Preface

India is the largest peninsula in the world with a coastline of about 7517 km with 12 major ports and 185 non major / intermediate ports with a very impressive water network consisting of rivers, lakes, creeks and canals.

An efficient transport sector is vital for development of the economy to stimulate optimum competitive business environment. Indian transport system comprises various modes, viz. Railways, Roadways, Inland Waterways, Coastal Shipping and Airways. Integrated development of waterways can generate waterway grid that may in future help shift cargo traffic from road transport to the cheaper and eco-friendly inland waterways.

The first national waterways were established in India in mid 1980s & 1993 with a combined length of 2,716 km:

NW 1 (1620 km): Ganga - Bhagirathi- Hooghly river system between Haldia & Allahabad declared as National waterway in 1986

NW 2 (891 Km): Brahmaputra River between Bangladesh Border and Sadiya declared as National waterway in 1988

NW 3 (205 km): West coast canal (168 km) - Udyogmandal canal (23 km) - Champakara canal (14 km) declared as National waterway in 1993

The government also declared the following two inland waterways as national waterways during 2008:

NW 4 (1078 km): Kakinada-Pondicherry canal - Godavari and Krishna rivers

NW 5 (588 km): East Coast Canal - Brahmani River and Mahanadi delta

Given the untapped potential of India's inland waterways, the Govt. of India desires to explore the commercial navigation potential on year round basis. Ministry of Shipping (MoS), Govt. of India has directed Inland Waterways Authority of India (IWAI) to identify the viable waterways in India for their phased development.

Accordingly, to make provisions for existing national waterways and to provide for the declaration of certain inland waterways to be national waterways and also to provide for the regulation and development of the said waterways for the purposes of shipping and navigation, National waterway act, 2016 has received the assent of the President on the 25th March, 2016 declaring a total of 111 National Waterways.

IWAI, a statutory body under MoS, Govt. of India, has entrusted WAPCOS with the responsibility for preparation of two stages DPR of proposed six waterways in Tamilnadu and Andhra Pradesh: **National waterway No's 55 (Kaveri-Kollidam), 75 (Palar), 77 (Pazhyar), 79 (Pennar), 80 (Ponniyar) and 99 (Tamaraparani)** for a total length of 763 km.

This Final Feasibility report (Stage-I) covers the review of data, reconnaissance survey, preliminary traffic and market analysis and navigation development feasibility for Pennar river. The consultant team has physically visited the 29 km river stretch and gathered all requisite information.

Acknowledgement

This Final Feasibility report (Stage 1) is the outcome of review of existing infrastructure along the Pennar River, present state of affairs and the probability of development as Inland waterway. This vision is shared jointly by IWAI and WAPCOS Limited.

This report gives the present status of water ways assets, topographic features, climatic variability, land use / land cover pattern, details of all cross structures, socio-economic information of the waterways and the feasibility of its development for navigation as per classification by Govt. of India (Gazette Notification).

We, WAPCOS project team acknowledge Cdr. P. K. Srivastava, Hydrographic Chief, Inland Waterways Authority of India; Sh Rajiv Singhal, AHS for constant encouragement and guidance, technical discussions and for evincing keen interest in the project and this report.

WAPCOS Team

Sector -18, Gurgaon
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List of Abbreviations

ATT	Admiralty Tide Table
BM	Bench Mark / Local Reference Level
CH	Chainage
CM	Central Meridian
CRZ	Coastal Regulation Zone
CWC	Central Water Commission
CVT	Calibration, Verification & Test
DF	Dual Frequency
DGPS	Differential Global Positioning System
DPR	Daily Progress Report
GPS	Global Positioning System
HFL	Highest Flood Level
HC	Horizontal Clearance
HSE	Health, Safety and Environment
kHz	kilohertz
km	kilometer
m	meter
MHWS	Mean High Water Spring
Mmtpa	Million metric tonne per annum
m/s	meter per second
ms	milliseconds
MSL	Mean Sea Level
PWD	Public Works Department
QA/QC	Quality Assurance / Quality Control
QMS	Quality Management System
Rev	Revision
Rep.	Representative
SBES	Single Beam Echo sounder
SD	Standard Deviation
Sr	Senior
UTM	Universal Transverse Mercator
VC	Vertical Clearance
WGS	World Geodetic System

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SUMMARY: SALIENT FEATURES AT A GLANCE

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<tr><td>3.</td><td>Waterway stretch, NW</td><td>29 km length of the river from Penna Barrage, Pothireddypalem to confluence with Bay of Bengal near Kudithipalem (National waterway 79)</td></tr>
<tr><td>4.</td><td><u>Navigability status</u></td><td></td></tr>
<tr><td>a)</td><td>Tidal & non-tidal portions (from…to, length, average tidal variation)</td><td>From the analysis of Survey of India toposheets for the coastal zone, it was found that the tidal reach of the river is 9 km.
The Nearest Port is Krishnapattnam and chennai. As per the tide data at Chennai port he tidal variation between MLLW springs (0.1) and MHW springs (1.1) is 1.0 m.
(Tide Source: Chennai Port Tide data from ATT tide table (Volume 3)) and Hydrographic chart no 357.</td></tr>
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<table>
<tr><th colspan="7">Stretch (KM)</th></tr>
<tr><th>LAD(m)</th><th>0-9.04</th><th>9.04-15</th><th>15-20</th><th>20-25</th><th>25-29</th><th>Total</th></tr>
<tr><td><1.0</td><td>5.70</td><td>5.99</td><td>4.11</td><td>4.60</td><td>2.78</td><td>23.18</td></tr>
<tr><td>1.0-1.2</td><td>0.61</td><td>0.00</td><td>0.24</td><td>0.30</td><td>0.19</td><td>1.35</td></tr>
<tr><td>1.2-1.4</td><td>0.63</td><td>0.00</td><td>0.29</td><td>0.16</td><td>0.21</td><td>1.29</td></tr>
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<tr><td>> 2.0</td><td>0.80</td><td>0.00</td><td>0.08</td><td>0.00</td><td>0.00</td><td>0.88</td></tr>
</table>
</td></tr>
<tr><td>c)</td><td>Cross structures
i) Dams, weirs, barrages etc. (total number; with navigation locks or not)

ii) Bridges, Power Cables etc. (total number; range of horizontal and vertical clearances)</td><td>Penna Barrage (Nellore Anicut) near Pothireddypalem (CH 28.153) was located at Lat. 14° 28’ 8.38”N, Long. 79° 59’ 9.31”E. The anicut was washed away in 2010 floods. Presently a new barrage is under construction (Lat 14°28'19.36" Long 79°58'57.47") 200 m upstream of dismantled Nellore Anicut. Navigational lock is not provided in any of the dams/weir/Anicuts/Barrages in the present study stretch.

Three existing road bridges, one under construction road bridges, two adjacent rail bridges crosses Pennar river in this stretch.
V.C. from H.F.L. for bridges varies from 2 m to 7m.
H.C. for bridges varies from 10m to 35m.

2 HT lines crosses Pennar River in this
V.C. from H.F.L of these two HT lines is about 5m</td></tr>
</table>

<table>
<tr><td></td><td></td><td>H.C. is 150m and 250 m.</td></tr>
<tr><td>d)</td><td>Avg discharge & no. of days</td><td>No of Gauge Stations: One (Nellore)
Nellore
June to September 30 to 600 m^3/s
October to December 40 to 20 m^3/s
January to May 20 to 10 m^3/s</td></tr>
<tr><td>e)</td><td>Slope (1 in ….)</td><td>Average slope of river : 1/4516
<table>
<tr><td colspan="2">Reach</td><td rowspan="2">River Bed Lvl Change</td><td rowspan="2">Distance</td><td rowspan="2">Slope</td></tr>
<tr><td>From</td><td>To</td></tr>
<tr><td>Nellore
RBL 6.24 m</td><td>Mouth
RBL 0.0 m</td><td>6.240 m</td><td>28.18 km</td><td>1 in 4516</td></tr>
</table></td></tr>
<tr><td>f)</td><td>Consultant’s inference</td><td>0-9.04 km
The Tidal reach of the river is 9.04 km. There are no cross-structures in this stretch. Local prawn farming is also observed all along the river bank. Hence this stretch of 9.04 km is feasible for navigation throughout the year (365 days). The waterway of Class I/II may be considered at the present situation with some dredging.

9.04-29 km
The depths of the order of 1.4 m will prevail in Pennar river reach downstream of Penna Barrage for period of 45 to 50 days in a year when discharge will exceed 10 m^3/s. Penna barrage was washed out in 2010 floods and a new barrage is under construction at chainage 29 km. To increase navigation period in this reach advantage of tidal reach of about 9 km could be taken along with some dredging. This needs further investigations and mathematical model studies which require cross-section survey in Stage 2.</td></tr>
<tr><td>5.</td><td><u>Traffic Potential</u></td><td></td></tr>
<tr><td>a)</td><td>Present IWT operations, ferry services, tourism, cargo, if any</td><td>Cargo
Industries would prefer transporting their goods directly to the port by roadways. No industrial areas except those, which are located near to the river, would prefer to shift their cargo on Pennar River. Due to the smaller length of Pennar River, It is not commercially attractive for industries to shift from roadways to waterways.
Ferry services
A no of villages are located along the Pennar river near river mouth for around 9 km stretch (from mouth). The locals use ferry services and prawn farming is predominant in this reach.</td></tr>
</table>

		Tourism A lot of temples, tourist sites including Pulicat lake, Nellapattu Bird Sanctuary, Venkatagiri Fort,Mypadu Beach, Irukkam Island are situated nearby Pennar River.
b)	Important Industries within 50 km	Nellore has several industries. Out of these, the leading industries in terms of total production are edible oils, pig iron, drugs and pharmaceuticals, cotton yarn and sugar. Food products are also an important industry in Nellore. Krishnapattnam port is located at about 40 km from river mouth.
c)	Distance of Rail & Road from industry	Nellore industrial area is located at a distance of about 10 km from the river. All the other industrial area is located in the south of the district. Their distance ranges between 70 km to 130 km from the river. SEZ at Naidupeta is about 70 km from the river and about 90 km from Krishnapatnam port.
6.	Consultant's recommendation for going ahead with Stage-II (DPR preparation)	The Tidal reach of 9.04 km is feasible for navigation for 365 days (whole year) with marginal dredging. Penna Barrage is under construction at Chainage 29 km. The 9.04-29 km stretch can be made feasible for navigation by dredging and using the releases of Penna Barrage after construction. The details can be worked out in stage II studies after detailed survey**.**
7.	Any other information/ comment	-----

1. About the Studies

M/s Inland Waterways Authority of India (IWAI), a statutory body under ministry of shipping, Govt. of India, has entrusted WAPCOS with the responsibility for preparation of two stage DPR for 6 inland waterways of rivers Pennar, Kaveri/Kollidam, Palar, Pazhyar, Ponniyar, Tamaraparani in Tamilnadu and Andhra Pradesh. The approximate length and approx. average width of all six rivers are given in the table below:

Sl. No.	Name of the River / Canal	Description of Inland Waterway	From:	Upto:
1.	**Pennar River, Andhra Pradesh**	**29 km length of the river from Penna Barrage, Pothireddypalem to confluence with Bay of Bengal near Kudithipalem (National Waterway 79)**	**14°28'8.38"N, 79°59'9.31"E**	**14°35'36.75"N, 80°11'30.61"E**
2.	Palar River, Tamilnadu	141 km length of the river from rail bridge at Virudampattu, Vellore to confluence with Bay of Bengal at Sadurangapattinam (National Waterway 75)	12°56'14.07"N 79° 7'29.70"E	12°27'52.16"N, 80° 9'13.47"E
3.	Ponniyar River, Tamilnadu	125 km length of the river from Sathanur Dam to Cuddalore at confluence of Bay of Bengal (National Waterway 80)	12°11'0.06"N, 78°51'1.25"E	11°46'21.76"N, 79°47'41.70"E
4.	Kaveri / Kollidam, Tamilnadu	364 km length of the river from Uratchikottai Barrage to confluence with Bay of Bengal at Pazhaiyar (National Waterway 55)	11°29'3.09"N 77°42'13.68"E	11°21'37.97"N79°49'53.23"E
5.	Tamaraparani River, Tamilnadu	64 km length of the river from Sulochana Mudalir bridge, Tirunelveli to confluence with Bay of Bengal near Punnaikayal (National Waterway 99)	8°43'43.17"N, 77°42'53.94"E	8°38'24.90"N, 78° 7'37.85"E
6.	Pazhyar River, Tamilnadu	20 km length of the river from Bridge near Veeranarayana Mangalam village to confluence with Arabian Sea at Manakudi (National Waterway 77)	8°13'48.97"N 77°26'27.34"E	8°5'15.01"N 77°29'7.61"E

Table 1: National Waterways in Tamilnadu and Andhra Pradesh

The Google Map showing all river stretches is enclosed as **Figure 1**.

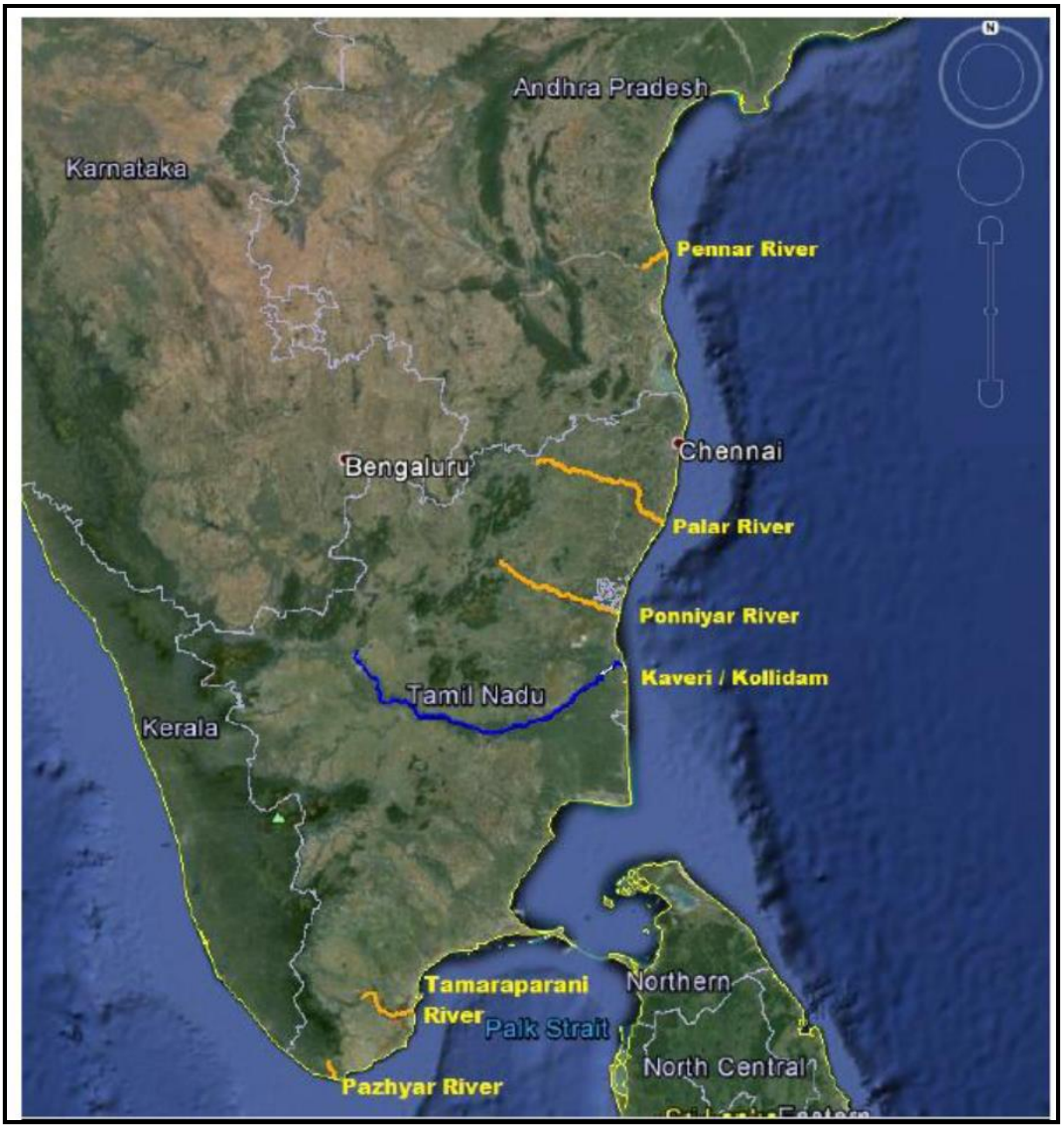


Figure 1: Google Map showing six rivers in Andhra Pradesh & Tamilnadu

Accordingly, WAPCOS Ltd. has undertaken the studies for 6 national waterways (Pennar, Kaveri Kollidam, Palar, Pazhyar, Ponniyar and Tamaraparani) in Tamilnadu and Andhra Pradesh. The brief scope of work is depicted as under:

Stage-1

A. Reconnaissance Survey

B. Collection and Review of available data

C. Feasibility Report

Stage-2

A. Hydrographic Survey & Hydro-morphological survey

B. Traffic Survey & Techno economic feasibility

C. Preparation of Detailed Project Report

The present studies are limited to establish the feasibility of waterways for Inland navigation i.e. up to Stage 1 only**.**

The present **Final Feasibility Report** covers the review of data, reconnaissance survey, present state of affairs, traffic analysis, possible navigable stretches for Pennar River as detailed below:

- ✓ **Introductory Considerations**
- ✓ **Classification of waterways**
- ✓ **Details of existing structures**
- ✓ **Reconnaissance survey & site visit**
- ✓ **Single Line Longitudinal Survey**
- ✓ **Bed Profile**
- ✓ **Soil Texture**
- ✓ **Hydrological Data collection and analysis**
- ✓ **Preliminary Traffic studies and Market analysis**
- ✓ **Results and feasibility of waterways**

2. Introductory Considerations

As discussed in previous chapter, Cluster 5 consists of six rivers in the states of Tamilnadu and Andhra Pradesh. This chapter covers the introductory considerations, origin, hydrological parameters like altitude, length, catchment area, Annual rainfall, major dams, and barrages along the river, tributaries, and major cities along river bank, historical and religious places for Pennar River.

2.1 Name of River: Pennar

2.2 Length of River

The total length of the river from origin to its outfall in the Bay of Bengal is 597 km. The length under consideration for present studies is detailed below:

29 km length of the river from Penna Barrage, Pothireddypalem to confluence with Bay of Bengal near Kudithipalem (National waterway 79)	**From: 14°28'8.38"N, 79°59'9.31"E**	**Up to: 14°35'36.75"N, 80°11'30.61"E**

2.3 States, District through which river passes

The Pennar River is one of the major East Flowing Rivers passing through Karnataka and Andhra Pradesh in southern India to reach Bay of Bengal in the east covering its 568 km length. The districts covered by Pennar River in its course are Kolar and Tumkur districts of Karnataka, Hindupur taluk of Anantapur district, Andhra Pradesh, Cuddappah and Nellore districts, Andhra Pradesh.

The main towns in the vicinity of Pennar River are Vidavalur, Kovur, Kodavalur, Allur, Buchireddypalem, Nellore, Thotapalli, Gudur and Indukurpet in its 29 km stretch.

2.4 Maps

A Map showing entire Pennar basin (Source: CWC) and Present study stretch is attached as **Figure 3** & **Figure 4** respectively.

2.5 River Characteristics

2.5.1 River Course

It rises in the Chenna Kasava hill of the Nandidurg range in Karnataka, flows in the North Westerly direction through Kolar and Tumkur districts of Karnataka and enters Andhra Pradesh in the Hindupur taluk of Anantapur district, runs east-wards before draining into the Bay of Bengal near Nellore. The Somasila is major project in the river catchment. (refer Figure 3 and Figure 4).

2.5.2 River Basin (Catchment Area)

The Pennar basin extends over states of Andhra Pradesh and Karnataka has a catchment area of 55,213 Sq.km lying between 77°1’ to 80°10’ East longitudes and 13°18’ to 15°49’ North latitudes. The fan shaped basin is bounded by the Erramala range on the North, by the Nallamala and Velikonda ranges of the Eastern Ghats on the East, by the Nandidurg hills on the South and by the narrow ridge separating it from the Vedavati

valley of the Krishna Basin on the West. The other hill ranges in the basin to the south of the river are the Seshachalam and Paliconda ranges. The Pennar (also known as Uttara Pinakini) is one of the major rivers of the peninsula. (Refer Figure 3 and Figure 4).

State	Drainage area (sq. km.)
Andhra Pradesh	48276
Karnataka	6937
Total	55213

Table 2 : Pennar River Catchment

2.5.3 Tributaries

The total length of the river from origin to its outfall in the Bay of Bengal is 597 km. The principal tributaries of the river are Jayamangali, Kunderu, Sagileru, Chitravathi, Papagni and Cheyyeru.

2.5.4 Topography

The highest peak with an elevation of 1439 m is located in Deccan plateau near Chikballapur tehsil, Kolar district in Karnataka. More than 13% of the area of the basin lies in the hilly region and dense forested area.

2.5.5 Climate, Temperature & Humidity

On the basis of the local rainfall conditions, four seasons including two monsoon regimes are recognized: South-West monsoon (June to September) North-East monsoon (October to December), winter period (January to February) and hot weather period (March to May).

The major part of the basin receives its rainfall from the South-West monsoon while areas adjacent to the sea-coast receive some rainfall from the retreating monsoon.

The annual average maximum, minimum and mean temperature for the basin for the years from 1969 to 2004 is found to be 32.71°C, 21.63°C and 27.17°C respectively.

Humidity is high during the monsoon period and moderate during non-monsoon period. The relative humidity in the catchment of Pennar ranges from 21% to 84%.

2.5.6 Rainfall

Pennar basin lies in a semi-arid region with low rainfall. Both, South-West and North-East monsoon produces rainfall in the Pennar basin. The rainfall during the non-monsoon period is not significant. The South West monsoon (June through September) provides a little precipitation but the predominant rain occurs from North-East monsoon (October through January).

The annual average rainfall is highest in Nellore region. Parts of Nellore district, adjacent to the sea-coast receive some rain from the retreating monsoon also.

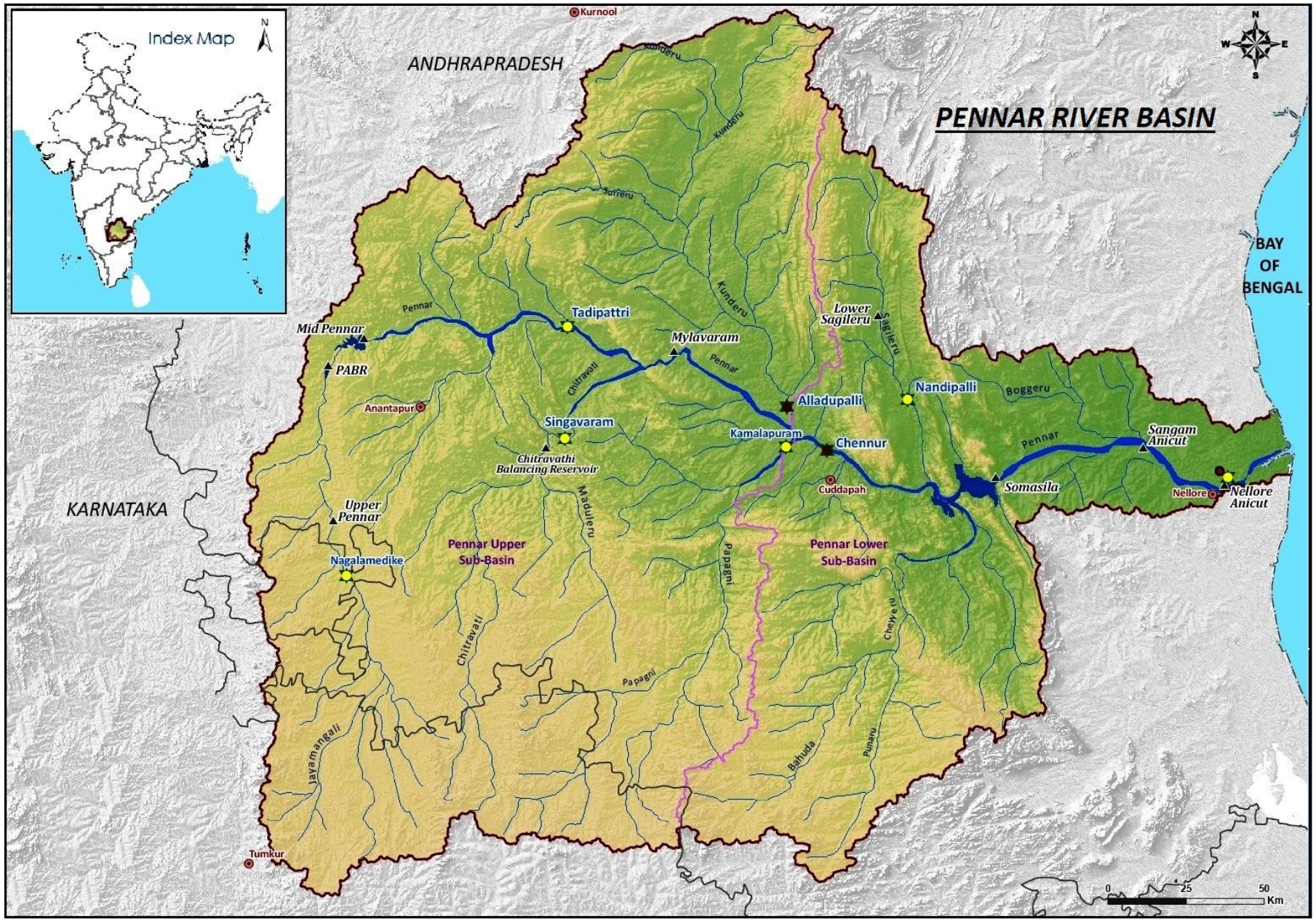


Figure 2: Pennar River Basin

Figure 3: Google image showing Pennar River stretch (29 km) under present studies

2.5.7 Land Use

The resources in the basin have not been put to intensive use and the area sown more than once is very limited. The food crops usually grown in the basin are paddy, jowar and ragi. Paddy crops are predominant near Nellore region. Commercially, Tobacco and Prawn farming is also observed in the coastal regions near river mouth.

2.5.8 Soil

Information on the soil type is also required for assessing the hydrological character of the basin and net water availability for Inland navigation. The important soil types found in the basin are red soil, black soil, sandy soil and mixed soil. The riverbed comprises of sand (non tidal zone) and sand & clay (tidal zone).

2.5.9 Dams, Barrages/ Weirs/ Anicuts in River Basin

There are a total of 62 water resource assets in Pennar basin. The biggest dam in the basin is Somasila dam located in Nellore district of Andhra Pradesh. There are 2 anicuts and 1 weir in the basin. The longest anicut in the basin is Sangam anicut located in Nellore. There are no barrage structures or lift irrigation schemes in the basin. All the hydraulic structures and bridges in the 29 km stretch of Pennar River under the present studies have been detailed in next chapter.

2.5.10 Tourism

There are four pilgrimage (temple) sites, one dam(Somasila Dam, Nellore District), one cave (3.5 kilometres long at Belum Kurnool district) and 1 waterfall (Talakona falls) exist in the Pennar basin.

Talpagiri Ranganatha Swamy Temple (Southern bank), Sri Talapagiri Ranaganatha swamy Temple (Nellore) are the main temples. The home of spiritual guru, Sathya Sai Baba, Puttaparthi is located in the Ananthapur district of Andhra Pradesh.

2.6 Methodology and Data collection

2.6.1 Importance of Hydrological and Topographical data

Navigability of a natural river channel or tidal creek primarily depends upon hydraulic parameters like water discharge, flow depth, velocity, sediment load and width of river channel. These parameters are function of topography/bathymetry of river bed and discharge in river during different seasons. Apart from these important parameters, there are other natural factors such as tidal range and length of tidal reach, type/nature of river bed (rocky, sandy, silty, clayey), bends in river course and stability of alignment of deep channel of river over long period. Apart from above natural factors, information on other factors such as various structures across (Dams/weirs/barrages/bridges) and along the river bank (river training and bank protection works) is also required.

2.6.2 Data Requirement

The following data was required for Stage-1 feasibility report:

1. Type of crops (in different seasons) and industries along the waterway
2. Availability of passenger ferry services. Prominent towns / City along the waterway.
3. Historical and tourist places.
4. Existing water sport and recreational activities and future probability.

5. Details of cross-structures (bridges, aqueducts, electric lines, telephone lines, pipe lines, cables) and their clearances. Salient features of Dams / Barrages / Weirs.
6. Availability of water in different seasons. Also to correlate this with CWC / Irrigation datum's.
7. Ponding level and limit of Dams / Barrages / Weirs.
8. Encroachment in the waterway, width of the waterway, sharp bends.
9. Environmental impacts. CRZ or wildlife clearances.
10. Local/pronounced name of the rivers in different stretches.
11. Any Border issue with other country.
12. Incorporation of topographical features (outside survey limits) from Google Earth imageries.
13. Obstructions to the navigation and un-approachable areas.
14. Photographs of all cross-structures, gauges, obstructions - annotated with location & chainage. In report with lat/long, easting/northing, chainage details
15. Permanent structures located within this corridor.
16. All prominent shore features (locks, bridges, aqueducts, survey pillars if available etc) and other conspicuous objects shall be fixed and indicated on the chart and included in the report.
17. Details of water intake/ structures shall be collected and shown on the charts and include in the report.
18. Availability of berthing place, existing jetty, ferry ghats, approach roads etc. in the area shall be indicated on the charts and include in the report.
19. During the survey, condition of the banks shall also be collected, whether that banks are pitched (protected) or not protected. The length of bank protection, where banks erosion is taking place shall also be estimated.
20. Positions and levels of corners of permanent structures within the corridor shall be physically surveyed and marked on survey charts.

2.6.3 Primary Data- Sources

A. Survey of India (SOI) Dehradun, during February & March 2016

Toposheets and satellite imageries are useful to obtain information such as extent of tidal reach, HTL & LTL, width of river and deep channel, important places, nature of river bed and bank along reach, channel bends, slope of river channel, and locations of various structures across and along river course and tendency of shifting of deep channel (general morphology of the deep channel of the river course).

As the coastal zone falls under restricted category, the restricted and non-restricted Toposheets of Survey of India /hydrographic charts and satellite imageries has been collected after taking approval from **Ministry of Water Resources, Govt. of India**. A total of 43 toposheets were procured from Survey of India (SOI) (39 no.'s toposheets of 1: 50000 scale and 04 No's toposheets of 1:25000 scale) and analyzed to study various aspects mentioned above. The satellite imageries of different years from Google are also analyzed. The details of toposheets for Pennar River as collected from SOI are given as under:

Pennar River	**57 N/14, 57 N/15, 66 B/2, 66 B/3 and Hydrographic chart No. 356**

Table 3: SOI Toposheets & Hydrographic charts

B. Data from Site Visit and Reconnaissance survey during March & April 2016

The site visit and reconnaissance survey was carried out in March and April 2016.

The details of existing cross-structures, Weirs, Barrages, Anicut, Dams, HT/ LT line, Type of Crops, Soils, shore protection along the waterway, Historical and tourist places, existing ferry services were collected. The collected data and photographs have been detailed in Chapter 3.

The details of existing industries, major commodities, production were also collected from various industries located around main industrial clusters, important towns in the vicinity of waterways and important ports near river mouth. These details have been presented in Chapter 5.

2.6.4 Secondary Data- Sources

A. Central Water Commission (CWC), Govt of India and Water Resource Division (WRD), Chennai during February, March and April 2016

These data give most vital information on water availability in river reach and sediment concentration in river water.

Gauge- discharge, sediment and river cross section data (at gauging site) was collected from CWC for one gauging station on Pennar River. Following Table gives details of gauging stations and data collected.

River	Gauging station	Data type	From	To	Frequency
Pennar	Nellore, AP 14^0 28′ 15” N 79^0 58′ 58” E	Gauge- discharge	1987	2013	daily
		Sediment	-	-	daily
		Cross-section	1999	2012	2 days/year

Table 4: Gauge Discharge Sediment data collected from CWC

2.6.5 Methodology

The studies are being carried out as detailed below:

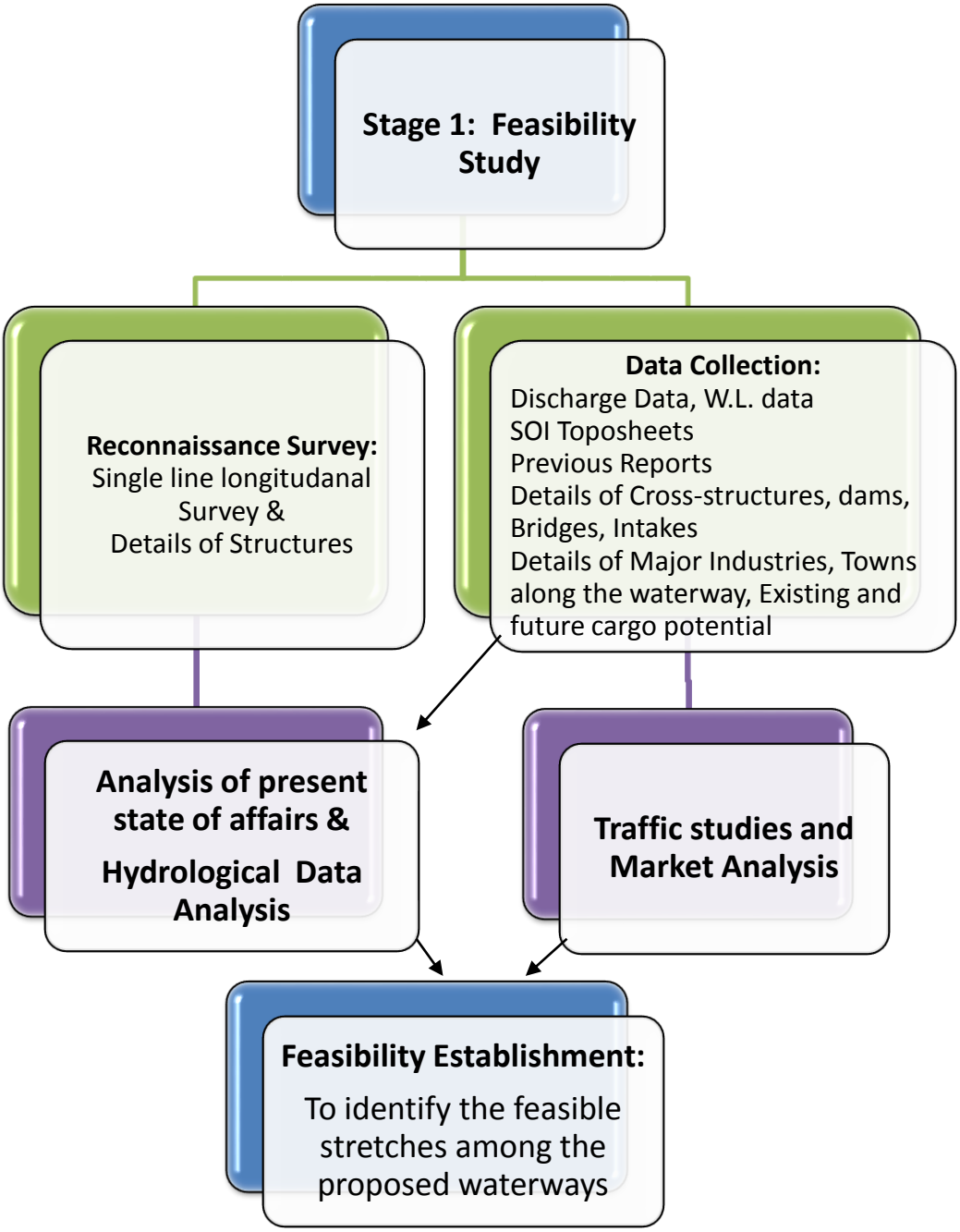


Figure 4: Feasibility Studies (Stage 1)

The detail methodology for reconnaissance survey, Hydrological data analysis and Traffic studies is given in their respective chapters. The feasibility of waterways is established after hydrological and traffic studies and analysis. Based on hydraulic conditions (depth, width, curvatures etc.) of the navigation channel, the class of the waterway are established in accordance with the classification notified by Inland Waterways Authority of India (IWAI) vides Gazette Notification dated 26 January 2007. The same has been detailed below:

2.6.6 Classification of Waterways

In India, the inland waterways are classified into seven categories for rivers as well as canals by Inland Waterways Authority of India (IWAI) vides Gazette Notification dated 26 January 2007 for safe passage of self-propelled vessels up to 2000 dead weight tonnage (DWT) and tug barge formation in push tow units of carrying capacity upto 8000 tonnes.

The classification of waterways is discussed below.

A. Classification of Inland waterways for Rivers

Class of Waterway	Rivers				
	Minimum Depth	Bottom Width	Bend Radius	Vertical Clearance	Horizontal Clearance
I.	1.2 m	30 m	300 m	4 m	30 m
II.	1.4 m	40 m	500 m	5 m	40 m
III.	1.7 m	50 m	700 m	7 m	50 m
IV.	2.0 m	50 m	800 m	10 m	50 m
V.	2.0 m	80 m	800 m	10 m	80 m
VI.	2.75 m	80 m	900 m	10 m	80 m
VII.	2.75 m	100 m	900 m	10 m	100 m

Table 5: Inland Waterway classification for Rivers

B. Classification of Inland waterways for Canals

Class of Waterway	Canals				
	Minimum Depth	Bottom Width	Bend Radius	Vertical Clearance	Horizontal Clearance
I.	1.5 m	20 m	300 m	4 m	20 m
II.	1.8 m	30 m	500 m	5 m	30 m
III.	2.2 m	40 m	700 m	7 m	40 m
IV.	2.5 m	50 m	800 m	10 m	50 m
V.	-	-	-	-	-
VI.	3.50 m	60 m	900 m	10 m	60 m
VII.	-	-	-	-	-

Table 6: Inland Waterway classification for Canals

The above classification for Rivers and Canals shall be effective if:

- Minimum depth of channel should be available for about 330 days in a year (about 90% days in a year).
- Vertical clearance at cross structures over the waterway should be available at least in central 75% portion of each of the spans in entire width of the waterway.

C. *Vertical Clearance for Power Cables / Telephone Lines for all Classes*

- Telephone lines and Low Voltage lines 16.5 m
- High Voltage Transmission lines not exceeding 110 KV – 19 m
- High Voltage Transmission lines exceeding 110 KV – 19 m + 1 cm per each KV

In case of underground pipe / power lines and other cables norms to be decided as per conditions and navigational requirement

D. *Reference level for vertical clearance for different types of channels*

- For rivers – over navigational HFL which is highest flood level at frequency of 5% in any year over a period of last 20 years
- HTL for tidal channels
- For channels design FSL

E. *Type of vessels to be used in different class waterways*

Class	Self-propelled vessel	Tug with barges
I.	Self-propelled, carrying capacity 100 DWT, Size (32m X 5m), Loaded draft 1m	1 Tug + 2 barges – 200 DWT, length 80m X breadth 5m , loaded draft 1m
II.	Self-propelled, carrying capacity 300 DWT, Size (45m X 8m), Loaded draft 1.2m	1 Tug + 2 barges – 600 DWT, length 110m X breadth 8m , loaded draft 1.2m
III.	Self-propelled, carrying capacity 500 DWT, Size (58m X 9m), Loaded draft 1.5m	1 Tug + 2 barges – 1000 DWT, length 141m X breadth 9m , loaded draft 1.5m
IV.	Self-propelled, carrying capacity 1000 DWT, Size (70m X 12m), Loaded draft 1.8m	1 Tug + 2 barges – 2000 DWT, length 170m X breadth 12m , loaded draft 1.8m
V.	Self-propelled, carrying capacity 1000 DWT, Size (70m X 12m), Loaded draft 1.8m	1 Tug + 2 barges – 2000 DWT, length 170m X breadth 24m , loaded draft 1.8m (moulded with 24 m)
VI.	Self-propelled, carrying capacity 2000 DWT, Size (86m X 14m), Loaded draft 2.5m	1 Tug + 2 barges – 4000 DWT, length 210m X breadth 14m , loaded draft 2.5m
VII.	Self-propelled, carrying capacity 4000 DWT, Size (86m X 14m), Loaded draft 2.9m	1 Tug + 4 barges – 8000 DWT, length 210m X breadth 28m , loaded draft 2.5m

Table 7: Type of vessels to be used in different class of waterways

All structures to be constructed across waterway classified should conform to respective requirement of vertical clearance and horizontal clearance before construction of any structure across the national waterway.

WAPCOS has carried out hydrological studies to establish the feasibility of development of river stretches as national waterways. In cases where minimum depth (of 1.2m as per Govt. of India notification) is not available round the year, the no. of days of availability and available depth is calculated and presented in chapter 4. The project authorities may review the waterway classification. The feasibility of these stretches may be established for some part of the year after detailed studies in stage 2 after the approval. Measures to improve the depth are also stressed upon.

3. Analysis of present state of affairs

This chapter identifies the existing cross-structures viz. Dams, Weirs, Barrages, Locks, Bridges, Crossings, pipelines, cables, HT/LT line, National and State highways including railway lines in the river stretch collected during the site visit and reconnaissance survey. The details of all structures are tabulated in Annexure 2.

3.1 Existing Dams, Weir, Barrage, Anicuts and Locks

Penna Barrage (Nellore Anicut) near Pothireddypalem (CH 28.153) is located at Lat. 14° 28’ 8.38”N, Long. 79° 59’ 9.31”E. The anicut was washed away in 2010 floods. Presently a new barrage is under construction (Lat 14°28'19.36" Long 79°58'57.47") upstream of dismantled Nellore Anicut. Navigational lock is not provided in any of the dams/weir/Anicuts/Barrages in the present study stretch.

3.2 Existing Bridges and crossing over River

Sl. No.	Structure Name	Chainage (km) as per Field Survey	Location	Position				Vertical clearance above H.F.L. (m)	Horizontal clearance (m)
				Latitude (N)	Longitude (E)	Easting [m]	Northing [m]		
1	Kavali Bridge (Two adjacent bridges)(NH-5)	25.93	Nellore	14°28'21.24"	80°00'41.80"	393480.181	1600220.493	2.0	35
2	Nellore Bridge (SH-57)	28.13	Nellore	14°28'06.65"	79°59'27.40"	391251.635	1599781.897	7.0	15
3	Railway Bridge (2 adjacent bridges)	28.23	Nellore	14°28'06.53"	79°59'24.50"	391163.895	1599778.596	5.0	15
4	Pennar Old Bridge	28.94	Nellore	14°28'04.74"	79°59'10.45"	390742.998	1599725.453	damaged	
5	Pennar under construction Bridge	29.00	Nellore	14°28'19.36"	79°58'57.47"	390356.372	1600176.393	7.5	10

Table 8: Details of existing Bridges and Crossings

Note: All bridges are to be considered as road bridges unless specified.

Note: Vertical clearance is measured above H.F.L. The HFL for tidal reach is MHWS as per ATT- Vol 3 and HFL at gauge site is calculated as maximum water level in last twenty years Gauge Discharge Data as collected from CWC.

3.3 Pipelines and cables

No pipeline and cable are observed in the river stretch.

3.4 Details of High Tension and Electric Lines across Pennar River

Sl. No.	Structure Name	Chainage (km) as per Field Survey	Location	Position				Vertical clearance above H.F.L. (m)	Horizontal clearance(m)
				Latitude (N)	Longitude (E)	Easting [m]	Northing [m]		
1	HT Lines	22.38	Kodurupadu	14°29'06.15"	80°02'00.21"	395833.517	1601590.384	5.0	150
2	HT Lines	28.05	Nellore	14°28'15.70"	79°59'02.34"	390501.679	1600063.595	5.0	250

Table 9: Details of High Tension and Electric Lines

Note: Vertical clearance is measured above H.F.L. The HFL for tidal reach is MHWS as per ATT- Vol 3 and HFL at gauge site is calculated as maximum water level in last twenty years Gauge Discharge Data as collected from CWC.

3.5 Horizontal and Vertical Clearances

Sl. No.	Structure Name	Chainage (km) as per Field Survey	Vertical clearance above H.F.L. (m)	Horizontal clearance (m)
1	HT Lines	22.38	5.0	150
2	Kavali Bridge (Two adjacent bridges	25.93	2.0	35
3	HT Lines	28.05	5.0	250
4	Nellore Bridge	28.13	7.0	15
5	Railway Bridge (2 adjacent bridges)	28.23	5.0	15
6	Pennar Old Bridge	28.94	Damaged	
7	Pennar under construction Bridge	29.00	7.5	10

Table 10: Details of Horizontal and Vertical clearance

Note: Vertical clearance is measured above H.F.L. The HFL for tidal reach is MHWS as per ATT- Vol 3 and HFL at gauge site is calculated as maximum water level in last twenty years Gauge Discharge Data as collected from CWC.

3.6 Hindrances in conducting the reconnaissance survey

No hindrance was encountered in the river stretch while carrying out the reconnaissance survey. Rocky and hard strata is not observed while carrying out reconnaissance survey in this stretch.

3.7 Encroachment to the waterway

There is no encroachment in the waterway in the reach under consideration in this study.

3.8 Details of Protected Area, Wildlife, Defense

There are no such areas present in the vicinity of river.

3.9 NH/SH/MDR along and/or in Vicinity

Mainly two main roads are found crossing the Pennar River:

SH 57: Bellary Nellore (Krishnapatnam) road – State Highway

NH 5: Guntur- Chennai road – National Highway

Apart from these, there are the major roads along both bank passing through the town of Jammipalem, Pallipadu, Inamaduga, kovur and utukuru.

3.10 Railway Line and stations in the vicinity

Padugupadu and Nellore Railway stations are located in the vicinity of Pennar River. Nellore- padugupadu Railway line also crosses the Pennar River at chainage 28.23 km.

4. Reconnaissance Survey

This chapter gives the stretch wise description (20-30 km stretch) of entire river stretches and presents the observed water level during survey. This chapter also covers the Hydrological analysis of the collected data viz. Minimum and maximum water levels, discharges, average 10 daily discharges, change in cross-section over the years and establishment of sounding datum in river. The route map of Pennar River is given below:

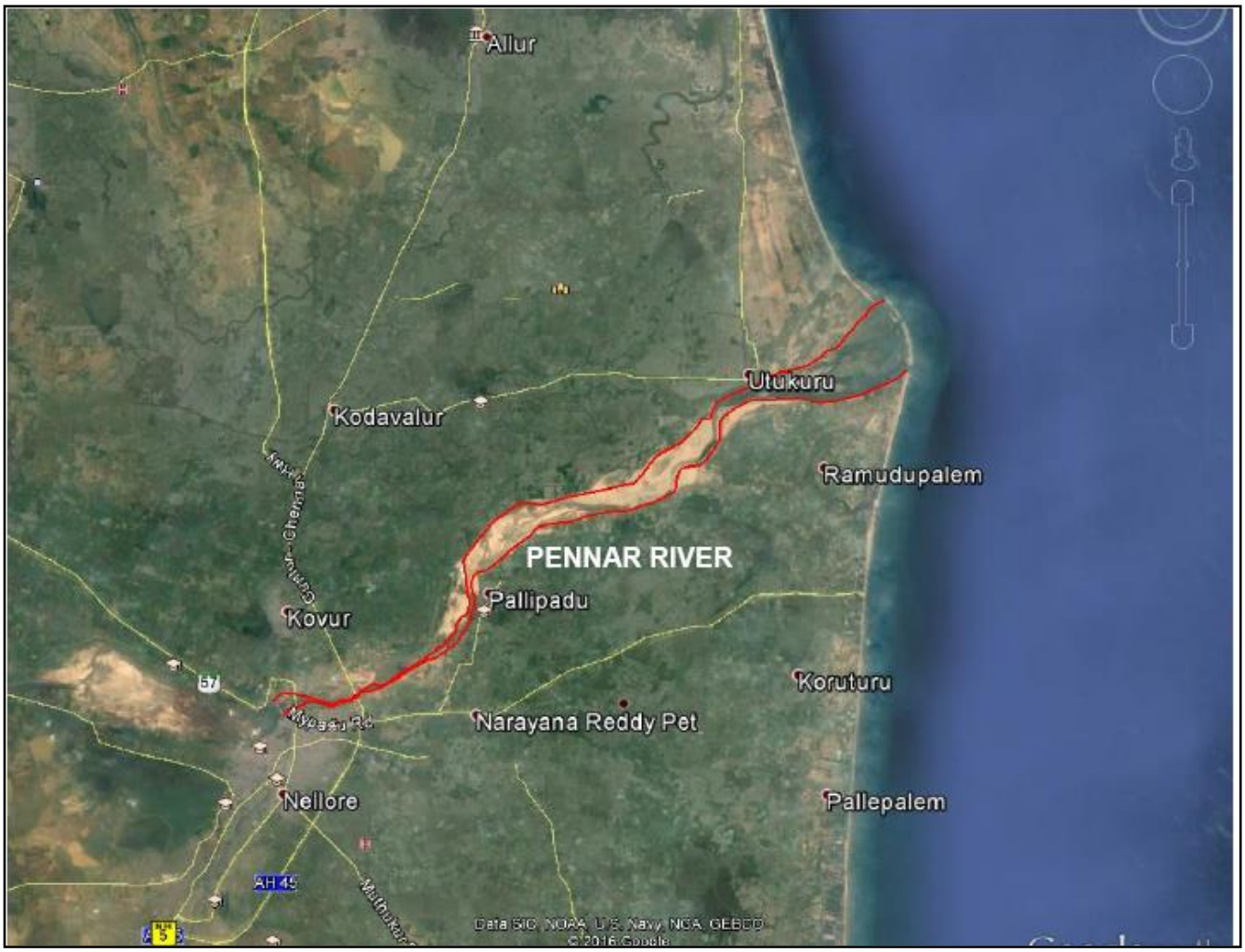


Figure 5: Route map of Pennar River from its mouth up to Nellore city

4.1 Resources, Equipment used and Methodology adopted

4.1.1 Resources & Equipment used

Personnel Name	Function
Santosh Nag	Surveyor , Fugro Limited
Ponlogesh	Asst. Surveyor, Fugro Limited

Table 11: Survey Personnel

Following equipment and systems were mobilised for the data acquisition.

Equipment / System	Description / Make / Model/Resolution /Accuracy
Software / Navigation	Starfix.Seis V. 10.1 PC based data acquisition and survey vessel navigation package and accessories
Positioning	12 Channel Single frequency (L1 & L2) DGPS System and accessories
Echo Sounder	ODOM Hydrotrac single Frequency Echo sounder, 210KHz Transducer and accessories
Soil sample collection	Grab Sampler with accessories
Trimble Total station with accessories & Laser Distometer	

Table 12: Equipments for data acquisition

Survey Vessel

Locally Hired boat 'Maldevi' was used for carrying out the bathymetry survey.

4.1.2 Detailed methodology adopted for survey

a) Specifications for survey: Survey Geodesy

The survey was conducted in WGS84 datum; UTM Projection (Zone 44 N, CM 081° E). The geodetic parameters used during the survey are as follows:

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984
Spheroid:	World Geodetic System 1984
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	1/f = 298.257 223 563
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 44 N;
Central Meridian:	081° 00' 00" East
Latitude of Origin:	0° 00' 00" North
False Easting:	500 000 m
False Northing:	0 m
Scale factor on Central Meridian:	0.9996
Units:	Meter

Table 13: Global Positioning System Geodetic Parameters

b) Field Calibrations & Verifications

All survey equipments used for the survey were calibrated and bench tested prior to their mobilisation for this task. After installation on the survey vessel, field verification and tests were carried out as per standard survey methods. On completion of successful Mobilization, Calibration, Verification and Testing of all equipment as per the relevant work practices, the survey task was commenced.

c) DGPS Calibrations

In order to ensure fault free operations, the performance of the GPS Receivers deployed on this job were bench tested against a known point, prior to mobilisation to site, and found to be satisfactory. The integrity of satellite based Starfix DGPS system was monitored round the clock at workshop, to ensure continuous differential corrections are transmitted to the mobile DGPS receivers at work sites.

d) *Single Beam Echo Sounder (SBES)*

Odom Hydrotrac single frequency (210 kHz) echo sounder was used for measuring water depths. The echo sounder system was bench calibrated at FSINPVT workshop prior to mobilization for the survey. The echo sounder transducer was side mounted on the survey vessel and its draft below the water-line was measured and recorded. Thereafter, the echo-sounder was calibrated by the standard bar-check method at site, prior to deployment on the survey job. The echo sounder system was interfaced with the Starfix.Seis navigation and survey system for navigation and data logging.

e) *Data Acquisition & Survey Run-Line Logs*

The Navigation and depth data from the Starfix.HP DGPS was logged continuously and monitored using the Starfix.Seis navigation suite. A survey run-line log book was maintained where the quality of data was noted. Details such as horizontal and vertical clearances above high flood level of bridges, aqueducts, electric lines, telephone lines, pipe lines, cables enroute were assessed on the spot and recorded, and their coordinates and location were plotted on the chart and included in the report. Photographs of important structures along the route are included as part of this report.

f) *Soil Sampling and Visual Analysis*

Soil samples were collected from the river bed along the surveyed route at about 10 km intervals, and the nature and texture of the samples collected were visually analyzed and reported.

g) *On-line QC of Data Logged*

Real Time Graphs and QC Plots as provided by the Starfix survey software suite were used by experienced surveyors to monitor and control the quality of sensor data on-line, before they are logged. Time stamping on all the data was done by means of Starfix Timing Module through Navigation network synchronized with the GPS (high precision) 1PPS time signal. The data / record obtained from each survey sensor such as Navigation, Heading, SBES and Motion Sensor etc. were quality checked and an extract of the same were made available for verification and confirmation to proceed further.

h) *Survey of Data Processing and interpretation methods*

The survey data was logged in Binary Format (BF), and processed using the Starfix.Proc software. Heading, motion and position data were processed and checked to ensure good data quality.

The measured offsets for all survey sensors was entered into the navigation system and processed using Starfix.Proc to enable track charts was plotted and 'corrected' navigation files was integrated with other sensor data at a later stage. These included:

- GPS position absolute of the primary & secondary positioning systems.
- Common Reference Point.
- Single beam echo sounder.

i) *Bathymetry Data Analysis and Presentation*

Starfix.Proc and Starfix. Workbench were used to import and process the navigation, bathymetry, tides and sound velocity data. The data was filtered, cleaned, and

combined to create geographically positioned bathymetric data set that has been corrected for tides and sound speed.

j) Equipment Layout Diagram

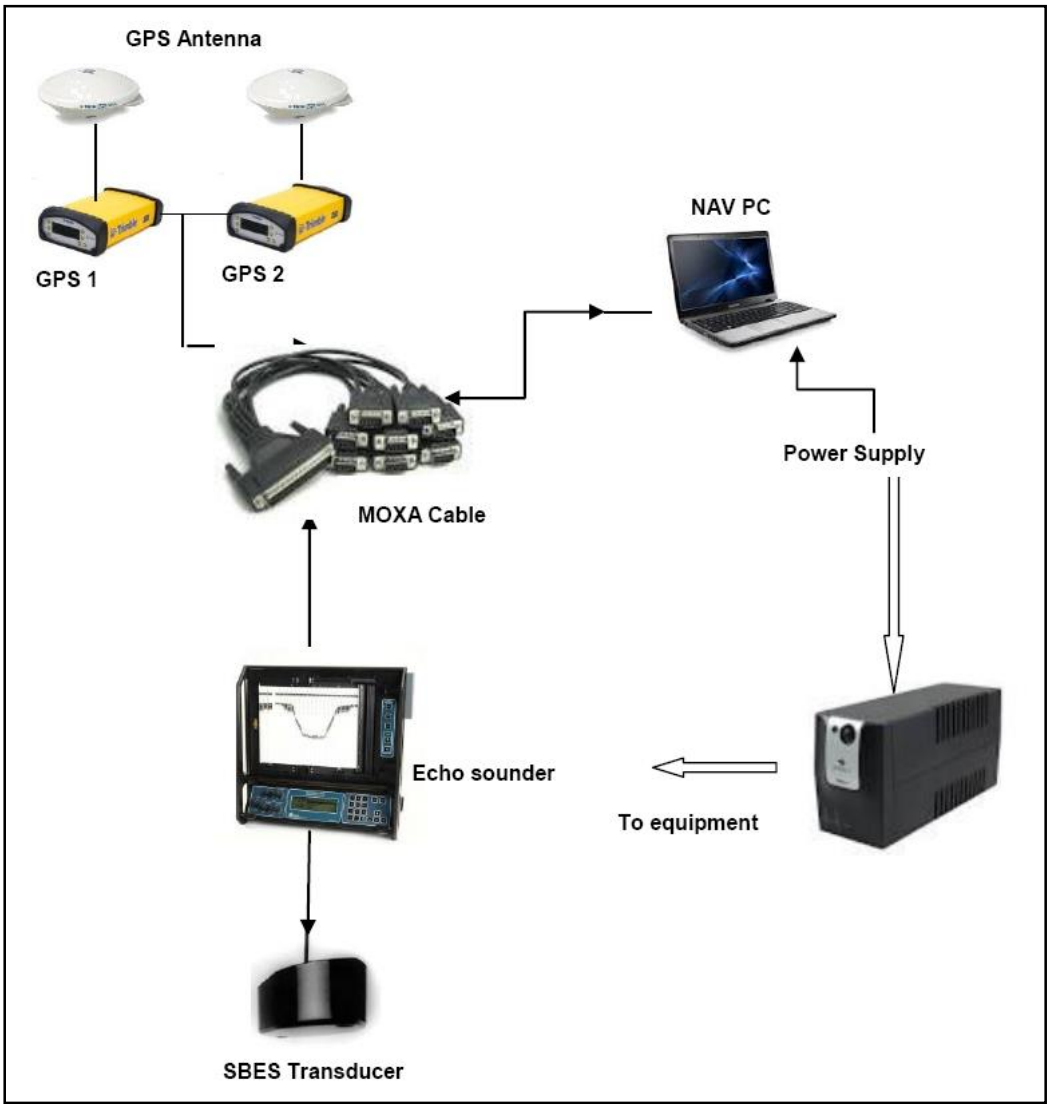


Figure 6: Equipment layout diagram

4.2 Description of bench marks (B.M.)/ Authentic reference level used

A GTS benchmark (1910) was successfully recovered at 30.0 km chainage on the river stretch beyond the Nellore Township. As per the details supplied by the Client, this BM was 25.609 m above the MSL. A photograph of the recovered BM and the CWC document describing its value and other details are placed at Figure 7 and Figure 8 respectively. There were no other bench marks available along the river stretch. Therefore, all the heights of the riverbed obtained from the current topographic survey are referred to MSL by linking it to this bench mark.

Brief Narrative on the Recovery of the Station	
a) What is the Source of Station Description Data;	Survey of India/ CWC office, Nellore
b) Was the station recovered successfully?	Yes
c) What were the differences in Coordinates after verification using Starfix.HP?	No earlier coordinates available
d) Give Link to Starfix Mean Posn/Final Fix Report.	Mean Position Report_GTS_BM_DKW COLLEGE. NELLORE.pdf

Final Coordinates in WGS84 Datum after verification using Starfix.HP

GEOGRAPHICAL COORDINATES:			UTM COORDINATES:	Zone No: 44	CM: 081 °E
LATITUDE :	14° 26' 20.4834"	N	EASTING:	388 525.08 m	(+/-0.07 m)
LONGITUDE :	79° 57' 56.8533"	E	NORTHING:	1 596 531.86 m	(+/- 0.05 m)
ELLIPSOIDAL HEIGHT :	-62.54 m		Ht above MSL/~~GD~~	84.018 Feet	
Describe the General Location & Access to the Station :	The station is situated on top of a concrete pillar (0.6mx0.6mx0.5m) situated 2.65 m South of soutern wall of the girls hostel (old) in the campus of Dodla Kousalyamma (DK) Government Degree college for women, Nellore, Andhra Pradesh -524003 (Ph:0861-2330102). The college is about 06 Kms from the Nellore Bus Stand and easily accessible by auto or local city buses plying regularly from the Nellore Railway Station and Bus Stand.				
Describe how the Stn is marked on the Ground	The station is marked by a black DOT on top of the pillar.				
Expected durability of the Station (in Years) :	10				

DETAILED DIAGRAM :

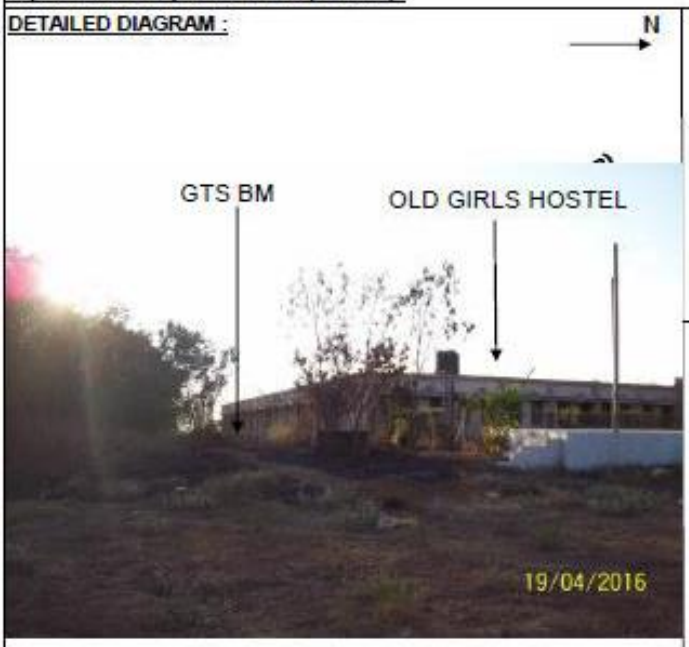


Figure 7: Details of Benchmark at Nellore

GOVT. OF INDIA
CENTRAL WATER COMMISSION
PENNAR SUB-DIVISION

GENERAL INFORMATION CHART OF SITE NELLORE

1	Name of Site	:	Nellore
2	Code No.	:	AP 000 A6
3	Name of River / Stream	:	Pennar
4	Type of Site	:	GDSQ
5	Date of Commencement of Site	:	16/06/1986
6	Place / Village	:	Nellore
7	District/State	:	Nellore / Andra Pradesh
8	Lattitude	:	14° 27' 00"
9	Longitude	:	79° 59' 00"
10	Zero of Gauge	:	7.230 m
11	Musto type Bench Mark Value	:	20.200 m
12	Nearest GTS Bench Mark & Value	:	25.609 m at Nellore
13	Catchment Area	:	51,800 Sq Km
14	Standard Bank	:	Right
15	River Width	:	775 m
16	Distance from Bridge to S/G Line	:	410 m
17	Distance of Up stream & Down stream gauge lines	:	200 m
18	Length of Bridge	:	763.5 m
19	No.of Spans	:	33 Nos.
20	Span Width	:	1-10 Nos-17.6 m, 11-33Nos-20.9 m
21	Road Width	:	6.70 m
	Historical Flood		
22	i)Max. water level observed so far	:	51.920 m on 17-10-2001
	ii)Corresponding Discharge	:	9600 m^3 / sec (Estimated)
23	i) Max. discharge observed so far	:	8688 m3/sec on 18-10-2001
	ii)Corresponding Stage	:	51. 92 m on 18-10-2001
24	Max. Rainfall observed so far	:	360.4 mm on 08-05-1995
25	Distance from Office to S/G Line	:	118 m
26	Distance from site to Sub Division	:	180 km
27	Distance from site to Division	:	180 km
28	Nearest Projects in i) Up stream	:	Somsila Project - 60 km
29	ii) Down stream	:	Bay of Bengal - 20 km
30	Nearest Railway Station/ Distance	:	Nellore - 1 km from site
	Site Office Building	:	Irrigation Department of A.P State

Figure 8: Nellore gauge station details and Benchmark Value

4.3 Tidal Influence Zone and Tidal Variation in different stretches

From the analysis of Survey of India toposheets for the coastal zone, it was found that the tidal reach of the river is 9 km. However during carrying out hydrographic survey length of tidal influence zone was found up to 9.04 km.

The Nearest Port is Chennai. As per tide data at Chennai port the tidal variation between MLLW springs (0.1) and MHW springs (1.1) is 1.0 m.

(Tide Source: Chennai Port Tide data from ATT tide table (Volume 3) and hydrographic chart no 357.)

4.4 Chart datum / Sounding datum and reduction details

4.4.1 Horizontal control

Worldwide Starfix.HP DGPS was used for positioning the survey vessel during this survey. The accuracy of the x, y, z position data obtained from the Starfix.HP DGPS system is +/- 10 cms at 95% assurance levels. Starfix software suite was used for navigation, data logging, and online quality control of the survey data logged.

4.4.2 Vertical control

a) Chart Datum at the River Estuary

From the information published by the Survey of India in their Coastal Bench Mark Pamphlet, it was evident that there are no established bench marks available anywhere near the estuary of the Pennar River. There was no benchmark available anywhere near the estuary of the Pennar River. Hence, it was decided to accept the Chart Datum value of the nearest port Chennai, which was 0.6 m below the MSL as published in the Admiralty Tide Tables (Vol-3). Thus in the river's estuary From KP 0.0 to KP 9.0, the observed echo sounder depths were reduced to chart datum using water level observations recorded at site, and applying MSL-CD relationship of 0.60 m. C.D. is below M.S.L.

b) Chart Datum for the Upstream part of the River

The gauge discharge data of Nellore gauging station was collected by WAPCOS. Chart datum/ Sounding Datum at this gauge station were taken as average of minimum water level of last six years. This is detailed in Para 4.18.

4.5 Hydrographic Survey

4.5.1 Hydrographic Survey

a) Length of stretch for which bathymetry survey has been carried out

The bathymetry survey has been carried out in the stretch of 9.04 km from Pennar river mouth.

b) Minimum and Maximum Depths

River Stretch (From CH 0.0 to CH 5.5)

This is the Estuarial part of the river where it meets the Bay of Bengal, and hence influenced by the tidal effects of the sea. There is a delta formed at the estuary of the river at Lat. 14° 35' 36.75"N, Long. 80° 11' 30.61"E as can be seen in the figure below. Depths shown in the diagram are reduced to Chart Datum which is 0.65 m below the MSL. Agricultural fields can be seen on either side of the river bank and within the delta. Minimum water depth below the Chart Datum as recorded in this section is 0.2 m (CH 4.2) and the maximum water depth is 2.6 m (CH 1.6).

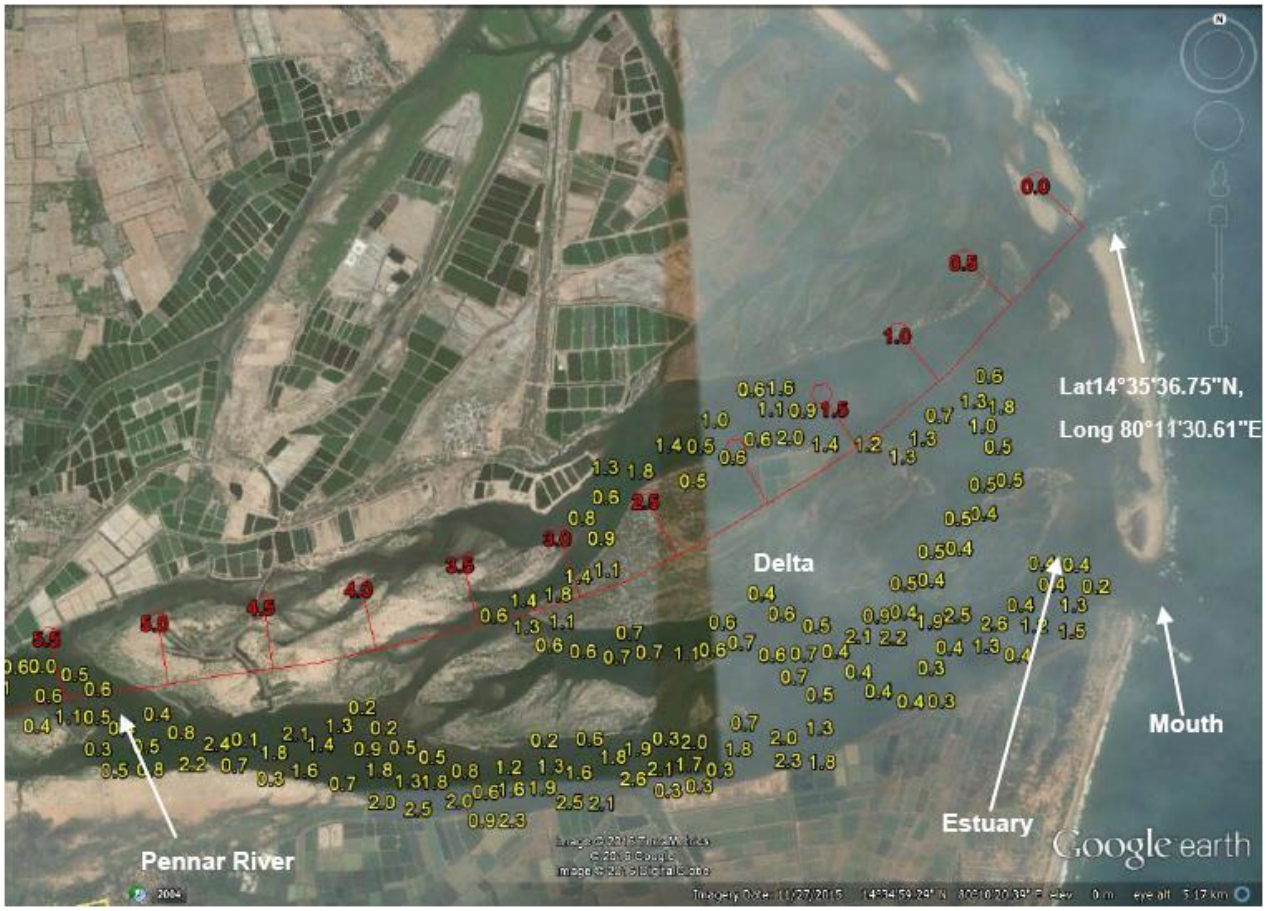


Figure 9: Pennar River from CH 0.0 to CH 5.5

Chainage (km)		Water Depth (m) w.r.t. Chart Datum	
From	To	Minimum	Maximum
0.0	5.5	0.2	2.6

River Stretch (From CH 5.5 to CH 9.04)

Shallow water depths were observed along this river stretch at CH 5.7, 6.2 & 7.0. This part of the river was influenced by Tidal effect and hence all observed depths are reduced to the Chart Datum. There are fields and vegetation cover on either side of the river bank. Village Utukuru is at the North bank of the river at CH 6.0. Minimum water depth recorded in this section is -0.2 m (CH 5.5) and the maximum water depth is 1.9 m (CH 9.0) w.r.t. CD.

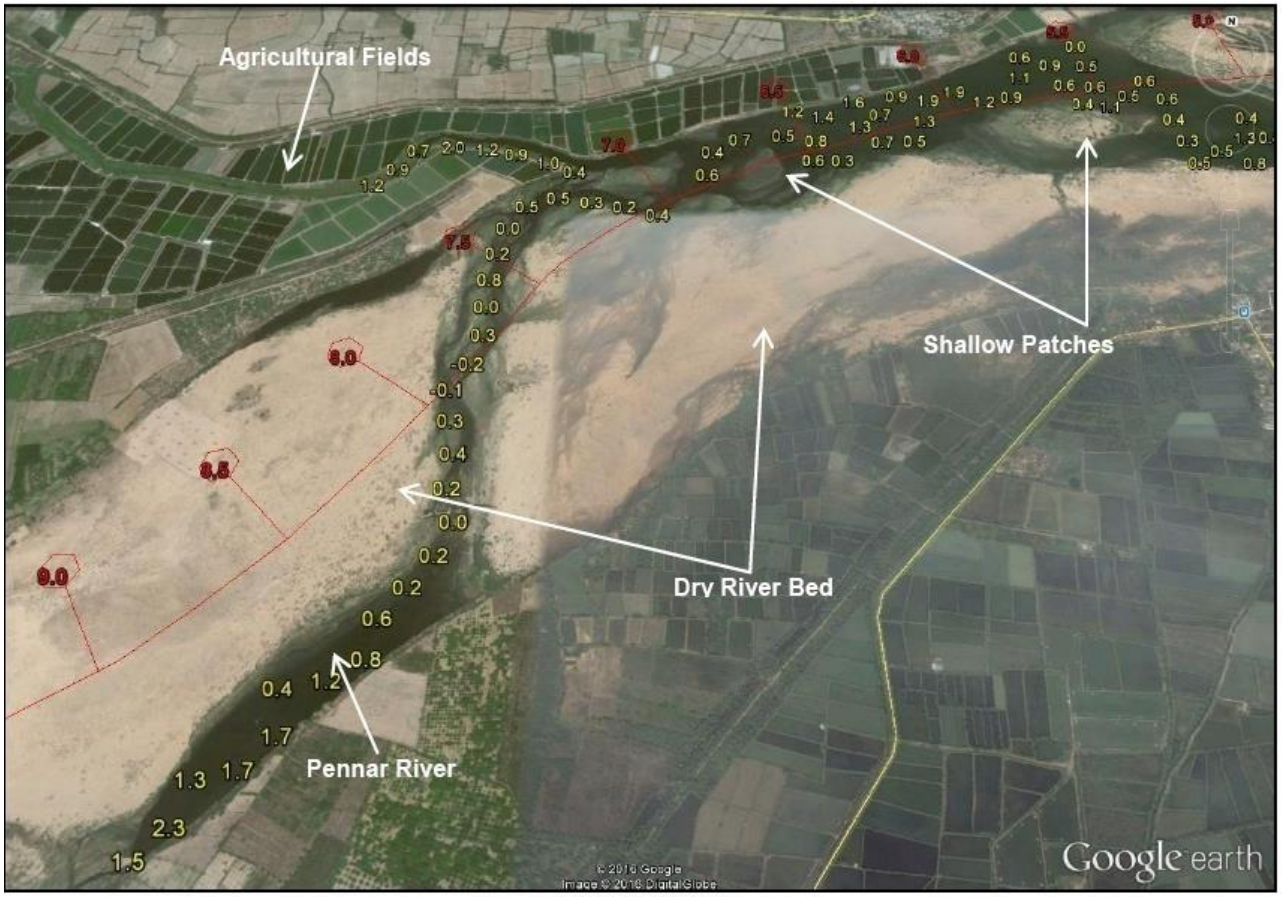


Figure 10: Pennar River from CH 5.5 to CH 9.0

Chainage (km)		Water Depth (m) w.r.t. Chart Datum	
From	To	Minimum	Maximum
5.5	9.0	-0.2	1.9

c) *Water levels (Observed, reduction factor, reduced water levels w.r.t. C.D./S.D.)*

Chainage (Km) A	Observed Water Depth(m) B	Tide(m) C	Reduced Depth (m) D = B - C
0.000	0.220	0.340	-0.120
0.101	0.250	0.340	-0.090
0.197	0.240	0.340	-0.100
0.289	0.350	0.340	0.010
0.381	0.410	0.350	0.060
0.478	0.450	0.350	0.100
0.576	0.430	0.350	0.080
0.673	0.460	0.360	0.100
0.771	0.580	0.360	0.220
0.869	0.930	0.360	0.570
0.900	2.190	0.360	1.830
0.937	1.380	0.370	1.010
0.943	0.840	0.370	0.470
0.949	1.630	0.360	1.270

Chainage (Km) **A**	Observed Water Depth(m) **B**	Tide(m) **C**	Reduced Depth (m) **D = B - C**
1.017	0.850	0.370	0.480
1.049	2.450	0.350	2.100
1.068	0.640	0.440	0.200
1.108	0.850	0.440	0.410
1.114	0.870	0.370	0.500
1.149	1.060	0.350	0.710
1.161	1.760	0.430	1.330
1.180	0.850	0.450	0.400
1.212	0.770	0.380	0.390
1.248	1.610	0.350	1.260
1.257	0.840	0.450	0.390
1.261	1.940	0.430	1.510
1.309	0.880	0.380	0.500
1.335	0.840	0.450	0.390
1.338	1.650	0.350	1.300
1.345	1.600	0.420	1.180
1.345	0.810	0.380	0.430
1.371	0.830	0.460	0.370
1.416	1.590	0.340	1.250
1.422	1.770	0.460	1.310
1.440	0.860	0.380	0.480
1.470	3.090	0.460	2.630
1.499	3.550	0.470	3.080
1.499	1.640	0.340	1.300
1.536	0.830	0.390	0.440
1.582	1.710	0.340	1.370
1.593	3.000	0.470	2.530
1.610	1.850	0.280	1.570
1.633	0.870	0.390	0.480
1.643	2.330	0.340	1.990
1.662	1.250	0.330	0.920
1.675	0.870	0.470	0.400
1.698	0.800	0.480	0.320
1.698	2.280	0.410	1.870
1.698	0.810	0.390	0.420
1.725	1.690	0.290	1.400
1.749	0.860	0.290	0.570
1.761	0.820	0.480	0.340
1.777	2.590	0.400	2.190
1.791	1.340	0.390	0.950
1.813	1.390	0.280	1.110
1.861	2.450	0.400	2.050

Chainage (Km) A	Observed Water Depth(m) B	Tide(m) C	Reduced Depth (m) D = B - C
1.861	0.850	0.480	0.370
1.900	0.850	0.280	0.570
1.911	0.870	0.490	0.380
1.974	0.850	0.490	0.360
1.989	0.840	0.270	0.570
2.021	0.840	0.490	0.350
2.035	0.810	0.270	0.540
2.064	1.260	0.270	0.990
2.074	0.850	0.500	0.350
2.123	0.970	0.500	0.470
2.146	0.980	0.500	0.480
2.178	0.920	0.510	0.410
2.203	1.140	0.510	0.630
2.204	1.390	0.180	1.210
2.213	1.580	0.250	1.330
2.218	0.850	0.180	0.670
2.234	0.810	0.260	0.550
2.261	1.240	0.180	1.060
2.264	0.880	0.180	0.700
2.301	1.010	0.520	0.490
2.310	0.830	0.190	0.640
2.313	1.640	0.250	1.390
2.348	0.860	0.190	0.670
2.350	2.340	0.530	1.810
2.350	1.450	0.180	1.270
2.375	0.840	0.190	0.650
2.384	1.610	0.170	1.440
2.419	2.880	0.530	2.350
2.427	2.520	0.250	2.270
2.438	0.820	0.190	0.630
2.475	2.540	0.540	2.000
2.526	2.080	0.250	1.830
2.538	0.840	0.200	0.640
2.580	2.110	0.170	1.940
2.606	1.590	0.240	1.350
2.610	1.240	0.540	0.700
2.631	1.340	0.200	1.140
2.675	1.920	0.170	1.750
2.694	0.850	0.240	0.610
2.718	0.930	0.200	0.730
2.720	1.080	0.240	0.840
2.741	1.120	0.240	0.880

Chainage (Km) A	Observed Water Depth(m) B	Tide(m) C	Reduced Depth (m) D = B - C
2.769	1.890	0.170	1.720
2.778	0.830	0.560	0.270
2.778	0.830	0.550	0.280
2.778	0.910	0.200	0.710
2.778	2.120	0.170	1.950
2.781	0.840	0.570	0.270
2.827	0.840	0.200	0.640
2.837	2.280	0.170	2.110
2.854	1.320	0.230	1.090
2.895	0.880	0.580	0.300
2.927	0.870	0.210	0.660
2.937	2.270	0.165	2.105
2.942	1.590	0.230	1.360
2.990	3.240	0.600	2.640
3.015	2.450	0.600	1.850
3.027	1.620	0.230	1.390
3.028	0.850	0.210	0.640
3.085	1.180	0.610	0.570
3.110	0.840	0.210	0.630
3.126	2.050	0.230	1.820
3.136	2.000	0.160	1.840
3.164	2.720	0.610	2.110
3.164	1.310	0.210	1.100
3.178	1.770	0.160	1.610
3.233	1.580	0.230	1.350
3.244	3.080	0.610	2.470
3.249	1.470	0.210	1.260
3.278	1.600	0.160	1.440
3.297	2.550	0.620	1.930
3.318	0.840	0.220	0.620
3.328	1.690	0.620	1.070
3.369	0.860	0.620	0.240
3.377	1.490	0.160	1.330
3.439	1.350	0.630	0.720
3.508	2.250	0.630	1.620
3.572	1.340	0.160	1.180
3.578	2.930	0.630	2.300
3.670	0.770	0.160	0.610
3.670	1.510	0.640	0.870
3.688	2.640	0.640	2.000
3.759	0.960	0.150	0.810
3.764	1.100	0.650	0.450

Chainage (Km) A	Observed Water Depth(m) B	Tide(m) C	Reduced Depth (m) D = B - C
3.852	1.980	0.150	1.830
3.936	2.660	0.150	2.510
4.020	1.150	0.670	0.480
4.027	1.990	0.660	1.330
4.030	1.660	0.670	0.990
4.032	2.690	0.660	2.030
4.039	0.860	0.680	0.180
4.087	0.880	0.680	0.200
4.116	0.760	0.130	0.630
4.120	1.540	0.680	0.860
4.159	2.510	0.690	1.820
4.206	0.800	0.130	0.670
4.257	2.640	0.690	1.950
4.274	2.070	0.700	1.370
4.284	2.040	0.700	1.340
4.284	1.100	0.130	0.970
4.327	1.730	0.130	1.600
4.347	1.740	0.710	1.030
4.406	2.830	0.710	2.120
4.420	1.380	0.130	1.250
4.458	2.470	0.710	1.760
4.542	1.050	0.720	0.330
4.593	2.340	0.720	1.620
4.656	3.530	0.720	2.810
4.702	0.850	0.730	0.120
4.705	0.780	0.130	0.650
4.784	3.130	0.730	2.400
4.816	2.310	0.120	2.190
4.915	2.360	0.120	2.240
5.015	1.730	0.120	1.610
5.017	1.540	0.740	0.800
5.050	1.180	0.750	0.430
5.088	2.060	0.750	1.310
5.093	0.900	0.120	0.780
5.174	1.260	0.750	0.510
5.260	1.390	0.770	0.620
5.263	1.280	0.760	0.520
5.264	1.090	0.760	0.330
5.272	1.170	0.770	0.400
5.304	1.410	0.780	0.630
5.379	1.290	0.780	0.510
5.450	0.800	0.800	0.000

Chainage (Km) **A**	Observed Water Depth(m) **B**	Tide(m) **C**	Reduced Depth (m) **D = B - C**
5.453	1.310	0.800	0.510
5.470	1.410	0.800	0.610
5.475	1.840	0.780	1.060
5.542	1.180	0.810	0.370
5.564	1.370	0.810	0.560
5.572	1.690	0.810	0.880
5.656	1.430	0.820	0.610
5.705	1.940	0.820	1.120
5.756	1.770	0.830	0.940
5.856	2.030	0.830	1.200
5.933	2.700	0.830	1.870
6.021	2.690	0.840	1.850
6.075	2.120	0.840	1.280
6.102	1.770	0.890	0.880
6.139	1.330	0.840	0.490
6.190	1.600	0.880	0.720
6.237	1.550	0.850	0.700
6.274	2.170	0.850	1.320
6.294	2.440	0.880	1.560
6.393	1.250	0.940	0.310
6.407	2.270	0.870	1.400
6.432	1.720	0.940	0.780
6.476	1.420	0.860	0.560
6.509	2.080	0.870	1.210
6.521	1.490	0.960	0.530
6.601	1.540	0.960	0.580
6.643	1.710	0.970	0.740
6.737	1.350	0.970	0.380
6.801	1.580	0.990	0.590
6.895	1.580	1.000	0.580
6.994	1.390	1.000	0.390
7.083	1.220	1.000	0.220
7.143	1.340	1.000	0.340
7.155	2.050	1.050	1.000
7.163	1.440	1.050	0.390
7.207	1.990	1.050	0.940
7.212	1.470	1.000	0.470
7.248	2.260	1.050	1.210
7.286	1.470	1.000	0.470
7.287	3.060	1.050	2.010
7.374	1.750	1.050	0.700
7.383	1.050	1.000	0.050

Chainage (Km) A	Observed Water Depth(m) B	Tide(m) C	Reduced Depth (m) D = B - C
7.403	1.960	1.050	0.910
7.438	1.190	1.000	0.190
7.453	2.240	1.050	1.190
7.527	1.800	1.010	0.790
7.599	1.040	1.010	0.030
7.688	1.340	1.010	0.330
7.786	0.840	1.010	-0.170
7.885	0.940	1.010	-0.070
7.960	1.300	1.010	0.290
8.032	1.380	1.010	0.370
8.120	1.170	1.020	0.150
8.184	1.030	1.020	0.010
8.268	1.220	1.020	0.200
8.368	1.170	1.020	0.150
8.468	1.660	1.020	0.640
8.503	1.860	1.020	0.840
8.604	2.220	1.020	1.200
8.688	1.380	1.020	0.360
8.756	2.700	1.030	1.670
8.839	2.680	1.030	1.650
8.925	2.310	1.030	1.280
8.951	3.370	1.040	2.330
9.041	2.530	1.030	1.500

Table 14: Bathymetry Water levels (Observed, Reduction factor and Reduced)

4.5.2 Topographic Survey

a) Length of stretch for which topographic survey has been carried out

Since the water depths are shallow for chainage above 9.04 km from river mouth and bathymetry survey was not possible, therefore the topography survey has been carried out from chainage 9.04 km to 29.0 km from Pennar river mouth.

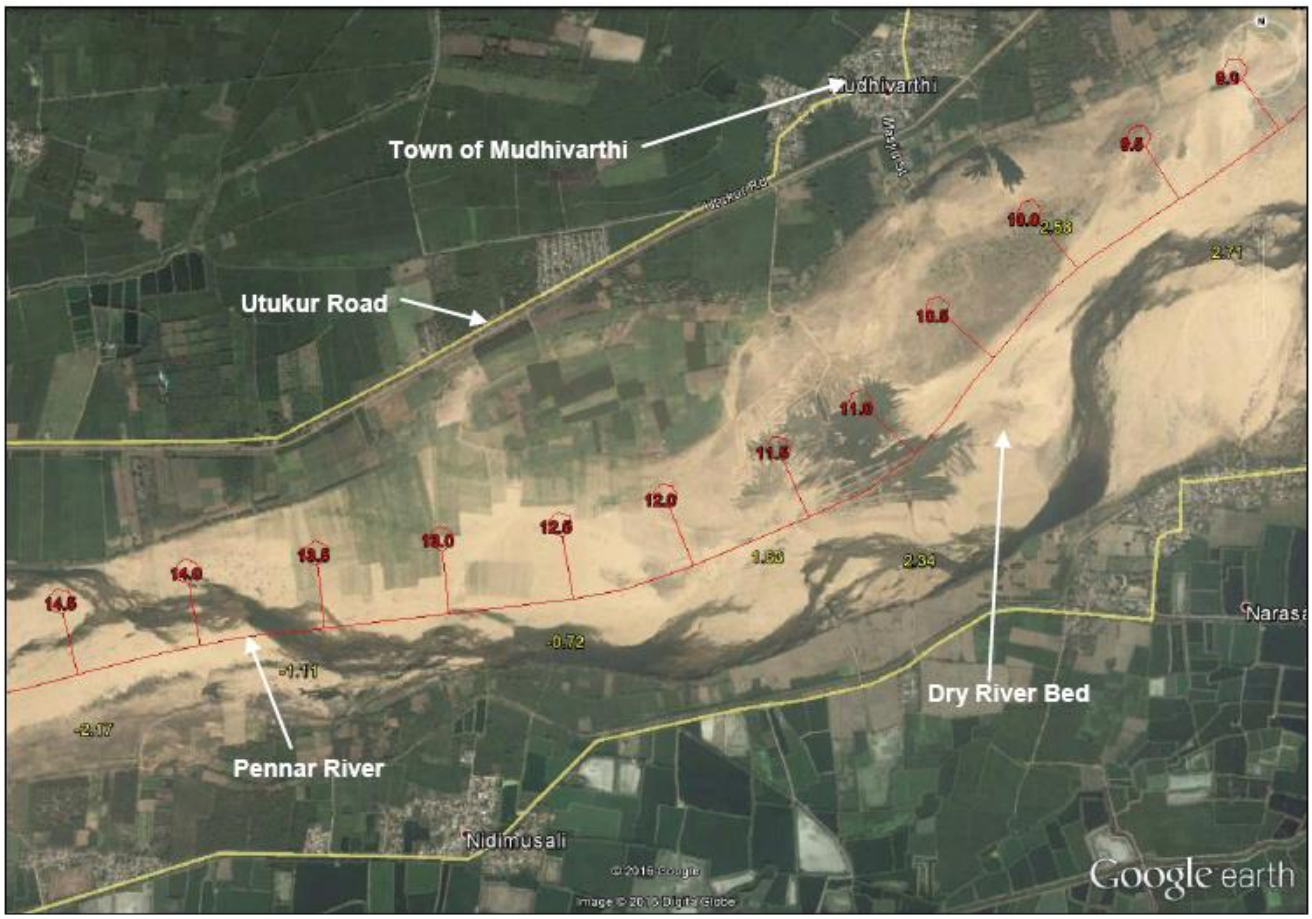
b) Minimum and Maximum Depths

As per IWAI suggestion, following sign convention is adopted

(+) : Riverbed below CD
(-) : Riverbed above CD
(+) : Water Depth below CD
(-) : Water Depth above CD

River Stretch (From CH 9.04 to CH 14.5)

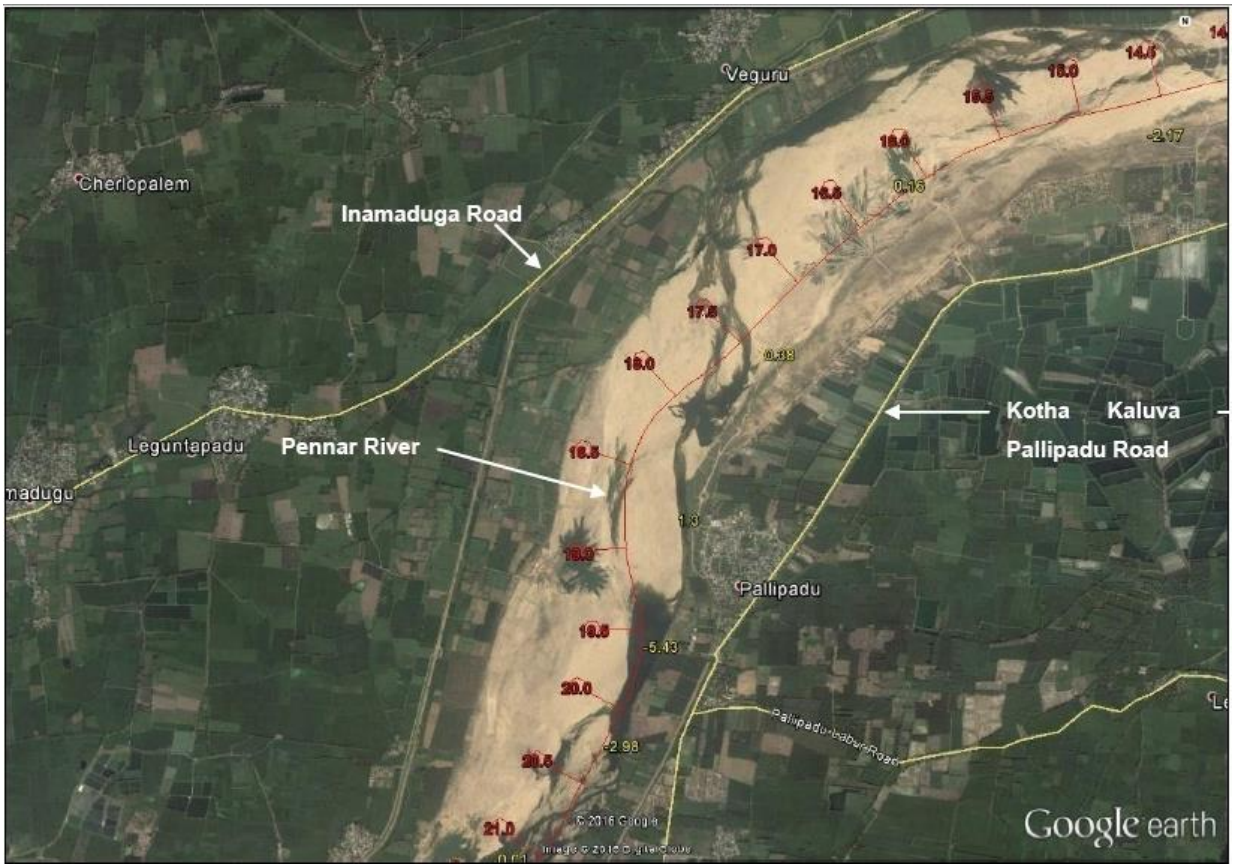
The river flows as a very narrow stream in this stretch. Town of Mudhivarthi and Utukuru Road lies on the north bank of the Pennar River at CH 10.0. There are fields seen on both sides and vegetation cover in the middle of the river. Minimum water depth recorded in this section is a dry land and the maximum reduce depth is 0.715 m.



Chainage (km)		Reduced Depth (m) w.r.t. Chart Datum	
From	**To**	**Minimum**	**Maximum**
9.04	14.5	Dry	0.71

River Stretch (From CH 14.6 to CH 21.0):-

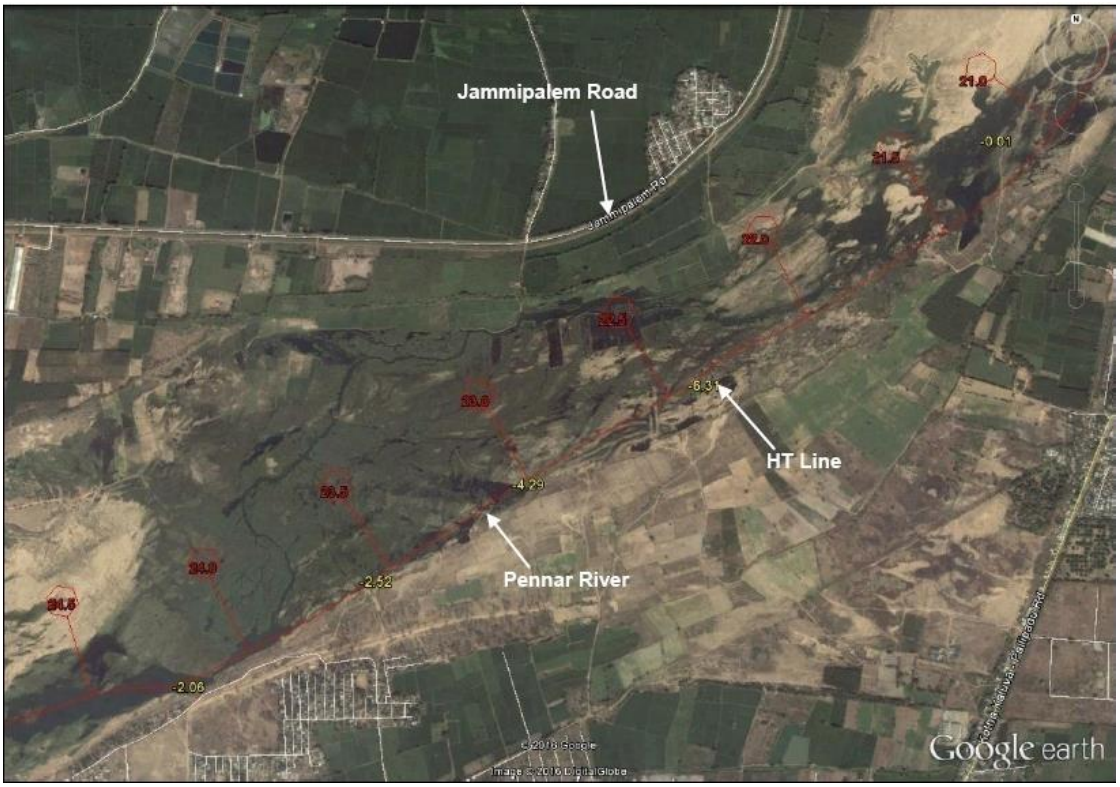
Few small meandering channels can be seen between CH 17.5 to CH 21.0. Both sides of the river have open fields flanking on the river banks. Minimum reduced depth recorded in this section is 0.000 m and the maximum reduced depth is 2.039 m.



Chainage (km)		Reduced Depth (m) w.r.t. Chart Datum	
From	**To**	**Minimum**	**Maximum**
14.5	21.0	0.000	2.039

River Stretch from CH 21.0 to CH 24.5

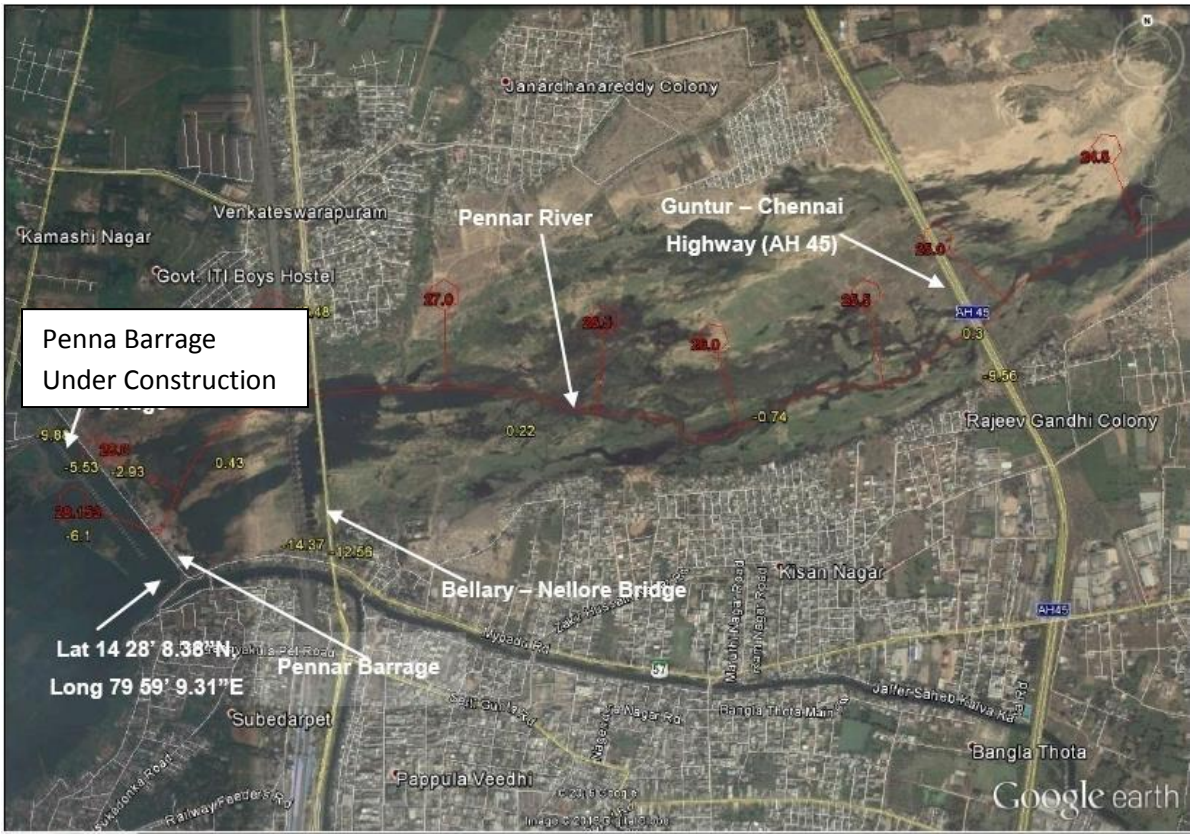
There are mostly fields seen along both the banks. The flood plains are covered with vegetation and open fields. A High Tension line crosses the river at CH 22.4 with a vertical clearance of 8 m and horizontal clearance of 150 m. Minimum reduced depth recorded in this section is 0.000 m and the maximum reduced depth is 1.067 m.



Chainage (km)		Water Depth (m) w.r.t. Chart Datum	
From	**To**	**Minimum**	**Maximum**
21	24.5	0.000	1.067

River Stretch from CH 24.6 to CH 29

Bellary – Nellore Bridge (SH 57) crosses the river at CH 27.5 with a vertical clearance of 10m, distance of 15m between columns and width of 10m. Penna Barrage near Pothireddypalem was located at CH 28.153. A High Tension line crosses the river at CH 28.0 with a vertical clearance of 8 m and horizontal clearance of 250m. Minimum reduced depth recorded in this section is 0.000 m and the maximum reduced depth is 1.674 m.



Chainage (km)		Water Depth (m) w.r.t. Chart Datum	
From	To	Minimum	Maximum
24	29	0.000	1.674

c) Water levels Topographic survey

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
9.125	0.481	0.300	0.600	0.119
9.207	0.472	0.300	0.641	0.169
9.324	0.525	0.300	0.700	0.175
9.424	0.580	0.300	0.751	0.171
9.500	0.594	0.300	0.789	0.195
9.577	0.609	0.400	0.828	0.219
9.657	0.640	0.420	0.868	0.228
9.730	0.638	0.350	0.905	0.268

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
9.806	0.652	0.350	0.943	0.291
9.882	0.667	0.350	0.982	0.315
9.941	0.710	0.400	1.012	0.302
10.021	0.726	0.400	1.052	0.326
10.110	0.742	0.400	1.097	0.355
10.190	0.758	0.450	1.137	0.379
10.285	0.774	0.400	1.186	0.412
10.381	0.800	0.350	1.234	0.434
10.476	0.806	0.350	1.282	0.476
10.571	0.822	0.350	1.329	0.507
10.677	0.838	0.350	1.383	0.545
10.775	0.854	0.400	1.433	0.579
10.851	0.870	0.400	1.471	0.601
10.945	0.886	0.500	1.518	0.632
11.010	0.902	0.400	1.551	0.649
11.087	0.950	0.400	1.590	0.640
11.174	0.934	0.400	1.634	0.700
11.236	0.950	0.400	1.665	0.715
11.247	1.039	0.400	1.671	0.632
11.272	1.250	0.400	1.683	0.433
11.363	1.216	0.400	1.729	0.513
11.453	1.305	0.300	1.775	0.470
11.539	1.450	0.400	1.818	0.368
11.631	1.483	0.400	1.864	0.382
11.711	1.660	0.400	1.905	0.245
11.723	1.900	0.350	1.911	0.011
11.823	2.087	0.400	1.961	0.000
11.923	2.301	0.400	2.012	0.000
12.018	2.550	0.400	2.060	0.000
12.118	2.728	0.400	2.110	0.000
12.217	2.942	0.400	2.160	0.000
12.300	3.250	0.400	2.202	0.000
12.398	3.369	0.400	2.251	0.000
12.496	3.583	0.300	2.301	0.000
12.555	4.320	0.400	2.331	0.000
12.584	4.040	0.350	2.345	0.000
12.684	4.070	0.350	2.396	0.000
12.784	4.450	0.400	2.446	0.000
12.884	4.130	0.400	2.497	0.000
12.983	4.160	0.400	2.546	0.000
13.083	4.190	0.400	2.597	0.000

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
13.183	4.560	0.400	2.647	0.000
13.283	4.250	0.400	2.698	0.000
13.384	4.280	0.400	2.749	0.000
13.484	4.550	0.300	2.800	0.000
13.582	4.340	0.400	2.849	0.000
13.629	4.400	0.400	2.872	0.000
13.681	4.496	0.400	2.899	0.000
13.780	4.560	0.400	2.948	0.000
13.897	4.550	0.300	3.007	0.000
13.996	4.496	0.200	3.058	0.000
14.096	4.496	0.100	3.108	0.000
14.206	4.496		3.163	0.000
14.305	4.450		3.214	0.000
14.405	4.250		3.264	0.000
14.510	4.496		3.317	0.000
14.512	5.460		3.318	0.000
14.610	5.478		3.367	0.000
14.710	5.496		3.418	0.000
14.799	5.515		3.463	0.000
14.899	5.533		3.513	0.000
14.999	5.551		3.564	0.000
15.110	5.569		3.620	0.000
15.210	5.588		3.670	0.000
15.323	5.606		3.727	0.000
15.422	5.624		3.777	0.000
15.521	5.642		3.827	0.000
15.628	5.661		3.881	0.000
15.726	5.679		3.931	0.000
15.840	5.697		3.988	0.000
15.936	5.715		4.036	0.000
16.028	5.734		4.083	0.000
16.103	5.770		4.121	0.000
16.120	5.754		4.129	0.000
16.217	5.739		4.178	0.000
16.314	5.723		4.227	0.000
16.410	5.707		4.276	0.000
16.507	5.691		4.324	0.000
16.609	5.676		4.376	0.000
16.707	5.660		4.425	0.000
16.810	5.644		4.477	0.000
16.908	5.629		4.527	0.000

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
17.007	5.613		4.577	0.000
17.114	5.597		4.631	0.000
17.220	5.581		4.684	0.000
17.320	5.566		4.734	0.000
17.384	5.550		4.767	0.000
17.413	5.479		4.781	0.000
17.509	5.408		4.830	0.000
17.606	5.338		4.879	0.000
17.659	5.267		4.906	0.000
17.755	5.196		4.954	0.000
17.823	5.125		4.988	0.000
17.980	5.055		5.067	0.013
18.067	4.984		5.111	0.128
18.365	4.913		5.262	0.349
18.511	4.842	0.500	5.336	0.493
18.757	4.772	0.700	5.460	0.688
18.837	4.630	0.800	5.500	0.870
18.837	4.303	0.800	5.500	1.197
18.965	4.976	0.900	5.599	0.623
19.116	4.649	0.900	5.715	1.066
19.206	4.322	0.800	5.784	1.462
19.296	4.995	0.900	5.854	0.859
19.397	4.668	0.700	5.932	1.264
19.466	4.341	0.800	5.985	1.644
19.534	5.014	0.900	6.038	1.024
19.593	5.360	1.000	6.083	0.723
19.616	5.088	0.900	6.101	1.013
19.708	4.816	0.900	6.172	1.356
19.805	4.543	0.900	6.247	1.703
19.888	4.271	0.800	6.310	2.039
19.984	4.999	0.850	6.385	1.386
20.083	5.727	0.850	6.461	0.734
20.191	5.454	0.900	6.544	1.090
20.210	5.910	1.000	6.559	0.649
20.277	5.613	1.000	6.610	0.997
20.379	6.316	1.100	6.689	0.373
20.469	6.019	1.000	6.759	0.740
20.568	6.722	1.000	6.835	0.113
20.663	7.425	1.000	6.908	0.000
20.755	7.128	1.000	6.979	0.000
20.866	6.831	1.000	7.064	0.233

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
20.967	6.534	1.000	7.142	0.608
21.077	6.237	1.000	7.227	0.990
21.145	5.940	1.000	7.280	1.340
21.171	6.390	0.900	7.300	0.910
21.280	6.840	0.800	7.334	0.494
21.404	7.290	0.700	7.372	0.082
21.514	7.740	0.500	7.407	0.000
21.605	8.190	0.400	7.435	0.000
21.701	8.640		7.464	0.000
21.805	8.090		7.497	0.000
21.905	7.540		7.528	0.000
22.008	7.990		7.560	0.000
22.106	7.440		7.590	0.150
22.203	7.890		7.620	0.000
22.307	8.340		7.652	0.000
22.383	8.240		7.676	0.000
22.405	8.016		7.683	0.000
22.503	7.791		7.713	0.000
22.604	7.867		7.745	0.000
22.702	7.442		7.775	0.333
22.806	7.918		7.807	0.000
22.904	7.393		7.838	0.444
23.004	6.969		7.869	0.900
23.010	7.220		7.871	0.651
23.105	7.567		7.900	0.333
23.205	7.714		7.931	0.217
23.305	7.461		7.962	0.501
23.404	7.209		7.993	0.784
23.505	7.557		8.024	0.467
23.568	7.450		8.044	0.594
23.605	7.399		8.055	0.656
23.705	7.548		8.086	0.538
23.805	7.297		8.117	0.820
23.905	7.246	0.300	8.148	0.903
24.005	7.394	0.500	8.179	0.785
24.104	7.143	0.500	8.210	1.067
24.202	7.522	0.500	8.240	0.718
24.222	7.990	0.700	8.247	0.257
24.295	8.050	0.700	8.269	0.219
24.386	8.200	0.700	8.297	0.097
24.508	7.953	0.600	8.335	0.382

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
24.609	7.562	0.700	8.367	0.805
24.703	7.380	0.800	8.396	1.016
24.810	7.487	0.900	8.429	0.942
24.957	7.561	1.000	8.475	0.914
25.044	7.859	1.100	8.502	0.643
25.134	7.762	1.100	8.530	0.768
25.143	7.373	1.200	8.532	1.159
25.208	7.016	1.200	8.553	1.537
25.319	6.913	1.100	8.587	1.674
25.416	7.214	1.000	8.617	1.403
25.530	7.421	0.900	8.652	1.231
25.624	7.367	0.800	8.682	1.315
25.728	7.692	0.700	8.714	1.022
25.837	7.927	0.600	8.748	0.821
25.893	7.824	0.300	8.765	0.941
25.931	8.214	0.400	8.777	0.563
26.026	8.618	0.400	8.806	0.188
26.149	8.522	0.300	8.844	0.322
26.267	8.426	0.400	8.881	0.455
26.366	8.330	0.500	8.912	0.582
26.466	8.234	0.400	8.943	0.709
26.564	8.138	0.300	8.973	0.835
26.649	8.042	0.300	8.999	0.957
26.725	7.850	0.300	9.023	1.173
26.760	8.209	0.200	9.034	0.825
26.859	8.569	0.200	9.065	0.496
26.978	8.928	0.200	9.102	0.173
27.076	9.288	0.200	9.132	0.000
27.177	9.647	0.300	9.163	0.000
27.276	10.006	0.400	9.194	0.000
27.373	9.951	0.500	9.224	0.000
27.473	9.865	0.500	9.255	0.000
27.572	10.121	0.500	9.286	0.000
27.686	9.976	0.500	9.321	0.000
27.794	9.724	0.600	9.355	0.000
27.884	9.291	0.600	9.383	0.000
27.934	9.597	0.700	9.398	0.000
27.970	9.824	0.600	9.410	0.000
28.024	10.065	0.600	9.426	0.000
28.045	9.928	0.700	9.433	0.000
28.104	9.768	0.800	9.451	0.000

Chainage (km) A	River Bed Level w.r.t M.S.L. (m) B	Observed Water Depths w.r.t. River Bed Level (m) C	Adopted C.D. w.r.t. M.S.L. (m) D	Reduced Depth w.r.t. C.D. (m) E = D-B
28.203	9.867	1.100	9.482	0.000
28.262	9.924	1.300	9.500	0.000

Table 15: Topographic survey Water levels (Observed, Reduction factor and Reduced)

Note: Negative (-)ive depths are reduced to zero as per discussions with IWAI officials.

4.6 Observed and reduced bed profile along the river

4.6.1 Observed bed profile along the river

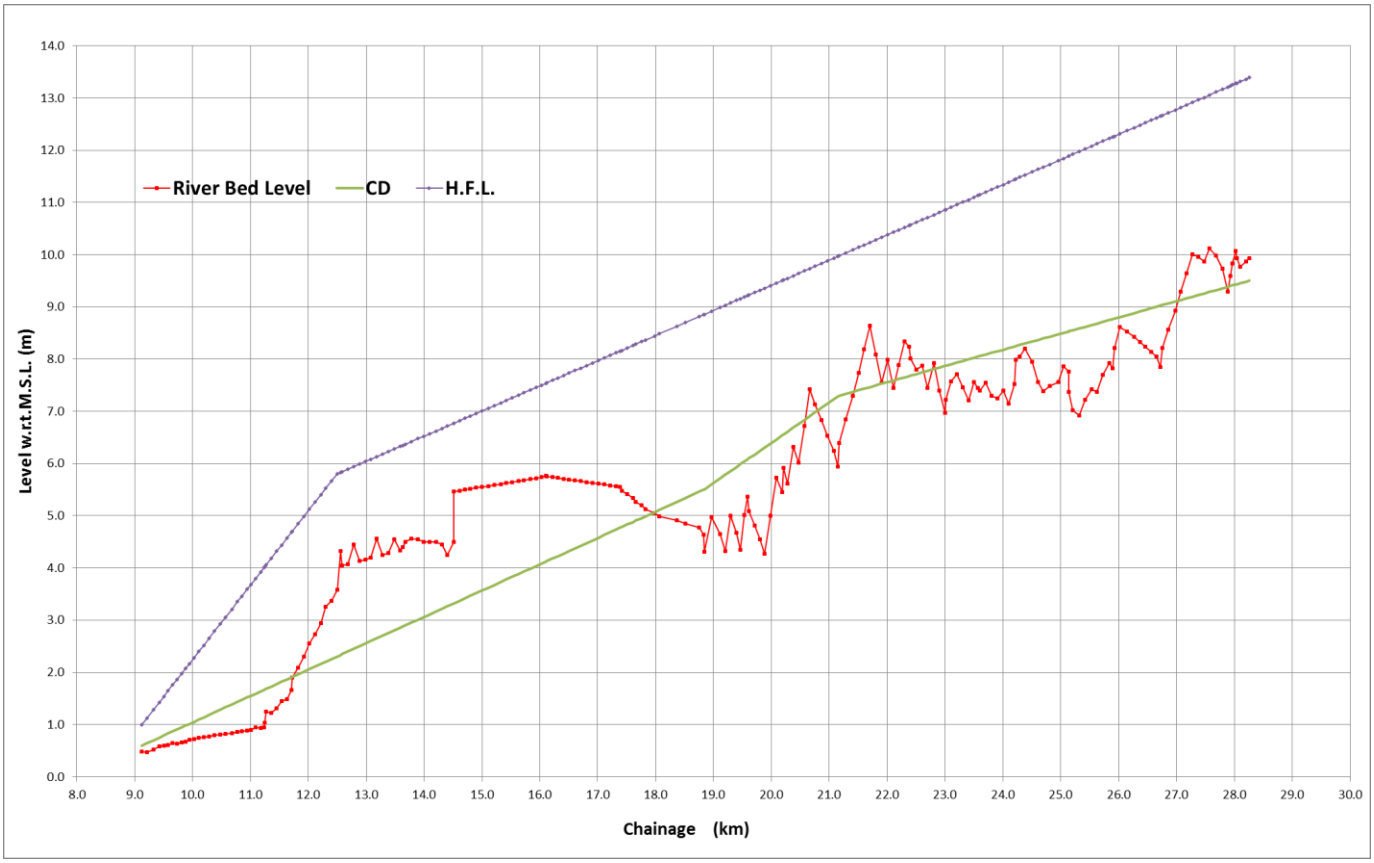


Figure 11: Riverbed profile from the end of tidal influence (Kp 9.04) till the end of 29 Km stretch.

Source data: *Deepest level single line longitudinal survey carried out at site during March-April 2016 and Gauge-Discharge data of last 20 years collected from CWC. Source data table is attached as Annexure 4.*

4.6.2 Reduced bed profile along the river

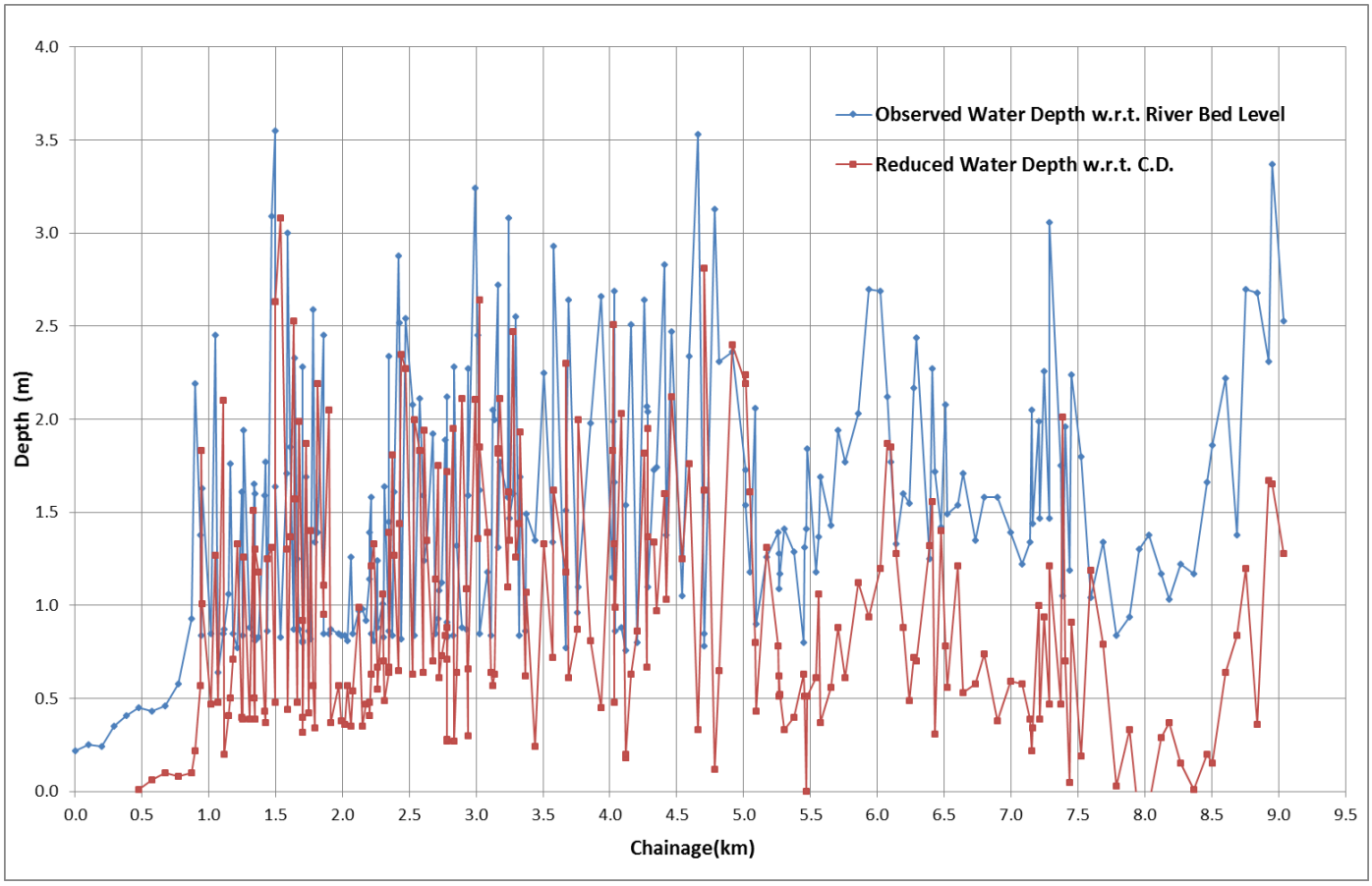


Figure 12: Depth Profile at the Estuary (Kp 0 to Kp 9.04), up to the end of tidal influence

4.7 Results from Hydrographic/Topographic Survey

- Tidal influence was observed upto 9.04 km from river mouth.
- Wherever very shallow patches of water were available, a suitable sounding pole was used to measure the depth of water over river bed.
- Wherever river is dry, deepest bed levels (visually) were taken using topographic survey.

4.8 Soil characteristics

At four (04) locations soil samples were collected and the details of CH vs depth & soil textures are tabulated in **Annexure 1.**

From visual observation, It can be seen that clay was present in riverbed from Ch 0 to 9 km and sand was found from chainage 9 to 29 km. Rocky starata was not observed in the river stretch.

Critical areas requiring detailed investigations

Detailed investigations shall be required at proposed ferry locations nearby temples, Existing boating points and Ghats.

4.9 Water characteristics

From visual observation, clear water was found from chainage 0 to 9 km and after 9 km, water mixed with sand was observed up to 13 km.

4.10 Condition of banks

Condition of banks was depicted in inventory of structures in **Annexure 2**. Natural banks were observed from chainage 0 to 2.1 km. The condition of banks was good. From ch. 2.1 to 28 km, natural banks were observed with protection. After chainage 28 to Penna barrage, banks were observed to be in good condition.

The photographs showing condition of banks along the riverbanks during the Stage-1 survey are also attached at the end.

4.11 Details of collected water level and Discharge data

The details of gauging stations and collected data as detailed in chapter 2 (refer 2.6.3 and 2.6.4) is again given below:

Chainage	Name	Location			
		Lat.	Long.	Northing	Easting
29.00 (Dismantled)	Gauging station Nellore, AP	14^0 28′ 15” N	79^0 58′ 58” E	----	-----

Table 16: Location details of gauging station

The details of Gauge station, jurisdiction, establishment and data availability are presented in the tables below:

General Details	
Station Name	Nellore
Station Code	AP000A6
Operational Status	Existing
Activity	HO/FF
Station Type (Current)	GDQ
Tehsil/Taluk	Nellore
District	Nellore
State	Andhra Pradesh
Latitude (DMS)	14°28'15"N
Longitude (DMS)	79°59'58"E
Altitude (m)	53.00
Distance to Outlet (km)	-
Toposheet No.	58N15
Catchment Area (sq. km)	50800.00

Table 17: Nellore GD site- General details

Jurisdiction Details	
Owner Agency	CWC
State/Regional Office	C&S RO, Coimbatore

Circle Office	S.E.(C&SR), Bangalore
Divisional Office	Hydrology Division, Chennai
Sub Divisional Office	Pennar SD, Cuddapa
Section Office	Nellore
Nearest Airport	Chennai
Town	Chennai
Railway Station	Nellore
Bus Stand	Nellore
Station Bank	Right
Zero of Gauge (m)	44.00 (1987-2003), 7.230 (2003-2013)

Table 18: Nellore GD site- Jurisdiction details

Establishment Details		
Date of establishment	14/8/1987	
Date of closure	-	
Parameters	**Start Date**	**End Date**
Gauge	14/8/1987	
Discharge	28/8/1987	
Sediment	-	
Water Quality	1/9/1988	
Rainfall(ORG)	3/11/1988	
Rainfall(SRG)	-	
Temperature	14/8/1987	
Wind Velocity	3/11/1988	
Evaporation	-	
Humidity	-	
Sunshine	-	

Table 19: Nellore GD site- Establishment details

Parameters	**Start Date**	**End Date**
Water Level	14/8/1987	31/5/2013
Discharge	28/8/1987	31/5/2013
Sediment	Not Available	
Water Quality	1/7/1995	1/5/2013
Rainfall	1/11/1988	31/5/2008
Temperature	14/8/1987	31/5/2009
Climatic	1/3/2006	31/3/2006

Table 20: Nellore GD site - Data availability

Figure 13: Nellore GD site

4.12 Methodology for analysis of Gauge- Discharge Data

The gauge-discharge data available for number of years for all gauging stations were analyzed in different ways as given below:

10 Daily average discharges

The ten daily average discharges in each month for each year were worked out and then the average of average 10 daily discharges over the entire period of data were worked out to get idea about availability of 10 daily average discharge during different months of the year. Based on these average 10 daily discharges it will be possible to work out available depth of flow for natural or design cross section of river. These data analysis will be helpful for navigation feasibility in given stretch of river. The outcome from this analysis will also be useful for mathematical model studies(to be carried out in stage II) to predict longitudinal water surface profiles for different discharges along given reach of river and also to design section of navigation channel on river bed.

Maximum minimum discharges and water levels

The yearly maximum discharge and water level for the entire period of data were extracted and then these data were statistically analysed using Gumbel extreme value distribution to estimate flood discharges for different return periods such as 2,5, 10, 25 ,50 and 100 years. Similarly high flood levels were analysed. The minimum flow and minimum water level data was also analysed. The estimated HFLs and Minimum water levels will be useful for planning navigation as well as for design of terminals for cargo and passenger traffic.

Gauge discharge curves

Using available gauge discharge data G-Q curves were developed for each gauge station. These will be helpful to compute water level for any discharge. Also for calibration and validation of mathematical model (studies required in stage II) this data will be very useful.

Comparison of River Cross Section Data:

The river cross sections at gauging stations on different station were available for different years. For a given gauging station the cross sections for different years including the latest cross section were superimposed to study changes in river bed levels and shifting of the deep channel if any over the period of data.

Period of availability for range of discharges

For a navigation channel to be feasible it is necessary that adequate discharge is available to maintain required depth/draft for fairly longer duration during the year. The data for each gauge station was analysed to find out period of availability for the different range of discharges. Based on past 20 to 30 years of data, % of days in a year for availability of different range of discharges were worked out. These data will be very useful to estimate number of days for which minimum discharge required to facilitate navigation will be available in different rivers.

Discharge- sediment flow data

These data was analyzed to prepare discharge v/s sediment concentration plot for each gauging station. This analysis will be useful to understand sediment concentration in reach for range of discharges.

4.13 Bed Slope

The average bed slopes for Pennar River for the reach under consideration are given in table below:

River	Reach		River Bed Level Change	Distance	Slope
	From	**To**			
Pennar	Nellore RBL 6.24 m	Mouth RBL 0.0 m	6.240 m	28.18 km	1 in 4516

Table 21: Bed Slopes of Pennar River

RBL – River Bed Level (These are taken from CWC river cross sections at gauging sites)

4.14 River Cross sections

The CWC data of river cross sections at gauging sites on Pennar river was available for number of years. The river cross sections at one gauging site for different years were compared to understand morphological changes over the longer period. Figure 16 shows plots for Pennar river cross section at Nellore gauging station indicating comparison of cross sections in different years. Following table shows abstract of review of these studies.

River & Gauge location	General Description & Bank to Bank width	River bed level in 2012	Bank Levels	Comments/ observations
Pennar at Nellore	Wide c/s, width - 770 m, deep channel near right bank (Figure 16)	6.24 m	18.4 m	Practically no change in river section during 1999 to 2012

Table 22: River cross-sections over different years

4.15 Ten- Daily average Discharges

Analysis of 10 daily average discharges is presented in **Table 23. Figure 17** shows bar chart indicating variation in 10 daily average discharges round the year. It could be seen from these data that practically negligible or no flow in river during February to August. In September – October also, discharges are less than 20 cumecs except for period of high floods. Higher 10 daily average discharges during Oct-Nov seen in Table 1 and figure 1 are mainly due to couple of high flood during period of data. The results of this analysis indicate range of average 10 daily discharges in different period of year as following.

- **June to August** — **0 to 5 m^3/s**
- **September to December** — **40 to 60 m^3/s**
- **January to May** — **less than 3 m^3/s**

The gauge- discharge curve derived from the daily flow data during periods of high floods is presented vide figure 18.

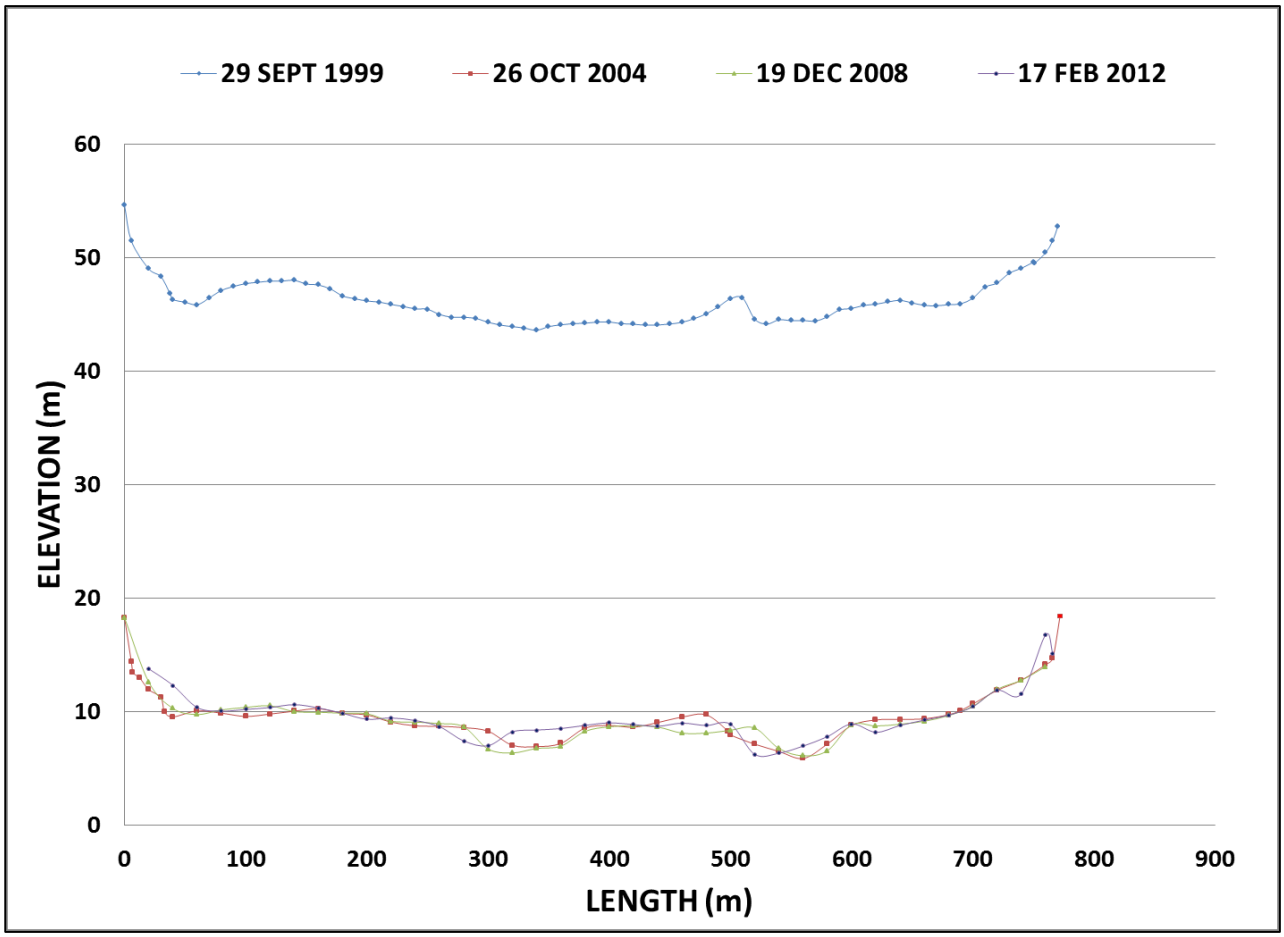


Figure 14: Comparison of Pennar river cross-section in different years at Nellore gauging station

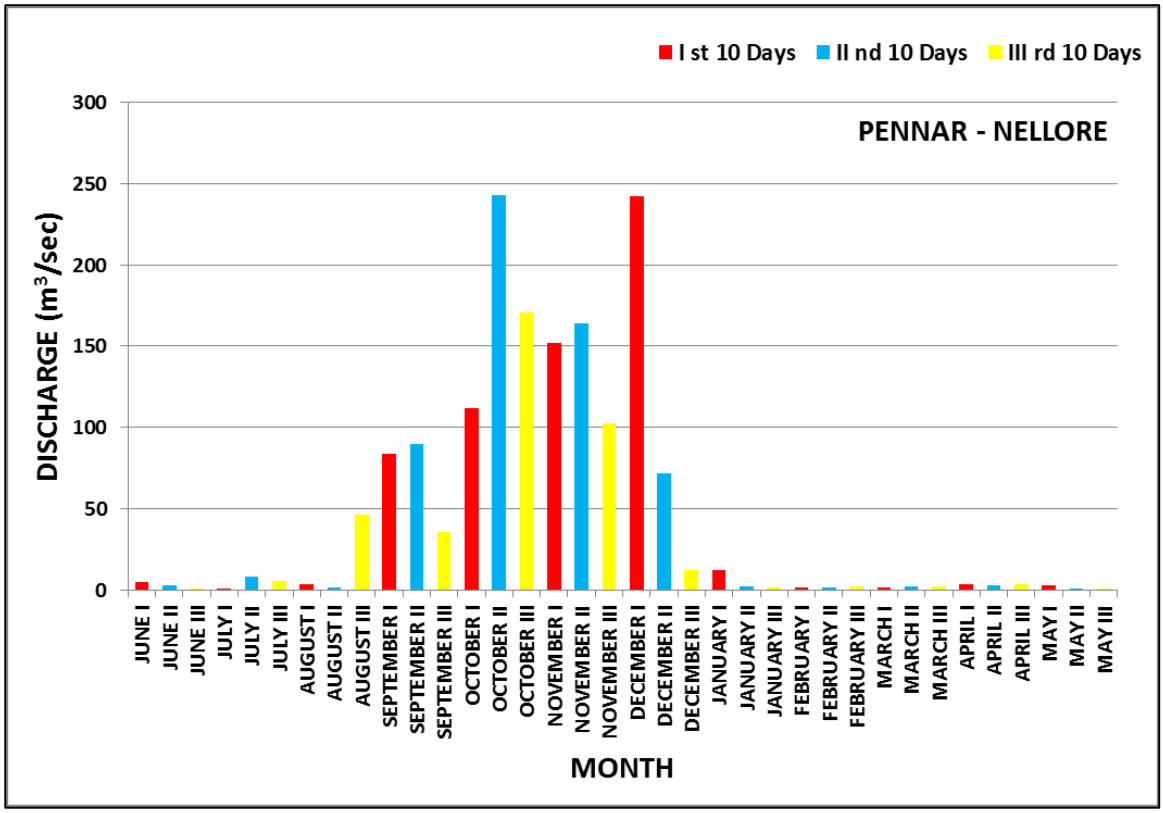


Figure 15: Average 10 daily discharges at Nellore gauging site on Pennar River

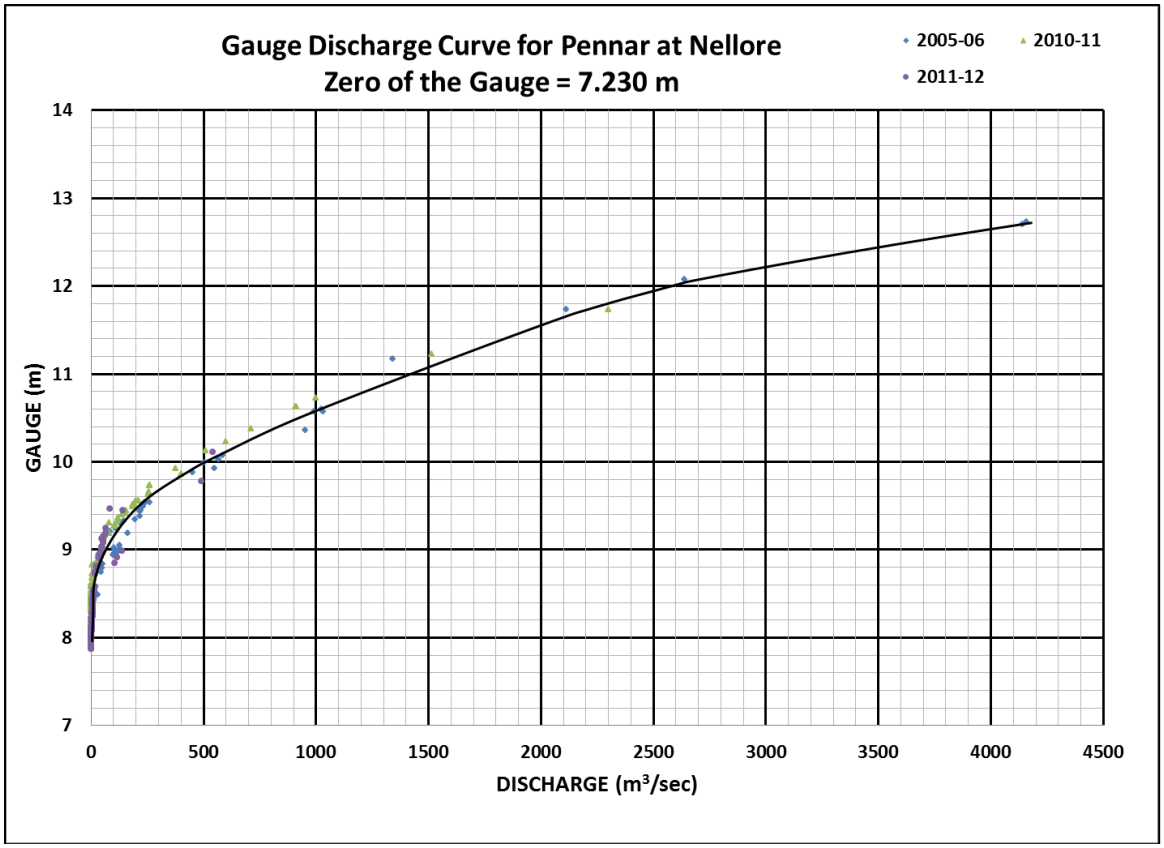


Figure 16: Gauge discharge curve for River Pennar at Nellore gauge station

YEAR	JUNE			JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER			JANUARY			FEBRUARY			MARCH			APRIL			MAY		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1987-1988	-	-	-	-	-	-	-	1.4	-	1.1	1.1	0.5	4.4	3.3	1.7	284.0	87.3	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1988-1989	0.1	0.1	0.1	0.2	0.2	0.6	0.4	7.8	1.7	1196.8	1880.7	704.9	562.1	202.1	52.5	74.3	12.3	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1989-1990	0.1	0.0	0.0	0.0	169.3	121.2	30.5	7.0	1.4	4.5	2.1	98.0	207.3	13.2	5.6	9.1	19.7	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1990-1991	0.5	0.7	0.4	1.9	1.5	0.7	0.5	2.1	3.4	4.3	2.5	0.3	0.5	2.4	101.3	144.9	34.0	481.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1991-1992	107.3	22.9	11.2	13.8	10.5	7.9	41.6	5.6	0.8	0.7	0.7	19.5	1.9	1.4	129.3	783.6	2394.5	710.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1992-1993	1.0	0.9	0.7	0.7	1.0	0.7	2.4	2.9	0.4	0.3	0.5	2.9	4.0	1.8	0.5	2.4	144.9	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1993-1994	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	28.2	42.1	7.5	125.7	476.1	23.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1994-1995	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1.5	397.4	43.1	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1995-1996	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	3.0	2.8	0.6	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1996-1997	0.1	26.2	0.3	0.2	0.2	0.2	0.2	0.2	94.0	932.1	403.1	36.9	1397.6	1224.0	2197.9	94.2	57.0	224.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.2	93.3	12.7	228.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1998-1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	642.1	1577.8	185.7	836.6	357.2	237.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1999-2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	12.7	8.1	0.5	0.0	0.0	7.7	-	-	-	-	-	-	0.0	0.0	2.3	-	-	-	-	-	-	-	-	-
2000-2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	994.6	0.0	0.0	2.3	0.0	0.0	63.3	0.0	0.0	0.5	125.9	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2001-2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	3196.6	565.1	97.4	17.8	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2002-2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.1	12.2	9.6	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2003-2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.6	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004-2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.6	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2005-2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.2	818.2	458.0	22.7	350.0	690.5	61.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-
2006-2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	12.0	14.2	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2007-2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	35.4	38.8	0.0	0.0	156.4	141.6	7.3	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008-2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.0	0.0	34.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009-2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.8	2.2	1.3	0.9	0.4	65.2	42.7	23.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010-2011	-	-	-	-	-	-	0.0	1.8	47.3	22.0	2.8	2.7	2.7	0.4	18.7	243.5	513.7	155.5	332.3	292.7	49.9	16.3	2.8	2.4	5.3	5.6	6.1	5.8	5.4	7.1	6.1	4.9	7.7	4.8	0.6	0.4
2011-2012	3.2	4.5	1.6	2.4	2.9	3.0	4.7	3.4	9.2	2.1	5.1	7.4	4.5	6.8	18.6	46.4	2.6	130.5	27.0	4.0	9.2	31.2	4.3	2.5	2.4	1.4	1.0	0.9	1.6	1.2	3.1	3.0	3.0	3.3	2.3	2.4
2012-2013	2.2	2.7	2.8	3.5	4.4	3.3	2.5	2.8	3.2	2.1	2.8	1.1	1.7	2.2	2.5	0.9	0.3	0.3	35.3	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.6	0.0	0.0	0.0	0.0	0.0
MAX.	107.3	26.2	11.2	13.8	169.3	121.2	41.6	7.8	994.6	1196.8	1880.7	704.9	1397.6	3196.6	2197.9	836.6	2394.5	710.0	690.5	292.7	49.9	31.2	4.3	2.5	5.3	5.6	6.1	5.8	5.4	7.1	6.1	4.9	7.7	4.8	2.3	2.4
MIN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
AVG.	4.8	2.5	0.7	1.0	7.9	5.8	3.4	1.4	46.3	83.8	89.9	35.4	111.8	242.9	170.9	151.9	164.2	102.4	242.2	71.8	12.3	11.9	1.8	1.3	1.6	1.4	1.9	1.7	1.8	2.2	3.3	2.6	3.6	2.7	1.0	1.0

Table 23: Mean 10 daily discharges in cumecs

4.16 Monthly minimum and maximum Water levels

The gauge-discharge data at Pennar available from 1987-2012 is analyzed in different ways. The monthly minimum and maximum water levels for the entire period of data were extracted and are tabulated below.

YEAR	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
Zero of the guage = 43.50 m																								
1987-1988	-	-	--	-	45.7	44.9	45.3	44.9	45.6	44.9	48.4	45	-	-	-	-	-	-	-	-	-	-	-	-
1988-1989	45.1	45	45.3	45	45.8	45	49.2	47	47.5	45.2	46.8	45.2	-	-	-	-	-	-	-	-	-	-	-	-
1989-1990	45.1	44.9	48.3	44.9	45.9	45.2	47.7	45.2	47.1	45.2	46	45	-	-	-	-	-	-	-	-	-	-	-	-
1990-1991	45.2	44.9	45.4	44.9	45.5	44.9	45.6	44.9	46.7	44.9	47.9	45	-	-	-	-	-	-	-	-	-	-	-	-
1991-1992	46.7	44.9	45.7	45.3	46.3	44.8	45.9	44.8	47.4	45	51.2	46	-	-	-	-	-	-	-	-	-	-	-	-
1992-1993	45.2	45.1	45.3	45	45.6	45	45.6	45	45.7	45	47	45	-	-	-	-	-	-	-	-	-	-	-	-
1993-1994	44.9	44.8	44.9	44.8	44.9	44.8	44.9	44.8	46.4	44.9	48.2	45	-	-	-	-	-	-	-	-	-	-	-	-
1994-1995	44.9	44.8	44.9	44.8	44.9	44.8	44.9	44.8	45.3	44.8	48.1	45	-	-	-	-	-	-	-	-	-	-	-	-
1995-1996	44.9	44.8	44.9	44.8	44.9	44.9	44.9	44.9	45.4	44.9	45.4	44.9	-	-	-	-	-	-	-	-	-	-	-	-
1996-1997	46.3	44.6	44.8	44.7	47.2	44.7	49.3	45.2	51.1	45.9	46.9	44.9	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	45.1	45	45.1	45.1	45.1	45.1	45.2	45.1	45.5	45.1	46.9	45.2	-	-	-	-	-	-	-	-	-	-	-	-
1998-1999	44.9	44.8	44.9	44.9	44.9	44.9	45	44.6	48.5	45.1	48.4	45.6	-	-	-	-	-	-	-	-	-	-	-	-
1999-2000	44.4	44.4	44.4	44.4	44.5	44.4	44.7	44.4	45	44.3	44.9	44.1	-	-	-	-	44.7	44.2	-	-	-	-	-	-
2000-2001	43.8	43.8	43.9	43.8	50	43.8	45.6	43.9	45.9	44.1	45.4	44.3	46.5	44.3	-	-	-	-	-	-	-	-	-	-
2001-2002	44.2	44.1	44.1	44.1	44.2	44.1	44.2	44.1	51	44.2	46.6	45.4	-	-	-	-	-	-	-	-	-	-	-	-
2002-2003	44.6	44.6	44.6	44.6	44.6	44.5	44.6	44.5	46.2	44.5	46.2	44.6	-	-	-	-	-	-	-	-	-	-	-	-
MAXIMUN	46.7	45.1	48.3	45.3	50	45.2	49.3	47	51.1	45.9	51.2	46	46.5	44.3	0	0	44.7	44.2	0	0	0	0	0	0
MINIMUM	43.8	43.8	43.9	43.8	44.2	43.8	44.2	43.9	45	44.1	44.9	44.1	46.5	44.3	0	0	44.7	44.2	0	0	0	0	0	0
Zero of the guage = 7.230 m																								
2003-2004	8.13	8.1	8.25	8.1	8.16	8.1	8.15	8.06	10	8.09	8.26	8.21	-	-	-	-	-	-	-	-	-	-	-	-
2004-2005	8.2	8.06	8.23	8.14	8.22	8.16	8.28	8.18	8.46	8.22	9.38	8.28	-	-	-	-	-	-	-	-	-	-	-	-
2005-2006	8.17	8.11	8.19	8.1	8.2	8.1	8.23	8.17	12.7	8.19	11.2	8.4	12.7	8.28	8.5	8.4	8.37	8.34	8.4	8.3	-	-	-	-
2006-2007	8.42	8.36	8.54	8.38	8.43	8.38	8.45	8.38	8.83	8.36	9.52	8.46	-	-	-	-	-	-	-	-	-	-	-	-
2007-2008	8.35	8.29	8.46	8.13	8.44	8.23	11.5	8.4	13.4	8.43	11.2	8.47	-	-	-	-	-	-	-	-	-	-	-	-
2008-2009	8.31	8.27	8.38	8.27	8.5	8.29	8.36	8.26	9.49	8.31	10.7	8.39	-	-	-	-	-	-	-	-	-	-	-	-
2009-2010	7.94	7.88	7.97	7.91	8.03	7.91	8.83	8.01	8.59	8.01	9.93	8.02	-	-	-	-	-	-	-	-	-	-	-	-
2010-2011					9.03	8.01	9.03	8.17	9.43	7.98	11.7	8.83	10.7	8.83	8.9	8.3	8.43	8.28	8.5	8.2	8.7	8	8.5	7.9
2011-2012	8.34	7.93			8.53	7.98	8.53	7.87	9.11	8.02	10.1	8.01	9.47	8.07	9.2	8	8.17	8.02	8.2	8	8.4	7.9	8.2	8
2012-2013	8.16	8.05			8.21	8.08	8.16	7.9	8.14	8.06	8.21	7.89	9.4	7.86	7.9	7.9	7.93	7.88	8.1	7.8	8.1	7.8	7.9	7.8
MAXIMUN	8.42	8.36	8.54	8.38	9.03	8.38	11.5	8.4	13.4	8.43	11.7	8.83	12.7	8.83	9.2	8.4	8.43	8.34	8.5	8.3	8.7	8	8.5	8
MINIMUM	7.94	7.88	7.97	7.91	8.03	7.91	8.15	7.87	8.14	7.98	8.21	7.89	9.4	7.86	7.9	7.9	7.93	7.88	8.1	7.8	8.1	7.8	7.9	7.8

Table 24: Monthly Minimum and Maximum Water levels

4.17 Yearly minimum and maximum Water levels

Below table shows yearly maximum and minimum water levels at Nellore gauging site.

YEAR	MINIMUM WATER LEVEL (m)	MAXIMUM WATER LEVEL (m)
Zero of the gauge = 43.50 m		
1987	44.895	48.400
1988	44.995	49.200
1989	44.895	48.265
1990	44.870	47.900
1991	44.760	51.220
1992	44.950	46.980
1993	44.810	48.180
1994	44.810	48.135
1995	44.780	45.430
1996	44.590	51.080
1997	45.000	46.870
1998	44.560	48.530
1999	44.100	44.960
2000	43.750	50.020
2001	44.120	51.000
2002	44.520	46.180
Zero of the gauge = 7.230 m		
2003	8.060	10.000
2004	8.055	9.380
2005	8.100	12.730
2006	8.305	9.520
2007	8.125	13.390
2008	8.255	10.650
2009	7.880	9.930
2010	7.840	11.730
2011	7.870	10.110
2012	7.860	9.395
2013	7.820	8.410
2014	7.850	8.320
MAXIMUN		12.730
MINIMUM	7.820	

Table 25: Yearly minimum and maximum Water Levels

4.18 Chart Datum/ Sounding Datum

As per discussion with IWAI, Chart Datum has been taken as following for different reaches

Tidal Reach:

C.D. is taken as C.D. of Chennai port from Admiralty Tide Table (ATT- Volume 3)

Non-Tidal Reach:

As per discussion with IWAI, Sounding datum in rivers is taken as Average of minimum yearly water level for Last six years (2009-14) at gauging sites for which data was available for maximum period in a year. The gauge-discharge data of CWC G.D. sites was collected from CWC. Accordingly, the C.D. at these G.D. sites has been arrived from year 1987 to 2014:

C.D. at Nellore G.D. Site = [7.880+ 7.840+ 7.870+ 7.860+ 7.820+ 7.850] / 6 = 7.853 m

River name	CD Value at the Nellore Gauge Station	Gauge Station Position	
		Latitude	Longitude
Pennar	7.853 meters above MSL at CH 28.1	14^0 28' 15" N	79^0 58' 58" E

In case of Dams/ Bridges/ Barrages/ Check Dam, the C.D. has been taken as Ponding level or MDDL.

It may be noted that during the recent floods (in 2014), Nellore anicut was damaged and a new barrage is under construction. Hence the river bed is silted up at Nellore gauge due to construction activities. Therefore the C.D. value of 9.5 m w.r.t. MSL is adopted at Nellore in place of 7.853 m.

4.19 High Flood Levels

Tidal Reach

In Tidal reach, MHWS at Chennai Port as per Admirality Tide Table (ATT-Vol 3) has been adopted as High Flood Level.

MHWS: 1.10 (w.r.t. C.D.)

MSL : 0.60 (W.r.t. C.D.)

MHWS (w.r.t. M.S.L.) : 1.10 – 0.60 = 0.50 m (w.r.t. M.S.L.)

Non-Tidal Reach

Gauge Sites: High flood levels are computed from last twenty years Gauge discharge data collected from CWC for gauge sites. The maximum water level in last twenty years from the collected data has been adopted as H.F.L.

Maximum flood discharge & HFL (during period of data) were 8673 m^3/s and 51 m respectively in October 2001. In October 2001 there was another major flood with discharge 4160 m^3/s and flood level 13.39 m (recorded with new gauge with zero at RL 7.23 m).

Frequency Analysis of yearly maximum flood data using Gumbel distribution indicate following flood discharges for different return periods.

Return Period in years	2	5	10	20	25	50	75	100	200
Discharge (m^3/s)	159	571	845	1107	1190	1446	1595	1700	1953

The 100 year return flood at Nellore is calculated as 1700 m^3/s.

4.20 Monthly minimum and maximum Discharges at Nellore

The monthly minimum and maximum discharges for the entire period of data were extracted and are tabulated below. "-" stands for Data nota available. **Zero of the gauge = 43.50 m (1987-2003)**

YEAR	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER		JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
1987-1988					2.6	0.3	2	0.1	32.6	0.1	1004	0.1	-	-	-	-	-	-	-	-	-	-	-	-
1988-1989	0.2	0.1	3.6	0.1	37.8	0.1	2726	417	795	0.4	347	0.3	-	-	-	-	-	-	-	-	-	-	-	-
1989-1990	0.1	0	1692	0	57	0.3	956	1	575	0.2	68	0.3	-	-	-	-	-	-	-	-	-	-	-	-
1990-1991	1.4	0.1	6.2	0.2	5.9	0.3	9.8	0.2	274	0.2	833	0.5	-	-	-	-	-	-	-	-	-	-	-	-
1991-1992	460	1.1	15.2	5.8	140	0.7	80	0.7	735	1.2	5789	77.9	-	-	-	-	-	-	-	-	-	-	-	-
1992-1993	1.2	0.6	1.6	0.6	10.3	0.3	10.7	0.2	17.8	0.5	437	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1993-1994	0.3	0.1	0.2	0.1	0.3	0.1	0.3	0.2	265	0.2	1422	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1994-1995	0.3	0.2	0.3	0.3	0.4	0.3	0.3	0.3	7.8	0.3	1762	0.7	-	-	-	-	-	-	-	-	-	-	-	-
1995-1996	0.4	0.2	0.5	0.3	0.5	0.4	0.5	0.4	12.6	0.4	11.4	0.4	-	-	-	-	-	-	-	-	-	-	-	-
1996-1997	247	0.1	0.3	0.2	605	0.2	2845	5.2	5363	113	467	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1997-1998	0	0	0	0	0	0	0	0	19.7	0	1.6	1.6	-	-	-	-	-	-	-	-	-	-	-	-
1998-1999	0	0	0	0	0	0	0	0	2371	14.6	2060	130	-	-	-	-	-	-	-	-	-	-	-	-
1999-2000	0	0	0	0	0	0	10.4	0	21.7	0	19.9	0	-	-	-	-	11.9	0	-	-	-	-	-	-
2000-2001	0	0	0	0	4589	0	19.7	0	224	0	5.1	0	430	0	-	-	-	-	-	-	-	-	-	-
2001-2002	0	0	0	0	0	0	0	0	8673	0	200	5.1	-	-	-	-	-	-	-	-	-	-	-	-
2002-2003	0	0	0	0	0	0	0	0	61.4	0	63.7	0	-	-	-	-	-	-	-	-	-	-	-	-
MAXIMUN	460	1.1	1692	5.8	4589	0.7	2845	417	8673	113	5789	130	430	0	0	0	11.9	0	0	0	0	0	0	0
MINIMUM	0	0	0	0	0	0	0	0	7.8	0	1.6	0	430	0	0	0	11.9	0	0	0	0	0	0	0
Zero of the gauge = 7.230 m																								
2003-2004	-	-	-	-	-	-	-	-	487	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004-2005	-	-	-	-	-	-	-	-	-	-	187	0	-	-	-	-	-	-	-	-	-	-	-	-
2005-2006	-	-	-	-	-	-	-	-	4140	0	1341	0	4159	0	-	-	-	-	-	-	-	-	-	-
2006-2007	-	-	-	-	-	-	-	-	19.4	0	142	0	-	-	-	-	-	-	-	-	-	-	-	-
2007-2008	-	-	-	-	-	-	349	0	757	0	293	0	-	-	-	-	-	-	-	-	-	-	-	-
2008-2009	-	-	-	-	-	-	-	-	58	0	202	0	-	-	-	-	-	-	-	-	-	-	-	-
2009-2010	-	-	-	-	-	-	7.7	0.4	2.9	0	412	0.1	-	-	-	-	-	-	-	-	-	-	-	-
2010-2011	-	-	-	-	55	0	52.2	2.4	150	0	2300	19	1001	20.7	42	2.4	7.7	2.4	9.2	3.9	13	1.5	11	0.4
2011-2012	8.2	0.4	5.9	0.5	12.4	0.8	12.6	0.2	55.2	1.1	541	0.9	83.4	2.2	67	1.4	4.3	1	5	0.6	9.3	0.1	4.9	0.5
2012-2013	3.4	1.4	5.2	2.6	4.6	2	3.4	0.1	3.1	1.4	4.6	0.2	147	0.2	0.3	0.2	0.3	0.2	3.2	0	3	0	0	0
2013-2014	7.9	7.82	8.29	7.88	8.13	7.85	8.41	7.85	8.19	7.98	8.28	7.89	7.91	7.89	8.32	7.9	8.07	7.93	7.93	7.89	7.89	7.85	7.88	7.87
MAXIMUM	8.2	1.4	5.9	2.6	55	2	349	2.4	4140	1.4	2300	19	4159	20.7	67	2.4	7.7	2.4	9.2	3.9	13	1.5	11	0.5
MINIMUM	3.4	0.4	5.2	0.5	4.6	0	3.4	0	2.9	0	4.6	0	83.4	0	0.3	0.2	0.3	0.2	3.2	0	3	0	0	0

Table 26: Monthly minimum and maximum Discharges in Cumecs at Nellore GD site

4.21 Yearly minimum and maximum Discharges

Below table shows yearly maximum and minimum discharges at Nellore gauging site.

YEAR	MAXIMUM DISCHARGE (m^3/sec)	MINIMUM DISCHARGE (m^3/sec)
Zero of the gauge = 43.50 m		
1987-1988	1004	0.1
1988-1989	2726	0.1
1989-1990	1692	0
1990-1991	833	0.1
1991-1992	5789	0.7
1992-1993	436.9	0.2
1993-1994	1422	0.1
1994-1995	1762	0.2
1995-1996	12.6	0.2
1996-1997	5363	0.1
1997-1998	19.7	0
1998-1999	2371	0
1999-2000	21.7	0
2000-2001	4589	0
2001-2002	8673	0
2002-2003	63.7	0
MAXIMUN	8673	0.7
MINIMUM	12.6	0
Zero of the gauge = 7.230 m		
2003-2004	486.9	0
2004-2005	186.8	0
2005-2006	4159	0
2006-2007	142.4	0
2007-2008	757.4	0
2008-2009	201.8	0
2009-2010	412.1	0
2010-2011	2300.3	0
2011-2012	540.8	0.1
2012-2013	146.6	0
MAXIMUN	4159	0.1
MINIMUM	142.4	0

Table 27: Yearly minimum and maximum Discharges at Nellore GD site

5. Preliminary Traffic studies and Market Analysis

This chapter deals with the status of land use pattern, crops, agriculture existing industries, cargo, jetties and terminals, passenger ferry services along the river route.

5.1 Land use Pattern along waterway

The resources in the basin have not been put to intensive use and the area sown more than once is very limited. The food crops usually grown in the basin are paddy, jowar and ragi. Paddy crops are predominant near Nellore region. Prawn farming is also observed in the coastal regions near river mouth.

Within Nellore, the total cropped area, at nearly 374,000 hectares, occupies the largest portion of the total geographical area. Next is net area sown (around 333,000 hectares), followed by land put to non-agricultural uses (around 306,000 hectares.) The district also has a vast forest area of roughly 271,000 hectares, followed by current fallows & other fallow lands. The district also has a lot of barren and uncultivable land at nearly 83,000 hectares. Fish and prawn culture take up a small portion (6,500 hectares) of the total land in Nellore district.

Category	Area (Ha.)
Forest	271,899
Non Agriculture	306,869
Cultivable Waste	43,879
Uncultivable Barren Land	82,857
Fish & Prawn Culture	6,538
Others	595,558
Total Area	1,307,600

Table 28: Land use Pattern of Nellore

5.2 Crops/Agriculture in the region

5.2.1 Agriculture

As of 2013-14, rice was the top crop in Nellore district. Rice cultivation took up an area of nearly 224,000 hectares and resulted in a production of more than 910,000 tonnes. The second largest crop of Nellore was sugarcane, with a production of over 817,000 tonnes. Apart from these two, the other top crops grown in the region are Fruits, Vegetables, Flowers, and Palm Oil etc.

Name of the Crop	2011-12		2012-13		2013-14	
	Area	Production	Area	Production	Area	Production
Fruits	19,865	1,070,216	20,658	1,073,805	17,807	925,794
Vegetables	254,572	1,031,426	251,269	1,026,432	224,893	911,108
Others	18,634	166,611	15,337	107,163	17,508	163,266
Flowers	19,830	92,791	20,792	100,427	22,251	98,600
Palm Oil	58,452	42,517	46,526	38,481	25,498	24,961
Maize	694	14,820	701	11,208	695	15,604
Grams & Pulses	1,426	10,222	1,437	9,666	1,917	13,064
Jowar	17,623	20,477	10,015	12,557	9,714	11,987
Amala(Usiri)	10,882	17,531	9,482	8,040	11,267	8,878

Rice	498	2,283	3,085	12,308	1,206	5,538
Bajra	653	1,552	755	2,645	1,153	4,189
Ragi	75	525	116	894	116	478
Tobacco	124	166	119	158	94	96
Total	403,328	2,471,137	380,292	2,403,784	334,119	2,183,563

Table 29: Major Crops Produced in Nellore (Area in Ha. & Production in Tonnes)

In terms of the gross area irrigated under principal crops, the gross area sown is 295, 469 hectares. Out of these, total food grains were the highest at 226,953 hectares. Within total food grains, rice is the top crop with an area of 223,049 hectares under irrigation.

Total food crops, which includes the total food grains, plus crops like sugarcane, fruits, and vegetables, saw a gross irrigated area of 268,229 hectares. Total non-food crops like cotton, groundnut, and oil seeds had a gross area irrigated of 27,240 hectares.

Gross area irrigated in Nellore is 295,469 hectares. Out of these, the largest source of irrigation is tube wells (110,535 hectares), followed by canals (99,795 hectares) and tanks (64,813 hectares). With respect to irrigation projects, the Pennar Delta system is a major irrigation source with gross actual area irrigated of 100,000 hectares.

Nellore district has 6 milk chilling centres. It also has several milk collection centres in the form of co-operative societies (150) and pick-up centres (425). The average monthly procurement of milk in the district is 27,000 litres.

5.2.2 Fisheries

In 2013-14, inland fish production in Nellore district was 73,806 tonnes. Out of these, prawns accounted for a large portion of it at 32,493 tonnes. Carps (Rohu/Catla/Mrigala) were the second largest at 30,571 tonnes. Other species like Barbus, Murrel, Catfishes, and Common Carbs, among others, contributed to the rest of the inland fish production in Nellore district.

Name of Species	Qty (Tonnes)		Value (Rs. In Lakhs)	
	2013	**2014**	**2013**	**2014**
Barbus	1,012	2,066	810	1,756
Carps (Catla / Rohu / Mrigala)	14,980	30,572	14,980	33,629
Cat Fishes	607	1,239	304	682
Common Carbs	607	1,239	364	806
Murrel	1,012	2,066	2,024	4,751
Mullets	405	826	243	496
Prawns	20,357	32,493	40,714	71,485
Hilsa	405	826	324	661
Miscellaneous	1,215	2,479	607	1,239
Total	**40,600**	**73,806**	**60,370**	**115,504**

Table 30: Inland Fish Production in Nellore

Total marine fish production, excluding shrimp, in Nellore district was over 68,000 tonnes, in 2013-14. Within these, mullets were the top fish produced at 8,340 tonnes. They were

followed by other mackarels (5,835 tonnes), skates (4,123 tonnes) and cat fish (3,865 tonnes). The production of marine shrimp in Nellore was around 10,000 tonnes.

Marine Fish Production	Qty (Tonnes)		Value (Rs. In Lakhs)	
Name of Species	**2013**	**2014**	**2013**	**2014**
Elasmobranches	10,210	10,292	7,533	7,655
Cat Fish	3,140	3,865	785	966
Clupeoids	4,776	6,943	1,179	1,720
Thread Fins	2,468	2,512	1,480	1,507
Ribbon Fish	2,345	2,480	938	992
Silver Bellies	2,736	2,815	1,915	1,970
Promferts	3,210	3,362	8,025	8,405
Mackerel	2,462	5,835	1,477	3,501
Mullets	2,243	8,340	1,346	5,004
Miscellaneous	14,689	22,286	13,220	22,286
Total	48,279	68,730	37,898	54,006
Shrimp				
a) Panaeid Shrimp	4,012	6,210	12,036	18,630
b) Non-Panaeid Shrimp	3,503	3,835	10,509	11,505
Marine Shrimp	7,515	10,045	22,545	30,135
Total	**55,794**	**78,775**	**60,443**	**84,141**

Table 31: Marine Fish Production in Nellore

Major exported items from Nellore districts are processed fish, prawns, lobsters and other sea food items, granite slabs and monuments, steel, etc. One thirds (35 no.) of the total large scale units (110 no.) are engaged in the manufacture of processed/ preserved sea foods. All of these units are concentraded along the coast of district in the hinterland of Pennar River.

5.3 Availability of Bulk / Construction Material

5.3.1 Minerals

Nellore district has abundant reserve of silica sand. Quarryring operations are carried out by Andhra Pradesh Mineral Development Corpoartion Ltd (APMDC). The corporation is having a mining lease of about 33 acres of silica sand in Varagalli, Mamidi and Chillakur areas of the district. These places are located far off from the river. Thus the river cannot move cargo to the industrial areas.

5.3.2 Coal

Sembcorp Utilities has installed a 660 MW thermal power plant in joint Venture with Gayatri Energy Ventures near Krishnapatnam Port. Pennarriver is located at a distance of about 13 km from the thermal plant. However, the port itself is at a distance of 17 km from the plant. Hence, the river cannot be used for transportation of raw material for the plant.

5.4 Existing Industries along Waterway

The industrial areas in Andhra Pradesh are located in the hinterlands far off from the ports. The industries transport their cargo via roadways to the Krishnapatnam Port. The objective of the study is to show the linkage of industrial areas located on the banks of the river in Andhra Pradesh with the ports in the state via waterways. In this section, we shall discuss the strategic location and infrastructural advantages of the ports in brief and analyze the amalgamation of river routes with these ports. Pennar River discussed in the study does not have adequate water. Hence, it has been assumed that Government would either themselves or through help of institutional investors makes necessary investments to maintain water depth of at least 2.5 m in all the rivers throughout the year.

Nellore has several industries. Out of these, the leading industries in terms of total production are edible oils, pig iron, drugs and pharmaceuticals, cotton yarn and sugar. Food products are also an important industry in Nellore. In terms of large and medium scale industries, as of 2013-14, Nellore district had 49 of them with a combined value of production at Rs. 890,265 lakhs. These large and medium scale industries employed more than 17,000 people.

There are nearly 1,400 factories registered in Nellore. Out of these food products and beverages were the maximum at 915 factories. Other leading factories were of wood and wood products (146 factories) and non-metallic mineral products (99 factories). There were 55 small scale industries in Nellore, employing nearly 1,500 people. Out of these, nearly 50%, or 27, were food and agro-based industries. They were followed by service industries (16.). There are 2 cottage industries in the Nellore district.

Commodities	Units (% shares)
Food and Agro	12.6
Engineering	12.3
Forest Products	9.86
Textile	8.9
Plastic and Rubber	5.95
Chemical	4.37
Electronics	3.01
Others	1.92

Table 32: % Shares of Manufacturing units in Nellore District

Service sector has the largest share in the total Micro and Small Enterprises (MSEs) in the district. In manufacturing sector, Food and agro based segment forms the biggest share, followed by engineering units and forest based units. Other major segments include textile based and plastic & rubber based industries. Chemical based units, electronics and other units constitute less than 10% share in the district. However, the actual output of these units in volume may vary largely as the textile based, forest based and chemical based units are volumetric in production.

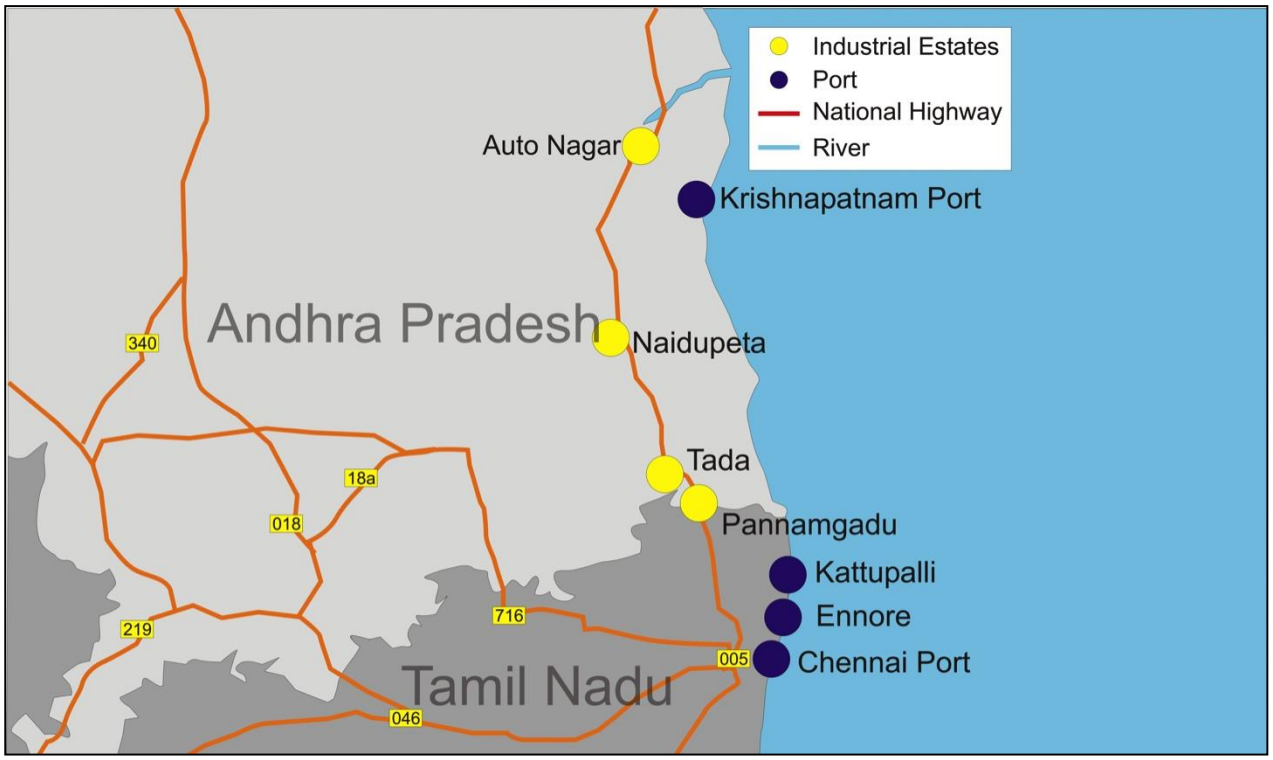


Figure 17: Port connectivity of Major Industrial Clusters via Pennar River

District	Industrial Area	Nearby Port	Distance from Industrial Area (km)			Opportunity
			To River	River - Port	Direct to Port	
Nellore	Naidupet	Krishnapatnam	73	72	60	No
	Tada	Chennai	112	210	70	No
	SEZ Naidupeta	Krishnapatnam	70	72	89	No
	Nellore	Krishnapatnam	10	75	32	May be
	Pannamgadu	Chennai	125	210	56	No

Table 33: Distance Comparison between Roadways & Waterways (Pennar River)

Pennar River flows at a distance of 38 km in the north of the port. Nellore industrial area is located at a distance of about 10 km from the river. All the other industrial area is located in the south of the district. Their distance ranges between 70 km to 130 km from the river. Pannamgadu and Tada are located on the border of the state and Chennai port is closer for them. SEZ at Naidupeta is about 70 km from the river and about 90 km from Krishnapatnam port. Hence we can say that no industrial area except that located in the city, would prefer Pennar River for its cargo movement. They will rather transport their goods directly to nearby ports.

Hence, it can be concluded that no industrial area except that located in the city, would prefer Pennar River for its cargo movement. They will rather transport their goods directly to nearby ports. Industries located near Nellore town are closer to the rivers. The waterway length from the location is more than double the road route. Following table evaluates possibility of moving Bulk commodities in huge volume might be considered for river movement to and from Krishnapatnam Port.

Commodity	Volume (mn T)	Attractive	Reasoning
Coal	29.2	No	Coal is the prominent cargo handled at Krishnapatnam Port. Majority of evacuation of Coal from Port is using railways. Krishnapatnam Port has power plant owned and operated by Reliance. Pennar River is too small and does not have any Power Plant in its vicinity. In the absence of any customer, it is not possible for evacuate imported coal from Krishnapatnam Port to Hinterland
Iron Ore	7.6	No	All the mines of Iron Ore are located in the North of Krishnapatnam Port. There is no mineral belt near Pennar river. Transporatation of Iron Ore is using Railways. Hence there does not exists any possibiilty of moving Iron Ore to Krishnapatnam Port using River.
Container	0.7	No	Small Volume of Trade and absence of hinterland in the vicinity of Pennar river restricts any possibility of container movement from Krishnapatnam to Pennar river. Moreover, containers are mostly high value and fast moving cargo, unless there is large volume with higher frequency of movement. It is not possible to commence container evacuation from Krishnapatnam port using Pennar River
Fertilizer	0.4	No	Fertiliser handled at Krishnapatnam port is mostly for retail segment. This is finished fertiliser that is directly used by farmers. Though, Pennar river has large land parcels for cultivation purpose. The volume of fertiliser consumed in the vicinity of river belt is small. Majority of Fertiliser handled in Andhra Pradesh is using Kakinada, Gangavaram and Visakhapatnam Port
Other	2.9	May Be	
Total	40.7	-	-

Table 34: Cargo distribution at Krishnapatnam Port and its possibility to shift to Pennar River

As can be seen in the above table, there does not exist any possibility of shifting cargo that is evacuated from Krishnapatnam Port to hinterland using Rail route or Road route to waterways.

5.5 Existing Jetties and Terminals (with conditions and facilities)

5.5.1 Krishnapatnam Port

Krishnapatnam port is located on the Eastern Coast of India. It lies near Krishnapatnam town of Muthukurmandal in Nellore district, of South Andhra Pradesh. It possesses a vast hinterland covering Southern Andhra Pradesh, Districts of Rayalseema, North Tamil Nadu and Eastern Karnataka. The port gains further significance with the introduction of Look East Exim Trade policy promoted by Government of India. The port mainly caters to the coal necessities of the power plants located in the eastern states of India. It handled volume more than 40 mntonnes in Fy15. Coal formed a staggering share of about 70%. Iron ore is the second major commodity attending the port. Container forms about 0.7

mntonnes of cargo. There are a large number of industries located near Nellore city. Major of them are located in Auto Nagar and Wood Complex. Pennarriver is located close to the industrial area.

State	Port	Category	Traffic ('000 T)	Draft (m)	Commodity Handled
Andhra Pradesh	Krishnapatnam	Private Port	40,741	18	Container, Edible Oil, Dry Cargo

Table 35: Traffic handled at existing Ports in FY'15

Krishnapatnam port is the only port located close to 75 km away from the mouth of the river Pennar. The penetration of river Pennar in the hinterland is very low. Hence, it is commercially less attractive to be viable. However detailed assessment on the potential is described in the later part of section. Following chart shows reasoning behind not considering smaller rivers for transportation.

5.6 Preliminary traffic identified – within 50km

As part of our study, we've had discussions with industries and locals situated around the Pennar River. All our discussions indicated that there's no traffic in the river. Following table describes, potential for cargo movement in the Pennar River of Andhra Pradesh

River	Commodity	Port	Production ('000 tonnes)	Volume ('000 Tonnes)	Reasoning
Pennar	Tourism	NA	NA	NA	Availability of draft assists in local ferry and tourism
	Ferry	NA	NA	NA	

Table 36: Potential Opportunity for Pennar River of Andhra Pradesh

Most of the consumption centers are located far away from the river. Industries would prefer transporting their goods directly to the port by roadways. No industrial areas except those, which are located near to the river, would prefer to shift their cargo on Pennar River. Due to the smaller length of Pennar River, It is not commercially attractive for industries to shift from roadways to waterways. Distance using Multimodal transportation would be closer to the movement by road or railways. Hence no saving in the distance traveled by cargo using river route is seen which discards the barge movement opportunity. Available draft of the river is good enough to plan some local ferry, tourism or fish process activities.

5.7 Existing cargo movement

Due to a lack of water, there is no existing cargo movement in the Pennar River. Water flows during the river only during monsoons, thus leaving it dry for the rest of the year. The river is now known for its rich availability of sand, making it vulnerable to sand mafia. There's a fear that the indiscriminate sand mining could completely destroy the river.

In our site visit, we had observed that there's even a road passing through the river. So apart from monsoons, the river is almost non-existent.

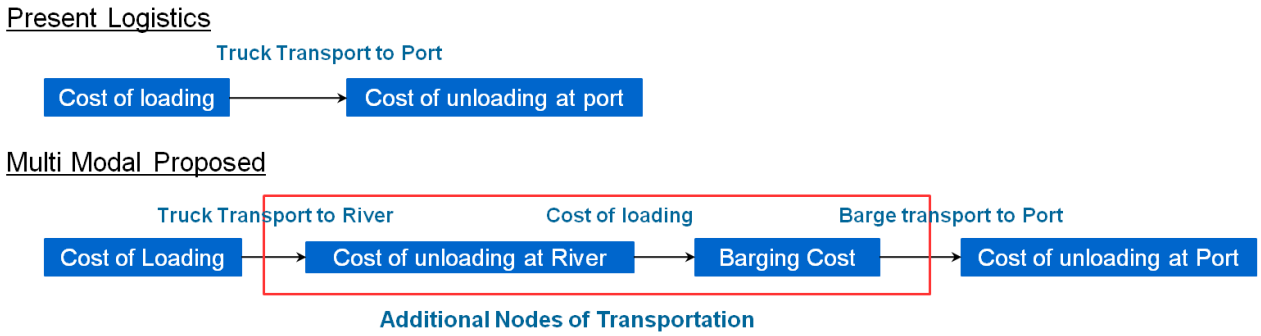


Figure 18: Present logistics and proposed Multi Modal Logistics

Shifting of trade to Pennar River from land route Multimodal logistics involves multiple handing at various nodes of transportation. Hence, a substantial share of cost saved by river route compared to land route gets offset by the multiple handing at additional nodes of transportation. Ideally, the shift is commercially viable when after shifting cargo from land route to waterways route, more than 75% of the cargo is moved using waterways and only 25% of the cargo is moved using roadways.

In the present case, due to smaller length of Pennar River, it is commercially not attractive to shift cargo to river from land route. The maximum distance travelled in the river leg would constitute about 40 km. Additional distance of about 75 km would be travelled using waterways from river mouth to Krishnapatnam Port. The total distance travel using Multimodal transportation including river would be closer to the land distance. There is no savings in the distance traveled by cargo using river route.

Road is considered to be most expensive mode of transportation with uncertainty in delivery of cargo due to congestion at Road. Hence, the potential to shift cargo from Road to Rivers would be maximum in case of road.

5.8 Prominent City / Town / Places of Worship / Historical places for Tourism

Nellore is a prominent city, which is a part of the Nellore district in Andhra Pradesh. The city is located on the banks of the Pennar River. Among all the cities in Andhra Pradesh, Nellore is the sixth most populous city. Nellore is famous for its production of mica and gold jewellery. The proximity to sea and the presence of fertile land have led to the flourishing of agriculture and aquaculture within Nellore.As per 2011 census, Nellore had a population of nearly 5.5 lacs. Nellore city is nearly 3 kilometers from Pennar river, and 20 kilometers away from Krishnapatam port.

5.8.1 Mypadu Beach

Mypadu is one of the topmost beaches in Nellore. The beach is known for its soft sands and long stretch of greenery. The beach is not very crowded. Mypadu beach is 25 kilometers away from Nellore city. The best time to visit the beach is between October and February. Mypadu beach is 9 kilometers away from the Pennar river.

5.8.2 Venkatagiri Fort

This is a popular tourist destination, located near Mypadu beach. The fort has tourists all throughout the year. Venkatagiri Fort was built in 1775 AD. Indira Mahal, the front portion

of the fort was built in 1883 AD. Apart from the fort, Venkatagiri town is known for its cotton sarees, weaved in Jamdari style. The fort is 72 kilometers from Pennar River.

5.8.3 Sri Ranganathaswamy Temple

Located on the banks of the Pennar river is the world famous, Sri Ranganathaswamy Temple. This ancient temple was built in around the 12th century. The temple is dedicated to Lord Vishnu, who is considered as 'Sri Rangam' in Andhra Pradesh. The temple has huge walls and doors. Its main entrance is 29 meters tall and features seven gold kalassams. Sri Ranganathaswamy Temple is less than 1 kilometers from Pennar river.

5.8.4 Sri Kalahasteeswara Swami Temple

It is one of the popular Shiva temples in South India. Sri Kalahasteeswara Swami Temple is dedicated to Lord Vayu, believed to be an incarnation of Lord Shiva. The temple was built in the 12th century by the Vijayanagara and Chola kings. Sri Kalahasteeswara Swami Temple is 92 kilometers from Pennar River.

5.8.5 Pulicat Lake

It is the second largest lake of brackish water in India. The area of the lake varies from 250 sq. kilometers (low tide) to 450 sq. kilometers (high tide). The lake has a rich diversity of flora and fauna. The lake also covers the Pulicat Lake Bird Sanctuary.

Each year, thousands of migratory birds can be seen at Pulicat, between October and March. Of these birds, the major attractions are flamingos. Nearly 15,000 flamingos visit Pulicat each year. At the start of January, a flamingo festival is organized at Pulicat. Apart from flamingos, other birds which can be seen here are ducks, herons, cranes and painted storks. Pulicat Lake is situated 115 kilometers from Pennar River.

5.8.6 Jonnawada

Jonnawada is a famous pilgrimage spot. The place has shrines dedicated to Goddess Kamakshi and Sri Mallikarjuna Swamy. The place has two Kamakshi temples, out of which one was made in the 12th century. In the Telugu month of Vaisaka, Brahmotsavam festival is celebrated here. During this time, lakhs of visitors come to this place to worship Goddess Kamakshi and attain salvation. Jonnawada is only 10 kilometers away from Pennar River.

5.8.7 Nellapattu Bird Sanctuary

This popular bird sanctuary attracts migratory birds from across the globe. During migratory season, you can find more than 1,500 pelicans. Some of the rare species found here are spoonbills, night herons, egrets, and ducks, among others. The sanctuary also has a museum, a library and an auditorium. From Pennar River, the sanctuary is 78 kilometers away.

5.8.8 Irukkam Island

The island is situated in the middle of Pulicat Lake. The island is accessible only by boat. Given the enormous potential for tourism at the island, it has been identified by the government as one of the top priority destinations for attracting visitors. Also, in the

vicinity of the island, industrial areas with special economic zones such as Apache and Sri City are coming up. The distance between Irukkam island and Pennar is 115 kilometers.

5.8.9 Penchalakona Temple & Waterfall

This is a very ancient pilgrim centre. One of the highlights of the temple is the annual festival, held during the month of May and April. The place is 70 kilometers away from Nellore city. There's also a waterfall at Penchalakona, which is the origination of Kandeleru River. Penchalakona is 60 kilometers from Pennar River.

5.8.10 Sriharikota

It is a barrier island which separates Pulicat lake from the Bay of Bengal. Sriharikotahouses the Satish Dhawan Space Centre. The satellite launch center is used by ISRO for launching satellites using multispace rockets. Sriharikota is at a distance of 100 kilometes from Pennar River.

5.8.11 Somasila Dam

This is one of the largest irrigation projects in the Nellore district, constructed across River Pennar. The project is based near Somasila village of Nellore district. There's also a temple in the village, known as Someswara Temple. An Ashram is situated on the other side of the River Pennar. The place is seeing an increase in tourist population. The distance between Pennar river and Somasila is 78 kilometers.

5.9 Availability of Passenger Ferry Services

5.9.1 Irukkam Island - Bimuni vari palem

Irukkam island, being located in the middle of Pulicat lake, can be accessed only by ferry. The ferry leaves from Bimuni vari palem jetty. It's a 14 kilometer boat ride. The ferry makes two trips a day. Private ferry services can be arranged for at other times of the day.

In 2016, the Zilla Parishad of Nellore announced two ferries for 150 students going to school from Irukkam Island.

5.9.2 Nellore to Kollam Karumadi

A ferry leaves from Nellore to Kollam Karumadi, Kerala. The travel time is roughly 19 hours to cover a distance of 926 kilometers.

5.10 Available and probable Water Sport Recreational Facilities

Mypadu beach offers watersports like jet skis and aquatic motorbikes. Jet Ski rides are charged at Rs. 250 for 3-4 minutes per person. Some private resorts near the Pulicat Lake offer water sports activities like boating and jet skiing.

6. Observations, Inferences and Conclusions

6.1 Waterway

The total length of the river under present studies is detailed below:

29 km length of the river from Penna Barrage, Pothireddypalem to confluence with Bay of Bengal near Kudithipalem	**From: 14°28'8.38"N, 79°59'9.31"E**	**Up to: 14°35'36.75"N, 80°11'30.61"E**

6.2 Length

The length of waterway under present studies under consideration is 29 km.

6.3 LAD

	Stretch (KM)					
LAD(m)	**0-9.04**	**9.04-15**	**15-20**	**20-25**	**25-29**	**Total**
<1.0	5.70	5.99	4.11	4.60	2.78	23.18
1.0-1.2	0.61	0.00	0.24	0.30	0.19	1.35
1.2-1.4	0.63	0.00	0.29	0.16	0.21	1.29
1.4-1.7	0.60	0.00	0.16	0.00	0.27	1.03
1.7- 2.0	0.69	0.00	0.10	0.00	0.00	0.79
> 2.0	0.80	0.00	0.08	0.00	0.00	0.88

6.4 Cross-Structures

There are 4 no's bridges (at Chainage 25.93, 28.13, 28.23 & 28.94 km) and two H.T. lines (at chainage 22.38 and 28.05 km) crossing Pennar River. It can be observed that from 0 to 28.13 km, there is no obstruction to waterway as there is only one bridge having HC = 35m and one H.T. line with HC = 150 m. Nellore bridge exists at Ch 28.13 km where HC = 15m.

6.5 Water availability

Results of analysis of data for assessing period of availability (% days in year) for different discharge ranges is presented in Table 37. Percentage of days in year for availability of discharge at this gauge site in excess of certain values is presented on a plot in figure 22. These results indicate following:

Sr	Discharge (m^3/s) in excess of	Availability period in % days in year	Estimated depth from gauge and river cross section
1	**10 (m^3/s)**	**15 %**	**1.40 m**
2	**20 (m^3/s)**	**12.5 %**	**1.50 m**
3	**40 (m^3/s)**	**10 %**	**1.70 m**

Table 37: Water availability in Pennar River

The table 37 shows that discharge in excess of 10 cumecs occurs only for 15 % of days in a year. Similarly, discharges in excess of 20 cumecs and 40 cumecs occurs only for 12.5 % and 10% of days in a year respectively. The estimated depths for 10, 20 and 40 cumecs are also shown in the above table 37. Table 38 shows the breakup of discharges in a particular

year from 1987 to 2013. It shows a range of discharge eg. 5-10 occurring for a no. of days in a particular year. As the data is not available for whole year, Total no of days for some years does not add up to 365.

No of Days / Years	Range of Discharge (m^3/s)													
	0 to 1	1 to 2	2 to 3	3 to 5	5 to 10	10 - 20	20 - 40	40 - 80	80 - 100	100-300	300-500	500- 1000	1000- 5000	5000- 9000
1987	35	28	1	0	5	6	4	3	3	6	3	0	1	0
1988	95	2	6	4	8	2	5	3	6	8	12	13	19	0
1989	72	20	10	22	19	8	9	7	1	10	1	3	1	0
1990	94	19	14	12	15	2	3	4	1	11	0	8	0	0
1991	33	27	5	8	21	36	9	7	3	8	7	8	8	3
1992	141	12	2	6	8	4	1	4	0	3	2	0	0	0
1993	140	0	1	1	1	8	12	5	0	7	5	1	2	0
1994	151	4	6	5	2	0	1	1	2	9	0	0	2	0
1995	174	0	3	2	2	2	0	0	0	0	0	0	0	0
1996	90	2	1	0	5	1	2	10	15	21	12	7	15	2
1997	142	10	4	3	5	6	0	0	2	7	2	2	0	0
1998	122	0	0	0	0	1	4	0	0	18	12	16	10	0
1999	151	0	0	3	19	9	1	0	0	0	0	0	0	0
2000	213	1	3	3	5	4	1	0	1	4	4	1	3	0
2001	133	1	0	0	16	5	2	3	2	6	8	2	1	4
2002	169	0	0	1	0	5	3	5	0	0	0	0	0	0
2003	177	0	0	1	0	2	0	1	0	1	1	0	0	0
2004	178	0	1	0	1	1	1	0	0	1	0	0	0	0
2005	160	1	1	1	1	3	4	7	2	20	1	6	7	0
2006	265	0	0	0	1	1	3	2	0	1	0	0	0	0
2007	139	2	1	7	9	1	6	5	1	9	1	2	0	0
2008	173	0	0	0	4	2	1	1	0	2	0	0	0	0
2009	128	10	11	5	4	15	4	3	0	2	1	0	0	0

No of Days / Years	Range of Discharge (m^3/s)													
	0 to 1	1 to 2	2 to 3	3 to 5	5 to 10	10 - 20	20 - 40	40 - 80	80 - 100	100-300	300-500	500- 1000	1000- 5000	5000- 9000
2010	34	0	34	1	1	6	12	17	2	31	3	5	3	0
2011	54	27	42	70	124	25	8	8	1	4	1	1	0	0
2012	100	76	99	67	13	2	2	4	2	1	0	0	0	0
2013	148	0	2	1	0	0	0	0	0	0	0	0	0	0
N	3511	242	247	223	289	157	98	100	44	190	76	75	72	9
ƐN	5333													
% occurrence	65.84%	4.54%	4.63%	4.18%	5.42%	2.94%	1.84%	1.88%	0.83%	3.56%	1.43%	1.41%	1.35%	0.17%

Table 38: Availability for days for discharge in different range at Nellore gauge station on Pennar River

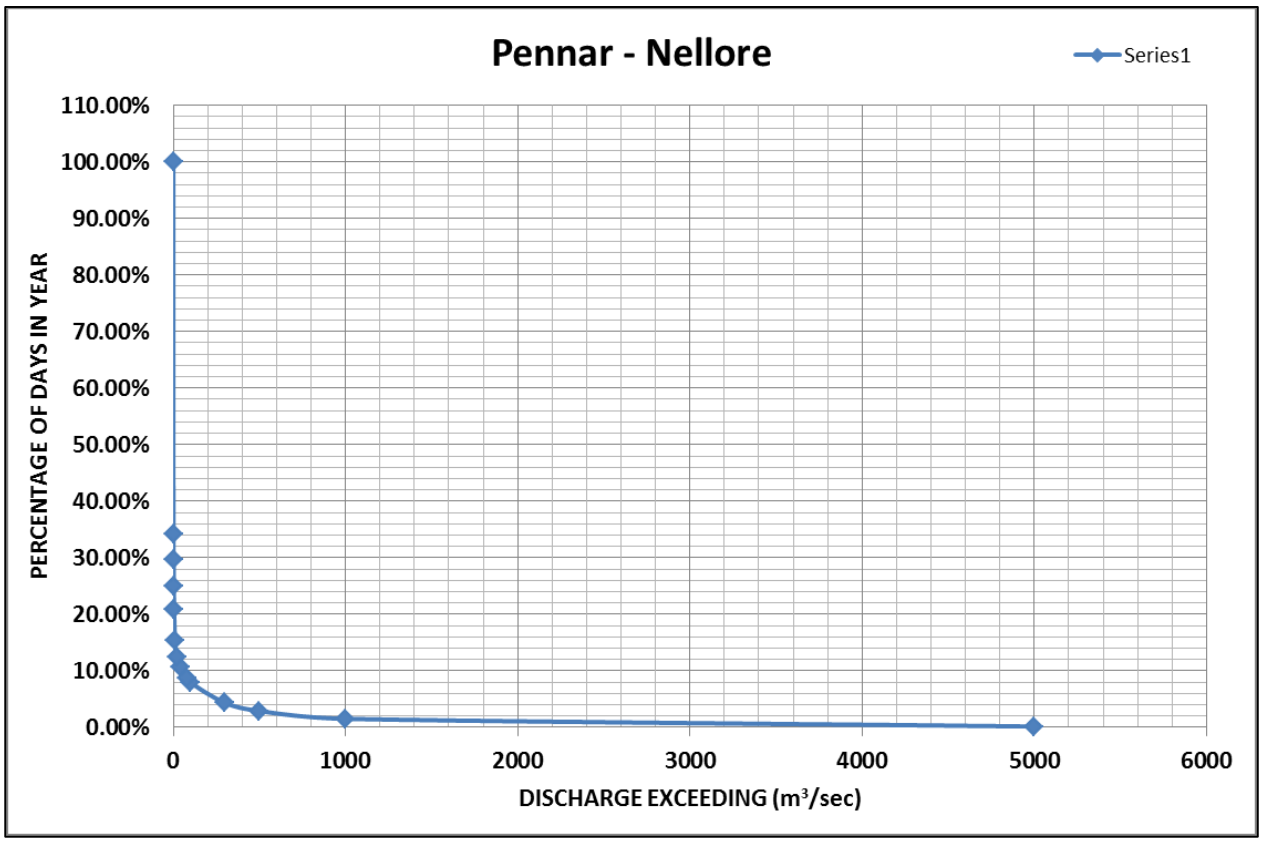


Figure 19: Period of exceedance of discharge in percentage of days in year for Pennar River at Nellore gauging station

6.6 Cargo / Passenger / Tourism / Ro-Ro Facility

As can be seen in para 5.4, there does not exist any possibility of shifting cargo that is evacuated from nearby Krishnapatnam Port to hinterland using Rail route or Road route to waterways. There does not exist any possibility of shifting cargo (Coal, Iron ore, fertilizers and container evacuated from Krishnapatnam Port) using Rail route or Road route to waterways.

Passenger facility can be provided in the Tidal zone of 9.04 km connecting the nearby towns namely utukuru, Kudithipalem, Ramudupalem, Mudivarthipalem, Nidimusali and Annareddypalem on both the banks. There is no existing Ro-Ro facility in the reach of 29 km but it can be provided in the tidal reach of 9 km from river mouth.

6.7 Classification of waterway: Suitable for Navigation

6.7.1 0-9.04 km

The Tidal reach of the river is 9.04 km. The minimum and maximum depth w.r.t. C.D. in tidal reach during the period of survey is -0.2m and is 3.1 m respectively. Further there are no cross-structures in this stretch. Local prawn farming is also observed all along the river bank. **Hence this stretch of 9.04 km is feasible for navigation throughout the year (365 days). The waterway of Class I/II may be considered at the present situation with some dredging. The details can be established after detailed survey in Stage –II.**

6.7.2 9.04-29 km

From table 28, it could be seen that depths of the order of 1.4 m will prevail in Pennar river reach downstream of Penna Barrage for period of 45 to 50 days in a year when discharge will exceed 10 m^3/s. To increase navigation period in this reach advantage of tidal reach of about 9 km could be taken along with some dredging. **This needs further investigations and mathematical model studies which require cross-section survey in Stage 2.**

It can be seen that Kaveli Bridge having HC of 35 m exists at chainage 26 km. and Nellore Bridge having HC of 15 m exist at chainage 28 km. Hence, Class I navigation with Width of 30 m can be developed for chainage **9.04 km to 29 km** without any expenditure for Infrastructure modification.

6.8 Proposed alternative methods for making waterway feasible

Penna Barrage is under construction at Chainage 29 km. The entire 29 km stretch can be made feasible by raising the water level at Barrage site and also by dredging downstream of Penna Barrage. The details of water release from Penna Barrage and provision of navigational lock may be studied in stage II.

6.9 SWOT Analysis

Strength:	Weakness
• Availability of water round the year (365 days) due to Tidal reach (0-9.04 km) • No cross-structures, therefore no need of Infrastructure measures (for 0-9.04km and 9.04 -29 km) • With some dredging, reach of 9.04 km – 29 km reach can be developed for class I navigation round the year (365 days). • Prawn Farming is predominant near banks in 9.04 km length. • Minimal capital dredging for 0-9.04 km length and little dredging for 9.04-29 km length	• No major Cargo • Nearest port is Krishnapatnam (60 km away)
Opportunities Possibility of Tourism and local ferry services Prawn farming is predominant along the tidal length of of 9.04 km	**Threats** **Closing of river mouth due to littoral drift along east coast**

6.10 Recommendation for going into Stage II

The Tidal reach of 9.04 km is feasible for navigation for 365 days (whole year) with marginal dredging.

Penna Barrage is under construction at Chainage 29 km. The 9.04-29 km stretch can be made feasible for navigation by dredging and using the releases of penna Barrage after construction. The details can be worked out in stage II studies after detailed survey.

Annexure 1: Soil characteristics

Chainage (km)	Texture
0 – 5 km	CLAY
5 – 9.04 km	CLAY
9.04 – 15 km	SAND mixed with clay
15 – 20 km	SAND mixed with clay
20 – 25 km	SAND mixed with clay
25 – 29 km	SAND mixed with clay

Annexure 1: Soil Characteristics

Sl No.	Chainage (Km)	Max Water Level obs.	Min. Water Level obs.	Utility/ Pipelines		Historical & tourist places		Bridges with VC & HC		H.T./ Electric Line		Permanent Structures		Bank Condition	Critical/ Not approachable Areas		Local Name	Dams		HFL/ Gauge stn. details		Types of Crops & Industry	Ferry/ Prominent Towns City/ Jetty/ Terminal	Remarks	Other Details
				Name	Position	Name	Position	Name	Position	VC HC	Position	Details	Position		Details	Position			Position		Position					
1	0	4 m (Raw water Depth)	0.8 m (Raw water Depth)	-	-	-	-	-	-	-	-	-	-	Natural	-	-	Pennar	-	-	-	-	Paddy, Sugarcane, Watermelon	Ferry operates in 2-3 Km length from River mouth	River Mouth approximately closed by littoral drift, only small creek is open	Water in patches in river bed, Sea-Shore,
2	2.1			-	-	-	-	-	-	-	-	Buckingham canal mouth (broken structure)	14°34'09.04"N 80°10'23.14"E	Natural	-	-		-	-	-	-			Water, Bushes & Trees on both Banks, Prawn farming is observed in the entire right bank upto 5 km length along right bank	Damaged gates and locks of Buckingham canal
3	23.23	1.2 m (Raw water Depth)	0.4 m (Raw water Depth)	-	-	-	-	-	-	High Tension Line, VC= 8m, HC= 150m	14°29'06.15"N 80°02'00.21"E	-	-	Protected	-	-		-	-	-	-		Nellore	-	-
4	25.93			-	-	-	-	Kavali Road Bridge (Two adjacent bridges, 10 m east), VC=6m, HC=35m	14°28'21.24"N 80°00'41.80"E	-	-	-	-	Protected	-	-		-	-	HFL is shown on the first pillar of the bridge, from Southern end. (Photo attached). HFL value = 12.7m	14°28'25.86"N, 80°00'39.11"E			Dry sandy bed & Vegetation on both sides of bridge, A small creek at one end of bridge	10.5m (7.5+1.5+1.5) wide Guntur-Chennai National Highway
5	28.13			-	-	-	-	Nellore Road Bridge, VC=10m, HC=15m	14°28'06.65"N 79°59'27.43"E	-	-	-	-	Protected	-	-		-	-	-	-			Bushes in River bed. Water flowing in small stream	Penna Road Bridge 57 (Bellary Nellore Road) 10.5m wide
6	28.23			-	-	-	-	Railway Bridge (2 adjacent bridges), VC= 8m, HC= 15m	14°28'06.53"N 79°59'24.50"E	-	-	-	-	Good	-	-		-	-	-	-			Bushes in River bed. Water flowing in small stream	Penna Railway Bridge
7	28.94			-	-	-	-	Dismantled Old Bridge over Dismantaled Nellore Anicut	14°28'04.74"N 79°59'10.45"E	-	-	-	-	Good				-	-	-	-			Dismantled Nellore Anicut system, sand bags	Pennar Old Bridge over nellore anicut
8	28.97			-	-	-	-	-	-	High Tension Line, VC= 8m, HC= 250m	14°28'15.71"N, 79°59'02.34"E	-	-	Good	-	-		-	-	-	-			-	-
9	29.00			-	-	-	-	Pennar Barrage, (Under Construction) VC=10m, HC=10m	14°28'19.36"N 79°58'57.47"E	-	-	-	-	Good	-	-		-	-	-	-			Barrage under construction	Pennar Barrage (Under Construction)

Annexure 2: Inventory of structures across Pennar River

Annexure 3: Photographs of structures across Pennar River

Annexure 3: Photographs

1: Pennar River Mouth

2: Buckingham Canal offtaking from Pennar River at chainage 2.1 km

3: Ferries operating in Pennar river stretch in Tidal reach (0-9.5 km)

4: Ponds along River Banks (Prawn Farming)

5: Guntur-Chennai National Highway-5 at chainage 25.93 km

6: Guntur-Chennai National Highway-5 at chainage 25.93

7: Penna Road Bridge 57 (Bellary Nellore Road) at chainage 28.13km

8: Penna Road Bridge 57 (Bellary Nellore Road) at chainage 28.13 km

9: Penna Railway Bridge at chainage 28.23 km

10: Penna Railway Bridge at chainage 28.23 km

11: Dismantled Nellore Anicut at chainage 28.94 km

12: Dismantled Nellore Anicut at chainage 28.94 km

13: Pennar Barrage under Construction at chainage 29 km

14: Pennar Barrage under Construction at chainage 29 km

Annexure 4: Source Data table for *Figure 11: Riverbed profile from the end of tidal influence (Kp 9.04) till the end of 29 Km stretch.*

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
9.125	0.48	0.60	1.00
9.207	0.47	0.64	1.12
9.324	0.53	0.70	1.28
9.424	0.58	0.75	1.43
9.500	0.59	0.79	1.53
9.577	0.61	0.83	1.64
9.657	0.64	0.87	1.76
9.730	0.64	0.91	1.86
9.806	0.65	0.94	1.97
9.882	0.67	0.98	2.08
9.941	0.71	1.01	2.16
10.021	0.73	1.05	2.28
10.110	0.74	1.10	2.40
10.190	0.76	1.14	2.52
10.285	0.77	1.19	2.65
10.381	0.80	1.23	2.79
10.476	0.81	1.28	2.92
10.571	0.82	1.33	3.06
10.677	0.84	1.38	3.21
10.775	0.85	1.43	3.35
10.851	0.87	1.47	3.46
10.945	0.89	1.52	3.59
11.010	0.90	1.55	3.68
11.087	0.95	1.59	3.79
11.174	0.93	1.63	3.92
11.236	0.95	1.67	4.01
11.247	1.04	1.67	4.02
11.272	1.25	1.68	4.06
11.363	1.22	1.73	4.19
11.453	1.31	1.77	4.32
11.539	1.45	1.82	4.44
11.631	1.48	1.86	4.57
11.711	1.66	1.90	4.68
11.723	1.90	1.91	4.70
11.823	2.09	1.96	4.84
11.923	2.30	2.01	4.98
12.018	2.55	2.06	5.12
12.118	2.73	2.11	5.26
12.217	2.94	2.16	5.40
12.300	3.25	2.20	5.52

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
12.398	3.37	2.25	5.66
12.496	3.58	2.30	5.80
12.555	4.32	2.33	5.83
12.584	4.04	2.35	5.84
12.684	4.07	2.40	5.89
12.784	4.45	2.45	5.94
12.884	4.13	2.50	5.99
12.983	4.16	2.55	6.03
13.083	4.19	2.60	6.08
13.183	4.56	2.65	6.13
13.283	4.25	2.70	6.18
13.384	4.28	2.75	6.23
13.484	4.55	2.80	6.28
13.582	4.34	2.85	6.32
13.629	4.40	2.87	6.35
13.681	4.50	2.90	6.37
13.780	4.56	2.95	6.42
13.897	4.55	3.01	6.47
13.996	4.50	3.06	6.52
14.096	4.50	3.11	6.57
14.206	4.50	3.16	6.62
14.305	4.45	3.21	6.67
14.405	4.25	3.26	6.72
14.510	4.50	3.32	6.77
14.512	5.46	3.32	6.77
14.610	5.48	3.37	6.82
14.710	5.50	3.42	6.87
14.799	5.51	3.46	6.91
14.899	5.53	3.51	6.96
14.999	5.55	3.56	7.01
15.110	5.57	3.62	7.06
15.210	5.59	3.67	7.11
15.323	5.61	3.73	7.16
15.422	5.62	3.78	7.21
15.521	5.64	3.83	7.26
15.628	5.66	3.88	7.31
15.726	5.68	3.93	7.36
15.840	5.70	3.99	7.41
15.936	5.72	4.04	7.46
16.028	5.73	4.08	7.50
16.103	5.77	4.12	7.54
16.120	5.75	4.13	7.54
16.217	5.74	4.18	7.59

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
16.314	5.72	4.23	7.64
16.410	5.71	4.28	7.68
16.507	5.69	4.32	7.73
16.609	5.68	4.38	7.78
16.707	5.66	4.43	7.83
16.810	5.64	4.48	7.88
16.908	5.63	4.53	7.92
17.007	5.61	4.58	7.97
17.114	5.60	4.63	8.02
17.220	5.58	4.68	8.07
17.320	5.57	4.73	8.12
17.384	5.55	4.77	8.15
17.413	5.48	4.78	8.17
17.509	5.41	4.83	8.21
17.606	5.34	4.88	8.26
17.659	5.27	4.91	8.29
17.755	5.20	4.95	8.33
17.823	5.13	4.99	8.36
17.980	5.05	5.07	8.44
18.067	4.98	5.11	8.48
18.365	4.91	5.26	8.63
18.511	4.84	5.34	8.70
18.757	4.77	5.46	8.81
18.837	4.63	5.50	8.85
18.837	4.30	5.50	8.85
18.965	4.98	5.60	8.91
19.116	4.65	5.71	8.99
19.206	4.32	5.78	9.03
19.296	5.00	5.85	9.07
19.397	4.67	5.93	9.12
19.466	4.34	5.98	9.16
19.534	5.01	6.04	9.19
19.593	5.36	6.08	9.22
19.616	5.09	6.10	9.23
19.708	4.82	6.17	9.27
19.805	4.54	6.25	9.32
19.888	4.27	6.31	9.36
19.984	5.00	6.38	9.41
20.083	5.73	6.46	9.45
20.191	5.45	6.54	9.50
20.210	5.91	6.56	9.51
20.277	5.61	6.61	9.55
20.379	6.32	6.69	9.60

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
20.469	6.02	6.76	9.64
20.568	6.72	6.83	9.69
20.663	7.43	6.91	9.73
20.755	7.13	6.98	9.78
20.866	6.83	7.06	9.83
20.967	6.53	7.14	9.88
21.077	6.24	7.23	9.93
21.145	5.94	7.28	9.96
21.171	6.39	7.30	9.98
21.280	6.84	7.33	10.03
21.404	7.29	7.37	10.09
21.514	7.74	7.41	10.14
21.605	8.19	7.43	10.19
21.701	8.64	7.46	10.23
21.805	8.09	7.50	10.28
21.905	7.54	7.53	10.33
22.008	7.99	7.56	10.38
22.106	7.44	7.59	10.43
22.203	7.89	7.62	10.47
22.307	8.34	7.65	10.52
22.383	8.24	7.68	10.56
22.405	8.02	7.68	10.57
22.503	7.79	7.71	10.62
22.604	7.87	7.74	10.67
22.702	7.44	7.77	10.71
22.806	7.92	7.81	10.76
22.904	7.39	7.84	10.81
23.004	6.97	7.87	10.86
23.010	7.22	7.87	10.86
23.105	7.57	7.90	10.91
23.205	7.71	7.93	10.96
23.305	7.46	7.96	11.00
23.404	7.21	7.99	11.05
23.505	7.56	8.02	11.10
23.568	7.45	8.04	11.13
23.605	7.40	8.06	11.15
23.705	7.55	8.09	11.20
23.805	7.30	8.12	11.24
23.905	7.25	8.15	11.29
24.005	7.39	8.18	11.34
24.104	7.14	8.21	11.39
24.202	7.52	8.24	11.44
24.222	7.99	8.25	11.45

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
24.295	8.05	8.27	11.48
24.386	8.20	8.30	11.52
24.508	7.95	8.34	11.58
24.609	7.56	8.37	11.63
24.703	7.38	8.40	11.68
24.810	7.49	8.43	11.73
24.957	7.56	8.47	11.80
25.044	7.86	8.50	11.84
25.134	7.76	8.53	11.88
25.143	7.37	8.53	11.89
25.208	7.02	8.55	11.92
25.319	6.91	8.59	11.97
25.416	7.21	8.62	12.02
25.530	7.42	8.65	12.07
25.624	7.37	8.68	12.12
25.728	7.69	8.71	12.17
25.837	7.93	8.75	12.22
25.893	7.82	8.77	12.25
25.931	8.21	8.78	12.27
26.026	8.62	8.81	12.31
26.149	8.52	8.84	12.37
26.267	8.43	8.88	12.43
26.366	8.33	8.91	12.48
26.466	8.23	8.94	12.53
26.564	8.14	8.97	12.57
26.649	8.04	9.00	12.61
26.725	7.85	9.02	12.65
26.760	8.21	9.03	12.67
26.859	8.57	9.06	12.71
26.978	8.93	9.10	12.77
27.076	9.29	9.13	12.82
27.177	9.65	9.16	12.87
27.276	10.01	9.19	12.92
27.373	9.95	9.22	12.96
27.473	9.87	9.26	13.01
27.572	10.12	9.29	13.06
27.686	9.98	9.32	13.11
27.794	9.72	9.35	13.16
27.884	9.29	9.38	13.21
27.934	9.60	9.40	13.23
27.970	9.82	9.41	13.25
28.024	10.07	9.43	13.28
28.045	9.93	9.43	13.29

Annexure 4			
Chainage (km)	River Bed Level w.r.t MSL (m)	Adopted C.D. w.r.t. M.S.L.	HFL w.r.t. M.S.L.
28.104	9.77	9.45	13.31
28.203	9.87	9.48	13.36
28.262	9.92	9.50	13.39