A STUDY OF THE NEGOMBO LAGOON WITH RESPECT TO THE
SALINITY VARIATION AND POLLUTION OF THE LAGOON
WATER AND EFFECTS OF PROPOSED DREDGING ACTIVITIES

By

R.N. Malawaraaratchi

This thesis was submitted to the department of Civil Engineering of the University
of Moratuwa in partial fulfilment of the requirement for the Degree of
Master of Science
in
Environmental Management

Research work supervised
By
Prof. Mrs. N. Rathnayake
Dr. S.P. Samarawickrama

Department of Civil Engineering
University of Moratuwa
Moratuwa
Sri Lanka
December 2003
Abstract

Negombo Lagoon is a shallow basin estuary, located on the West coast of Sri Lanka, serving important functions including fishing and tourism. It drains water carrying nutrients and organic matter from the heavily populated catchment area and has faced the threat of the degradation of water quality. The objectives of this research are to study the seasonal and diurnal variation of salinity in the estuary, study the pollution status of the estuary; study the effects of dredging on the water quality and to recommend remedial measures.

17 sampling locations were selected for the study, which included points in the estuary and fresh water feeders. A Sampling programme of 6 days which covered both wet and dry weather as well as the spring and neap tidal periods was carried out. Salinity, nutrients and COD were measured at the flood and ebb tides.

According to the salinity measurements, in the dry period, the estuary is fully mixed. Stratified conditions occur when the fresh water flow rate increases. Chl a measurements were used to assess the trophic state of the estuary and fresh water feeders. The estuary is eutrophicated both in the wet and dry periods and some locations are even hypertrophic. Out of the fresh water feeders, Hamilton canal is mesotrophic and has faced the threat of eutrophication. According to the literature, limiting potential of the tropical estuaries has been found to shift from N to P with higher fresh water flow rates and results of this study agree well with the above finding. Limiting P inflows is a remedial measure to improve the water quality. Where the loads of DIN and TN are concerned, Dandugam-Oya was found to bring the highest loads irrespective of the climatic conditions. Where the Phosphate loads are concerned, Ja-ela brings significant, constant loads on rainy season, while Dandugam-Oya brings the highest load with the highest flow rate. Out of the 7 dredging options studied, option 6 is the most feasible one.
Acknowledgement

This is to express my deep gratitude to all those who have helped me to complete this research project successfully.

I have been privileged to work with two dedicated supervisors, Professor (Mrs.) N. Ratnayake and Dr. S.P. Samarawickrama.

First and foremost let me extend my heartiest gratitude and deep appreciation to Professor (Mrs.) N. Ratnayake for her great contributions to the research project. Amidst her heavy work schedule as the Director of the postgraduate Studies, University of Moratuwa, she devoted her valuable time on this research project. She provided me with all the necessary resources to make this research a success.

I would like to extend my whole hearted gratitude to Dr. S. P. Samarawickrama for his constant support and valuable guidance. He provided me many resources such as books and journals. His great assistance is greatly appreciated.

A special vote of thanks goes to Dr. Mahesh Jayaweera, Senior Lecturer, Department of Civil Engineering, University of Moratuwa for his generous contribution to make this study a success.

I would like to thank Dr. N. Gunawardene, Senior Lecturer, Department of Civil Engineering, University of Moratuwa for helping me with statistical analysis.

My sincere gratitude is extended to Miss Priyanka Dissanayaka and Mrs. Nilanthi Gunathilaka, Environmental Engineering Division, Department of Civil Engineering, University of Moratuwa for helping me in many ways and their willingness to support me at any time.

A special vote of thanks goes to Mr. Thisara Welhenge for his great support.
I am greatly indebted to Mr. Justin De Silva, Environmental Engineering Division, Department of Civil Engineering, University of Moratuwa and Mr. Anthony Joseph Fernando of Negombo for their devotion in the sampling programme.

I would like to thank all the members of the staff of the Department of Civil Engineering, University of Moratuwa who helped me in various ways.

I express my gratitude to Mr. C. Fernando, Mr. P. Egodawatta and Mr. Sepala in the Lanka Hydraulic Institute for providing me journals and necessary information.

The financial assistance provided by the Asian Development Bank (ADB) and APN/IGBP project on Biogeochemical Budgeting is greatly appreciated.

I thank my colleagues Lashan, Jagath, Dilani, Anusha, Dayani, Nilmini, Thamara, Sudesh, Ranil, Botheju, Rukma and Kolitha for their encouragement.

My deepest gratitude goes to my parents for their constant encouragement.

Finally I would like to give my special thanks to my husband Gamini and my son Gihan whose patient love enabled me to complete this work.
Contents

Abstract i
Acknowledgment ii
Table of contents iv
List of figures vi
List of tables viii
List of annexes x
Abbreviations xi
1.0 Introduction 1
  1.1 Background 1
    1.1.1 Climate 3
    1.1.2 Geology 4
  1.2 Research objectives 4
  1.3 Structure of thesis 4
2.0 Literature Review 6
  2.1 General 6
  2.2 Water Quality 6
    2.2.1 COD 7
    2.2.2 pH 7
  3.3 Salinity 7
    2.3.4 Nutrients 9
  2.3 Major Problems Encountered in the Negombo estuary 16
    2.3.1 Reduction of the water area by sedimentation 16
    2.3.2 Poor Water Exchange 18
    2.3.3 Unplanned Human Settlement 19
    2.3.4 Unplanned Fishery Harbour 21
    2.3.5 Degradation of the Ecosystem 21
    2.3.6 Water Pollution 22
  2.4 Reduction of Flushing Time with Dredging 29
  2.4 Previous Studies on Dredging 30
3.0 Methodology 34
  3.1 General 34
  3.2 Sampling Sites 34
  3.3 Sampling Programme 35
    3.3.1 Hydrology 36
    3.3.2 Physico-Chemical data 36
    3.3.3 Nutrients 36
  3.4 Sample Preservation 36
  3.5 chemical analysis 37
4.0 Results 38
  4.1 Physico-Chemical Parameters 38
    4.1.1 Hydrology 38
    4.1.2 Salinity 39
    4.1.3 DO 40
    4.1.4 Temperature 41
4.1.5 pH

4.2 Nutrients
   4.2.1 Nitrogen
   4.2.2 Phosphorus

4.3 Temporal Variations (Average Flood and Ebb)
   4.3.1 Temperature
   4.3.2 Organic Pollutants (COD)
   4.3.3 Nitrate-N
   4.3.4 Ammoniacal- N
   4.3.5 TN
   4.3.6 Total Reactive Phosphorus (TRP)
   4.3.7 TP

4.4 Loads of Nutrients
   4.4.1 Loads of DIN
   4.4.2 Loads of TN
   4.4.3 Loads of Phosphate-P
   4.4.4 Loads of TP

4.5 Limiting Nutrient
   4.5.1 Limiting Nutrient in Dry Season
   4.5.2 Limiting Nutrient in Wet Season

4.6 Variations in Flood and Ebb Tides

4.7 Determination of the Trophic State
   4.7.1 Chlorophyll

4.8 Dredging Scenarios
   4.8.1 Option 1
   4.8.2 Option 2
   4.8.3 Option 3
   4.8.4 Option 4
   4.8.5 Option 5
   4.8.6 Option 6
   4.8.7 Option 7

4.9 Comparison of Dredging

5.0 Conclusions
   5.1 General
   5.2 Key Results and Comments
   5.3 Recommendations to Improve the Water Quality
   5.4 Recommendations for Future Researches
List of Figures

1.1 Muthujawela Marsh and Negombo Estuary .............................. 1
1.2 Various fishing gears, used in the Negombo estuary ................. 3
2.1 Sampling locations (Previous study) ..................................... 8
2.2 Transformation of nitrogen ................................................. 9
2.3 Phosphorus cycle .............................................................. 11
2.4 Schematic cross-sections of an estuary with (A) natural rates of sedimentation (B) increased sedimentation .................... 17
2.5 Housing development in the islands ..................................... 20
2.6 Visual pollution ............................................................... 27
2.7 Estuary inlet Showing the Selected Channel Sections ............... 31
3.1 Sampling locations ............................................................ 34
4.1 Monthly Rainfall in Year 2002 ............................................ 38
4.2 Variation of Total Fresh Water Discharge from River and Canals ... 39
4.3 Variation of average salinity ............................................... 39
4.4 Variation of average temperature ....................................... 41
4.5 Variation of pH .................................................................. 41
4.6 Variation of average nitrate-N ............................................. 43
4.7 Variation of average ammoniacal-N .................................... 44
4.8 Variation of average TN ...................................................... 44
4.9 Variation of average TRP ..................................................... 45
4.10 Variation of average size .................................................... 45
4.11 Temporal and Spatial variations of temperature ..................... 46
4.12 Temporal and Spatial variations of COD ............................... 46
4.13 Variation of Mean COD with fresh water discharge ............... 47
4.14 Temporal and Spatial variations of nitrate-N ......................... 47
4.15 Temporal and Spatial variations of ammoniacal-N ................. 48
4.16 Temporal and Spatial variations of TN ................................. 49
4.17 Temporal and Spatial variations of TRP ............................... 49
4.18 Temporal and Spatial variations of TP ................................. 50
4.19 Variation of DIN loads ....................................................... 51
4.20 Variation of TN loads ........................................................ 53
4.21 Variation of phosphate-P loads .......................................... 54
4.22 Variation of TP loads ........................................................ 56
4.23 Temporal and spatial variation of N/P ratio .......................... 56
4.24 Difference of nitrate-N in flood and ebb .............................. 59
4.25 Difference of ammoniacal-N in flood and ebb ....................... 59
4.26 Difference of TN in flood and ebb ...................................... 60
4.27 Difference of TRP in flood and ebb .................................... 61
4.28 Difference of TP in flood and ebb ...................................... 61
4.29 Maximum flood discharge for option 1 ............................... 72
4.30 Maximum flood discharge for option 2 ............................... 73
4.31 Maximum flood discharge for option 3 ............................... 74
4.32 Maximum flood discharge for option 4 ............................... 75
4.33 Maximum flood discharge for option 5 ............................... 76
4.34 Maximum flood discharge for option 6 77
4.35 Maximum flood discharge for option 7 78
4.36 Maximum flood discharges at the existing condition 80
4.37 Computational domain showing output points 81
4.38 Variation of surface elevation at point 4 81
4.39 Variation of longitudinal component of velocity at point 4 82
4.40 Variation of transverse component of velocity at point 4 82
4.41 Comparison of longitudinal velocities at points 5 and 5A 83
4.42 Comparison of cumulative exchange of water into and out of the estuary 84
# List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Average characteristics of lakes, streams and coastal marine waters of different trophic states.</td>
<td>12</td>
</tr>
<tr>
<td>2.2</td>
<td>Growth of the Population in the Negombo Municipality</td>
<td>19</td>
</tr>
<tr>
<td>2.3</td>
<td>Significant Adverse Impacts that could occur by each type of Pollution</td>
<td>23</td>
</tr>
<tr>
<td>2.4</td>
<td>Proposed Classification of use for Coastal Waters in Sri Lanka</td>
<td>24</td>
</tr>
<tr>
<td>2.5</td>
<td>Classification of Inland Waters</td>
<td>25</td>
</tr>
<tr>
<td>2.6</td>
<td>Total and Faecal coliforms in the Negombo Estuary</td>
<td>26</td>
</tr>
<tr>
<td>3.1</td>
<td>Sampling Programme</td>
<td>35</td>
</tr>
<tr>
<td>3.2</td>
<td>Preservation Techniques Used For Various Parameters</td>
<td>37</td>
</tr>
<tr>
<td>3.3</td>
<td>Methodology used for chemical analysis</td>
<td>37</td>
</tr>
<tr>
<td>4.1</td>
<td>DO</td>
<td>40</td>
</tr>
<tr>
<td>4.2</td>
<td>Calculation of loads of DIN in the Morning Sampling Session</td>
<td>50</td>
</tr>
<tr>
<td>4.3</td>
<td>Calculation of loads of DIN in the Evening Sampling Session</td>
<td>51</td>
</tr>
<tr>
<td>4.4</td>
<td>Calculation of Average loads of DIN</td>
<td>51</td>
</tr>
<tr>
<td>4.5</td>
<td>Calculation of loads of TN in the Morning Sampling Session</td>
<td>52</td>
</tr>
<tr>
<td>4.6</td>
<td>Calculation of loads of TN in the Evening Sampling Session</td>
<td>52</td>
</tr>
<tr>
<td>4.7</td>
<td>Calculation of Average loads of TN</td>
<td>52</td>
</tr>
<tr>
<td>4.8</td>
<td>Calculation of loads of phosphate-P in the Morning</td>
<td>53</td>
</tr>
<tr>
<td>4.9</td>
<td>Calculation of loads of phosphate-P in the Evening</td>
<td>53</td>
</tr>
<tr>
<td>4.10</td>
<td>Calculation of Average loads of phosphate-P</td>
<td>54</td>
</tr>
<tr>
<td>4.11</td>
<td>Calculation of loads of TP in the Morning</td>
<td>55</td>
</tr>
<tr>
<td>4.12</td>
<td>Calculation of loads of TP in the Evening</td>
<td>55</td>
</tr>
<tr>
<td>4.13</td>
<td>Calculation of Average loads of TP</td>
<td>55</td>
</tr>
<tr>
<td>4.14</td>
<td>Variation of N/P Ratio at Different Locations</td>
<td>57</td>
</tr>
<tr>
<td>4.15</td>
<td>Chlorophyll and Algal Biomass on 5th of January 2003</td>
<td>62</td>
</tr>
<tr>
<td>4.16</td>
<td>Chlorophyll and Algal Biomass on 10th of February 2003-Day 6</td>
<td>63</td>
</tr>
<tr>
<td>4.17</td>
<td>TN, TP and Chlorophyll a levels at Location 1(Sea)</td>
<td>63</td>
</tr>
<tr>
<td>4.18</td>
<td>TN, TP and Chl a Levels at the Mouth of the Estuary</td>
<td>64</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>4.19</td>
<td>TN, TP and Chl a Levels at the Middle Part of the Estuary</td>
<td>65</td>
</tr>
<tr>
<td>4.20</td>
<td>TN, TP and Chl a Levels of the Fresh water Inflows</td>
<td>65</td>
</tr>
<tr>
<td>4.21</td>
<td>Maximum Flood Discharges (m$^3$/s) for Different Dredging Scenarios</td>
<td>70</td>
</tr>
<tr>
<td>4.22</td>
<td>Percentage (%) increase/decrease in Flood Discharge for Different Dredging Scenarios</td>
<td>71</td>
</tr>
<tr>
<td>4.23</td>
<td>Comparison of Discharge, Velocity and Cross Sectional Areas</td>
<td>85</td>
</tr>
</tbody>
</table>
List of Annexes

A 1  Proposed Ambient Water Quality Standards for Inland Waters
A 2  Coastal Water Quality Standards
A 3  Data Sheet on 25 September 2002-Morning
A 4  Data Sheet on 25 September 2002-Evening
A 5  Data Sheet on 15 October 2002-Morning
A 6  Data Sheet on 15 October 2002-Evening
A 7  Data Sheet on 7 November 2002-Morning
A 8  Data Sheet on 7 November 2002-Evening
A 9  Data Sheet on 2 January 2003
A 10 Data Sheet on 10 February 2003
A 11 Discharges of Fresh Water Feeders
List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>CEA</td>
<td>Central Environmental Authority</td>
</tr>
<tr>
<td>Chl a</td>
<td>Chlorophyll a</td>
</tr>
<tr>
<td>Chl b</td>
<td>Chlorophyll b</td>
</tr>
<tr>
<td>Chl c</td>
<td>Chlorophyll c</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>DIN</td>
<td>Dissolved Inorganic Nitrogen</td>
</tr>
<tr>
<td>DIP</td>
<td>Dissolved Inorganic phosphorus</td>
</tr>
<tr>
<td>DON</td>
<td>Dissolved Organic Nitrogen</td>
</tr>
<tr>
<td>DOP</td>
<td>Dissolved Organic Phosphorus</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Poly Ethylene</td>
</tr>
<tr>
<td>IRMP</td>
<td>Integrated Resource Management Programme</td>
</tr>
<tr>
<td>LHI</td>
<td>Lanka Hydraulic Institute</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>P</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>PON</td>
<td>Particulate Organic Nitrogen</td>
</tr>
<tr>
<td>POP</td>
<td>Particulate Organic Phosphorus</td>
</tr>
<tr>
<td>PP</td>
<td>Particulate Phosphorus</td>
</tr>
<tr>
<td>SD</td>
<td>Secchi Depth</td>
</tr>
<tr>
<td>SE</td>
<td>Standard Error</td>
</tr>
<tr>
<td>TN</td>
<td>Total Nitrogen</td>
</tr>
<tr>
<td>TP</td>
<td>Total Phosphorus</td>
</tr>
<tr>
<td>UOM</td>
<td>University of Moratuwa</td>
</tr>
</tbody>
</table>
Declaration

This thesis is a report of research work carried out in the department of Civil engineering, University of Moratuwa, Sri Lanka, between February 2002 and April 2003. The work included in the thesis in part or whole has not been submitted for any other academic qualification at any institution.

R. N. Malawaraaratchi
Department of Civil Engineering
University of Moratuwa

Prof. (Mrs). N. Rathnayake
Supervisor
University of Moratuwa