Navigation channels and tidal power plants (250 mw) for Chennai City

R. Ramasamy, SP. Subramanian and R. Sundaravadivelu

Abstract— **The Chennai City is blessed with rivers of Adayar, Coovum, Kortralaiyar, Ennore creek, Araniyar Rivers, Pulicat Lake and interconnecting Buckingham canal. Training walls of 2500 m lengths, with submerged barrages at about 500 m inside the entrances are to be constructed to generate rip currents, which prevent deposition of sedimentation and mouth closure by littoral drifts. A navigation channel in the Coovum River of 70 m width to 64 km long to Thiruvallore may be constructed with 5 lock and gate systems to rise and lowering boats and barrages. Another navigation channel for 36 km long in the Adayar valley up to Karisangal village may be constructed in similar manner. The entries of tidal waters far into Thiruverkadu, Thiruneermalai, and Buckingham canal flush out sewerages far into the sea. The dredging and deepening of these waterways -3 m msl always allow groundwater seepages enhancing river discharge potential. Disposal of sewerages and waste waters further increase this potential. Beyond these tidal basins, both Coovum and Adayar valleys, dredging up to 5 m depth is sufficient. Below the valley floor sufficient groundwater seepage enhance waters for navigations in these water ways. Construction of lock and gates at suitable places always maintain sufficient water level for navigation. Using volume of specific yield of groundwater supply (>10 l/s), river water and sewerage discharges, assumed potential of river-discharges and tidal prisms of saline water are calculated. The volume of water discharge of tidal prism has potential to generate 250 MW power by constructing suitable barrage type of tidal power plants at the mouths of Coovum, Adayar, Muthukkadu, Ennore Creek, Karungali and Thangaperumbalam near old Pulicat Lake. These plants can work for 20 hours per day. To reduce environmental problems plants may be constructed following the model of Severn Tidal Power Plant in United Kingdom.**

Index Terms—**Adayar River, Chennai City, Coovum River, Navigation channels, Tidal Power plants.**

I. INTRODUCTION

The growing Chennai City needs more electric power supply for its domestic and industrial needs. Chennai has more than 120 km length of coastline. In India only a few places like Gujarat and Bengal coastline tidal range exceeds 5 m. Even in these places installation of tidal power stations is still has a critical issue. It is known that to generate tidal electric power minimum of 5 m mean tidal range is required. On the other hand Chennai is blessed with Coovum River, Adayar River, Kortralaiyar River and Araniyar Rivers, Pulicat Lake and Buckingham canal over 120 km stretch. Inadequate environmental monitoring of these water bodies, they are silted and contaminated with pollutants and sewerages owing to urban development and sewage disposal. Of late, cleaning and monitoring of river flows of Coovum and Adayar Rivers, are major problem because of periodic mouth closures of these rivers by the movement and deposition of littoral drift sediments. The prevailing wind blows for more than 9 months towards NE and littoral drift moves towards NE rate of +0.14 m^3/ month with depositional environment and -0.04 m^3/ month towards SW with erosional effect along the seashore of Chennai [1]. Therefore, most of the river mouths in Tamil Nadu are closed by sand bar of varying widths 10 to 150 m from SW to NE. When the sun, the moon and the earth form a line, the reinforced spring tide rise happens twice a month during new moon and full moon times and the mean spring tide range in Chennai harbour is hardly 1.1 m [1]. When the sun and moon are separated by 90^o when viewed from the Earth, the tide's range at its minimum and the neap tide range in Chennai harbour is 0.4 m only. However, in order to clean the river valleys and to solve associated environmental problems, it is necessary to extend tidal channels far into the land over a distance of 25 km to the interior of the city. Navigation is the cheap transportation system. Network of navigation canals, not only solve transportation problem of the growing city, it also cleans the city and promotes aquaculture. In addition to these networks of transporting system, it can supply enormous quantity of water to be discharged into the sea. In order to maintain and regulate river flow, a tidal channel is necessary for a distance of 2.5 km from the shoreline into the sea where optimum depth of 7.5 m depth prevails. The width of the tidal channel may be designed according to the existing width of the river mouth. Tidal power generation depends on the volume of water discharged through tidal channel. Allowing tidal water to considerable distance into the city by deepening river valleys and river mouths and constructing suitable structures to arrest mouth closures, it is possible to generate tidal electric power. The paper highlights, the possibility of development of navigation channels and installation of tidal power plants.

Manuscript received August 29, 2013.

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II. MOUTH STABILIZATION

The mouths of Coovum River, Adayar River, Kortralaiyar River, Araniyar River, Muthukkadu River, Karungali and Thangalperumpallam are closed by development of sandbars, spits and shoals at their mouths. The Pulicat Lake mouth located at 650 m NE of Thangalperumpallam (13.390 N & 80.332 E) where the old Pulicat mouth was closed after opening a new mouth (13.469N &80.311E) at 5.75 km NE of Pulicat Town in Andhra Pradesh. Though, PWD has taken many measures to arrest closure of Coovum mouth to discharge the flow of Coovum River water, the problem of mouth closure is not yet solved. Although two groins one lying in the north trends N 130°E for a distance of 140 m into the sea and other in south trends N60° E for a distance of 150 m, the end points of the groins meet hardly a depth of 2 m contour line. The average storm surge is 3 m [1]. Waves produced by strong winds and spring tides break at these shallow depth and deposits sand at its mouth. The failure of the structure is due to insufficient length of groins and absence of a submerged barrage sufficiently inner portion of the groins to produce rip currents. Other unprotected mouths of various rivers along the coastal tract of Chennai are closed. The slope gradient of near shore regions in the sea is very gentle 1:350. In order to reach 7.5 m depth, it is necessary to go 2.5 km inside the sea. At this depth waves oscillate without any breaking. For construction of a tidal channel, the channel depth might be maintained for 7.5 m depth, so that any storm surge tides rarely exceeds of 15 m wave height. Two parallel training walls for a length of 3 km from the shoreline into the sea, perpendicular to the shore on the mouth are essential to regulate river water flow into the sea. Minimum 5 m depth foundation column should be treated. Further a submerged barrage of 5 m height above seafloor (Fig. 1) should to be constructed at a distance. The submerged barrage prevents sand migration into the tidal channel by generating rip currents in front of the barrage. By this construction littoral drift sedimentation in front of the channel will be prevented. The development of rip currents also prevents littoral drift sedimentations of the southern side and scouring on the northern side of the tidal channel.

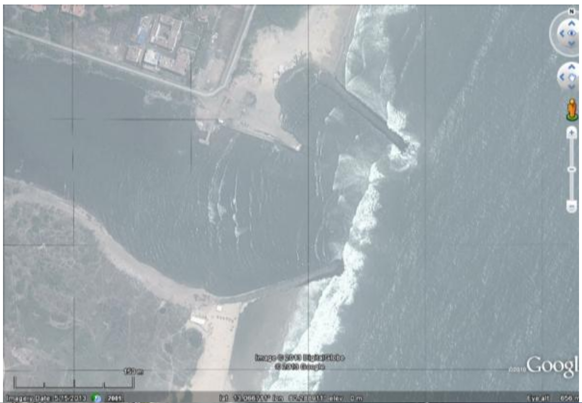

Fig. 1. Coovum River mouth groins constructed lying within surf zone breaking waves carry sediments into the tidal basin. Fig. 2. Locations of training walls, tidal plant, submerged barrage and development of rip currents to arrest dissipation of sediments outside the tidal channel are seen.

Fig. 3. A tidal channel 2500 m long from the mouth of Coovum River with 2 tidal power stations at 1000 m intervals and a submerged barrage 7.5 m above sea bed and -2.5 m below CD near the entrance. The width of tidal channel may be widened from 70 m to 200m

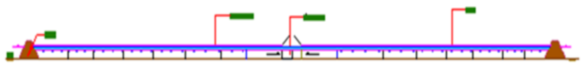

Fig. 4. A tidal power plant 200 m long between training walls following the model of Severn Tidal Power Plant at United Kingdom

III. GROUNDWATER POTENTIAL

The Chennai Basin is situated between latitudes 12°40'N and 13°40'N and longitudes 79°10'E and 80°25'E at the north east corner of Tamil Nadu. The total area of the basin is 7282 km². District Resource Planning maps for Kancheepuram, Thiruvallore and Chennai [2] indicate specific yield of groundwater potential is >10 liters per second along the river valleys and along the coastal tracts. Along the river valleys pool of water cutting groundwater table are seen at number of places. The groundwater table contour maps show that groundwater table is cut the topographical elevation contour map often less than 3 m depth below ground level in these alleys. Many intersecting fault lineaments interconnect deep confined aquifers with shallow unconfined aquifers in the Chennai basin [1]. A NE-SW trending fault lineament intersects Cheyyaar, Adayar, Coovum, Kortralaiyar Rivers and boundary fault of Pulicat Lake. Numerous buried channels with groundwater potentials are seen along his lineament. The Pulicat Sub basin of Cauvery Basin is more than 3000 m deep near the coast. However porosity and permeability of local soil cover and rock types vary locally. Dredging of 3 m below the riverbed will yield sufficient quantity of water for navigation with installation of lock and gate system in the upstream side. In the downstream side, dredging of –3m below mean sea level often cuts groundwater table in the river valleys invariably at all places and it will form a large tidal basin. Thus, cutting and deepening of 18 m bgl in the Coovum River valley near Thiruverkadu, allows -3 msl tidal waters with enormous seepage of groundwater (>10 l/s [2]. In addition to groundwater seepage from river bed, river carries flood water, waste-water disposal like sewerage and industrial effluents. However, because of these admixtures, tidal range cannot be altered and it should be uniformly maintained either by flood tides or ebb tide periods. Calculating the volume of maximum storage capacity of tidal water potential at peak period during spring tide condition, the discharge potential is 107 m^3/s for productive 5 hours (i.e. 18000 seconds) from Coovum River and Adayar River. It is assumed that the tidal channel can yield initially 100 m^3 from the area covered 10 x 10 m^2 area per second with sequential increment of 0.1 m^3/s for 5 hours. Using arithmetic progression for estimation n^{th} term and summation of its arithmetic series

$$an = a_1 + (n - 1) * d \quad (1)$$

where, a1 = initial term of the arithmetic progression (100 m^3. 10 m^3); d = common difference between successive terms (0.1 m^3) ; an = n^{th} term of the sequence; n= 18000 (s)

The cumulative water potential can be calculated by the sum of the arithmetic series is

$$S_n = n * (a_1 + a_n)/2 \quad (2)$$

The table 1 shows cumulative yield of tidal waters discharge in the barrage type of tidal power station. Since, the freshwater output is comparatively very higher than the volume of seawater mixed. Though enormous quantity of groundwater seepage, river flow and sewerage water, the density of tidal prism is greatly reduced from 1.025 and it is assumed to be 1.008 based on the volume proportions of seawater and freshwater.

Table 1 Potential mean water supply for turbine operation during spring and neap tide periods and their mean electrical energy potential is to be produced

Particulars	ST ~ 1.1m	NT ~0.4m	Sp. Yield	Neap yie	R.Discharge	Sprng potential	Spring	Neap potential	Neap	20 hrs
Place	length m	width m	STY m3	NTYm3	m3	STP m3	HTMW	NTP m3	NTMW	Mean MW
Coovum-Thiruverkadu	25000	70	1925000	700000	17999100	19924100	5.47	18699100	5.14	21.22
Adayar-Thiruneermalai	25000	70	1925000	700000	17999100	19924100	5.47	18699100	5.14	21.22
Buckinham canal	100000	20	2200000	800000	17999100	20199100	5.55	18799100	5.16	21.42
Muthukadu	1000	500	550000	200000	16379100	16929100	4.65	16579100	4.55	18.41
Ennore	5000	500	2750000	1000000	16379100	19129100	5.25	17379100	4.77	20.06
Karungali	2000	250	550000	200000	16379100	16929100	4.65	16579100	4.55	18.41
Thangalperumpallam	1000	500	550000	200000	16379100	16929100	4.65	16579100	4.55	18.41
			10450000	3800000	119513700	109063700	35.70	123313700	33.87	139.14

Mean spring tide range~1.10 m; Mean neap tide range ~0.4m; River discharge includes groundwater seepage. flood water, effluents and sewerages and it is assumed to be common for flood tide and ebb tide periods and also for spring tide and neap tides. It is assumed that flood tide and ebb tides have similar potential for power generation. But spring tides have higher production potentials than neap tides. For 20 hours duration potentials for 2 high tides and 2 low tides are utilized for power generation. The table shows that proposed tidal plants at Chennai can produce 125 MW, if single row of turbines is installed for 20 hours of 18-20 MW power production in a single row of Tidal Power Plant.

IV. TIDAL PRISM

A tidal prism is the volume of water in an estuary or inlet between mean high tide and mean low tide. The volume of tidal prism [3, 4] is H*A (H= tidal range; A = area). , The river discharge mixes with the volume of the tide flooding in (Vp) from the ocean at oceanic salinity (So) and the mixed VR + VP) water flows out at ebb tide [5]. When the volume of river discharge (including groundwater seepage, waste water effluents led into the river and flood water) exceeds over the volume of flood tide water, the river discharges its water even during flood tide or high tide period. Even though the river discharges considerable amount of water regularly during flood tide, the tidal rise maintains a constant level. Therefore, the release of quantity of discharged water increases till the tidal rise reaching to its maximum height. Hence, the hydrodynamic potential increases both during high tide and low tide conditions as wells as during spring tide and neap tide conditions. Tidal channels are deepened -3 m msl; enormous quantity of groundwater is to be seeped into the tidal channels. Added to this, river water discharge, flood water discharge during monsoon, industrial effluents and sewerage water accumulates in the river valleys and canals. Though, tidal range would not be altered, these waters have impacts tidal water hydrodynamic pressure by increasing the potential discharge of tidal water, when barrage type of tidal power stations are in operating conditions. Tidal power is essentially a specific form of hydro power. A reversible hydraulic turbine is used so the inflow and outflow of the tide can generate electricity. The theoretical extractable energy for each tidal period is given [6] by

$$E = \rho g A R^2 \quad J/m^2 \quad (3)$$

where ρ is the density of water (1025 kg/m^3 for seawater since the ratio of fresh water to sea water is very high the density is assumed to be 1008 kg/m^3), g is the acceleration due to gravity, A is the area of the tidal pool, and R is the range of the tide. J/m^2 is then converted to W/m^2. Average power for a tidal period is calculated by dividing the extracted energy by the tidal period of 12hr 25min. The

Velocity of the water through the penstock can be calculated by using the following formula

$$v = \sqrt{2gH} \quad (4)$$

where v is the velocity of water in meters per second. Although it varies from 4.6 m/s to 2.8 m/s, the mean value always exceeds >3 m/s during peak period of discharge. However, in the table effective 5 hours in the high tide peak period and 5 hours in the low tide operation only calculated. From high tide, low tide, spring tide and neap tide power production mean power production for 20 hours duration is estimated. The possible power production of 139.14 MW optimized to 125 MW can be produced by installation of single row of turbines accompanied in the power plant. Since the training walls bounded power plant is 2.5 km long, two such plants may be installed 1000 m apart from the first one. [7], have revealed that the potential of power generation increases, if the plants would be installed in the sea, the slope gradient (1:350) impacts and accelerates gravitational force for additional potential for power generation.

V. TIDAL POWER PLANTS

Tidal power plants may be installed at the mouths of river / coastal inlets. Special types of training walls are to be constructed to prevent mouth closures. Generate rip currents in front of submerged barrages lying 7.5 m above sea floor. Table 1 shows setting up tidal power plants at 6 places at the mouths of Coovum, Adayar, Muthukkadu, Ennore Creek, Karungali and Thangalperumpallam. The hydro potential of Buckingham canal may be evenly distributed to these power plants, therefore no separate tidal power plant is required. Since the training walls of tidal channel in the sea are very long for 2500 m, two tidal power stations may be installed in each mouth at a distance of 1000 m apart from one plant to other for economic optimization. Table 1 shows total output of power is 139.14 MW i.e. 125 MW capacity. Again this power generation may be enhanced by installation of another row of tidal plants each turbines of 0.5 MW capacities. Thus total production of 125 MW is doubled for 250 MW. After generating energy for power production in the first row of turbines, before reaching the second row of turbines no net loss of tidal energy will be encountered. Due to presence of training walls on both sides of the tidal channels, the hydrodynamic forces will be preserved and utilized in the second row of tidal power plants. Tidal power plants may be set up at 1000 m intervals. Tidal power may be generated continuously for 10 hours starting 1 hour from the null point (ceasing of ebb tide discharge to the beginning of high tide rise) and ceasing out earlier 1 hour before reach null point. Similarly, next cycle may be started for 10 hours i.e., 5 hours at peak high tide rise and immediately after 5 hours duration from the maximum tidal rise to possible minimum low tide height. The volume of waters stored in the tidal channel during flood tide period must be discharged during ebb-tide water discharging. Hence velocity of ebb-tide is always greater than the flood tide-waters entering. During monsoon flood period, due to increase of flood water discharge the plants have higher potential to produce power supply.

VI. NAVIGATION CHANNEL

In order to reduce traffic congestion, it is necessary to develop navigation system through river channels and Buckingham canal. The Buckingham canal is already declared as National Inland waterway-4. Buckingham canal was constructed in 1878 for navigation between Vijayawada in Andhra Pradesh and Kaliveli Lake in Marakanam for a distance of 422 km parallel to the Coramandal coast. Within the Chennai city limit it was highly polluted with industrial effluents, sewerage and garbage. Inland Water Ways Authority has adopted it as Water way -4 and proposed to revive the canal during 2008. South Buckingham Canal will be widened from 25 m to 100 m between Okkiyam Madu and Muthukkadu, which is a distance of 13.5 km [8]. Apart from the widening of the canal, a straight-cut 2 km canal from Okkiyam Madu will head directly to the sea [9,10]. Coovum and Adayar Rivers have sufficient width for navigation in the city area. Deepening of the riverbed with installation of lock and gate system following optimum slope gradient, it is possible to develop a navigation system in the Coovum River Up to Thiruvallore for 64 Km from Cheapaukkam and similarly in Adayar mouth to Karisangal village.

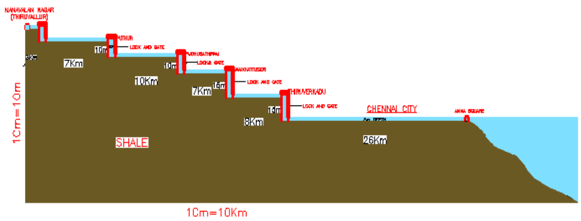

Fig.5. A typical cross section of Coovum Navigation channel from Cheapaukkam to Thiruvallore for a distance of 64 km with lock and gate system is seen. Tidal water enters up to Thiruverkadu for 26 km from mouth clean the channel twice a day

Similar navigation channel may be developed in the Kortralaiyar valley from Ennore to Poondi Reservoir. When topographical elevation exceeding over +15 m msl, the river valley may be leveled for optimum gradient by 3 m deepening the river-bed is sufficient to feed enough water in the navigation channel. Construction of lock and gate system not only stores enough water in the navigation channel but also useful for lifting and lowering of boats and barages.

VII. CONCLUSION

The Chennai City is blessed with rivers of Adayar, Coovum, Kortralaiyar, Ennore creek, Araniyar Rivers, Pulicat Lake and interconnecting Buckingham canal. At present the mouths of these rivers are closed and the Buckingham canal is damaged and silted. In order to reduce drainage congestions and to make free flow of these rivers, it is necessary to stabilize their mouths without any shifting and also closure by littoral drift. For these, it is necessary to construct tidal channels enclosed with training walls for a length of 2.5 km distance in the sea where 7.5 m depth is prevailed. A submerged barrage at a distance of 500 m inward is to be constructed for a height of 5.0 m from seabed to generate rip currents to dissipate sediments outside the training walls. In these long tidal channel 2 rows of turbines each of 0.5 MW capacities may be installed to improve twice of its tidal power production and for economic optimization for these huge expenditures to be incurred for stabilization of river mouths. Net work of navigation channels provide adequate water supply for the tidal power stations. Nearby port-connectivity is possible only during high tide periods. An environment impact analyses made in barrage type tidal plants indicate that (1) very few fish using this portion of the river, (2) those fish which did use this area were not using the portion of the river which would subject them to blade strikes, and (3) no evidence of fish traveling through blade areas (Garrett et.al, 2005). However, fish corridor may be designed with separate sluice gates on either sides of tidal power plant within the tidal channel as that provided in the Severn Tidal Power Plant in United Kingdom [11].

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