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HYDRODYNAMIC MODELLING OF THE VEMBANAD LAKE

भारतीय प्रौद्योगिकी संस्थान दिल्ली
Indian Institute of Technology Delhi

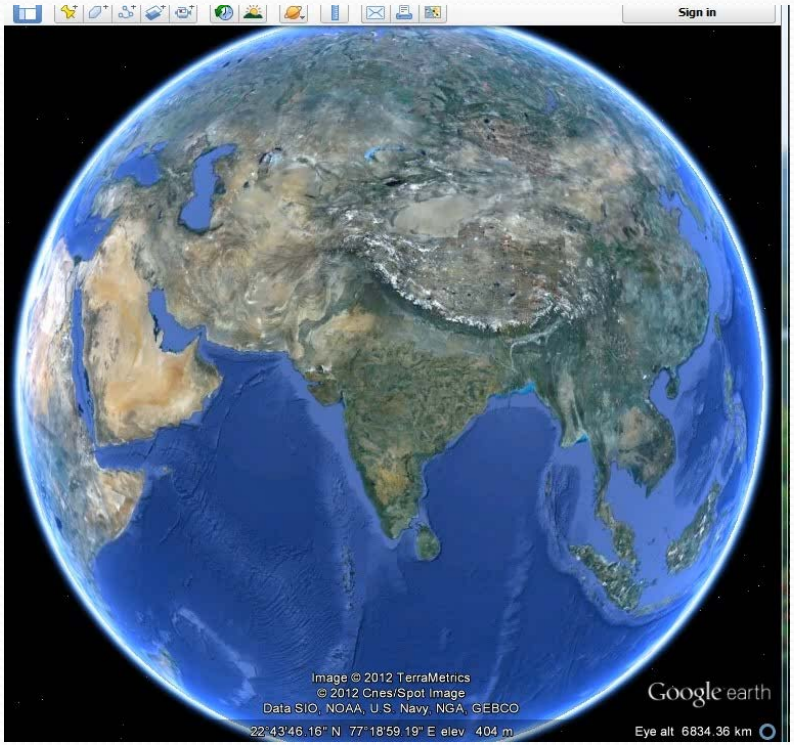
Raktim Haldar
Research Scholar
Department of Civil Engineering
Indian Institute of Technology, Delhi

Issues to be addressed

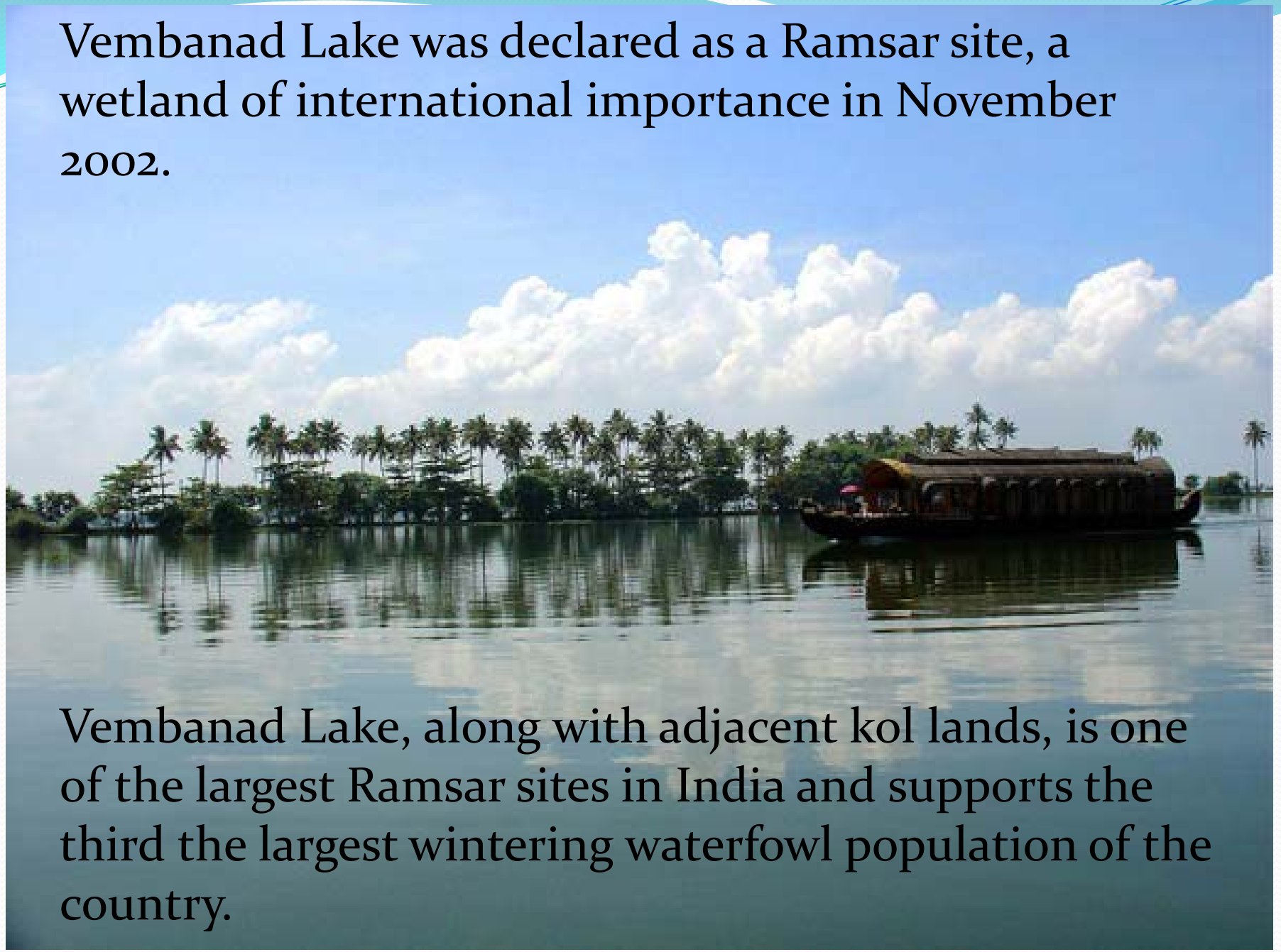
- Introduction to the Vembanad Lake and surrounding scenario of development
- Anthropogenic impacts on lake environment
- Purpose of modelling
- Modelling requirements
- Data collection and shortcoming
- Methodology and Instruments
- Results for different scenarios

Study Area

- The Vembanad wetland system lies in the Indian state of Kerala, between the latitudes 9°5’ N and 10° N and the longitudes 76°15’ E and 76°45’E.



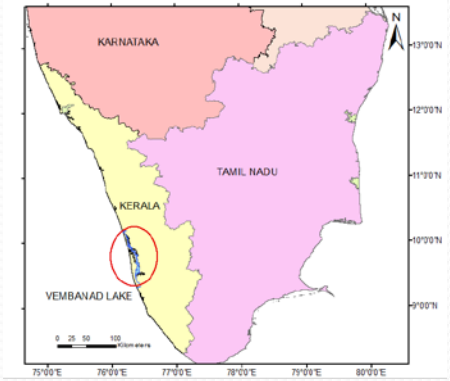
Vembanad Lake was declared as a Ramsar site, a wetland of international importance in November 2002.

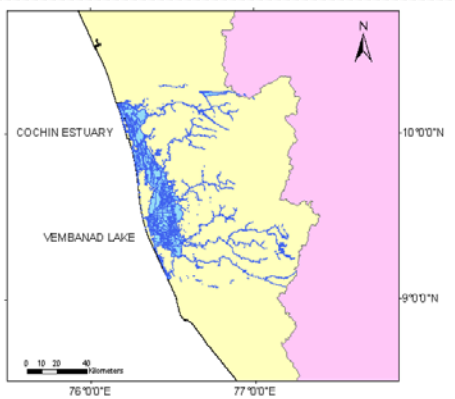


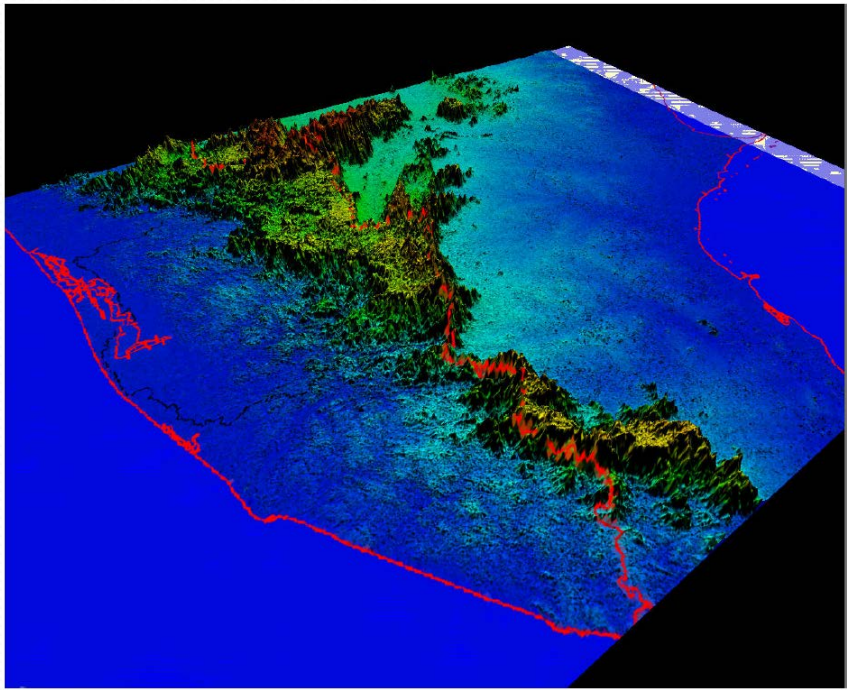
Vembanad Lake, along with adjacent kol lands, is one of the largest Ramsar sites in India and supports the third the largest wintering waterfowl population of the country.

The Morphologic Background

- The rivers joining the Vembanad Lake form a natural wetland surrounding the main lake body.
- The five major rivers joining the Vembanad Lake are Muvattupuzha, Meenachil, Manimala, Pamba and Achenkovil form the southern network of channels; while Periyar, the largest of the rivers of Kerala joins the northern part of the wetland system.
- The lake lies at the sea level with depths varying from 1 to 13 meters below mean sea level.
- The lake is separated from the Lakshadweep Sea by series of islands and at places by minor sand bar formations.







Sea-connectivities

- The wetland system has three major connectivities with the sea, at Munambam, at Cochin and at Thottapally.
- The water from Periyar exits the system mainly at Munambam and has meager influence on the Vembanad Lake flow dynamics, which lies south of the Cochin outlet.
- Keeping this in view the five rivers have been considered for the study.

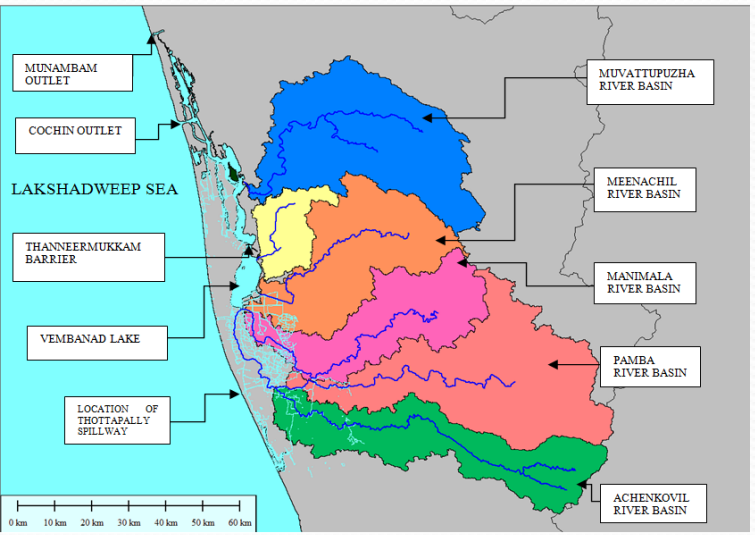
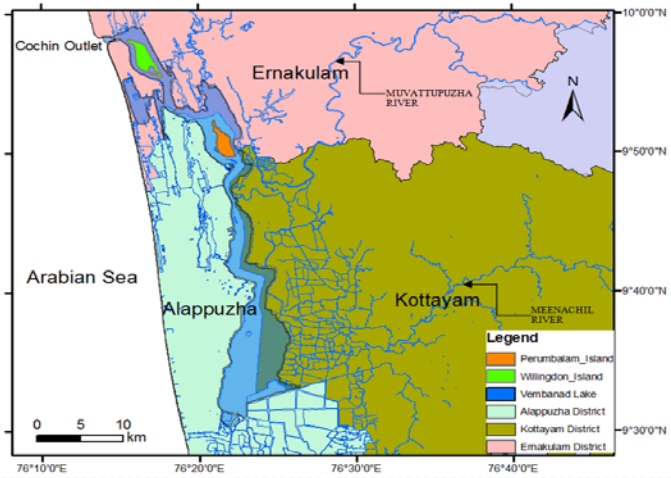
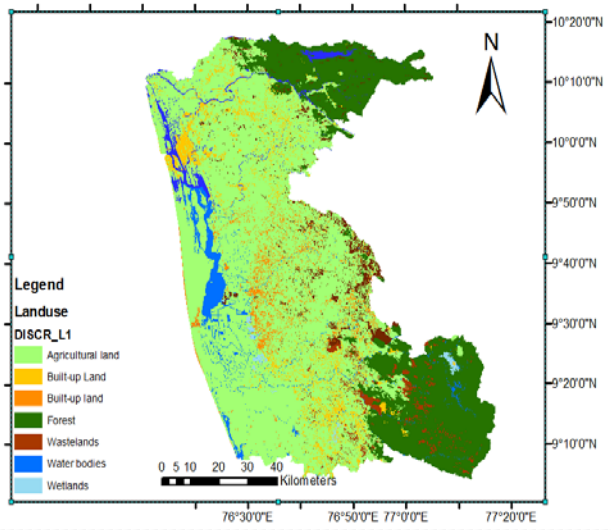
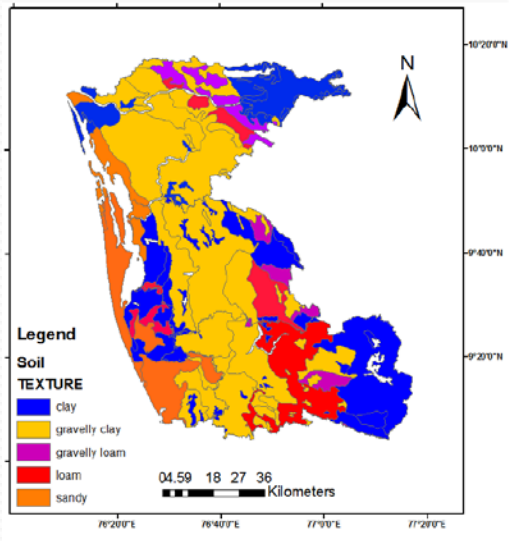


Figure showing the Vembanad Lake and contributing river basins, namely, Muvattupuzha, Meenachil, Manimala, Pamba and Achenkovil

Administrative Boundaries



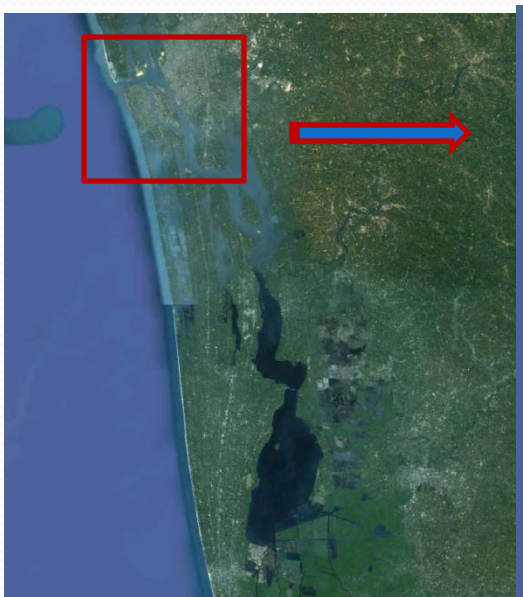


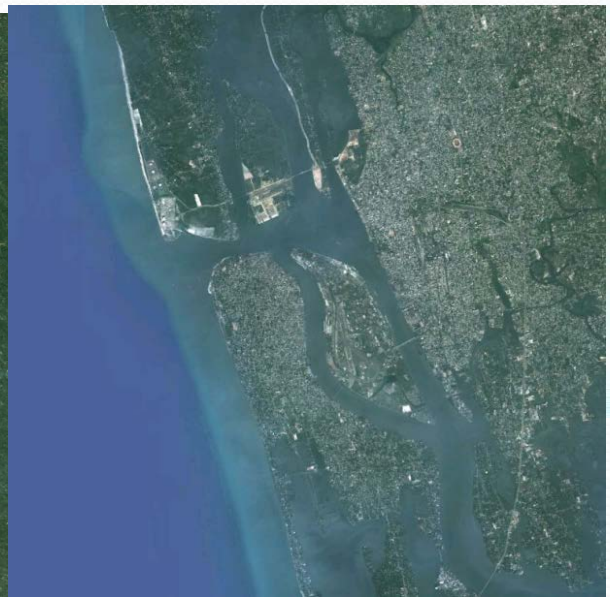


Land-use and Soil map

Anthropogenic Influences

1. **Port of Kochi - Wellington Island was created (1838-1845)**
2. Thottapally Spillway (completed in 1955)
3. Thaneermukkom Saltwater barrier (commissioned in 1975)
4. Embankments for paddy cultivation





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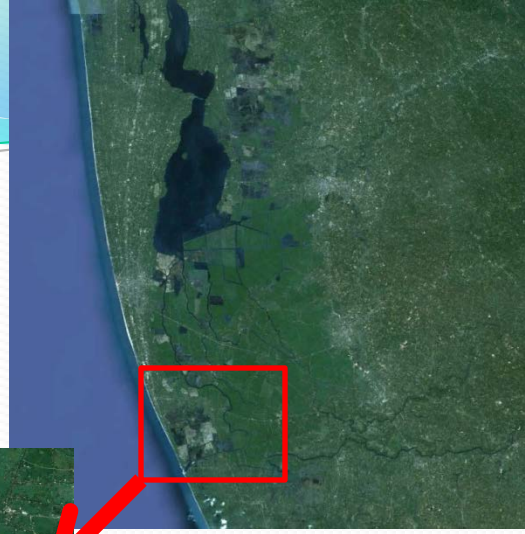

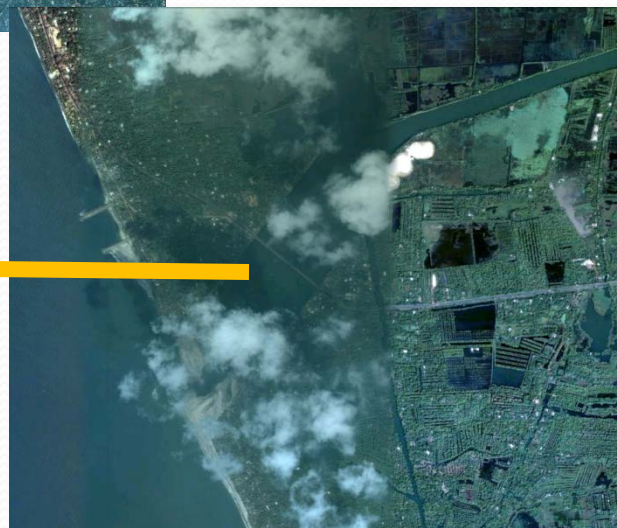

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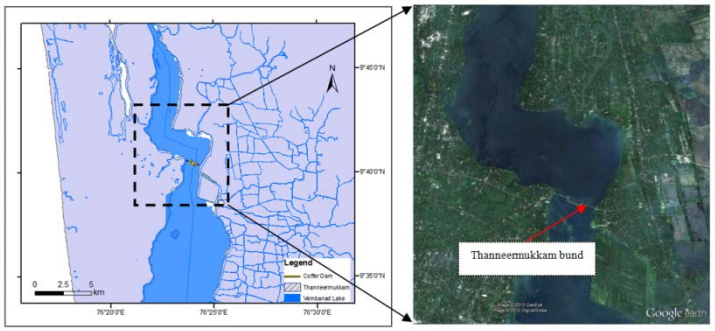

Location of Thanneermukkam Bund in the Vembanad Lake

The Thanneermukkam Bund is operated so as to maintain the salinity of the lake water below 2 ppt on its southern side.

Anthropogenic Influences

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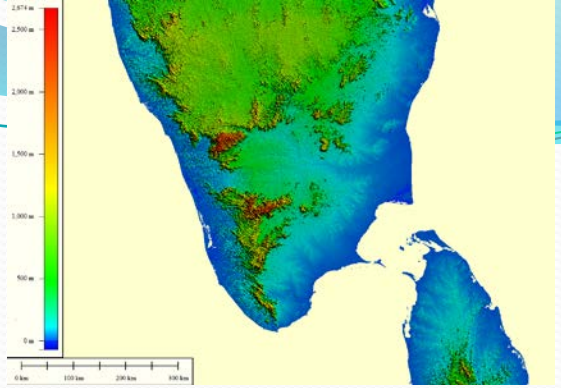
4. **Embankments for paddy cultivation**

Reclamations in the Vembanad lake (Source: Gopalan et al., 1983)

Period	Area reclaimed (ha)	(%)	Purpose
1834–1903	2227	6.1	Agricultural
1912–1931	5253	14.4	Agricultural
1920–1936	364	1.0	Willingdon island
1941–1950	1325	3.6	Agricultural
Till 1970s	5100	14.0	Paddy–cum–shrimp culture
1970–1984	800	2.2	Paddy–cum–shrimp culture
1975	6900	18.9	Ecologically severed from backwater as a result of bunding at Thannirmukham
1978	11	0.03	Fishing harbour
1981–1985	142	0.4	Vallarpadam – Ramanthuruthu Candle island
1981–1985	142	0.4	Southern extension to Willingdon island
1981–1985	24	0.06	Foreshore urban development
1981–1985	12	0.03	Cochin Shipyard & tanker berths
1900–1984	1500	4.1	Housing, agricultural & traditional industries

In the Kuttanad region, construction of embankments (bunds) in the shallow parts of the backwaters started at least a century ago. The purpose was to create large tracts of land in which paddy could be grown in the period between the end of the flood season (Nov) and the dry season when water becomes too saline for agriculture. In course of time these tracts have grown to 550 km^2, even to areas where water depth used to be 2.5m and the people live on the embankments.

Motivation

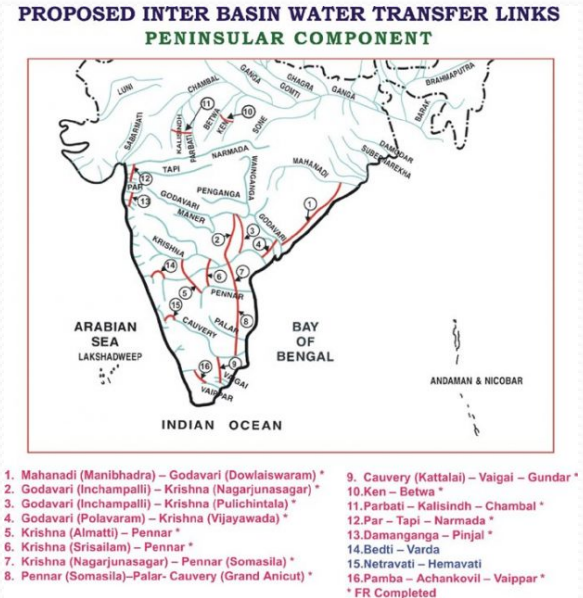


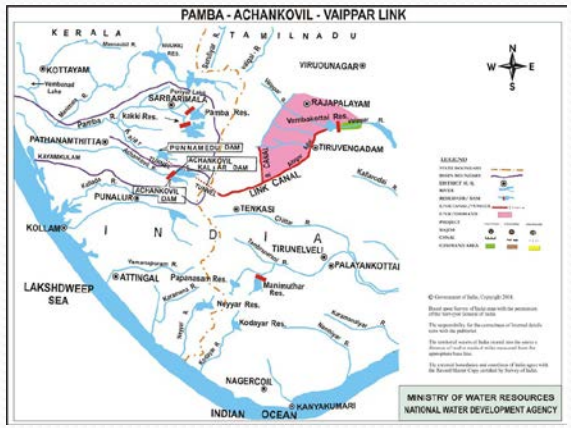
Topography depicting the Western Ghats

- Abundance of rainfall in Kerala owing to its favourable location
- Paucity on the leeward side

1. However, there is a possibility that the lake water stage and quality in Vembanad might be adversely affected.
2. Necessity of detailed hydrodynamic model

The **Pampa - Achankovil - Vaippar Link Project** (PAVLP) is one among the inter-basin water transfer schemes formulated by the NWDA for utilising the surplus water available in the river basin to another river basin facing acute water shortage. The Pampa Achankovil-Vaippar Link Project, proposes a **diversion of 634Mm³ of waters** from Pampa and Achankovil rivers in Kerala to irrigate areas in the Vaipar river basin in Tamil Nadu.





Model used for hydrodynamic modelling –MIKE 21 (DHI)

- MIKE 21 is a software package containing a comprehensive modeling system for 2 – dimensional free surface flows and can be used for simulation of hydraulic and environmental phenomena in lakes, estuaries, bays, coastal areas and seas.
- It may be applied wherever stratification can be neglected.

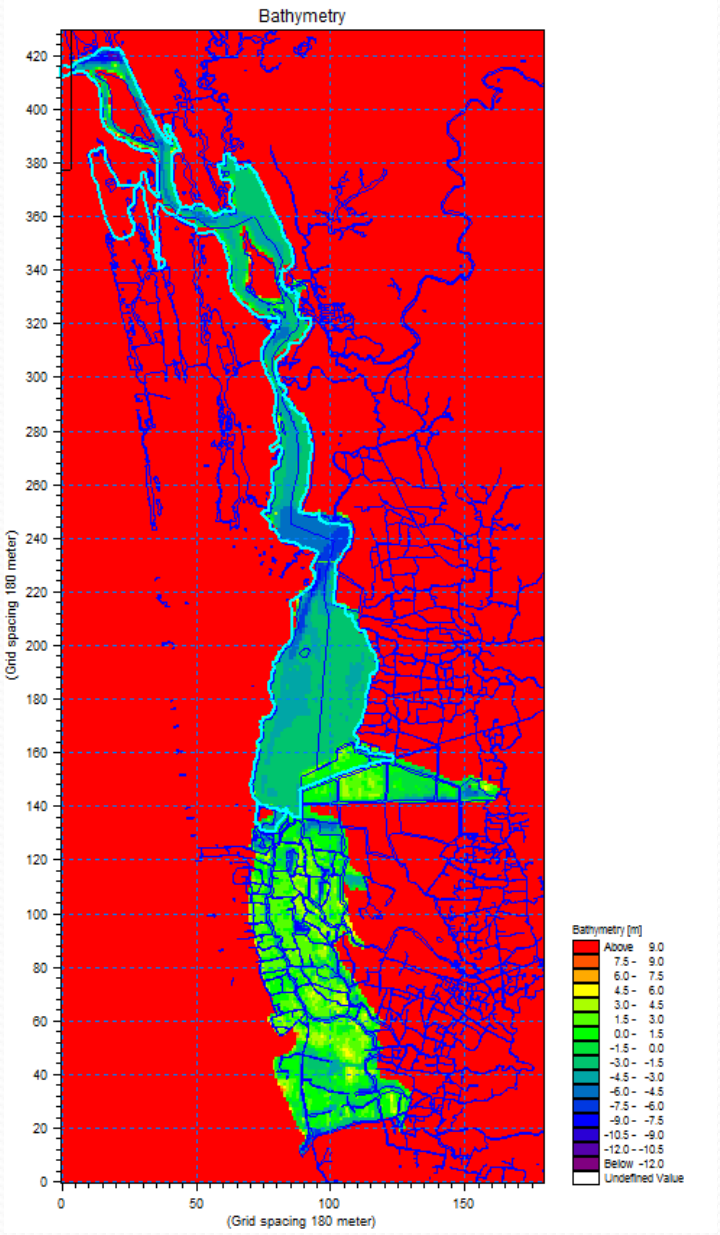
Modules used for modelling

1. HD module – Hydrodynamic module simulates unsteady two-dimensional flows in one layer (vertically homogeneous) fluids
2. AD module – Advection Dispersion module simulates the spreading of dissolved substances subject to advection and dispersion processes, for example – salinity, temperature, etc.

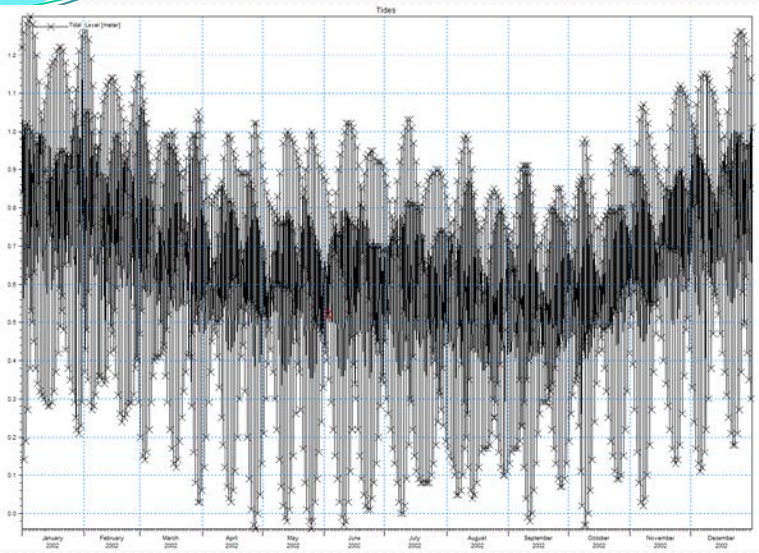
DHI: Danish Hydraulic Institute

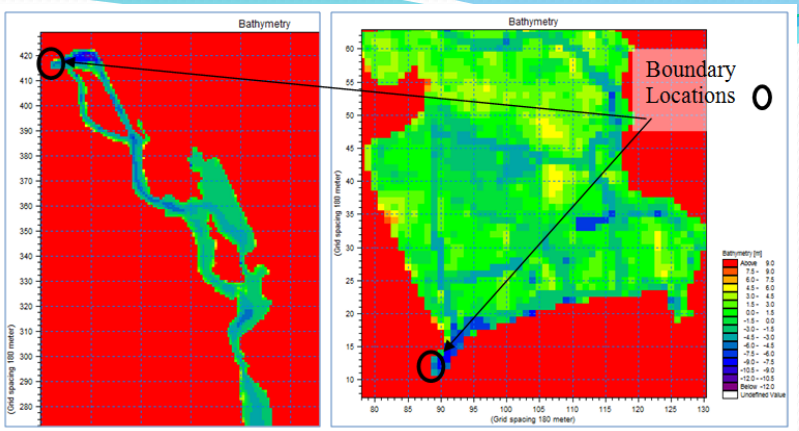
Model Setup

- Lake Bathymetry – as received from Water Resources Department, Government of Kerala
- Flow input from connected rivers is given from SWAT model simulated results
- Rainfall –nearest possible station –Arookutty
- Calibration and Validation



Tidal Forcing

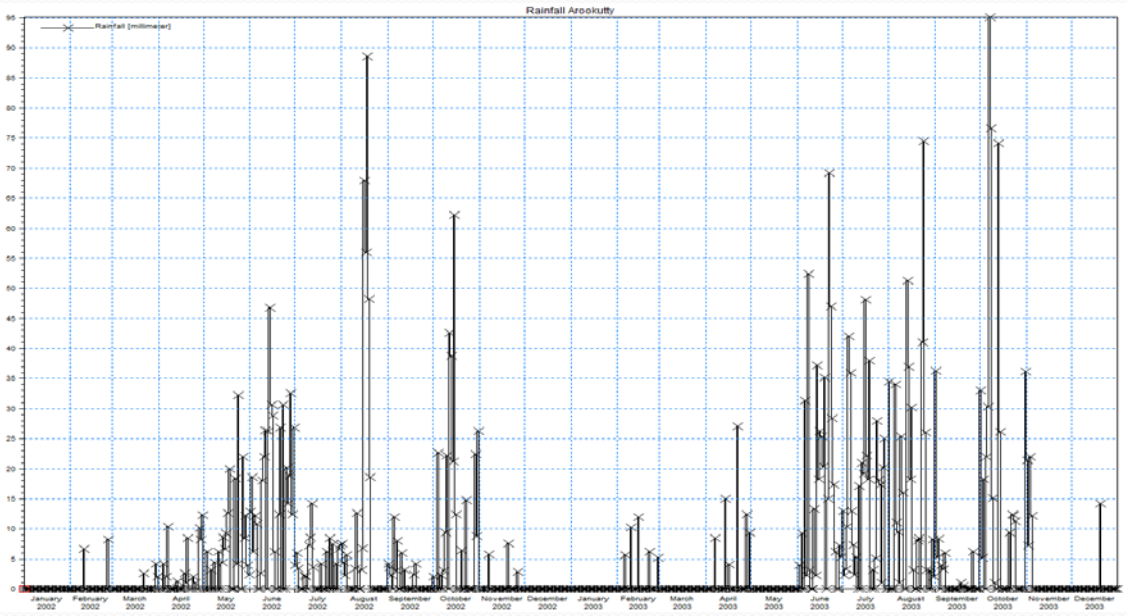




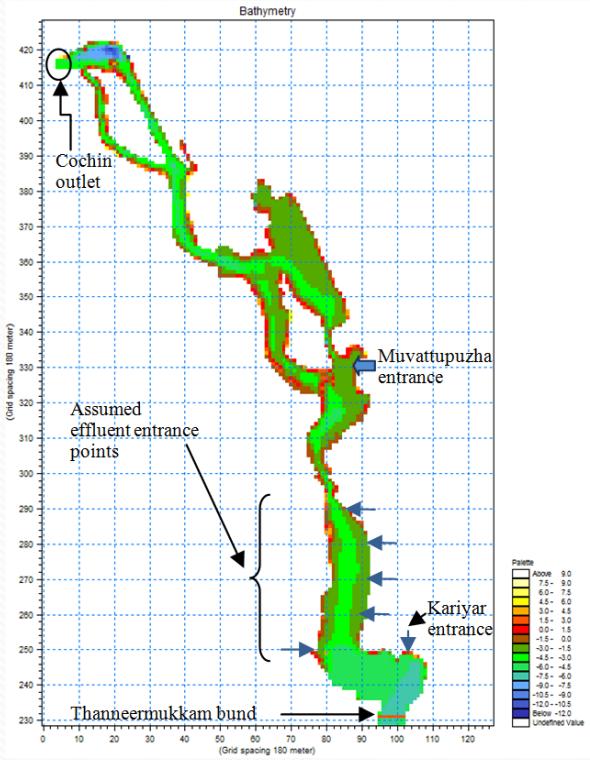
Tidal Boundary locations for the model at Cochin and Thottapally

As observed from the plot of the tidal data the variation in the sea level along the boundary is between -0.04 to 1.3 m.

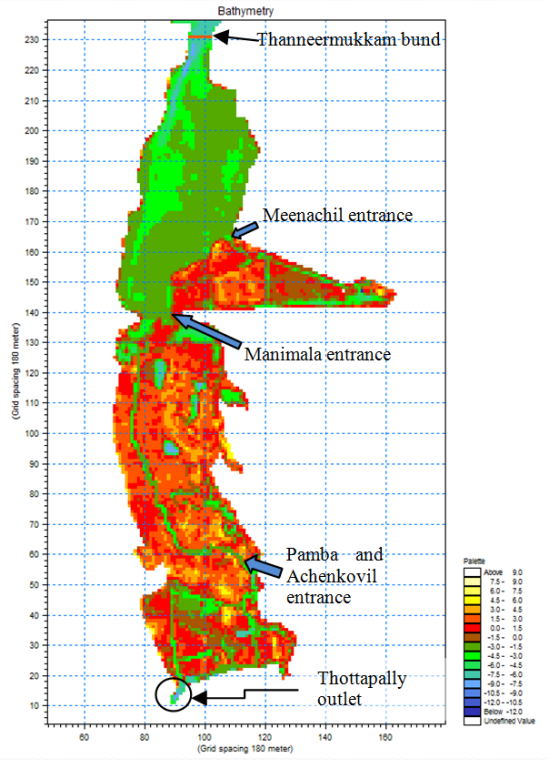
Rainfall at Arookutty



Sources of Water



Point source locations for river/drain entrance north of Thanneermukkam bund



Point source locations for river/drain entrance south of Thanneermukkam bund

Data collected and limitations

- The rainfall data, tidal data and daily flow and quality data of the five rivers was made available through the office of ISW, Govt. of Kerala.
- However, the flow data was having missing values for short and long periods, therefore, SWAT modelling was used for generating daily flow values. The SWAT model was run for two scenarios (a) existing scenario of water resources development, and (b) including anthropogenic changes.

Data collected and limitations

- Apart from the river sources, few other direct pollution sources that enter the lake from the agricultural and industrial effluents through surface runoff and man-made drains have been considered. As established by various studies these polluting substances are loaded onto the estuary mainly in the northern part of the system (Harikumar et al., 2009; Unni and Nair, 1995).
- The Central Pollution Control Board (1996) estimated that 0.104 Mm^3d^{-1} of industrial wastes and 260tons per day of domestic wastes are released into the Cochin backwaters.

Data collected and limitations

- In absence of the detailed information about the spatial distribution of the pollution sources, the known pollution volume was distributed homogeneously in the zone in order to make the model consistent with the current physical reality.
- Another limitation of the model is that there is no measured water stage and quality data of the lake. For model calibration, observations at various locations in the lake would be needed.
- **So, how to formulate a suitable model?**

Compensation

- It is known that the Thanneermukkam Bund is closed and opened as per the salinity standard requirement. And the dates of gate closure and opening at Thanneermukkam is known.
- A period of two years (2002-03) was chosen for simulation. It was attempted to make the simulated water quality suit the above criterion, as far as possible.

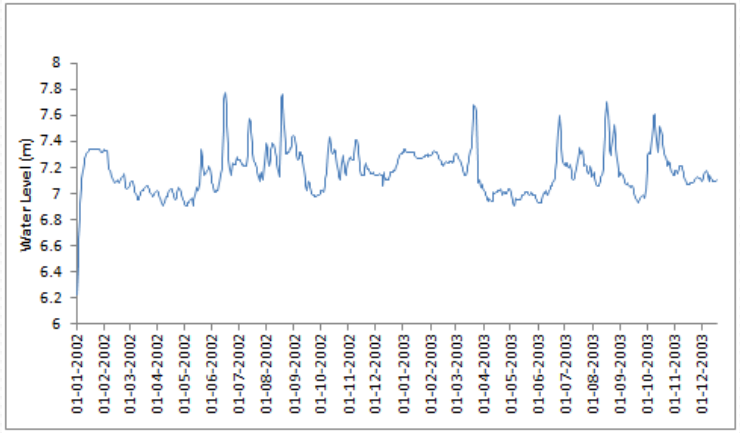
Modeling Scenarios

The model simulations have been run for three cases:

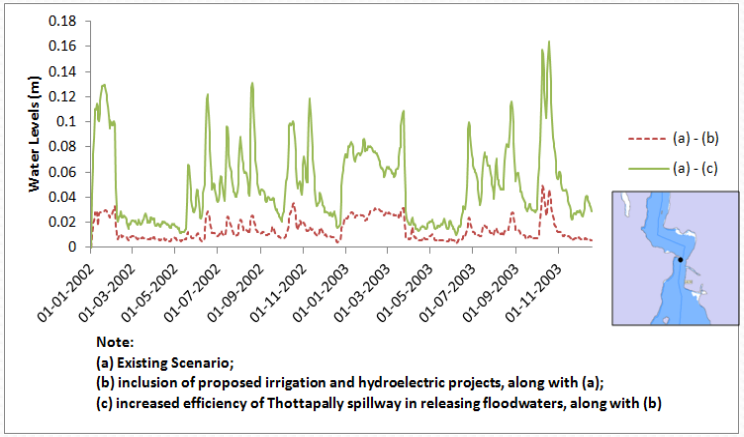
- The first case corresponds to the existing scenario.
- The second case corresponds to the inclusion of proposed irrigation, hydroelectric and diversion projects in the Pamba and Achenkovil basins.
- And the third case corresponds to the scenario of increased efficiency of Thottapally spillway in releasing floodwaters, along with projects contained in case (b).

Model Results

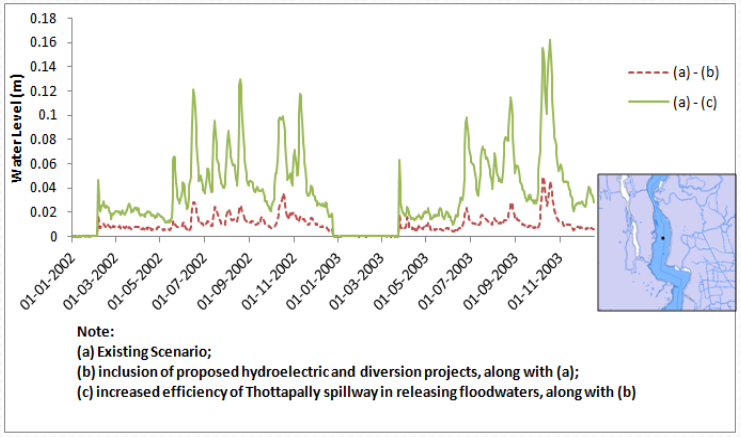
- Water elevation results



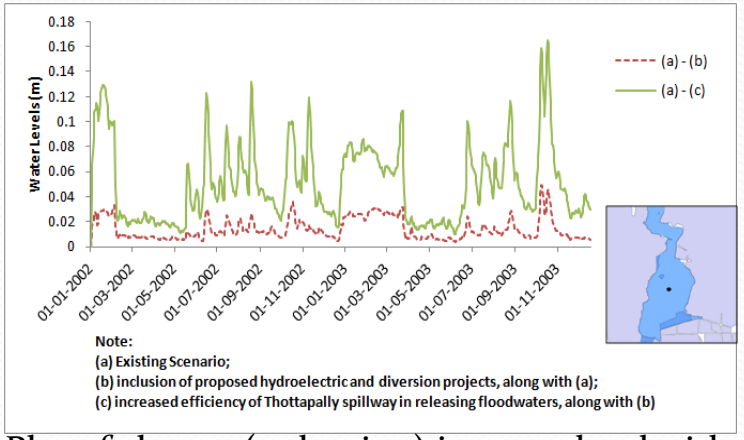
Plot of simulated depth of water for a point located near Thanneermukkam bund



Plot of reduction in water level with respect to existing scenario near Thanneermukkam bund



Plot of change (reduction) in water level with respect to existing scenario near Vaikom



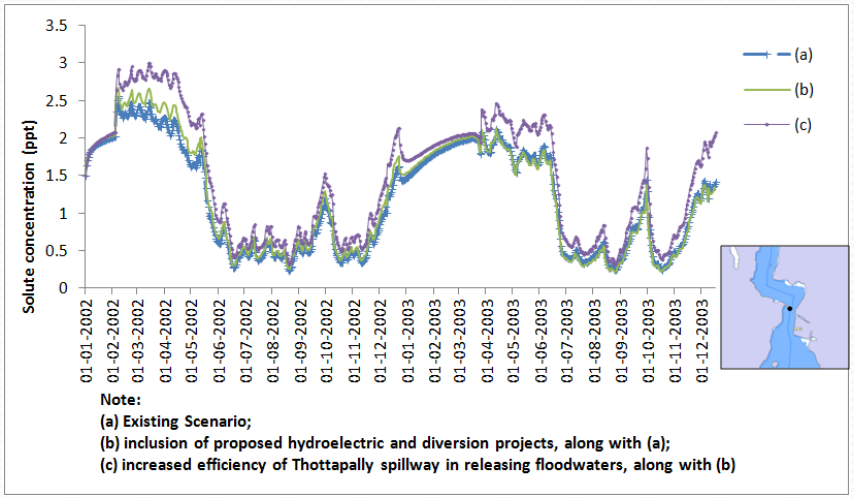
Plot of change (reduction) in water level with respect to existing scenario in between the lake body

Inference

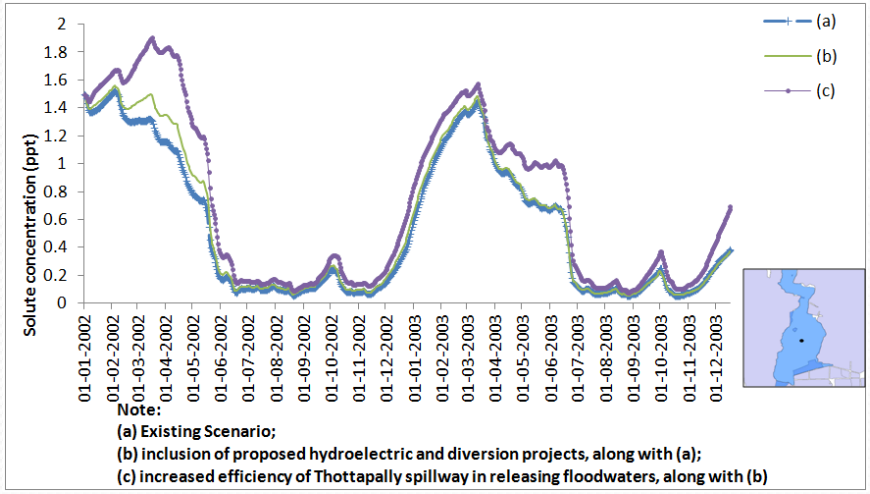
- The aforementioned comparisons clearly establish that the water levels in the lake are expected to register a fall of varying degrees at various locations across the lake under influence of various development scenarios and the maximum impact is expected to result if the proposal to widen the link to Thottapally spillway is carried out as envisaged. This anticipated drop in water levels has the potential to disrupt various lake processes and may result in a disturbed ecological balance in the region.

Model Results

- Water quality simulation results



Plot of simulated solute concentration level in water near Thanneermukkam bund



Plot of simulated solute concentration level in water in between the lake body

The show the solute concentration results from the simulation for the three locations – near Thanneermukkam bund, near Vaikom and at a point in between the lake. In all the three figures it is observed that:

•The solute concentration for the case (a) and (b) are more or less same.

•The case (c) varies widely from (a) and (b).

•The solute concentration differences increase during the months of January to May, which is the low flow season

Conclusions

Apart from these, the other conclusions that can be drawn from the study are:

- There is a strict necessity to stop any further wetland reclamation.
- The four basins contributing to the southern part of the lake have a total area of 4707 km^2. An out of basin transfer of almost 5% of the total water resources of these contributing catchments may cause saline water intrusion along the western coast and lead to a substantial deterioration in ground water quality.
- The fluctuation in water levels and solute concentration may have serious effects on the lake biology because of probable shift in the littoral zone (due to shift in water levels) and benthic zone (due to change in settling pattern).
- Measures should be taken to treat the waste water coming from the various industrial and domestic sources because it can be clearly seen that these effluents accumulate in the lake during the period of bund closure (more than three months). This is harmful for the aquatic life.

Conclusions

•If the proposed projects and diversions are implemented the closure period of the Thanneermukkam barrier will be still lengthened. This is because on account of lesser fresh water entering the lake from the rivers, it will take more time for the solute concentration to get stabilized to 2 ppt. level which is a borderline for the operation of the bund. Thus it may affect the paddy cultivation schedule as well as increase the pollution accumulation.

•The results also suggest that the model is not able to capture the effect of salinity intrusion from the sea very accurately, and the possible cause is that this model is not able to simulate three dimensional aspects of flow. Earlier observations (Joseph et al., 2009; Renosh, 2010) have established that seasonal stratification is found in the Cochin estuary, which is not possible to be modeled by a two-dimensional hydrodynamic model. This brings in the need to apply a 3-D model for studying the salinity and water quality aspects of the estuary in a more proper way.

Acknowledgement

First of all, I would like to thank the people who have made it possible for this study to substantiate. First of them is the **Hon'ble Minister for Water Resources, Government of Kerala, Shri P.J. Joseph**. Other officials whose guidance led to the prosperous progress of the work are:

1. Smt. P. Lathika, Chief Engineer, Inter-State Water (ISW), Government of Kerala;
2. Mr. M.K. Parameswaran Nair, Chairman, Mullaperiyar Cell;
3. Mr. Abraham Koshy and Mr. R. Mohanan, Assistant Executive Engineers, Irrigation Department, Government of Kerala

Thanks for your attention!