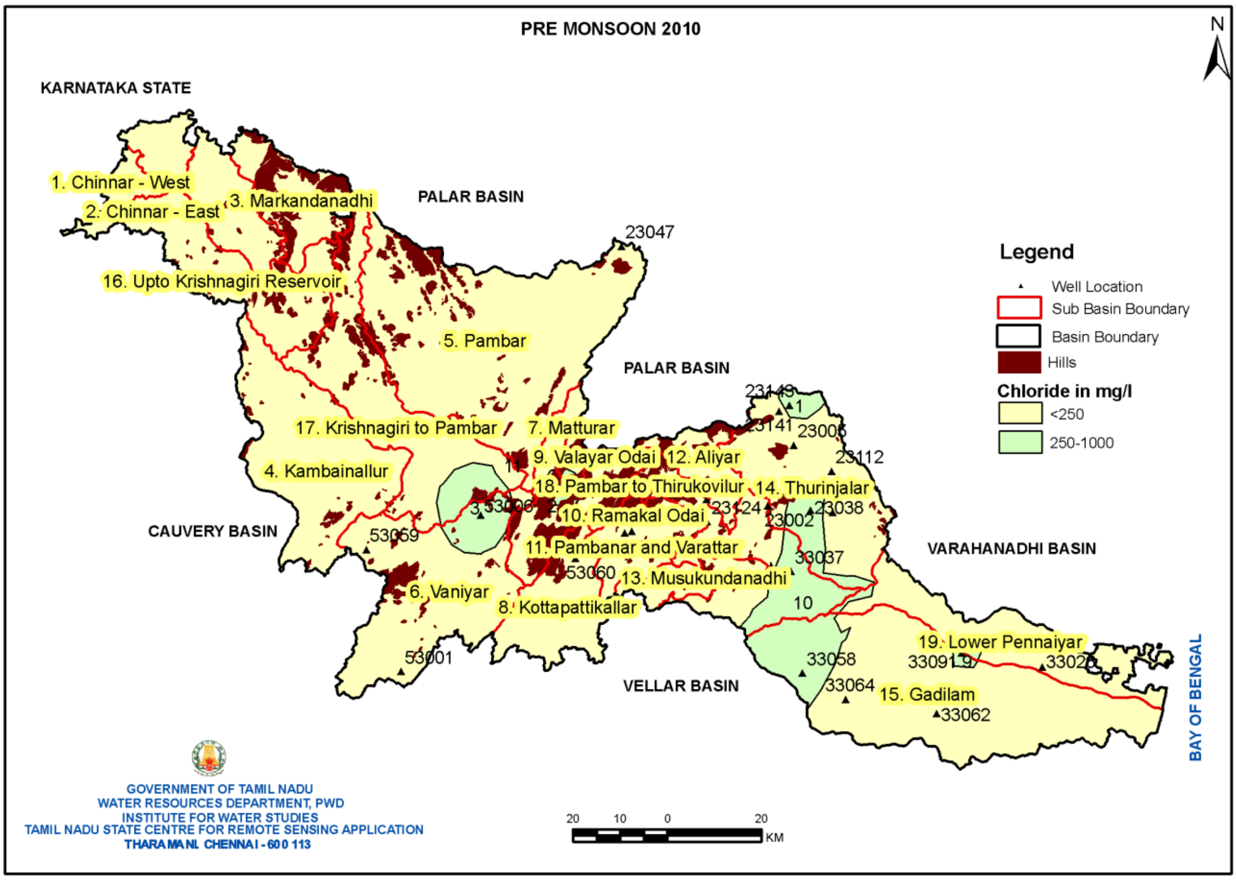


Plate:PEN - 46

PENNAIYAR RIVER BASIN - WATER QUALITY MAP

CHLORIDE



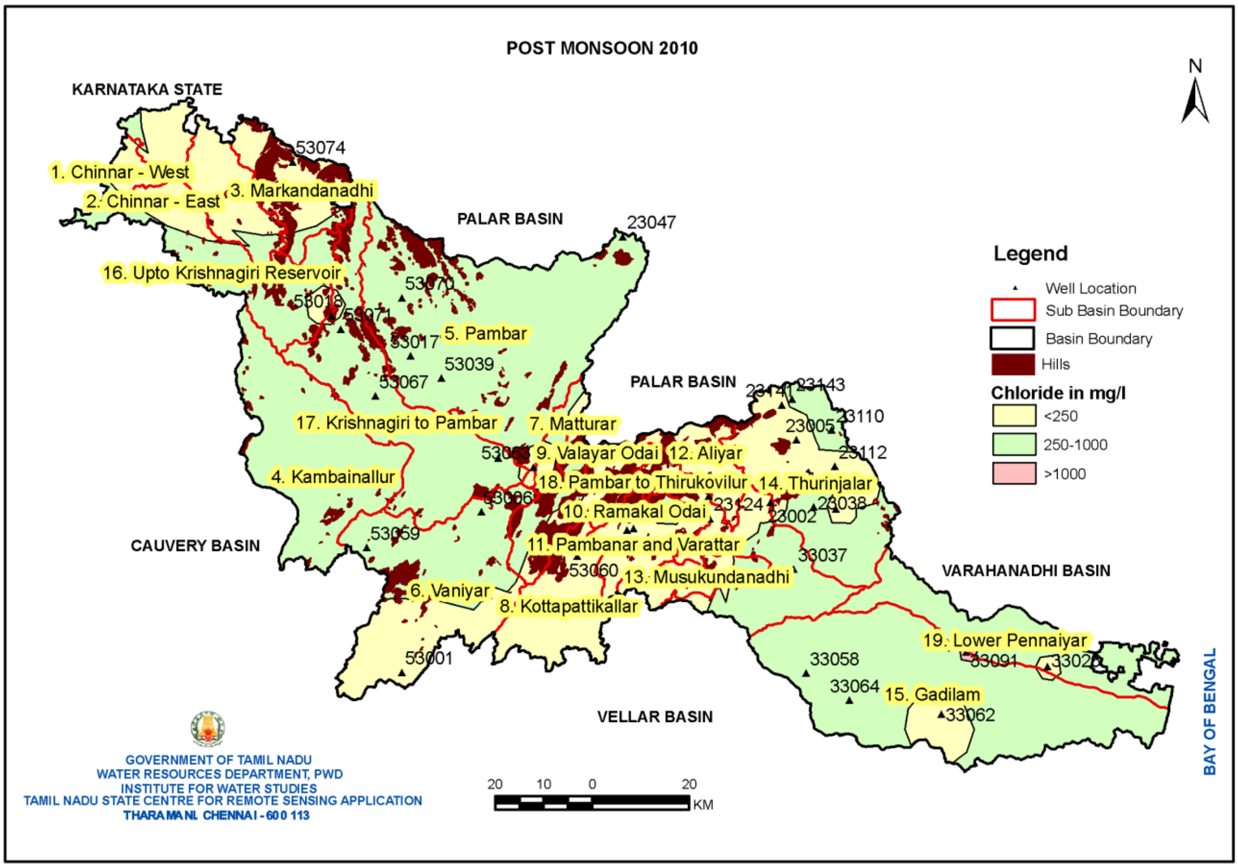
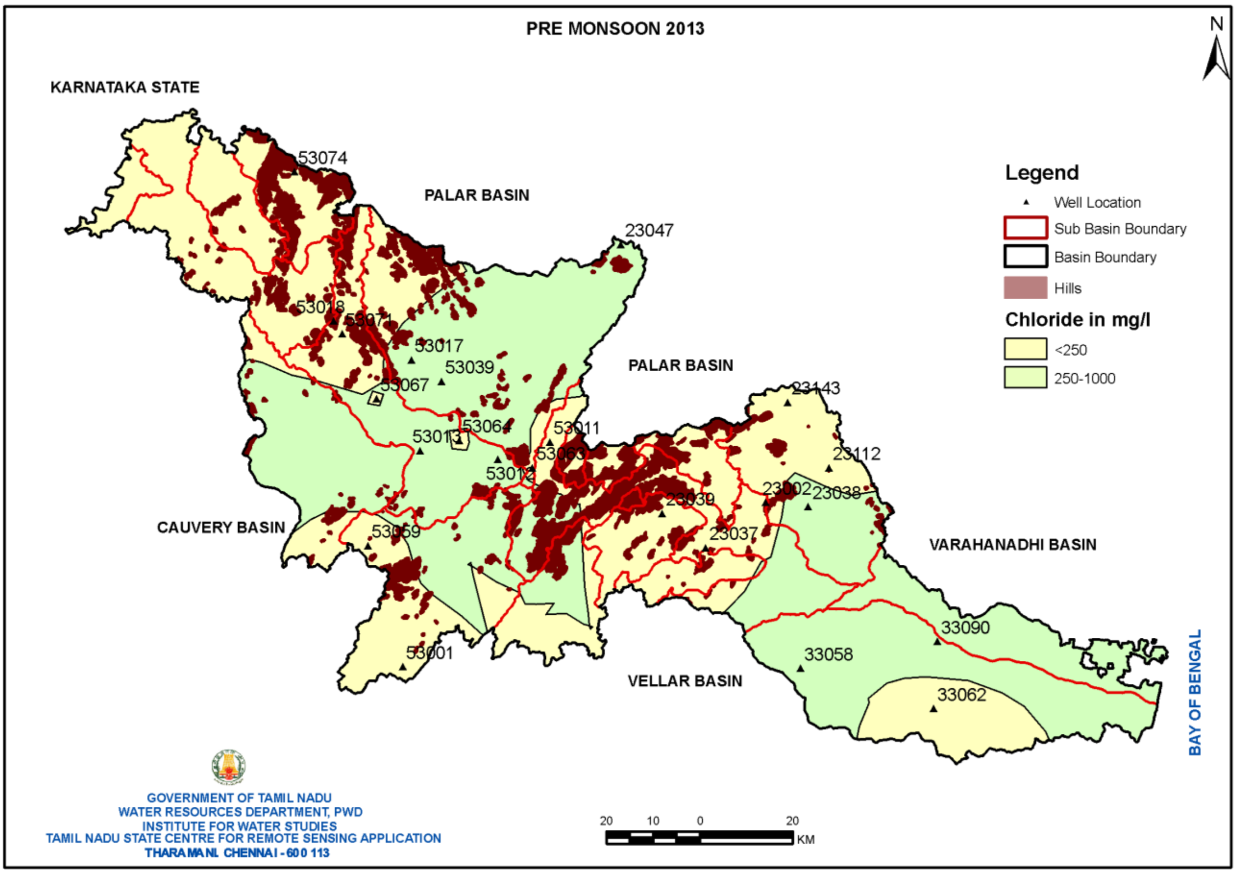
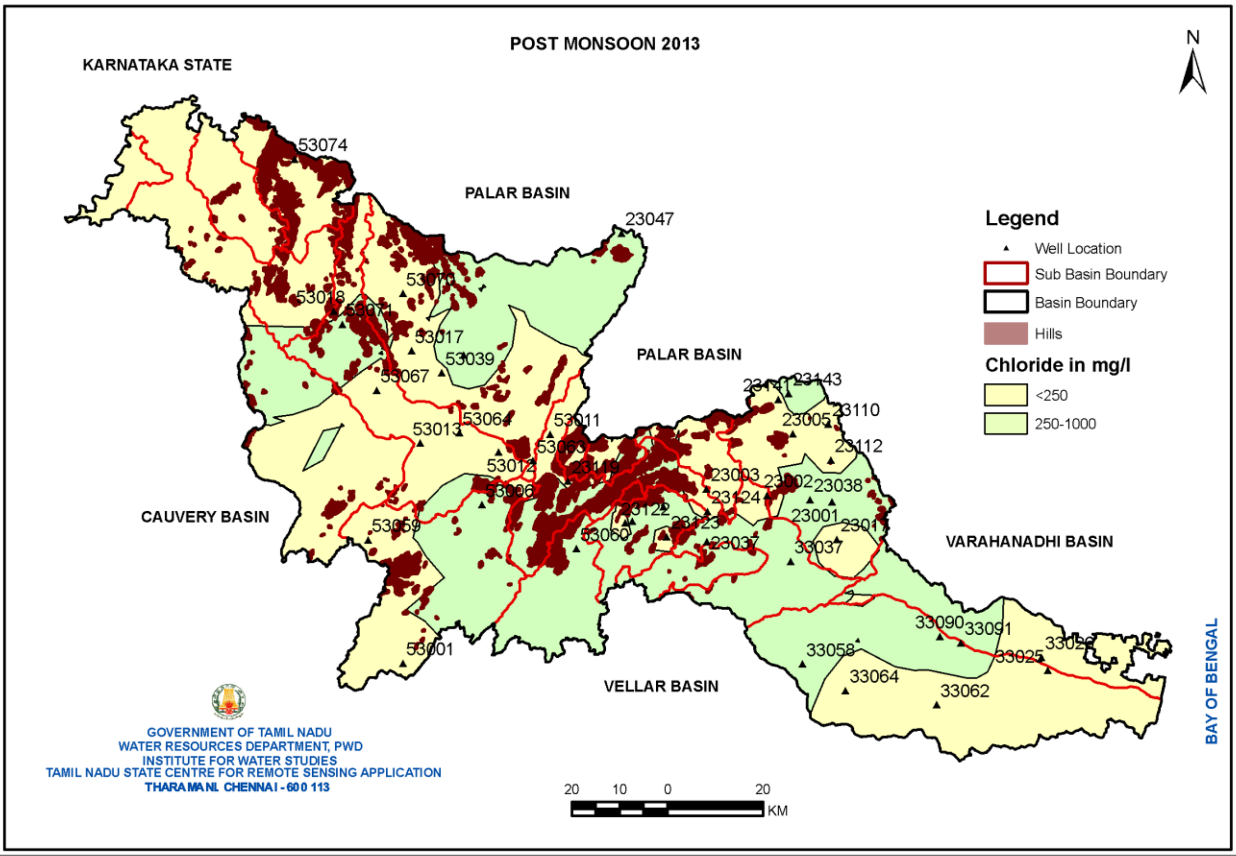


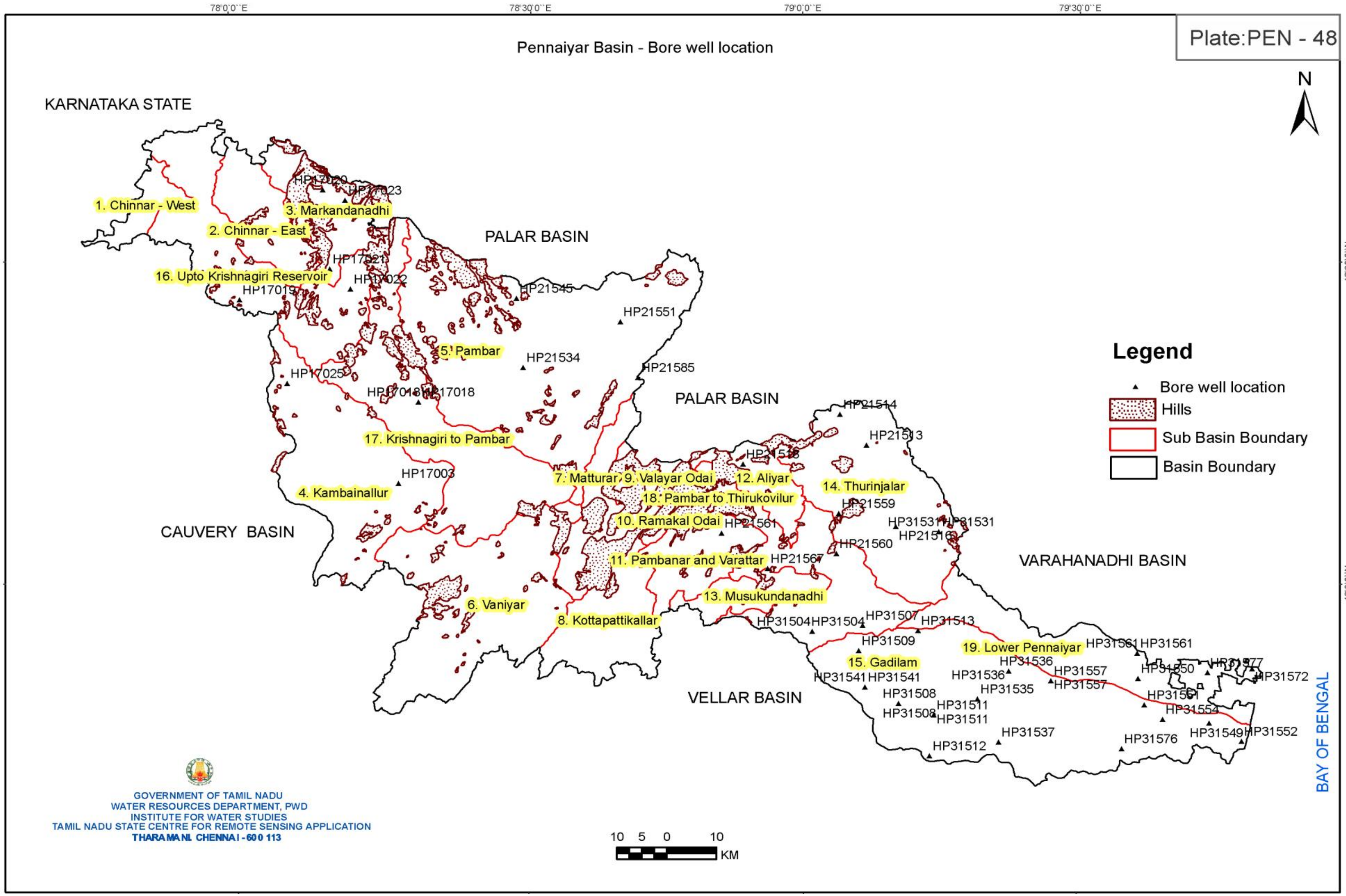
Plate:PEN - 47

PENNAIYAR RIVER BASIN - WATER QUALITY MAP

CHLORIDE






Pennaiyar Basin - Bore well location
Plate:PEN - 48
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
1. Chinnar - West
2. Chinnar - East
3. Markandanadhi
4. Kambainallur
5. Pambar
6. Vaniyar
7. Matturar
8. Kottapattikallar
9. Valayar Odai
10. Ramakal Odai
11. Pambanar and Varattar
12. Aliyar
13. Musukundanadhi
14. Thurinjalar
15. Gadilam
16. Upto Krishnagiri Reservoir
17. Krishnagiri to Pambar
18. Pambar to Thirukovilur
19. Lower Pennaiyar
Legend
Bore well location
Hills
Sub Basin Boundary
Basin Boundary
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113
10 5 0 10
KM

CHAPTER - 7

PRESENT AND

FUTURE WATER DEMAND

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**, where water is taken from a surface or ground water source, and after use returned to a natural water body, e.g., water used for cooling in industrial processes that is returned 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** that starts with a withdrawal or an abstraction but in this case without any return flow. Water consumption is the water abstracted that is no longer available for use 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 water that is no longer available directly for subsequent uses.
- **Non-Consumptive water use** i.e., 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 sectors 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 Pennaiyar 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 Pennaiyar River Basin is also 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 this 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 allocated in the same way as water occurring in rivers and 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 demand at a 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 others to use the water afterwards (eg. recreational water uses). However, some non-consumptive uses alter when this water becomes available for other users. A typical example is water used for the generation of hydropower: electricity is needed also during the wet season, and thus water has to be released from dams for 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 can be maintained periodically and rectified.
- Improve the supply system and storage structures by properly removing the accumulated silt, weeds and plastic wastes.
- Constructing diversion structures across rivers / streams for diverting and storing flood water.
- Artificial recharge through construction of check dams, anicuts and erection of recharge shafts.
- Construction of rain water harvesting structures for augmenting the run off 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 for domestic and industrial purposes.

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 Central Public Health and Environmental Engineering Organization (CPHEEO) recommended the norms for per capita water demand is given in **Table 7.1** as follows:-

Table 7.1: Recommended Norms for Per Capita Water Supply 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 Pennaiyar River Basin as per census 2011 given in Chapter 2 of this report is used for calculating the domestic water requirement in Pennaiyar River Basin.

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 norms 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 Formula Method

The exponential growth formula is

$$P_t = P_o (1+X)^t$$

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 Pennaiyar River Basin arrived in Chapter 2 sub basin wise is projected for the present year 2015 and the target years 2020, 2023, 2030 & 2040. The sub-basin wise population projection for the Pennaiyar river basin for the present year 2015 and the target years 2020, 2023, 2030 & 2040 are arrived as **5.594 million, 6.018 million, 6.288 million, 6.969 million & 8.078 million** respectively and is given in **Table No. 7.2.**

Accordingly, the domestic water demand for the present year 2015 and the target years 2020, 2023, 2030 & 2040 are obtained as **200.555 Mcum, 216.808 Mcum, 227.217 Mucm, 253.589 Mcum & 296.950 Mcum** respectively and are given in **Table No.7.3.**

Table 7.2 Sub basin wise Projected Population for Pennaiyar River Basin

Population in Million

Sl.No.	Name of the Sub Basin	Population in 2011		Population during 2015			Population during 2020			Population during 2023			Population during 2030			Population during 2040		
		Rural	Urban	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
1	Chinnar West	0.089	0	0.094	0.000	0.094	0.100	0.000	0.100	0.104	0.000	0.104	0.114	0.000	0.114	0.129	0.000	0.129
2	Chinnar East	0.049	0.219	0.052	0.237	0.289	0.055	0.262	0.317	0.057	0.278	0.335	0.063	0.319	0.382	0.071	0.389	0.460
3	Markandaya nadhi	0.101	0	0.106	0.000	0.106	0.113	0.000	0.113	0.118	0.000	0.118	0.129	0.000	0.129	0.147	0.000	0.147
4	Kambai nallur	0.366	0.086	0.385	0.093	0.478	0.411	0.103	0.514	0.427	0.109	0.536	0.468	0.125	0.593	0.532	0.153	0.685
5	Pambar	0.611	0.132	0.643	0.143	0.786	0.686	0.158	0.844	0.713	0.167	0.881	0.781	0.192	0.973	0.889	0.234	1.123
6	Vaniyar	0.247	0.046	0.260	0.050	0.310	0.277	0.055	0.332	0.288	0.058	0.347	0.316	0.067	0.383	0.359	0.082	0.441
7	Matturar	0.016	0	0.017	0.000	0.017	0.018	0.000	0.018	0.019	0.000	0.019	0.020	0.000	0.020	0.023	0.000	0.023
8	Kottapatti kallar	0.039	0	0.041	0.000	0.041	0.044	0.000	0.044	0.046	0.000	0.046	0.050	0.000	0.050	0.057	0.000	0.057
9	Valayar odai	0.021	0	0.022	0.000	0.022	0.024	0.000	0.024	0.025	0.000	0.025	0.027	0.000	0.027	0.031	0.000	0.031
10	Ramakal odai	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Pambanar and Varattar	0.069	0	0.073	0.000	0.073	0.078	0.000	0.078	0.081	0.000	0.081	0.088	0.000	0.088	0.100	0.000	0.100

Sl. No.	Name of the Sub Basin	Population in 2011		Population during 2015			Population during 2020			Population during 2023			Population during 2030			Population during 2040		
		Rural	Urban	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
12	Aliyar	0.063	0	0.066	0.000	0.066	0.071	0.000	0.071	0.074	0.000	0.074	0.081	0.000	0.081	0.092	0.000	0.092
13	Musukunda nadhi	0.058	0	0.061	0.000	0.061	0.065	0.000	0.065	0.068	0.000	0.068	0.074	0.000	0.074	0.084	0.000	0.084
14	Thurinjalar	0.347	0.181	0.365	0.196	0.561	0.390	0.216	0.606	0.405	0.230	0.635	0.444	0.264	0.707	0.505	0.321	0.826
15	Gadilam	0.768	0.334	0.809	0.362	1.170	0.863	0.399	1.262	0.897	0.424	1.320	0.982	0.487	1.468	1.117	0.593	1.710
16	Upto krishnagiri Reservoir	0.233	0.021	0.245	0.023	0.268	0.262	0.025	0.287	0.272	0.027	0.299	0.298	0.031	0.328	0.339	0.037	0.376
17	Krishnagiri to Pambar	0.301	0.164	0.317	0.178	0.494	0.338	0.196	0.534	0.351	0.208	0.559	0.385	0.239	0.624	0.438	0.291	0.729
18	Pambar to Thirukovilur	0.3	0.013	0.316	0.014	0.330	0.337	0.016	0.353	0.350	0.016	0.367	0.383	0.019	0.402	0.436	0.023	0.459
19	Lower pennaiyar	0.343	0.06	0.361	0.065	0.426	0.385	0.072	0.457	0.401	0.076	0.477	0.438	0.087	0.526	0.499	0.107	0.605
Total		**4.021**	**1.256**	**4.234**	**1.360**	**5.594**	**4.517**	**1.501**	**6.018**	**4.695**	**1.593**	**6.288**	**5.139**	**1.830**	**6.969**	**5.848**	**2.230**	**8.078**

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

Water Demand in Mcum

Sl. No	Name of the Sub Basin	Water Demand 2015			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	Chinnar West	2.737	0.000	**2.737**	2.919	0.000	**2.919**	3.034	0.000	**3.034**	3.322	0.000	**3.322**	3.780	0.000	**3.780**
2	Chinnar East	1.507	13.411	**14.918**	1.607	14.807	**16.414**	1.671	15.713	**17.384**	1.829	18.050	**19.879**	2.081	22.003	**24.083**
3	Markanda nadhi	3.106	0.000	**3.106**	3.313	0.000	**3.313**	3.444	0.000	**3.444**	3.769	0.000	**3.769**	4.289	0.000	**4.289**
4	Kambai nallur	11.254	5.267	**16.520**	12.005	5.815	**17.819**	12.479	6.171	**18.649**	13.660	7.088	**20.748**	15.543	8.640	**24.183**
5	Pambar	18.787	8.083	**26.871**	20.041	8.925	**28.965**	20.832	9.471	**30.303**	22.804	10.879	**33.683**	25.948	13.262	**39.209**
6	Vaniyar	7.595	2.817	**10.412**	8.101	3.110	**11.212**	8.422	3.301	**11.722**	9.218	3.791	**13.010**	10.489	4.622	**15.111**
7	Matturar	0.492	0.000	**0.492**	0.525	0.000	**0.525**	0.546	0.000	**0.546**	0.597	0.000	**0.597**	0.679	0.000	**0.679**
8	Kottapatti kallar	1.199	0.000	**1.199**	1.279	0.000	**1.279**	1.330	0.000	**1.330**	1.456	0.000	**1.456**	1.656	0.000	**1.656**
9	Valayar odai	0.646	0.000	**0.646**	0.689	0.000	**0.689**	0.716	0.000	**0.716**	0.784	0.000	**0.784**	0.892	0.000	**0.892**
10	Ramakal odai	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**
11	Pambanar and Varattar	2.122	0.000	**2.122**	2.263	0.000	**2.263**	2.353	0.000	**2.353**	2.575	0.000	**2.575**	2.930	0.000	**2.930**
12	Aliyar	1.937	0.000	**1.937**	2.066	0.000	**2.066**	2.148	0.000	**2.148**	2.351	0.000	**2.351**	2.675	0.000	**2.675**

Sl. No	Name of the Sub Basin	Water Demand 2015			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
13	Musukunda nadhi	1.783	0.000	**1.783**	1.902	0.000	**1.902**	1.978	0.000	**1.978**	2.165	0.000	**2.165**	2.463	0.000	**2.463**
14	Thurinjalar	10.670	11.084	**21.754**	11.381	12.238	**23.619**	11.831	12.987	**24.818**	12.951	14.918	**27.869**	14.736	18.185	**32.921**
15	Gadilam	23.615	20.454	**44.068**	25.190	22.583	**47.773**	26.185	23.965	**50.150**	28.663	27.528	**56.191**	32.615	33.556	**66.171**
16	Upto Krishnagiri Reservoir	7.164	1.286	**8.450**	7.642	1.420	**9.062**	7.944	1.507	**9.451**	8.696	1.731	**10.427**	9.895	2.110	**12.005**
17	Krishnagiri to Pambar	9.255	10.043	**19.298**	9.873	11.088	**20.961**	10.263	11.767	**22.030**	11.234	13.517	**24.751**	12.783	16.477	**29.260**
18	Pambar to Thirukovilur	9.224	0.796	**10.021**	9.840	0.879	**10.719**	10.229	0.933	**11.161**	11.197	1.071	**12.268**	12.740	1.306	**14.046**
19	Lower Pennaiyar	10.547	3.674	**14.221**	11.250	4.057	**15.307**	11.695	4.305	**16.000**	12.801	4.945	**17.747**	14.566	6.028	**20.594**
Total		**123.639**	**76.916**	**200.555**	**131.887**	**84.921**	**216.808**	**137.098**	**90.119**	**227.217**	**150.071**	**103.518**	**253.589**	**170.762**	**126.188**	**296.95**

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 – 12th 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.

Existing Cropping pattern in Pennaiyar Basin

The major crops cultivated in Pennaiyar Basin are Paddy, Maize, Ragi, Sugarcane, Ground nut, Coconut and Fruits & Vegetables.. The irrigated area for the year 2013-14 in Pennaiyar Basin under different crops is 318854.97 ha with paddy the main crop of the basin cultivated in 124276.01ha. In the remaining area, other crops are cultivated. Sub basin wise irrigated area of crops in Pennaiyar river basin.

The forecast for normal rainfall is +19 to -19, moderate is –19 to –59 and below -59 indicates severe drought. These figures are the deviation from average rainfall. The distribution of rain also plays a vital role in crop productivity. Existing cropping pattern during normal rain year and suggested cropping pattern for drought rain year for the Districts covered in this basin.

Table - 7.4

Irrigation Water Demand (Mcum)At 75 % Rainfall Dependability Pennaiyar River Basin

Sl. No.	Sub Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Chinnar - West	0.17	0.20	0.30	0.07	0.09	1.04	0.71	1.05	1.21	1.38	0.38	0.54	**7.14**
2	Chinnar - East	0.53	0.58	0.97	0.49	0.17	1.90	1.90	3.18	2.53	3.20	0.39	0.82	**16.63**
3	Markandanadhi	0.61	0.13	1.22	0.51	0.45	1.53	0.96	4.60	2.35	1.65	0.85	0.99	**15.85**
4	Kambainallur	3.63	0.06	6.36	2.75	3.56	7.68	4.78	30.99	5.97	12.90	2.61	3.39	**84.67**
5	Pambar	12.02	10.09	19.36	12.92	6.70	17.34	21.70	35.85	8.80	12.51	3.41	18.04	**178.76**
6	Vaniyar	2.26	2.18	2.64	2.90	2.64	4.97	0.45	23.61	4.65	9.84	3.15	1.48	**60.77**
7	Matturar	0.53	0.12	0.22	0.17	0.14	0.47	0.81	1.06	0.74	1.74	0.29	0.65	**6.94**
8	Kottapattikallar	1.04	0.79	1.17	1.53	0.41	3.16	0.05	12.80	2.24	4.63	3.09	2.54	**33.43**
9	Valayar Odai	0.97	0.11	0.20	0.39	0.76	0.63	1.06	3.82	1.14	1.24	0.60	1.59	**12.51**
10	Ramakal Odai	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**
11	Pambanar and Varattar	2.52	0.33	0.66	1.50	2.07	1.88	4.57	5.07	1.84	3.64	1.61	6.18	**31.88**
12	Aliyar	2.40	0.25	0.53	1.68	2.23	1.66	3.93	11.42	1.96	3.29	1.44	2.70	**33.48**
13	Musukundanadhi	0.38	0.17	0.31	1.54	2.68	2.26	6.04	6.37	2.12	4.29	0.92	5.40	**32.48**
14	Thurinjalar	8.75	0.80	1.40	7.34	14.28	17.90	19.33	37.55	10.55	22.23	7.52	29.62	**177.28**
15	Gadilam	16.24	1.14	2.07	13.27	20.68	29.29	1.53	30.96	43.97	105.91	30.88	29.83	**325.78**
16	Upto Krishnagiri Reservoir	1.71	1.56	3.10	1.18	0.45	5.14	4.98	19.17	10.27	9.10	1.80	5.05	**63.50**
17	Krishnagiri to Pambar	7.50	8.96	13.31	9.11	0.47	5.34	12.43	48.26	19.12	21.31	8.35	11.74	**165.91**
18	Pambar to Thirukovilur	4.09	1.63	2.53	9.48	0.88	9.49	1.47	59.95	10.65	20.58	9.14	32.32	**162.22**
19	Lower Pennaiyar	2.65	0.63	1.11	6.15	13.73	13.72	0.04	41.08	12.51	26.53	5.51	28.25	**151.91**
	Total	**67.99**	**29.74**	**57.47**	**72.98**	**72.40**	**125.38**	**86.74**	**376.81**	**142.57**	**265.97**	**81.94**	**181.13**	**1561.15**

Table - 7.5

IRRIGATION WATER DEMAND (Mcum) AT 75 % RAINFALL DEPENDABILITY IN PENNAIYAR RIVER BASIN (SEASON WISE)

Sl. No.	Sub Basin	Winter	Summer	South west	North east	Total
1	Chinnar - West	0.37	0.45	4.02	2.30	**7.14**
2	Chinnar - East	1.11	1.62	9.51	4.40	**16.63**
3	Markandanadhi	0.74	2.18	9.44	3.49	**15.85**
4	Kambainallur	3.69	12.67	49.41	18.90	**84.67**
5	Pambar	22.12	38.98	83.69	33.97	**178.76**
6	Vaniyar	4.43	8.18	33.68	14.48	**60.77**
7	Matturar	0.65	0.54	3.08	2.68	**6.94**
8	Kottapattikallar	1.82	3.11	18.24	10.25	**33.43**
9	Valayar Odai	1.08	1.35	6.65	3.43	**12.51**
10	Ramakal Odai	0.00	0.00	0.00	0.00	**0.00**
11	Pambanar and Varattar	2.86	4.24	13.36	11.43	**31.88**
12	Aliyar	2.65	4.43	18.97	7.42	**33.48**
13	Musukundanadhi	0.56	4.53	16.79	10.60	**32.48**
14	Thurinjalar	9.54	23.03	85.33	59.38	**177.28**
15	Gadilam	17.38	36.02	105.75	166.62	**325.78**
16	Upto Krishnagiri Reservoir	3.27	4.73	39.55	15.95	**63.50**
17	Krishnagiri to Pambar	16.46	22.89	85.15	41.41	**165.91**
18	Pambar to Thirukovilur	5.73	12.89	81.55	62.05	**162.22**
19	Lower Pennaiyar	3.28	20.99	67.35	60.29	**151.91**
	Total	**97.74**	**202.86**	**731.50**	**529.05**	**1561.15**

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, Dharmapuri, Krishnagiri, Salem, Thiruvannamali, Vellore and Villupuram districts along with their water requirement is collected from the Department of Industries and Commerce. From that, small, medium and large scale industries falling in Pennaiyar River Basin are listed out. At present in the Pennaiyar River Basin there are 190 numbers of large and medium industries and 1738 numbers of small scale industries. Accordingly, the yearly requirement of water for Large & Medium and small scale industries at present is estimated as **214.985Mcum.** The sub basin wise water requirement of Industries is given in **Table 7.8.(c).**

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 been adopted.

While comparing the previous reappraisal study of Pennaiyar River Basin carried out during 2004, it is learnt that the number of small scale industries (SSI) in the Pennaiyar River Basin found to have decreased at present. Hence the estimated value of Industrial Water Demand in Pennaiyar River Basin for the present year for the small scale industries **of 1.967 Mcum** may be taken for the target years 2020, 2023, 2030 and 2040 also and is given in **Table 7.6 (a).**

The number of large & medium scale industries has also found to be decreased. 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 demand for the years 2015, 2020,2023,2030& 2040 of large & medium scale industries is estimated as **214.985Mcum , 300.979Mcum, 373.214Mcum, 462.785Mcum and 573.853Mcum** respectively and is given in **Table 7.6 (b).**

The total Industrial water demand of Pennaiyar River Basin for the years 2015, 2020, 2023,2030 & 2040 is estimated as**, 216.950Mcum, 303.731Mcum, 376.626Mcum, 468.108Mcm & 583.435Mcum r**espectively and is given in **Table 7.7.**

Table 7.6 (a) Water Demand of Small Scale Industries in Pennaiyar River Basin											
Sl. No.	**Name of the Sub Basin**	**2015**		**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	Chinnar West	33	0.031	47	0.043	58	0.053	91	0.083	163	0.149
2	Chinnar East	82	0.075	115	0.105	142	0.130	222	0.202	399	0.364
3	Markandanadhi	98	0.089	137	0.125	170	0.155	265	0.242	478	0.436
4	Kambainallur	78	0.071	109	0.100	136	0.124	212	0.193	381	0.347
5	Pambar	658	0.601	922	0.841	1143	1.043	1783	1.627	3210	2.929
6	Vaniyar	138	0.126	193	0.176	239	0.218	373	0.340	671	0.612
7	Matturar	10	0.009	14	0.013	17	0.016	27	0.025	48	0.044
8	Kottapattikallar	40	0.036	56	0.051	69	0.063	107	0.098	193	0.177
9	Valayar odai	6	0.006	9	0.008	11	0.010	17	0.015	30	0.028
10	Ramakal odai	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
11	Pambanar and Varattar	24	0.021	33	0.030	41	0.037	64	0.058	115	0.105
12	Aliyar	15	0.014	21	0.019	26	0.024	40	0.037	73	0.066
13	Musukundanadhi	27	0.025	38	0.035	47	0.043	74	0.067	133	0.121
14	Thurinjalar	71	0.064	99	0.090	123	0.112	191	0.175	345	0.314
15	Gadilam	250	0.229	351	0.320	435	0.397	678	0.619	1221	1.114
16	Upto Krishnagiri Reservoir	203	0.186	285	0.260	353	0.322	551	0.503	991	0.905
17	Krishnagiri to Pambar	200	0.182	279	0.255	347	0.316	541	0.493	973	0.888
18	Pambar to Thirukovilur	131	0.120	184	0.168	228	0.208	356	0.325	641	0.585
19	Lower Pennaiyar	89	0.081	125	0.114	155	0.141	242	0.221	435	0.397
Total		**2154**	**1.965**	**3015**	**2.752**	**3739**	**3.412**	**5833**	**5.323**	**10499**	**9.581**

Table 7.6 (b) Water Demand of Large & Medium Scale Industries in Pennaiyar River Basin											
Sl. No	Name of the Sub Basin	2015		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	Chinnar - West	5	4.526	7	6.336	9	7.857	11	9.743	13	12.081
2	Chinnar - East	15	13.578	21	19.009	26	23.571	32	29.229	40	36.243
3	Markandanadhi	16	14.710	23	20.593	28	25.536	35	31.664	43	39.264
4	Kambainallur	5	4.526	7	6.336	9	7.857	11	9.743	13	12.081
5	Pambar	66	59.970	92	83.957	114	104.107	141	129.093	175	160.075
6	Vaniyar	9	7.921	12	11.089	15	13.750	19	17.050	23	21.142
7	Matturar	1	1.132	2	1.584	2	1.964	3	2.436	3	3.020
8	Kottapattikallar	2	2.263	3	3.168	4	3.929	5	4.871	7	6.041
9	Valayar Odai	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
10	Ramakal Odai	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
11	Pambanar and Varattar	1	1.132	2	1.584	2	1.964	3	2.436	3	3.020
12	Aliyar	1	1.132	2	1.584	2	1.964	3	2.436	3	3.020
13	Musukundanadhi	1	1.132	2	1.584	2	1.964	3	2.436	3	3.020
14	Thurinjalar	5	4.526	7	6.336	9	7.857	11	9.743	13	12.081
15	Gadilam	24	21.499	33	30.098	41	37.321	51	46.279	63	57.385
16	Upto Krishnagiri Reservoir	35	31.682	49	44.355	60	55.000	75	68.200	93	84.568
17	Krishnagiri to Pambar	32	29.419	45	41.187	56	51.071	69	63.329	86	78.527
18	Pambar to Thirukovilur	10	9.052	14	12.673	17	15.714	21	19.486	26	24.162
19	Lower Pennaiyar	7	6.789	10	9.505	13	11.786	16	14.614	20	18.122
Total		**236**	**214.985**	**330**	**300.979**	**409**	**373.213**	**507**	**462.785**	**629**	**573.853**

Table 7.7 Total Industrial Water Demand in Pennaiyar River Basin																
Sl. No	**Name of the Sub Basin**	**2015**			**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	Chinnar - West	4.526	0.031	**4.557**	6.336	0.043	**6.379**	7.857	0.053	**7.910**	9.743	0.083	**9.826**	12.081	0.149	**12.230**
2	Chinnar - East	13.578	0.075	**13.653**	19.009	0.105	**19.114**	23.571	0.130	**23.701**	29.229	0.202	**29.431**	36.243	0.364	**36.607**
3	Markandanadhi	14.710	0.089	**14.799**	20.593	0.125	**20.718**	25.536	0.155	**25.691**	31.664	0.242	**31.906**	39.264	0.436	**39.699**
4	Kambainallur	4.526	0.071	**4.597**	6.336	0.100	**6.436**	7.857	0.124	**7.981**	9.743	0.193	**9.936**	12.081	0.347	**12.429**
5	Pambar	59.970	0.601	**60.570**	83.957	0.841	**84.798**	104.107	1.043	**105.150**	129.093	1.627	**130.720**	160.075	2.929	**163.004**
6	Vaniyar	7.921	0.126	**8.046**	11.089	0.176	**11.265**	13.750	0.218	**13.968**	17.050	0.340	**17.390**	21.142	0.612	**21.754**
7	Matturar	1.132	0.009	**1.141**	1.584	0.013	**1.597**	1.964	0.016	**1.980**	2.436	0.025	**2.460**	3.020	0.044	**3.064**
8	Kottapattikallar	2.263	0.036	**2.299**	3.168	0.051	**3.219**	3.929	0.063	**3.991**	4.871	0.098	**4.969**	6.041	0.177	**6.217**
9	Valayar Odai	0.000	0.006	**0.006**	0.000	0.008	**0.008**	0.000	0.010	**0.010**	0.000	0.015	**0.015**	0.000	0.028	**0.028**
10	Ramakal Odai	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**	0.000	0.000	**0.000**
11	Pambanar and Varattar	1.132	0.021	**1.153**	1.584	0.030	**1.614**	1.964	0.037	**2.002**	2.436	0.058	**2.494**	3.020	0.105	**3.125**
12	Aliyar	1.132	0.014	**1.145**	1.584	0.019	**1.603**	1.964	0.024	**1.988**	2.436	0.037	**2.472**	3.020	0.066	**3.086**
13	Musukundanadhi	1.132	0.025	**1.156**	1.584	0.035	**1.619**	1.964	0.043	**2.007**	2.436	0.067	**2.503**	3.020	0.121	**3.142**
14	Thurinjalar	4.526	0.064	**4.590**	6.336	0.090	**6.427**	7.857	0.112	**7.969**	9.743	0.175	**9.918**	12.081	0.314	**12.396**
15	Gadilam	21.499	0.229	**21.727**	30.098	0.320	**30.418**	37.321	0.397	**37.718**	46.279	0.619	**46.898**	57.385	1.114	**58.500**
16	Upto Krishnagiri Reservoir	31.682	0.186	**31.868**	44.355	0.260	**44.615**	55.000	0.322	**55.322**	68.200	0.503	**68.702**	84.568	0.905	**85.473**
17	Krishnagiri to Pambar	29.419	0.182	**29.601**	41.187	0.255	**41.442**	51.071	0.316	**51.388**	63.329	0.493	**63.822**	78.527	0.888	**79.415**
18	Pambar to Thirukovilur	9.052	0.120	**9.172**	12.673	0.168	**12.841**	15.714	0.208	**15.922**	19.486	0.325	**19.811**	24.162	0.585	**24.747**
19	Lower Pennaiyar	6.789	0.081	**6.870**	9.505	0.114	**9.619**	11.786	0.141	**11.927**	14.614	0.221	**14.835**	18.122	0.397	**18.519**
Total		**214.985**	**1.965**	**216.950**	**300.979**	**2.752**	**303.731**	**373.214**	**3.412**	**376.626**	**462.785**	**5.323**	**468.108**	**573.854**	**9.581**	**583.435**

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 Pennaiyar 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,

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

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 15^{th}, 16^{th}, 17^{th}, 18^{th} and 19^{th} census of livestock conducted by the Department of Animal Husbandry, Tamil Nadu during 1989-94, 1994-97, 1997-2004 , 2004-2007, 2007 -2012 is 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 calculated in **Appendix 7.4** and given 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 can be projected with respect to the 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 and projected for the present year 2015 and for the target years 2020, 2023, 2030 & 2040 and is presented in **Table No. 7.10.** The livestock water demand during 2015, 2020, 2023, 2030 & 2040 is worked out as 49.512Mcum, 50.413Mcum, 51.119Mcum, 53.368Mcum & 58.781Mcum respectively and presented in **Table 7.11.**

Table 7.10 Sub Basin wise Projected Livestock Population in Pennaiyar River Basin

Sl. No	Year	Livestock	Livestock Population									
			Chinnar West	Chinnar East	Markanda nadhi	Kambai nallur	Pambar	Vaniyar	Matturar	Kottapatti kallar	Valayar odai	Ramakal odai
1	2012	Cattle	7885	19377	23168	62707	130839	74823	5437	30478	9334	0
		Buffallo	264	648	775	9853	4233	11638	140	4187	214	0
		Sheep	5617	13804	16504	27120	79084	35190	2513	12683	3561	0
		Goat	3083	7576	9058	38022	59139	49221	1948	18540	3121	0
		Pigs	54	133	159	385	3029	1031	83	300	146	0
		Poultry	109652	269457	322175	775266	1397511	1051581	21955	338866	6287	0
Total			**126555**	**310995**	**371839**	**913353**	**1673835**	**1223484**	**32076**	**405054**	**22663**	**0**
2	2015	Cattle	7966	19575	23405	63349	132178	75589	5493	30790	9430	0
		Buffallo	232	570	682	8666	3723	10236	123	3682	188	0
		Sheep	5641	13862	16573	27234	79417	35338	2524	12736	3576	0
		Goat	3235	7950	9505	39900	62060	51652	2044	19456	3275	0
		Pigs	47	116	138	335	2634	897	72	261	127	0
		Poultry	140406	345032	412536	992705	1789471	1346518	28113	433908	8050	0
Total			**157527**	**387105**	**462839**	**1132188**	**2069483**	**1520229**	**38368**	**500833**	**24646**	**0**
3	2020	Cattle	8102	19910	23806	64433	134440	76883	5587	31317	9591	0
		Buffallo	187	460	550	6996	3006	8264	99	2973	152	0
		Sheep	5680	13959	16690	27425	79974	35586	2541	12826	3601	0
		Goat	3506	8615	10301	43238	67252	55974	2215	21084	3549	0
		Pigs	37	92	110	265	2087	710	57	207	101	0
		Poultry	212000	520965	622889	1498889	2701929	2033112	42447	655159	12155	0
Total			**229513**	**564001**	**674345**	**1641247**	**2988688**	**2210529**	**52947**	**723565**	**29149**	**0**

Sl. No	Year	Livestock	Livestock Population									
			Pamba-nar and Varattar	Aliyar	Musukund anadhi	Thurin jalar	Gadilam	Upto Krishna-giri Reservoir	Krishnagiri to Pambar	Pambar to Thirukovilur	Lower Pennaiyar	Total
1	2012	Cattle	31264	23072	20196	93712	165054	48696	57424	99367	59780	962613
		Buffallo	890	529	442	2136	4570	1757	3737	4153	1616	51782
		Sheep	11766	8801	6455	34913	45726	34399	36796	37564	16813	429309
		Goat	11518	7714	10849	34072	110849	19262	25614	46162	39358	495106
		Pigs	495	362	416	1536	4611	333	383	1689	1624	16769
		Poultry	43854	15540	58973	93450	499603	675560	775873	388482	181412	7025497
Total			**99787**	**56018**	**97331**	**259819**	**830413**	**780007**	**899827**	**577417**	**300603**	**8981076**
2	2015	Cattle	31584	23308	20403	94671	166743	49194	58012	100384	60392	972465
		Buffallo	783	465	389	1879	4019	1545	3287	3653	1421	45542
		Sheep	11815	8838	6482	35060	45918	34544	36951	37722	16884	431115
		Goat	12087	8095	11385	35755	116324	20213	26879	48442	41302	519560
		Pigs	430	315	362	1336	4010	290	333	1469	1412	14583
		Poultry	56154	19899	75513	119660	639727	865034	993482	497440	232293	8995940
Total			**112853**	**60920**	**114533**	**288360**	**976741**	**970821**	**1118944**	**689109**	**353704**	**10979204**
3	2020	Cattle	32125	23707	20752	96292	169597	50036	59005	102102	61425	989110
		Buffallo	632	376	314	1517	3245	1248	2653	2949	1147	36768
		Sheep	11898	8900	6528	35306	46241	34786	37210	37987	17002	434141
		Goat	13098	8772	12337	38746	126057	21905	29128	52495	44758	563030
		Pigs	341	249	287	1058	3177	229	264	1164	1119	11554
		Poultry	84787	30045	114018	180675	965926	1306119	1500062	751086	350739	13583001
Total			**142881**	**72049**	**154235**	**353594**	**1314242**	**1414323**	**1628322**	**947782**	**476191**	**15617603**

Sl. No	Year	Livestock	Livestock Population									
			Chinnar West	Chinnar East	Markanda nadhi	Kambai nallur	Pambar	Vaniyar	Matturar	Kottapatti kallar	Valayar odai	Ramakal odai
4	2023	Cattle	8185	20114	24049	65093	135816	77669	5644	31637	9689	0
		Buffallo	165	405	484	6153	2643	7268	87	2615	134	0
		Sheep	5704	14018	16760	27541	80310	35736	2552	12880	3616	0
		Goat	3679	9041	10809	45374	70574	58738	2325	22125	3724	0
		Pigs	32	80	95	231	1815	618	50	180	87	0
		Poultry	271459	667080	797591	1919282	3459739	2603340	54353	838912	15564	0
		Total	**289225**	**710737**	**849789**	**2063673**	**3750899**	**2783369**	**65010**	**908348**	**32815**	**0**
5	2030	Cattle	8382	20598	24628	66658	139082	79537	5780	32398	9922	0
		Buffallo	122	300	359	4560	1959	5386	65	1938	99	0
		Sheep	5760	14156	16925	27812	81101	36087	2577	13006	3652	0
		Goat	4117	10117	12096	50776	78977	65732	2601	24759	4168	0
		Pigs	23	58	69	167	1310	446	36	130	63	0
		Poultry	483319	1187699	1420067	3417179	6159880	4635107	96772	1493637	27712	0
		Total	**501723**	**1232928**	**1474143**	**3567151**	**6462308**	**4822295**	**107831**	**1565868**	**45615**	**0**
6	2040	Cattle	8671	21309	25478	68959	143884	82283	5979	33517	10265	0
		Buffallo	80	195	234	2972	1277	3511	42	1263	65	0
		Sheep	5841	14355	17163	28203	82243	36596	2613	13190	3703	0
		Goat	4835	11881	14205	59628	92745	77191	3055	29075	4895	0
		Pigs	15	36	43	105	822	280	23	81	40	0
		Poultry	1099846	2702744	3231523	7776177	14017501	10547708	220216	3398939	63061	0
		Total	**1119288**	**2750521**	**3288646**	**7936044**	**14338473**	**10747569**	**231928**	**3476065**	**82027**	**0**

Sl. No	Year	Livestock	Livestock Population									
			Pambanar and Varattar	**Aliyar**	**Musukund anadhi**	**Thurin jalar**	**Gadilam**	**Upto Krishnagiri Reservoir**	**Krishnagir i to Pambar**	**Pambar to Thirukovilur**	**Lower Pennaiyar**	**Total**
4	2023	Cattle	32453	23950	20964	97277	171333	50549	59609	103147	62054	999233
		Buffallo	556	330	276	1334	2854	1097	2334	2593	1009	32337
		Sheep	11948	8937	6555	35454	46435	34932	37367	38147	17074	435967
		Goat	13745	9206	12947	40660	132283	22986	30567	55088	46968	590839
		Pigs	297	217	249	920	2763	200	229	1012	973	10047
		Poultry	108567	38472	145996	231349	1236839	1672446	1920785	961743	449111	17392628
Total			**167566**	**81112**	**186988**	**406995**	**1592506**	**1782210**	**2050890**	**1161730**	**577190**	**19461051**
5	2030	Cattle	33234	24526	21468	99616	175453	51764	61042	105627	63546	1023259
		Buffallo	412	245	205	989	2115	813	1729	1922	748	23965
		Sheep	12066	9025	6620	35803	46892	35276	37734	38522	17242	440257
		Goat	15382	10302	14488	45501	148033	25723	34206	61647	52560	661186
		Pigs	214	157	180	664	1994	144	166	730	702	7252
		Poultry	193297	68496	259938	411904	2202125	2977700	3419855	1712332	799619	30966637
Total			**254605**	**112750**	**302899**	**594478**	**2576612**	**3091420**	**3554732**	**1920780**	**934417**	**33122556**
6	2040	Cattle	34381	25372	22210	103055	181510	53551	63149	109274	65740	1058587
		Buffallo	268	160	133	644	1379	530	1127	1253	487	15620
		Sheep	12236	9153	6713	36308	47553	35773	38266	39065	17485	446460
		Goat	18063	12098	17014	53434	173840	30208	40169	72394	61723	776454
		Pigs	134	98	113	417	1252	90	104	459	441	4552
		Poultry	439870	155871	591519	937335	5011185	6776092	7782265	3896604	1819623	70468078
Total			**504953**	**202752**	**637702**	**1131193**	**5416718**	**6896245**	**7925081**	**4119048**	**1965499**	**72769751**

Table 7.11 Sub Basin wise Livestock Water Demand in Pennaiyar River Basin

Sl. No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum										
				Chinnar West	Chinnar East	Markanda nadhi	Kambai nallur	Pambar	Vaniyar	Matturar	Kotta patti kallar	Valayar odai	Rama kalodai	Pambanar and Varattar
1	2012	Cattle	**110**	0.317	0.778	0.930	2.518	5.253	3.004	0.218	1.224	0.375	0.000	1.255
		Buffallo	**150**	0.014	0.035	0.042	0.539	0.232	0.637	0.008	0.229	0.012	0.000	0.049
		Sheep	**20**	0.041	0.101	0.120	0.198	0.577	0.257	0.018	0.093	0.026	0.000	0.086
		Goat	**20**	0.023	0.055	0.066	0.278	0.432	0.359	0.014	0.135	0.023	0.000	0.084
		Pigs	**40**	0.001	0.002	0.002	0.006	0.044	0.015	0.001	0.004	0.002	0.000	0.007
		Poultry	**0.25**	0.010	0.025	0.029	0.071	0.128	0.096	0.002	0.031	0.001	0.000	0.004
			Total	**0.405**	**0.996**	**1.191**	**3.609**	**6.666**	**4.369**	**0.262**	**1.716**	**0.438**	**0.000**	**1.485**
2	2015	Cattle	**110**	0.320	0.786	0.940	2.543	5.307	3.035	0.221	1.236	0.379	0.000	1.268
		Buffallo	**150**	0.013	0.031	0.037	0.474	0.204	0.560	0.007	0.202	0.010	0.000	0.043
		Sheep	**20**	0.041	0.101	0.121	0.199	0.580	0.258	0.018	0.093	0.026	0.000	0.086
		Goat	**20**	0.024	0.058	0.069	0.291	0.453	0.377	0.015	0.142	0.024	0.000	0.088
		Pigs	**40**	0.001	0.002	0.002	0.005	0.038	0.013	0.001	0.004	0.002	0.000	0.006
		Poultry	**0.25**	0.013	0.031	0.038	0.091	0.163	0.123	0.003	0.040	0.001	0.000	0.005
			Total	**0.411**	**1.010**	**1.207**	**3.603**	**6.745**	**4.366**	**0.264**	**1.716**	**0.442**	**0.000**	**1.497**
3	2020	Cattle	**110**	0.325	0.799	0.956	2.587	5.398	3.087	0.224	1.257	0.385	0.000	1.290
		Buffallo	**150**	0.010	0.025	0.030	0.383	0.165	0.452	0.005	0.163	0.008	0.000	0.035
		Sheep	**20**	0.041	0.102	0.122	0.200	0.584	0.260	0.019	0.094	0.026	0.000	0.087
		Goat	**20**	0.026	0.063	0.075	0.316	0.491	0.409	0.016	0.154	0.026	0.000	0.096
		Pigs	**40**	0.001	0.001	0.002	0.004	0.030	0.010	0.001	0.003	0.001	0.000	0.005
		Poultry	**0.25**	0.019	0.048	0.057	0.137	0.247	0.186	0.004	0.060	0.001	0.000	0.008
			Total	**0.423**	**1.038**	**1.241**	**3.627**	**6.914**	**4.404**	**0.269**	**1.730**	**0.448**	**0.000**	**1.520**

Sl. No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum								
				Aliyar	Musukun danadhi	Thurin-jalar	Gadilam	Upto Krishnagiri Resorvoir	Krishnagiri to Pambar	Pambar to Thirukovilur	Lower Pennaiyar	Total
1	2012	Cattle	**110**	0.926	0.811	3.763	6.627	1.955	2.306	3.990	2.400	38.649
		Buffallo	**150**	0.029	0.024	0.117	0.250	0.096	0.205	0.227	0.088	2.835
		Sheep	**20**	0.064	0.047	0.255	0.334	0.251	0.269	0.274	0.123	3.134
		Goat	**20**	0.056	0.079	0.249	0.809	0.141	0.187	0.337	0.287	3.614
		Pigs	**40**	0.005	0.006	0.022	0.067	0.005	0.006	0.025	0.024	0.245
		Poultry	**0.25**	0.001	0.005	0.009	0.046	0.062	0.071	0.035	0.017	0.641
			Total	**1.083**	**0.973**	**4.414**	**8.133**	**2.510**	**3.042**	**4.888**	**2.939**	**49.118**
2	2015	Cattle	**110**	0.936	0.819	3.801	6.695	1.975	2.329	4.030	2.425	39.044
		Buffallo	**150**	0.025	0.021	0.103	0.220	0.085	0.180	0.200	0.078	2.493
		Sheep	**20**	0.065	0.047	0.256	0.335	0.252	0.270	0.275	0.123	3.147
		Goat	**20**	0.059	0.083	0.261	0.849	0.148	0.196	0.354	0.302	3.793
		Pigs	**40**	0.005	0.005	0.020	0.059	0.004	0.005	0.021	0.021	0.213
		Poultry	**0.25**	0.002	0.007	0.011	0.058	0.079	0.091	0.045	0.021	0.821
			Total	**1.091**	**0.983**	**4.451**	**8.216**	**2.543**	**3.071**	**4.926**	**2.969**	**49.512**
3	2020	Cattle	**110**	0.952	0.833	3.866	6.809	2.009	2.369	4.099	2.466	39.713
		Buffallo	**150**	0.021	0.017	0.083	0.178	0.068	0.145	0.161	0.063	2.013
		Sheep	**20**	0.065	0.048	0.258	0.338	0.254	0.272	0.277	0.124	3.169
		Goat	**20**	0.064	0.090	0.283	0.920	0.160	0.213	0.383	0.327	4.110
		Pigs	**40**	0.004	0.004	0.015	0.046	0.003	0.004	0.017	0.016	0.169
		Poultry	**0.25**	0.003	0.010	0.016	0.088	0.119	0.137	0.069	0.032	1.239
			Total	**1.108**	**1.003**	**4.522**	**8.379**	**2.614**	**3.139**	**5.007**	**3.028**	**50.413**

Sl. No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum										
				Chinnar West	**Chinnar East**	**Markandanadhi**	**Kambai nallur**	**Pambar**	**Vaniyar**	**Matturar**	**Kottapatti kallar**	**Valayar odai**	**Ramakal odai**	**Pambanar and Varattar**
4	2023	Cattle	**110**	0.329	0.808	0.966	2.613	5.453	3.118	0.227	1.270	0.389	0.000	1.303
		Buffallo	**150**	0.009	0.022	0.026	0.337	0.145	0.398	0.005	0.143	0.007	0.000	0.030
		Sheep	**20**	0.042	0.102	0.122	0.201	0.586	0.261	0.019	0.094	0.026	0.000	0.087
		Goat	**20**	0.027	0.066	0.079	0.331	0.515	0.429	0.017	0.162	0.027	0.000	0.100
		Pigs	**40**	0.000	0.001	0.001	0.003	0.026	0.009	0.001	0.003	0.001	0.000	0.004
		Poultry	**0.25**	0.025	0.061	0.073	0.175	0.316	0.238	0.005	0.077	0.001	0.000	0.010
			Total	**0.431**	**1.060**	**1.268**	**3.661**	**7.041**	**4.453**	**0.273**	**1.748**	**0.453**	**0.000**	**1.535**
5	2030	Cattle	**110**	0.337	0.827	0.989	2.676	5.584	3.193	0.232	1.301	0.398	0.000	1.334
		Buffallo	**150**	0.007	0.016	0.020	0.250	0.107	0.295	0.004	0.106	0.005	0.000	0.023
		Sheep	**20**	0.042	0.103	0.124	0.203	0.592	0.263	0.019	0.095	0.027	0.000	0.088
		Goat	**20**	0.030	0.074	0.088	0.371	0.577	0.480	0.019	0.181	0.030	0.000	0.112
		Pigs	**40**	0.000	0.001	0.001	0.002	0.019	0.007	0.001	0.002	0.001	0.000	0.003
		Poultry	**0.25**	0.044	0.108	0.130	0.312	0.562	0.423	0.009	0.136	0.003	0.000	0.018
			Total	**0.460**	**1.130**	**1.351**	**3.814**	**7.441**	**4.661**	**0.283**	**1.821**	**0.464**	**0.000**	**1.578**
6	2040	Cattle	**110**	0.348	0.856	1.023	2.769	5.777	3.304	0.240	1.346	0.412	0.000	1.380
		Buffallo	**150**	0.004	0.011	0.013	0.163	0.070	0.192	0.002	0.069	0.004	0.000	0.015
		Sheep	**20**	0.043	0.105	0.125	0.206	0.600	0.267	0.019	0.096	0.027	0.000	0.089
		Goat	**20**	0.035	0.087	0.104	0.435	0.677	0.563	0.022	0.212	0.036	0.000	0.132
		Pigs	**40**	0.000	0.001	0.001	0.002	0.012	0.004	0.000	0.001	0.001	0.000	0.002
		Poultry	**0.25**	0.100	0.247	0.295	0.710	1.279	0.962	0.020	0.310	0.006	0.000	0.040
			Total	**0.531**	**1.305**	**1.560**	**4.284**	**8.415**	**5.293**	**0.304**	**2.035**	**0.485**	**0.000**	**1.658**

Sl. No	Year	Livestock	Standard Norms in lpcd	Live Stock Water Demand in Mcum								
				Aliyar	Musukunda nadhi	Thurinjalar	Gadilam	Upto Krishnagiri Resorvoir	Krishnagiri to Pambar	Pambar to Thirukovilur	Lower Pennaiyar	Total
4	2023	Cattle	**110**	0.962	0.842	3.906	6.879	2.030	2.393	4.141	2.491	40.119
		Buffallo	**150**	0.018	0.015	0.073	0.156	0.060	0.128	0.142	0.055	1.770
		Sheep	**20**	0.065	0.048	0.259	0.339	0.255	0.273	0.278	0.125	3.183
		Goat	**20**	0.067	0.095	0.297	0.966	0.168	0.223	0.402	0.343	4.313
		Pigs	**40**	0.003	0.004	0.013	0.040	0.003	0.003	0.015	0.014	0.147
		Poultry	**0.25**	0.004	0.013	0.021	0.113	0.153	0.175	0.088	0.041	1.587
			Total	**1.119**	**1.016**	**4.569**	**8.493**	**2.668**	**3.196**	**5.066**	**3.069**	**51.119**
5	2030	Cattle	**110**	0.985	0.862	4.000	7.044	2.078	2.451	4.241	2.551	41.084
		Buffallo	**150**	0.013	0.011	0.054	0.116	0.045	0.095	0.105	0.041	1.312
		Sheep	**20**	0.066	0.048	0.261	0.342	0.258	0.275	0.281	0.126	3.214
		Goat	**20**	0.075	0.106	0.332	1.081	0.188	0.250	0.450	0.384	4.827
		Pigs	**40**	0.002	0.003	0.010	0.029	0.002	0.002	0.011	0.010	0.106
		Poultry	**0.25**	0.006	0.024	0.038	0.201	0.272	0.312	0.156	0.073	2.826
			Total	**1.148**	**1.054**	**4.695**	**8.813**	**2.842**	**3.385**	**5.244**	**3.185**	**53.368**
6	2040	Cattle	**110**	1.019	0.892	4.138	7.288	2.150	2.535	4.387	2.639	42.502
		Buffallo	**150**	0.009	0.007	0.035	0.075	0.029	0.062	0.069	0.027	0.855
		Sheep	**20**	0.067	0.049	0.265	0.347	0.261	0.279	0.285	0.128	3.259
		Goat	**20**	0.088	0.124	0.390	1.269	0.221	0.293	0.528	0.451	5.668
		Pigs	**40**	0.001	0.002	0.006	0.018	0.001	0.002	0.007	0.006	0.066
		Poultry	**0.25**	0.014	0.054	0.086	0.457	0.618	0.710	0.356	0.166	6.430
			Total	**1.198**	**1.128**	**4.920**	**9.455**	**3.280**	**3.881**	**5.632**	**3.417**	**58.781**

7.6 Power Generation (Hydro-Electric)

There are one Hydro-electric power stations functioning within the Pennaiyar River Basin. The power generation details for year 2014 -15 and the minimum storage requirement are furnished in the **Table 7.12**

Table 7.12 Power Generation Details of Hydro Power station

Sl. No	Name of the power station	Installed capacity (MW)	Details of the year	Gross Generation in MU	Auxiliary Consumption in MU	Net Generation in MU	Minimum Storage required Mcft
1	Sathanur Dam Power house	7.5	2014-15	1.03	0.034	0.996	306

Source: Chief Engineer/Hydro,TANGEDCO, Annasalai,Chennai 2.

7.6.1 Minimum Flow Requirement

The provisions of minimum flow in the river for maintaining river eco-system and other public necessity have to be made at a rate of 0.5% of surface water potential.

Table 7.13 Sub Basin Wise Projected Total Water Demand in Pennaiyar River Basin

Sl. No	Name of the Sub Basin	Total Water Demand in Mcum 2015					Total Water Demand in Mcum2020					Total Water Demand in Mcum 2023					Total Water Demand in Mcum 2030					Total Water Demand in Mcum 2040				
		Domestic	Irrigation	Industries	livestock	Total	Domestic	Irrigation	Industries	livestock	Total	Domestic	Irrigation	Industries	livestock	Total	Domestic	Irrigation	Industries	livestock	Total	Domestic	Irrigation	Industries	livestock	Total
1	Chinnar West	2.737	7.14	4.557	0.411	**14.847**	2.919	7.14	6.379	0.423	**16.864**	3.034	7.14	7.910	0.431	**18.519**	3.322	7.14	9.826	0.460	**20.750**	3.780	7.14	12.230	0.531	**23.684**
2	Chinnar East	14.918	16.63	13.653	1.010	**46.215**	16.414	16.63	19.114	1.038	**53.201**	17.384	16.63	23.701	1.060	**58.780**	19.879	16.63	29.431	1.130	**67.074**	24.083	16.63	36.607	1.305	**78.630**
3	Markanda nadhi	3.106	15.85	14.799	1.207	**34.962**	3.313	15.85	20.718	1.241	**41.123**	3.444	15.85	25.691	1.268	**46.252**	3.769	15.85	31.906	1.351	**52.877**	4.289	15.85	39.699	1.560	**61.399**
4	Kambainallur	16.520	84.67	4.597	3.603	**109.392**	17.819	84.67	6.436	3.627	**112.553**	18.649	84.67	7.981	3.661	**114.963**	20.748	84.67	9.936	3.814	**119.169**	24.183	84.67	12.429	4.284	**125.567**
5	Pambar	26.871	178.76	60.570	6.745	**272.944**	28.965	178.76	84.798	6.914	**299.436**	30.303	178.76	105.150	7.041	**321.253**	33.683	178.76	130.720	7.441	**350.602**	39.209	178.76	163.004	8.415	**389.387**
6	Vaniyar	10.412	60.77	8.046	4.366	**83.597**	11.212	60.77	11.265	4.404	**87.653**	11.722	60.77	13.968	4.453	**90.916**	13.010	60.77	17.390	4.661	**95.834**	15.111	60.77	21.754	5.293	**102.931**

Sl. No	Name of the Sub Basin	Total Water Demand in Mcum 2015					Total Water Demand in Mcum2020					Total Water Demand in Mcum 2023					Total Water Demand in Mcum 2030					Total Water Demand in Mcum 2040				
		Domestic	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**
7	Matturar	0.492	6.94	1.141	0.264	**8.839**	0.525	6.94	1.597	0.269	**9.333**	0.546	6.94	1.980	0.273	**9.740**	0.597	6.94	2.460	0.283	**10.282**	0.679	6.94	3.064	0.304	**10.990**
8	Kottapatti kallar	1.199	33.43	2.299	1.716	**38.648**	1.279	33.43	3.219	1.730	**39.662**	1.330	33.43	3.991	1.748	**40.503**	1.456	33.43	4.969	1.821	**41.679**	1.656	33.43	6.217	2.035	**43.341**
9	Valayar odai	0.646	12.51	0.006	0.442	**13.603**	0.689	12.51	0.008	0.448	**13.655**	0.716	12.51	0.010	0.453	**13.689**	0.784	12.51	0.015	0.464	**13.774**	0.892	12.51	0.028	0.485	**13.914**
10	Ramakal odai	0.000	0.00	0.000	0.000	**0.000**	0.000	0.00	0.000	0.000	**0.000**	0.000	0.00	0.000	0.000	**0.000**	0.000	0.00	0.000	0.000	**0.000**	0.000	0.00	0.000	0.000	**0.000**
11	Pambanar and Varattar	2.122	31.88	1.153	1.497	**36.654**	2.263	31.88	1.614	1.520	**37.279**	2.353	31.88	2.002	1.535	**37.772**	2.575	31.88	2.494	1.578	**38.530**	2.930	31.88	3.125	1.658	**39.596**

Sl. No	Name of the Sub Basin	Total Water Demand in Mcum 2015					Total Water Demand in Mcum2020					Total Water Demand in Mcum 2023					Total Water Demand in Mcum 2030					Total Water Demand in Mcum 2040				
		Domestic	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**
12	Aliyar	1.937	33.48	1.145	1.091	**37.650**	2.066	33.48	1.603	1.108	**38.254**	2.148	33.48	1.988	1.119	**38.732**	2.351	33.48	2.472	1.148	**39.448**	2.675	33.48	3.086	1.198	**40.437**
13	Musukunda nadhi	1.783	32.48	1.156	0.983	**36.406**	1.902	32.48	1.619	1.003	**37.007**	1.978	32.48	2.007	1.016	**37.484**	2.165	32.48	2.503	1.054	**38.204**	2.463	32.48	3.142	1.128	**39.215**
14	Thurinjalar	21.754	177.28	4.590	4.451	**208.075**	23.619	177.28	6.427	4.522	**211.847**	24.818	177.28	7.969	4.569	**214.635**	27.869	177.28	9.918	4.695	**219.760**	32.921	177.28	12.396	4.920	**227.516**
15	Gadilam	44.068	325.78	21.727	8.216	**399.788**	47.773	325.78	30.418	8.379	**412.347**	50.150	325.78	37.718	8.493	**422.138**	56.191	325.78	46.898	8.813	**437.679**	66.171	325.78	58.500	9.455	**459.903**
16	Upto Krishnagiri Reservoir	8.450	63.50	31.868	2.543	**106.361**	9.062	63.50	44.615	2.614	**119.791**	9.451	63.50	55.322	2.668	**130.942**	10.427	63.50	68.702	2.842	**145.472**	12.005	63.50	85.473	3.280	**164.258**

Sl. No	Name of the Sub Basin	Total Water Demand in Mcum 2015					Total Water Demand in Mcum2020					Total Water Demand in Mcum 2023					Total Water Demand in Mcum 2030					Total Water Demand in Mcum 2040				
		Domestic	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**	**Domestic**	**Irrigation**	**Industries**	**livestock**	**Total**
17	Krishnagiri to Pambar	19.298	165.91	29.601	3.071	**217.878**	20.961	165.91	41.442	3.139	**231.450**	22.030	165.91	51.388	3.196	**242.521**	24.751	165.91	63.822	3.385	**257.865**	29.260	165.91	79.415	3.881	**278.464**
18	Pambar to Thirukovilur	10.021	162.22	9.172	4.926	**186.339**	10.719	162.22	12.841	5.007	**190.786**	11.161	162.22	15.922	5.066	**194.370**	12.268	162.22	19.811	5.244	**199.543**	14.046	162.22	24.747	5.632	**206.645**
19	Lower Pennaiyar	14.221	151.91	6.870	2.969	**175.968**	15.307	151.91	9.619	3.028	**179.862**	16.000	151.91	11.927	3.069	**182.904**	17.747	151.91	14.835	3.185	**187.674**	20.594	151.91	18.519	3.417	**194.438**
Total		**200.554**	**1561.150**	**216.950**	**49.512**	**2028.166**	**216.808**	**1561.150**	**303.731**	**50.413**	**2132.102**	**227.217**	**1561.150**	**376.626**	**51.119**	**2216.111**	**253.589**	**1561.150**	**468.108**	**53.368**	**2336.215**	**296.950**	**1561.150**	**583.435**	**58.781**	**2500.316**

7.7 Total Water Demand

The sub basin wise total water demand of four sectors, i.e., Domestic, Irrigation, Livestock, and Industries of Pennaiyar River Basin for the present year 2015 and the projected target years 2020, 2023, 2030 & 2040 are worked out as **2028.166Mcum, 2132.102Mcum, 2216.11Mucm, 2336.215Mcum & 2500.316Mcum** respectively and are given in **Table No.7.13.**

7.8 Summary

While comparing the previous reappraisal study of Pennaiyar River Basin carried out during 2004, it is learnt that

1. The population has been increased from 4.788 million to 5.594 million for the present year (2015). Therefore the domestic water demand has been increased from 141.728Mcum to 200.555 Mcum during 2015.
2. The livestock population have also been decreased at present (2015) and hence the livestock demands has been decreased from 154.623Mcum to 49.512 Mcum
3. The number of small scale and large scale industries in the Pennaiyar River Basin found to have decreased at present. Hence the estimated value of Industrial Water Demand in Pennaiyar River Basin for the present year 2015 has been decreased from 222.97 Mcum to 216.950 Mcum.
4. As per 2004 pennaiyar study report, irrigation demand was given as 1330.02 Mcum at 75% rainfall dependability with then crop area of 296233Ha. The net irrigation demand of this basin for the year 2015 at 75% dependable rainfall is 1561.15 Mcum.

The Comparision between the reappraisal study of Pennaiyar River Basin carried out during 2004 and 2015 is presented in the T**able 7.14**

Table 7.14 Comparision between the reappraisal study of Pennaiyar River Basin carried out during 2004 and 2015

Domestic Demand in Mcum		Livestock Demand in Mcum		Industrial Demand in Mcum		Irrigation Demand in Mcum		Total demand in Mcum	
2004	2015	2004	2015	2004	2015	2004	2015	2004	2015
141.728	200.555	154.623	49.512	222.97	216.950	1330.02	1561.150	1849.341	2028.166

The total water demand of four sectors, i.e., Domestic, Irrigation, Livestock, and Industries of Pennaiyar River Basin for the present year 2015 was worked out as 2028.166Mcum**.** This shows that that there is 8.18% increase in water demand, when compared to the water demand during 2004.

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. Hence water balance is a tool to study the water availability in a river basin.

8.1 Water Potential of Pennaiyar River Basin

Total water potential is the sum of surface water potential and ground water potential. The surface water potential of Pennaiyar 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 Groundwater Estimation Committee (GEC) Norms 2009 and is furnished in Chapter 6**.** The 75% dependable total water potential of Pennaiyar river basin is 3459.67 Mcum as given below:

Surface water potential	= 1319.58 MCM
(Vide Chapter - 5)	
Ground water potential	= 2140.09 MCM
(Vide Chapter - 6)	

Total Water Potential of the basin	= 3459.67MCM

8.2 Water Demand of Pennaiyar River Basin

Total water demand is the sum of the sectoral demands such as domestic, irrigation, livestock and industrial sector. Domestic demand is calculated from the population of Pennaiyar 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 recommendations of the Industries and Commerce department i.e., 2500 cum/day/unit for large and medium scale industries and 2.5 cum/day/unit for small scale industries are adopted for estimating the industrial demand. 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 Environmental Flow Requirement (EFR) is necessary. Hence in this assessment provisions are given for ecological requirements at a rate of 0.5% of surface Water Potential at 75% dependability for 2015 and at 1% for 2020,2023 and 2040.The above demand calculations are detailed in **Chapter – 7**. The total water demand in Pennaiyar river basin for different planning stages is tabulated below:

Table 8.1
Total Sectoral Water Demand in Pennaiyar River Basin (75% dependability)

Sl. No.	Type of Demand	Total Demand in Mcum				
		2015	2020	2023	2030	2040
1	Domestic	**200.55**	**216.81**	**227.22**	**253.59**	**296.95**
2	Irrigation (including losses at 33.30% = 1561.15*1.33)	**2076.33**	**2076.33**	**2076.33**	**2076.33**	**2076.33**
3	Live Stock	**49.51**	**50.41**	**51.12**	**53.37**	**58.78**
4	Industries	**216.95**	**303.73**	**376.63**	**468.11**	**583.43**
5	Ecological	**6.60**	**13.20**	**13.20**	**13.20**	**13.20**
	Total	**2549.94**	**2660.48**	**2744.50**	**2864.60**	**3028.69**

Water Balance

Water Potential for the year 2015 = **3459.67** Mcum

Water demand for the year 2015 = **2549.94** Mcum

Surplus = **909.73** Mcum

% of Surplus with respect to potential = 26.30%

Pennaiyar basin is surplus by 909.73 Mcum (26.30 %) at present, i.e., for the year 2015 for 75% dependable values.

8.3 Water Balance at 75% Dependability

Water balance is also projected for the future, i.e., 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 3459.67 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 Pennaiyar River Basin at 75% dependability
Water Potential, Demand and Deficit (Both long & short term)

Sector	2015	2020	2023	2030	2040
Total Water Potential (Surface Water + Ground Water Potential) in Mcum	**3459.67**	**3459.67**	**3459.67**	**3459.67**	**3459.67**
Total Water Demand (Domestic + Livestock+ Industrial+ Agricultural Demand) in Mcum	**2549.94**	**2660.48**	**2744.50**	**2864.60**	**3028.69**
Total water surplus in Mcum	**909.73**	**799.19**	**715.17**	**595.07**	**430.98**
% of surplus with respect to potential	**26.30%**	**23.10%**	**20.67%**	**17.20%**	**12.45%**

From the table, it seen that the basin is surplus by 26.03% at present. For future years, the trend in the surplus seems to be decreasing towards the year 2040, this is because of increase in population, livestock and industrialization.

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

During 2015, Pennaiyar basin is surplus by 909.73 Mcum. Chinnar East, Matturar and Krishnagiri to Pambar sub basins have a deficit percentage of the order of 0.3 %, 9.6% and 17.1 % respectively, While the remaining sub basins of Chinnar West, Markandanadhi, Kambainallur, Pambar, Vaniyar, Kovilar, Valayar Odai, Ramakkal Odai, Pambanar & Varattar, Musukandanadhi, Aliyar, Thurinjalar, Gadilam, Upto Krishnagiri Reservoir, Pambar to Thirukovilar and Lower Pennaiyar Sub Basins are surplus by 15%, 51.7%, 42.3%, 14.8%, 53.5%, 79.6%, 21.0%, 99.7%, 25.7%, 9.1%, 9.6%, 12.5%, 37%, 17.4%, 16.0% ,38.1% and 26.2% respectively. The surplus water from the surplus sub basins may be diverted to the nearby deficit sub basins.

Water balance statements are also given for future projected years. During the years of 2020, 2023, 2030 and 2040 also the whole Pennaiyar basin is a surplus basin.

8.4 Water Balance at 50% Dependability

Water balance is also worked out for 50% dependable values so that it could be adopted for years having good rainfall. For this purpose, Surface water potential value at 50% dependability of 1850.57 MCM, taken from the output of MRS model and the irrigation demand values at 50% dependable rainfall taken from the output of CROPWAT model is taken for calculation. Water balancing for Pennaiyar river basin at 50% dependability is given in the following table. While the water availability at 75% dependability for the year 2015 is on the average of 26.30% and the water availability at 50% dependability is on the average of 39.1%. 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 Pennaiyar River Basin at 50% dependability Water Potential, Demand and Deficit (Both long & short term)

Sector	2014	2020	2023	2030	2040
Total Water Potential (Surface Water + Ground Water Potential) in Mcum	**3990.66**	**3990.66**	**3990.66**	**3990.66**	**3990.66**
Total Water Demand (Domestic + Livestock+ Industrial+ Agricultural Demand) in Mcum	**2428.96**	**2542.15**	**2626.16**	**2746.26**	**2910.36**
Total water Surplus in Mcum	**1561.70**	**1448.51**	**1364.50**	**1244.40**	**1080.30**
% of Surplus with respect to potential	**39.1%**	**36.3%**	**34.2%**	**31.2%**	**27.1%**

Table 8.4

PENNAIYAR BASIN - Sub Basin wise water balance at 75% dependability (Existing scenario)

2015

		Chinnar West	**Chinnar East**	**Markandanadhi**	**Kambainallur**	**Pambar**	**Vaniyar**	**Mattu-rar**	**Kottaipattikallar**	**Valayar Odai**	**Ramakal Odai**	**Pamba-nar & Varattar**	**Aliyar**	**Musukudanadhi**	**Thurinjalar**	**Gadilam**	**Upto Krishnagiri Resr.**	**Krish-nagiri to Pambar**	**Pambar to Thirukovilur**	**Lower Pennai-yar**	**Total**
Water sources potential in Mcum	Surface water potential (a)	9.17	29.44	40.34	102.75	189.01	115.01	7.05	37.40	9.51	1.96	31.74	24.60	20.25	98.51	208.21	68.69	100.85	115.15	109.96	**1319.58**
	Ground water potential (b)	13.14	22.24	43.26	136.27	201.58	109.31	8.10	47.78	13.00	1.67	31.98	29.08	31.98	206.81	598.56	85.94	132.49	170.96	255.94	**2140.09**
	Total water potential (c = a+b)	**22.31**	**51.68**	**83.60**	**239.02**	**390.59**	**224.32**	**15.15**	**85.18**	**22.51**	**3.63**	**63.72**	**53.68**	**52.23**	**305.32**	**806.77**	**154.63**	**233.34**	**286.11**	**365.90**	**3459.67**
Water demand in Mcum	Domestic demand (d)	2.74	14.92	3.11	16.52	26.87	10.41	0.49	1.20	0.65	0.00	2.12	1.94	1.78	21.75	44.07	8.45	19.30	10.02	14.22	**200.55**
	Irrigation demand (e)	9.50	22.12	21.08	112.61	237.75	80.83	9.23	44.47	16.64	0.00	42.40	44.52	43.20	235.78	433.28	84.46	220.66	215.75	202.04	**2076.33**
	Livestock demand (f)	0.41	1.01	1.21	3.60	6.75	4.37	0.26	1.72	0.44	0.00	1.50	1.09	0.98	4.45	8.22	2.54	3.07	4.93	2.97	**49.51**
	Industrial demand (g)	4.56	13.65	14.80	4.60	60.57	8.05	1.14	2.30	0.01	0.00	1.15	1.15	1.16	4.59	21.73	31.87	29.60	9.17	6.87	**216.95**
	Ecological demand (h)	0.05	0.15	0.20	0.51	0.95	0.58	0.04	0.19	0.05	0.01	0.16	0.12	0.10	0.49	1.04	0.34	0.50	0.58	0.55	**6.60**
	Total water demand (h = d+e+f+g)	**17.25**	**51.85**	**40.39**	**137.85**	**332.88**	**104.23**	**11.17**	**49.87**	**17.78**	**0.01**	**47.33**	**48.82**	**47.23**	**267.07**	**508.34**	**127.66**	**273.13**	**240.45**	**226.65**	**2549.94**
Surplus / Deficit in Mcum (c-h)		**5.06**	**-0.17**	**43.20**	**101.18**	**57.71**	**120.09**	**3.98**	**35.31**	**4.73**	**3.62**	**16.39**	**4.86**	**5.01**	**38.25**	**298.43**	**26.97**	**-39.80**	**45.66**	**139.25**	**909.73**
Percentage		**22.7%**	**-0.3%**	**51.7%**	**42.3%**	**14.8%**	**53.5%**	**26.3%**	**41.5%**	**21.0%**	**99.7%**	**25.7%**	**9.1%**	**9.6%**	**12.5%**	**37.0%**	**17.4%**	**-17.1%**	**16.0%**	**38.1%**	**26.3%**

Surplus in Pennaiyar basin = **909.73 Mcum - 26.3%**

Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated = **138.85 Mcum**

Surplus in Pennaiyar basin considering waste water reuse = **1048.58 Mcum**

Table 8.9

PENNAIYAR BASIN - Sub Basin wise water balance at 50% dependability (Existing scenario)

2015

		Chinnar West	**Chinnar East**	**Markandanadhi**	**Kambainallur**	**Pambar**	**Vaniyar**	**Mattur**	**Kottaipattikallar**	**Valayar Odai**	**Ramakal Odai**	**Pambanar & Varattar**	**Aliyar**	**Musukandanadhi**	**Thurinjalar**	**Gadilam**	**Upto Krishnagiri Resr.**	**Krishnagiri to Pambar**	**Pambar to Thirukovilur**	**Lower Pennaiyar**	**Total**
Water sources potential in Mcum	Surface water potential (a)	13.07	38.76	61.03	140.59	272.36	153.19	9.78	51.03	14.56	2.54	41.38	35.59	24.60	140.71	304.07	104.33	128.59	175.15	139.24	**1850.57**
	Ground water potential (b)	13.14	22.24	43.26	136.27	201.58	109.31	8.10	47.78	13.00	1.67	31.98	29.08	31.98	206.81	598.56	85.94	132.49	170.96	255.94	**2140.09**
	Total water potential (c = a+b)	**26.21**	**61.00**	**104.29**	**276.86**	**473.94**	**262.50**	**17.88**	**98.81**	**27.56**	**4.21**	**73.36**	**64.67**	**56.58**	**347.52**	**902.63**	**190.27**	**261.08**	**346.11**	**395.18**	**3990.66**
Water demand in Mcum	Domestic demand (d)	2.74	14.92	3.11	16.52	26.87	10.41	0.49	1.20	0.65	0.00	2.12	1.94	1.78	21.75	44.07	8.45	19.30	10.02	14.22	**200.55**
	Irrigation demand (e)	8.51	20.41	18.23	101.82	200.64	84.09	8.81	41.09	13.56	0.00	36.45	39.34	38.51	184.18	521.93	76.08	200.45	176.38	182.19	**1952.69**
	Livestock demand (f)	0.41	1.01	1.21	3.60	6.75	4.37	0.26	1.72	0.44	0.00	1.50	1.09	0.98	4.45	8.22	2.54	3.07	4.93	2.97	**49.51**
	Industrial demand (g)	4.56	13.65	14.80	4.60	60.57	8.05	1.14	2.30	0.01	0.00	1.15	1.15	1.16	4.59	21.73	31.87	29.60	9.17	6.87	**216.95**
	Ecological demand (h)	0.07	0.19	0.31	0.70	1.36	0.77	0.05	0.26	0.07	0.01	0.21	0.18	0.12	0.70	1.52	0.52	0.64	0.88	0.70	**9.25**
	Total water demand (h = d+e+f+g)	**16.28**	**50.18**	**37.65**	**127.24**	**296.19**	**107.68**	**10.76**	**46.56**	**14.73**	**0.01**	**41.43**	**43.69**	**42.56**	**215.68**	**597.46**	**119.47**	**253.06**	**201.37**	**206.95**	**2428.96**
Surplus / Deficit in Mcum (c-h)		**9.93**	**10.82**	**66.64**	**149.62**	**177.75**	**154.82**	**7.12**	**52.25**	**12.83**	**4.20**	**31.93**	**20.98**	**14.02**	**131.84**	**305.17**	**70.80**	**8.02**	**144.74**	**188.23**	**1561.70**
Percentage		**37.9%**	**17.7%**	**63.9%**	**54.0%**	**37.5%**	**59.0%**	**39.8%**	**52.9%**	**46.6%**	**99.7%**	**43.5%**	**32.4%**	**24.8%**	**37.9%**	**33.8%**	**37.2%**	**3.1%**	**41.8%**	**47.6%**	**39.1%**

Surplus in Pennaiyar basin = **1561.70 Mcum - 39.1%**

Quantity of waste water from Large & Medium Industries that can be used for irrigation if treated = **138.85 Mcum**

Surplus in Pennaiyar basin considering waste water reuse = **1700.55 Mcum**

8.5 Simulation Studies for Water Planning

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

1) Existing scenario

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

2) Double tank scenario

In this scenario, two fillings per year for the tanks in Pennaiyar 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

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 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 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 vide Table No. 8.1 to 8.5 given in Volume II. The bar charts are given in **Figure 8.1 to Figure 8.5** for various scenarios.

For the year 2015, the basin is surplus in all the five scenarios at 75% dependable values. When projected for the years 2020, 2023, 2030 and 2040, the surplus values are slightly decreased due to increase in domestic, irrigation and livestock demands, as shown in Figures 8.2 and 8.3. **Thus**

Pennaiyar river basin is found to be surplus when simulated for scenarios involving various scenarios such as double tank, no silt, decrease irrigation and improving efficiency. Hence steps may be taken to utilize the surplus water apart from the basin needs, by forming more water bodies for conservation within the basin or transferring the available surplus to other deficit sub basins and basins and also steps may be taken to limit the Ground water Extractions.

8.6 Summary

Thus Pennaiyar river basin is found to be a Surplus basin both at 75% and 50% dependable rainfall and surface water potential values for the existing scenario. In 75% dependable calculations, the surplus percentage is 26.2% during 2015 and it decreases to 12.5% during 2040 due to increase in domestic, irrigation and livestock demands.

Description	2015	2020	2023	2030	2040
Total water surplus in Mcum	**907.26**	**799.20**	**715.19**	**595.08**	**430.98**
% of surplus with respect to potential	**26.2%**	**23.1%**	**20.7%**	**17.2%**	**12.5%**

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 water balance.

In addition, the proposals for Inter linking, as per **Vision 2023** and also the new proposals for Reservoirs and Check dams as received from the Chief Engineer, Chennai Region are suggested in Chapter 5, for implementation to tide over the crisis of water shortage during lean periods.

Figure - 8.1

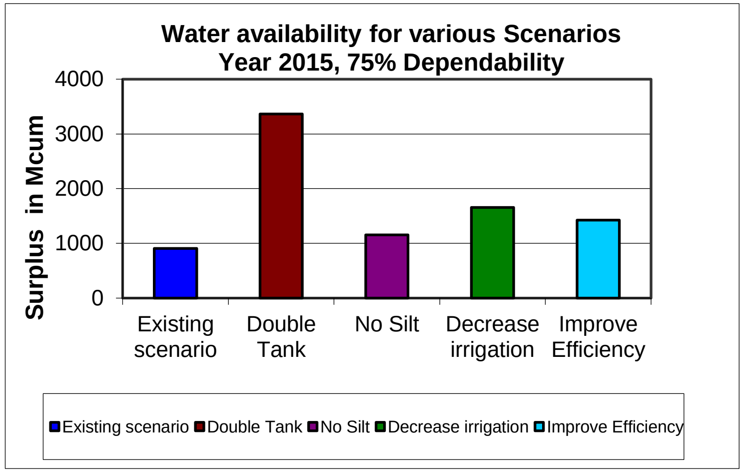
Pennaiyar river basin - Water availability at 75% & 50% dependabilities during 2015 for various Scenarios

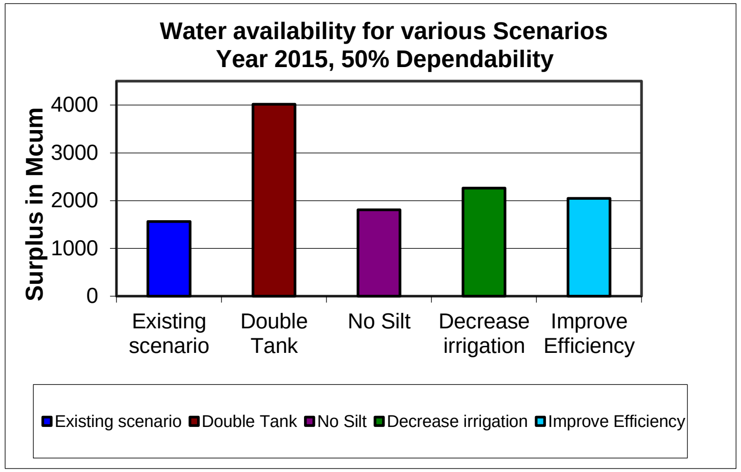
Water avilability during 2015 at 75% dependability

Sl.No.	Scenario	Surplus in Mcum
1	Existing scenario	909
2	Double Tank	3364
3	No Silt	1155
4	Decrease irrigation	1656
5	Improve Efficiency	1425

Water availability during 2015 at 50% dependability

Sl.No.	Scenario	Surplus in Mcum
1	Existing scenario	1561
2	Double Tank	4016
3	No Silt	1807
4	Decrease irrigation	2261
5	Improve Efficiency	2046





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	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 sources 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 into development planning, policy and practices.
- Promoting environmental governance through legislation, policy and advocacy.

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. The various environmental aspects each have a number of different impacts on 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 as 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 are solid waste disposal, weeds, encroachment, sand quarrying, sedimentation, catchment area degradation, salinity, natural calamities, public health, wild life, tourism, fisheries, socio-economic aspects, etc.

9.1 Pollution Sources

The major pollution sources identified in the basin are as follows.

- Industries
- Domestic
- Agriculture.

9.1.1 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 (ECI) 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 from water sources.

The wastewater generated from the industries is assumed as 80% of the water utilized and waste water generated for the year 2015 is given below in **Table 9.1**

Table 9.1

Reuse of Industrial Waste & Economic Evaluation cost of Treatment of Industrial Effluents

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
1	Chinnar – West	38	4.557	3.65
2	Chinnar – East	97	13.653	10.92
3	Markandanadhi	114	14.799	11.84
4	Kambainallur	83	4.597	3.68
5	Pambar	724	60.570	48.46
6	Vaniyar	146	8.046	6.44
7	Matturar	11	1.141	0.91
8	Kottapattikallar	42	2.299	1.84
9	Valayar Odai	6	0.006	0.00
10	Ramakal Odai	0	0.000	0.00
11	Pambanar and Varattar	25	1.153	0.92
12	Aliyar	16	1.145	0.92
13	Musukundanadhi	29	1.156	0.93
14	Thurinjalar	76	4.590	3.67
15	Gadilam	274	21.727	17.38
16	Upto Krishnagiri reservoir	238	31.868	25.49
17	Krishnagiri to Pambar	232	29.601	23.68
18	Pambar to Thirukovilur	141	9.172	7.34
19	Lower Pennaiyar	97	6.870	5.50
Total		**2389**	216.95	173.56

Source: Analysis

Benefits by using Treated Industrial Effluents for irrigation

Total quantity of water utilized by the industries	:	216.95 MCum per year
The wastewater generated from the industries is assumed as 80% of the water utilized.		
Total quantity of waste water available for treatment per year	:	173.56 MCum
Assuming that 80% of treated waste water can be used for Irrigation		
Total quantity of treated waste water to be used for irrigation per year	:	138.85 MCum
Total irrigation area adopting 85 ha/ MCum	:	11802 ha
Adopting paddy production as 4 Tonnes / ha	:	4 tons/ha
Possible paddy production	:	47208 tons
Procurement rate per quintal	:	Rs.1450 / Qtl
Total revenue expected	:	Rs.6845 lakhs/year

9.1.1.1 Effluent Disposal and Utilization

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 as per schedule vi of Environment Protection Rules 1986.The nature and degree of treatment given to the sewage is dependent upon the requirement imposed by the regulatory authorities.

9.1.1.2 Reclamation of Treated Effluent

Reclamation is restricted to meet the needs depending upon the availability and cost of fresh water, transportation and treatment costs and the water quality standards and its end uses like watering of lawns and grass lands, cooling, boiler-feed and process water; forming artificial lakes, wetting of refuse for compaction and composting and raising agricultural crops. Some of these uses may need tertiary treatment.

Artificial Recharge of Aquifers

Artificial recharge of ground water aquifers is one of the methods for combining effluent disposal with water use. Replenishment of ground water sources has been done on a practical scale. Treated effluent has been used to arrest salt water intrusion which may take place due to the lowering of ground water table by excessive pumping to meet large water demands.

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 primary objective of disposal of sewage combined with its utilization to the possible extent in a sanitary manner without polluting the soil, open water courses or artesian waters or contaminating crops raised on the sewage farm, or impairing the productivity of the soil.

Though sewage after primary treatment can be applied to the farms, the temptation of providing only primary treatment and eliminating secondary treatment merely on cost considerations should be resisted. 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 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 resources 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 Pennaiyar river basin, domestic sewage pollution is more severe than the industrial pollution. 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 agricultural drains and the raw sewage contain more Nitrogen, Potassium and Phosphate load that cause eutrophication, which in turn reduces the efficiency of the irrigation structures. A detailed statement is furnished hereunder regarding the quantity of domestic effluent generated, assuming 80% of the per capita water supply. 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 generations of sewage in Rural and Urban areas in Pennaiyar river basin are shown in **Table 9.2** and **9.3** respectively**.**

Table No. 9.2 - Generation of Sewage in Rural Areas in Pennaiyar River Basin

Collection of sewage is assumed as 80% of 70 lpcd based on TWAD board norms:

Sl. No.	Name of the Sub basin	Population as on 2011	Growth rate in %	Population in 2015	Norms of pro-rata supply in lpcd	Volume of sewage generate in Mcum/ year
1	Chinnar – West	49883	1.3	52528	70	1.07
2	Chinnar – East	89169	1.3	93897	70	1.92
3	Markandanadhi	100511	1.3	105840	70	2.16
4	Kambainallur	365901	1.3	385302	70	7.88
5	Pambar	611087	1.3	643489	70	13.15
6	Vaniyar	246829	1.3	259916	70	5.31
7	Matturar	16388	1.3	17257	70	0.35
8	Kottapattikallar	38846	1.3	40906	70	0.84
9	Valayar Odai	20777	1.3	21879	70	0.45

10	Ramakal Odai	0	1.3	0	70	0.00
11	Pambanar and Varattar	69445	1.3	73127	70	1.49
12	Aliyar	62955	1.3	66293	70	1.36
13	Musukundanadhi	57854	1.3	60922	70	1.25
14	Thurinjalar	346542	1.3	364916	70	7.46
15	Gadilam	767527	1.3	808224	70	16.52
16	Upto Krishnagiri Reservoir	233241	1.3	245608	70	5.02
17	Krishnagiri to Pambar	301174	1.3	317143	70	6.48
18	Pambar to Thirukovilur	300324	1.3	316248	70	6.46
19	Lower Pennaiyar	343370	1.3	361576	70	7.39
Total		4021823		4235072		86.56

Source:Analysis

Table No. 9.3 - Generation of Sewage in Urban Areas in Pennaiyar River Basin

Collection of sewage is assumed as 80% of 90 lpcd based on TWAD board norms:

Sl. No.	**Name of the Sub basin**	**Population as on 2011**	**Growth rate in %**	**Estimated population in 2015**	**Norms of pro-rata supply in lpcd**	**Volume of sewage generated in Mcum/ year**
1	Chinnar – West	219408	2.0	237494	90	6.24
2	Chinnar – East	0	2.0	0	90	0.00
3	Markandanadhi	0	2.0	0	90	0.00
4	Kambainallur	85715	2.0	92781	90	2.44
5	Pambar	131769	2.0	142631	90	3.75
6	Vaniyar	46220	2.0	50030	90	1.31
7	Matturar	0	2.0	0	90	0.00
8	Kottapattikallar	0	2.0	0	90	0.00

9	Valayar Odai	0	2.0	0	90	0.00
10	Ramakal Odai	0	2.0	0	90	0.00
11	Pambanar and Varattar	0	2.0	0	90	0.00
12	Aliyar	0	2.0	0	90	0.00
13	Musukundanadhi	0	2.0	0	90	0.00
14	Thurinjalar	180955	2.0	195871	90	5.15
15	Gadilam	333912	2.0	361437	90	9.50
16	Upto Krishnagiri reservoir	20866	2.0	22587	90	0.59
17	Krishnagiri to Pambar	164174	2.0	177707	90	4.67
18	Pambar to Thirukovilur	13394	2.0	14498	90	0.38
19	Lower Pennaiyar	60201	2.0	65163	90	1.71
TOTAL		1256615		1360200		35.75

Source: Analysis

Benefits by using treated Domestic sewage for irrigation

Sewage from Rural Areas	= 86.56 Mcum per year
Sewage from Urban Areas	= 35.75 Mcum per year
Total	=122.31 Mcum per year

Assuming that 80% of waste water can be reused for irrigation.

Therefore 80% of total sewage per year	= 97.85 Mcum
Total irrigable area adopting 85 ha/Mcum	= 8317 ha
Adopting paddy production as 4 Tonnes/ha,	
Possible paddy production	= 33269 Tonnes
Procurement rate per quintal	= 1450 / Qtl
Total revenue expected	= Rs. 4824 Lakhs / year

Initial cost for setting up of STP

Waste water generated in MLD	= 122.31 x 2.738
	= 335 MLD
Adopting the cost of installing per MLD	=100 lakhs

Adopting the cost of O & M per MLD	= 12 lakhs
Captial Cost	=33500 lakhs
Operation and maintenance for one year	=4020 lakhs

By proper planning the capital and O & M cost of treatment could be recovered

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.

9.1.3 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 (from a single discharge point) to more diffuse, landscape-level causes, also known as non point source pollution. Management techniques range from animal management and housing to the spread of pesticides and fertilizers in global agricultural practices.

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.

9.1.3.1 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.

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 main elements of agricultural pollution are phosphates, nitrates, pesticides, sediment and fecal bacteria. The year wise consumption of fertilizers used in nutrient terms and Pesticides/Fungicides in the entire districts associated with Pennaiyar basin are furnished in **Table 9.4 and 9.5**

Table 9.4

Consumption of fertilizers in Krishnagiri, Dharmapuri, Salem, Vellore, Thiruvannamalai, Villupuram, and Cuddalore Districts

Year	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Total (NPK)
2004-2005	151000	68000	70000	289000
2005-2006	138000	63000	64000	265000
2006-2007	163535	86346	73581	323462
2007-2008	159721	69166	81776	310663
2008-2009	192192	65767	106601	364560
2009-2010	182944	82845	94295	360084
2010-2011	199641	91695	98591	389927
2011-2012	233792	109691	80256	423739
2012-2013	348728	85202	73208	507138
2013-2014	333513	74451	78984	486948
Total (MT)	**2103066**	**796163**	**821292**	**3720521**

Source: Department of Agriculture, Chennai

Table 9.5

Consumption of Pesticides in Krishnagiri, Dharmapuri, Salem, Vellore, Thiruvannamalai, Villupuram, and Cuddalore Districts

Year	Liquid (Litres)	Dust/Solid(Kgs)
2005-2006	203266	239
2006-2007	223630	195
2007-2008	156652	1786
2008-2009	166672	1612
2009-2010	138400	1450
2010-2011	152606	1204
2011-2012	139900	1078
2012-2013	142302	1132
2013-2014	142898	1023
Total (MT)	1466326	9719

Source: Department of Agriculture, Chennai

The consumption of fertilizers Nitrogen, Phosphorus and Potassium (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 entire Districts of Pennaiyar River Basin

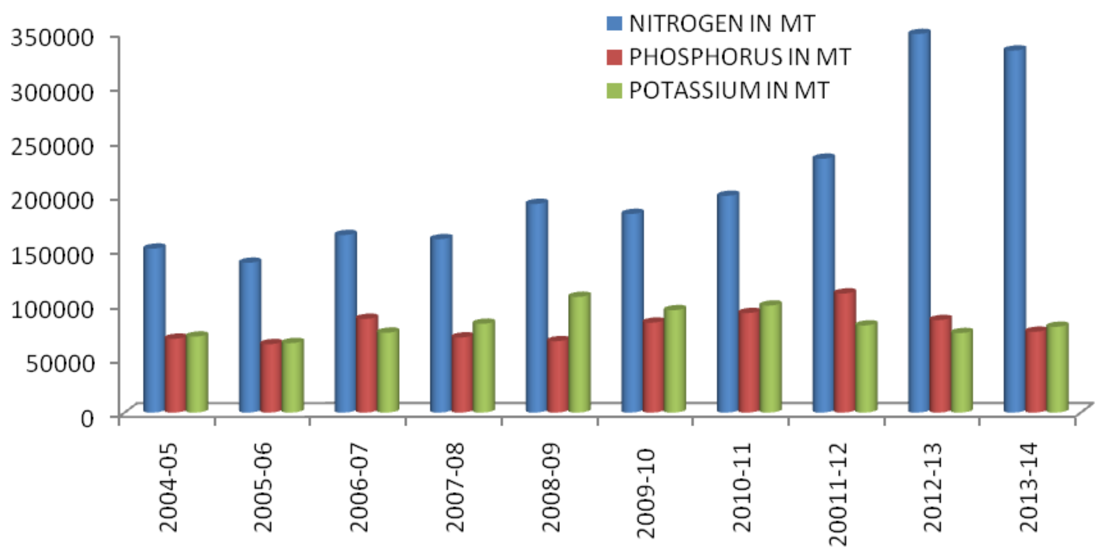
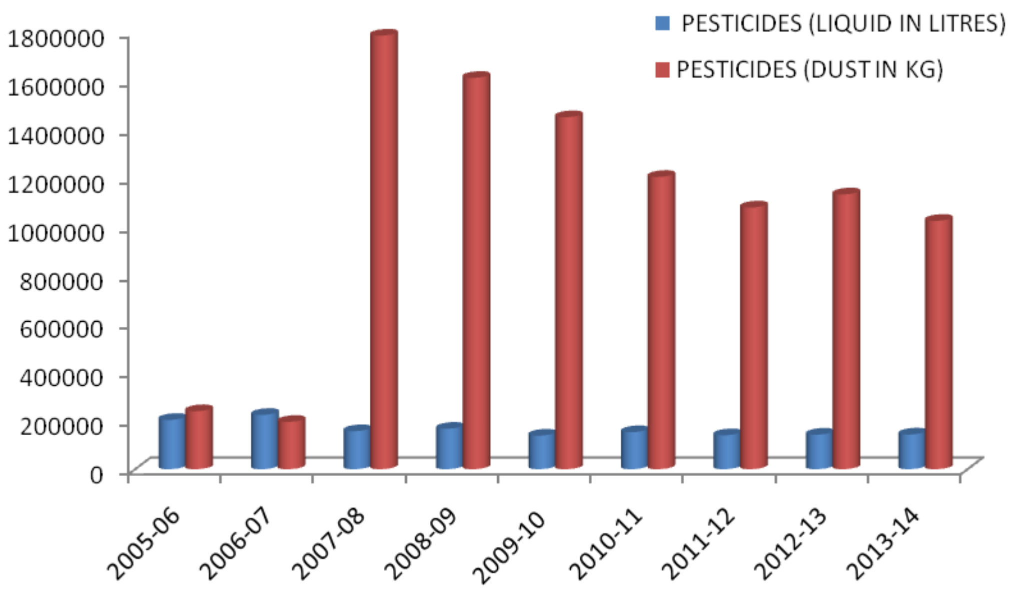


Fig:-9.2 Consumption of Pesticides in entire Districts of Pennaiyar River Basin



9.1.3.2 Effects of Agricultural pollution

- The excess usage of potassium fertilizers has reduced the availability of micronutrients like calcium, zinc, manganese, and magnesium etc.
- 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 those pollution.
- Encouraging crop residue management, green manuring, organic manure and composting.
- Organic farming may be practiced which has the following advantages
- Maintain the environment health by reducing the level of pollution
- Reduce human and animal health hazards by reducing the level of residues in the product.
- Helps in keeping agricultural production at a higher level and makes it sustainable.
- 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.
- Conserving wildlife (biodiversity)
- Protecting natural resources (water and soil)
- Application of organic wastes from animals and crops, and use of crop rotation.
- Development of less intensive farming methods with reduced levels of fertilizer application

9.2 Sedimentation

The process of sediment deposition is unique to every reservoir. In general the coarser, heavier sediments, the gravel and sand, tend to settle out at the upper end of reservoir, forming a backwater delta which gradually advances towards the dam. The lighter sediments, the silt and clay tend to be deposited nearer the dam. The rate of reservoir sedimentation depends mainly on the size of reservoir relative to the amount of sediment flowing into it. Also the sediment flows vary widely both annually and seasonally over time. The amount of sediment carried into a reservoir is at its highest during floods. As the sediment accumulate in the reservoir, the dam gradually loses its ability to store water for the purposes for which it was built.

Reservoir Sedimentation Problems:

The loss of storage capacity is the major problem. Other few important problem is listed below:

1. In a single purpose reservoir, the loss of storage capacity and thus the useful life and its service function.
2. In a multipurpose reservoir, the loss of storage allotted to each purpose by vertical zones and the necessity to correct it from time to time.
3. Loss of storage due to urbanization. An useful concept for recreation facilities to consider depth area-time relationship.
4. Raising of stream beds and increasing flood heights, meandering and overflow along the banks devastating the fertile lands, and choking up of irrigation and navigation canals.
5. Shoaling of the inlets and caves that are attractive for boat launching and docking. This area may become useless due to deposition of sediments or blocked by a bar formed by lateral transport by wave action or materials eroded from adjacent high banks.

The dams constructed in Pennaiyar river basin are as follows:-

1. Krishnagiri Dam
2. Sathanur Dam
3. Vaniar Dam
4. Thumballahalli Dam
5. Shoolagiri Chinnar Dam
6. Pambar Dam
7. Kelavarapalli Dam

Among the above said dams, the sedimentation study was conducted by the Water Shed Management Division and the details are as follows in **Table 9.6**

Table 9.6 List of Reservoirs in which sedimentation studies conducted

Name of the Reservoir	Year of completion of the dam	Last Capacity Survey done during the Year	Present capacity in Mcum	Capacity loss in Mcum	Annual silting rate in M.Cum /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	Capacity Loss in %
Krishnagiri	1958	2006 (Fourth)	39.700	26.500	0.850	1.280	0.005	2.120	19.00
Sathanur	1958	1982 (Second)	207.30	27.530	1.100	0.470	0.005	1.360	12.00
Vaniar	1985	2010 (First)	11.151	0.685	0.025	0.210	0.006	0.060	6.00

Source: Executive Engineer, Water Shed Management, Pollachi,WRD,PWD

From the above table it is inferred that in Krishnagiri dam, the loss in capacity over 57 years was found to be 19.00%, in Sathanur dam the loss in capacity over 57 years was found to be 12.00%. and in Vaniar dam the loss in capacity over 30 years was found to be 6.00%.

Mitigation measures

- Operation of reservoir may be arranged in such a way that more of suspended sediment water is withdrawn at appropriate time.
- Construction of dykes, check dams and detention basins may be formed in the main river and tributaries.
- Formations of Gullies control and stream bank protection measures may be adopted.
- 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 reservoirs.
- Ensure environmentally acceptable methods for the disposal of dredged sediments, ensuring use for enhancement where appropriate.
- Manage sediment supply at source by putting in place agricultural best practice techniques.
- Reinstate sediment to increase the quantity and / or quality of spawning habitat for targeted species and reducing fine sediment deposition in spawning and / or rearing habitats.
- Prevent or control the distribution of contaminated sediments.
- Eco-restoration may be done such as contour trenching, check dams, percolation ponds, etc.,
- Encourage tree planting
- Conversion of Agro foresting.

9.3 Sand Mining

Sand is an important mineral for our society in protecting the environment. Sand mining is a practice that is used to extract sand, mainly through an open pit. However, sand is also mined from beaches, inland dunes and dredged from ocean beds and river beds, where this practice of sand and soil mining is becoming an environmental issue as the demand for sand increases in industry and construction. Sand is also used to replace eroded coastline.

Mining and its associated activities are responsible for considerable environmental damage. Pollution of the water is evident by the colouration of water which in most of the rivers and streams in the mining area varies from brownish to reddish orange. River sand is not just molecules of silica, but a bed of huge sponge that nature in its endless wisdom has developed to retain and distribute water in order the lives it creates do not perish. Riverbeds, rich with sand cover, are a natural resource, environmental preservative and defender of livelihood and human rights of millions of people. The level of riverbed goes down because of excess sand mining and feeder canals for irrigation from riverbeds stand high and dry. Taking cognizance of pernicious practice of unsustainable over exploitation of sand, the Government of Tamil Nadu vide G.O.Ms.No.95 Industries (MMC.1) Department dated 01.10.2003, issued orders and given powers to the Water Resources Department, Public Works Department to sell the sand in the notified areas to avoid excess sand mining and illegal mining.

Impact due to sand mining

- Depletion of groundwater.
- Drainage channels to lakes/ponds/tanks are blocked since there is no water flow.
- River bridges, irrigation structures and railway tracks are severely damaged.
- Bed degradation from in-stream mining lowers the elevation of stream flow and the floodplain water table which in turn can eliminate water table-dependant woody vegetation in riparian areas.
- Loss in vegetative cover, loss of ecology, destruction of sand dunes and the mangrove ecosystem.
- Due to minus bed level of rivers, high level sluices are not commandable . Hence more quantity of water is required for mean supply level, it depletes the reservoir level quickly and water management is very difficult.

Details of sand quarry

The details of the quantum of sand taken in Pennaiyar river basin from different quarries from the year 2008 to 2015 is depicted in the **Table 9.7, 9.8, 9.9 and 9.10** as follows:

Table 9.7 Sand Quarry details in Vellar Basin Division

Sl. No	Quarry Name	Sub Basin Name	River	Taluk	District	Quantity of sand mined in loads (200 cft/ Load)						
						2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
1	Enathirimangalam	Lower Pennaiyar	Pennaiyar	Panruti	Cuddalore	42210	51996	57610	43977	49694	26778	5894
2	Melkumaramangalam	Lower Pennaiyar	Pennaiyar	Panruti	Cuddalore	956	-	-	-	20409	37337	2543
3	kavanur	Lower Pennaiyar	Pennaiyar	Panruti	Cuddalore	-	-	-	-	-	205	26261
TOTAL LOADS						43166	51996	57610	43977	70103	64320	34698

Source : Executive Engineer,Vellar Basin Divsion, Virudhachalam,WRD,PWD.

Table 9.8 Sand Quarry details in Upper Pennaiyar Basin Division

Sl. No	Quarry Name	River	Taluk	District	Quantity of sand mined in loads (200 cft/ Load)						
					2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
1	Vadakattu Maduvu	Pennaiyar	Harur	Dharmapuri	6136.0	4099.0	1029.0	3640.5	515.0	Quarry Not Operated	Quarry Not Operated
2	Naranapuram	Pennaiyar	Pappireddipatti	Dharmapuri	228.0	-	198.0	11.0	-		
3	Ippikonpalli/ Konjoji Kothur	Pennaiyar	Krishnagiri	Krishnagiri	5886.5	2110.5	2271.0	3603.5	321.5		
4	Theertham/ Nerlagiri	Pennaiyar	Krishnagiri	Krishnagiri	14680.5	6985.0	1786.5	2240.5	394.0		
5	Pathimaduvu/ Balanapalli	Pennaiyar	Krishnagiri	Krishnagiri	4733.0	1961.0	1747.5	845.5	69.0		
6	Nallavanpatti / Pudur	Pennaiyar	Uthankarai	Krishnagiri	3297.0	2241.5	720.5	11.5	-		
7	Ganga Maduvu	Pennaiyar	Krishnagiri	Krishnagiri	1019.5	1692.0	-	1947.5	15.0		
8	Nachikuppam	Pennaiyar	Krishnagiri	Krishnagiri	1290.0	3433.0	2102.0	4775.0	380.0		
9	Dulicheety	Pennaiyar	Palacode	Dharmapuri	16.50	1111.0	3404.0	-	-		

10	Sellakodapatty	Pennaiyar	Pochampalli	Krishnagiri	-	1143.5	4204.0	10709.0	3882.0		
11	Kollatti	Pennaiyar	Denkanikotai	Krishnagiri	1084.5	787.5	1392.0	305.5	-		
12	Kadavarahalli	Pennaiyar	Krishnagiri	Krishnagiri	353.5	20.0	-	-	-		
13	Kathiripalli	Pennaiyar	Krishnagiri	Krishnagiri	397.0	21.0	-	-	-		
14	Alapatti	Pennaiyar	Krishnagiri	Krishnagiri	2361.0	747.5	562.5	1520.0	-		
15	Kolimekkanoor	Pennaiyar	Pappiredipati	Dharmapuri	-	-	-	39.0	22.0	30	
16	Irumathur	Pennaiyar	Harur	Dharmapuri	-	-	150.5	34.0	332.5	528	
17	O.v. Kuppam	Pennaiyar	Krishnagiri	Krishnagiri	-	-	-	252.0	-	0.5	
18	Pavalanthur	Pennaiyar	Pennagaram	Dharmapuri	364.5	139.5	-	1.5	-	-	
19	Mathapatti	Pennaiyar	Pennagaram	Dharmapuri	-	-	-	-	34.0	-	
20	Mathapatti	Pennaiyar	Pennagaram	Dharmapuri	-	-	-	-	17.5	-	
TOTAL LOADS					41847.5	26492	19567.5	29936	5982.5	558.5	

Table 9.9 Sand Quarry details in Middle Pennaiyar Basin Division (April 2014-March 2015)

Sl. No	Quarry Name	River	Taluk	District	Quantity of sand mined in loads (200 cft/ Load)						
					2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
1	Karapoondi	Pennaiyar	Polur	Tiruvannamalai	-	305.5	4980.0	250.0	Quarry Not Operated		
2	Kalur	Pennaiyar	Polur	Tiruvannamalai	-	-	5735.0	112.5			
3	Pillur	Pennaiyar	Polur	Tiruvannamalai	-	111.0	610.0	161.0			
4	Thachur	Pennaiyar	Arani	Tiruvannamalai	-	-	1150.0	21.0			
5	Melsesamangalam	Pennaiyar	Arani	Tiruvannamalai	-	-	1800.0	17.5			
6	Soraiyur	Pennaiyar	Cheyyar	Tiruvannamalai	-	-	385.0	9.5			
7	Arumbaloor	Pennaiyar	Polur	Tiruvannamalai	3288.0	3801.5	1515.0	63.5			
8	Sanikkavadi	Pennaiyar	Polur	Tiruvannamalai	926.5	267.5	2749.0	197.5			
9	Santhavasal	Pennaiyar	Polur	Tiruvannamalai	-	-	962.0	50.0			
10	Panampattu	Pennaiyar	Polur	Tiruvannamalai	-	8.0	479.0	0.5			
11	Thenmathimangalam	Pennaiyar	Polur	Tiruvannamalai	-	194.0	920.0	0.0			
12	Pazankovilur	Pennaiyar	Polur	Tiruvannamalai	-	84.0	1544.0	1.5			
				TOTAL LOADS	4214.5	4771.5	22829	884.5			

Table 9.10 Sand Quarry details in Lower Pennaiyar Basin Division (April 2014-March 2015)

Sl. No	Quarry Name	River	Taluk	District	Quantity of sand mined in loads (200 cft/ Load)						
					2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
1	Andrayanallur	Pennaiyar	Tirukkoilur	Villupuram	9792.0	69477	83193.0	47217	19218.5	-	Quarry Not Operated
2	Karadipakkam	Pennaiyar	Ulundhurpet	Villupuram	5367.0	33960	32208.5	3575.5	46654	27287	
3	Marangiyur	Pennaiyar	Tirukkoilur	Villupuram	29462.5	-	25200.5	36405.5	99.0	-	
4	Perangiyur	Pennaiyar	Ulundhurpet	Villupuram	14364.0	4353	21181.0	8763.5	121.5	-	
5	Maragathapuram	Pennaiyar	Villupuram	Villupuram	-		10572.0	55944.0	35418.0	-	
6	Pidagam	Pennaiyar	Villupuram	Villupuram	-	8023	8581.5	-	20401.0	-	
7	Athiyur Thiruvathigai	Pennaiyar	Villupuram	Villupuram	-	-	29951.0	22277.0	10594.0	33774	
8	Koraikany	Pennaiyar	Vanur	Villupuram	2607.0	-	-	264.5	-	-	
9	Enathimangalam	Pennaiyar	Tirukkoilur	Villupuram	-	-	-	7506.0	-	38293.5	
10	Anthily	Pennaiyar	Tirukkoilur	Villupuram	24229.0	-	-	14426.0	45120.5	-	

11	C. Kallipattu	Pennaiyar	Villupuram	Villupuram	19950.0	15075	-	4121.0	32585.5	18419	
12	Parvathapuram	Pennaiyar	Villupuram	Villupuram		-	-	-	355.5	-	
13	Paiyur	Pennaiyar	Tirukkoilur	Villupuram	-	-	-	-	21309.0	5322.5	
14	Paiyur (Koraiyar)	Pennaiyar	Tirukkoilur	Villupuram	-	-	-	-	31986.0	35996.5	
15	Thenkutchi Palayam	Pennaiyar	Villupuram	Villupuram	-	-	-	-	-	2809.5	10606.5
16	Thirupachanur	Pennaiyar	Villupuram	Villupuram	1652.0	-	-	-	-	2666	32741.0
17	Karadi / Mudiyanur	Pennaiyar	Tirukovilur	Villupuram	-	-	-	-	-	3	-
				TOTAL LOADS	107424	130888	210888	200500	263863	164571	43347.5

Mitigation

- The Government of Tamil Nadu initiated the use of M-Sand (Manufactured Sand) as an alternate to river sand, based on the recommendations of the High Level Committee consisting of Scientists, Geologists and Environmentalists constituted in G.O (2D) No 46, Industries dt 25.09.2002, vide the Circular Memorandum No.AEE/T10/57017/2012, dated 30.08.2012.
- Alternative materials for sand in construction practices have to be introduced by conducting active research programme.
- River Protection Force may be established.
- Sand quarrying is to be carried out in skillful, scientific and systematic manner and that the pits shall not be more than one metre in depth.

9.4 Water Logging

The Soil becomes waterlogged when water balance of an area is disturbed because of excess recharge. This may occur due to seepage from canals and distributions system. Water logging occurs when agricultural land is located over underground layers of material that are impenetrable to water, such as heavy clay which impede natural percolation of water and leads to rising groundwater levels.

Water logging results from excess irrigation and poor drainage. The surplus water present in excess of field capacity give rises to soil saturation and water logging with deleterious effects on crop growth and development. Defective drainage accumulates water, which becomes breeding ground mosquitoes and other harmful bacteria. Mosquitoes multiply in large numbers, which may finally infect the people with malaria.

The causes for water logging may be due to the following reasons:

1. Natural basins without outlet for water
2. Low permeability of surfaces horizons
3. Internal drainage
4. Low intake rate of surface soils
5. Obstructions to natural flow of rainwater.

Inefficient use of surface irrigation water, poor land development, seepage and poor drainage have resulted in high water tables.

Mitigation measures:-

1. Proper drainage.
2. Efficiency of irrigation systems could be improved and maintained.
3. More appropriate crops (less water hungry) could be grown.
4. Encroachment around the tanks and ponds should be removed.

9.5 Water Weeds

A plant that grows partly or wholly in water whether rooted in the mud or floating without anchorage. Water bodies are often adversely affected by waterweeds, creating problems related to storage, flow, agriculture, navigation, pisciculture and public health. The problem is global, but more pronounced in tropical and subtropical zone, where warm weather supports profuse growth of aquatic plants.

Types of water weeds

Floating type
Roots of the floating plants hang in water and not attached to soil.

Eichhornia crassipes (Water hyacinth), Pistia stratoites (Water lettuce), *Salvia cuculata* and *Salvinia natans*, *Spirodela polyrhiza*, *Lemna minor* and *Wolffia arrhiza* (duck weed), *Azolla pinnata* (water fern).

Submerged type
Weeds growing below the water surface

Hydrilla verticillata(Hydrilla), Vallisneria, Myriophyllum spicatum(water milfoil).

Emergent type
Rooted waterweeds extending above the water surface

Typha spp (Cattails), *Cyperus spp*, *Scirpus spp* (bulrush), *Phragmites communis* (reed) etc.

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.

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

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. Reduced water flow due to the construction of dams.
6. Lack of controlling measures of weed invasion.

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 evopo-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.

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.

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. In searing 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 form a boat. The harvested weeds float to the water surface and are removed manually or by sieve buckets.

Biological Methods

In the biological control of aquatic weeds, **grass carp** fish is considered as an excellent bio-agent directly on **Hydrillla**. A 1.20 kg grass carp 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: 9.3 GRASS CARP

A 1.20 kg grass carp 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.

9.6 Encroachment

Rivers, streams, supply channels and tanks are becoming the easiest pray for land grabbing for various uses across the basin. The encroachments shall be broadly categorized into two as public and private. The farmers, general public and others do the private encroachments mostly for economical reasons such as cultivation, well digging, tree plantations, housing, dumping yards and cattle yards etc. Encroachments are done by different segments of the society varying from the landless, poor and the rich farmers.

The places and the nature of activity in the encroached areas are depicted in **Table 9.11**

Table 9.11 REPORT OF EVICTION IN TANKS

Sl. No.	District	No.of tanks under the control of W.R.D	No.of tanks fully restored	No.of tanks under different stages of restoration.				No of Tanks yet to be Surveyed
				Surveying	Eviction of encroachments	Erecting boundary stones	Live fencing	
1	Krishnagiri	87	43	21	10	13	0	0
2	Dharmapuri	73	41	18	5	9	0	0
3	Vellore	519	73	118	96	108	0	124
4	Tiruvannamalai	698	46	315	100	93	0	144
5	Villupuram	843	272	29	70	21	1	450
6	Cuddalore	229	138	5	7	0	0	79

Impacts due to Encroachment

- The water holding capacity of rivers, ponds, and channels gets decreased.
- The dumping of domestic wastes, kitchen wastes, garden wastes, etc., into the ponds leads to decaying of organic matter, stagnation of water, egg laying mosquitoes and consequent health problems including water borne diseases.
- Reducing the flow-width of the river decreases the inflow of water resulting in reduced storage capacity, which leads to scarcity of water for agricultural and domestic purpose
- During monsoon the rain water drainage systems are not functioning effectively and hence it overflows the encroached tanks and the water invades the surrounding human habitations and roads.
- Encroachment in riverbanks and channels reduces the carrying capacity of the system, which results in serious problems of drainage systems during rainy season.
- Encroachment by house construction etc reduces the storage capacity of ponds, which in turn reduces the underground water levels and pollutes the water bodies.

Mitigation Measures

- Implementation on Tamil Nadu Protection of tanks and Eviction of Encroachment Act No 8 of 2007 effectively at all levels.
- Effective steps have to be taken by the Government at initial stage itself to prevent encroachments in water bodies.
- Construction of buildings near to water bodies should be avoided. Looking into the land requirements of marginalized people and house sites to be provided.
- Periodic monitoring has to be done to avoid the encroachments.
- Physical and mechanical removal of encroachment by the Government.
- Awareness regarding the importance of the water bodies to the human livelihood is to be created among the public by encouraging and active participation of various Governmental and non-Governmental organization, Institutions, Forest department, Agriculture and public representation is vital.

9.7 Catchment Area Degradation

The area from which precipitation would flow to a stream is denoted as catchment area. The quantity of water in the river depends upon the extent of catchment area, amount and duration of rainfall, which contribute to the river water.

The rainwater soaks the ground and accumulates as groundwater. Some of this groundwater seeps into the river system and keeps water flowing in most rivers even during dry periods. Such a river is known as “perennial”, which is normally having a “healthy watershed”. In dry regions there is not always a flow of water and they dry up in some seasons, which are known as intermittent rivers or seasonal rivers.

Pennaiyar river originates on the south eastern slopes of Chennakesava Hills, North west of Nandidurg in Karnataka State at an altitude of 1000 m. above MSL. The river is called Dakshina pinakine in Karnataka state. After flowing through Karnataka, the river enters Tamil Nadu near Bagalur village of Hosur taluk and takes the name of Pennaiyar. Pennaiyar river basin is sandwiched between Cauvery river basin at its west and south and Palar and Varahanadhi basins at its east and north. The total area of the basin is 11465.55sqkm including the area under Union Territory of Pondicherry (90 sq.km).

The total length of Pennaiyar River is 432 kms. It spreads over 112 kms. in Karnataka state, 180 kms. in Dharmapuri, Krishnagiri & Salem districts, 34 kms. in Thiruvannamalai and Vellore districts and 106 kms. in Cuddalore and Villupuram districts of Tamil Nadu. There is no flow in the pennaiyar river normally except during monsoon seasons. The main factors of environment degradation in any river basin are Deforestation, Land slides, Soil erosion and Sedimentation

9.7.1 Catchment area treatment

The catchment area treatment is an improved land management of the watershed to arrest soil erosion and improve its hydrological behaviour. The catchment area treatment is done for the following purposes:-

1. To prevent degradation of land and enhance its productivity of optimum level use pattern.
2. To improve ecological balance between land, water, plant and animal life.
3. To reduce the silting of the reservoir by soil conservation methods in the catchment area.

Catchment area protection is vital for sustainable development of watersheds and for sustainable management of environment. Catchment areas of the Pennaiyar include forest eco systems, grassland eco systems, reed land eco systems and plantation eco systems. Protection of all these eco systems is important for preserving the integrity of the catchment area.

Catchment area Treatment – Krishnagiri Dam.

In the Dam Rehabilitation and Improvement Project (DRIP) a provision of Rs.15.41 crore has been allotted for taking up Catchment Area Treatment Works in Krishnagiri and Kundha Reservoirs by Agriculture Engineering Department(AED) based on the capacity survey done by the Water Resources Department. For Krishnagiri Reservoir an amount of Rs.66.60 lakhs has been sanctioned for the catchment area works to be done by the Agricultural Engineering Department vide G.O. Ms.No.45 Agriculture (WD2) Department Dated 02.03.2015.

The catchment area treatment in Krishnagiri Reservoir includes the following.

S.No.	Description of Works	Nos.	Estimate amount In lakhs
1.	Construction of Check dam	9	50.965
2.	Construction of Silt Detention Tank	1	6.709
3.	Construction of Silt Monitoring Station	1	8.926
	Total	11	66.600

Fig 9.4 SILT DETENTION STRUCTURE

Impound the run off through streams thus arrest the silt.

Mitigation Measures :

- Prevention of mining in the forest areas.
- Prevention of soil erosion by preserving the forests and grasslands.
- Afforestation in the degraded forest areas by gap planting to create dense forests.
- Construction of contour stonewalls (stone terracing) and bench terracing.
- Construction of gully plugging and temporary check dams.
- Construction of major check dams and percolation ponds.
- Involving local people in catchment protection activities.
- Mechanical and soil conservation techniques may be adopted.

For the sustainable development, monitoring and improving the water shed using modern tools may be adopted.

9.8 Sea Water Intrusion

Introduction

Sea water intrusion is a major concern commonly found in coastal aquifers around the world. Seawater intrusion is the flow of seawater into freshwater aquifers primarily caused by over development of groundwater near the coast, where groundwater is being over exploited from aquifers that are having hydraulic connection with the sea. Generally, development of ground water for aquaculture, small scale industries and coastal resort makes impact on the coastal aquifer. The total coastal length of Tamilnadu is 1071 km of which Pennaiyar basin area is covering a coastal length of 22.09 km.

Location

The study area is situated in the Northeastern part of Tamilnadu and lies between North latitude 11°51′56″ and 11°41′01″ and East longitudes 79° 47′ 12″ and 79° 46′ 49″ and falls in the survey of India toposheet Nos.58 M/12 & 58 M/14 The study area covers the coastal length of 22.09 km and width of 5km from coastline of Cuddalore block. The extent of area is 111sqkm from Singirikudi village to capper quarry village.

Methodology

The State Ground and Surface water resources data centre, Water Resources Department, PWD has been under taking sea water intrusion study systematically along the Coast of Tamilnadu.

For Sea Water Intrusion study in Pennaiyar basin, six open well water samples chemical analysis data were collected for post monsoon & pre monsoon period from 2011 to 2014 from the above department (**Table 9.12 & 9.13**). The above well location map is plotted **(Fig 9.5).** 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 for indicating sea water intrusion which are shown in the **Fig 9.5 to 9.8**.

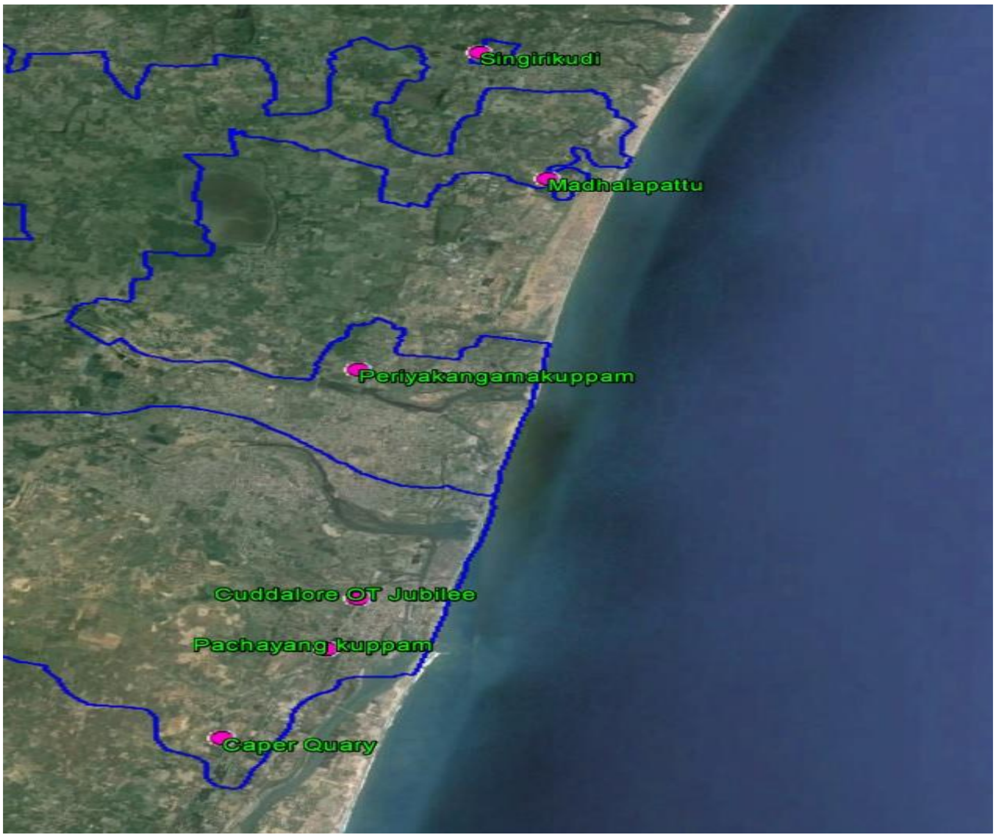
Table 9.12

Chemical Analysis of water samples for sea water intrusion study in Pennaiyar basin (Cuddalore block-2011 Pre Monsoon)

Village	Latitude	Longitutud	pH	Ec mhos/(	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
Singirigudi	11 51 56	79 46 47	8.5	680	412	200	34	28	33	71	53	40	36	189	22	0.35
Madhalapattu	11 49 48	79 47 37	8.5	1340	790	235	22	44	204	47	216	66	24	299	18	1.07
Periyakankanan kuppam	11 46 41	79 45 49	8.5	2310	1438	310	48	46	401	65	362	47	72	616	89	0.82
Cuddalore OT Jubilee	11 47 07	79 46 02	8.2	2400	1356	365	104	26	327	42	390	137	48	519	22	1.09
Pachayankuppam	11 42 21	79 45 46	8.5	990	574	235	64	18	63	72	121	62	60	165	31	0.73
Capper Quary	11 41 01	79 44 49	8.4	910	583	230	68	15	99	26	291	28	18	49	13	5.85
Chemical Analysis of water samples for sea water intrusion study in Pennaiyar basin of Cuddalore block-2012-Pre Monsson)																
Village	Latitude	Longitutud	Ph	Ec mhos/(	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
Singirigudi	11 51 56	79 46 47	7.9	620	342	185	36	23	32	43	46	6	0	293	9	0.27
Madhalapattu	11 49 48	79 47 37	8.1	1150	672	160	22	26	143	82	138	34	0	409	22	0.58
Periyakankanan kuppam	11 46 41	79 45 49	8	1140	664	240	42	33	116	61	117	48	0	384	55	0.52
Cuddalore OT Jubilee	11 47 07	79 46 02	8	2710	1502	610	88	95	293	85	532	67	0	634	25	1.44
Pachayankuppam	11 42 21	79 45 46	7.8	1220	699	365	52	57	73	68	142	12	0	427	81	0.57
Capper Quary	11 41 01	79 44 49	8.1	1040	563	345	44	57	76	7	255	60	0	122	3	3.60
Chemical Analysis of water samples foe sea water intrusion study in Pennaiyar basin (Cuddalore block-2013 Premonsoon))																
Village	Latitude	Longitutud	Ph	Ec mhos/(	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
Singirigudi	11 51 56	79 46 47	8.3	1020	603	235	68	16	86	69	103	54	0	317	49	0.56
Madhalapattu	11 49 48	79 47 37	8.2	1610	892	240	40	34	228	54	262	52	0	409	18	1.10
Periyakankanan kuppam	11 46 41	79 45 49	8.3	1910	1114	310	56	41	193	176	206	24	0	641	97	0.55
Cuddalore OT Jubilee	11 47 07	79 46 02	8	2890	1619	660	152	68	300	103	532	22	0	787	49	1.16
Pachayankuppam	11 42 21	79 45 46	8	1140	636	325	90	24	76	62	106	12	0	372	80	0.49
Capper Quary	11 41 01	79 44 49	7.9	1030	532	350	86	33	76	0	230	33	0	133	13	2.98
Chemical Analysis of water samples for sea water intrusion study in Pennaiyar basin (Cuddalore block-2014 Pre Monsoon))																
Village	Latitude	Longitutud	Ph	Ec mhos/(	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
Singirigudi	11 51 56	79 46 47	8.2	1180	648	285	62	32	97	55	106	86	0	384	18	0.47
Madhalapattu	11 49 48	79 47 37	8.2	1280	689	350	84	34	115	16	184	67	0	342	18	0.93
Periyakankanan kuppam	11 46 41	79 45 49	8.2	1940	1128	425	100	43	225	33	284	130	0	439	93	1.11
Cuddalore OT Jubilee	11 47 07	79 46 02	7.7	1950	1099	395	128	18	189	113	291	93	0	525	4	0.95
Pachayankuppam	11 42 21	79 45 46	7.8	1460	823	395	94	39	115	59	184	96	0	366	53	0.87
Capper Quary	11 41 01	79 44 49	7.9	870	436	280	70	26	51	6	184	23	0	134	9	2.36

EC- Electrical conductivity, TDS- Total Dissolved Solids, TH- Total Hardness, Ca- Calcium, Mg- Magnesium, Na-Sodium, K- Potassium, Cl- Chloride, SO_4- Sulphate
CO_3- Carbonate, HCO_3- Bicarbonate, NO_3 - Nitrate.

Fig 9.9 Sea Water Intrusion Study Well Location Map



9.8.1. Conclusion:

In the study area of Pennaiyar river basin (22.09kms) the following main villages are covered. They are,

1)Singirigudi 2) Madalapattu 3) Periyakankanankuppam 4) Cuddalore OT 5) Pachayankuppam 6) Caper quarry. The moderate high value of Electrical conductivity (EC) in Singirigudy, Madalapattu, Peryakankanankuppam & cuddallore OT location is due to geological formation, whereas remaining wells shows no remarkable sea water intrusion

9.8.2 Recommendation

The following recommendations are given to have an effective control of Sea water intrusion into the inland aquifer.

1) The land ward movement of sea water can be checked or prevented by maintaining the water level.

2) The Construction of the well above the mean sea level.
3) There should not be any over exploitation of ground water with in 10 km, from the coastal line.
4) If any unavoidable development activities arises in the coastal area, construction of Sub dyke along the coast is the remedy for preventing sea water intrusion.

9.9 Natural Calamities (Flood)

Pennaiyar River Basin has an area of 11375.55sqkm. and the entire basin lies in Cuddalore, Dharmapuri, Krishnagiri, Salem, Thiruvannamalai, Vellore & Villupuram districts. 44 Rain gauge stations and six climatic stations lie in this Basin. Rain gauge stations are maintained by Public Works Department, Revenue Department, and all the climatic stations are maintained by PWD.

Pennaiyar basin area receives an average of 882.43mm annual rainfall. The rainfall varies from 800 mm in the western part to 1300 mm in the coastal belt. The basin area in the western part gets considerable rainfall during Southwest monsoon while the coastal belt receives copious rainfall during Northeast monsoon period. Generally flood occur during Northeast monsoon period when there is heavy rainfall coupled with cyclonic storm. Flood had already occurred during 2005 and 2015 causing considerable damages to irrigation structures, crops, and properties. During Northeast Monsoon Rainfall For the Period from 01.10.2015 to 16.12.2015 the districts Cuddalore, Vellore, Villupuram, Tiruvannamalai, Krishnagiri and Dharmapuri received more than 40% to 100 % excess rainfall which results in unprecedented floods in the above districts as shown in the table below.

Rainfall in Pennaiyar Basin from 01.10.2015 t o 16.12.2015

District	Actual Rainfall in mm	Normal rainfall in mm	Percentage Excess
Krishnagiri	442.40	280.50	58 %
Dharmapuri	449.60	320.60	40 %
Vellore	746.70	337.20	121 %
Tiruvannamalai	595.80	429.00	39 %
Villupuram	928.10	467.50	99 %
Cuddalore	1240.50	645.40	92 %

Source : IMD, Chennai

Many irrigation tanks, canals, flood banks and roads breached causing heavy losses to human habitations and their properties including inundation of standing crops and loss of cattle wealth. Due to the above Flood, the road NH 45 was heavily damaged and also railway bridges and tracks were heavily damaged.

Mitigation

- Restoring the capacity of the existing storage structures.
- Construct diversion structures like bed dams across streams/ Rivers for storing and diverting the flood waters.
- Integrate Non system tanks wherever possible with the system tanks to harness flood waters.
- Intra linking of river basins results in diverting of flood waters to deficit basins for storing and utilizing.

9.10 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.

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.

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.
- Salinity affects production in crops, pastures and trees by interfering with nitrogen uptake, reducing growth, stopping plant reproduction and ultimately results in soil erosion.
- 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.
- Recovery of coastal aquifer is near impossible.

In Pennaiyar river basin, even though water logging and salinity are not prevalent like other major problems, they are observed in few locations. The quality of formation of water in the fractured aquifer varies from place to place. The water quality standards in India for Irrigation in respect of salinity are given in **Table 9.14** and the Electrical conductivity values with respect to the district of Pennaiyar basin is given in **Table 9.15**

Table 9.14 Water quality standards in India for Irrigation in respect of salinity

Salinity	EC (micro mhos cm^{-1}) at 25^0C	Remarks
Low	0-250	Can be used for most crops on most soils with little likelihood of soil salinity development. Some leaching may be required in soils with low permeability
Moderate	250-750	Can be used for all but extremely salt-sensitive crops when grown on soils of high to medium permeability. With soils of low permeability, some leaching and at times growing moderate salt tolerant crops are necessary.
Medium	750-2250	Can be used only on soils of moderate to good permeability. Regular leaching may be needed to prevent development of salinity, Crops with moderate to good salt tolerance should be grown.
High	2250-4000	Can be used only on soils of good permeability and where special leaching is provided to remove excess salts. Only salt tolerant crops should be grown.
Very High	4000-6000	Undesirable for irrigation and should be used only on highly permeable soils with frequent leaching and with plants of high salt tolerance
Excessive	Above 6000	Unsuitable for irrigation

Source: SG & SWRDC, WRD

Table 9.15 Electrical Conductivity in Pennaiyar River Basin					
DISTRICT	TALUK	VILLAGE	Electrical Conductivity		REMARKS
			JANUARY 2012	JULY 2012	
Krishnagiri	Denkanikottai	Anchetty	1097	1417	Medium
	Hosur	Gudisadanapalli	1617	945	Medium
	Krishnagiri	Chinnamuthur	1972	1900	Medium
	Krishnagiri	Theertham	1455	1348	Medium
	Uttangarai	Uthangarai	2450	2191	High
Dharmapuri	Dharmapuri	Narthampatti	906	598	Medium
	Harur	Kambainallur	1592	2266	Medium
	Palakkodu	Jakkasamudram	1644	1938	Medium
	Palakkodu	Pulikarai	2030	1181	Medium
	Pappireddipatti	Sungarahalli	1723	1573	Medium
Vellore	Tirupattur	Andiyappanur	1542	2336	High
	Tirupattur	Kakankarai	1055	1303	Medium
	Tirupattur	Kothur	752	1156	Medium
	Tirupattur	Udaymuthur	1398	1106	Medium
	Vaniyambadi	Alangayam	2550	1995	High
Thiruvannamalai	Chengam	Melchengam	644	1194	Medium
Villupuram	Gingee	Aviyur	631	420	Moderate
	Kallakkurichi	Thandalai	653	452	Moderate
	Sankarapuram	Arulampadi	1242	1958	Medium
Cuddalore	Cuddalore	Cuddalore OT	2994	2855	High
	Cuddalore	Palur	938	1073	Medium
	Panruti	Pulavanur	1697	1530	Medium

From the above table, it is inferred that the water quality is bad for irrigation in the villages Cuddalore OT, Pulikarai, Uthangarai and Alangayam as the Electrical conductivity Values are in the range of 2000 μS/cm to 3000 μS/cm.

In the above areas only salt tolerant crops should be grown such as Sunflower etc..

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 levelling, 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

9.11 Fisheries

Tamil Nadu is one of the leading States in India in fisheries development having a coastal length of 1076 km. 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 2500 species of fishes found in different aquatic environment.

Pennaiyar River Basin has a coastal length of 22.09 kilometers. The fisheries sector has been broadly categorized as Inland fisheries and Marine fisheries.

- Out of 591 marine fishermen villages in Tamilnadu, 49 marine fishermen villages in are in Cuddalore district. The reservoir fisheries scheme is implemented in Wellington Reservoir at Tittagudi Taluk with a total extent of 780 hectares .
- There are about 19 fishermen co-operative societies covering 20 villages in Viluppuram District. The fishermen population is estimated at 13998 in the district.
- Tilapia(fresh water fish) Research Centre is located in Pungampatti village in Barur, Krishnagiri district. This centre is mandate for Tilapia breeding techniques, tilapia seed production, etc. The centre provide training to farmers of Krishnagiri, Salem and Dharmapuri, Vellore and Thiruvannamalai districts.

9.11.1 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.

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 Harbor, Mudasalodai Fishing Landing Centre and Annankoil Fish Landing Centers, total annual fish landing is 40,000 tones in Cuddalore District. Year wise Inland Fish production in Pennaiyar River Basin is depicted below in **Table 9.16** and Year wise Marine Fish production in Pennaiyar River Basin is depicted below in **Table 9.17**

Table 9.16 Year wise Inland Fish production in Pennaiyar River Basin

(in Tonnes)

Sl.No	Districts	2004-05	2005-06	2006-07	2007-08	2009-10	2010-11	2011-12	2012-13	2013-14
1	Krishnagiri	0	32.38	0	136.05	60.81	56.75	86.62	0	112.88
2	Dharmapuri	510.00	1100.40	1363.51	1738.53	1558.36	2001.51	2343.70	1732.73	2238.86
3	Salem	441.00	541.23	5626.68	816.62	777.71	1156.37	1372.93	948.65	1531.80
4	Vellore	8629.00	15984.68	16304.65	16625.94	16392.17	18679.57	20047.61	22462.90	20894.68
5	Thiruvannamalai	0	0.19	148.92	1.12	1.12	0.50	0.76	0	141.86
6	Villupuram	180.00	180.50	159.88	190.57	290.87	1729.31	1791.93	1751.93	1934.09
7	Cuddalore	6549.00	14631.19	14893.76	15206.37	15641.84	15548.13	16656.03	16848.01	17382.35

Table 9.17 Year wise Marine Fish production in Pennaiyar River Basin (in Tonnes)

Sl.No	Districts	2004-05	2005-06	2006-07	2007-08	2009-10	2010-11	2011-12	2012-13	2013-14
1	Villupuram	7231	7637.67	8225.24	10731.50	14054.81	20457.02	15874.56	15982.66	16080.14
2	Cuddalore	35385	21380.61	29625.27	30503.21	22086.13	25531.73	25646.62	25820.68	25978.19

From the above table it is derived that both the inland fish production and marine fish production in Pennaiyar River Basin has been increased tremendously in all the districts from the year 2004 to 2014.

Under TNIAMWARM Project, Earthen Seed rearing centers is functioning at Saravanakuppam, Kanaiyar and Ulundurpet villages and Ulundurpet block and also in Aquaculture Irrigation tanks, fish seed rearing in cages stocking for Rohu, Catla and Mrigal and also fish fingerlings culture in Gadilam basin, and fish implements. Fish culture activity is in progress in the fish ponds of Ulundurpet block. The Fish Kiosk is successfully functioning at Thirukoilur & Rishivandiyam blocks of Villupuram District. Hence Farmers were most benefited through TN-IAMWARM project

Source:Environmental Cell Division, Tharamani, Chennai-113.

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; Introduction of short seasonal fish varieties like Gift Tilapia, Amur carp, Pangasius and JayanthiRohu.
- 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.

9.12 Public Health

Urbanization in India has been taking place at a rapid pace at an average rate of around two percent per annum. In Pennaiyar river basin the total population is 5595272. Due to Urbanization and drastic increase in population, the water demands in domestic, agricultural and industrial sectors have gone very high. But the available potential of both surface and ground water is not sufficient to meet the requirements. The used water 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. Some of the water borne diseases and the cause for the disease is shown in **Table 9.18** and District wise prevalent diseases in the Pennaiyar basin are depicted in **Table 9.19**

Table 9.18 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 cholerare. This disease happens when cholerabacterium present in drinking water or in the food that we eat.
3	Japanese Encephalitis	Mosquito borne zoonotic viral disease
4	Leptospirosis	Re-emerging infection of zoonotic origin.
5	Malaria	This is a parasitic disease transmitted from one person to another. It happens from the bite of female Anophelesmosquitoes.
6	Dengue Fever	An outbreak prone viral disease is transmitted by Aedes mosquitoes.
7	Dysentery	An intestinal inflammation, especially in the colon, that can lead to severe diarrhoea with mucus or blood in the faeces.
8	Chikungunya	Caused by a virus and is transmitted to humans by Aedes mosquitoes.

Table 9.19 - District wise prevalence diseases in Pennaiyar River Basin

Acute Diarrhoeal Disease

District	2005		2006		2007		2008		2009		2010		2011		2012		2013	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Krishnagiri	-	-	251	3	160	1	115	1	62	1	260	8	3171	0	5248	2	4120	4
Dharmapuri	884	5	7	0	1	0	57	3	124	0	106	3	3471	0	209	2	179	0
Vellore	4038	4	3400	0	3805	4	3871	5	2700	0	3355	1	10840	0	11241	0	9644	3
Thiruvannamalai	8003	3	6499	1	6425	2	7311	0	7371	1	9423	0	10963	1	12497	0	12754	1
Villupuram	2961	10	1850	2	955	2	787	7	12219	2	655	5	4890	5	11549	0	10759	2
Total	15886	22	12007	6	11346	9	12141	16	22476	4	13799	17	33335	6	40744	4	37456	10

Cholera

District	2005		2006		2007		2008		2009		2010		2011		2012		2013	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
Krishnagiri	-	-	10	0	2	0	38	0	6	0	0	0	0	0	0	0	4	0
Dharmapuri	7	0	0	0	0	0	38	0	3	0	2	0	0	0	0	0	0	0
Vellore	5	0	3	0	15	0	38	0	7	0	57	0	43	0	18	0	9	0
Thiruvannamalai	5	0	0	0	5	0	38	0	9	0	7	0	4	0	0	0	8	0
Villupuram	1	0	0	0	2	0	2	0	3	0	20	0	3	0	0	0	2	0
Total	18	0	13	0	24	0	154	0	28	0	86	0	50	0	18	0	23	0

Source : ENVIS Centre,Department of Environment **C** – No. of Cases **D**- No. of Death

It is observed that the number of cases reported to be higher and the death rate has been declined. The main cause for all these diseases are the polluted water. Clean water is most important to reduce the spread of these diseases.

Mitigation measures:

- The domestic and Trade effluents have to be treated 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.

9.13 Solid Waste Management

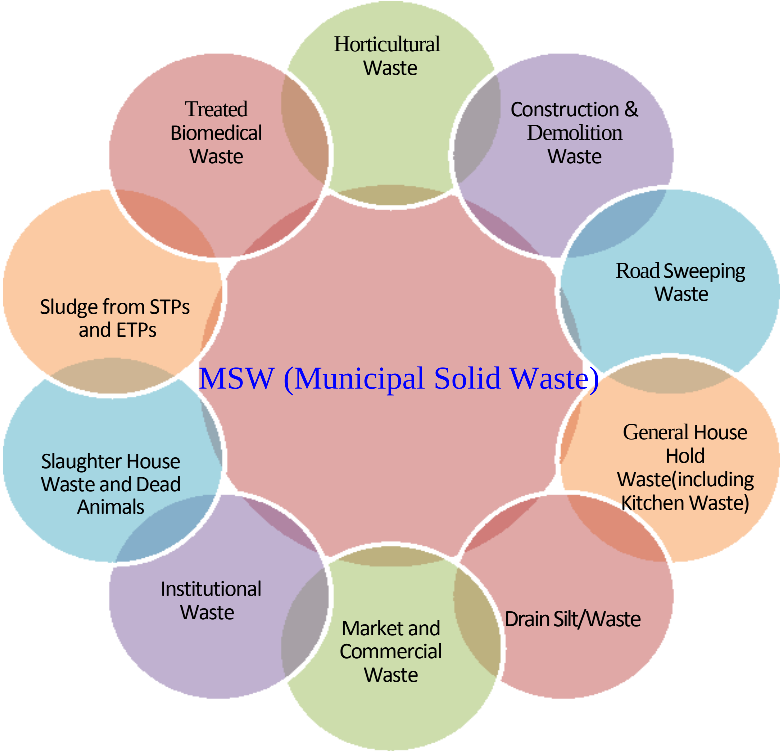
9.13.1 Solid Waste

Solid wastes are domestic, commercial, agricultural and industrial wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. Integrated Solid Waste Management is the term applied to all of the activities associated with the management of society’s waste. The basic goal of Integrated Solid Waste Management is to manage society’s waste in a manner that meets public health and environmental concerns and the public’s desire to reuse and recycle waste materials.

Solid wastes include all solid or semisolid material that the possessor no longer considers as sufficient value to retain. The management of these waste materials is the fundamental concern of all the activities encompassed in solid waste management – whether the planning level is local, regional or sub regional, or state and federal.

The various kinds of Municipal Solid Waste are depicted in the **fig 9.6**

Fig 9.6 Sources of Solid Wastes



Typical waste generation facilities, activities, or locations associated with each of these sources are reported in **Table 9.20**

Table 9.20 - Sources of solid wastes with in a community

Source	Typical facilities, activities, or locations where wastes are generated	Types of solid wastes
Residential	Single family and multifamily detached dwellings, low, medium, and high-rise apartments, etc.,	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, street leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately, oil and tires), household hazardous wastes.
Commercial	Stores, restaurants, markets, office buildings, hotels,	paper, cardboard, plastics, wood, food wastes, glass, metals, special

	motels, print shops, service stations, auto repair shops, etc;	wastes, hazardous wastes, etc.,
Institutional	Schools, hospitals, prisons, Government centers, etc.,	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, etc
Construction and demolition	New construction sites, road repair/ renovation sites, razing of buildings, broken pavement.	Wood, steel, concrete, dirt, etc.,
Municipal services(excluding treatment facilities)	landscaping, parks and beaches, other recreational areas, Street cleaning, etc.,	Special wastes, rubbish, street sweepings, landscape and tree trimmings, general wastes from parks, beaches, etc.,
Treatment plant sites; municipal incinerators	Water, wastewater, and industrial treatment processes, etc.,	Treatment plant wastes
Municipal solid waste	All of the above	All of the above
Agricultural	Field and row crops, orchards, vineyards, dairies, farms, etc.,	Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes

Source :*Journal Club for Applied Sciences* (JCAS)

The haphazard dumping of civic garbage on open lands in Town Panchayats and Municipalities causes pollution to water and atmosphere. The solid waste is dumped without segregating vegetables and organic matter, inert materials like glass, metal, stones, ashes, cinders, textiles, wood, grass etc. Raw sewage is let in freely which go into the soil and pollute the soil and groundwater. The type of litter generated and the approximate time it takes to degenerate is given in the **Table 9.21**

Table 9.21 - Type of litter generated and the approximate time it takes to degenerate

Type of litter	Approximate time it takes to degenerate
Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two
Paper	10-30 days
Cotton cloth	2-5 months
Wood	10-15 years
Woolen items	1 year
Metal items, Plastic bags and Glass bottles	Above 50 years

Source: edugreen.teri.res.in

The quantity of solid waste will also bear a relation with socio-economic conditions of the Society, the climate condition of the city or town, the growth rate of the city or town, density of population, development of residential and commercial areas or activities and the degree of salvaging waste at source.

The collection, segregation, transportation, processing and disposal of solid wastes in Municipalities are depicted in the **Table no. 9.22**

Table 9.22 Status of Solid Waste Management in Municipality in Cuddalore, Dharmapuri, Tiruvannamalai and Vellore districts

District	Municipality	MSW collection	MSW segregation	MSW storage	Transportation	Processing	Disposal
Dharmapuri	Dharmapuri	Door to Door by Municipality Staff & SHG	Partial segregation at source	No intermediate storage	Through Tractor & Lorry	No Process	Dumping as it is
	Hosur	Door to Door by Municipality & SHG	Partial segregation at Source	No intermediate storage	Through Tractor & Lorry	Market waste alone composting	Dumping as it is
	Krishnagiri	Door to Door by Municipality & SHG	Partial segregation at Source	No Storage	Trucks & Tippers	Steps taken for composting	At present dumping
Vellore	Jolarpet	The solid waste collected in the street bins are transferred to the open dumping yard through trucks.	The local body has carried out source segregation of solid waste by door to door collection in 4 wards	No transfer stations provided/ The solid waste collected in street bins are directly disposed through trucks and dumped in open dumping yard.	The solid waste collected in street bins are transported to the open dumping yard through 2 No. of trucks	No waste processing facility provided.	The solid waste collected are dumped in the open dumping yard
Tiruvannamalai	Tiruvannamalai	Daily collected by sanitary workers	No segregation	open dumping	Truck TIPPER -2 Tricycle-22 Dumper placer-1	NIL	open dumping

Cuddalore	Cuddalore	Collection is one by house to house	Partial segregation at source	Dumped in the site	Tricycle, Push Cart and Tractor Trailor	Composting	Dumping as it is at one site
	Nellikuppam	Collection is done by house to house	Partial segregation at source	Dumped in the site	Dumper – Placer, Push cart, Mini auto, TATA ACE	Composting	Dumping as it is at one site
	Panruti	Collection is done by house to house	Partial segregation at source	Dumped in the site	Tricycle, Tractor Trailorand Dumper – Placer	Composting	Dumping as it is at one site

Source: Tamil Nadu Pollution Control Board MSW Annual Report 2013-2014.

The Solid Waste generated from various sectors has been calculated based on Ready Reckoner on Implementation of MSWM for Urban Local Bodies in Tamil Nadu. The quantity of solid wastes generated from Urban and Rural areas of this basin have been calculated as 92344 tonnes and 250420 tonnes respectively.

Out of the total solid waste, 60% of the solid waste can be converted into manure. Based on these calculations manure generation in Census Town, Town Panchayats, Municipalities and Corporation has been worked out at the rate of Rs.500 per tonne and is depicted in **Table9.23 and 9.24**

Table 9.23

Generation of Manure in Rural Areas in Pennaiyar river basin

The solid waste assumed is 0.27 Kg/capita/day as per the norms for generation of garbage in Ready Reckoner on Implementation of MSWM for Urban Local Bodies in Tamil Nadu

Sl. No	Name of Sub Basin	Population as on 2011	Estimated Population as on 2015	Solid Waste generated in tonnes/ year	Manure generated in tonnes / year	Revenue from manure in Lakhs / year
1	Chinnar – West	49883	52528	5177	3106	16
2	Chinnar – East	89169	93897	9254	5552	28
3	Markandanadhi	100511	105840	10431	6258	31
4	Kambainallur	365901	385302	37972	22783	114
5	Pambar	611087	643489	63416	38050	190
6	Vaniyar	246829	259916	25615	15369	77
7	Matturar	16388	17257	1701	1020	5
8	Kottapattikallar	38846	40906	4031	2419	12
9	Valayar Odai	20777	21879	2156	1294	6
10	Ramakal Odai	0	0	0	0	0
11	Pambanar and Varattar	69445	73127	7207	4324	22

12	Aliyar	62955	66293	6533	3920	20
13	Musukundanad hi	57854	60922	6004	3602	18
14	Thurinjalar	346542	364916	35963	21578	108
15	Gadilam	767527	808224	79650	47790	239
16	Upto Krishnagiri reservoir	233241	245608	24205	14523	73
17	Krishnagiri to Pambar	301174	317143	31254	18753	94
18	Pambar to Thirukovilur	300324	316248	31166	18700	93
19	Lower Pennaiyar	343370	361576	35633	21380	107
	Total	4021823	4235071	417368	250421	1253

Source: Analysis

Table 9.24

Generation of Manure in Urban Areas in Pennaiyar river basin

The solid waste assumed is 0.31 Kg/capita/day as per the norms for generation of garbage in Ready Reckoner on Implementation of MSWM for Urban Local Bodies in Tamil Nadu

Sl. No	Name of Sub Basin	Population as on 2011	Estimated Population as on 2015	Solid Waste generated in tonnes/ year	Manure generated in tonnes / year	Revenue from manure in Lakhs / year
1	Chinnar – West	219408	237494	26872	16123	81
2	Chinnar – East	0	0	0	0	0
3	Markandanadhi	0	0	0	0	0
4	Kambainallur	85715	92781	10498	6299	31
5	Pambar	131769	142631	16139	9683	48

6	Vaniyar	46220	50030	5661	3397	17
7	Matturar	0	0	0	0	0
8	Kottapattikallar	0	0	0	0	0
9	Valayar Odai	0	0	0	0	0
10	Ramakal Odai	0	0	0	0	0
11	Pambanar and Varattar	0	0	0	0	0
12	Aliyar	0	0	0	0	0
13	Musukunda-nadhi	0	0	0	0	0
14	Thurinjalar	180955	195871	22163	13298	66
15	Gadilam	333912	361437	40897	24538	123
16	Upto Krishnagiri reservoir	20866	22587	2556	1533	8
17	Krishnagiri to Pambar	164174	177707	20108	12065	60
18	Pambar to Thirukovilur	13394	14498	1641	984	5
19	Lower Pennaiyar	60201	65163	7373	4424	22
	Total	1256614	1360199	153908	92344	461

Source: Analysis

The total revenue of manure from Urban and Rural areas of this basin is Rs.1714 lakhs/year. This manure generated from solid waste can be used for crops and thereby the use of chemical fertilizers and pesticides can be avoided. It also serves as an additional income to the farmers.

The Ministry of Environment and Forest, Government of India has issued MSW (management and handling) rules in the year 2000 for scientific MSWM, ensuring proper collection, segregation, transportation, processing and disposal of MSW and upgrade of the existing facilities to arrest contamination of soil and groundwater. TNPCB is now actively involved in creating public awareness about this issue.

Impacts of solid waste to the Environment:

1. Groundwater and surface water pollution
2. Reduction in infiltration rate
3. Artificial flooding
4. Reduction in capacity of Reservoir and tanks
5. Reduction in carrying capacity of rivers, streams, canals and channels.
6. Health problems
7. Odour and flies

Mitigation

- Proper segregation would lead to better options and opportunities for scientific disposal of waste.
- Solid Wastes have to be segregated into Recyclables, Compostable or combustible materials and Inert materials at the source itself.
- By recycling, the quantity of solid waste dumping can be reduced and recycling leads to the mobilization of income for survival of downtrodden people.
- The site for Municipal Solid Waste dumping yard have to be suitably selected to prevent flow of surface water from such dumping yard directly in to streams.
- By Vermi composting and Indigenous composting method, the combustible solid waste can be made as organic manure. This is one way of disposing the solid waste and due to this, the usage of chemical fertilizers also gets reduced.
- The debris and the inert materials can be used as filling materials, so that the quarrying of filling sand in riverbed can be reduced to some extent.
- Landfill gas extraction systems adds to climate change initiatives, as it helps reduce Green House Gas emissions through avoidance of landfill gas (mainly comprising of methane) into the atmosphere. This has been effective in Kodungaiyur and Perungudi dumping yards in Chennai. The same can be implemented in this basin also.
- The involvement of people and private sector through NGOs could improve the efficiency of MSWM.
- Littering of MSW (Municipal Solid Waste) should be prohibited in cities, towns and urban areas notified by the state government.

- Public awareness, effective community participation, transparent and clean administration, and accountability at all levels can only bridge the gap of governance in waste management and issues pertaining to successful management of waste.
- Organizing the informal sector and promoting micro-enterprises are an effective way of extending affordable services.
- Hence urban local bodies must ensure that biomedical wastes and industrial wastes should not be mixed with municipal solid wastes, failing which will result in economic losses.

9.14 Wild Life

Wildlife and wildlife habitats which are products of millions of years of evolution should be conserved and sustainably managed to meet the social, economic, ecological, cultural, recreational and spiritual needs of the present and future generations. Wilderness areas and particularly forests which are the repository of wildlife and biodiversity have either shrunk or disappeared due to severe agricultural, natural and domestic pressures. Natural processes, forests and other wildlife habitat recharge aquifers maintain water regime and moderate impacts of floods, droughts and cyclones and thereby they ensure food security and regulate climate change.

Forests and the wilderness areas are the treasure-house for multitude of biodiversity beyond our imagination.. These areas forms the best underground water tank holding volumes of precious pure water which are released gradually into the streams, rivers and wells down below. They form the carbon sink, sucking and storing the lethal carbon-di-oxide for the benefit of all living things. They are the most natural lungs providing the vital oxygen for all the living things to breathe and survive.

Dharmapuri district is predominantly covered with forests. Spider valley located near hogenakkal is home for many wild animals. The district falls in the migratory path of elephants. Man and elephant conflicts are most common in these parts.Many tribal communities depend on these forests. Vathalmalai,a mountain hamlet on top of shervarayan hill chain has suitable conditions to cultivate coffee and jack fruit. Wild boars and spotted deers are commonly seen in Morappur and Harur forest region. Gaurs sometimes stroll near villages near Bommidi region. Thoppur ghat section has one of the scenic highways surround by mountains and forests.

SATHANUR CROCODILE FARM

"Crocodylus Palustris"- Type of crocodiles is in existence here

HOGENAKKAL CROCODILE FARM

Sathanur crocodile farm is being maintained by the forest department since 1977. This is suituated in the South East corner of Sathanur Dam which is 35 km from Tiruvanammalai. At present 395 nos of Marsh Crocodiles (Crocodylus Palustris) are there in the farm.

Some of the strategies adopted by the Forest department for preserving the wild life are as follows:-

- Providing absolute protection of the area from all factors causing degradation, depletion and destruction of wildlife and wildlife habitats by strict enforcement of the Wildlife (Protection) Act, 1972 and Tamil Nadu Forest Act, 1882.
- Eco-development works in and around protected areas.
- Encourage appropriate monitoring and research works to develop programmes and plans, and thereby tackle the identified problems.
- Create awareness on the need to conserve our natural bio-resources through various mass media and other means.
- Take fire prevention and control measures in and around Sanctuaries through specific programmes.
- Prevention of outbreak of contagious diseases among wild animals by taking prophylactic measures among domestic animals entering Sanctuaries and National Parks.
- Construction of crop protection structures like fences, trenches and walls, etc.

- Restriction and regulation for pollution causing industries and activities in a radius of 25 kms around the protected areas as per the Environment Protection Act.
- Integrate the wildlife Protected Areas on a watershed or landscape basis with other sectors like Rural Development, Animal Husbandry, etc. for the sustained conservation and development of the area.
- Conserve the medicinal plants in the protected area by creation and management of Medicinal Plants Conservation Area (MPCAs).
- Tourism demands are subservient to conservation and to the interest of the protected area and therefore wildlife tourism exists for the Parks and not Parks for tourism

(Source: www.forests.tn.nic.in)

Conclusion

- The Protected Areas of Tamil Nadu have the immense potential to arouse the senses, humans are endowed with - be it visual, auditory, smell, taste or touch.
- Even though traditionally we have respected and revered and conserved our natural wealth and biodiversity, they have come under severe threat recently due to various anthropogenic causes. Degradation of forests, the habitats of wildlife, fragmentation, overgrazing by domestic cattle, forest fires, poaching and killing of animals due to man-animal conflict are the main threats our wildlife population in Tamil Nadu facing today. People's involvement and support is absolutely essential to make the wildlife conservation a success in our State.

9.15 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 Pennaiyar basin and district wise most popular tourist spots are as follows in **Table 9.25**

Table 9.25 - Tourist attractions in Krishnagiri district

S.No	Tourist Spot	Description
1	Krishnagiri Reservoir Project (KRP) Dam, Krishnagiri	KRP dam is situated at a distance of 7 Kms from Krishnagiri. It is in between Dharmapuri and Krishnagiri. Thousands of acres of land around Krishnagiri is irrigated with the help of this dam. This is a famous tourist spot too
2	Thali (little England), Denkanikottai	This place is about 25Kms from Hosur. It is at the border of Tamil Nadu adjoining Karnataka. It is situated in the land of valleys and cliffs. The climate is very cool and pleasant. It experiences cold and cloudy weather resembling England
3	Kelevarapalli Reservoir Project(KPRP), Hosur	It is situated at a distance of 10Kms from Hosur. It is only 8Kms away from Karnataka state. This has become a picnic spot for citizens of Hosur area.
4	Government Museum, Krishnagiri	The museum is functioning since 1993 AD, situated on Gandhi Salai in Krishnagiri. Historical monuments are preserved and exhibited here. It is not only a place of tourism but also a center of education. This museum collects the monuments, Classifies and preserves them to conduct research on it's historical worthiness.
5	Rajaji Memorial – Thorapalli	In memory of the great leader Rajaji, the Tamil Nadu Government has converted the house in Thorapalli where Rajaji was born, as a memorial. It is located 10 Km

		from Hosur near Onnalvadi. Some of his belongings and a photo gallery depicting his various walks of life are displayed here.
6	Rayakottah, Hosur	Rayakottah, a hill fort, situated at a distance of 30Km from Hosur marks the border of the Palghat plateau. Even after the Mysore wars, British troops were stationed till 1861.
7	Mallachandram, Samalpallam	It is located 19km from krishnagiri and 4 km from samalpallam. Samalpallam lies on the krishnagiri-Bangalore Road N.H 7. The Ancestors cult was worshiped by the Megalithic people in the ancient period. In krishnagiri District three kinds of memorials are observed and they were named a Cairn circle, Dolmen and Urnburials. In Mallachandram more than 100 Dolmens are identified in the Moral Pari. Four types of dolmens in this single place.

Tourist attractions in Dharmapuri district

S.No	Tourist Spot	Description
1	Hogenakal	It is situated at the borders of Karnataka at 46 kms from Dharmapuri. In Hogenakal the river Cauvery enters into Tamil Nadu as a big river with gushing water presentably as a natural falls.
2	Theerthamalai	It is an important sacred place in Harur taluk of Dharmapuri

		District. Shri Theerthagirishwarar Temple is located at the top of a hillock. Chola and Vijayanagara Kings donated liberally to this temple.

Tourist attractions in Tiruvannamalai district

S.No	Tourist Spot	Description
1	Arunachaleswarar Temple	It is a Hindu temple dedicated to the deity Shiva, located at the base of Annamalai hills in the town of Thiruvannamalai. The temple at Tiruvannamalai is one of the biggest and grandest temples in South India. With the hill as back ground it gives the appearance of a fort to those who see it from a distance. It is unique on account of its stately towers, high rampart walls, broad quadrangles, spacious gateways, large mantapams and fine tanks. It has also much architectural importance and sculptural beauty. The Karthigai Deepam festival is celebrated during the day of the full moon between November and December, and a huge beacon is lit atop the hill. It can be seen from miles around, and symbolizes the Shiva lingam of fire joining the sky. The event is witnessed by three million pilgrims. On the day preceding each full moon, pilgrims circumnavigate the temple base and the Annamalai hills in a worship called Girivalam, a practice carried out by one million pilgrims yearly.
2	Sri Ramana Ashram	Sri Ramana Ashram is one the holy places in this town. People from all over the world

		visit his Ashram.
3	Sri Seshadri Swamigal Ashram	Sri Seshadri Swamigal Ashram is one of the holy places in Tiruvannamalai. People from all over the world visit this Ashram, which is situated near the Sri Ramana Ashra the people who visit here.
4	Yogi Ram Surathkumar Ashram	Yogi Ram Surathkumar Ashram, also known as Visiri Samiyar Ashram, is one of the beautiful place in the Town. It is situated near the Ramana Ashram.
5	Sathanur Dam	Sathanur dam is one of the major dam constructed across Pennaiyar River among Chennakesava Hills. This Dam was constructed during the year 1958. It has beautiful parks and a mini zoo. The garden is dotted with colourful statues and plants. **POTENTIAL FOR DEVELOPMENT OF TOURISM IN SATHANUR DAM** The Sathanur Dam parks and lawns is one of the main Tourist place in Tiruvannamalai District and more over day by day the No. of Tourists were increased. During the past so many years the Tiruvannamalai is being a very Holy place and every month during full moon day lakhs of devotional people comes to Tiruvannamalai for praying god Annamalaiyar and girivalam (Going round the Hill). Among the devotees considerable numbers are visiting the Sathanur dam also. This trend is increasing year by year. And further every month an full moon day so

		many people were visiting Melmalayanur Angala parameswari temple and Melmaruvathur temple. This devotees are also coming to Sathanur Dam for enjoying the tourist potential, more over Tiruvannamalai is centrally located in north side of Tamilnadu many people going to Tirupathi from south Tamilnadu and those going sabarimalai from Andhra Pradesh are also visiting Tiruvannamalai and Sathanur Dam throughout the year. Hence the following parks (Nehru park, Japan park, Gingee Fort Park) have to be renovated and also by proving musical dancing Fountain will attract more tourist to the reservoir which will also generate more revenue.

Tourist attractions in Villupuram district

S.No	Tourist Spot	Description
1	Gingee Fort	The small town of **Gingee was once a capital city,** With its province extending from Nellore in the north to the Coleroon (Kollidam) in the south. Gingee today, with its ruined forts, temples and granaries, presents a different picture from the glorious splendor of its bygone days. But the remains of that valorous past, speak volumes about the numerous invasions, warfare and bravery that it witnessed.
2	Mailam temple	Arulmigu Subramaniya Swami Temple located on small hillock at Mailam is a famous place for of pilgrimage. It is about 32 kms from Viluppuram. The Panguni Uthiram festival held in March - April fascinates a large crowd of devotes from all over Tamil

		Nadu.
3	Tirukoilur Temple	The temple is situated on the Cuddalore - Chittoor trunk road and 37 kms from Viluppuram. the presiding deities of the Vishnu Temple are Ulagalanda Perumal and Pushpavallithayar. Kabilar Kundru is also yet another picnic spot at Thirukkoilur which is situated in the middle of the river Pennayar. Kabilar was saint here and his last resting place, is maintained by the state Archaeological Department.

Statistical Data of the tourist arrivals in the following districts from the year 2005 to 2013 if given in Table **9.26**

Table 9.26 Tourist Arrivals during the Year 2005 to 2013

District	Tourist Arrivals during the Year								
Years	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dharmapuri	1752781	217316	267621	459275	737417	1046704	5667554	8234783	11355709
Vellore	46057	59658	68444	10849	702003	811736	589835	1032307	1731590
Tiruvannamalai	643049	3797903	2209638	2290762	3634034	5028922	8105126	11299628	14100120
Cuddalore	278014	344003	469745	1085868	858067	1947901	4282740	6055275	7391184

Source: Department of Tourism

From the above chart, 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.

9.15.1 Impact of Tourism

The following are tourism's three main impact areas:-

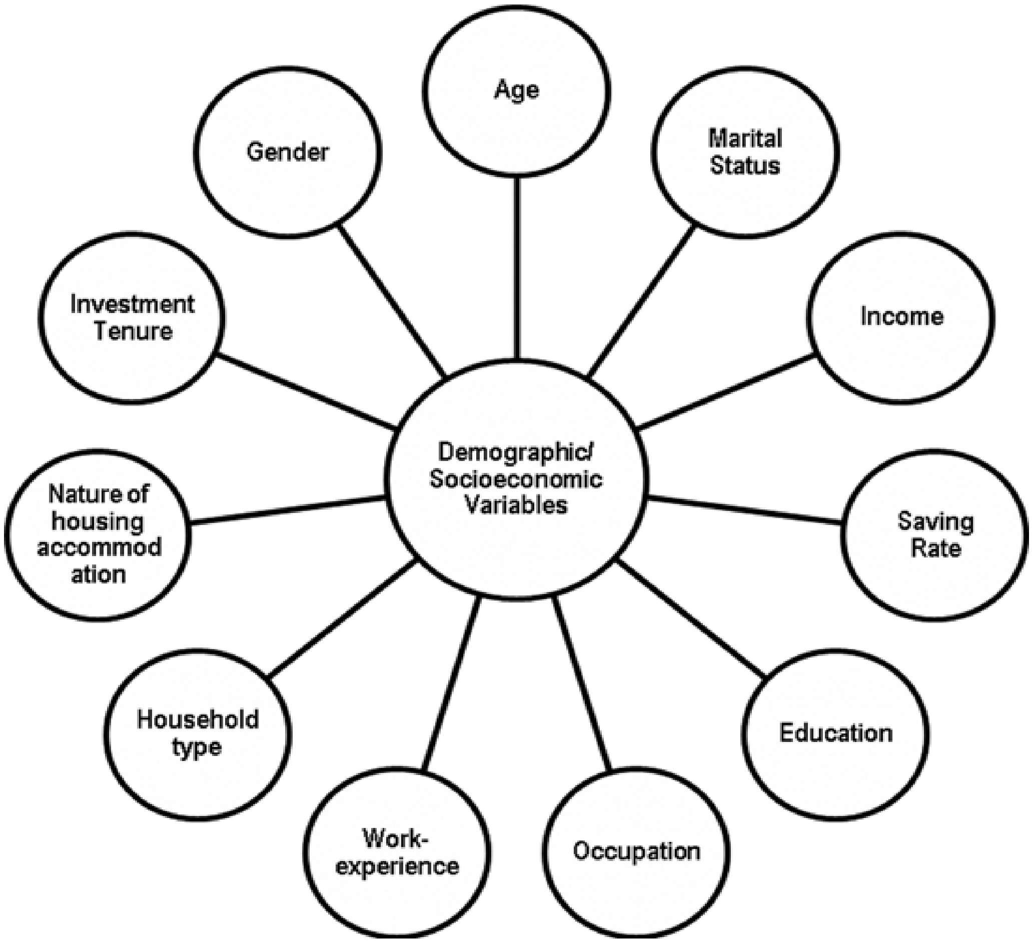
- **Depletion of Natural Resources :** These include Water resources, Local resources and Land degradation
- **Pollution :** The pollution includes Air pollution, Noise pollution , Waste disposal, sewage pollution, etc.,
- **Physical Impacts** includes degradation of ecosystems, continuing tourist activities, etc.,

Mitigation measures

- Revenue from park-entrance fees and similar sources may be allocated specifically to pay for 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 of the environmental consequences of their 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.

9.16 Socio Economic Aspects & Legal Issues

The socio economic aspects of the people depend on the factors which has been depicted in the diagram as below.



In Pennaiyar basin total population is 5.6 million which includes urban polulaiton is 1.36 million and Rural population is 4.23 million. Agriculture is practicing in all most entire basin. The Important food crops Paddy, Groundnut, Sugarcane, Cholam, Cambu, Redgram, Cotton, Gingelly, Tapioca, Greengram, Blackgram, Coriander, Banana, Maize, Varagu, Cashewnut ,Important nonfood crops Gingelly, Cotton, Groundnut, Coconut.

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 participated in the developmental activities. The alternative options such as brick works, small engineering works are major off-farm occupations of the people. Fishing is mainly carried out in Cuddalore districts.

The majority of the RED category industries are located in the Cuddalore District The Sipcot industrial park in Cuddalore consists of mainly large scale industries.

The Important Industries in the Cuddalore District are

- Neyveli Lignite Corporation , Neyveli
- MRK Sugar Mill, Sethiathopu
- EID Parry (I) Ltd, Nellikuppam
- Ambiga Sugar Mills, Pennadam
- TANFAC, Cuddalore O.T
- Vanavil , Cuddalore O.T
- National Cotton Mills, Chidambaram
- SPIC Pharma Chemicals , Cuddalore O.T
- Asian Paints (I) Limited, Cuddalore O.T
- Tagros Chemicals (I) LTD.CuddaloreO.T
- Clariant Chemicals LTD., Cuddalore O.T

Because of the rapid urbanization urban population is increased based on the demand in the Districts.

From the table 2.13, it is observed that male and female population has been equal in vellore and Tiruvannamalai Districts. The Dharmapuri district has shown a negative growth in population whereas krishnagiri district shown a nil growth. The literacy rate in urban rate is greater than the rural rate. The Cuddalore district in urban literacy rate is the highest at 86.38% whereas in Salem district the literacy rate in rural is 65.74% which is the least.

9.16.1. 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.

Article 48-A.: The state shall endeavor to protect and improve the environment and tosafe 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.

9.16.2. Acts related to Water resources & Environment & Encroachment.

Table 9.27 - Acts related to Water resources & Environment & Encroachment.

Sl. No.	Name of Act
1	The Tamilnadu 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.

9.16.3 The Government Orders related to Environmental aspects

Table 9.28 - The Government Orders related to Environmental aspects

Sl. No	G.O.Ms. No	Content
1	G.O.Ms. No. 957 PWD dated 29.5.1972	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. However, departmental emergency needs can be met with from the prohibited area without endangering water supply works.
2	G.O. Ms. No. 938 PWD dated 07.06.1988.	Condition of removal of earth from tank beds was stipulated.

3	G.O. Ms. No. 1210 PWD dated 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 dated 01.10.2003	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) dated 19.4.2004	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.
6	G.O.Ms.No.110/P.W. (W.Spl) Dept. dated 6.7.2006	New sand quarry proposals have to be sent to the District Collector for approval.

Table 9.29 The Government orders related to Industries, Environment and Forest

1	TNPCB BP Ms.No. 30 dated 21.02.1984.	The TNPCB has prescribed the effluent standards
2	G.O. Ms. No. 213 Environment and Forest ECI dept dated 30.03.1989	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.
3	G.O. Ms.No.127 /Environment and Forest Dept/ECII dt. 08.05.98 and in G.O Ms.No. (1D) 223/ Environment and Forest Dept/ECIII/dt.2.9.98	Orders imposing a total ban of setting up of the highly polluting industries within 5 Kilometers from the embankment of the following Rivers. 1. Cauvery and its tributaries 2. Pennaiyar 3. Palar 4. Vaigai 5. Tamiraparani

9.17 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 Pennaiyar River Basin, Awareness programmes have been conducted for the public, school students, farmers and local bodies by the Environmental Cell Divisions Chennai and Coimbatore, under TNIAMWARM Project, Public Works Department, Water Resources Department, 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 tanneries, 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. sand mining, effluent discharged by tanneries, Organic farming, global warming

- **Demonstration of Vermi Compost to farmers /WUA members:**

Demonstration to farmers /WUA members about the preparation of vermin compost manure in vermin 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 sand mining, effluent discharged by tanneries, etc

- **Field Visit to the farmers:**

Herbal Garden, Organic Farm, etc.

The list of awareness programmes conducted in Pennaiyar River Basin under Environmental Cell Division, Tharamani, Chennai-113 is as shown in **Table 9.30**

Table 9.30 - List of awareness programmes conducted in Pennaiyar River Basin

S.No	Name of the Programme	Name of the Sub Basin	Conducted Place	District
1	Motivating Local Bodies for Solid Waste Management	Gadilam	Ulundurpet	Villupuram
		Thurinjalar	Kilpennathur	Thiruvannamalai
		Pambar to Thirukovilur	Thandarampattu	Thiruvannamalai
		Pambanar to Varattar	Thandarampattu	Thiruvannamalai
		Pennaiyar upto Krishnagiri	Krishnagiri Soolagiri	Krishnagiri
2	Vermi Compost Demonstration to WUA	Gadilam	Pinnalvadi	
		Thurinjalar	Kilpennathur	Thiruvannamalai
		Pambar to Thirukovilur	Perungulathur, Thandrapattu block	Thiruvannamalai
		Pambanar to Varattar	Thanipadi, Thandrapattu block	Thiruvannamalai
		Pennaiyar upto Krishnagiri	Hosur	Krishnagiri
3	Awareness programme for public	Gadilam	Ulundurpet Thirunavalur Semakottai	

		Thurinjalar	Thiruvannamalai	
		Pennaiyar upto Krishnagiri	Soolagiri Krishnagiri	Krishnagiri
4	Awareness programmes for school students	Gadilam	Villupuram	Villupuram
		Thurinjalar	Thiruvannamalai	Thiruvannamalai
		Pambar to Thirukovilur	Thandrampattu	Thiruvannamalai
		Pambanar to Varattar	Thanipadi	Thiruvannamalai
		Pennaiyar upto Krishnagiri	Rayakottai Krishnagiri	Krishnagiri
5	Environmental Fair/Exhibition	Pennaiyar upto Krishnagiri	Krishnagiri	Krishnagiri
6	Field Visit	Gadilam	Organic farms in Trichy and Karur	Farmers from Cuddalore District
		Thurinjalar	Vijayanagaram, Vedanthavadi	Farmers from Thiruvannamalai district
		Pambar to Thirukovilur	Organic farms in Vijayanagaram, Vedanthavadi	Farmers from Thiruvannamalai district
		Pambanar to Varattar	Integrated Organic Farm in Vijayanagaram, Vedanthavadi	Farmers from Thiruvannamalai district

Awareness Programme Photos

Awareness Programme held at G.H.S.S, Thanipadi, Thiruvannamalai District on 04-01-2012 in Pambanar to Varattar Sub Basin.

Exhibition held in Pennaiyar upto Krishnagiri sub basin at Govt Arts College in krishnagiri, Krishnagiri District on 28.3.2012

Demonstration of Vermi Compost at Arivozhi Angahapannai, Kilpennathur on 16-02-2012 in Thurinjalar sub basin

Awareness Programme held at Shanmuga Industries Govt. Higher Secondary School, Thiruvannamalai on 05-01-2012 in Thurinjalar sub basin.

9.18 Problem Areas

In water planning, identification of problem areas is the most important aspect since the policy makers and the planners have to give top priority for the problematic areas of the basin in the developmental activities.

As per the 2009 Ground water potential assessment, the groundwater development is between 80% and above 100% in the following blocks, where the water level is depleted due to over groundwater extraction, the following blocks are assessed as over exploited.

- Chengam
- Thandrampet
- Thiagadurugam
- Ulundurpet
- Cuddalore
- Kammapuram
- Dharmapuri
- Krishnagiri
- Morappur
- Nallampalli
- Harur
- Pappireddipatti
- Bargur
- Karimangalam
- Uthangarai
- Valapady
- Tiruvannamalai
- Veppanapalli
- Mathur
- Thirupathur
- Jolarpet
- Kandhili
- Kolianur
- Kanai

Hence these areas are to be prioritized to avoid further groundwater depletion and deterioration. More over the problem of sea water intrusion has been widely recognized in coastal aquifers where the higher values of electrical conductivity may be due to semi marine conditions. The inland ward movement of sea water to be checked periodically.

The ground water quality in respect of TDS is classified as Good, Moderate and poor as per the Bureau of Indian Standards and it is found that the ground water quality is good and observed more than 50% in Cuddalore districts and 7% in Krishnagiri districts respectively. The moderate quality is observed in more than 90% in Krishnagiri district.

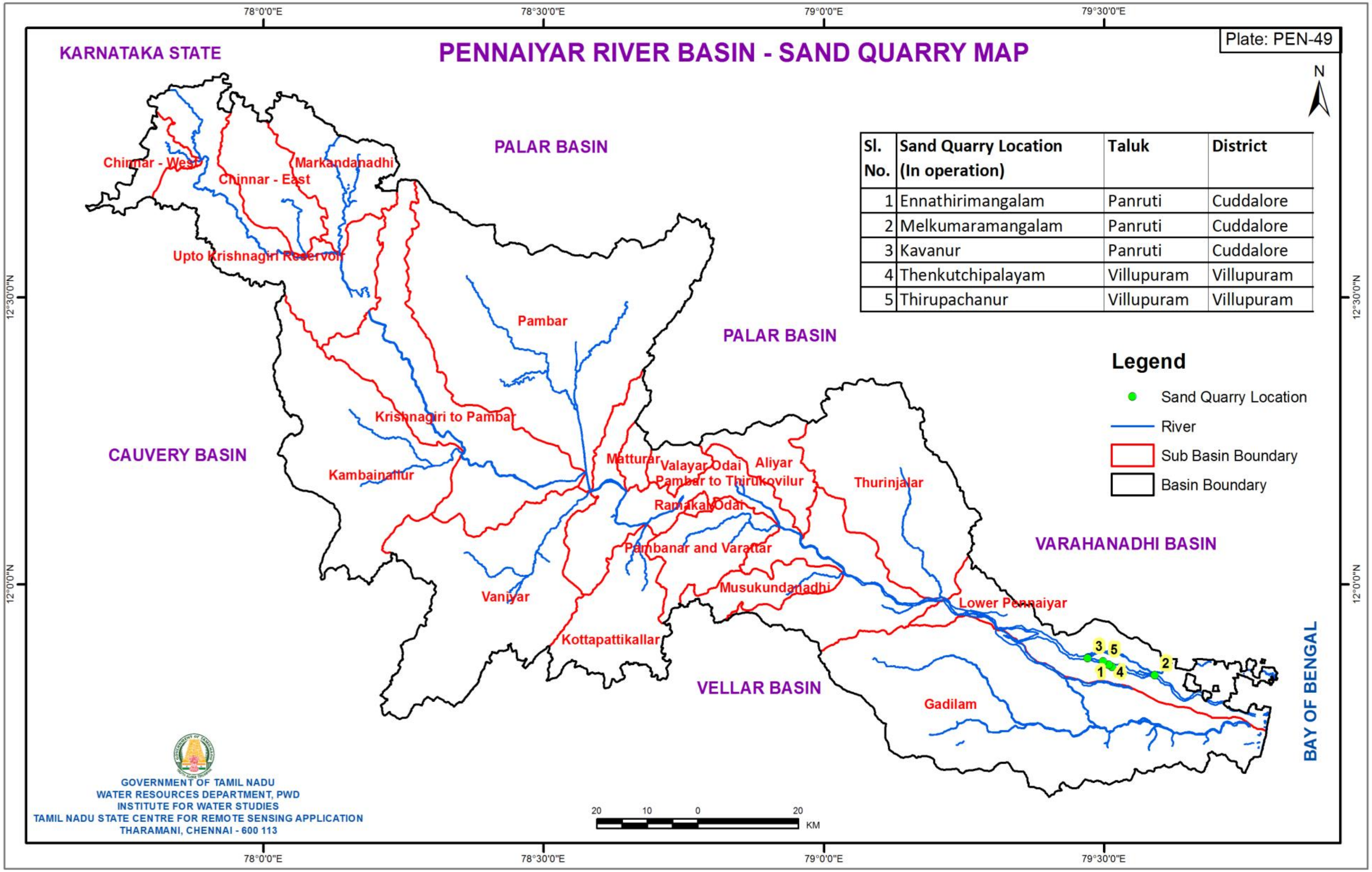
The poor quality is observed as 1% in Tiruvannamalai districts. Hence suitable measures like constructing of rain water harvesting structures, dykes, check dams etc will improve the quality of the Ground water.

9.19 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. Efficiency of irrigation systems could be improved
4. 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.
5. Necessary steps may be taken to plant tree saplings on the tanks of water bodies so as to curtail the effects of climatic changes or global warming.
6. 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.
7. 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.
8. Wherever the sand mining is done, the condition that mining should be done only upto 1m depth may be strictly imposed.
9. The metals and plastics should be recycled for further use and also awareness programmes have to be conducted on the ill effects of plastics.
10. Water weeds in water bodies may be controlled by introducing fish species like common carp, grass carp which destroys the water weeds.
11. Waterweeds as well as domestic waste can be effectively used as Protein source, as fertilizer, as Biogas source, as Soil additive and as a source of income generation.
12. Environmental protection information has to be given to the people through viable media and other sources.

13. Encroachments in and around water bodies have to be evicted, controlled and periodical monitoring has to be done. Strict Enforcement of Tamil Nadu Land Encroachment Act will protect the water bodies from encroachers.
14. Silt sedimentation studies should be carried out periodically for reservoir and tanks etc., and remove the silt to restore the designed capacity. Catchment area treatment in the upreaches of the reservoir should be carried out to minimize the rate of sedimentation. Desilitng of reservoirs can be taken up after detailed investigation.
15. Environmental management of facilities to tourism spots can boost the revenue to Government and increase the benefits by careful planning for controlled development.
16. Rainwater harvesting projects have to be carried out effectively; to increase the ground water potential.
17. Plantation program to regenerate the degraded forests.
18. Drainages and water bodies should be de-silted once a year before rainy season.
19. The garbage should not be dumped in pond and channels.
20. Farmers may resort to control the soil erosion in their fields.
21. Chemical fertilizers should be replaced with organic fertilizers in a phased manner.
22. 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.



Sl. No.	Sand Quarry Location (In operation)	Taluk	District
1	Ennathirimangalam	Panruti	Cuddalore
2	Melkumaramangalam	Panruti	Cuddalore
3	Kavanur	Panruti	Cuddalore
4	Thenkutchipalayam	Villupuram	Villupuram
5	Thirupachanur	Villupuram	Villupuram

CHAPTER - 10

PRESENT INSTITUTIONAL SETUP

CHAPTER–10

PRESENT INSTITUTIONAL SETUP

Institutional arrangements are 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 Tamilnadu, the Tamilnadu Water Resources Consolidation Project is a State-wide program implemented during 1995 – 2004 in selective sub basins to improve the productivity and sustainability of State's Irrigation 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.

10.1 Present Institutional Set Up

The various Departments / Institutions of the Government of Tamilnadu / Government of India vested with different categories of responsibilities in water resources management and supply in Pennaiyar River Basin are detailed as below;

10.1.1 Water Resources Department (WRD)

The Water Resources Department is one of the wings functioning under 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 Tamilnadu. 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 Tamilnadu.

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 regions 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.

10.1.2 Institute for Water Studies (IWS)

The Government of Tamilnadu 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 Tamilnadu 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 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 referred to it. The IWS prepared the draft Tamilnadu State Water Policy and also the Member Secretary of all water resources.

Institute for Water Studies is responsible for the delineation of River Basin and Sub Basin boundaries of all the rivers in Tamilnadu. The IWS has grouped the 34 rivers in

Tamilnadu into 17 major river basins. The Institute for Water Studies has prepared GIS based unique coding for all WRD tanks in Tamilnadu. The preparation of GIS based unique coding for all reservoirs and anicuts is in progress. The IWS is a research organization which carries out water balance study of all the river basins periodically and suggests developmental actions that are necessary to be taken up in a river basin.

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 and Tamiraparani River Basins have been taken up and completed during 2010 to 2014.This Micro level Reappraisal study of Pennaiyar 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.

Pennaiyar River Basin falls under the jurisdiction of the Chief Engineer, WRD, Chennai Region, Chennai. The Superintending Engineer, Pennaiyar Basin Circle, Tiruvannamalai coordinates the management of water resources in Pennaiyar River Basin along with the Executive Engineer, Upper Pennaiyar Basin Division, Dharmapuri; Executive Engineer, Middle Pennaiyar Basin Division, Tiruvannamalai; Executive Engineer, Lower Pennaiyar Basin Division, Villupuram; Executive Engineer, Sathanur Sub Project Implementation Division, Tiruvannamalai. The Executive Engineer along with the Sub Division and section officers responsible for execution of all the works viz., maintenance and improvements to irrigation structures, water regulation of dams / reservoirs / tanks in their jurisdiction, construction of new irrigation structures etc,.

10.1.3 Central Water Commission

Central Water Commission is a Central Government organization functioning under the Ministry of Water Resources, Government of India. Pennaiyar River Basin falls under the jurisdiction of Cauvery & Southern Rivers Organization (C&SRO) of Central Water Commission (CWC). The organization is headed by a Chief Engineer based 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. Details regarding flow particulars at gauging sites maintained by CWC are collected and these particulars are used to arrive the surface water potential.

10.1.4 Tamilnadu Water Supply and Drainage Board (TWAD)

Tamilnadu Water Supply and Drainage Board is responsible for implementation of Water Supply and Sewerage facilities to the public of the entire State of Tamilnadu except for Chennai Metropolitan city. Pennaiyar river basin falls under the jurisdiction of the Chief Engineer, Chennai. The Engineering Director, Chennai; Superintending Engineer, Cuddalore-Villipuram, Superintending Engineer, Dharmapuri-Krishnagiri, Superintending Engineer, Villipuram and the Superintending Engineer, Vellore under the control of Chief Engineer, Chennai implements the various schemes with the assistance of their Executive Engineers in Pennaiyar River Basin. Details of water supply schemes implemented in urban and rural areas of pennaiyar 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 has control in their respective fields. The Conservator of Forests at Vellore Circle, Divisional office at vellore and Assistant Conservator of Forests, Vellore, Villupuram territorial division that forms the part of Villupuram and Cuddalore districts ; Conservator of Forests, Dharmapuri Circle; Regional Manager ,Tamilnadu Forest Plantation Corporation Limited, Cuddalore; District forest officers, Tiruvannamalai Division; Regional Manager, Tamilnadu Forest Plantation Corporation, Tirukovilur are the Various forest offices operating in the Pennaiyar 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 Dharmapuri, Vellore, Cuddalore, Krishnagiri, Villipuram along with their team of officers implement and execute the schemes of this department in Pennaiyar River Basin. This department coordinates with Water Resources Department to increase the water 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 to fetch better return to improve the economic status of the farming community. Details regarding consumption of fertilizers and Pesticides in pennaiyar 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.

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.

Agricultural Engineering Department is headed by Chief Engineer, located at Chennai. The Agricultural Engineering division offices are functioning at the district head quarters of Dharmapuri, Vellore, Cuddalore, Salem, Krishnagiri, Tiruvannamalai and Villipuram districts. 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 and agricultural mechanization apart from hiring of Land Development & Minor Irrigation machinery to farmers. Details of Catchment area treatment in the Upstream side of reservoir 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, Villipuram, Tiruvannamalai, Vellore, Krishnagiri and Salem covers Pennaiyar river basin area. Details of vector-borne diseases and water borne diseases are collected from the territorial Public Health & Preventive Medical Department. These details are used to document the prevailing health conditions in Pennaiyar river basin.

10.1.9 Animal Husbandry & Veterinary Science Department

Animal Husbandry Department is headed and governed by the Director, Animal Husbandry & Veterinary Sciences. The Regional Joint Directors at Chennai, Cuddalore, Villipuram, Vellore, Tiruvannamalai, Krishnagiri along with their Additional Director are responsible for all the activities of this Department in Pennaiyar river basin area.

The livestock sector provides livestock based food products such as milk, egg, meat, raw materials like wool and hide for industries, manure etc,. The Animal Husbandry Department provides comprehensive veterinary assistance and health cover to all livestock and poultry across the State of Tamilnadu 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's census and schemes implemented in pennaiyar river basin are collected from the territorial Animal Husbandry &

Verterinary Science Department offices. These details are used to arrive the Livestock demand at present and in future. The infrastructure facilities of the Veterinary health services available in the districts of Pennaiyar River Basin are given in **Table 10.1.**

Table 10.1 Veterinary Health Services Pennaiyar River Basin

Sl. No	**District**	**Division**	**P.U**	**Poly Clinic**	**Clinician Centers**	**Hospitals**	**Dispensaries**	**Rural Veterinary Dispensaries**	**Mobile Units**	**Sub centers**	**Visiting Sub centers**
1	Krishnagiri	2	10	-	1	2	54	12	1	7	6
2	Dharmapuri	2	8	-	1	2	48	15	2	3	1
3	Vellore	3	20	-	1	8	81	27	4	27	6
4	Tiruvannamalai	2	18	-	1	5	78	25	3	25	-
5	Villupuram	4	22	-	1	7	107	34	4	18	2
6	Cuddalore	3	13	-	1	5	65	13	1	59	-

10.1.10 Fisheries Department

This department is concerned with the Marine and island 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 Pennaiyar River Basin is concerned, there is a Joint Director of Fisheries (Regional)at Chennai and under his control there are 7 Assistant Director Fisheries viz., Assistant Director Fisheries(Marine),Kanchipuram; Assistant Director Fisheries (Inland Fisheries), Villipuram; Assistant Director Fisheries(Marine), Cuddalore; Assistant Director Fisheries

(Inland Fisheries), Vellore; Assistant Director Fisheries (Inland Fisheries), Dharmapuri and Assistant Director Fisheries(Inland Fisheries), Krishnagiri.

The fisheries sector of Pennaiyar 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. Quality seeds of Indian major carps viz., catla, rohu, mrighal and common other carps are stocked in the reservoir every year. Details regarding marine fisherman population, fish production for 2005-2015, inland fisherman population and Inland fish production for 2005-2015 in pennaiyar river basin area are collected and documented.

10.1.11 Tamilnadu Pollution Control Board (TNPCB)

Tamilnadu 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. 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 Tamilnadu Pollution Control Board functioning with the District Environmental Engineer as head located at Cuddalore, Salem, Vellore, Villipuram, Thiruvannamalai, Hosur, and Chennai. The District Environmental Engineer monitors and controls the Industrial Pollution in Pennaiyar 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 offices. 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 to take final decision on the proposals seeking surface/ ground water drawl permission from 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 drawl of water of less than one MGD should be placed before the said committee for consideration and clearance.

10.3 Participatory Irrigation Management (PIM) / Water User's Association (WUA)

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 may be 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.

The details of WUA's formed in Pennaiyar river basin under WRCP and IAMWARM Project are given in the **Table No.10.2** and **Table No.10.3**

Water User Associations are formed under IANWARM Project for eight sub basins namely, Markandanadhi, Kotapattiikallar, Pambanar & Varattar, Thurinjalar, Gadilam, Upto Krishnagiri Reservoir, Kambainallur and Pambar to Thirukovilur. WUAs are not formed for the remaining sub basins, as they are not covered under IAMWARM Project. But WUA's are already formed for the Pennaiyar river basin under WRCP. The details of WUA's formed in Pennaiyar river basin under IAMWARM Project and WRCP are stated in the **Table No.10.2** and **Table No.10.3**

Table – 10.2 Details of WUA's Formed in Pennaiyar River Basin Under IAMWARM

Sl.No.	Name of the Sub Basin	President – Details			TC Members - Details		
		Total	Elected as on date	Balance left out	Total	Elected as on date	Balance left out
1	Markandanadhi	6	6	-	26	26	-
2	Kambainallur	25	25	-	104	104	-
3	Kotapallikallar	3	3	-	12	12	-
4	Pambanar & Varattar	9	9	-	52	52	-
5	Thurinjalar	47	47	-	198	198	-
6	Gadilam	95	95	-	388	388	-
7	Upto Krishnagiri Reservoir	20	20	-	90	90	-
8	Pambar to Thirukovilur	14	14	-	60	60	-

Table – 10.3 Details of WUA's Formed in Pennaiyar River Basin under WRCP

SI.No	Name of District	Total Nos. of WUA	Total Nos. of TCs
1	Krishnagiri	27	140
2	Dharmapuri	20	116
3	Vellore	229	1028

4	Tiruvannamalai	155	734
5	Villupuram	79	372
6	Cuddalore	78	430

10.4 Agencies Responsible for Various activities

The agencies responsible for the various main activities related to Water Resources Management in the Pennaiyar 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 Environment Forest (MoEF), Government of India.	✓Clearance for New Irrigation Projects.

		Institute for Water Studies, WRD.	✓ Develop broad principles for planning and management of water 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.
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 Hydro meteorological data. ✓ Collection and Testing of water samples from rivers at selected locations.
		Indian Meteorological Department (IMD)	✓ Observation of Rainfall& Hydro meteorological data.

4	Providing Drinking Water and Sanitation facilities.	Tamilnadu Water Supply and Drainage Board	✓Planning, Designing and Execution of New Drinking Water Schemes. ✓Planning, Designing and Execution of New Under Ground Drainage 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.	Agricultural Department	✓Providing facilities to the farmers including supply of 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.
8	Pollution Prevention.	Tamilnadu 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	Comprehensiv e 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
CONCLUSION AND ACTION PLAN

11.1 Conclusion

Pennaiyar River is an East flowing river originates on the south eastern slopes of Chennakesava Hills in North West of Nandidrug Mountain in Karnataka State and the river is called Dakshina Pinakine in Karnataka state. After flowing through Karnataka, the river enters Tamil Nadu near Bagalur village of Hosur Taluk and called as “Pennaiyar” and confluences with the Bay of Bengal at Cuddalore. The total length of Pennaiyar River is 432 km, of which flows over 112km in Karnataka state and 320km in Tamilnadu state (180km in Dharmapuri, Krishnagiri & Salem districts, 34km in Thiruvannamalai and Vellore districts and 106km in Cuddalore and Villupuram districts). Pennaiyar river basin is sandwiched between Cauvery river basin at its west and south and Palar & Varahanadhi basins at its east and north.

The main tributaries of Pennaiyar River are Chinnar West, Chinnar East, Markandanadhi, Kambainallur, Mathurar, Pambar, Vaniyar, Kottapatti-kallar, Vayalar Odai, Ramakal Odai, Pambanar, Aliyar, Musukundanadhi and Thurinjilar.

The total area of the basin is **11,375.55**sqkm. The Pennaiyar basin encompasses 7 districts viz. Cuddalore, Dharmapuri, Krishnagiri, Salem, Tiruvannamalai, Vellore and Villupuram either fully are partially of the district area. The Pennaiayar basin is sub divided into 19 Sub-basins.

The surface Geology of Pennaiyar basin is covered by the Archaean rocks such as Pyroxene granulites, Quartzite, Ferruginous Quartzite, Amphibolites, Gneiss and Hornblende biotite gneiss with younger intrusive of Pegmatite and Dolerite in the central and western parts and the overlying sedimentaries of upper cretaceous tertiary and quarternary formations of the eastern part.

The population of Pennaiyar river basin based on **2011 Census** is **5.277 million** and the population projected for the year **2015** and the target years **2020, 2023, 2030 & 2040** are **5.594 million, 6.018 million, 6.288 million, 6.969 million & 8.078 million** respectively.

The hydro-meteorological study of Pennaiyar river basin comprises of rainfall, temperature, humidity, wind speed, sunshine and evapotranspiration. There are 44 rain gauge stations and 6 weather stations (full climate stations) are available in Pennaiyar basin and whilst considering the coverage of rain gauge station and availability of data for a period of 44 years, only 33 stations out of 44 rain gauge stations are considered for obtaining average annual rainfall of this basin.

Probable Mean Areal rainfall analysis for 25%, 50%, 75% & 90% dependability and the average for southwest, northeast, winter, summer and annual rainfall for all the sub basins have been analysed.

The **44 years annual average rainfall of the basin is 882.43 mm** which is **lower than Tamil Nadu State normal rainfall of 921.10 mm**. (Statistical hand book of Tamil Nadu 2014).

The previous Micro Level Study (water plan study) of Pennaiyar River Basin was done in 2004 and the data period considered for the study was from 1935-2003 and the average annual rainfall of the basin was reported as 874.89 mm. Whilst comparing the average annual rainfall of Pennaiyar River Basin of previous study report (874.89 mm) with this report (882.43mm), no significant change in average annual rainfall.

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

- Harur area comes under the grip of **moderate to severe drought** more frequently i.e 4 times out of 15 years.
- Severe drought was occurred in Thirupathur of Villupuram district in 2 times out of 15 years.

There are 9 reservoirs in Pennaiyar basin with a total storage capacity of **339.307MCM** and 7 anicuts were constructed to irrigate an area of 39,995ha. There are 206 system and 403 Non-system tanks in this basin. The total storage capacity of these 609 tanks is around 2176.50 MCM i.e. under system tanks 1209.18 MCM and under non-system tanks 967.32 MCM.

The Surface Water Potential estimated at 75% dependability rainfall by following methods:

1. **Rainfall – Run-off Co-efficient Method: 1,263.38 MCM**
2. **NWDA Approach: 1,334.61 MCM**
3. **MRS Model: 1,319.58 MCM**

Almost all the tanks in Tamil Nadu suffered from neglect in recent years. The statistics relating to tanks in this basin have the same fate. There is only disparate information available for tanks and tank irrigation. The tank memoirs, which were prepared during British period, were attempted to be updated, but they were discontinued in the recent years. This resulted in the non-availability of essential data on tanks to the researchers and the practising Irrigation Engineers.

The storage capacity of tanks has been reduced 15 to 20 percent due to siltation, foreshore encroachment and poor tank structures. Therefore necessary steps may be taken to improve and maintain the existing storage structures like reservoirs, anicuts, tanks etc.

It is proposed to rehabilitate 7 dams (Sathanur, Krishnagiri, Pambar, Thumbalahalli, Vaniyar, Shoolagiri Chinnar & Kelavarapalli) in Pennaiyar basin under World Bank loan funded project of Dams Rehabilitation and Improvement Project (DRIP).

The Project Proposals are being prepared under Repair Renovation Restoration (RRR) scheme to renovate some of the 21 tanks (8 tanks in Pambar sub-basin, 6 tank in Kambainallur sub-basin, 3 tanks in Krishnagiri upto Pambar sub-basin, 2 tanks in Markendayanadhi sub-basin, 1 tank in Vaniyar sub-basin and 1 tank in Chinnar West sub-basin) in Pennaiyar basin in phased manner.

The surface water quality in Pennaiyar basin is good and the water can be used for both domestic and agricultural purposes.

The Sornavur anicut is the tail end anicut constructed across Pennaiyar River in Melpathy village of Villupuram taluk and assessed a surplus flow from Sornavur Anicut of 46.53MCM at 50% dependability rainfall is let into the sea.

An inventory of about 139 observation wells spread over the entire Pennaiyar Basin has been scrutinized for study purpose based on the availability of data period, ranging from four years (4) to forty three (43) years.

The long-tern water level rise found in 78 observation wells and high rise in water level (more than 3.00m) found in 20 wells and the long-term water level depletion found in 58 observation wells and high depletion in water level (more than 3.00m) found in 24 wells. Within the highly water level depleted 24 wells, more depletion occurred in 1 well during 2012-13, 6 wells during 2013-14 and 2 wells during 2014-15 .

Pennaiyar basin encompassed 50 blocks with its area either fully or partially covered and the categorization summary is as stated below:

Sl.No	Category	As per 2003 Assessment	As per 2009 Assessment
1	**Safe**	4	11
2	**Semi Critical**	12	5
3	**Critical**	2	8
4	**Over Exploited**	32	26

Total groundwater potential of Pennaiyar Basin is **2,140.09 MCM** and total groundwater extraction of the basin is **2,043.97 MCM**. The balance groundwater potential available for further development is **364.07 MCM.**

By comparing 2003 and 2009 assessment, it is observed that the total groundwater potential of Pennaiyar Basin has been increased by 6.33% (from 2,012.70 MCM in 2003 to 2,140.09 MCM in 2009) and groundwater extraction in Pennaiyar basin has been decreased (from 2,412.12 MCM in 2003 to 2,043.97 MCM in 2009) by 15.26%, which is a positive trend

Based on the stage of groundwater development, Pennaiyar Basin is assessed as "Critical" in groundwater category. Only Chinnar West sub-basin is in "Safe" category, 4 sub-basins (Musukundanadhi, Gadiam, Pamber to Thirukovilur & Lower Pennaiyar) are in "Semi Critical", 2 sub-basins are in "Critical" and the balance 12 sub-basins are in "Over Exploited" category.

Gadilam sub-basin has the highest groundwater potential while Matturar sub-basin has the lowest potential and Gadilam sub-basin has the highest groundwater extraction and Ramakal Odai sub-basin has the lowest groundwater extraction. Thurinjalar, Gadilam and Lower Pennaiyar sub-basins combined together contribute nearly half of Pennaiyar basin's groundwater potential.

In general, the groundwater quality of Pennaiyar basin is "good to moderate" condition.

In Pennaiyar basin, groundwater extracted for irrigation is worked out as 1,793.39 MCM which is alarmingly 87.74%, of the total groundwater extraction of 2,043.97 MCM. The irrigation demand is more than 90% in 15 out of the 19 sub basins in Pennaiayar basin.

The ayacut area of Pennaiyar basin is 2,04,128ha. In the year 2013-14, gross area irrigated is 3.54 Lakh Ha and gross area sown is 7.098 Lakh Ha. The main crops cultivated are paddy, Ground nut, Maize, Ragi, Coconut and Sugarcane. The total land holding is 8,46,194.

- Marginal farmers (area less than 1 ha) – 6,24,884
- Small farmers (1 to 2 ha) – 1,50,739
- Semi-medium farmers (2 to 4 ha) – 47,788
- Medium farmers (4 to 10 ha) – 8,678
- Large farmers (more than 10 ha) – 14,105

The average Gross irrigated area in Pennaiyar Basin is reported to be 3,18,855ha. Out of the total area irrigated, about 44% is under paddy cultivation and 23% is under Sugarcane cultivation.

Gadilam sub basin has the maximum irrigated area of 68,626ha which accounts for about 22% of the total irrigated area. Maturar sub basin has the lowest irrigated area of 1499ha which accounts for about 0.5% of the total irrigated area.

Net Irrigation demand of this basin at 75% dependable rainfall is 1561.15MCM. Net Irrigation demand of this basin at 50% dependable rainfall is 1468.19 MCM.

The latest modern irrigation type viz. Precision Farming is being adopted in this basin to save irrigating water and under IAMWARM project, in Kambainallur sub basin, water savings is achieved in the cultivation of following crops using drip fertigation system.

- Banana - 23%, Tomato – 84%, Brinjal – 42%, Bhendi – 32.4%, Ribbed gourd – 34%, Watermelon- 69% , muskmelon – 58.6%

Benefits of precision farming are as stated below:

- 90-95 % water application efficiency. Fixed network of pipes, ensures accurate and application at known rates
- 40-80% water saving. Water applied to root zone in droplets. Soil moisture is kept at constant optimum level. Application rate matching the consumptive use of crop
- 30 -130 % increased yield. Optimum plant performance resulting in higher yield and better quality produce

By adopting modern water saving cultivation techniques water saving achieved in Pennaiyar basin is as stated below:

Sl.No.	Crop	Cultivated area in Ha	Water requirement-conventional method (MCM)	Percentage of saving by adopting Water saving technique	Water Saving (MCM)
1	SRI-Paddy	90,325	826.4	40	330.56
2	SSI-Sugarcane	64,655	328.45	40	131.38
3	Banana	4,325	21.9	33.33	7.23
4	Coconut	20,416	165.2	63	102.00
5	Groundnut	22,618	57.27	49.4	28.29
6	Vegetables	24,086	43.4	29	13.46
				Total	**612.92**

The domestic water requirement may increase in future due to increase in Population, development in living standards of the people etc, The TWAD Board has recommended the annual growth rate norms 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)

In Pennaiayar basin certain livestock viz. cattle, sheep, goat & poultry are indicating growing trend, so the future water demand is to be estimated according to growth rate.

At present in Pennaiyar River Basin, there are 190 numbers of large and medium industries and 1,738 numbers of small scale industries. Accordingly, the yearly requirement of water for Large & Medium and Small Scale industries is estimated as **214.985MCM. Neyveli Lignite Corporation at Neyveli is a mega electricity power producing industry located in the Pennaiyar basin.**

Some of other major industries in Pennaiyar basin are as stated below:

- MRK Sugar Mill, Sethiathopu, EID Parry (I) Ltd, Nellikuppam, Ambiga Sugar Mills, Pennadam, TANFAC, Cuddalore O.T, Vanavil , Cuddalore O.T, National

Cotton Mills, Chidambaram, SPIC Pharma Chemicals , Cuddalore O.T and Asian Paints (I) Limited, Cuddalore O.T.

The number of small scale industries in the Pennaiyar River Basin has been decreased at present whilst comparing with the previous micro level study carried out during 2004. Hence the estimated quantity of Industrial Water Demand in Pennaiyar River Basin for the present year for the small scale industries **of 1.967MCM** may be taken for the target years 2020, 2023, 2030 and 2040.

The present water potential of Pennaiyar Basin:

- Surface water potential - 1,319.58 MCM (At 75% dependability rainfall)
- Ground water potential - 2,140.09 MCM
- Total Potential - 3,459.67 MCM

The various sectoral demand in Pennaiyar Basin for the year 2015

- Domestic - 200.55 MCM
- Irrigation (Including losses) - 2,076.33 MCM
- Livestock - 49.51 MCM
- Industrial - 216.95 MCM
- Ecological - 6.60 MCM
- Total Damand - 2,549.94 MCM

Water Balance

- Water Potential for the year 2015 - **3,459.67** MCM
- Water demand for the year 2015 - **2,549.94** MCM
- Surplus - **909.73** MCM

Pennaiyar basin is surplus by **909.73 MCM (26.30 %)** at present, i.e., for the year 2015 at 75% dependability rainfall.

The projected Water Balance for the year 2020, 2023, 2030 and 2040 are also surplus by 23.10%, 20.67%, 17.20% and 12.45% respectively but the surplus percentage is in decreasing tread consequent to increase in population, livestock and industrialization.

The major pollution sources identified in the basin are Industries, Domestic and Agriculture.

The industries are to be encouraged to use the treated waste water for flushing the cisterns in rest rooms to reduce fresh water requirements.

The total water demand of industries is 216.95MCM per year. The wastewater generated from the utilised quantity is assumed as 80% of utilized water (173.56MCM) per year. If that wastewater get treated and utilized for irrigation and from that water, crop production may generate a revenue of Rs.6,845 lakh/year

In Pennaiyar river basin, domestic sewage pollution is more severe than the industrial pollution.

It is found that consumption of fertilizer has been increased from 2,89,000Mt during 2004-05 to 4,86,948Mt during 2013-14. Application of liquid form pesticide has been decreased from 2,03,266L during 2005-06 to 1,42,898L during 2013-14 but the application of dust/sold form pesticide has been increased from 239kg during 2005-06 to 1,023kg during 2013-14.

The excess usage of fertilizers will reduce the availability of micronutrients like calcium, zinc, manganese, and magnesium etc and will adversely affect crop growth.

Due to urbanization in Pennaiyar basin, the water borne disease cases has been increased from 15,904 during 2005 to 37,479 during 2013 but, death due to water borne disease has also been decreased from 22 during 2005 to 10 during 2013.

An appreciating trend in Sand Mining in Pennaiyar basin is that the quantity of sand mined is decreased from 1,96,652 lorry loads (200cft capacity) during 2008-09 to 79,489 lorry loads (200cft capacity) during 2014-15.

The Sea Water Intrusion study in Pennaiyar basin shows that the Electrical Conductivity in the sea water has been increased whilst comparing the study result of the year 2011 with the year 2015, which means the sea water intrusion is in increasing trend.

The higher value of Electrical Conductivity, Total Dissolved Solids (TDS) and ratio of chloride with carbonate and bicarbonate (Cl/CO_3+HCO_3) are the main factors for sea water intrusion.

To implement the Participatory Irrigation Management (PIM) system, Water Users Association (WUA) is being formed in Pennaiayar basin and till date 588 WUAs are formed in this basin.

Water Resources Department of PWD is the apex organization in overall management of Water Resources in Tamilnadu State with the technical guidelines from Central Water Commission, and support from Central Ground Water Board functioning under Ministry of Water Resources, New Delhi. The other departments viz. Agricultural

Department, Agricultural Engineering Department, Department of Statistics and Economics, Tamil Nadu Water Supply and Drainage Board, Forest Department, Tamil Nadu Pollution Control Board, Directorate of Industries & Commerce, Department of Animal Husbandry & Veterinary Services, Directorate of Medical & Rural Health Services, Directorate of Census Operation, Department of Fisheries and Tamil Nadu Generation and Distribution Corporation are the allied departments connected with water resources and data were obtained from those departments for Pennaiyar Basin Micro Level Reappraisal Study.

11.2 Strategic Objectives and Action Plan

- **Strategic Objective 1: Strengthening The Rain Gauge Stations**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
1.1	Non availability of Rain Gauge Station	❖ Install Rain Gauge Station in Kottapattikallar (410.23 Sq.Km), Mushkundanadhi (179.26 Sq.km) and Markandanadhi (368.21 Sq.Km) sub basins.	**The Chief Engineer, SG&SWRDC**

➢ **Strategic Objective 2: Augmentation of Groundwater**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
2.1	Pennaiyar basin is assessed as "Critical" in groundwater development.	To improve the groundwater potential Artificial Recharge Structure viz. Vertical Shaft, Percolation Pond, Check Dam and Anicut are proposed (Ref Tables: 6.10 & 6.11) In Over Exploited Bocks: ❖ Gadilam – 2no ❖ Kambainallur – 3no ❖ Kottapatilkallar – 1no ❖ Krishnagiri to Pambar – 3no ❖ Lower Pennaiyar – 2no ❖ Markandanadhi – 1no ❖ Pambanar and Varattar – 1no ❖ Pambar – 6no ❖ Pambar to Thirukovilur – 1no ❖ Thurinjalar – 3no ❖ Vniyar – 1no In Critical Bocks: ❖ Lower Pennaiyar – 2no ❖ Thurinjalar – 3no	**The Chief Engineer, Chennai Region** **and** **The Chief Engineer, SG&SWRDC**
2.2	Groundwater extraction is rampant in Musukundanadhi, Gadiam and Pamber to Thirukovilur sub-basins.	❖ Groundwater development is to be maintained at present level in Musukundanadhi, Gadiam and Pamber to Thirukovilur sub-basins	**The Chief Engineer, SG&SWRDC**

- **Strategic Objective 3: Storing the Surplus Water**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
3.1	The surplus flow assessed at 50% dependability rainfall at the tail end storage structure, Sornavur Anicut in Pennaiyar river is being let into the sea.	❖ Construct a off take channel for a length of 23.55Km and then a feeder canal for a length of 38.720Km at LS 12.88Km from the main canal, to divert the surplus water of Pennaiyar Basin from Sathanur to Palar River through Cheyyar and augmenting the supply to Nandan Canal in Thiruvannamalai District.	**The Chief Engineer, Chennai Region**

- **Strategic Objective 4: Modernisation of Irrigation & Agriculture**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
4.1	Low Irrigation Efficiency	❖ Apply drip irrigation for the cultivation of Vegetables to save 29% (13.46MCM) of water ❖ Apply micro irrigation method for the cultivation of Groundnut to save 49.40% (28.29MCM) water. ❖ Apply drip irrigation for the cultivation of Banana and Sugarcane to save 33.33% (7.23MCM) and 40% (131.238MCM) water respectively.	**Agricultural Department and Water Resources Department**
4.2	Water wastage in conventional cultivation method	❖ Change the old paddy cultivation to SRI cultivation to save 40% (330.56 MCM)	**Agricultural Department**

- **Strategic Objective 5: Sustainability of Environment**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
5.1	In Pennaiyar river basin, domestic sewage pollution is more severe than the industrial pollution.	❖ Treat the sewage and reuse the treated water for fire fighting, toilet flushing etc in a phased manner to meet the growing demand. ❖ Completely stop open discharge of domestic effluents into the river. ❖ Sanitary facilities have to be provided at public places.	**TWAD Board and** **Local Bodies Authorities**
5.2	Excessive use of fertilizer	❖ Encourage crop residue management, green manure, organic manure and composting method. ❖ Promote Organic farming.	**Agricultural Department**
5.3	Increase in number of Water Borne decease case and death.	❖ Domestic and industrial effluents have to be treated before letting into any sources after ascertaining the permissible limits.	**Pollution Control Board and** **Local Body Authorities**
5.4	Reduction in storage capacity of reservoir due to sedimentation in Krishnagiri and Sathanur reservoirs	❖ Construction of dykes, check dams and detention basins may be formed in the main river and tributaries ❖ Gullies control measures and stream bank protection measures may be adopted.	**The Chief Engineer, Chennai Region**

Sl. No	Issues	Strategies Recommended	Action to be Taken by
5.5	Sea water intrusion into the aquifer.	❖ The land ward movement of sea water has to be checked or prevented by maintaining the water level. ❖ There should not be any over exploitation of ground water with in 10 km, from the coastal line	**The Chief Engineer, Chennai Region** **and** **The Chief Engineer, SG&SWRDC**

11.3 New Schemes Suggested by The Chief Engineer, Chennai Region and supported by Chief Engineer, Plan Formulation:

Sl.No	Description	Estimate Cost Rs in Crores
1	Formation of Earthen Dam and Construction of Spillway and river Sluices across Malattar River at Bathallapalli village in Gudiyatham taluk of Vellore District	29.55
2	Excavation of New Supply Channel to feed Kagankarai tank in Thirupattur Taluk of Vellore District.	2.71
3	Excavation of Supply Channel from Senganbasuvanthalav tank to divert surplus flood water of Chinnar river to feed Endapatti tank, Kondasamanahallu tank and 8 other inter –mediate tanks in Palacode Taluk of Dharmapuri District.	10.20
4	Construction of Check dam in Bellarapalli Village in Krisnagiri Taluk and District.	0.72
5	Construction of Check Dam across Pambar River in Singarapettai Village in Pambar Sub basin at Uthangarai taluk of Krisnagiri District	0.57
6	Construction of Check dam across Nachikuppam river in Markandeyanadhi Sub basin at Viruppasandriam Village of Krishnagiri Taluk and District.	0.84

Sl.No	Description	Estimate Cost Rs in Crores
7	Construction of Check Dam across Kambainallur Village in Kambainallur Sub basin at Harur Taluk of Dharmapuri District.	1.16
8	Construction of Check dam across Kovilar river in Bairanaikampatti village in Kovilar Sub basin at Harur Taluk of Dharmapuri District.	0.83
9	Construction of Check dam across Pambanar river near Narayanakuppam village in Pambanar Sub basin at Thandarampattu Taluk of Thiruvannamalai District.	2.18
10	Construction of Check dam across Gadilam river near Koothambakkam village in Gadilam Sub basin at Cuddalore Taluk and District.	16.24
11	Construction of Artificial Recharge well Structures in Thurinjalar Sub basin in Thiruvannamalai District (7 Tanks-Aradapattu,Su.Andapattu,Pavithram,Mallavadi,Mathulampadi,Nookampadi and Somasipadi)	3.54
12	Construction RMS wall at Devanampattinam (LS 800m - LS 1220m) in Cuddalore Taluk of Cuddalore District.	1.80
13	Construction RMS wall for a length of 650m from right bank of Pennaiyar mouth to Thazhanguda Village in Cuddalore Taluk of Cuddalore District.	2.54
14	Construction RMS wall for a length of 210m from left bank of Pennaiyar mouth to Subauppalavadi village in Cuddalore Taluk of Cuddalore District.	0.84
15	Construction RMS wall at Devanampattinam (LS 1220m – LS 2140m) in Cuddalore Taluk of Cuddalore District.	3.90
16	Construction of Sea Wall from LS from LS 1850m to 2470m and LS 2710m to LS 3090m (1000m) in Chinnamudaliyar Chavadi Village in Vanur Taluk in Villupuram District.	2.80
17	Construction of series of 2 Groynes (5 and 6) in Mudaliyar Chavadi in Vanur Taluk in Villupuram District.	9.65
18	Construction of series of 3 Groynes in Bommaiyarpalayam in Vanur Taluk in Villupuram District.	6.90
19	Construction of series of 5 Groynes in Sodhanaikuppam in in Vanur Taluk in Villupuram District.	4.72
20	Construction of new supply channel for Diversion of flood waters of Betamugaliampallam to Kesarigulihalla reservoir in Palacode Taluk of Dharmapuri District.	1.00
21	Construction of Diaphragm wall across Pennaiyar river between Perandaiyur village in Ulundurpet Taluk and Pidagam village in Villupuram Taluk of Villupuram District.	12.63

The issues in the strategic objectives and the developments required in various aspects as discussed above are recommended to be implemented by **Water Resources Department** in co-ordination with **Tamil Nadu Water Supply and Drainage Board**, **Tamil Nadu Pollution Control Board**, **Agriculture Department, Agricultural Engineering Department** and connected **Local Body Authorities** for effective Water Resources Management of **Pennaiyar River Basin.**

Pennaiyar River Basin is a peculiar basin with seasonal Pennaiyar river has a surplus water and by effective utilization and judicious management of water, the basin could lead for further development in the 7 districts that are falling in Pennaiyar Basin.

Effects of Recent North East Monsoon Rainfall in Pennaiyar River Bain Area:

During November & December 2015 very heavy rainfall was experienced in Pennaiyar Basin and particularly, Cuddalore received 1,627.90mm of rainfall. Due to this very heavy rainfall, flash floods were occurred in Cuddalore, Villupuram and Vellore districts of Pennaiyar basin. According to a conservative estimate, one lakh people have been marooned and thousands stranded and loss of life & property.

North East monsoon of 2015 was the severest in over a hundred years. The main cause of this flooding is due to unplanned development & urbanization on the banks of the river, adjacent to water bodies. The water bodies which function as water storage structure were chocked and affected due to encroachment. This resulted in heavy loss to life and property. Crops were damaged and the livelihood of farmers and general public were severely affected.

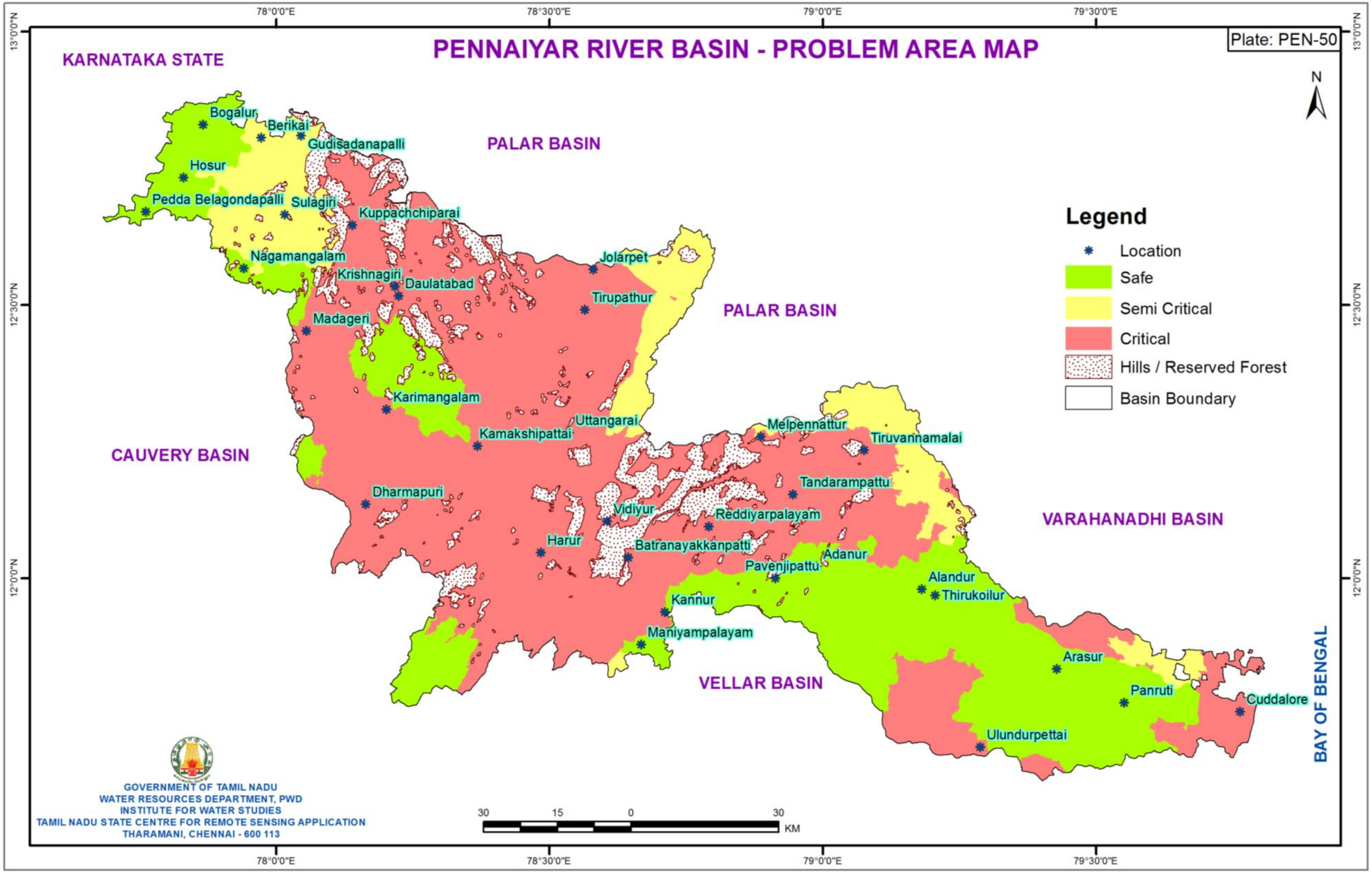
So due importance and insight should be given to protect and preserve the water bodies to its original standards.

The encroachment on the banks and inside the water bodies should be evicted and prevented from further encroachment. The existing land use pattern should be upheld ie. no permission shall be given for construction of buildings on agriculture and irrigation marked areas.

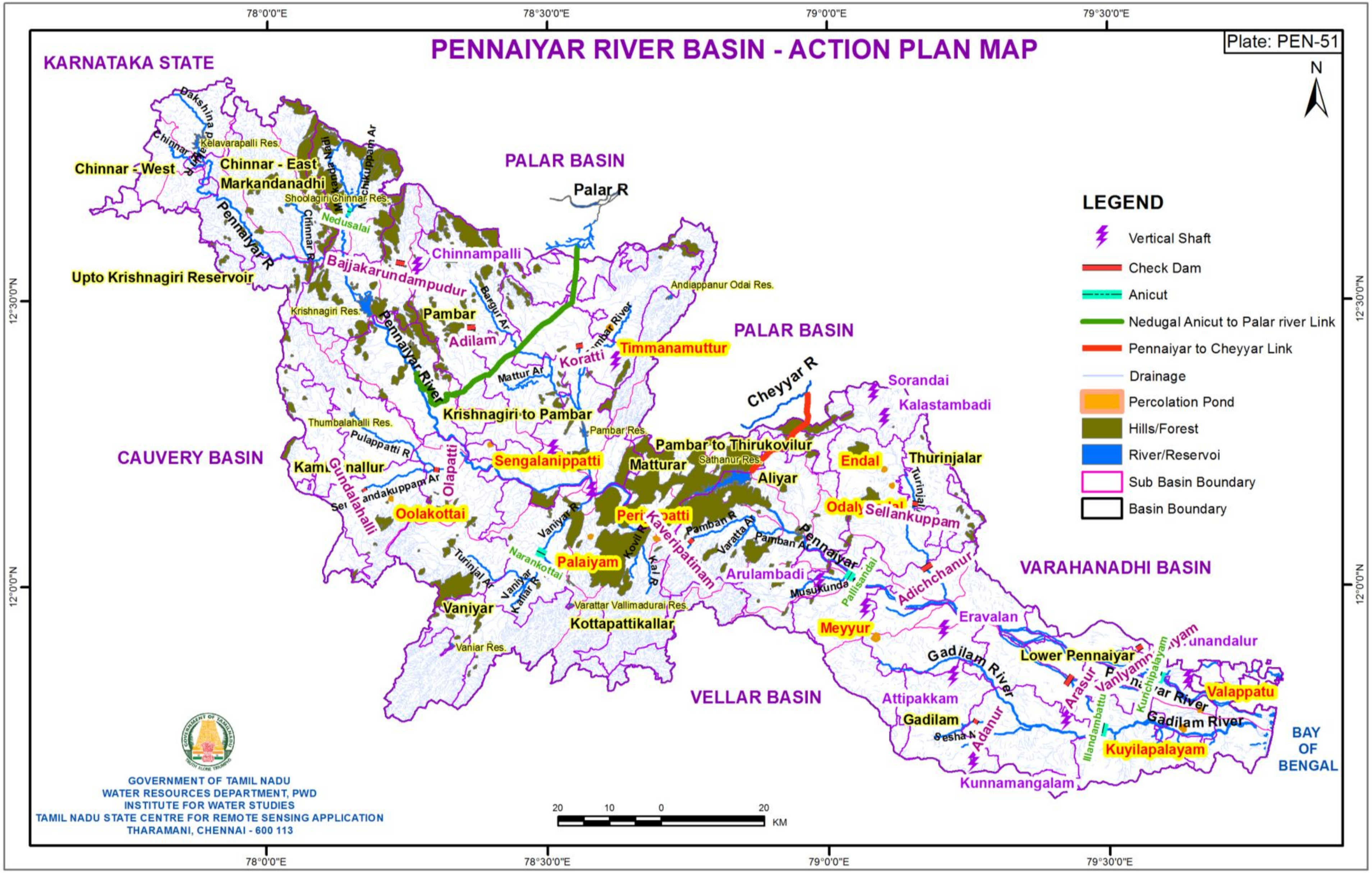
WATER IS PRECIOUS.

LET US ALL STRIVE TO PRESERVE IT

Chief Engineer & Director, WRD
Institute for Water Studies.



PENNAIYAR RIVER BASIN - PROBLEM AREA MAP
Plate: PEN-50
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Legend
Location
Safe
Semi Critical
Critical
Hills / Reserved Forest
Basin Boundary
Bogalur
Berikai
Gudisadanapalli
Hosur
Pedda Belagondapalli
Sulagiri
Kuppachchiparai
Nagamangalam
Krishnagiri
Daulatabad
Jolarpet
Tirupathur
Madageri
Karimangalam
Kamakshipattai
Uttangarai
Melpennattur
Tiruvannamalai
Tandarampattu
Dharmapuri
Vidiyur
Reddiyarpalayam
Harur
Batranayakkanpatti
Adanur
Pavenjipattu
Alandur
Thirukoilur
Kannur
Maniyampalayam
Arasur
Panruti
Cuddalore
Ulundurpettai
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
13°0'0"N
12°30'0"N
12°0'0"N
30 15 0 30
KM
N
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
TAMIL NADU STATE CENTRE FOR REMOTE SENSING APPLICATION
THARAMANI, CHENNAI - 600 113


PENNAIYAR RIVER BASIN - ACTION PLAN MAP
Plate: PEN-51
N
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
12°30'0"N
12°0'0"N
KARNATAKA STATE
PALAR BASIN
PALAR BASIN
CAUVERY BASIN
VARAHANADHI BASIN
VELLAR BASIN
BAY OF BENGAL
Chinnar - West
Chinnar - East
Markandanadhi
Upto Krishnagiri Reservoir
Bajjakarundampudur
Chinnampalli
Pambar
Adilam
Koratti
Timmanamuttur
Krishnagiri to Pambar
Sengalanippatti
Pambar to Thirukovilur
Matturar
Aliyar
Endal
Thurinjalar
Sellankuppam
Sorandai
Kalastambadi
Olapatti
Oolakottai
Gundalahalli
Palaiyam
Kaveripatinam
Arulambadi
Adichchanur
Meyyur
Eravalan
Lower Pennaiyar
Vaniyar
Kottapattikallar
Attipakkam
Gadilam
Adanur
Kunnamangalam
Arasur
Kuyilapalayam
Valappatu
Palar R
Cheyyar R
Pennaiyar R
Pennaiyar River
Gadilam River
Kelavarapalli Res.
Shoolagiri Chinnar Res.
Nedusalai
Krishnagiri Res.
Andiappanur Odai Res.
Thumbalahalli Res.
Pambar Res.
Sathanur Res.
Varattar Vallimadurai Res.
Vaniar Res.
Narankottai
Pallisandai
Musukunda
Illandambattu
Kunchipalayam
Mattur Ar
Bargur Ar
Pulappatti R
Vaniyar R
Turinjal Ar
Kallar R
Pamban R
Varatta Ar
Pamban Ar
Kal R
Kovil R
LEGEND
Vertical Shaft
Check Dam
Anicut
Nedugal Anicut to Palar river Link
Pennaiyar to Cheyyar Link
Drainage
Percolation Pond
Hills/Forest
River/Reservoi
Sub Basin Boundary
Basin Boundary
20 10 0 20
KM
GOVERNMENT OF TAMIL NADU
WATER RESOURCES DEPARTMENT, PWD
INSTITUTE FOR WATER STUDIES
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