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One-Dimensional Modelling of Tidal Water Levels in Chilaw Lagoon, Sri Lanka

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INTRODUCTION & AIM

COASTAL LAGOONS OF SRI LANKA

Sri Lanka has 82 coastal lagoons distributed along its coastline. These are shallow water bodies connected to the sea through narrow and often restricted inlets. These physical features strongly affect tidal water level variations and water exchange within lagoons.

RESEARCH GAP

A limited number of modelling studies have been conducted in the country due to the complexity of the dynamical processes and lagoon geometry.

OBJECTIVES

- Develop a 1-D numerical modelling framework for tidal lagoons.
- Incorporate a choking model for the restricted inlet.
- Simulate temporal and spatial water level variations in Chilaw Lagoon.
- Provide a foundation for future extended lagoon studies.

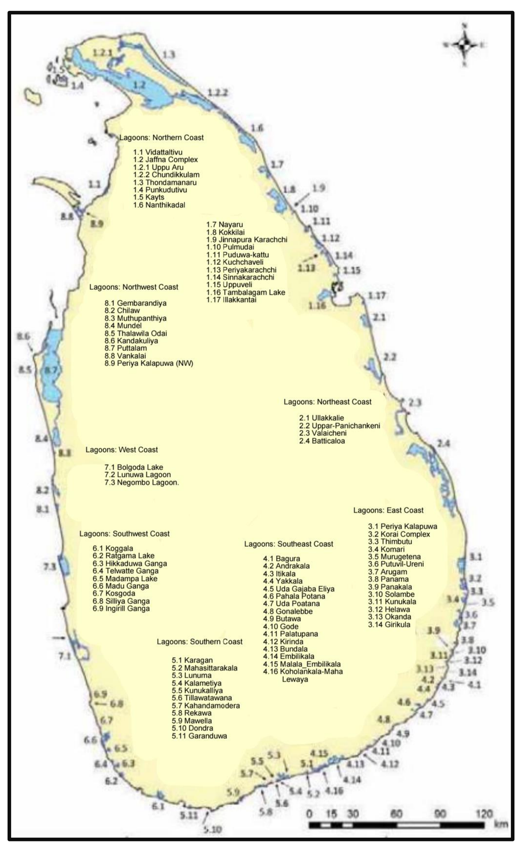

Figure 01: Distribution of coastal lagoons in Sri Lanka [1]

METHOD

METHODOLOGY

1. Develop and implement the continuity and momentum equations in their simplified form.
2. Incorporate a choking-flow model to represent the restricted inlet exchange.
3. Used observed sea-level data as boundary conditions for the model.
4. Compute the spatial and temporal variations in water levels within the study area.
5. Apply and validate the model using data from Chilaw Lagoon.

MATHEMATICAL FRAMEWORK

❖ Continuity Equation - conservation of mass [2]:

$$\frac{\partial \eta}{\partial t} = -\frac{1}{B}\frac{\partial Q}{\partial x}$$

η – free surface elevation
Q – cross-sectionally averaged volume flux
B – channel width

❖ Momentum Equation - conservation of momentum [2]:

$$\frac{\partial Q}{\partial t} + \frac{1}{A}Q\frac{\partial Q}{\partial x} = -gA\frac{\partial \eta_l}{\partial x} - B\frac{1}{\rho_0}\tau_x^b$$

A- cross-sectional area
ρ_0- density of the water
τ_x^b- bottom shear stress

❖ Choking Model - restriction of water exchange at narrow, shallow lagoon inlets [3]:

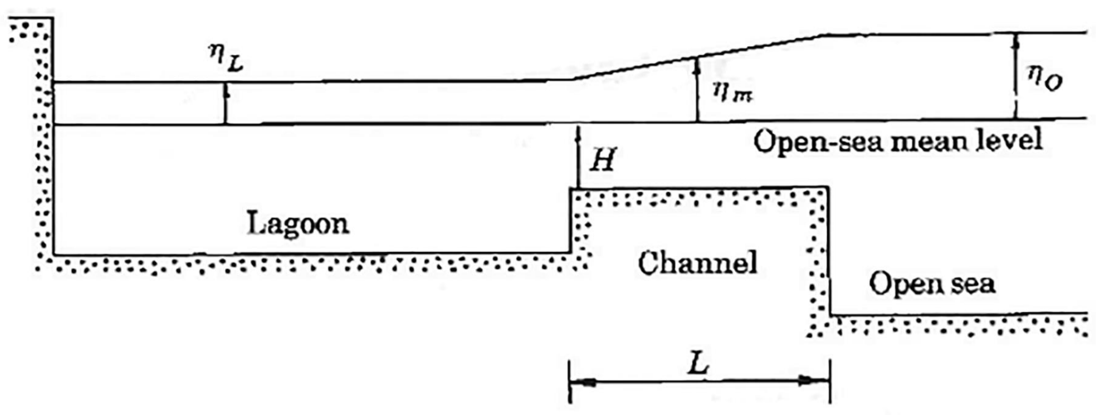

Figure 02: Geometry of a lagoon connected to the open sea by a shallow frictional channel [4]

η_l- sea level within the lagoon
η_o - oceanic sea level
η_m - mean sea level in the channel
H – mean depth of the channel

$$\frac{\partial \eta_l^*}{\partial t^*} = \sqrt{\frac{gB^2T^2H^3}{Y^2LC_d a}}\;\frac{\left(1+\frac{a}{H}\eta_m^*\right)^{\frac{3}{2}}}{\left(1+\frac{H}{2C_dL}\left(1+\frac{a}{H}\eta_m^*\right)\right)^{\frac{1}{2}}}\left(\frac{\eta_o^*-\eta_m^*}{\sqrt{|\eta_o^*-\eta_m^*|}}\right)+\frac{TQ_f}{aY}$$

Q_f – net freshwater supply
$\eta_m = (\eta_o + \eta_l)/2$
$\eta_l^* = \eta_l/a$
Y – surface area
$t^* = t/T$
a – tidal amplitude
T – tidal period
L – channel length

STUDY AREA

Location
Chilaw Lagoon, Northwestern Coast of Sri Lanka.

Characteristics
A shallow coastal lagoon connected to sea through a narrow, restricted inlet.

Significance
Important for local fisheries, ecology and coastal water exchange.

Challenge
The restricted inlet causes complex tidal damping and phase lag inside the lagoon.

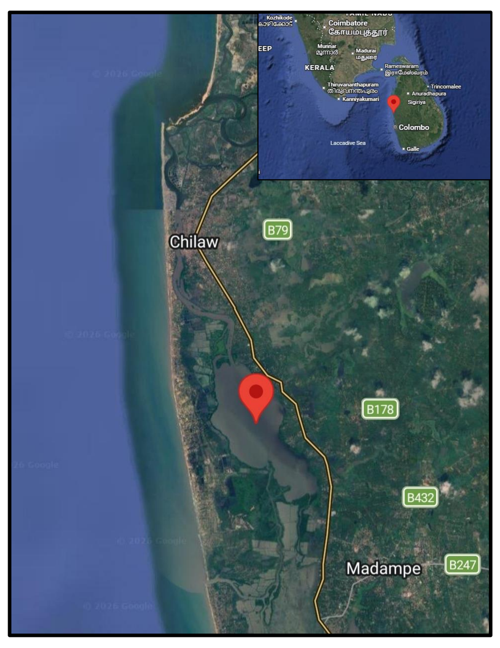

Figure 03: Chilaw Lagoon

RESULTS & DISCUSSION

➢ Numerical simulations show the propagation of tidal water levels within a shallow lagoon with a restricted inlet.

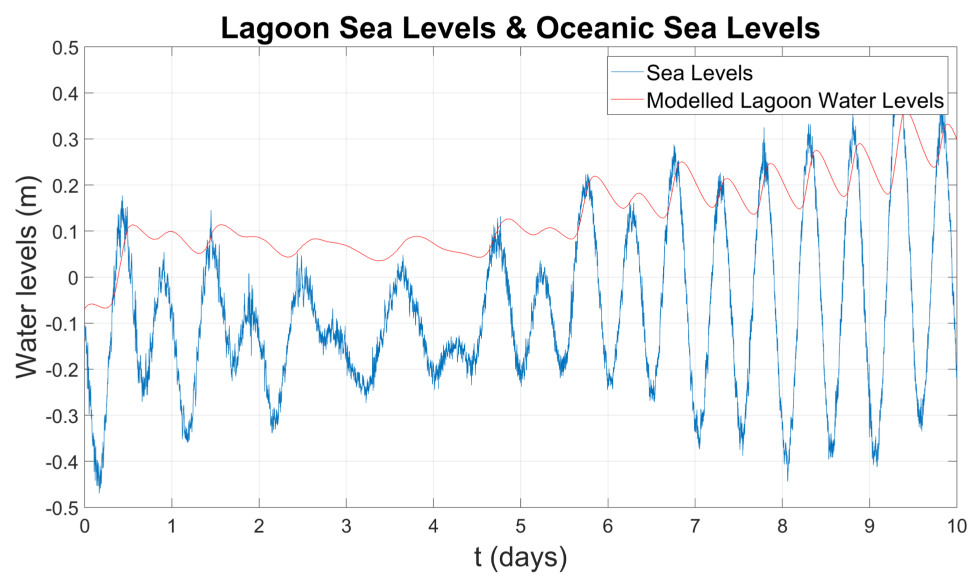

Figure 04: Comparison of ocean tidal elevation and simulated lagoon water levels over a 10-day period.

- The blue curve represents the ocean tidal elevation, while the red curve represents the simulated lagoon water level.
- A drag coefficient of Cd = 0.0022 was used following [3].
- Tidal amplitudes decrease within the lagoon, indicating damping caused by inlet restriction and bottom friction.

➢ Both temporal and spatial variations of lagoon water levels are illustrated.

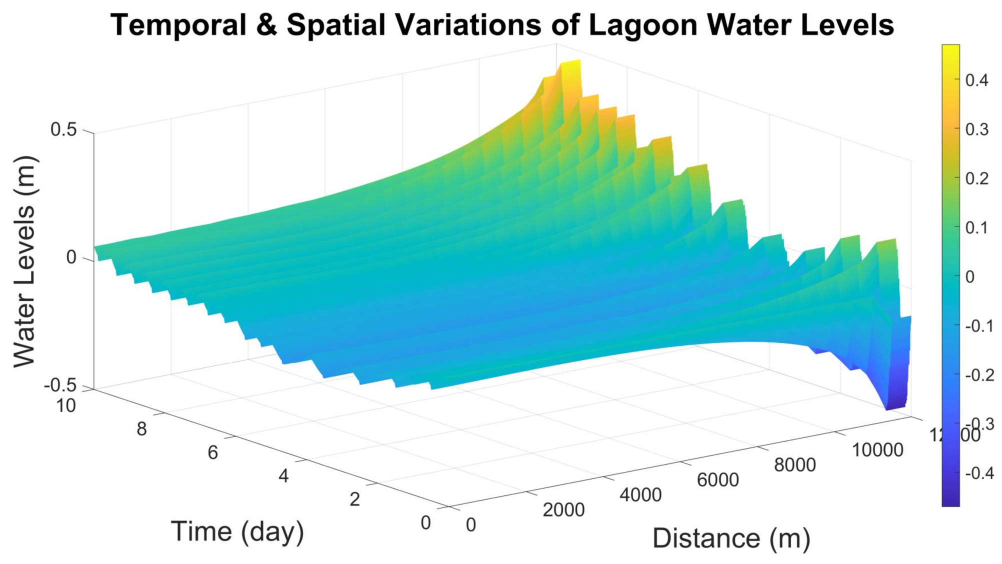

Figure 05: Temporal and spatial variations of lagoon water levels for 10 days

- The model reproduces the expected temporal and spatial tidal response of a shallow restricted lagoon system.

CONCLUSION

❑ Successfully developed a one-dimensional numerical framework for tidal lagoons.
- ✓ Captured the principal hydrodynamic behaviour of tidal lagoons.
- ✓ Effectively represented restricted inlet dynamics using the choking model.
- ✓ Reproduced temporal and spatial tidal variations in Chilaw Lagoon.
- ✓ Provided an initial understanding of tidal behaviour in restricted lagoon systems.

FUTURE WORK

+ Validation using observed lagoon water level data.
+ Model improvement through calibration using field measurements.
+ Extension of the model to include freshwater discharge processes.
+ Integration of salinity transport modelling.

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