Design of a sustainable flood carrier system in Cuddalore of Tamilnadu

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Abstract. Cuddalore district is located along the south west coast of Indian in the state of Tamilnadu bordering bay of Bengal. The district is blessed with presence of wetlands, minor port and beach. The annual rainfall of the place is about 1300 mm. The district receives 70% of rainfall during north east monsoon from October to December. Agriculture is the main occupation. The rainfall along the coast is higher compared to upper regions. The high intensity rainfall occurrence is a common one. The district has anciently constructed hydraulic structures for conserving water called tanks. Perumal tank is the last source. The entire flood water during rainy season flows through a drain called Paravanar. This runs almost parallel to the coast for about 18km and finally merges with Bay of Bengal. Because of length and shallow slope, it takes more time for the water to recede. Hence a new canal was designed to drain some water directly into the sea. HECRAS numerical model was adopted to study canal performance. The details of hydraulic studies and coastal sediment transport computations are highlighted.

Introduction
The district of Cuddalore is located along 78°45'E and 11°15'N coordinates along the south west coast of India in Tamilnadu state. The sea of Bay of Bengal is bordering the district on its east side. The river Pennar is draining in the sea along the north side and river Vellar is confluencing at the south side. Apart from this another drain called Paravanar river is also draining in the sea in between Pennar (Fig 1). Cuddalore is a low lying area and highly flood prone as described by Evany Nithya and Priyanka(2019).

Hydrology of Paravanar
The river is drain carrying the rainwater during floods. The drain commences from surplus portion of the existing Perumal tank. The river takes a crescent like plan shape at a place called Aruvamukku and then flows for a distance of about 18km and finally confluences with Bay of Bengal at Cuddalore port. The average slope of the river is 1 in 3000. The annual rainfall of the district is about 1300mm. Number of effective rainfall days are around 30 in a year. Nearly 60% of the rainfall occur during north east monsoon period from October to December. Out of this it is common to have high intensity rainfall based on studies of Sandeep and Jegankumar (2018) which results in drainage problem. Moreover, due to very shallow slope the drainage process is getting more delayed (Fig 2 to 4).
Figure 1. Index map

Figure 2. Details of Paravanar

Figure 3. Aruvamukku location
The district of Cuddalore is generally a low lying one. The slope of river Paravanar is very shallow. The place is highly flood prone especially during north east monsoon. So this drain because of its geometry takes a long time for complete drainage of flood water. This in turn results in heavy water logging as observed by Yovan Felix and Sasipraba (2020). Because of waterlogging the people living here are in high flood threat for more days even if the rainfall stops. It also results in unhygienic situation. Based on their representation the PWD officials have proposed a flood carrier directly connecting Paravanar river to sea by a flood carrier canal. (Fig 5). The existing river Paravanar can carry 1190 m$^3$/s. It is proposed to diver 600 m$^3$/s to new canal.

This study was taken up to examine the feasibility of the proposal. The study consists of (1) Desk studies (2) Model studies (3) Design components if needed
1.1. Desk studies
This includes study of shoreline changes and rainfall data. The satellite imageries will give the historical coastline changes over a period of time. In the present case the imageries during 2003, 2005, 2006, 2008, 2011 and 2015 were downloaded from google earth and analysed. The pattern of changes that takes place along the estuary was studied. The river mouth is already trained by constructing a pair of breakwater. Hence it was not all creating any block. Accretion of beach was noticed on the south side and erosion on the north side of breakwater indicating that littoral drift is towards north. (Fig 6).

![Fig 6. Historical changes along estuary: (a) Paravanar estuary 2003 / May. (b) Paravanar estuary 2006 / August. (c) Paravanar estuary 2011 / July. (d) Paravanar estuary 2015/December](image)

2.1.2. Rainfall. The district has a hot tropical climate. The summer season, which is very oppressive, is from March to May. The southwest monsoon, which follows, lasts till September. October to December constitutes northeast monsoon season. January to February is the comparatively cooler period. The annual normal rainfall for the period (1901-2000) ranges from 1050 – 1400 mm. The normal annual rainfall over the district varies from about 1050 mm. The contributions of individual seasons are as follows: NE-57%, SW-31%, Summer- 7% and winter 5%. But the rainfall pattern in third decade shows high magnitudes of north east monsoon. (Fig 7 &8).
The study of rainfall pattern indicates that north east monsoon is dominating. The number of rainy days is in the range of about 25. But during high intensity rains the flooding process is the creating inundation.

**Table 1. Proposal**

| The hydraulic particulars                     | scheme               |
|-----------------------------------------------|----------------------|
| High tide level:                              | (+) 1.30m            |
| Low tide level:                               | (+) 0.70m            |
| Width of Paravanar at proposed site:          | 200 m                |
| Sill level of proposed regulator at Aruvalmukku:| (+) 0.70m            |
| Length of proposed canal:                     | 1600 m               |
| Top width of proposed canal:                  | 80 m                 |
| Bottom width of proposed canal:               | 60 m                 |
| Bed fall proposed:                            | 1 in 3000            |
| Maximum design discharge:                     | 21200 cusecs/600 m3/s|
| Top bund level:                               | 1.50m above high water level |
| Maximum flow depth:                           | 4.5m                 |
Based on the field particulars hydraulic computations were made using the model HEC-RAS developed by US army engineers (Table 1). The computations were performed for following conditions

1) Maximum discharge of 21200 cusecs
2) High tide level (+) 1.30m
3) Low tide level (+) 0.30m
4) Storm surge of 1.50m

1.2. Numerical model study
In order to assess the existing hydraulic conditions of the field, numerical model studies were made. For the present study the U.S. Army Corps of Engineers’ River Analysis System (HEC-RAS) software is used. This software is developed by the Hydrologic Engineering Center (HEC-2008), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. HEC-RAS allows users to perform one-dimensional steady and unsteady flow calculations (HEC, 2008). In a HEC-RAS steady state simulation, water surface profiles are computed from one cross-section to the next by solving the standard step iterative procedure to solve the energy equation. The energy equation is intended to calculate water surface profiles for steady gradually varied flow. The inputs are geometric, flow and boundary data. The geometric data consisting of cross section and chainages were keyed in after making a base map of the study area.

The model run was performed for different tidal heights such as low tide, high tide and storm surge. In all the case no spill over was noticed. The average velocity was about 2m/s (Fig. 11 & 12)

1.3. Wave climate
A quantitative understanding of wave characteristics in the near shore is essential for the estimation of sediment transport and morphological changes along the coastal areas. The coast has three seasons namely non monsoon (January-May), south west monsoon (June-September) and north east monsoon (October-December). The procedure to generate wave climate was as per Suresh & Sundar (2009). The wave directions are indicated vide fig 13 to 15 and table as taken from Suresh (2010). Dominant wave direction is from south east (Tab 1).
### Table 2. Average monthly wave climate

| Month    | Wave Height (m) | Period (sec) | Angle deep water (deg) w r t north |
|----------|-----------------|--------------|-----------------------------------|
| January  | 0.78            | 7            | 96.4                              |
| February | 0.66            | 6            | 101.84                            |
| March    | 0.66            | 10           | 118.33                            |
| April    | 0.97            | 11           | 132.07                            |
| May      | 1.07            | 8            | 140.06                            |
| June     | 1.26            | 10           | 140.54                            |
| July     | 1.06            | 8            | 138.06                            |
| August   | 1.22            | 9            | 143.96                            |
| September| 1.02            | 8            | 145.14                            |
| October  | 0.96            | 8.5          | 120.98                            |
| November | 0.93            | 7            | 93.6                              |
| December | 0.86            | 8            | 67.22                             |

1.4. Sediment transport

In order to understand the shoreline dynamics, it is very much essential to have an estimation of littoral drift that takes place along the coast. This will be useful to arrive any training works at river entrance. Here the littoral drift is estimated adopting Van Rijn (2001) approach (Table 2). It is to be mentioned that the net littoral drift along east coast during Jan to Sept is towards north, while during Oct to Dec it is directed toward south as pointed out by NarasimhaRao (1983).

**Formula of Van Rijn (2001)**

\[
Q = 40 K_{\text{swell}} * K_{\text{grain}} * K_{\text{slope}} * (H_{sb})^3 \sin(2\alpha_b)
\]

- \(Q\) = Alongshore sediment transport (kg/s)
- \(T_p\) = Peak period, Swell correction factor
- \(K_{\text{swell}}\) = \(T_p/6\)
- \(\alpha_b\) = Breaker angle
- \(D_{50}\) = Particle size (mm)
- \(K_{\text{grain}}\) = Particle size correction factor = 0.20 / \(D_{50}\)
- \(K_{\text{slope}}\) = Slope correction factor = \((\tan\beta/0.01)0.5\)
- \(H_{sb}\) = Breaker height

**Table 2. Average monthly Sediment transport**

| Month   | Sediment transport (Cum) |
|---------|--------------------------|
| January | 3431.433                 |
| February| 650.712                  |
| March   | -5273.74                 |
| April   | -30968.3                 |
| May     | -30291.3                 |
| June    | -63990.5                 |
3. Conclusions

The proposed carrier canal designed for 600cumecs or 12200 cusecs was modelled for different boundary conditions without any spill

- The channel is hydraulically capable of carrying the designed discharges
- The sea bed bathymetry and coast line changes using the imageries were analysed. The estimation of alongshore sediment transport is directed towards north direction
- Even though it was initially felt that there is a need to construct training wall for about 100m length to keep the outlet of proposed channel open, the littoral drift pattern indicate that it will create high erosion on its north side which is populated. Hence it is recommended not to adopt any such hard measures.
- The present site is located at about 10km south side of existing Cuddalore minor port. It was assessed that present opening of new inlet to sea will not be permanently open as the net drift is towards north. Hence the confluence point is to be periodically dredged and the dredge material should be dumped on the coast on the north side so as to maintain the sediment transport equilibrium. Hence no artificial interferences were made at exit and it is designed as a sustainable one.
- The present canal will definitely reduce the receding of flood water because the distance is reduced by the construction of flood carrier
- The project in general will help the social population in clearing the flood.

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