

Chapter 5

Hydrology and Water Assessment

5.0 General

The hydrological analysis for Cauvery (Kattalai) - Vaigai - Gundar link project is dependent on the nine link system connecting Mahanadi - Godavari - Krishna - Pennar - Cauvery - Vaigai - Gundar. Hydrological studies carried out earlier for various river basins by NWDA revealed that the surplus in the Mahanadi basin near Manibhadra is about 12165 Mcum and that in Godavari basin at Inchampalli and Polavaram is about 20327 Mcum and 15020 Mcum respectively at 75% dependability duly considering the demands at the ultimate stage of development (i.e. by the year 2050 AD). These studies in Mahanadi and Godavari have been updated recently. The water balance study in Mahanadi basin at Barmul (2018) indicates a surplus of 6794 Mcum. Similarly, as per the updated water balance study in Godavari basin at Inchampalli (2018) indicates a surplus of 5002 Mcum while similar study for Godavari basin upto Polavaram is under preparation. As can be seen, the surpluses in Mahanadi & Godavari have reduced which are proposed to be compensated from a part of about 11 BCM of water transfer being envisaged through Himalayan links to the Peninsular nine link system, which is under finalisation. The nine link system provides about 2252 Mcum of water in Cauvery and the same was proposed for diversion to Vaigai and Gundar basins through Cauvery (Kattalai) - Vaigai - Gundar link project.

The entire nine link system is now planned to be taken up in two phases to avoid delay in assessment of waters available in Himalayan rivers and finalization of diversion structure on river Mahanadi.

- a) Phase I: Identifying surplus waters in Godavari basin without affecting the interests of the co-basin states and transferring these waters upto Cauvery through Godavari - Krishna - Pennar - Palar - Cauvery link system while meeting the requirements of the areas enroute, to the extent possible.

- b) Phase II: Linking Brahmaputra - Ganga - Subernarekha - Mahanadi - Godavari rivers, thus enriching the Phase I with additional water and suitable modifications.

Thus, the proposed Cauvery (Kattalai) - Vaigai - Gundar link project envisages diversion of 2252 Mcum of water received from Mahanadi and Godavari basins including augmentation of water from Himalayan component river basins for the purpose of providing irrigation, domestic and industrial water supply benefits to the area lying below Cauvery river upto Gundar basin in Tamil Nadu State. The link canal provide irrigation in the districts of Karur, Tiruchirappalli, Pudukkottai, Sivaganga, Ramanathapuram, Virudhunagar and Thoothukudi of Tamil Nadu State. The Cauvery (Kattalai) - Vaigai - Gundar link project has four distinct seasons viz., dry period from January to February, hot period from March to May, south-west monsoon from June to September and north-east monsoon from October to December. The climate is cold from December to February followed by hot season from March to May. In general, the project area has humid and hot climate. The hydrology and water availability studies of the project are based on the Rainfall-runoff relationship developed at various G&D sites of different basins/sub-basins. However, divertible quantity of water is based on water surpluses assessed in various basins of Peninsular & Himalayan component made available at the Grand Anicut by transfer through series of links canal.

5.1 General information about the regions

The salient features/general information of basins concerning the Cauvery (Kattalai) - Vaigai - Gundar link viz., Cauvery, basin area covered by streams between Cauvery and Vaigai, Vaigai and basin area covered by streams between Vaigai and Vaippar are discussed in the following paragraphs.

5.1.1 Cauvery basin

The Cauvery river rises in the Western Ghats in Kodagu district of Karnataka at an altitude of about 1341 m above mean sea level and flows through the States of Kerala, Karnataka, Tamil Nadu and the Union Territory of

Puducherry. The total length of the river from the source to its outfall in Bay of Bengal is about 800 km of which 320 km is in Karnataka, 416 km in Tamil Nadu and 64 km in the common boundaries between Karnataka and Tamil Nadu. The basin extends over an area of 81,155 Km² in the States of Karnataka, Kerala, Tamil Nadu and Puducherry (UT). The principal tributaries of the Cauvery are Lakshmanthirtha, Hemavathi, Harangi, Shimsha, Kabini, Arkavati, Suvarnavathi, Palar, Bhavani, Amaravathi, Noyil and Ponnair.

The Cauvery basin experiences tropical climate. Here, the main climatic feature is the monsoon rain. The south-west monsoon provides the greater portion of the annual precipitation. The far north-western part of the drainage basin has a pre-humid climate which passes eastwards into humid, moist sub-humid, dry sub-humid and semi-arid zones. The recorded maximum and minimum temperatures are 44°C and 18° C respectively.

The highest rainfall in the basin is received along the western border of the basin during the south-west monsoon. The eastern side of the basin gets most of the rain during the north-east monsoon. Depressions in the Bay of Bengal affect the basin in the monsoon, causing cyclones and widespread heavy rains.

The Kattalai barrage across Cauvery is proposed as the off taking point for the link canal.

5.1.2 Streams between Cauvery and Vaigai

The climate of the basin area is cool from December to February and the hottest period is from March to May. The average annual rainfall in the basin varies from 597 to 1167 mm. The basin receives about 82% of the annual rainfall during monsoon period i.e., from June to December. The normal daily maximum and minimum temperature are found to be 34.1° C and 20.9°C in the months of May and January respectively. The maximum and minimum values of relative humidity observed in the basin area are 86% and 36% respectively. The normal maximum and minimum wind speed are 17.6 km/hr occurs in June and 7.7 km/hr occurs in November. The normal maximum cloud cover is 5.6 Oktas during the

month of July, whereas the normal minimum cloud cover is 2.9 Oktas is found during the month of March.

5.1.3 Vaigai basin

The climate of the basin area is mostly humid particularly in coastal area of basin where humidity is experienced throughout the year. The basin has four distinct seasons viz. south-west monsoon from June to September, north-east monsoon from October to December, winter from January to February and summer from March to May. The average annual rainfall varies from 604 mm to 2848 mm. The basin receives about 78.6% of the annual rainfall during the monsoon period from June to December. One IMD observatory at Madurai (Airport) is located in the basin. The normal daily maximum and minimum temperatures are found to be 37.9°C and 20.6°C in the months of May and January respectively. The maximum and minimum values of relative humidity observed in the basin area are 80% and 36% respectively. The normal maximum and minimum wind speed are 7.3 km/hr in January and 4.4 km/hr in October respectively. The cloud cover in the basin ranges from 2.9 octas in February to 6.1 oktas in July.

5.1.4 Streams between Vaigai and Vaippar

The climate of the basin area is generally hot and humid. Three seasons prevail in the area viz. monsoon (south-west & north-east) from May to December, winter from January to February and summer from March to April. The average annual rainfall varies from 635 mm to 932 mm. The basin receives about 84.8% of the annual rainfall during monsoon period from May to December. There is no IMD observatory within the basin. However, there is an IMD observatory at Madurai (Airport) which is located in the close proximity of the basin, based on the data of which climate of this basin has been described. The normal daily maximum and minimum temperatures are found to be 37.9°C and 20.6°C in the months of May and January respectively. The maximum and minimum values of relative humidity observed in the basin area are 80% and 36% respectively. The normal maximum and minimum wind speed are 7.3 km/hr in January and 4.4 km/hr in October respectively. The cloud cover in the basin ranges from 2.9 octas in February to 6.1 oktas in July.

5.2 Specific information

5.2.1 Drainage basin

a) Cauvery basin

The river Cauvery is one of the major rivers of the Peninsular India. It rises in the Kodagu district of Karnataka at an elevation of about 1341 m and falls in the Bay of Bengal in Tamil Nadu after travelling a distance of about 800 km in the South-East direction. The Cauvery basin extends over an area of 81155 Km² in the states of Kerala, Karnataka and Tamil Nadu. In size, it ranks fourth, next to Godavari, Mahanadi and Krishna in the Peninsular India. The basin lies between longitudes 75° 30' E and 79° 45' E latitudes 10° 05' N and 13° 30' N. It is bounded in the west by the western ghats, in the east and south by the eastern ghats and in the north by the ridges separating it from the Krishna and the Pennar basins. The basin is near rectangular in shape.

There are three important waterfalls along the course of Cauvery river viz. (i) the Chunchankatte falls (20m) (ii) the Shiva samudram falls (100 m) and (iii) the Hogenakal falls (25m).

State-wise drainage area of the Cauvery basin are given in **Table-5.1**

Table -5.1
State-wise drainage area of the Cauvery basin

State	Drainage area (km ²)	Percentage of total drainage area
Karnataka	34273	42.23
Kerala	2866	3.53
Tamil Nadu	43687	54.05
Pondicherry	149	0.19
Total	81155	100.00

The Cauvery basin can broadly be divided into three main physiographic regions, viz., (i) the Western Ghats (ii) the plateau of Karnataka and (iii) the delta.

The Cauvery basin covers, Bengaluru urban including rural Bengaluru, Tumkur, Mandya, Mysore, Hassan and Chamaraja Nagar districts of Karnataka, Idukki, Palakkad, Wyanad districts of Kerala, Udagamandalam, Erode, Dharmapuri, Salem, Namakkal, Karur, Tiruchirappalli, Pudukkottai, Thanjavur, Ariyalur, Nagapattinam and Cuddalore districts of Tamil Nadu and Union Territory of Puducherry.

The important tributaries of the Cauvery are Harangi, Hemavathi, Shimsha, Arkavathi, Lakshmanathirtha, Kabini and Suvarnavathi in Karnataka and Bhavani, Noyil and Amaravathi in Tamil Nadu.

b) Streams between Cauvery and Vaigai

Basin area of streams between Cauvery and Vaigai consists of 7 small to medium streams namely Agniyaru, Ambuliyaru, Vellar, Koluvanuru, Pambar, Manimuttar and Kottakarairu each draining independently in the Bay of Bengal. The area lies between Latitudes $9^{\circ} 36'$ and $10^{\circ} 14'$ North and the longitudes $78^{\circ} 07'$ and $79^{\circ} 27'$ East. It is bounded on the north and west by the Cauvery basin, on the south by the Vaigai basin and on the east by the Bay of Bengal. Vellar and Manimuttar rivers with their tributaries are the important streams in this basin area. The river Vellar rises in the Velamalai near Marugangapuri in Tiruchirappalli district and the length of this river is 136 km. The Manimuttar river rises in Karandamalai in Madurai district and length of this river is 150 km. Stream between Cauvery and Vaigai is found to be 10040 Km^2 covering parts of Dindigul, Madurai, Tiruchirappalli, Thanjavur, Pudukkottai, Sivaganga and Ramanathapuram districts of Tamil Nadu.

c) Vaigai basin

The Vaigai basin comprises of (i) Upper Vaigai (ii) Suruliyar (iii) Marudhanadhi (iv) Manjalar and (v) Lower Vaigai. The Vaigai basin consisting the above four tributaries have been considered as a single basin for the purpose of study. The basin lies between north latitudes $9^{\circ} 18'$ and $10^{\circ} 19'$ and east longitudes $77^{\circ} 10'$ and $79^{\circ} 01'49''$.

The Vaigai rises in the western slopes of the Varushanad hills near Kottaimalai in Antipatti taluk of Theni district of Tamil Nadu state and flows in a northerly and north-easterly direction upto the confluence with the Varahanadi and flows through the Madurai and Ramanathapuram districts of Tamil Nadu state and falls into the Bay of Bengal close to the Palk Strait. During its course, the river travels over a distance of about 258 km. Suruliarnadi, Varahanadi, Manjalar and Marudhanadi are its principal tributaries. The basin has a catchment area of 7741 Km²

d) Streams between Vaigai and Vaippar

The basin area comprises the catchments of all streams between Vaigai and Vaippar, draining independently and falling into the Bay of Bengal. The Gundar river is one of the important streams in this area. Terku Ar, Kanal Odai, Gridhamal Nadhi and Paralai Ar. are the main tributaries of the Gundar river. Two more rivers viz. Uttarakosamangal Aru and Vembar also drain this area. The area lies between Latitudes 9 ° 01' N and 10 ° 04' and Longitudes 77 ° 36' E and 79 ° 11'E. The Gundar river rises from the foot of the Andipatti hills at an elevation of about 260 m and the other streams originate from the plains. They all flow in a south easterly direction and drain into the Bay of Bengal. The catchment area is found to be 5409 Km² covering parts of Madurai, Ramanathapuram, Virudhunagar, Sivaganga and Thoothukudi districts in Tamil Nadu.

5.2.2 Command area

Cauvery (Kattalai) -Vaigai - Gundar link project envisages diversion of 2252 Mcum of water received from Mahanadi and Godavari basins including augmentation of water from Himalayan component river basins to the water short area of Karur, Tiruchirappalli, Pudukkottai, Sivaganga, Ramanathapuram, Virudhunagar and Thoothukudi districts of Tamil Nadu for providing irrigation to an area of 448340 ha. The irrigation water requirement is estimated to be 1931 Mcum. Apart from irrigation, it is also proposed to provide for future domestic and industrial water requirements in the command area. Additional domestic and industrial requirements projected to 2050 AD, are estimated to be 79 Mcum and 139 Mcum respectively.

5.2.3 Floods and drainages

a) Cauvery basin

The flood discharging capacity of Kattalai barrage is 13111 cumecs. The gauge and discharge (G&D) data is being observed by CWC at Musiri G&D site on Cauvery river, which is about 21 km downstream of the existing Kattalai barrage. The daily discharge data is available from 1973-74 to 1993-94 and from 2001-02 to 2016-17. The maximum observed flood at Musiri G&D site was 7690.36 cumecs on 25th October 2005. The design flood of Kattalai barrage is 11305 cumecs.

b) Streams between Cauvery & Vaigai

The basin area covered by the streams between Cauvery and Vaigai has only one gauge and discharge site maintained by CWC at Pallapatty on the Palar stream, a tributary of Manimuthar river. The data is available for a period of 5 years only from 1983-84 to 1987-88.

c) Vaigai basin

There are nine gauge and discharge (G&D) sites on the Vaigai river and its tributaries. Two G&D sites are being maintained by Central Water Commission and rest are being maintained by PWD, Tamil Nadu. Paramakkudi G&D site of CWC covering the maximum area of catchment is having data from 1972 onwards.

d) Streams between Vaigai and Vaippar basin

There are 8 Gauge & Discharge (G&D) sites on Gundar river and its tributaries. All G&D sites are being maintained by PWD, Tamil Nadu. Malattar (Anicut) G&D site on Gundar river covering the maximum area of catchment is having flow data from 1980 onwards.

5.2.4 River geometry

The river Geometry of Cauvery, streams between Cauvery and Vaigai and streams between Vaigai and Vaippar river systems along with the canal alignment is shown in **Fig 1**.

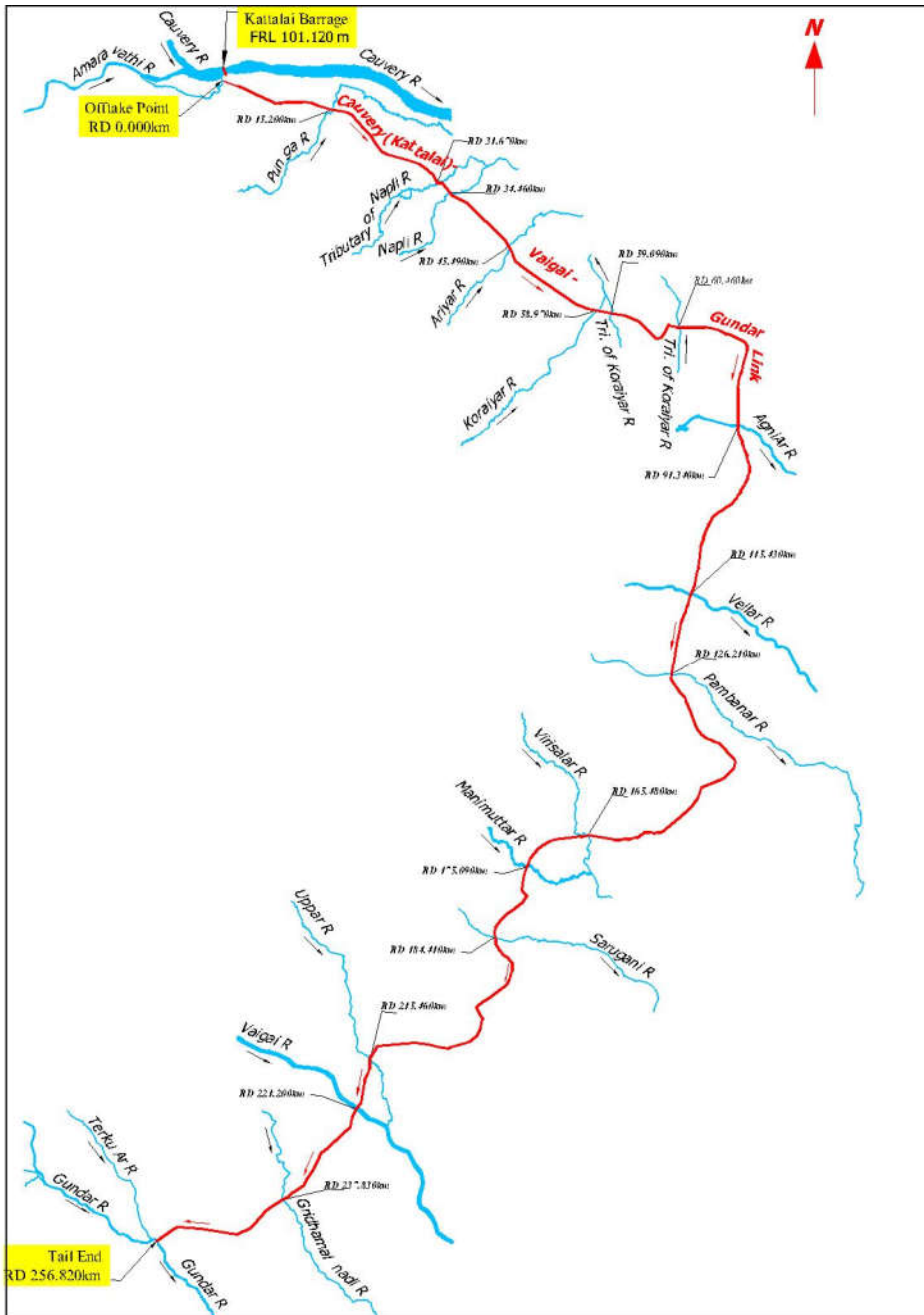


Fig.5.1 Geometry of the river system along with the canal alignment

5.2.5 Ground water recharge

The proposed diversion through 256.82 km long link canal is expected to recharge ground water enroute link canal as well as command area, thereby raising the ground water table including improvement in the quality of ground water. The project area is situated in sub-basins of Cauvery basins viz., Tirumanimuthar besides streams between Cauvery and Vaigai, Vaigai basin and streams between Vaigai and Vaippar. The districts that are traversed by the link in which its command lies are Tiruchirappalli, Pudukkottai, Sivaganga, Virudhunagar, Thoothukudi, Ramanathapuram and Karur of Tamil Nadu. As per the "National Compilation on Dynamic Ground Water Resource of India,2017" published by CGWB in July, 2019, the ground water potential, existing draft for irrigation, balance and stage of utilization in these districts of the project area given in **Table 5.2**

Table 5.2
Ground water resources and utilization in districts
falling in the project command area **Unit: Mm³**

Sl. No	District	Annual Replenishable GWR	Annual extractable GWR	Annual GW draft for irrigation	Projected demand for M&I uses up to 2025	GW available for future irrigation use	Stage of GW development (%)
1.	Karur	310	279	275	12	49	102
2.	Tiruchirappalli	687	619	480	76	170	90
3	Pudukkottai	1025	922	413	20	488	47
4.	Ramanathapuram	615	554	57	17	480	13
5.	Sivaganga	995	896	149	17	730	18
6.	Virudhunagar	583	525	323	24	200	65
7.	Thoothukudi	550	495	198	19	289	43
Total		4765	4290	1895	185	2406	54

5.2.6 Barrage area

The Cauvery (Kattalai) - Vaigai - Gundar link canal is proposed to off-take from the right flank of the existing barrage at Kattalai across river Cauvery near Mayanur village in Krishnarayapuram taluk of Karur district. The latitude and longitude of Kattalai barrage are 10 ° 58' N and 78 ° 14' E respectively. The link canal will take off from Kattalai barrage with FSL of 100.75m. The pond level of barrage is 101.20 m and the submergence are confined to river portion only.

5.2.7 Other water usage

The main purpose of the link project is to provide assured annual irrigation to an extent of 448340 ha in the needy areas along the alignment. It will also provide drinking water to the tune of 79 Mcum benefitting 28.05 lakh population of which 11.84 lakh is urban by 2050 AD. Besides, the link will supply about 139 Mcum to the industries in the vicinity.

5.2.8 Navigation

There is no proposal of providing navigation in the proposed Cauvery (Kattalai) - Vaigai -Gundar link project.

5.3 Data availability

In the catchment of Cauvery basin upto Kattalai barrage, the availability of data on rainfall, pan evaporation, climate, river discharge, sediment and water quality are discussed below:

5.3.1 Hydrological and meteorological investigation

5.3.1.1 Rainfall and snowfall

There is no snowfall ever experienced in Cauvery basin. The precipitation in basin is in the form of rainfall and intensity of rainfall varies fairly in time and space as obtained from the data. The inventory of 263 rain

gauge stations as considered for the hydrological studies of Cauvery basin upto Kattalai are given in **Annexure: 5.1**.

5.3.1.2 Pan evaporation

In simulation studies, it is considered that the entire storage of Kattalai barrage would be utilized for its canal system/or downstream releases. Therefore, no evaporation losses at the barrage site are separately taken into account.

5.3.1.3 Climatological parameters like temperature, humidity and wind speed

The normal values (1981-2010) of Climatological parameters recorded at Tiruchirappalli IMD observatory which lies in the vicinity of Kattalai barrage are as follows:

	Maximum	Minimum
Air Temperature (°C)	40.8 (May)	18 (Jan)
Humidity (%)	82 (Nov)	37 (March)
Wind Speed (km/hr)	15.2 (Jan)	8 (Oct.)
Cloud Cover (Oktas)	5.9 (July)	1.0 (May)
Monthly Rainfall (mm)	696.7(Oct)	134.9 (March)

5.3.1.4 River gauge & discharge

There are a number of G&D sites, reservoir sites and Anicut on river Cauvery and its tributaries used for measuring discharges. It is being maintained by State Govts. and Central Agencies. The details of G&D site and other discharge measuring sites considered for assessment of yields of the Cauvery basin upto Kattalai are furnished as **Table 5.3**

Table 5.3
G&D sites & other discharge measuring sites for assessment of yields of the
Cauvery upto Kattalai barrage.

Sl. No	Name of Basin/Sub-basin	Name of G&D sites	Maintained by	River/ Tributary	Catch -ment Area (Km ²)
1	Upper Cauvery i) Hemavathi ii) Main Cauvery iii) Lakshmanthirtha	Akkihebbel Chunchankatte Unduwadi	CWC CWC State Govt.	Hemavathi Cauvery Laxamanthi rtha	5410 3519 1690
2	Kabini	T. Narsipur	CWC	Kabini	7040
3	Suvarnavathi	Chikkahole & Suvarnavathi reservoirs	State Govts.	Chikkahole & Suvarnavathi	1787
4	Shimsha	Tonekadanhalli	CWC	Shimsha	8469
5	Arkavati	Karnakapura	CWC	Arkavati	4351
6	Middle Cauvery	Gundal Reservoir Site	State Govt.	Gundal	2676
7	Palar	Uduthorehalle	State Govt.	Palar	3214
8	Chinnar	Chinnar Reservoir	State Govt.	Chinnar	4061
9	Bhawani	Kodiveri Anicut	State Govt	Bhawani	6154
10	Noyil	Kannanur G&D site of Tirumanimuttar	CWC	Tirumanimuttar	2999
11	Amravathi	Nallamaranpatty	CWC		9013
12	Tirumanimuttar	Kennanur	CWC	Tirumanimuttar	8429

5.3.1.5 Sediment (Suspended and bed load inflow)

Sediment data analysis is being carried out by CWC at Musiri G&D site in Cauvery in the downstream of Kattalai barrage. From the data on sediment inflow at Musiri G&D site available for the period from 1973-74 to 2017-18 the average annual sediment inflow works out to 508811MT of which 445126 MT is during monsoon period. The data on year-wise sediment inflow at Musiri G&D site for the period from 1973-74 to 2017-18 is furnished in **Table 5.4**.

Table 5.4
Annual Sediment load at Musiri G&D site on Cauvery river
Unit: Metric Tons

Year	Sediment load observed during		Annual
	Monsoon period	Non-monsoon period	
1973-74	907720	55641	963361
1974-75	442845	43339	486184
1975-76	604524	49274	653798
1976-77	182434	61840	244274
1977-78	3399864	210641	3610505
1978-79	1676954	455996	2132950
1979-80	2055737	69634	2125371
1980-81	1064037	50818	1114855
1981-82	1188991	61478	1250469
1982-83	388850	37219	426069
1983-84	246673	101981	348654
1984-85	401417	69835	471252
1985-86	174798	24239	199037
1986-87	192144	30881	223025
1987-88	62969	63016	125985
1988-89	171821	23465	195286
1989-90	138397	89454	227851
1990-91	72645	13642	86287
1991-92	381621	35828	417449
1992-93	455657	42245	497902

Year	Sediment load observed during		Annual
	Monsoon period	Non-monsoon period	
1993-94	875212	80350	955562
1994-95	561469	78623	640092
1995-96	158563	43516	202079
1996-97	203097	126681	329778
1997-98	267785	122259	390044
1998-99	227294	51378	278672
1999-00	209120	72397	281517
2000-01	833079	90794	923873
2001-02	147902	48056	195958
2002-03	38989	18935	57924
2003-04	27821	14337	42158
2004-05	146208	71940	218148
2005-06	558850	110703	669553
2006-07	291602	34026	325628
2007-08	387284	87039	474323
2008-09	169592	37977	207569
2009-10	106925	21810	128735
2010-11	131921	47601	179522
2011-12	104947	33699	138646
2012-13	42990	8367	51357
2013-14	163350	13739	177089
2014-15	70319	24493	94812
2015-16	60898	28504	89402
2016-17	19973	20	19993
2017-18	15392	8118	23510
Average	445126	63685	508811

5.3.1.6 Water quality

The Central Water Commission (CWC) has been collecting water samples from Musiri G&D site downstream of Kattalai barrage and conducting tests for determining various parameters of water quality. The water samples are

being tested for both physical (pH, Temperature) and physio-chemical. The latest water quality data at Musiri G&D site available for the year 2013 to 2016 are furnished in **Table 5.5**.

Table 5.5**Test results of water samples at Musiri G&D site of CWC on river Cauvery**

Sl. No	Characteristic (Parameter)	unit	Analysis Result				Drinking Water Specifications (IS 10500: 2012)
			2016	2015	2014	2013	Requirement (Acceptable Limit)
1	pH		7.87	8.20	8.09	8.04	6.5 to 8.5
2	Dissolved Oxygen	mg/lit	6.42	6.48	6.66	6.68	6 mg/l Min as per CPCB class A Tolerance limit
3	Total Dissolved Solids	mg/lit	334	341	295	276	500 Max
4	Turbidity	NTU	0.73	0.78	0.71	0.71	1 Max
5	Total Alkalinity (as CaCO ₃)	mg/lit	158	176	156	136	200 Max
6	Chloride (as Cl)	mg/lit	82	78	72	45	250 Max
7	Sulphate (as SO ₄)	mg/lit	30	32	27.9	21.1	200 Max
8	Fluoride (as F)	mg/lit	0.48	0.51	0.39	0.32	1.0 Max
9	Total Hardness (as CaCO ₃)	mg/lit	171	195	170	150	200 Max
10	Calcium (as Ca)	mg/lit	29	31	28.3	28.5	75 Max
11	Magnesium (as Mg)	mg/lit	23.7	28.3	23.8	18.9	30 Max
12	Boron (as B)	mg/lit	0.09	0.12	0.05	0.05	0.5 Max
13	Nitrate as NO ₃ -N	mg/lit	0.5	2.55	1.38	0.28	10ppm
14	BOD	mg/lit	2.23	1.97	2.4	2.34	2 mg/l Max as per CPCB class A Tolerance limit
15	Silica	mg/lit	14.33	17.45	17.5	NA	----
16	Iron (as Fe)	mg/lit	0.01	0.02	0.05	0.10	0.3 Max

Source: WRIS India web site

5.4 Water availability studies

The proposed Cauvery (Kattalai) - Vaigai - Gundar link project envisages diversion of 2252 Mcum of water from Kattalai barrage on Cauvery for extending irrigation, domestic and industrial water supply benefits to the area lying between Cauvery and Gundar river in Tamil Nadu. The hydrological studies are carried out for the Cauvery basin upto Kattalai barrage.

5.4.1 Methodology

The observed flow data at the terminal G&D site and the rainfall observed at various rain gauge stations in and around the catchment of each of the sub basins are collected. The year-wise upstream utilizations are added to these observed flows and the regenerated flows are subtracted to get the virgin monsoon yields at the G&D site. Weighted monsoon rainfall for the catchment upto the G&D site and for the whole sub-basin are worked out. Rainfall-runoff relationship is developed by regression analysis, using these virgin flows and weighted rainfall upto the G&D site. Monsoon yields are computed using the best fit equation and weighted rainfall for the entire sub-basin. Non-monsoon yields are added to arrive at the annual gross yields for the entire sub-basin. The annual gross yields, thus arrived at are arranged in descending order, from which 50% and 75% dependable annual gross yields are obtained.

The overall surface water available in each sub basin is arrived at by summing up the yield at the respective dependability and imports and by deducting the exports, if any.

Water requirement

The requirements of water at the ultimate stage of development for various uses viz. irrigation, domestic, industrial and hydro-power are worked out as follows:

Irrigation needs

The irrigation water requirements are worked out for all the existing, ongoing and proposed major, medium and minor projects in the sub basins. The designed annual utilizations are considered for the existing and ongoing projects. In case of future projects, the irrigation water requirement is estimated as per the NWDA guidelines laid down by its Technical Advisory committee (TAC). In a deficit sub basin, if the ultimate annual irrigation considering all the existing, ongoing and future major, medium and minor projects works out to less than 30% of the maximum culturable area of the sub-basin, additional areas are considered, to bring annual irrigation upto 30%. In a surplus sub basin, the annual irrigation at the ultimate stage is increased to 60% of the maximum culturable area or to such maximum percentage (upto 60%) that may be possible to utilized the entire available waters of the sub-basin. The increased annual irrigation is considered 50% each under future medium projects and minor schemes.

Domestic needs

The domestic water requirement for the projected (2050 AD) human population and livestock is estimated using the available latest available Census. The daily requirements per capita are considered at 70 litres, 135 litres and 50 litres for the rural and urban human population and livestock population respectively as per the recommendations of the Ministry of Works and Housing in their manual “Water Supply and Treatment”. The requirement of 50% of the rural human population and of the entire livestock is considered to be met from groundwater and the requirement for the remaining 50% of rural population and the entire urban population is considered to be met from the surface water.

Industrial needs

In the absence of actual industrial water needs at the ultimate stage of development, the industrial water requirement is considered to be equal to the total domestic water requirement for human population and livestock. The entire industrial requirement is considered to be met from surface water.

Hydro power needs

The hydro-power requirement is taken to be the evaporation losses from the reservoirs with hydro-power production. Wherever the evaporation data of the projects is available, the same is made use of and wherever the data is not available, the same assumed to be certain percentage of the storage capacity.

Regeneration

The regeneration is considered as (a) 18% of the net utilization for existing old irrigation projects of Cauvery basin as per Cauvery Dispute Tribunal Award, (b) 20% from all other existing, ongoing and future identified major and medium projects as per Task Force for ILR and (c) 80% of the domestic and industrial use to be met from the surface water.

Water balance

The total water requirement of each of the sub-basins is worked out on the methodology outlined above is subtracted from the overall availability of water in the sub basin to determine the water balances (surplus/deficit) at 75% and 50% dependability.

5.4.2 Hydrological and water balance studies of the Cauvery basin Upto Kattalai barrage

The catchment area of the Cauvery river from the source upto Kattalai barrage site includes the independent catchments of 12 upper sub-basins i.e., Upper Cauvery, Kabini, Suvarnavathi, Shimsha, Arkavati, Middle Cauvery, Palar, Chinnar, Bhavani, Noyil, Amaravathi, and part of the Tirumanimuttar sub-basin upto Kattalai barrage site. The catchment extends over an area of 63694 km², which works out to 78.5% of the total catchment area of the Cauvery basin and lies in the States of Karnataka (34273 km²), Kerala (2866 km²) and Tamil Nadu (26555 km²). The hydrological studies in respect of the individual sub basins have been carried out based on rainfall-runoff relationship developed at G & D sites and using these relationship and weighted monsoon runoff, the gross

monsoon of the sub basins have been generated and considering the non monsoon yield, the annual gross yield series were also obtained. The details of the G & D sites considered for assessment of yield of the sub basins are furnished as **Table 5.3**. The annual gross yield series of the catchment of Cauvery basin upto Kattalai barrage site for the period from 1951-52 to 2014-15 have been arrived at by summing up the annual yield series of the part of Tirumanimuttar sub-basin upto Kattalai barrage site to the annual yield series of the 11 upstream sub-basins. From this series, the 75% and 50% dependable annual gross yields are determined to be 14138 Mcum and 17126 Mcum respectively. The details are furnished in **Annexure: 5.2**. The isohyets map of Cauvery basin is appended at **Plate 5.1**.

The water balance has then been worked out by deducting the ultimate water requirements for various uses like irrigation, industrial, domestic and others from the overall availability duly considering the regeneration, import and export.

Surface water needs for irrigation have been assessed by considering the ultimate annual irrigation. The state wise annual irrigation and utilization for all the existing, ongoing and future major, medium and minor projects is given in **Table 5.6**. The details of sub-basin wise annual irrigation and utilization from existing, ongoing and future projects are furnished in **Annexure: 5.3 to 5.5**.

Table 5.6
Surface water requirement for ultimate irrigation in the catchment of Cauvery basin upto Kattalai barrage

State	Category of project	Annual irrigation (ha)	Annual utilisation (Mcum)
Karnataka	Existing	598763	6557
	Ongoing	250590	1643
	Proposed	82170	784
	Additional area	62133	312
	Sub-total	993656	9296
Kerala	Existing	33170	280
	Ongoing	8387	120
	Proposed	67001	740
	Additional area	930	9
	Sub-total	109488	1149

State	Category of project	Annual irrigation (ha)	Annual utilisation (Mcum)
Tamil Nadu	Existing	299769	4347
	Ongoing	12415	83
	Proposed	21472	214
	Additional area	150323	1689
	Sub-total	483979	6333
Total	Existing	931702	11184
	Ongoing	271392	1846
	Proposed	170643	1738
	Additional area	213386	2010
	Grand total	1587123	16778

The requirement of water for domestic consumption computed by projecting the rural and urban human population and the livestock to 2050 AD are given in **Table 5.7**. The domestic requirement for the entire urban population and 50% of the rural population to be met from surface water sources works out to 1294Mcum.

Table 5.7
Domestic water requirement in Cauvery basin upto
Kattalai barrage by 2050 AD

Category	Population ('000')	Daily needs per capita (litres)	Water requirement (Mcum)
Rural	13925	70	356
Urban	15577	135	768
Bangalore (UA)	3377	-	348
Live stock	12507	50	228
Total			1700

In the absence of relevant data on the industrial water needs, the industrial needs by 2050 AD have been assumed to be of the same order as that of domestic water requirement, which is 1700 Mcum.

The regeneration from irrigation uses at (a) 18% of the net utilization for existing old irrigation projects of Cauvery basin as per Cauvery Dispute Tribunal Award & (b) 20% from all other existing, ongoing and future identified major and medium projects as per Task Force for ILR is 2409 Mcum. The regeneration at 80% of the domestic and industrial water uses to be met from surface water resources are 1035 Mcum and 1360 Mcum respectively.

The total evaporation losses of all the hydel projects have been taken as hydro power needs which is worked out to be 70 Mcum. Thus, the computation of surface water balance of the Cauvery basin upto Kattalai barrage site is given in **Table 5.8**.

Surface water balance at Kattalai barrage site		Unit:Mcum	
1.	Availability		
a)	Gross monsoon yield		
i)	At 75% dependability		14138
ii)	At 50% dependability		17126
b)	Surface water import (+)		744
c)	Surface water export (-) (Including D/s requirement for delta)		12479
d)	Overall availability		
i)	At 75% dependability		2403
ii)	At 50% dependability		5391
2.	Surface water requirement for		
i)	Irrigation	16778	
ii)	Domestic	1294	
iii)	Industrial use	1700	
iv)	Hydro-power needs	70	
	Sub-total	19842	19842
3.	Regeneration (+)		
i)	Irrigation	2409	
ii)	Domestic	1035	
iii)	Industrial use	1360	
	Sub-total	4804	4804

4. Surface water balance

a)	At 75% dependability	(-) 12635
b)	At 50% dependability	(-) 9647

5.4.3 Hydrological and water balance studies of streams between Cauvery and Vaigai

The basin area covered by streams between Cauvery and Vaigai comprises of the independent east flowing streams viz. Agni ar, Ambuliar, Vellar, Koluvar, Pambar, Manimuttar and Kottakaraiar.

Within the basin area covered by the streams between Cauvery and Vaigai, there is only one G & D site namely Pallappatty maintained by Central Water Commission. However, the catchment area upto the above site is 275 km², which is only 2.74% of the entire basin area. Also, the flow data of this site is available only for a short period, i.e. from 1983-84 to 1987-88, and even the flow data at this site is not consistent. Hence, for the hydrologic studies of the basin area between Cauvery and Vaigai, the observed flow data at Paramakudi G & D site, which is situated in adjacent Vaigai basin is considered.

There are 47 rain gauge stations in and around the basin area between Cauvery and Vaigai and the rainfall data is available for varying periods from 1951-52 to 2014-15

The rainfall - runoff relationship for the monsoon period has been developed by regression analysis at Paramakudi G&D site and using this relationship and weighted monsoon runoff, the gross monsoon yield series of the basin for the period from 1951-52 to 2014-15 have been generated. Considering the non-monsoon yield as 5.94% of the monsoon yield, the annual gross yield series for the period from 1951-52 to 2014-15 were obtained, from which the 75% and 50% dependable annual yields are found to be 808 Mcum and 1096 Mcum respectively.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin, duly considering the regeneration, import and export.

The isohyets map of streams between Cauvery and Vaigai basin is appended at **Plate 5.2**. The ultimate surface water requirement for irrigation in the basin is furnished in the **Table 5.9**

Table 5.9
Surface water requirement for irrigation in streams between Cauvery and Vaigai

Project category	Annual irrigation (ha)			Annual utilisation (Mcum)		
	In-basin	Import	Total	In-basin	Import	Total
Existing	119735	61088	180823	1085	837	1922
Ongoing	-	-	-	-	-	-
Proposed	19739	-	19739	224	-	224
Total	139474	61088	200562	1309	837	2146

The requirement of water for domestic use by the rural and urban human population and livestock has been computed by projecting the rural and urban human and livestock population of the basin to 2050 AD. The total domestic water needs are assessed to be 262 Mcum as shown in **Table 5.10**.

Table 5.10
Domestic water requirement by 2050 AD in the streams between Cauvery and Vaigai

Category	Population ('000')	Per capita daily needs (litres)	Water requirement, (Mcum)
Rural	2553	70	65
Urban	2856	135	141
Livestock	3057	50	56
Total			262

The entire requirement for the urban population and 50 per cent of the requirement for the rural human population are proposed to be met from the surface water resources, which works out to 175 Mcum.

Information regarding water needs of the existing, ongoing and proposed industries in the basin is not readily available. In the absence of relevant information, the water requirement for industrial use has been assumed to be of the same order as that for domestic use, which is 262 Mcum.

20% of the net irrigation use by the major and medium projects is considered as regeneration. Eighty percent (80%) of the domestic and industrial water use, to be met from surface water resources, is considered as regeneration to the stream. The water balance in the basin area covered by streams between Cauvery and Vaigai, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.11**.

Table 5.11
Surface water balance in streams between Cauvery and Vaigai

1.	Availability	Unit: Mcum	
a)	Gross monsoon yield		
	i) At 75% dependability		808
	ii) At 50% dependability		1096
b)	Surface water import (+)		837
c)	Surface water export (-)		0
d)	Overall availability		
	i) At 75% dependability		1645
	ii) At 50% dependability		1933
2.	Surface water requirement for		
	i) Irrigation	2146	
	ii) Domestic	175	
	iii) Industrial use	262	
	iv) Hydro-power needs	0	
	Sub-total	2583	2583

3.	Regeneration (+)		
	i) Irrigation	178	
	ii) Domestic	139	
	iii) Industrial use	210	
	Sub-total	527	527
4.	Surface water balance		
	a) At 75% dependability		(-) 409
	b) At 50% dependability		(-) 121

Source: Technical study No.WBS/155/2019 prepared by NWDA.

5.4.4 Hydrological and water balance studies of Vaigai basin

The observed flow data for the period from 1972-73 to 1994-95 of G & D site at Paramakudi on the river Vaigai, maintained by Central Water Commission, has been used for the hydrological studies. The catchment area of Vaigai river upto Paramakudi G & D site is 6796 km² which is 87.8% of the total catchment area of the basin. There are 33 rain gauge stations in and around Vaigai basin.

The rainfall - runoff relationship for the monsoon period has been developed by regression analysis at Paramakudi G&D site and using this relationship the gross monsoon yield series of the basin for the period from 1951-52 to 2014-15 have been generated. Considering the non-monsoon yield as 5.94% of the monsoon yield, the annual gross yield series for the period from 1951-52 to 2014-15 are obtained, from which the 75% and 50% dependable annual yields are found to be 439 Mcum and 659 Mcum respectively.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin, duly considering the regeneration, import and export.

The isohyets map of Vaigai basin is appended at **Plate 5.3**. The ultimate surface water requirement for irrigation in the basin is furnished in the **Table 5.12**.

Table 5.12
Surface water requirement for irrigation in Vaigai basin

Project category	Annual irrigation (ha)			Annual utilisation (Mcum)		
	In-basin	Import	Total	In-basin	Import	Total
Existing	54921	78426	133347	706	589	1295
Ongoing	-	3746	3746	23	12	35
Proposed	6404	-	6404	54	-	54
Total	61325	82172	143497	783	601	1384

The requirement of water for domestic use in the rural and urban human population and for livestock has been computed by projecting the rural and urban human and livestock population of the basin to 2050 AD. The total domestic water needs are assessed to 184 Mcum as shown in **Table 5.13**.

Table 5.13
Domestic water requirement by 2050 AD in Vaigai basin

Category	Population ('000')	Per capita daily needs (litres)	Water requirement, (Mcum)
Rural	1993	70	51
Urban	2230	135	110
Livestock	1268	50	23
Total			184

The entire requirement for the urban population and 50 per cent of the requirement for the rural human population are proposed to be met from the surface water resources, which works out to 136 Mcum.

Information regarding water needs of the existing, ongoing and proposed industries in the basin is not readily available. In the absence of relevant information, the water requirement for industrial use has been assumed to be of the same order as that for domestic use, which is 184 Mcum.

20% of the net irrigation use by the major and medium projects is considered as regeneration. Eighty percent (80%) of the domestic and industrial water use, to be met from surface water resources, is considered as regeneration to the stream. The water balance in the Vaigai basin, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.14**.

Table 5.14
Surface water balance in Vaigai basin

1.	Availability	Unit: Mcum	
a)	Gross monsoon yield		
i)	At 75% dependability		439
ii)	At 50% dependability		659
b)	Surface water import (+)		601
c)	Surface water export (-)		260
d)	Overall availability		
i)	At 75% dependability		780
ii)	At 50% dependability		1000
2.	Surface water requirement for		
i)	Irrigation	1384	
ii)	Domestic	136	
iii)	Industrial use	184	
iv)	Hydro-power needs	0	
	Sub-total	1704	1704

3.	Regeneration (+)		
	i) Irrigation	223	
	ii) Domestic	109	
	iii) Industrial use	147	
	Sub-total	479	479
4.	Surface water balance		
	a) At 75% dependability		(-) 445
	b) At 50% dependability		(-) 225

5.4.5 Hydrological and water balance studies of streams between Vaigai and Vaippar

The basin area of the streams between Vaigai and Vaippar comprises the catchment of all small to medium streams between Vaigai and Vaippar of which, Gundar is the main stream. Terkuar, Kanalodai, Gridhamalnadi and Paralaiar are the main tributaries of Gundar river. Two more rivers viz. Uttara kosamangaiar and Vembar also drain this area.

The Malattar Anicut site on Gundar river having a catchment area of 3113 Km² (57.55% of total basin area of 5409.40 Km²) has been considered for the hydrological study. The entire monthly flow data of this site is available for the period from 1980-81 to 1994-95.

There are 20 rain-gauge stations in and around this basin area. The rainfall data of these rain-gauge stations are available for varying periods from 1951-52 to 2014-15.

The rainfall - runoff relationship for the monsoon period has been developed by regression analysis at Malattar Anicut site and using this relationship, the gross monsoon yield series of the basin for the period from 1951-52 to 2014-15 have been generated. Considering the non-monsoon yield as Nil, the monsoon yield has been considered as the annual gross yield for the period

from 1951-52 to 2014-15, from which the 75% and 50% dependable annual yields are found to be 502 Mcum and 591 Mcum respectively.

The water balance has then been worked out, deducting the ultimate surface water requirement for various uses in the basin, duly considering the regeneration, import and export.

The isohyets map of streams between Vaigai and Vaippar basin is appended at **Plate 5.4**. The ultimate surface water requirement for irrigation in the basin is furnished in the **Table 5.15**.

Table 5.15
Surface water requirement for irrigation in
streams between Vaigai and Vaippar

Project category	Annual irrigation (ha)			Annual utilisation (Mcum)		
	In-basin	Import	Total	In-basin	Import	Total
Existing	35304	12750	48054	413	147	560
Ongoing	985	1231	2216	12	13	25
Proposed	72432	-	72432	790	-	790
Total	108721	13981	122702	1215	160	1375

The requirement of water for domestic use in the rural and urban human population and for livestock has been computed by projecting the rural and urban human and livestock population of the basin to 2050 AD. The total domestic water needs are assessed to be 161 Mcum as shown in **Table 5.16**.

Table 5.16
Domestic Water Requirement by 2050 AD in
streams between Vaigai and Vaippar

Category	Population ('000')	Per capita daily needs (litres)	Water requirement, (Mcum)
Rural	1692	70	43
Urban	1892	135	93

Livestock	1356	50	25
Total			161

The entire requirement for the urban population and 50 percent of the requirement for the rural human population are proposed to be met from the surface water resources which works out to 115 Mcum.

Information regarding water needs of the existing, ongoing and proposed industries in the basin is not readily available. In the absence of relevant information, the water requirement for industrial use has been assumed to be of the same order as that for domestic use, which is 161 Mcum.

20% of the net irrigation use by the major and medium projects is considered as regeneration. Eighty percent (80%) of the domestic and industrial water use, to be met from surface water resources, is considered as regeneration to the stream. The water balance in the basin area covered by streams between Vaigai and Vaippar, considering the availability, water needs, import and regeneration etc. is presented in **Table 5.17**.

Table 5.17
Surface water balance in Streams between Vaigai and Vaippar

1.	Availability	Unit: Mcum
a)	Gross monsoon yield	
i)	At 75% dependability	502
ii)	At 50% dependability	591
b)	Surface water import (+)	160
c)	Surface water export (-)	0
d)	Overall availability	
i)	At 75% dependability	662
ii)	At 50% dependability	751
2.	Surface water requirement for	
i)	Irrigation	1375

ii)	Domestic	115	
iii)	Industrial use	161	
iv)	Hydro-power needs	0	
	Sub-total	1651	1651
3.	Regeneration (+)		
i)	Irrigation	97	
ii)	Domestic	92	
iii)	Industrial use	129	
	Sub-total	318	318
4.	Surface water balance		
a)	At 75% dependability		(-) 671
b)	At 50% dependability		(-) 582

5.5 Proposed diversion from Cauvery at Kattalai barrage

As mentioned earlier, a quantity of 2252 Mcum is proposed to be diverted from Cauvery at Kattalai to the basins south of Cauvery from the waters available from peninsular and Himalayan river basins in Phase II of the inter basin water transfer in peninsular component. For this purpose, the net availability at Kattalai barrage after deducting all the upstream requirements and the committed downstream requirements is worked out to be (-) 7199 Mcum at 75% dependability as per NWDA studies.

The water balance at the Kattalai barrage site shows a net deficit of 12635 Mcum at 75% dependability. The Cauvery delta located downstream of Kattalai barrage having utilization of 9937 Mcum is presently getting water from the reservoirs viz., Mettur, Bhavani and Amaravathi rivers. The requirement for the Cauvery basin area between Kattalai and Grand Anicut is 696 Mcum. Thus, the total downstream requirement works out to 10633 Mcum.

The Pennar (Somasila)- Palar - Cauvery link project will deliver 1395 Mcum at Grand Anicut after meeting enroute requirements as part of Phase I of the peninsular component and the Phase II will add the 2252 Mcum of requirements of Cauvery (Kattalai) - Vaigai - Gundar link project. Thus, the total quantity of augmentation will become 3647 (1395+2252) against the earlier planned quantity of 3855 Mcum.

5.5.1 Generation of monthly flows

The net surface water requirement for each sub-basin of Cauvery basin up to Kattalai barrage is computed taking into account the import, export, water needs for various purposes and regeneration which works out to 13546 Mcum. Details are furnished in **Annexure: 5.6**. The net annual yield series of Cauvery basin up to Kattalai barrage for each sub-basin is generated for the period from 1973 -74 to 2014 - 15 and furnished in **Annexure: 5.7**. From the net annual yield series, the net annual yield at 75% dependability is found to be 3434 Mcum. When the downstream requirement of 10633 Mcum is also accounted then the net annual yield at 75% dependability is found to be (-) 7199 Mcum. Details are furnished in **Annexure: 5.8**. The inflows at Kattalai barrage have not been measured. The Musiri G&D site maintained by CWC is located 21 km downstream of Kattalai barrage and no major/medium size river/tributaries joining with main Cauvery river in the intermediate catchment area (2549 km²) between Kattalai barrage and Musiri G&D site. As such it may be presumed that there will be little contribution of flow from intermediate catchment between Kattalai barrage and Musiri G&D site.

The net annual inflows derived at Kattalai barrage at ultimate stage of development has been converted into monthly inflows at Kattalai barrage based on actual monthly discharge of Musiri G&D site for the period from 1973-74 to 2014-15. The computation of monthly inflows at Kattalai barrage is furnished in **Annexure 5.9**. These computations are furnished for revealing the scenario in Cauvery basin at Kattalai and the diversion of water through the link canal has no relevance with the inflows at Kattalai barrage.

5.5.2 Duration of the water diversion

The diversion of water is proposed as per the monthly demands and planned to be brought through the Pennar (Somasila) - Palar - Cauvery (Grand Anicut) link from Somasila reservoir. The maximum diversion is 438.4 Mcum proposed during the month of December. It is estimated that about 2252 Mcum of water will be available for transfer during June to January. The monthly diversion details are furnished in **Table 5.18**.

Table 5.18
Details on monthly diversion from Kattalai barrage

Month	Irrigation requirement (Mcum)	Domestic and industrial requirement (Mcum)	Transmission losses (Mcum)	Total (Mcum)
June	47.79	27.25	10.09	85.13
July	172.60	27.25	12.55	212.40
August	250.01	27.25	13.15	290.41
September	149.32	27.25	11.05	187.62
October	396.16	27.25	14.46	437.87
November	243.52	27.25	12.95	283.72
December	353.04	27.25	14.71	395.00
January	318.80	27.25	14.23	360.28
February	-	-	-	-
March	-	-	-	-
April	-	-	-	-
May	-	-	-	-
Total	1931.23	218.00	103.19	2252.42

5.6 Consistency of data

5.6.1 Internal consistency

In any analysis, the consistency of the considered data is vital for obtaining reliable and realistic outcome. Therefore, in the above analysis, before using the rainfall data for hydrological analysis, the rainfall records of each of the rain-gauge stations pertaining to the sub-basins of Cauvery basin upto Kattalai barrage

have been checked for continuity and consistency as it is the main contributing sub-basin for the link project. Double - Mass Curve (DMC) technique is employed to check the consistency of rainfall records. This analysis is based on the principle that when each recorded data comes from the same parent population, they are consistent.

A group of base stations in neighborhood of the index station (for which the consistency test is required) is selected. The data of the monsoon rainfall of the index station X and the average monsoon rainfall of the group of base stations covering a long period is arranged in the reverse chronological order i.e. the latest record as the first entry and the oldest record as the last entry in the list. The accumulated monsoon precipitation of the index station X (i.e. P_x) and the accumulated average monsoon precipitation values of the group of base stations (i.e. P_{av}) are calculated starting from the latest record. Individual cumulative rainfall values of the index station are plotted against cumulative mean values of group of base stations for consecutive time periods. The plot should be an ascending straight line to indicate good consistency of the rainfall data of the index station with that of the base stations.

In this way, the double-mass curve technique was employed for checking the consistency of rain gauge stations considered for hydrological studies in Cauvery's sub-basin. It was observed that the rainfall records of most of the stations are almost consistent. Minor deviations are noticed in case of some of the stations which are negligible.

5.6.2 External consistency

The weighted monsoon rainfall and the gross monsoon yields (virgin flows) upto respective G&D site of Cauvery sub-basins for concurrent period from different period of each sub-basins (considered for developing the rainfall - runoff relationship) have been plotted. The plot indicates fair amount of external consistency between the rainfall and run-off data in the catchment displaying almost similar trends of ascent, descent and peaks with occasional minor deviations.

5.6.3 Stationarity and homogeneity test

Stationarity and homogeneity test for the weighted monsoon rainfall have been carried out for the catchment of Cauvery upto Kattalai barrage.

5.7 Cauvery (Kattalai) - Vaigai - Gundar link project: Effect on hydrological regime of Lower Cauvery sub-basin d/s of Kattalai barrage site

Cauvery (Kattalai) - Vaigai - Gundar link project envisages diversion of 2252 Mcum of water annually out of water available at Kattalai barrage in exchange of delivery at Grand Anicut. The diversion through the link project is proposed monthly mostly during the eight months from June to January. Therefore, the hydrological regime of the Cauvery delta downstream of Kattalai barrage site is unlikely to be affected significantly on account of the link diversion.

5.8 Presentation of hydrological inputs for simulation

5.8.1 Water inflows

Based on the water availability study carried out, the net annual inflows at Kattalai barrage have been worked out by adding the net annual yields from sub-basins of Cauvery upto Kattalai including part catchments of Tirumanimuttar sub-basin upto Kattalai for the period from 1973-74 to 2014-15 is furnished in **Annexure.5.7**

5.8.2 Sedimentation studies

Rate of Sedimentation

Sediment analysis has been carried out by CWC at Musiri G&D site on Cauvery river downstream of the Kattalai barrage site. As per the available sediment data at Musuri G&D site for the period from 1973-74 to 2017-18 (Table 5.4), the rate of average annual sediment inflow at Kattalai works out to

508811 MT, out of which 445126 MT is during the monsoon period. The average annual sediment rate works out to 7.99 MT/km².

Elevation area capacity curves

The Kattalai barrage site on Cauvery river is proposed as a controlling structure for transfer of water through the link canal. The storage capacity of Kattalai barrage is 29.40 Mcum only. The elevation-area-capacity details are not available.

5.8.3 Potential evapo - transpiration and rainfall

The command area under the Cauvery (Kattalai) -Vaigai - Gundar link project is spread in 7 districts located in the state of Tamil Nadu. Normal potential evapo-transpiration and rainfall data of 3 IMD observatories viz., Tiruchirappalli Madurai and Tondi as available is used for computation of crop water requirement in the command area.

5.8.4 Flood inputs

The diversion of 2252 Mcum for the project is planned at 75% success rate from water made available at 75% dependability at Kattalai barrage from Peninsular component including augmentation from Himalayan component.

5.8.5 Inputs for water quality

The Central Water Commission (CWC) has been collecting water samples from Musuri G&D site downstream of the Kattalai barrage site and conducting tests for determining various parameters of water quality. The water samples are tested for determining both physical (pH, Temperature), physio-chemical (Cl, Ca, K, Mg, etc.) and two biological/ bacteriological (BOD, DO) parameters. Besides, chemical indices (Na%, SAR, RSC) are determined and total hardness is observed.

5.8.6 Low flow inputs

It is seen, from the flow data for lean season at Musuri G&D site on Cauvery river for the period from 2001-02 to 2017-18, the average flow during non-monsoon (January to May) is worked out as 11.80% of average of annual flow.

5.8.7 Surface to ground water recharge

The Cauvery (Kattalai) - Vaigai - Gundar link envisages diversion of 2252 Mcum from Kattalai barrage on Cauvery river. Out of this, 1931 Mcum is planned to be utilized for irrigation in the command area. A part of this quantum as conveyance and application losses would obviously contribute to the groundwater recharge in the command area. Further, the transmission losses in the main link canal are assessed to be about 103 Mcum, which may recharge the ground water in its periphery. The contemplated domestic use of 79 Mcum and Industrial use of 139 Mcum in the command area will also likely to recharge groundwater to a significant extent.

5.9 Simulation studies of Kattalai barrage

The hydrological studies of various sub-basins upstream reveal that, the Cauvery basin upto Kattalai barrage site is deficit by 12631 Mcum. Since, most of the flows reaching Kattalai are regulated releases from Mettur, Bhavani and Amaravathi reservoirs and earmarked for Cauvery delta, the diversion of 2252 Mcum through Cauvery (Kattalai) - Vaigai - Gundar link is proposed from the waters that are made available through the preceding link project of Pennar (Somasila) - Palar - Cauvery (Grand Anicut) as part of Phase II of the peninsular component.

The Pennar (Somasila) - Palar - Cauvery (Grand Anicut) in Phase I of inter basin water transfer in peninsular component is already designed for accommodating the ultimate stage of Phase II and the same will be provided with Kattalai feeder branch canal proposed to take off from its Arani river crossing to

transfer 2252 Mcum of water to Kattalai barrage for further transfer of the same through Cauvery (Kattalai) - Vaigai - Gundar link project.

Hence, monthly demands of Cauvery (Kattalai) - Vaigai - Gundar link project will be regulated at Somasila reservoir along with the demands of Pennar (Somasila) - Palar - Cauvery (Grand Anicut) link project.

5.9.1 Project demands

The Cauvery (Kattalai) - Vaigai - Gundar link is envisaged to carry 2252 Mcum of water annually to meet the following demands.

- i) 218 Mcum towards the domestic and industrial water requirements of the areas en route the link canal.
- ii) 1931 Mcum for irrigation of the proposed command area en route the link between Cauvery and Gundar.
- iii) 103 Mcum of transmission losses en route the link canal from Kattalai barrage to Gundar.

The computation of all the above demands and their monthly distribution pattern are dealt in detail in **Chapter 8: Water and Irrigation Planning**.

Since the diversion is proposed from the Kattalai barrage, the aspects of design flood and diversion flood etc. are not discussed in the present study.

5.10 Studies for design drainage in the command area

New command area of about 448340 ha is proposed to be brought under irrigation from the link project. Most of this command area is situated in the water short areas of Tamil Nadu state. Therefore, in order to judiciously utilize the waters being transported through the 256.82 km link canal, proper drainage arrangements would-be set-in place. Adequate provision for the same is made in the cost estimate. Detailed studies will be carried out for design of drainage system in the command area during pre-construction stage.

5.11 Determination of levels for locating structures on outlets

The FPL of the proposed Kattalai barrage is 101.2 m while its crest level is 96.30 m. The off-take FSL of canal at Kattalai is proposed to be 100.75 m. A head regulator with a crest level of 96.500 m is proposed to regulate the discharge into the canal.

5.11.1 Location of outlets

Suitable structures such as cross regulators, outlets etc., are proposed to be provided to supply water to the command area. The hydraulic particulars of these structures are discussed in the **Chapter 6: Design aspects**

5.12 Model studies

Mainly the existing structures at Kattalai are proposed for regulation and diversion of waters through the link project. Therefore, no model studies are proposed to be carried out, at this stage.

5.13 Minimum flow for environmental consideration

Since water being proposed for diversion through the link project only from water made available at Kattalai barrage through series of links viz., Krishna (Nagarjunasagar) - Pennar (Somasila) and Pennar (Somasila) - Palar - Cauvery (Grand Anicut) link, no adverse effect on account of diversion is anticipated. It is expected that sufficient flows would be available in the Cauvery river from upstream resources as well as the streams joining downstream to cater environmental flows. As such, no adverse effect on river ecology is anticipated due to diversion of water through the link canal.

5.14 Effect of project on hydrologic regime

No adverse effect on downstream hydrologic regime is anticipated on account of water transfer through the link project, since the diversion of water is

proposed out of water made available at Grand Anicut from the other water surplus basins.

5.14.1 Impact on existing projects in the downstream of planned project

The Cauvery (Kattalai) - Vaigai - Gundar link project envisages diversion of surplus waters available from Mahanadi, Godavari and the other Himalayan rivers after accounting for unutilized waters in the respective basins. Therefore, the proposal will not have any impact on the existing water use of any riparian states downstream.

5.14.2 Effect on low flows

Diversion through the link project is proposed from water made available at Kattalai barrage through series of link canals from water surplus basins and hence, there will be no adverse effect on low flows downstream of Kattalai barrage.

5.14.3 Effect on flood hydrology

The Kattalai barrage will act as just balancing structure as the inflows will be regulated at Somasila reservoir on Pennar river and the same will be taken through the link project. Hence there will not be any effect on peak flood in Cauvery river downstream.

5.14.4 Effect on total runoff

The diversion of water through the proposed link project from Kattalai barrage is mostly out of the surplus made available from water surplus basins and hence there will be no effect on the total runoff as such.

5.14.5 River hydraulics

The diversion of water is not likely to cause any effect on the river hydraulics as the Kattalai barrage will act as balancing structure.

5.14.6 Sediment yields, sediment carrying capacities and aggradations and degradations at various locations.

No additional storage structure is contemplated as part of the link project. The link diversion is planned from the barrage mostly during the monsoon period. The sediment reached at the barrage site would get flushed downstream. It is also not being expected that any aggradations / degradation takes place downstream of the barrage site.

5.14.7 Water quality

No ill effect on the quality of water available in Cauvery river at the Kattalai barrage site is perceived on account of the proposed link project.

5.14.8 Water demand

As indicated in the earlier paras, diversion of 2252 Mcum of water is contemplated from the surplus made available at Kattalai barrage from the waters of surplus basins in peninsular and Himalayan component. Thus, the proposed link diversion is not likely to affect the demands of downstream projects in any way.

5.15 Water allocation and inter-state aspects

The Cauvery Water Disputes Tribunal (CWDT) in its Award, allocated water among the basin states, since no water is proposed to be transfer from Cauvery basin, the Cauvery (Kattalai) - Vaigai - Gundar link is not expected to involve any such aspect from the inter-state disputes point of view. This aspect has already been discussed in detail in **Chapter 3: Inter-state aspects**.