ASSESSMENT OF IMPACT OF POLLUTANTS IN THE RIVER BURIGANGA USING A WATER QUALITY MODEL

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DHAKA, BANGLADESH

DECEMBER, 1996

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I hereby certify that the research work embodied in this thesis has been performed by the author under the supervision of Dr. A.B.M. Badruzzaman, Assistant Professor of the Department of Civil Engineering, BUET. Neither this thesis nor any part of it has been submitted or is being concurrently submitted else where for any other purpose (except for publications).

December, 1996

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ACKNOWLEDGEMENT

The author wishes to express his deepest gratitude and indebtedness to his supervisor Dr. A.B.M. Badruzzaman, Assistant Professor, Department of Civil Engineering, BUET for his persistent guidance and encouragement at all stages of this research work. The author considers it a great opportunity to have a share of some of his knowledge and expertise in the field of water quality modelling.

The author is grateful to Dr.M. Azadur Rahman, Professor and Head, Department of Civil Engineering, BUET, Dr.M. Rezaur Rahman, Research Associate Professor, IFCDR, BUET and Dr.M. Ashraf Ali, Assistant Professor, Department of Civil Engineering, BUET for their valuable suggestions for the improvement of the organisation and contents of this thesis.

Sincerest gratitude is expressed to Mr. Jalaluddin Md. Abdul Hye, Executive Engineer, BWDB and Deputy Project Coordinator, SWSMP-III, SWMC. It is Mr. Jalal who first introduced to the author the idea of carrying out a research work regarding the Buriganga.

The author is grateful to Mr. Anders Malmgren-Hansen, Head of the Ecological Modelling Centre, Denmark for his interest and valuable suggestions for this research work.

Sincerest thanks are extended to the authorities of the DOE and BUET for the arrangement of testing of a huge number of samples at their laboratory. Special gratitude is due to the laboratory personnel for their genuine help extended to the author.

The author expresses his gratefulness to the authority of the Surface Water Modelling Centre (SWMC) for allowing him to use the MIKE 11 river modelling system along with all relevant data and computer facilities to carry out the research work. Sincere gratitude is expressed to Mr. Emaduddin Ahmad, Superintending Engineer, BWDB and Project Coordinator, SWSMP-III, SWMC, Dr. Guna Nidhi Paudyal, Chief Technical Advisor, SWSMP-III, SWMC, Mr. Abu Saleh Khan, Head of the Special Topics Division, SWMC and Mr. M. Fazle Rabbi, Local Consultant of SWMC, for their help and encouragement in carrying out this work. Special thanks to Mr.K.N. Alam, Draftsman of SWMC for providing the author with a number of complicated tracings, and thanks to Mr. F.K. Noon, Typist of SWMC for typing a considerable portion of this thesis. Interests shown by all other members of SWMC to make this work a success were sources of inspiration for the author.

Finally, the author wishes to thank his parents, sister, wife and daughter for their support in conducting this study.

ABSTRACT

The river Buriganga, which runs by the side of the Dhaka city, is at present one of the most polluted rivers in Bangladesh. The Dhaka city is one of the densely populated cities in the world, but only partly sewered. Consequently, an enormous amount of domestic and industrial wastes are being released in the Buriganga everyday. This disposal rate is increasing at an alarming rate. The objectives of this study were to investigate the status of the Buriganga river water quality in terms of some important water quality parameters, and to assess the impact of pollutants using an existing water quality model.

To assess the water quality, extensive sampling of water and wastewater were carried out for subsequent laboratory investigations. In situ measurements were carried out for some water quality parameters. In addition, extensive literature survey was conducted to collect available data on water quality of the Buriganga river. The present status of pollution in the Buriganga as well as the trend of pollution was addressed through the analyses of the water quality data.

The modelling study focuses on the impact of pollutant of biodegradable nature which causes depletion of Dissolved Oxygen (DO) in a river. Suitable DO concentration in river water is the most important criterion for the survival of aquatic life, and maintenance of the aquatic ecosystem. A one dimensional water quality model was developed for the assessment of impact of oxygen demanding wastes on the Dissolved Oxygen (DO) in the river. MIKE 11 river modelling system developed by the Danish Hydraulic Institute (DHI) and available with the Surface Water Modelling Centre (SWMC) was used for the development of the model. In this study, the December, 1994 hydrodynamic and water quality data were used for dry season calibration. Alternative scenarios with varying loading conditions of the biodegradable pollutant were considered and the most likely condition of the river water quality under each scenario was predicted.

In lieu of the inherent shortcomings of a one-dimensional model, the observed DO levels of the Buriganga river were well replicated. Alternative scenario study gives possible response of the Buriganga river quality following different loading conditions. The model results indicate that the Buriganga river water quality may not improve appreciably with respect to DO, following reduction of a single major point source such as the Dholai Khal or the

Hazaribagh tannery outfall. An integrated approach involving treatment of a number of major point sources followed by their disposal at a distant point near the confluence of the Dhaleswari-Lakhya river may prove effective in improving the DO of the Buriganga river.

However, lack of data and time constraint have restricted the model verification process in this study. In addition, other water quality parameters such as Ammonia, Nitrate, Phosphate, Coliforms could not be modelled due to lack of sufficient data. Thus, verification of the model using additional set of data may provide valuable assistance in making policy decisions using this model.

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LIST OF ABBREVIATIONS

AD	Advection-Dispersion
ADB	Asian Development Bank
BOD	Biochemical Oxygen Demand
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
COD	Chemical Oxygen Demand
DIFP	Dhaka Integrated Flood Protection
DIFPA	Dhaka Integrated Flood Protection Authority
DND	Dhaka Narayanganj Demra
DO	Dissolved Oxygen
DOE	Department of Environment
DWASA	Dhaka Water and Sewerage Authority
EIP	Environmental Improvement Project
FAP	Flood Action Plan
HD	Hydrodynamic
HIS	Hydrological Information System
IFCDR	Institute of Flood Control and Drainage Research
JICA	Japan International Cooperation Agency
MODS	Maintenance, Operation, Distribution and Supply
NCRM	North Central Region Model
NEMPCP	National Environmental Monitoring and Pollution Control Project
PSTP	Pagla Sewage Treatment Plant
SS	Suspended Solids
STP	Sewage Treatment Plant
SWMC	Surface Water Modelling Centre
TSS	Total Suspended Solids (same as SS)
USEPA	United States Environmental Protection Agency
WQ	Water Quality
WQM	Water Quality Model

CHAPTER 1

INTRODUCTION

River water is a resource on which large parts of the world's population are highly dependent. The river water is used for water supply, irrigation, power production, cooling water, navigation, fishing and aquaculture, industrial production, receiver of wastes and swimming/bathing. Pollutants entering into a river can be broadly divided into five groups: organic, inorganic, sediments, radioactive materials and heat. These broad five groups of pollutants can be further subdivided into a number of groups, e.g. oxygen consuming, toxic, pathogenic etc. In assessing impact of pollutants on a river water two issues need to be considered: the nature of pollutants entering into the river and its potential use for specific purposes. Usually, standards are set in terms of different physical, chemical and bacteriological parameters of water depending on the desired use. Acceptability of the water depends on the conformity to these standards. Although polluted, the Buriganga river is currently being used for various purposes including domestic, industrial as well as drinking purposes.

1.1 Background of the Study

Rapid expansion of population and industry in the metropolitan cities such as Dhaka, Khulna and Chittagong and the increased use of fertiliser and agrochemicals countrywide necessitated an increased awareness of water quality and environmental standards.

Pollution in the surface water of Bangladesh is principally due to uncontrolled disposal of untreated industrial and domestic wastes. Human population and industrialization are increasing at an alarming rate in Bangladesh. The population density is extremely high in and around the city areas. Consequently, the huge amount of liquid waste - industrial and domestic - find their easy way to the nearby water courses. e.g. the river Buriganga near the Dhaka city. As there is no control over or treatment for the industrial wastes discharged to the surface water, the trend of pollution in the rivers are increasing day by day. The problem has been compounded by the extremely inadequate sewerage facility.

1.2 Scope of the study

The Dhaka city is situated by the side of the river Buriganga. It is one of the most densely populated cities in the world. Approximately, nine million people are at present living in this city which is only partly sewered. Also, a number of industries have been installed during the last decade with a large number in the process of installation. In turn, the amount of sewage (treated or untreated) and industrial wastes (mostly untreated) disposed in the river have been increasing tremendously.

Untreated domestic sewage contains pollutants mainly of biodegradable nature which results in oxygen depletion in a river. On the other hand, the parameter of highest importance for the state of a river system is the concentration of Dissolved Oxygen (DO). The most important water quality standards are then related to parameters, which affect the oxygen concentration. Therefore, when pollutants entering into a river are addressed, importance is normally attributed to the concentration of oxygen consuming substances. Untreated industrial wastes may contain toxic substances, e.g. Chromium from tanneries which, if present in excess quantity, may cause diseases in fish and other aquatic life and may cause fish kills. If used for bathing or household purpose, river water containing toxic substances may adversely affect human health.

The Department of Environment (DOE) analyzed cumulative data from 1984 to 1992 for three parameters, namely Total Solids (TS), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) and found a definite deterioration in water quality trend albeit in very small quantity (DOE, 1992). They found that the total solids concentration was significantly on the rise, which was attributed to erosion and human activities over the period. Decrease of the DO was also noted. The DOE then opined that close monitoring should be carried out to investigate the pollution as contamination of such magnitude might be disastrous to the aquatic ecosystem.

Browder (1992) carried out monitoring programme in the Buriganga in the months of May, July, November and February, 1991-92. He concluded that the Buriganga experienced severe water quality problem during the dry season when the DO levels were below the accepted minimum of 4.0 mg/l from Hazaribagh to Pagla. In addition, the coliform values were very high, ranging from 10,000 to 100,000 per 100 ml. According to Browder, the high level of domestic and industrial discharges, as evidenced by the low DO levels and the high coliform levels, had made the Buriganga unsuitable as a raw water source.

Ahmed (1988) conducted an investigation to assess the effects of effluents discharged in the Buriganga on DO. A dissolved oxygen model was developed considering hydraulic characteristics, DO balancing parameters of the river and effluent characteristics. He concluded that in the dry season, the critical DO of about 3.0 mg/l occurs about 12 km upstream of the Dhaleswari river. In about 9 km of the river flowing by the densely populated area of Dhaka city, DO remains below the desirable level of 4.0 mg/l.

The Institute of Flood Control and Drainage Research (IFCDR), BUET has carried out a research on Management of Buriganga River Water Quality Under Alternative Scenarios' (IFCDR, 1994). They have calibrated and verified a hydrodynamic model using MIKE 11 for the Buriganga river system. An example management programme was also formulated. The management programme showed that considerable waste load can be assimilated by the river, if managed properly, without violating the water quality standards.

The brief reviews of some of the major studies presented above seem to indicate that there exists considerable difference in opinion among different researchers/authorities regarding the severity of pollution in the Buriganga. Thus, an extensive data collection programme conducted along the entire reach of the Buriganga river system over a prolonged period may provide some insight in the present status of pollution.

The assimilative capacity of the Buriganga river is dependent on the present status of pollution. Adoption of restoration option depends on studying different management alternatives using a mathematical tool specifically developed for the surface water system. Thus, a water quality model may be developed or an existing one may be applied following calibration and verification with the available data to assess the impact of various management alternatives for the Buriganga river system. This may provide the information to select a single or a combination of a number of alternatives for restoration of the water quality of the Buriganga river.

1.3 Objective of the Study

The overall objectives of this study are to assess the present status of water quality of the Buriganga river, and to assess the impact of pollutants in the river using an existing water quality model. The specific objectives are:

- Assessment of the existing quality of water of the Buriganga, in terms of some standard water quality parameters: DO, BOD, COD, TSS, NH_3, NH_4, NO_3, Ortho-PO_4, Cr, E.Coli and Total coliforms.

- Detection/assessment of the potential sources and mode of pollution.

- Application of an existing water quality model to assess the impact of different management alternatives on the DO of the Buriganga river.

1.4 Methodology

The following steps have been adopted to attain the objectives of the study:

- The water quality conditions in the Buriganga have been assessed through in situ measurements of water temperature and DO concentrations at a number of monitoring locations on three different occasions in the dry season from December, 1994 to April, 1995. Samples have been collected from those locations for testing of other water quality parameters.

- Direct measurements of wastewater discharges from major point sources have been carried out on two different occasions in the dry season. Samples, for laboratory testing, have been collected at the time of discharge measurements. The wastewater discharge and concentration of water quality parameters (from laboratory testing) have been used for wet loading estimates.

- Dry loading estimates for water quality parameters have been made using available information on drainage zones and sewerage facilities in Dhaka city.

- Information/data on the performance of the Pagla Sewage Treatment Plant have been collected to estimate the pollutant loads to the Buriganga.

- The major water polluting industries in Dhaka city have been identified, and pollution discharges from these industries have been estimated.

- Historical water quality data published by the DOE have been collected and analysed for the assessment of pollution trend in the Buriganga.

- To assess the impact of oxygen demanding wastes in the Buriganga, a water quality model has been used. The model was developed implementing the integrated Hydrodynamic (HD), Advection-Dispersion (AD) and Water Quality (WQ) modules of the MIKE 11 river modelling system, available with the Surface Water Modelling Centre (SWMC). In the present study, only the effect of biodegradable pollutant, which causes oxygen depletion in the aquatic environment, has been addressed.

- Model sensitivity has been assessed implementing few alternative scenarios with different waste load conditions of biodegradable nature. Impact on the DO levels in the Buriganga following different probable management alternatives have been studied through these scenarios.

1.5 Organisation of the Thesis

Chapter 2 describes the profile of the study area - encompassing hydrological feature and river network, drainage feature, sewerage network and industrial areas.

In Chapter 3, a detailed review of literature, pertaining to the pollution in the Buriganga, has been presented. In addition, brief review of literature, concerning water quality modelling carried out elsewhere in the world, has been presented.

In Chapter 4, sampling procedures and results of laboratory analysis of water and wastewater samples have been presented. A comprehensive analyses of a set of water quality data, procured in partial fulfilment of the objectives of this study, have also been presented in this chapter. Analyses of relevant historical data collected from the DOE and the Pagla Sewage Treatment Plant have also been presented.

Chapter 5 has been devoted to the analyses of pollution sources, and estimation of pollutant loadings being received by the Buriganga river system.

In Chapter 6, modelling strategy has been described. It includes the description of different modules of MIKE 11 river modelling system along with their theoretical background, model setups and calibrations of the hydrodynamic and water quality models.

Chapter 7 has been devoted to the study of the impact of pollutants in the Buriganga river system under alternative scenarios. For the present study, only the depletion of DO in the river due to the presence of oxygen consuming pollutants have been discussed.

In Chapter 8, concluding remarks have been made about the outcome of the study, along with relevant recommendations.

CHAPTER 2

PROFILE OF THE STUDY AREA

2.1 Hydrological Feature and River Network

Dhaka city, the study area, lies within the north central region of Bangladesh. The area is enclosed by the Tongi Khal on the north, the DND embankment on the south, the Balu river on the east, and the Turag and Buriganga rivers on the west.

The local surface water hydrology around Dhaka is complex. The Buriganga is a tributary of the Dhaleswari river which empties into the Meghna. The Turag, a small river demarcating the western boundary of Dhaka falls into the Buriganga just north of the main urban area. The upstream of the Buriganga, above the confluence of the Turag, was formerly a branch of the Dhaleswari and contributed substantially to the flow in the Buriganga. However, in recent times this portion of the river has silted up. During the lean flow period, the discharge of the Turag along with the local runoff are the main sources of water into the Buriganga. In the monsoon season, from the months of June to October, the flow rate in the Buriganga river is on the order of 400 to 850 cumec (Camp Dresser & McKee, et al, 1989). In the dry season, with tidal effect, the net flow is very low or non-existent (SWMC, 1996). This low flow rates of the Buriganga during the dry season implies that there is little dilution capacity in the Buriganga during this period causing serious degradation in quality of water as described in the subsequent sections.

The Lakhya river meets the Dhaleswari, only 11 km downstream of the Buriganga river. These rivers are tidal during the dry season when flows are low. Saline intrusion into the river system stops well downstream of Dhaka.

The Buriganga-Lakhya river system is shown in Figure 2.1.

At the beginning of this study, while modelling with the Buriganga river alone, the downstream boundary was considered at Hariharpara at Chianage 40.00 on the Buriganga.

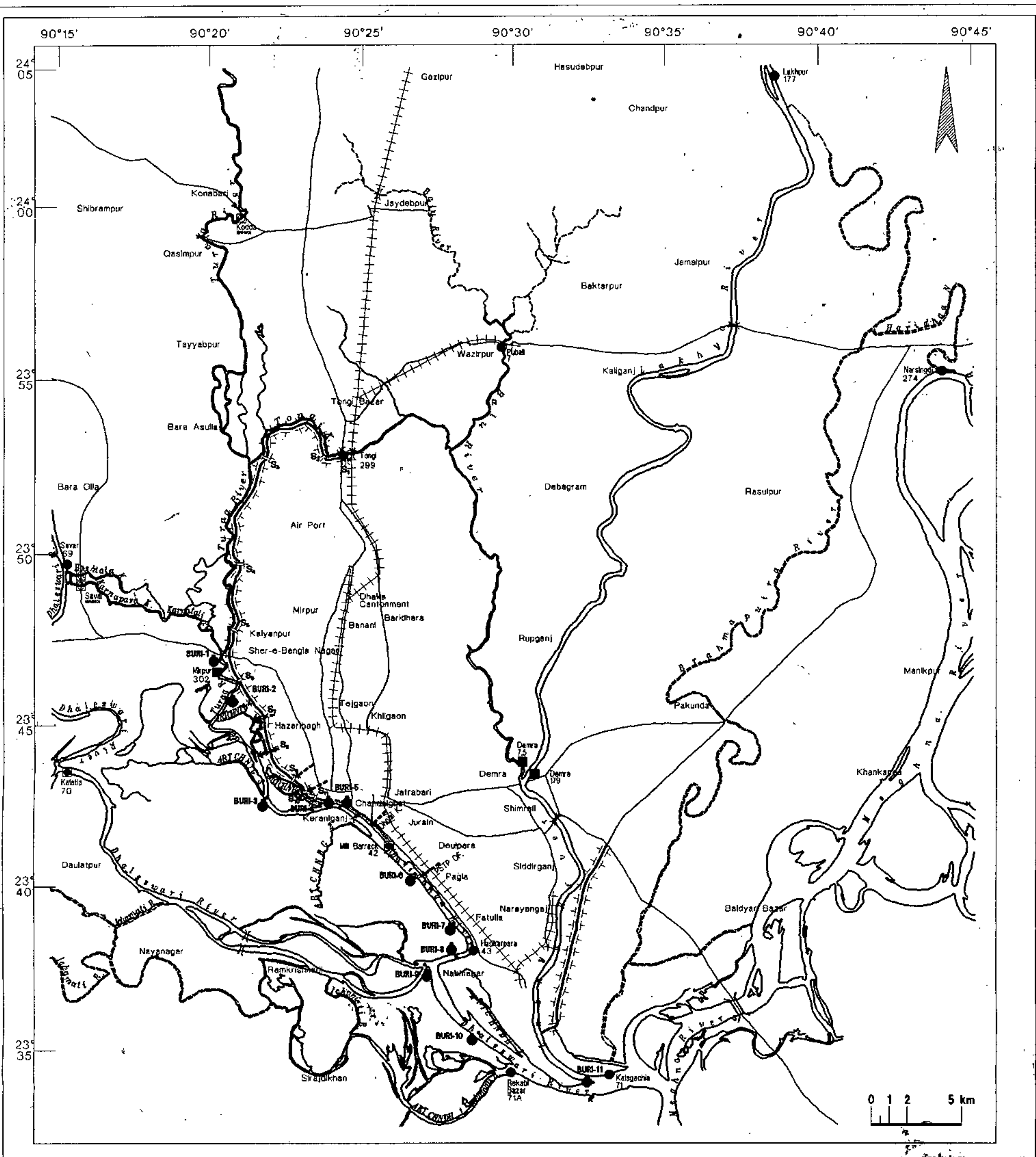
However, on trial runs with the advection-dispersion (AD) model, it was found that pollutant released at the upstream of the Buriganga dispersed far beyond the downstream boundary at Hariharpara. Thus, the downstream boundary was extended up to Kalagachia on the Dhaleswari, which in turn necessitated the inclusion of the Lakhya for a fuller description of the hydrodynamic behaviour of the Buriganga-Lakhya river system.

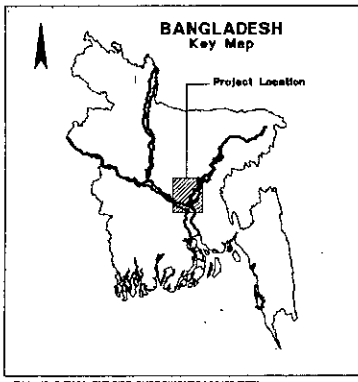
Finally, the following rivers have been considered for the schematisation of river-network used for the hydrodynamic and water quality computations for the Buriganga-Lakhya river system:

The Lakhya from Lakhpur to Kalagachia
The Balu from Pubail to Demra
The Tongi Khal
The Turag from Kodda to Keraniganj
The Karnatali
The Buriganga
The Dhaleswari from Kalatia to Kalagachia

2.2 Drainage Feature

The Greater Dhaka city was subdivided into a number of stormwater drainage zones by many authorities during specific studies. Information from only three different sources regarding zoning for stormwater drainage could be collected. These are: the Dhaka Metropolitan Development Project (JICA, 1991), Updating Study on Stormwater Drainage System Improvement Project in Dhaka City (JICA, 1989) and Stormwater Drainage Areas for the Design of Sluice Gates along the Dhaka Integrated Flood Protection (DIFP) Embankment Project (Technoconsult, 1994). No published report could be collected for the third reference; only relevant maps and information were collected from 'Technoconsult', the engineering consultant of the DIFPA. Every project had its own objectives and criteria in defining drainage zones, therefore, these do not match with one another. However, the information collected on different drainage zones helped in computing pollution loadings generated from these areas and comparisons thereof. Figure 2.2 to Figure 2.4 show different drainage zones delineated out by the three authorities.





LEGEND:

GENERAL

- Metalled Road
- Railways
- Embankment
- River and Khal
- River / Khal almost dry during dry period
- City Drains along the river
- Sluice Gate
- Waste Water Outlet Drain

HYDROMETRIC & WATER QUALITY STATIONS

- Water Quality Monitoring Location (SWMC)
- Water Level Station (BWDB)
- Water Level (BWDB) & Discharge (SWMC)
- Discharge Station (BWDB)
- Water Level & Discharge Station (SWMC)

BURIGANGA WATER QUALITY MODEL

HYDROMETRIC AND WATER QUALITY NETWORK

Source: Surface Water Modelling Centre (1996)

Figure 2.1

N/P081/CAD/P3607.BUR/XRF_BMSC.DWG/XRF/D049T/DDR's

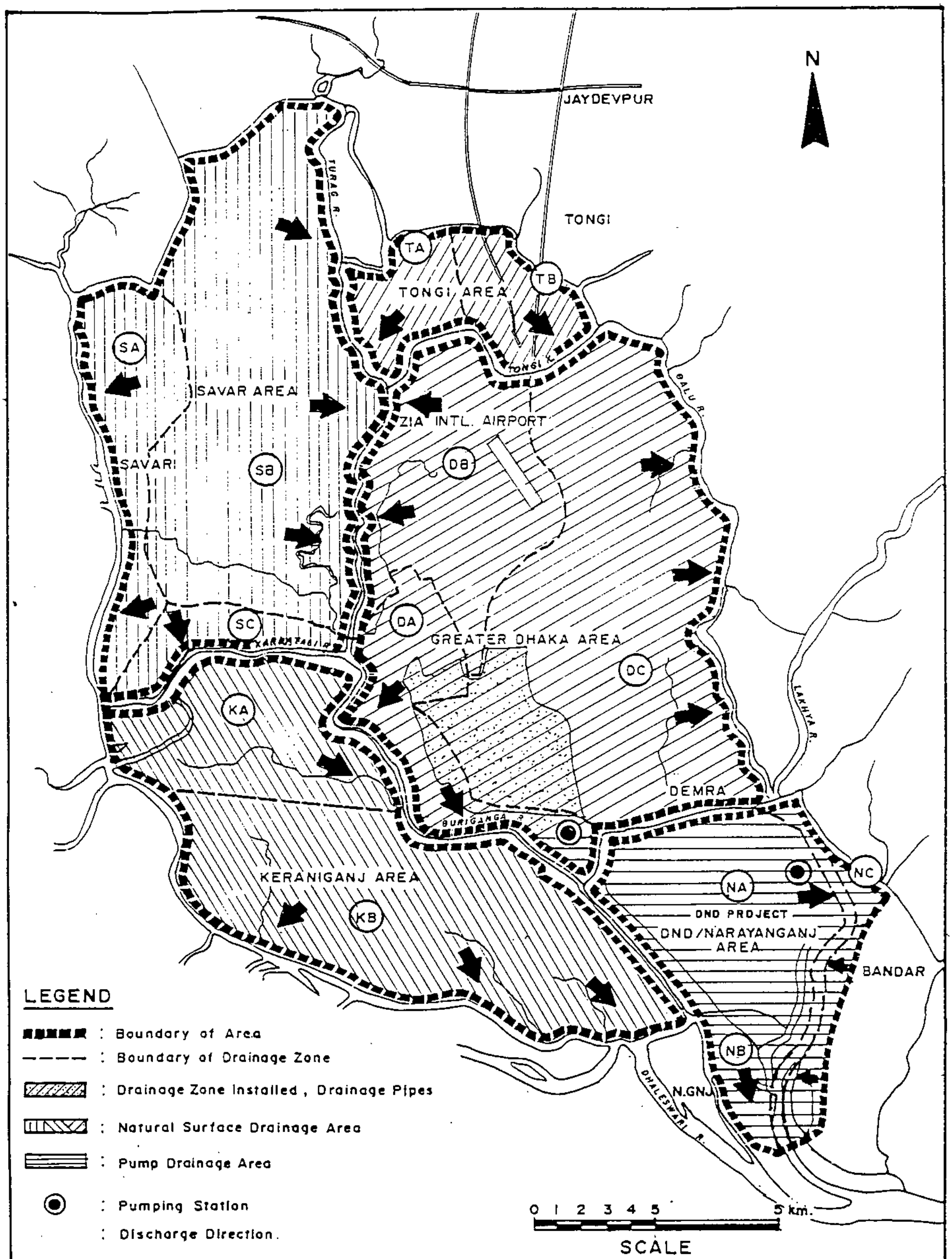
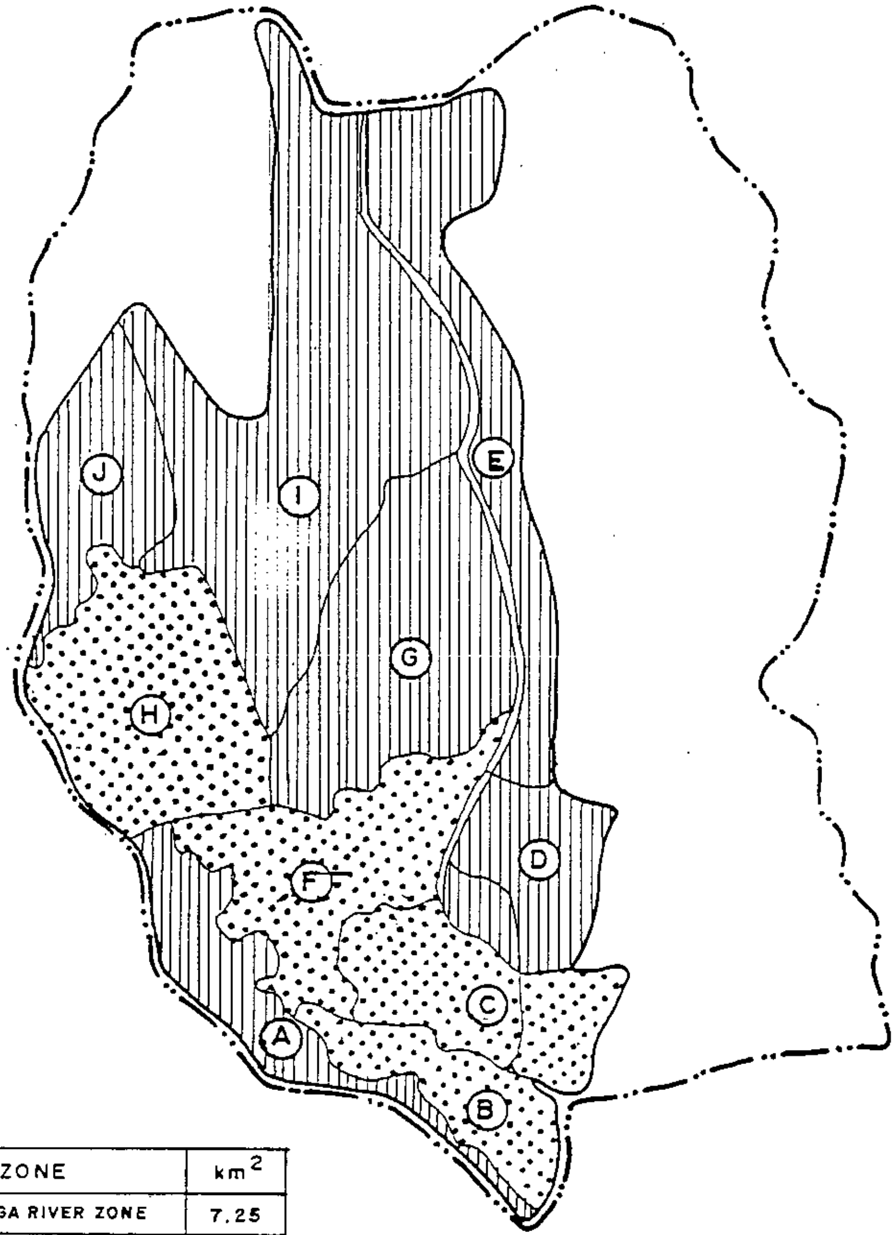


Figure 2·2 EXISTING STORM WATER DRAINAGE AREA SYSTEM

Source: FAP-8A, 1991 (GREATER DHAKA PROTECTION PROJECT STUDY IN DHAKA METROPOLITON AREA)

Fig. 2-3 DHAKA DRAINAGE DISTRICTS

SOURCE: JICA, 1989 (NEMPCP, 1992)



DRAINAGE ZONE		km^2
A	BURIGANGA RIVER ZONE	7.25
B	DHOLAI KHAL ZONE	7.24
C	SEGUNBAGHICHA K. ZONE	10.92
D	BASHABO ZONE	7.46
E	NORTH EAST EIXIE ZONE	13.93
F	BEGUNBARI KHAL ZONE	13.70
G	GULSHAN-BANANI ZONE	17.64
H	KALLYANPUR ZONE	17.60
I	NORIH ZONE	31.42
J	TURAG RIVER BANK ZONE	7.69
	TOTAL DRAINAGE AREA	134.85

LEGEND

: First Priority Area.

: Second Priority Area.

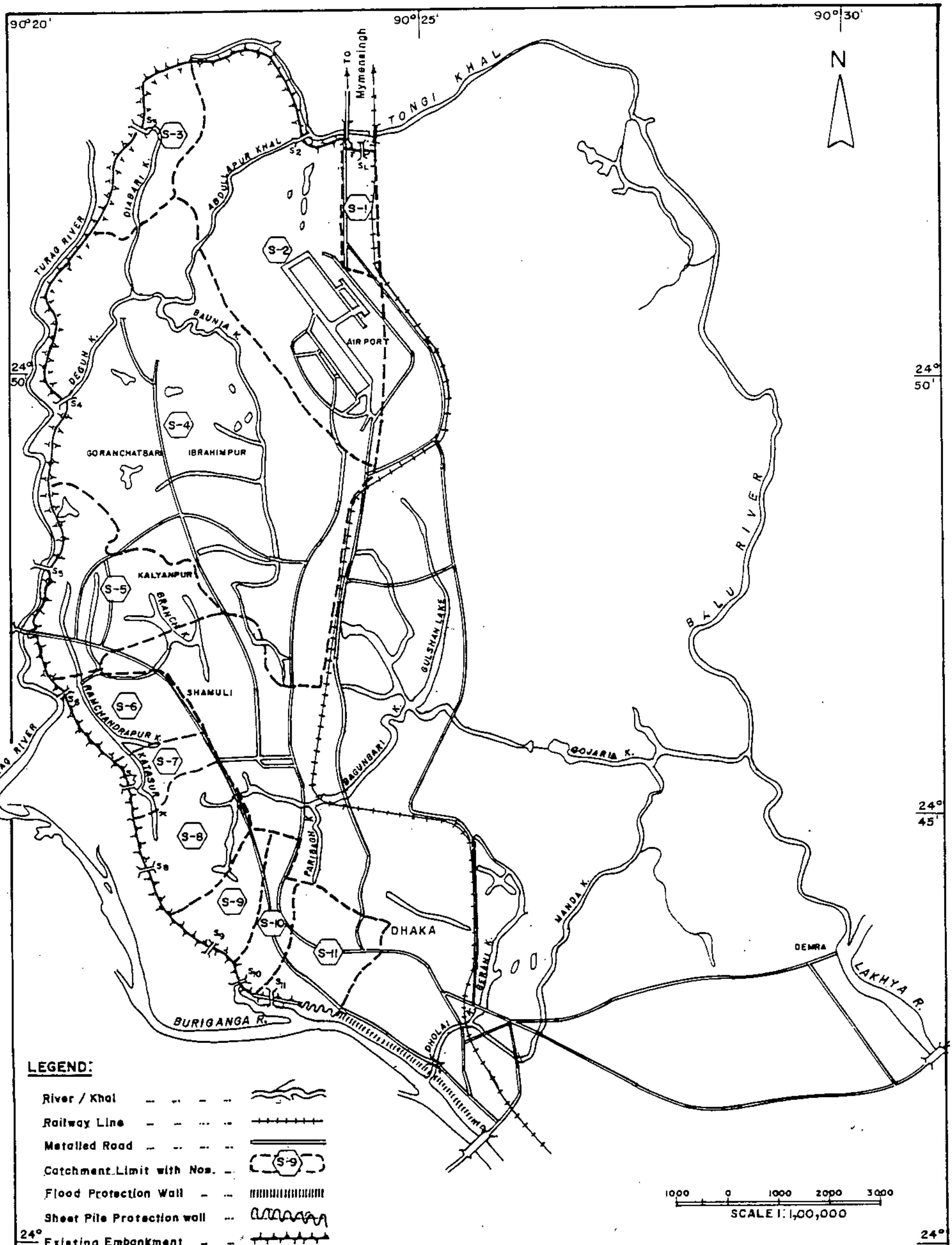


Figure 2-4 DRAINAGE ZONES OF THE DIFP SLUICE GATES

Source: TECHNOCONSULT, Bangladesh

2.3 Sewerage Network

The Dhaka Water and Sewerage Authority (DWASA) has divided the Dhaka city (not the Greater Dhaka City) into six zones, which are called MODS (Maintenance, Operation, Distribution and Supply) zones. Among these zones, Zone-IV is completely unsewered. Sewerage network in other five zones serves not more than 30% of the total population of the Dhaka city. All the sewages collected from these MODS zones are then diverted to Pagla Sewage Treatment Plant (PSTP) at Narayanganj. Figure 2.5 shows the MODS zones and the sewerage network in the Dhaka city.

2.4 Industrial Areas

According to the Industrial Management Control Task report (BKH, 1994), a group of industries is called a 'cluster' if at least five industries are contained within the specified area. Among nine clusters, six are situated in Dhaka and Narayanganj and rest three in Chittagong. The six clusters are shown in Figure 2.6 and described in the following Table 2.1. The wastewater quantities and BOD_5 loads of the major individual industries within the clusters have been estimated, by the aforementioned authority, based on size of factories (number of workers), production capabilities and emission factors. Figure 2.7 shows the BOD loadings from the six industrial clusters along with their percentile distribution.

Table 2.1 Industrial Areas in and around Dhaka City (BKH, 1994)

Cluster Name	Type of Industry	Number of Industries	Total Wastewater Discharge (m^3/day)	Total BOD load (kg/day)	Discharged into
Hazaribagh	Leather	136	15,800	17,600	Turag
Tongi BSCIC	Textiles	13	4,300	4,400	Tongi Khal
Fatulla	Textiles	6	3,400	3,850	Buriganga
Kanchpur	Textiles	9	4,300	3,480	Lakhya
Tejgaon	Textiles, Chemical	16 27	3,350 535	1,960 475	Part of Begunbari Khal
Tarabo	Textiles	14	1,150	1,475	Lakhya

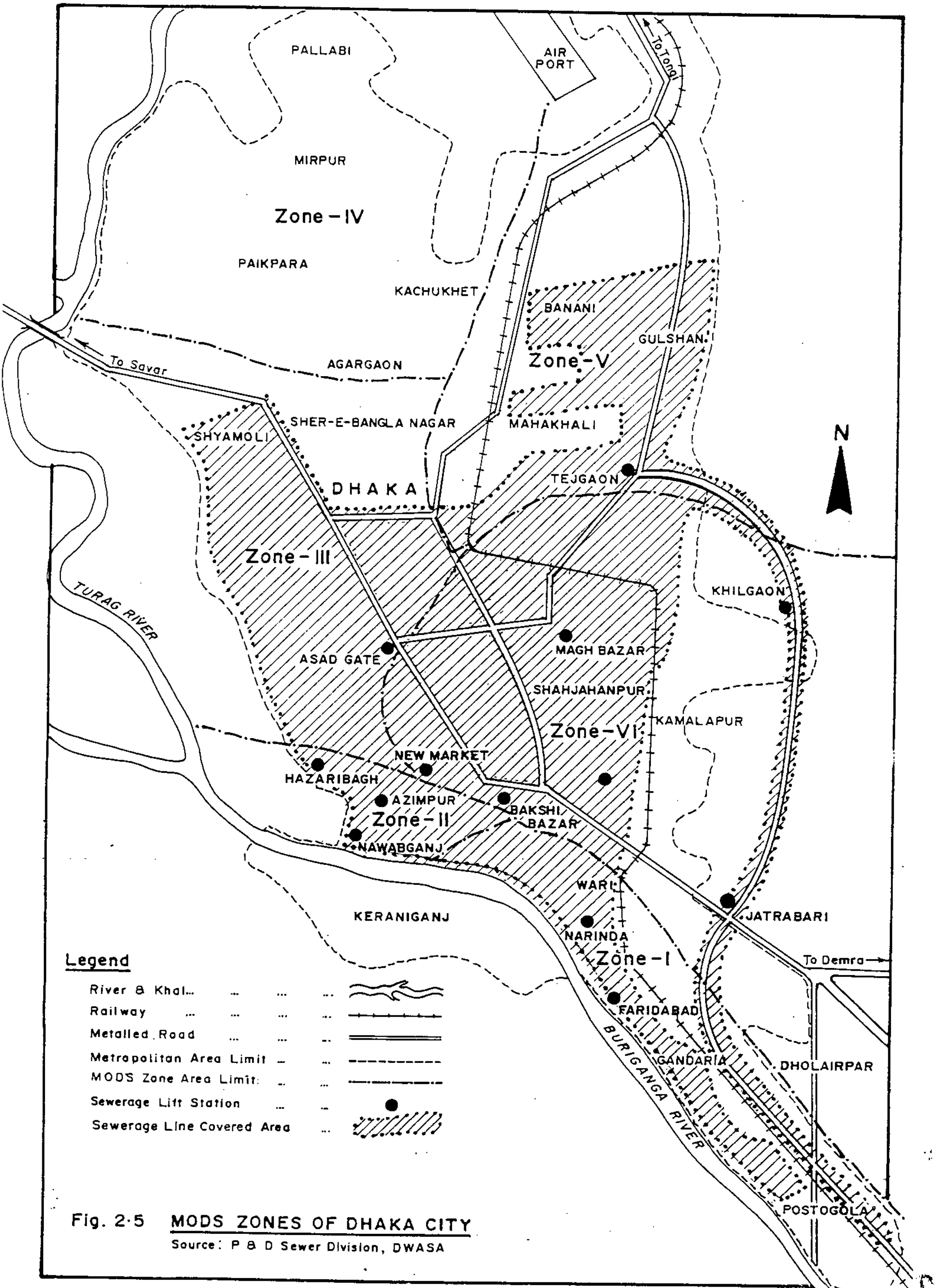
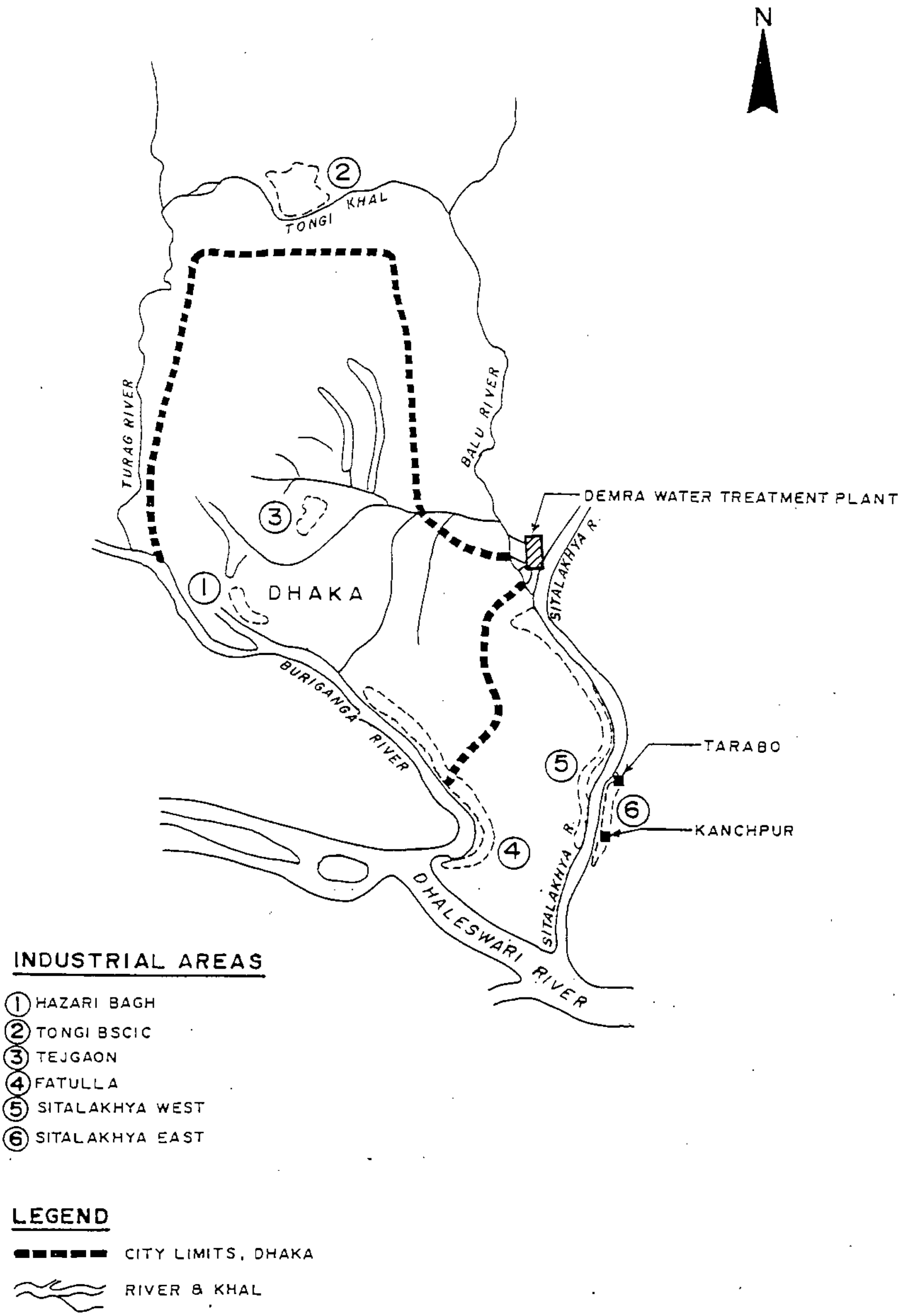


Fig. 2·5 MODS ZONES OF DHAKA CITY

Source: P & D Sewer Division, DWASA

Fig. 2·6 MAIN INDUSTRIAL ZONES IN AND AROUND DHAKA

Source: BKH Consulting Engineers (1994)



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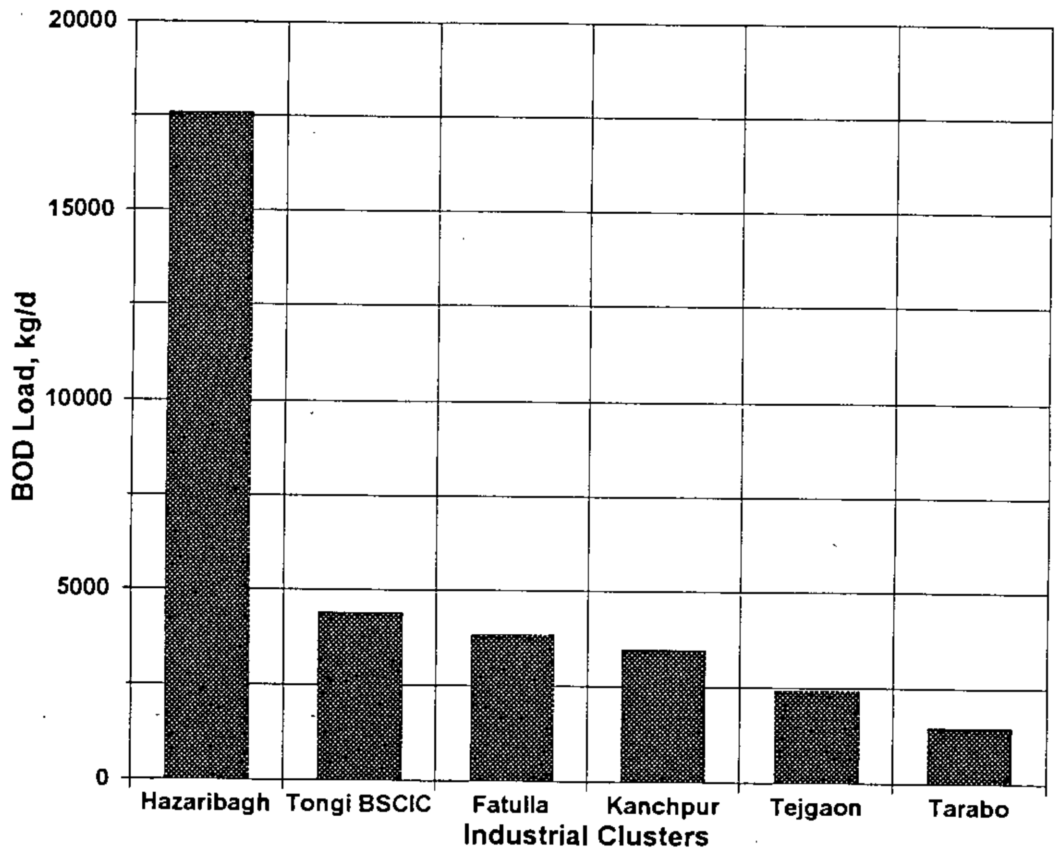


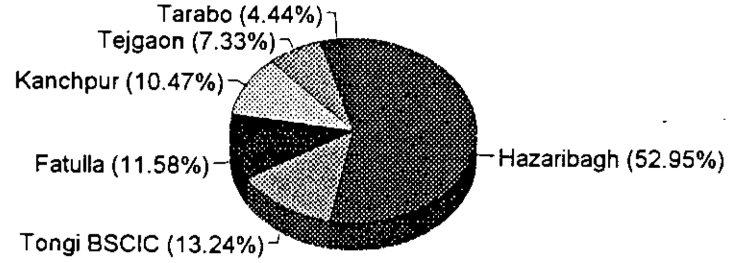


Figure 2.7 BOD Loadings Contributed by Industrial Clusters and their Percentile Distribution (BKH, 1994)

CHAPTER 3

LITERATURE REVIEW

Water quality models are tools for policy decisions, assessment of loading alternatives and future planning. Application of such model requires extensive analysis of present and past status of the water body in question. The following sections of this chapter are an attempt to review of literature dealing with studies related to the Buriganga river. In addition, the modelling tools currently applied in various parts of the world addressing similar situations have also been discussed. Furthermore, water quality modelling using the MIKE 11 river modelling system has been discussed since it is being used for the development of the water quality model for this study.

3.1 Studies on the Buriganga River

DOE (1992)

The DOE maintains three monitoring locations along the Buriganga from which samples are collected on an irregular basis. The choice of DOE sampling stations is based mainly on the location of different industrial setups along the river banks mainly to assess the impacts on water quality due to effluent discharges.

According to the study, the major rivers in Bangladesh are in good condition and well within the proposed national standards (DOE, 1991) of relevant four parameters. Only the Balu river during the dry season and the Buriganga at the Hazaribagh location are unacceptable in terms of pollution according to the 1990 figures. The Buriganga river is comparatively the major polluted river in Dhaka with Hazaribagh station being the most polluting station. The DOE found that the Dissolved Oxygen (DO) concentration at Hazaribagh falls below 2 mg/l in May. Whereas for fish, the DO should be at least around 4 mg/l. Total solids and Chloride were also very high there. The estimated discharge from Hazaribagh into the Buriganga is around 15000 tons of BOD per day (Browder, 1992). They mentioned that Hazaribagh main effluent drain discharges wastewater from tanneries which contains high levels of COD in the order of 1100 mg/l and Chromium at around 11.5 mg/l whereas suitable standard for industrial water is around 200 mg/l for COD and 0.5 mg/l for Chromium.

The DOE stated that the number of Coliform bacteria, which is an indicator organism for excreta contamination, showed that Buriganga river is highly polluted in terms of being a potential source of enteric diseases and epidemics. They mentioned after Morshed, et al (1986) that Buriganga bottom sediment in high human use area act as a potential reservoir for coliform and faecal bacteria. Greatest number of bacteria was found in the upper 1 cm and was almost always higher in the water sample. Bacteria population in sediment did not vary seasonally like it did for water. The average total coliform count was between 1.1×10^5/100 gm to 1.3×10^6/100 gm of sediment. Similarly, faecal coliform count average varied between 7.6×10^4/100 gm to 9.0×10^5/100 gm of sediment.

In 1992, Chromium, Lead and Mercury were tested by the DOE for Buriganga river water at Chandnighat, near Aluminium Factory. Concentrations recorded are 0.005, 0.012 and 0.01 mg/1 for Cr, Pb and Hg, respectively. First two values are well within the proposed standard for Bangladesh (0.05 and 0.05 mg/1), but Mercury concentration is well over the standard limit of 0.001 mg/l for drinking and fishing water. However, it should be noted here that the water at Hazaribagh was not tested for Chromium. Higher concentration of Chromium at Hazaribagh portion of the river is most likely as the tannery industry uses Chromium as a raw material and discharges it into the Buriganga. The DOE has tested the groundwater at Hazaribagh for Chromium beginning of the year which was found to be 0.04 mg/1 approaching the safety limit of 0.05 mg/1, the proposed standard for drinking and fishing water in Bangladesh. This indicates that surface water contamination is possibly much higher at Hazaribagh.

Cumulative data for three parameters namely TS, DO and BOD were analysed in the study from 1984 to present time for the river Buriganga. In general, the parameters are within acceptable limits, but a definite deterioration in water quality trend is seen albeit in very small quantity. The following observations are made about the river water quality of the Buriganga:

Total solids (TS) concentration of the Buriganga river for both wet and dry season is steadily increasing. In the dry season, the rate of change had been more marked because of less dilution. Concentration has gone up from about 225 to 275 mg/1. Similarly, BOD is approaching 3 mg/1 for both dry and wet seasons. It is interesting to note that seasonal variation of BOD is not very prominent as for the earlier years during the eighties. In other words, dilution during the wet season is not sufficient to lower down the BOD load. Correspondingly, oxygen depletion has been quite abrupt. During the dry season, it has fallen sharply below 5 mg/1 in the past two years; in the wet season the rate of change is less abrupt but still under 6 mg/1.

Condition of the Buriganga was found to be worse than the Sitalakhya. Total solids concentration is significantly on the rise. This indicated an increase in erosion and human activities over the period. Decreases in DO for the Buriganga is particularly noteworthy as the rate of change was found to be abruptly high.

These findings by the DOE indicate the need for close monitoring as contamination of such sharp trend may be disastrous for the aquatic ecosystem. In addition, better understanding of the backflow from the Meghna river into the study system is essential from the hydrodynamic point of view.

Browder (1992)

Browder carried out a comprehensive study regarding the status of pollution of the Buriganga. Two approaches were used by Browder to estimate the mass of pollutants generated and discharged to the outside environment: 'dry study' approach and `wet study' approach. In the dry study approach, population zones were defined first. Then, using information about population sewered/unsewered and the per capita contribution of BOD load, resulting BOD loadings from the zones to the environment were computed. The wet study involved actually measuring the flow and concentration of various pollutants at the discharge point into receiving water bodies. Reasonable estimates were then made based upon the wet and dry study results. It is found that the dry study and wet study yielded approximately the same results.

Browder found that domestic wastewater produces approximately 88% of Dhaka's BOD load while industrial sources account for the remaining 12%. He opined that those figures were consistent with other large South Asian cities which did not have a large industrial base such as Dhaka.

The total amount of BOD discharged in Dhaka was estimated by Browder as 182 tons per day. Of that amount, approximately 55 tons were being treated at the Sewage Treatment Plant which used to lower the BOD load to approximately 5 tons per day. The remaining 127 tons per day of BOD was being discharged through the stormwater conveyance system to receiving water bodies. Browder then estimated that approximately 65 tons of BOD per day, representing about half of the total BOD load, was being discharged to the Buriganga. Contribution form Hazaribagh discharge was estimated to be about 30% of the total load being discharged to the Buriganga. Discharges to the Turag river, which is a tributary of the Buriganga, were estimated as approximately 14 tons per day, representing about 10% of the total BOD.

Finally, Browder identified that there were four main pollutant discharge routes into the Buriganga: (I) Hazaribagh Tanneries, (ii) City Drains along the river, (iii) Dholai Khal, and (iv) Pagla Sewage Treatment Plant Outfall. Browder described the Dholai Khal as the largest source of pollution with an estimated discharge of 35 tons of BOD per day. Hazaribagh was the next largest source of pollution with an estimated discharge of 15 tons per day of BOD. The city drains were considered to account for 10 tons of BOD per day and the Pagla Sewage Treatment Plant discharges approximately 5 tons per day of BOD.

Seven monitoring locations along the Buriganga were chosen by Browder. All seven locations were monitored on the same day within a three-hour period in order to get a 'snapshot' of the river. Monitoring was undertaken in the following months: May, July, November and February, 1991-1992, in order to obtain seasonal data.

The data clearly indicates that the Buriganga experiences severe water quality problems during the dry season. During the lean flow period, the DO was below the generally accepted minimum standard of 4.0 mg/l from Hazaribagh to Pagla. In addition, the coliform values are very high during lean flow period, ranging from 10,000 to 100,000 per

100 ml. In the high flow period, the situation is much better due to the dilution capacity of the Buriganga.

The deteriorated condition of the Buriganga reflects the high pollutant loading rates as described earlier. The water quality data indicate that the pollution has a negative impact on the water supply, fishing, and bathing beneficial uses.

Special circumstances existed during the period of water quality monitoring by Browder. There were no discharges from Pagla STP due to the temporary shutdown of the plant for modifications. It was postulated by Browder that collected sewage was being diverted to Dholai Khal but he could not verify the location of actual diversion. Hazaribagh discharges into the Buriganga were also stopped, at least part of the year, due to construction of the DIFP embankment. Hence, two of the major discharge points, Hazaribagh and Pagla STP, were not discharging. Therefore, the water quality monitoring results of Browder should be considered in the light of those facts.

JICA (1987)

JICA reported the data on water quality analysis for Hazaribagh (1983-85), Chandnighat (1983-85) and Farashganj (1985) on the Buriganga river. The BOD variation was 1-90 mg/1. However, the most frequent range of BOD variation was 3 to 5 mg/1. The DO variation was between 0 to 9 mg/1.

Mohammed (1988)

Mohammed reported a comparison of sampling data of the Buriganga river water near Chandnighat during 1968-80 period. It is apparent from the study that DO level has decreased considerably during 1968-80. While average DO during 1968 was 6.7 mg/1, it came down to 3.3 mg/1 during 1980. The average BOD value increased almost fourfold during that period. Number of coliforms also increased considerably during the same period.

In February 1987, Mohammed conducted a sampling programme of the Buriganga river.

Six different sampling stations were established along a 10 miles stretch of the river starting from 6 miles upstream of Pagla outfall up to 4 miles downstream. Six samples were taken from different depths at each sampling station. It was assumed for the study that the flows, temperature, BOD loads and rate constants at each point remained constant with time. It was further assumed that the concentrations of BOD and DO were uniform over the cross-section of any river station. Since, in most cases, there is daily variations in pollution loads, flows, temperature, oxygen produced by photosynthesis throughout 24 hours etc., the assumption of steady state condition introduces errors. Mohammed argued that for planning purposes, the simplified version of the DO sag curve determination was an acceptable assumption.

The oxygen sag curve indicates that the major pollution impact is from the sources upstream of the direct municipal discharges at Pagla. These upstream pollution sources are principally uncontrolled industrial discharges (especially from Hazaribagh tanning area), storm sewers and khals and runoff from agricultural land, city streets etc.

The DO and BOD of river water at Pagla outfall is 4.2 mg/1 and 2.1 mg/1 respectively, whereas the DO and BOD at a location 3.5 miles downstream of outfall are 7.8 mg/1 and 1.4 mg/1, respectively. These data indicate that a very high degree of mixing occurs in the Buriganga river. Any waste water discharged into the river is dispersed very quickly. Mixing of the river water will also result in a relatively high degree of reaeration. Algae was found to play a small role in the river flow aeration. This information and the associated computation lead to the conclusion that the river acts essentially as a large dilution and stabilization pond.

Azim (1992)

Azim reported results of two sampling programmes. One during monsoon, when the DO values at different locations were 6 mg/1 or above which indicated that there was no problem. During dry season, except two locations, the DO values were all above 6 mg/1. DO value just downstream of the Dholai Khal was 1.2 mg/1 which is much below than the standard limits set for fishing and bathing. Coliform values were very high during the lean flow period.

Karim (1992)

Karim found that minimum DO concentration is higher for the post-embankment period than that of pre-embankment period for the month of June. Situation also improved during post-embankment period with respect to BOD, Chloride and SS. He attributed this improvement to the accumulation of pollutants within the embankment area.

Ahmed (1993)

Ahmed reported the pollution load from industries in and around Dhaka. The discharges were estimated as 49000 kg/d of polluting load (BOD) in the river system in and around Dhaka. Ahmed opined that the polluting industrial load along with an approximately equal amount of BOD load from domestic sewage and other municipal wastes reaching the river system was responsible for the pollution and degradation of the quality of the rivers around the Dhaka city.

Ahmed showed the expected improvement in DO profile after implementation of pollution control measures. It is seen that pollution control measures including discontinuation of tannery waste discharge in the river and upgrading of DWASA sewage treatment plant significantly improves the DO situation in the Buriganga in lean flow period.

IFCDR (1994)

The Institute of Flood Control and Drainage Research (IFCDR) of BUET carried out a research project entitled 'Management of Buriganga River Water Quality Under Alternative Scenarios'. The main objective of the research work was to formulate appropriate water quality management programs under different scenarios. A hydrodynamic (HD) model, using MIKE 11 river modelling system, was calibrated (for 1989-90 and 1990-91) and verified (1991-92 and 1992-93) for the Buriganga river system. Calibration and verification showed good matching with observed water level data. The HD model was used for determining hydraulic parameters of the Buriganga river, which were then used for a water quality model. DO profiles were simulated at different levels of flows. When violation regarding water quality standards were detected, then a linear program was run to determine maximum allowable loads. Approximate management program was then suggested. It was assessed that considerable waste load can be assimilated by the river, if they are properly managed, without violating the water quality standards. However, it was remarked that future pollution load would pose considerable water quality problem, and the Pagla Sewage Treatment Plant would need to be expanded to handle extra loading. As a recommendation for future study, an unsteady water quality model has been suggested which is expected to provide further insight into the water quality problem. Also, study on the effect of Nitrogen, Phosphorus and algae on DO has been recommended.

In this research work, the HD model was calibrated and verified against observed water levels only. Good matching of simulated water levels with observed values may not ensure the correct volume of flows, i.e. discharge from a model. But, discharge is of prime importance in water quality assessment of a river. Therefore, the discharges considered in the study for various analyses might not be representative of the actual discharges in the Buriganga.

3.2 Water Quality Modelling

Summers, et al (1991)

Summers, et al reported that during low flow periods in summer, portions of the Pigeon River, North Carolina, had experienced depressed dissolved oxygen concentrations. The Pigeon river receives multiple point source effluents from several wastewater treatment facilities and a large kraft paper mill located in Canton, North Carolina which contribute the oxygen-demanding and nutrient loads to the river. A water quality model was constructed, from survey data specifically collected to meet the model's requirements, to examine the processes and sources contributing to the observed oxygen declines and to evaluate specific management alternatives. The model was validated using two independent data sets. Simulations showed that relatively little of the CBOD materials released by the mill were degraded within the river and were subsequently 'deposited' in the reservoir at the end of river reach selected for modelling. Reductions in CBOD concentrations could be generally accounted for by tributary dilution. However, nitrogenous oxygen demanding materials released by the mill (e.g. NH_3) created a considerable demand for oxygen within the modelled segment of the river. Model results showed this relatively rapid degradation of NBOD could depress oxygen levels to low levels (i.e., <4 ppm) if artificial oxygenation was not used to supplement existing concentrations. The model also showed the majority of this oxygen supplement was released to the atmosphere and not maintained within the water column. Model analyses showed that the effluents associated with the wastewater treatment facilities had little effect on the water quality of the Pigeon River.

Bicknell, et al (1984)

Bicknell, et al described a comprehensive hydrology and water quality modelling on a large river basin to evaluate the effects of agricultural non-point pollution, and proposed best management practices (BMP). The model application combines detailed simulation of agricultural runoff and soil processes, including calculation of surface and subsurface pollutant transport to receiving water, with subsequent simulation of instream transport and transformation. The result is a comprehensive simulation of river basin water quality.

The investigation of the Iowa River Basin described in this paper was part of a large study which included application and evaluation of the Hydrological Simulation Program-FORTRAN (HSPF) to both the data-intensive Four Mile Creek watershed and the Iowa River above Coralville Reservoir. In this study, the methodology developed on Four Mile Creek was extrapolated to the Iowa River Basin to demonstrate its applicability and functionality on a large river basin. Many model parameter values from four Mile Creek were applied directly to the study area without adjustment while other parameters were modified based on available information and calibration. This study allowed the exploration of problems associated with modelling hydrology, sediment, and chemical fate and transport in a large river basin with varying meteorologic conditions, soils and agricultural practices.

Tischler, et al (1984)

Tischler, et al reported that the Han River Basin in the Republic of Korea covers an area of about 27,000 sq. km south of the Demilitarized Zone, almost one quarter of the total area of the country. The total popultion in the basin is of the order of 13 million, of which more than 80 percent are concentrated in the urban community of Greater Seoul alongside the Lower Han River. Within the vicinity of Seoul the river is used extensively for water supply, irrigation and recreation. Treated nightsoil, untreated sullage, partially treated sewage and industrial wastes generated in the urban areas are also discharged to the river which is heavily polluted in the downstream reaches as a result. The finite difference water quality model QUAL-II was adapted to the Lower Han River using data obtained from extensive field water quality surveys especially designed to provide the necessary calibration and verification database. Hydraulic data for the model were obtained from operation of the U.S. Army Corps of Engineers HEC-II computer model. Model calibration and verification was confirmed by statistical comparison of model simulations with the field data. The calibrated model was used to evaluate a number of differnt treatment alternatives for two different future years. Extensive model sensivity analyses were run on both the key model parameters and the treatment alternatives to quantify the reliability of the prediction.

Beken, et al (1987)

Beken, et al presented application of two surface water quality mdoels, namely QUA-II from USEPA., applied as a planning model for evaluating waste water treatment along the river Velpe in Belgium, and a series of quality management models for the Albert canal and Campine canal system in Belgium, developed in cooperation wtih the Antwerp Waterworks. The water quality model QUA-II was applied as a planning model for evaluating the effects of alternative waste water treatment schemes along the river Velpe and its tributaries in Belgium. The steady state model simulates the dispersion and advection of conservative and reacting constitutents by numerical integration of the one-dimensional form of the equations. The computer program was modified in order to face specific problems in smaller basins. Reaction at water mills and weirs was introduced by using the Gameson formula. The aim of the study was to compare water quality in the river, using either regional large-scale waste water treatment plants or small-scale autonomous plants or techniques, attaining a better ecological integration, such as lagooning, reaction techniques, cascades, etc.

The present situation was simulated along with the regional large-scale treatment system and several scenarios of small-scale treatment techniques. Each scenario was simulated using as input a fairly detailed inventory of all point and non-point sources of waste water at a specific low flow rate. Water quality was represented by dissolved oxygen and biochemical oxygen demand.

The large-scale conventional water treatment plants, collecting all the waste water in the catchment, show a substantial increase of the water quality, but similar water quality could be obtained with lagooning, local small treatment plants and reaeration techniques. QUA-II proved to be applicable as a planning model.

3.3 Water Quality Modelling by MIKE 11

Bach, et al, (1989)

In 1987, the Danish Water Authorities and Ministry of Industry started a project aimed at the transfer of a fully integrated one-dimensional modelling system to personal computers. This consists of submodules describing hydrodynamics, sediment transport, transport-dispersion and water quality. The micro-computer package is built up with a complete menu-driven user-interface and built-in expertise, allowing also non-experienced users to apply the models.

An application of the modelling system is demonstrated for the Grindsted River in Denmark, which receives demestic sewage as well as industrial wastewater. Oxygen levels in the river are endangered because of oxygen consumption by degradation of organic material and nitrification of ammonia.

The combined modelling system has been used to evaluate the effects of considered alternative waste water treatment schemes for obtaining acceptable water quality in the Grindsted River.

The modelling system, called MIKE 11, is a further development of the well-known one-dimensional model SYSTEM 11. MIKE 11 is a generalized modelling system for simulation of rainfall-runoff, unsteady flow, sediment transport, transport-dispersion, and water quality in rivers, channels and estuaries. It represents one of the first, fourth-generation modelling packages and is already used as standard tool in planners' and decision-makers' day-to-day work in Denmark and many other countries.

Aforementioned MIKE 11 river modelling system was used to study water quality related problems in the Grindsted River in Denmark. The river runs by the town of Grindsted, where it receives waste water from a large chemical industry and from two municipal wastewater treatment plants.

The wastewater contains significant amounts of organic matter and ammonium/ammonia. Three problems were identified:

- Oxygen depletion in the river because of consumption by decay of organic matter and nitrification of ammonium/ammonia,
- High concentration levels in both ammonia and ammonium, the latter being a toxicant to fish,
- High concentration levels of organic matter expressed as BOD.

The authorities, the Ribe County of Denmark, had classified the Grindsted River as a future habitat and spawning area for fish, especially for trout. For the river to fulfill that goal, the existing treatment plants should have to be enlarged and modified. To ensure that the chosen treatment scheme was sufficient to meet the required river quality standards, the MIKE 11 river modelling system was implemented.

SWMC (1996)

The Surface Water Modelling Centre (SWMC) carried out water quality modelling, as a pilot approach, for the Buriganga-Lakhya river system. SWMC collected pertinent information/data, both hydrometric-hydrometeorological and water quality, from different organizations, carried out field investigations, launched field data collection programmes, and finally calibrated a water quality model. SWMC then, on the basis of model calibration, concluded that a serious water quality problem exists during the dry season in the Turag, Buriganga and Lakhya rivers, the Buriganga being the worst.

CHAPTER 4

ANALYSIS OF BURIGANGA WATER QUALITY DATA

To address the status of pollution in a river, enormous amount of data are required. An extensive programme was conducted in this study to collect hydrometric as well as water quality data of the Buriganga river system. In addition, relevant historical data collected by different organisations such as, the DOE and Pagla Sewage Treatment Plant of the DWASA were also analysed to study the pollution trend and the wastewater loadings entering into this river system. Following sections provide the sampling programme along with the analysis of the data collected during this study and analysis of the historical data.

4.1 Sampling Programme

Recent as well as historical data are essential for conducting a pollution trend analysis of a waterbody. In addition, extensive data are also required to calibration and verification of a water quality model which will be applied for assessment of impact of different management alternatives on the quality of the water of the Buriganga river system. Therefore, to attain these objectives, a sampling programme was conducted during this study. Since, the Surface Water Modelling Centre (SWMC) was conducting a study on the pollution status around the waterbodies of the Dhaka city, a coordinated sampling programme was adopted. It involved selection of appropriate sampling techniques, selection of river water/wastewater monitoring locations, sampling of river water and wastewater, and testing of samples.

4.1.1 Techniques Involved in Sampling

Sampling in the rivers were done at the mid-stream of the selected locations, as mentioned above. For a depth more than 3 meter, two samples were collected: 1 meter below the water Surface, and 1 meter above the river bed (Bottom). Otherwise, one sample from the mid-depth at the mid-stream of the location was collected. A 'JABSCO' pump was used to abstract water from a specified depth. Samples of river water were collected in the dry period of December 1994 to April 1995 on three different occasions.

Wastewater samples were collected manually at the rate of one sample per location from the mid-depth of the mid-stream. As these wastewater outfalls are affected by the flooding of tides in the river system, samples were collected from the outfalls when ebbing in the rivers were fully established, thus rendering the flow of the wastewaters unaffected by the high water levels in the river.

4.1.2 Selection of Water Quality Parameters

For all the samples, ten water quality parameters were selected for testing. These parameters were selected mainly because these adequately describe the status of pollution of a river, when no special type of pollution is to be studied. One heavy metal, Chromium, was tested as tannery waste from Hazaribagh had been reported to contain considerable amount of this harmful element. The water quality parameters tested are:

- BOD_5 (at 20^0C)
- COD
- Ammonia as NH_3-N_2
- Ammonium as NH_4^+-N_2
- Nitrate as NO_3^--N_2
- E. Coli
- Total Coliform
- Total Suspended Solids (TSS)
- Ortho-phosphate as PO_4-P
- Chromium (Cr)

4.1.3 In situ Data collection and Sampling of River Water

Three measurement campaigns were carried out in the months of December 1994, February 1995 and April 1995. During these campaigns, DO, Temperature and Secchi-depth were measured at each location at an interval of approximately one hour, starting early in the morning and ending in the evening. DO and Temperature were measured by a 'MOBRO'

Oxygen Meter and Secchi-depths were measured by a Secchi Disk. A total of 11 locations were selected in the Turag-Buriganga-Dhaleswari river system. Table 4.1 and Figure 2.1 show the positions of these monitoring locations.

Table 4.1 Positions of River water Monitoring Locations

Location Name	River	Chainage (km)	Position (Lat., Long)	
BURI-1	Turag	65.000	$23^0 47.006'N$	$90^0 20.145'E$
BURI-2	Turag	67.000	$23^0 45.503'N$	$90^0 20.100'E$
BURI-3	Turag	74.000	$23^0 42.577'N$	$90^0 21.783'E$
BURI-4	ARTCHNBG1*	4.000	$23^0 42.826'N$	$90^0 22.849'E$
BURI-5	Buriganga	27.500	$23^0 42.516'N$	$90^0 24.134'E$
BURI-6	Buriganga	32.000	$23^0 40.317'N$	$90^0 26.760'E$
BURI-7	Buriganga	36.000	$23^0 38.936'N$	$90^0 27.878'E$
BURI-8	Buriganga	38.500	$23^0 38.055'N$	$90^0 27.928'E$
BURI-9	Dhaleswari	164.000	$23^0 37.620'N$	$90^0 27.213'E$
BURI-10	Dhaleswari	169.000	$23^0 35.540'N$	$90^0 28.624'E$
BURI-11	Dhaleswari	176.500	$23^0 34.055'N$	$90^0 32.270'E$

Note: 1. Positions of the locations were observed from a Trimble NavTrac GPS owned by the SWMC.

2. * ARTCHNBG1 ultimately drains into the Buriganga

4.1.4 Sampling of Wastewater

Samples of wastewater were collected from six wastewater outfalls as shown in Table 4.2 and Figure 2.1. Samples were collected at the same time when wastewater flows from these outfalls were being measured. One sample per location were collected for two times, one in February 1995, another in April 1995.

Table 4.2 Positions of Wastewater Monitoring Locations

Location Name of WW Outfall	Drains into River/Channel	Chainage (km)	Position (Lat., Long)	
Sluice No. S-7	ARTCHNTG4 [a]	2.500	23°44.704'N	90°21.639'E
Sluice No. S-8	ARTCHNTG4 [a]	6.500	23°43.639'N	90°22.042'E
Sluice No. S-9	ARTCHNBG1 [b]	1.500	23°43.296'N	90°22.563'E
Sluice No. S-10	ARTCHNBG1 [b]	2.500	23°43.124'N	90°22.728'E
Dholai Khal	Buriganga	28.500	23°42.028'N	90°25.104'E
Kashipur Khal	ARTCHNDH2 [c]	6.500	23°36.317'N	90°29.052'E

Note: 1. Positions of the Outfalls were observed from a Trimble NavTrac GPS owned by the SWMC.

2. a ARTCHNTG4 ultimately drains into the Turag river
   b ARTCHNBG1 ultimately drains into the Buriganga river
   c ARTCHNDH2 ultimately drains into the Dhaleswari river

4.1.5 Testing of Samples

Since, a water quality model requires enormous amount of data for a short duration run, a large number of samples were collected within a short span of time. A short duration run is necessary to reduce computational time enabling numerous runs required for calibration. However, these enormous number of samples, each requiring testing of ten different parameters, was difficult to be handled by one laboratory alone.

Testing were done for all the samples at the laboratory of the Department of Environment (DOE), Dhaka Division. In addition, 25 samples collected during the second field campaign in February 1995 were sent for testing at the laboratory of the Environment Division, BUET for three parameters, viz. Nitrate, Ortho-phosphate and Chromium. Four wastewater samples collected during the third field campaign in April 1995 were sent for testing for all the 10 parameters at the laboratory of the DOE, Chittagong Division. In addition, 7 wastewater samples collected during the third field campaign were tested at the SWMC laboratory using a 'Filter Photometer' for three parameters, viz. Nitrate, Ortho-phosphate and Ammonium.

4.1.6 Data Analyses

Samples of river water were collected at the 11 monitoring locations (Table 4.1) on three occasions, and wastewater samples were collected at the 6 monitoring locations (Table 4.2) on two occasions for laboratory testing. Although the total number of samples tested during this study is considerable, number of samples tested per location are not enough to predict any definite trend or range, with respect to each of the location, for most of the water quality parameters. As, DO were collected in-situ at each location covering a period of 9 to 10 hours on every occasion, the DO variation during the period in the Turag, Buriganga and Dhaleswari can be described. To summarise the findings of the data analyses, both from in-situ and laboratory testing, monitoring locations from BURI-1 to BURI-3 have been considered to represent the status of the Turag, BURI-4 to BURI-8 for the Buriganga and BURI-9 to BURI-11 for the Dhaleswari. Table 4.3 shows the DO measured in-situ, Table 4.4 to Table 4.6 show the results of testing for the 10 parameters, and Figure 4.1 to Figure 4.11 show plots of these 11 parameters. Table 4.7 summarises the findings of data analyses for the three rivers.

In Figure 4.1, there are values of very high DO concentrations in the Buriganga and the Dhaleswari rivers. These high values were obtained in monitoring locations situated in the downstream portion of the Buriganga (BURI-7 and BURI-8), and monitoring locations situated in the Dhaleswari river (BURI-9 to BURI-11) during February, 1995 (second field campaign), when there was local rainfall associated with high wind, and during April, 1995 (third field campaign) when huge fresh water flow from the Meghna into the river system occurred for the Spring tide. However, Figure 4.1 indicates that DO values in the Buriganga mostly vary between 0.1 to 4.0 mg/l, in the Turag between 0.1 to 5 mg/l and in the Dhaleswari between 4.0 to 8.0 mg/l. Although for other water quality parameters it is difficult to make such generalised comments, the following comments can be made regarding the Buriganga river.

Table 4.3 Measured Dissolved Oxygen (DO) during December, 1994 to April, 1995

Location: BURI-1 River: Turag

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	19	8	10	6.1
1994	12	19	9	25	5.8
1994	12	19	10	25	5.2
1994	12	19	11	30	4.8
1994	12	19	12	30	4.6
1994	12	19	13	30	4.7
1994	12	19	14	40	5
1994	12	19	15	30	5.4
1994	12	19	16	20	5.6
1994	12	19	17	0	5.8
1995	2	14	8	10	1.1
1995	2	14	9	25	0.3
1995	2	14	10	25	0.3
1995	2	14	11	25	0.3
1995	2	14	12	35	0.4
1995	2	14	13	30	0.5
1995	2	14	14	20	0.5
1995	2	14	15	15	0.8
1995	2	14	16	0	1
1995	4	19	8	0	1
1995	4	19	9	0	1.8
1995	4	19	10	12	1.3
1995	4	19	11	5	2
1995	4	19	12	3	2.4
1995	4	19	13	8	2.5
1995	4	19	14	5	3.3
1995	4	19	15	0	3.4
1995	4	19	15	55	4.4
1995	4	19	16	45	5

Location: BURI-2 River: Turag

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	19	9	0	3.6
1994	12	19	10	0	3.7
1994	12	19	11	5	3.4
1994	12	19	12	0	2.6
1994	12	19	13	0	3.5
1994	12	19	14	0	3.8
1994	12	19	15	5	4.1
1994	12	19	15	55	4.5
1995	2	14	9	0	0.3
1995	2	14	10	0	0.3
1995	2	14	10	55	0.1
1995	2	14	12	0	0.3
1995	2	14	13	0	0.3
1995	2	14	13	55	0.5
1995	2	14	14	45	0.7
1995	2	14	15	40	0.5
1995	4	19	8	35	1.6
1995	4	19	9	48	1.9
1995	4	19	10	41	1.8
1995	4	19	11	36	1.8
1995	4	19	12	40	2.3
1995	4	19	13	40	4.2
1995	4	19	14	30	4.4
1995	4	19	15	22	4.6
1995	4	19	16	20	8.2

Table 4.3 Contd.

Location: BURI-3 River: Turag

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	26	8	20	2.7
1994	12	26	9	40	2.9
1994	12	26	10	50	2.7
1994	12	26	11	45	2.9
1994	12	26	12	45	3
1994	12	26	13	45	3.1
1994	12	26	14	50	3.1
1995	2	16	9	35	0.4
1995	2	16	11	10	0.3
1995	2	16	12	20	0.8
1995	2	16	13	45	2
1995	2	16	14	55	2.8
1995	4	20	8	50	1.7
1995	4	20	10	10	2.5
1995	4	20	11	10	3.9
1995	4	20	12	20	3.8
1995	4	20	13	30	5.2
1995	4	20	14	50	5.3
1995	4	20	16	0	4.3

Location: BURI-4 River: Buriganga

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	26	7	55	0.2
1994	12	26	9	15	0.8
1994	12	26	10	25	0.3
1994	12	26	11	25	0.3
1994	12	26	12	25	1.6
1994	12	26	13	20	1.2
1994	12	26	14	30	2
1995	2	16	9	5	0.2
1995	2	16	10	45	0.1
1995	2	16	11	50	0.2
1995	2	16	13	20	0.3
1995	2	16	14	25	1.4
1995	2	16	15	25	1.6
1995	4	20	8	15	1
1995	4	20	9	45	0.7
1995	4	20	10	50	2.4
1995	4	20	11	50	3.2
1995	4	20	13	5	2.8
1995	4	20	14	20	3.8
1995	4	20	15	35	2.8

Table 4.3 Contd.

Location: BURI-5 River: Buriganga

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	26	7	40	0.9
1994	12	26	8	45	1.1
1994	12	26	10	0	1.5
1994	12	26	11	10	1.7
1994	12	26	12	12	1.9
1994	12	26	13	5	1.3
1994	12	26	14	15	0.3
1995	2	16	8	30	0.8
1995	2	16	10	10	0.1
1995	2	16	11	35	0.2
1995	2	16	12	55	0.3
1995	2	16	14	10	0.5
1995	2	16	15	45	0.6
1995	4	20	7	45	0.6
1995	4	20	9	15	1.3
1995	4	20	10	35	2.7
1995	4	20	11	40	2.6
1995	4	20	12	50	3.3
1995	4	20	14	0	2.2
1995	4	20	15	15	2.1
1995	4	20	16	25	2.2

Location: BURI-6 River: Buriganga

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	21	8	10	0.3
1994	12	21	9	45	0.9
1994	12	21	10	50	1.4
1994	12	21	12	25	1.5
1994	12	21	13	30	1.7
1994	12	21	14	40	2.5
1994	12	21	15	50	0.8
1994	12	21	17	0	0.5
1995	2	19	8	30	2.4
1995	2	19	10	10	6.2
1995	2	19	11	13	9.4
1995	2	19	12	21	12.7
1995	2	19	13	29	11.8
1995	2	19	15	5	8.8
1995	4	22	8	10	1.7
1995	4	22	9	35	2.6
1995	4	22	11	15	3
1995	4	22	12	15	4.3
1995	4	22	13	20	3.5
1995	4	22	14	30	3.8
1995	4	22	15	25	3
1995	4	22	16	30	3.5

Table 4.3 Contd.

Location: BURI-7 River: Buriganga

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	21	8	40	1
1994	12	21	10	5	2.7
1994	12	21	11	10	3.8
1994	12	21	12	40	4.3
1994	12	21	13	45	2.6
1994	12	21	15	0	2
1994	12	21	16	10	1.7
1994	12	21	16	45	1.5
1995	2	19	9	0	9.9
1995	2	19	10	30	14.5
1995	2	19	11	36	15.5
1995	2	19	12	40	17.2
1995	2	19	14	23	16.2
1995	2	19	15	25	13.6
1995	4	22	8	40	2.3
1995	4	22	10	15	2.4
1995	4	22	11	30	3.4
1995	4	22	12	35	2.7
1995	4	22	13	44	3.3
1995	4	22	14	50	4.5
1995	4	22	15	45	4.2

Location: BURI-8 River: Buriganga

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	21	9	0	4.1
1994	12	21	10	20	5.2
1994	12	21	11	30	4.8
1994	12	21	12	55	4.9
1994	12	21	14	0	4.5
1994	12	21	15	20	3.2
1994	12	21	16	25	2.3
1995	2	19	9	20	14.6
1995	2	19	10	45	15.8
1995	2	19	11	52	15.1
1995	2	19	12	55	16
1995	2	19	14	35	16.5
1995	2	19	15	35	16.8
1995	4	22	8	55	3.1
1995	4	22	10	45	2.9
1995	4	22	11	45	3
1995	4	22	12	50	4.2
1995	4	22	14	0	4.8
1995	4	22	15	5	5.4
1995	4	22	16	0	5.2

Table 4.3 Contd.

Location: BURI-9 River: Dhaleswari

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	22	8	40	3.5
1994	12	22	11	15	4.9
1994	12	22	12	5	4.9
1994	12	22	13	10	5
1994	12	22	14	15	5.1
1994	12	22	15	35	5
1994	12	22	16	20	4.9
1995	2	20	9	15	15.1
1995	2	20	10	30	16.8
1995	2	20	12	22	16.8
1995	2	20	13	20	19.2
1995	2	20	14	20	22.7
1995	2	20	15	30	17.8
1995	2	20	16	25	18.8
1995	4	23	8	25	4.5
1995	4	23	9	40	4.8
1995	4	23	11	15	4.8
1995	4	23	12	30	5.3
1995	4	23	13	25	7.1
1995	4	23	14	30	5.9
1995	4	23	15	25	5.7

Location: BURI-10 River: Dhaleswari

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	22	9	30	5
1994	12	22	10	55	5
1994	12	22	11	40	4.9
1994	12	22	12	40	4.7
1994	12	22	13	45	5
1994	12	22	14	45	5.1
1994	12	22	16	0	4.9
1994	12	22	16	45	5.1
1995	2	20	10	0	15.9
1995	2	20	11	40	12.1
1995	2	20	12	51	11.9
1995	2	20	13	50	11.9
1995	2	20	14	53	13.5
1995	2	20	15	58	18
1995	4	23	9	0	6.2
1995	4	23	10	52	5.8
1995	4	23	11	45	5.8
1995	4	23	13	0	5.9
1995	4	23	14	0	5.8
1995	4	23	14	55	6.3
1995	4	23	16	5	6.3

Table 4.3 Contd.

Location: BURI-11 River: Dhaleswari

Year	Month	Day	Hour	Minute	DO (mg/l)
1994	12	23	8	35	2.8
1994	12	23	10	40	8
1994	12	23	11	45	6.8
1994	12	23	12	37	6.9
1994	12	23	13	40	7.1
1994	12	23	14	35	7.5
1994	12	23	15	25	7.3
1994	12	23	16	20	7.6
1995	2	21	9	20	9
1995	2	21	10	18	9.5
1995	2	21	12	0	10.5
1995	2	21	12	53	10.6
1995	2	21	13	40	10.2
1995	2	21	14	25	10
1995	2	21	15	12	10.8
1995	4	24	8	45	7.1
1995	4	24	10	25	7.6
1995	4	24	11	15	7.7
1995	4	24	12	5	7.3
1995	4	24	13	0	6.4
1995	4	24	14	35	6.7
1995	4	24	15	35	7.8
1995	4	24	16	30	8.2

Table 4.4 Test Results of Water Quality Parameters (December, 1994)

Tests carried out at The Department of Environment, Dhaka

Date	Locationn	B.O.D.	C.O.D.	NH3	NH4+	E-Coli	Tot-Coli	TSS	NO3	Orth-PO4	Cr
19-Dec-94	BURI-1S	1	4	0	0	2400	4000	9	0	0.06	0.016
19-Dec-94	BURI-1B	2.6	8	0.06	0.45	1600	3500	56	0	0.12	0.014
19-Dec-94	BURI-2S	9	25	0.08	0.61	1200	3200	13	2.2	3.67	0.008
19-Dec-94	BURI-2B	3.6	10	0.051	0.38	1000	3000	16	0	0.69	0.006
20-Dec-94	BURI-3S	4.6	16	0.066	0.495	2500	4500	29	0	0.14	0
20-Dec-94	BURI-3B	4.9	16	0.101	0.76	1600	3000	22	0	0.58	0.004
20-Dec-94	BURI-4	2.5	10	0.032	0.24	900	2850	15	0.9	1.53	0
20-Dec-94	BURI-5S	3.8	12	0.275	2.05	18000	36000	10	7.5	12.83	0.014
20-Dec-94	BURI-5B	4.2	15	0.233	1.75	1200	2500	20	6.4	10.83	0.01
21-Dec-94	BURI-6S	12	28	0.29	2.19	15000	40000	12	8	13.68	0.012
21-Dec-94	BURI-6B	12.5	30	0.325	2.44	1400	3000	16	8.9	15.22	0.011
21-Dec-94	BURI-7S	8.2	20	0.31	2.3	8500	12000	22	8.4	14.36	0
21-Dec-94	BURI-7B	6.9	15	0.27	2.03	7000	9500	25	7.1	12	0
21-Dec-94	BURI-8S	4.9	14	0.09	0.685	3500	5000	14	0.09	0.685	0
21-Dec-94	BURI-8B	4.4	12	0.24	1.81	3000	5000	18	6.6	11.22	0
22-Dec-94	BURI-9	3.2	10	0.01	0.13	4000	6500	10	2.8	4.73	0.01
22-Dec-94	BURI-10	3	8	0.08	0.65	3000	4500	20	0.5	0.855	0
23-Dec-94	BURI-11	3.5	10	0.11	0.76	1300	3500	16	2.4	4.104	0
26-Dec-94	BURI-3S(R)	4	7	0.24	1.84	1600	8000	18	6.7	5.36	0
26-Dec-94	BURI-4(R)	4.1	8	0.03	0.24	3000	6600	16	0	0.91	0
26-Dec-94	BURI-5S(R)	4.2	8.4	0.16	1.21	24000	44000	14	4.43	3.95	0

S - sample from 1m below the water surface, B - sample from 1m above the river bed, (R) - revised programme
All values are in mg/l except E.Coli and T.Coli, which are in Nos./100 ml

Table 4.5 Test Results of Water Quality Parameters (February, 1995)

Tests were carried out at The Department of Environment, Dhaka

Date	Locationn	B.O.D.	C.O.D.	NH3	NH4+	E-Coli	Tot-Coli	TSS	NO3	Orth-PO4	Cr
14-Feb-95	BURI-1S	100	255	9.73	73	700	3100	65	0.02	0.34	0
14-Feb-95	BURI-1B	150	382	10.4	78	800	1800	80	0.08	0.53	0
14-Feb-95	BURI-2	90	222	10.13	76	400	4500	45	1.8	0.2	0
16-Feb-95	BURI-3S	130	332	13.6	102	7500	12000	52	0.94	0.71	0
16-Feb-95	BURI-3B	120	290	14.53	109	5000	20000	38	0.04	0.25	0
16-Feb-95	BURI-4	170	428	8.53	64	3800	16000	38	0.28	0.49	0
16-Feb-95	BURI-5S	180	456	8.93	67	4500	18000	36	1.12	0.84	0
16-Feb-95	BURI-5B	100	245	15.2	114	5500	30000	42	0.8	1.2	0
19-Feb-95	BURI-6S	10	30	0	0	350	1200	26	0	0.75	0
19-Feb-95	BURI-6B	14	40	0	0	35	700	25	0.34	10.5	0
19-Feb-95	BURI-7S	11	32	0	0	2500	8000	22	0	8	0
19-Feb-95	BURI-7B	16	45	0	0	700	1900	20	0.78	0.87	0
19-Feb-95	BURI-8S	5	15	0	0	300	1400	25	2.4	7.5	0
19-Feb-95	BURI-8B	4.2	14	0	0	400	3200	26	0.89	8.4	0
20-Feb-95	BURI-9S	5.1	16	0	0	70	4500	20	1.97	0.78	0
20-Feb-95	BURI-9B	5.2	16	0	0	400	1200	20	2.18	0.97	0
20-Feb-95	BURI-10S	1	4	0	0	400	1800	22	0.21	2.4	0
20-Feb-95	BURI-10B	3.6	12	0	0	700	1400	16	2.48	7.95	0
21-Feb-95	BURI-11	2.3	8	0	0	100	3200	16	4.58	11.54	0
08-Feb-95	S-7 *	310	416	10.71	80.3	UC	UC	110	0	10.7	0.11
08-Feb-95	S-8 *	136	192	8.1	60.8	UC	UC	60	0	4.54	0
08-Feb-95	S-9 *	260	323	4.8	36	UC	UC	300	0	8.97	0
12-Feb-95	S-10 *	130	256	5.73	43	UC	UC	195	0	3.42	0.004
11-Feb-95	Kashipur K. *	20	105	1.29	9.7	UC	UC	80	0	5.87	0.004
13-Feb-95	Dholai K. *	220	374	6.8	51	UC	UC	270	0	5.01	0.004

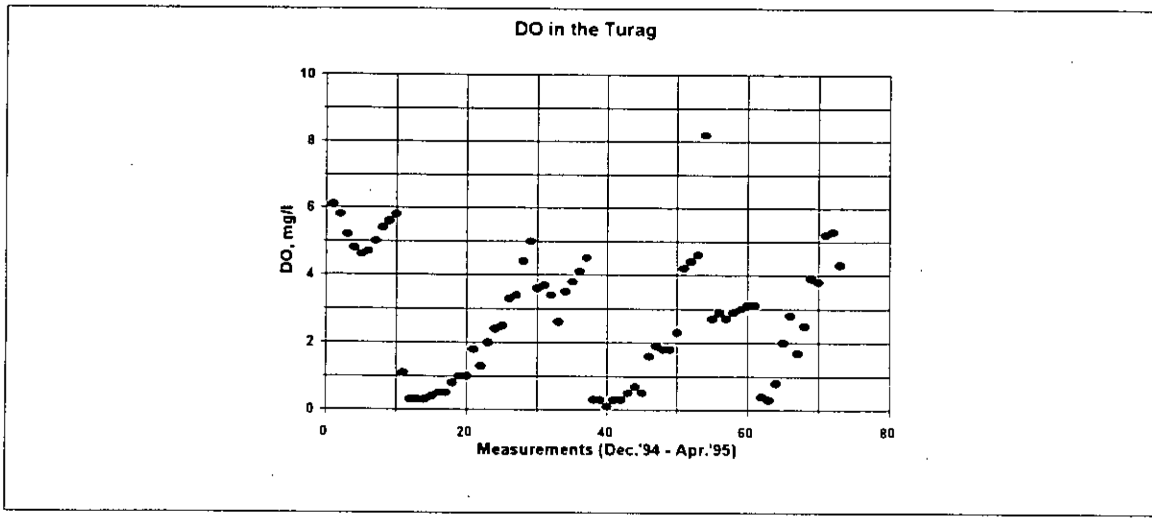
S - sample from 1m below water surface; B - sample from 1m above river bed; * - wastewater sample
All values are in mg/l except E.Coli and T.Coli, which are in Nos./100 ml; UC - uncountable

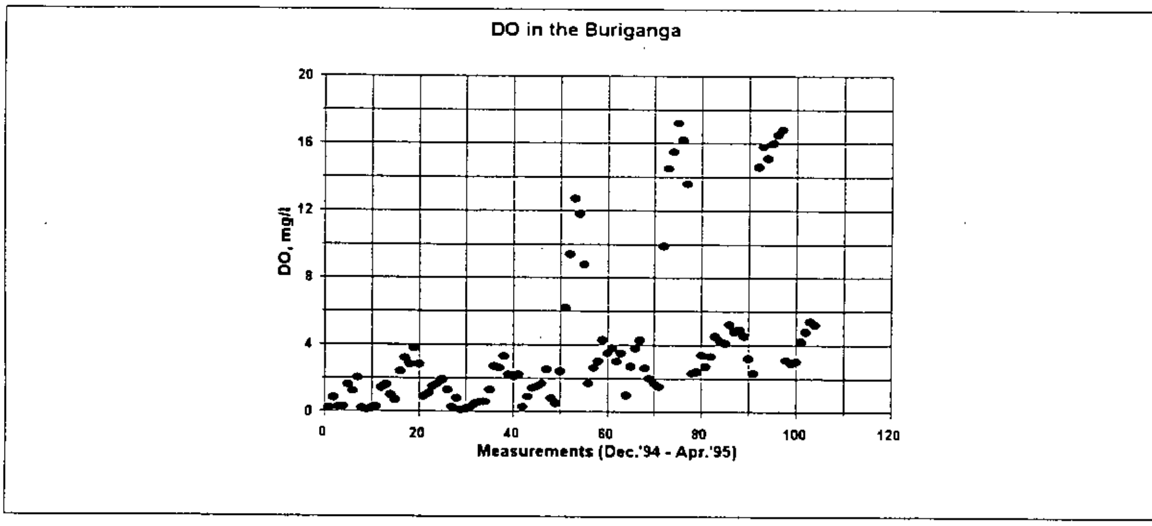
Table 4.6 Test Results of Water Quality Parameters (April, 1995)

Tests were carried out at The Department of Environment, Dhaka

Date	Locationn	B.O.D.	C.O.D.	NH3	NH4+	E-Coli	Tot-Coli	TSS	NO3	Orth-PO4	Cr
19-Apr-95	BURI-1S	130	380	0	0	75	300	36	2.2	2.47	0
19-Apr-95	BURI-1B	30	78	0	0	180	250	22	1.8	4.07	0
19-Apr-95	BURI-2	100	210	0	0	1200	2500	24	0	0.46	0
20-Apr-95	BURI-3S	10	18	0.29	0.3	1200	2000	15	0	1.04	0
20-Apr-95	BURI-3B	20	30	0.73	0.77	450	500	18	0	0.28	0
20-Apr-95	BURI-4	80	270	4.62	4.89	3000	3500	15	0	1.24	0
20-Apr-95	BURI-5S	20	90	0	0	1800	3000	14	0	1.08	0
20-Apr-95	BURI-5B	130	440	0.32	0.33	4500	5000	24	0	2.08	0
22-Apr-95	BURI-6S	40	70	0	0	6400	9000	18	0.37	10.96	0
22-Apr-95	BURI-6B	430	540	0	0	55000	80000	22	2.2	10.44	0
22-Apr-95	BURI-7S	30	50	0	0	50	130	25	2.7	0.89	0
22-Apr-95	BURI-7B	190	240	0	0	700	1900	20	0.78	0.87	0
22-Apr-95	BURI-8S	50	120	0	0	10	125	18	4.9	1.08	0
22-Apr-95	BURI-8B	130	410	0	0	120	550	16	3	0.45	0
23-Apr-95	BURI-9S	190	530	0	0	500	1000	24	1.3	1.28	0
23-Apr-95	BURI-9B	200	420	0	0	1200	2000	35	1.6	1.4	0
23-Apr-95	BURI-10S	3.4	7.8	0	0	10	80	22	0.37	7.6	0
23-Apr-95	BURI-10B	2	6	0	0	4	50	34	1.2	2.3	0
24-Apr-95	BURI-11S	1.8	12	0	0	75	100	28	0	0.98	0
24-Apr-95	BURI-11B	2	18	0	0	80	115	32	0.42	1.02	0
26-Apr-95	S-7 *	140	200	0.73	0.77	800	1500	55	1.98	1.08	0.18
26-Apr-95	S-8 *	10	30	79.04	83.72	10	80	160	2.34	6.4	0
26-Apr-95	S-9 *	90	70	10.94	11.96	70	110	80	0.99	3.1	0
26-Apr-95	S-10 *	120	220	15.2	16.1	50	200	184	1.26	3.21	0
15-Apr-95	Kashipur K. *	30	78	1.14	1.21	70	220	35	0	6.01	0
16-Apr-95	Dholai K. *	50	272	21.88	23.18	170	250	350	0	7.65	0
18-Apr-95	PSTP O.F. *	20	120	0.6	0.64	150	180	34	0	4.08	0

All values are in mg/l except, E.Coli and T.Coli in Nos./100 ml; S - sample from 1m below water surface, B - from 1m above river bed; * - wastewater sample





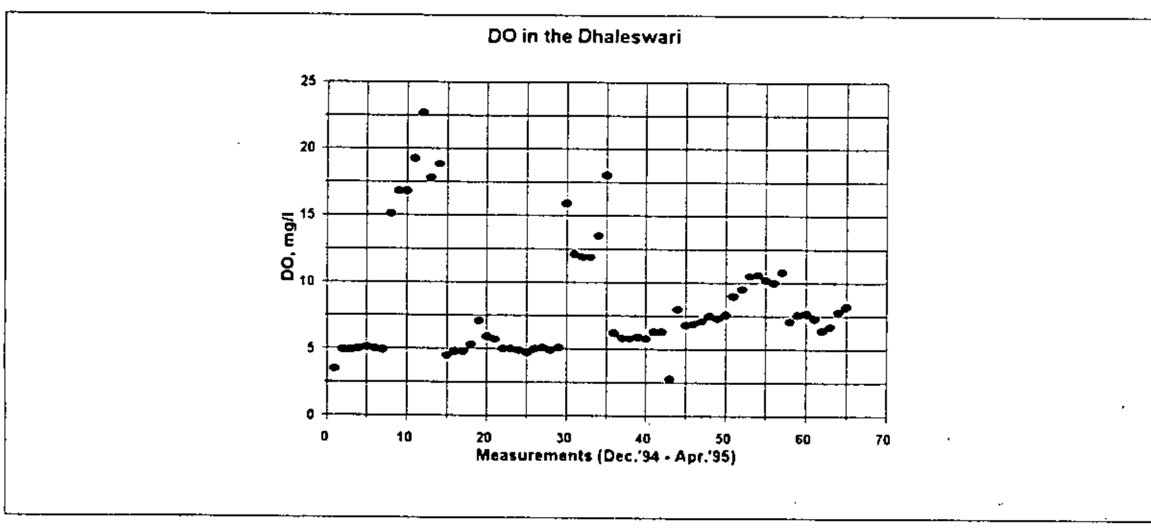
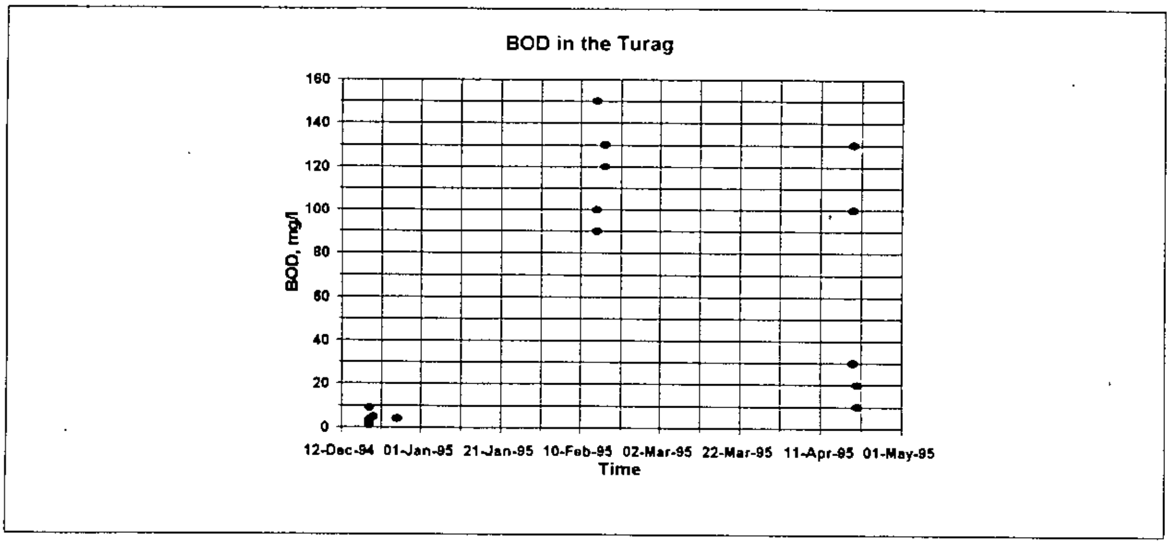
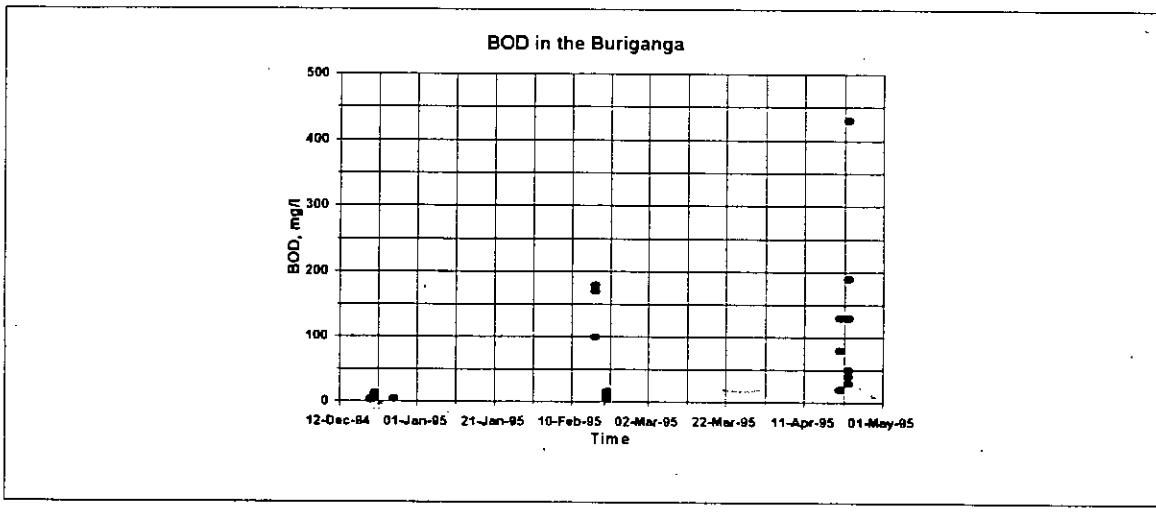


Figure 4.1 DO in the Turag, Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





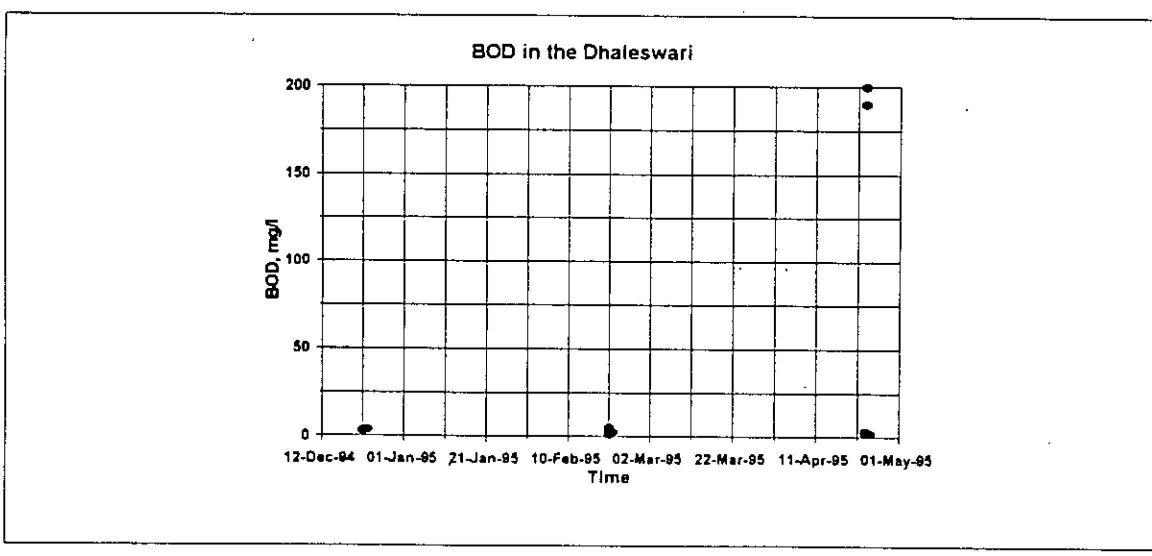
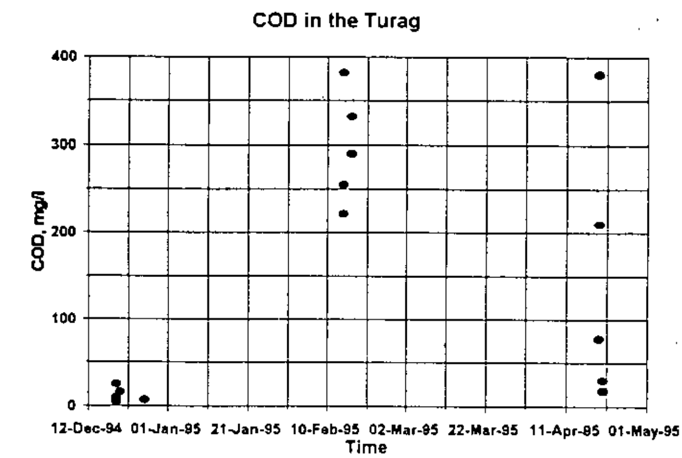
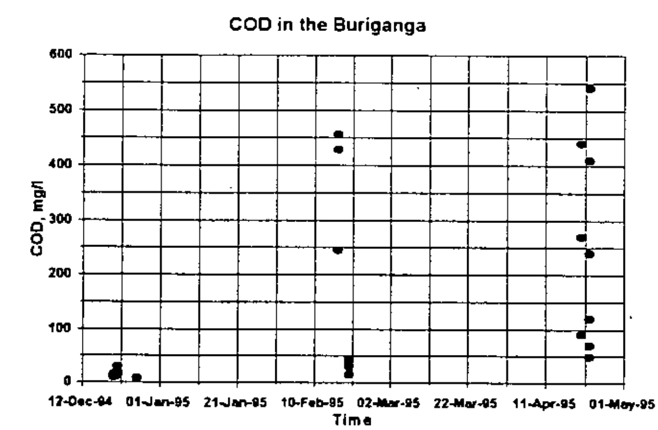


Figure 4.2 BOD in the Turag, Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





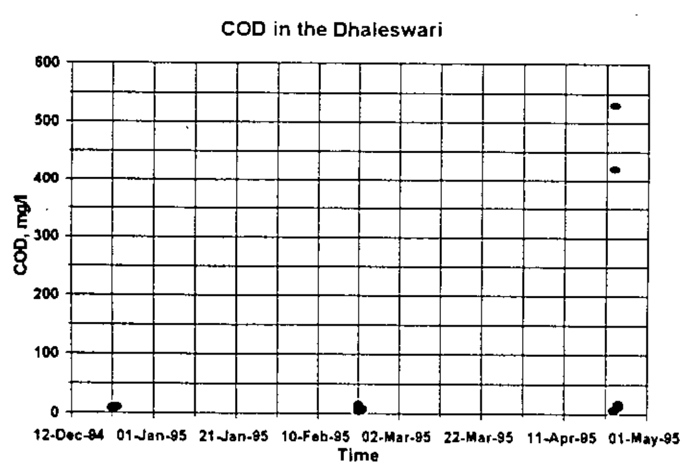
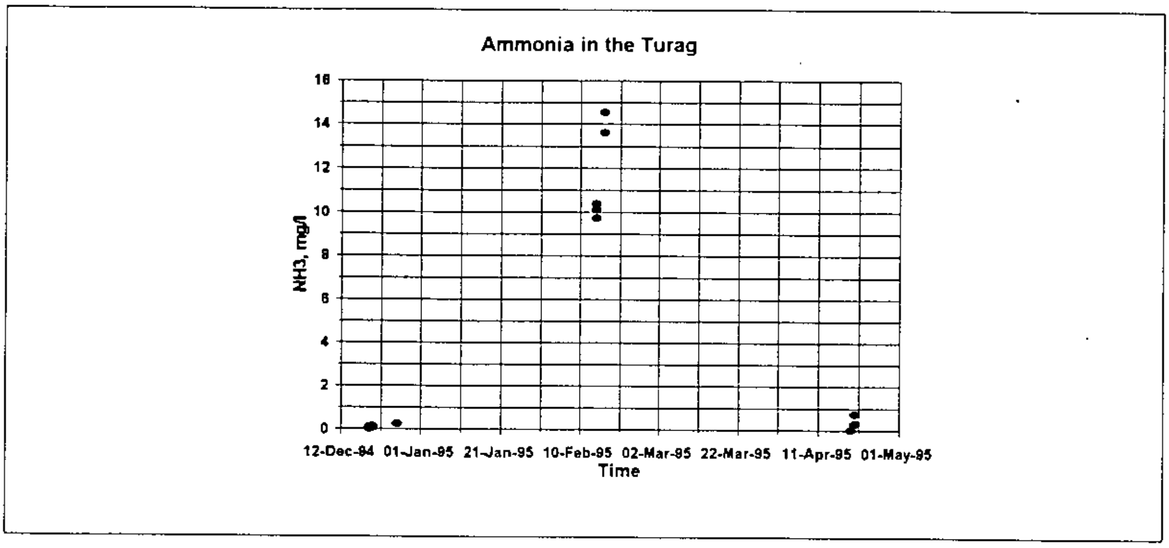
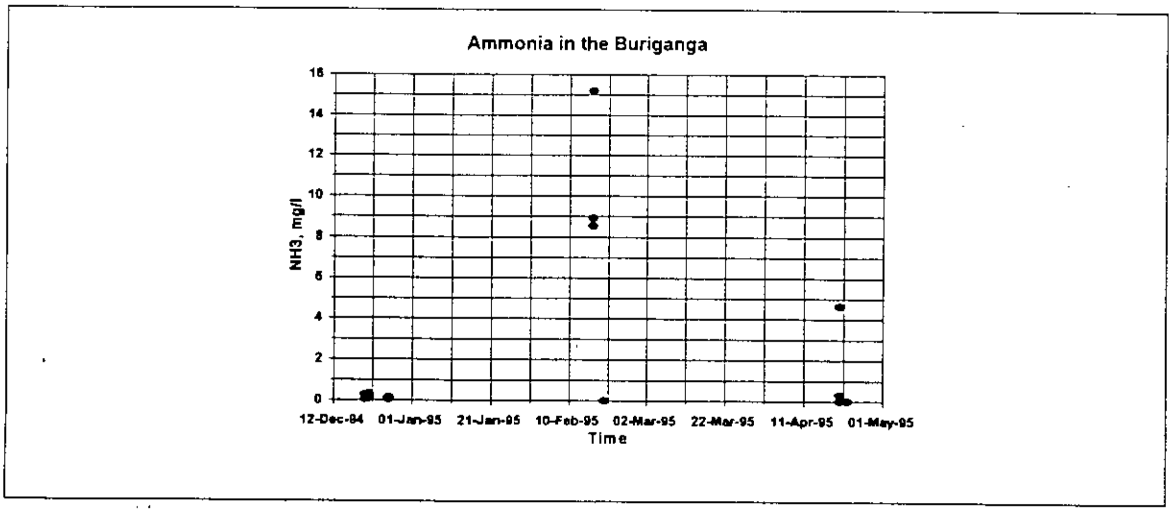


Figure 4.3 COD in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





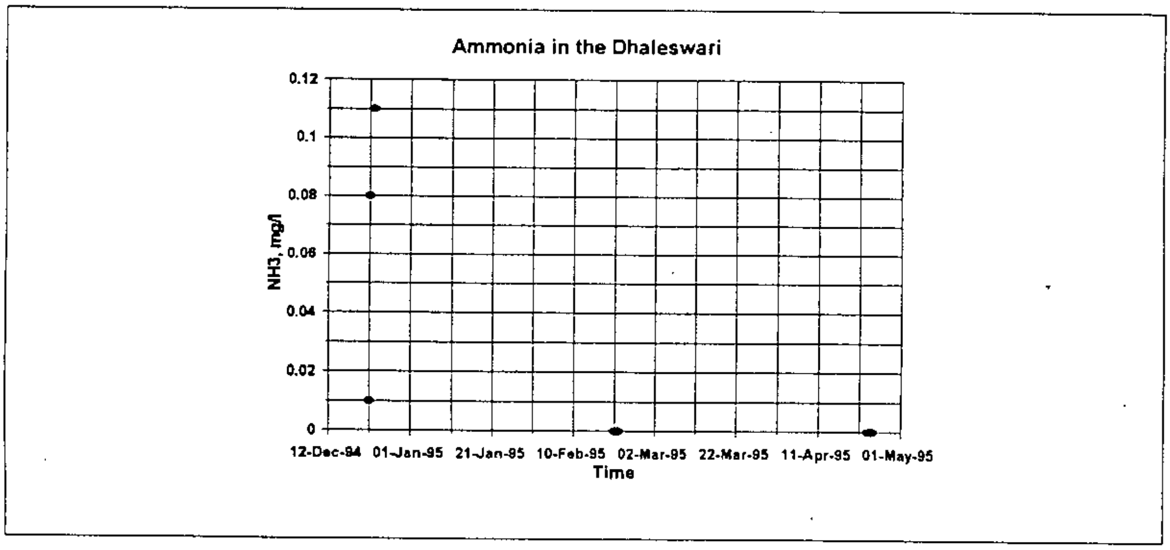
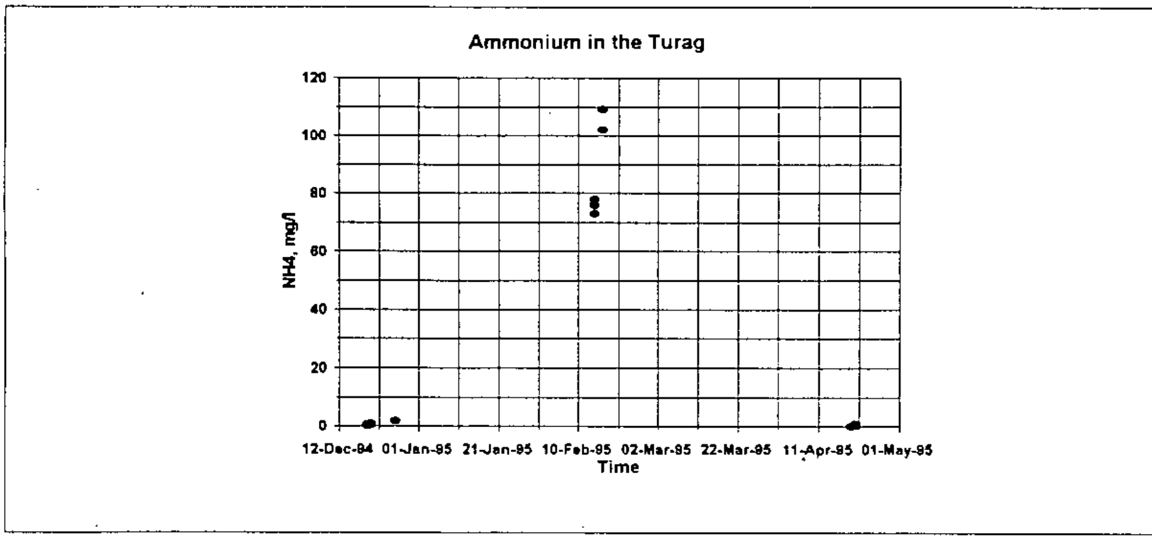
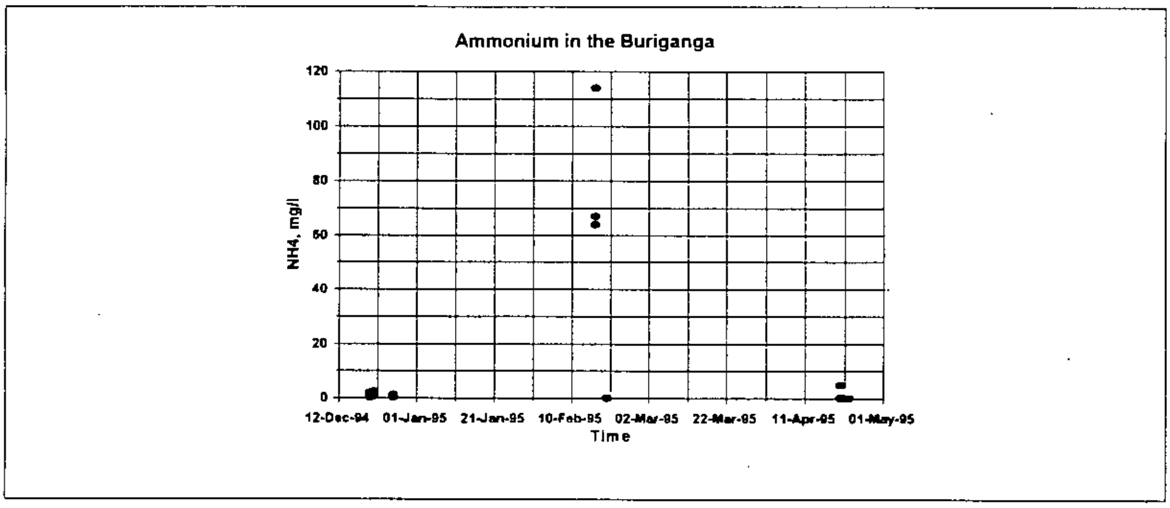


Figure 4.4 NH3 in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





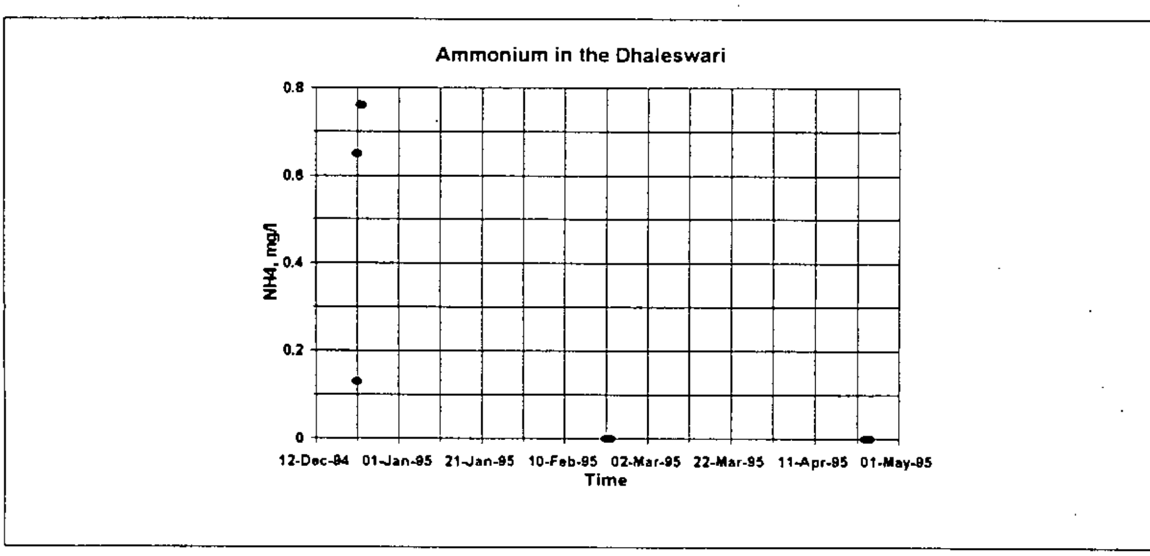
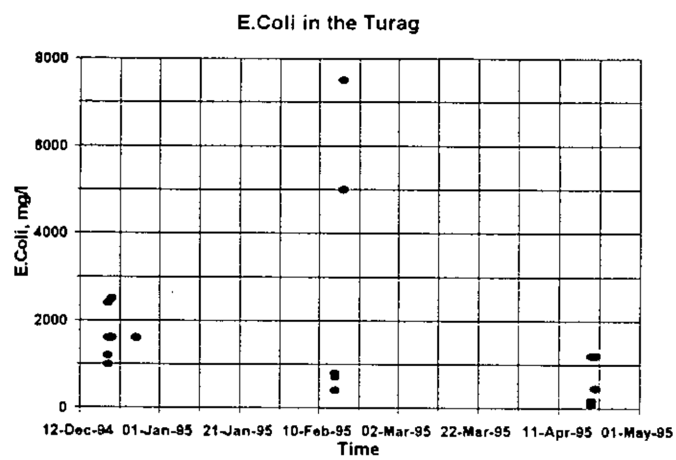
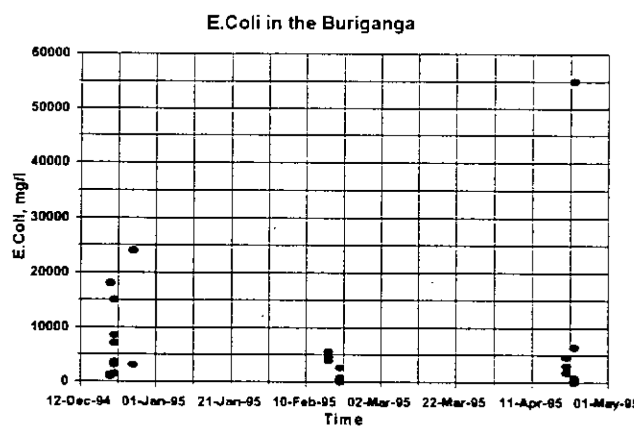


Figure 4.5 NH4 in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





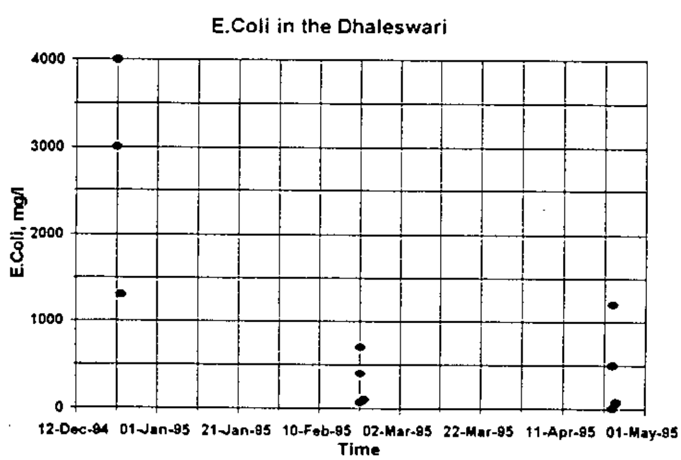
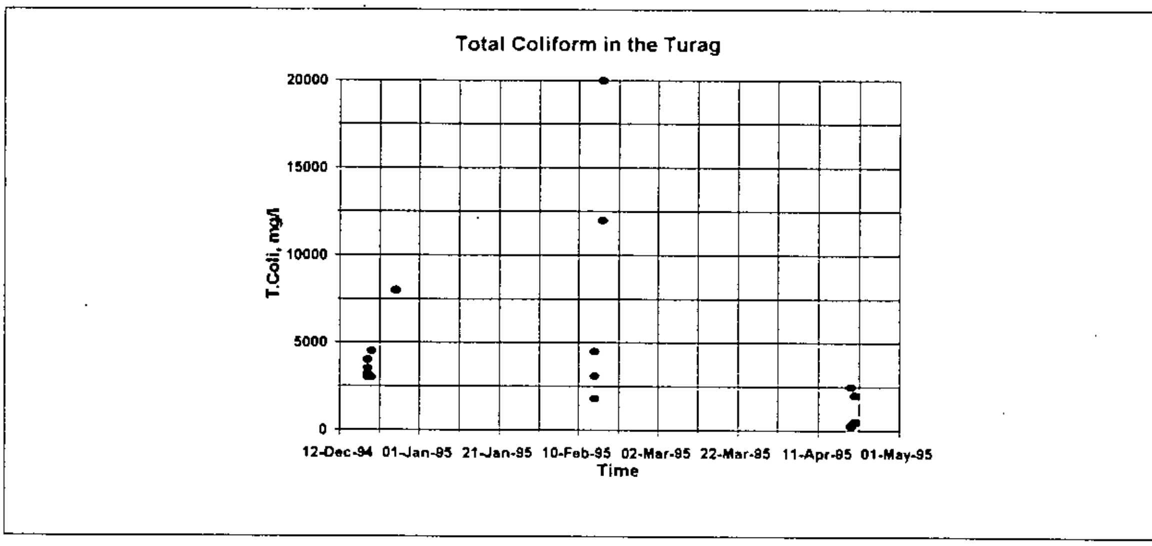
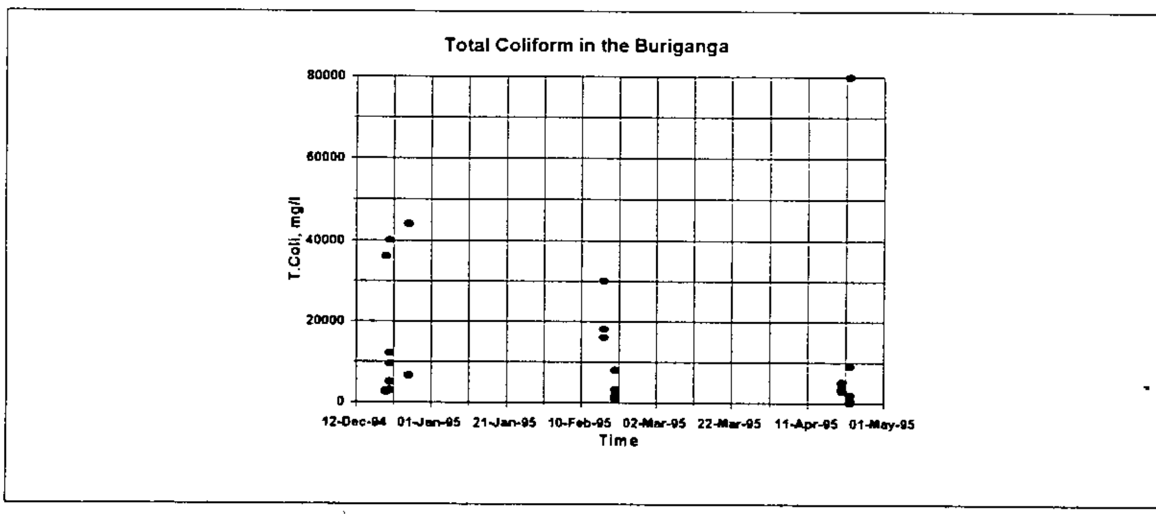


Figure 4.6 E.Coli in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





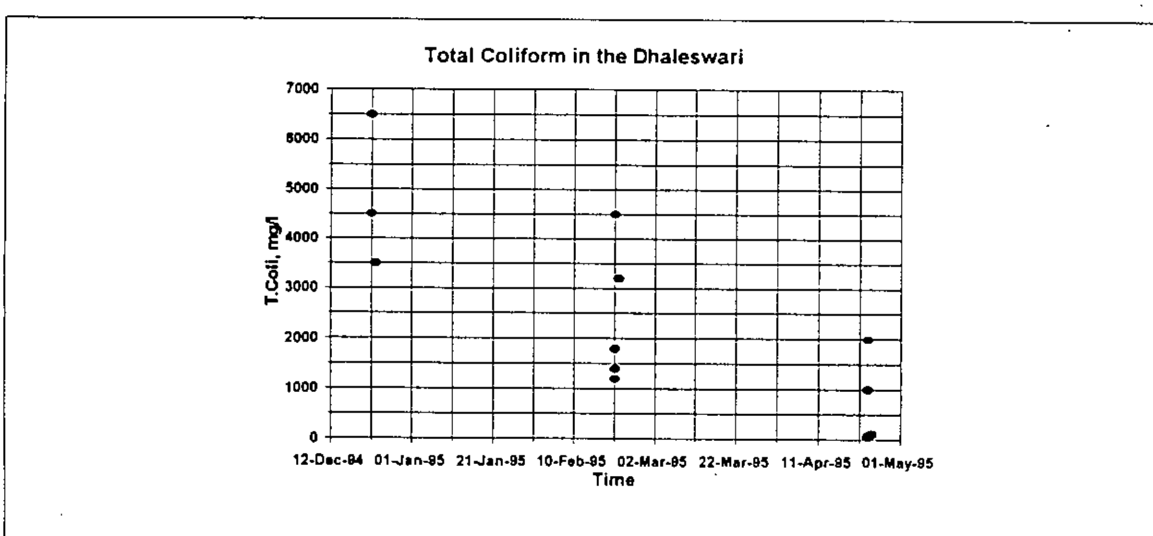
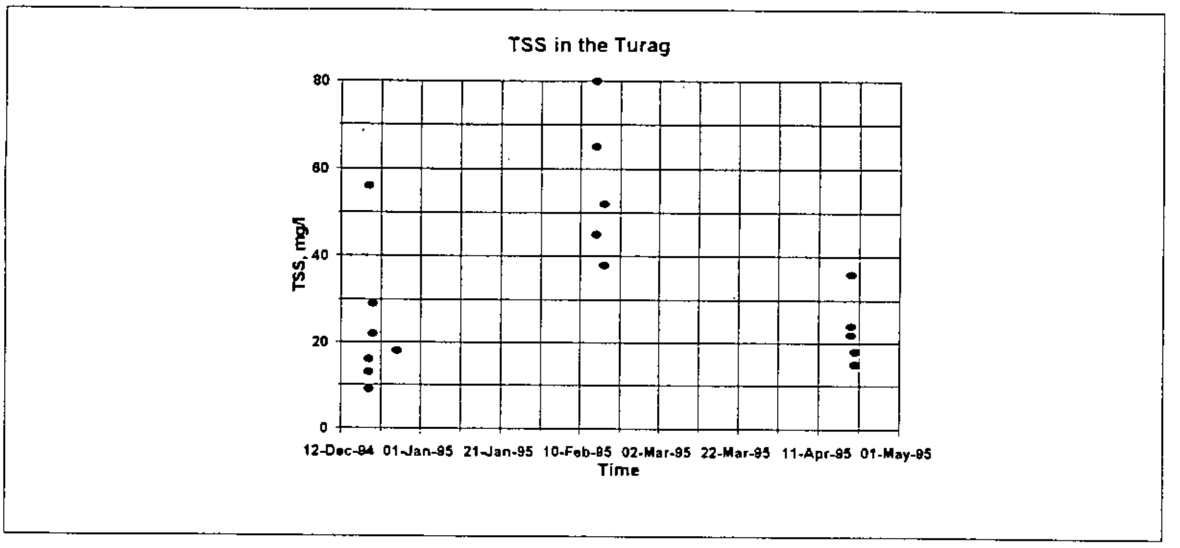
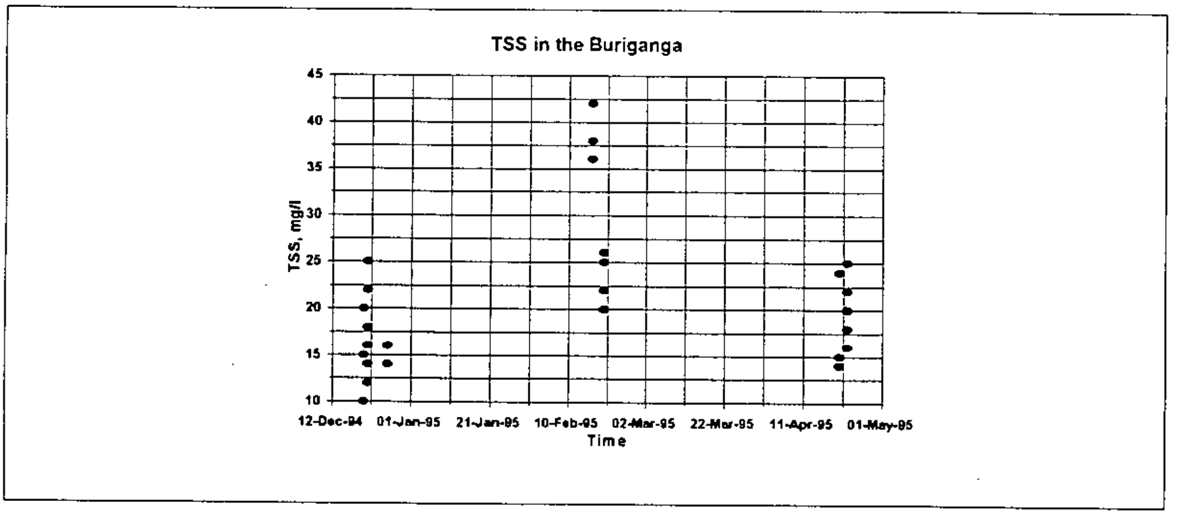


Figure 4.7 T.Coli in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





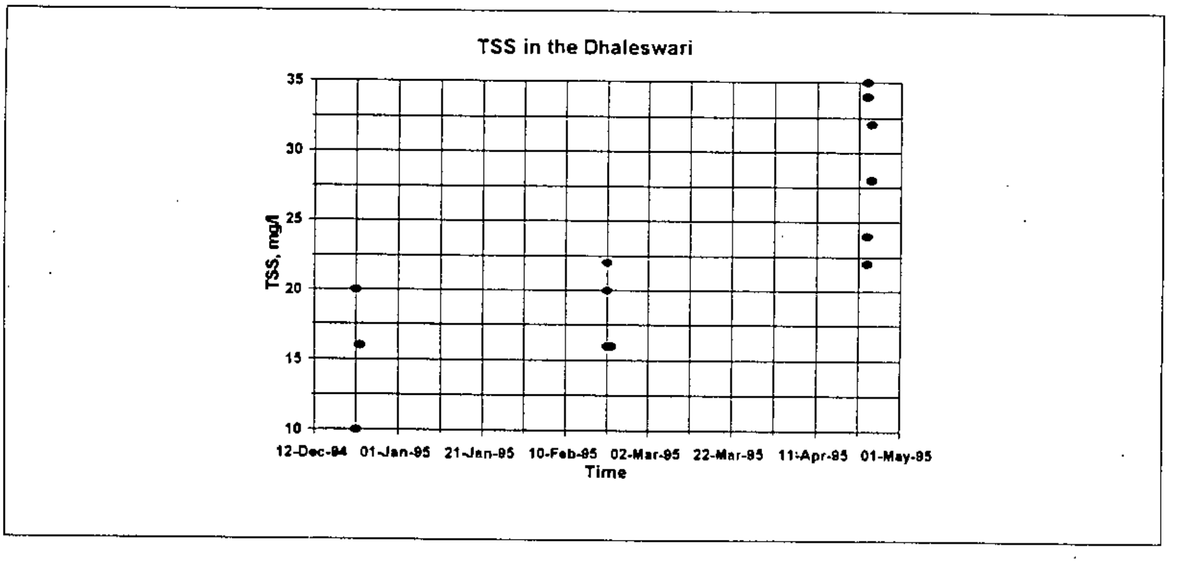
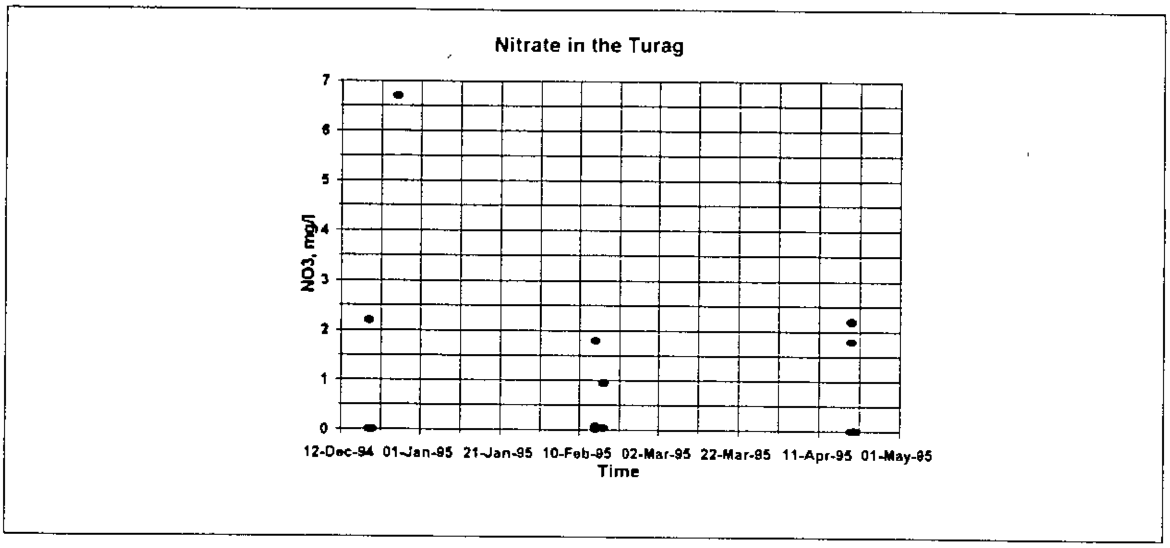
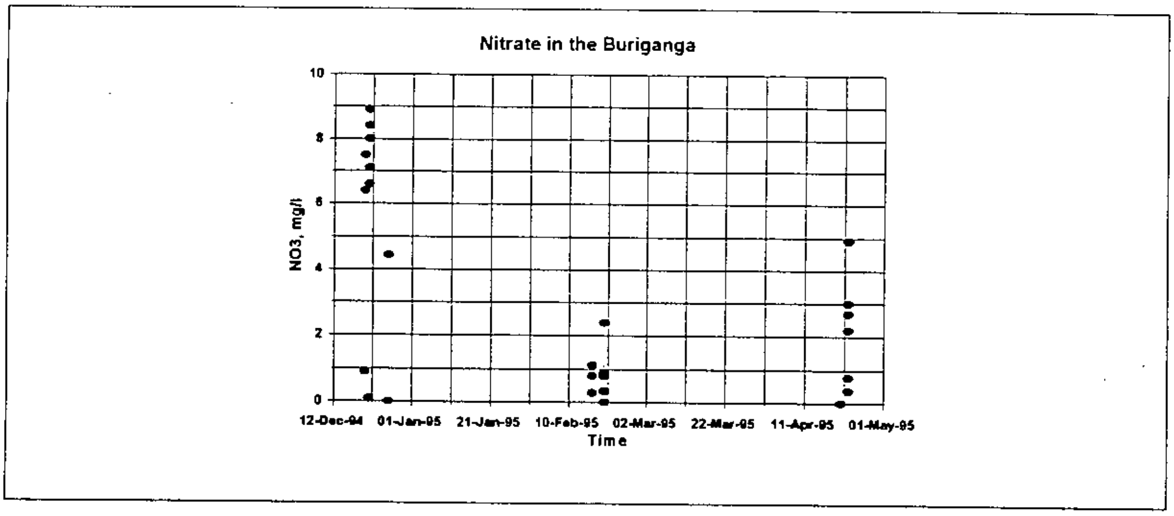


Figure 4.8 TSS in the Turag, Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





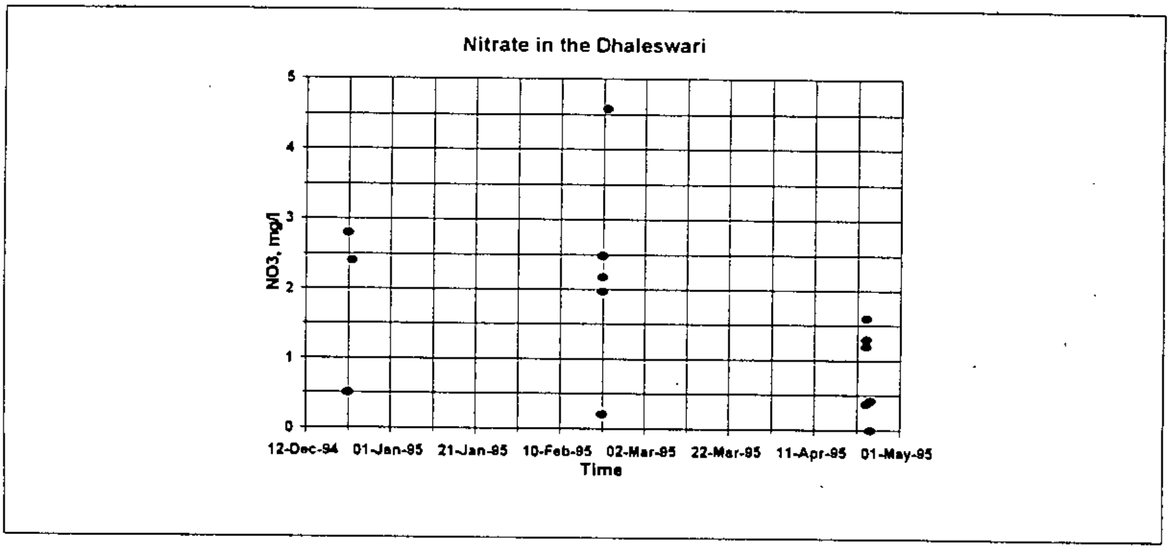
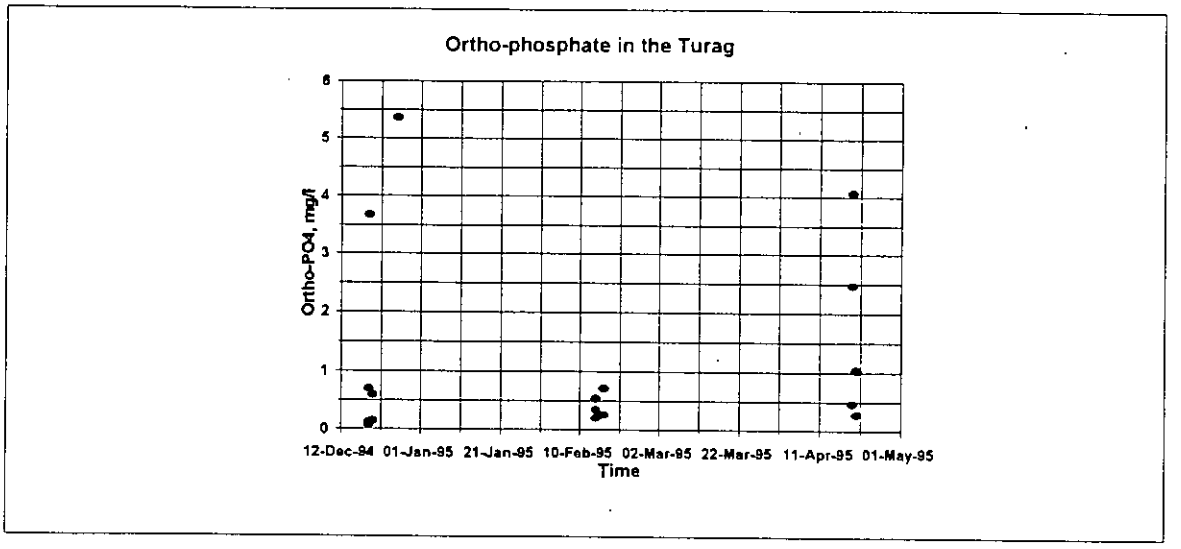
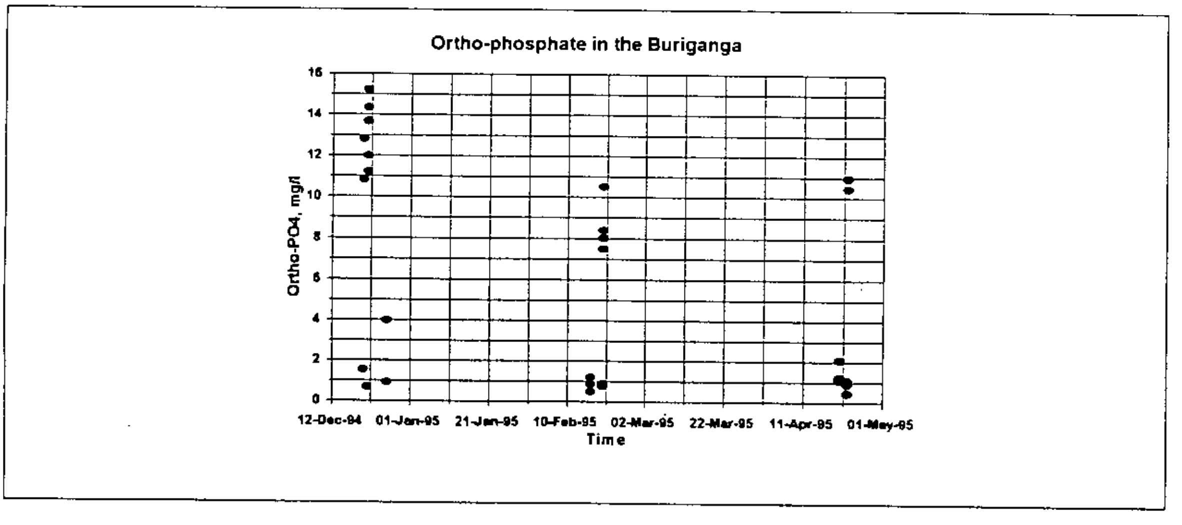


Figure 4.9 NO3 in the Turag, Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95





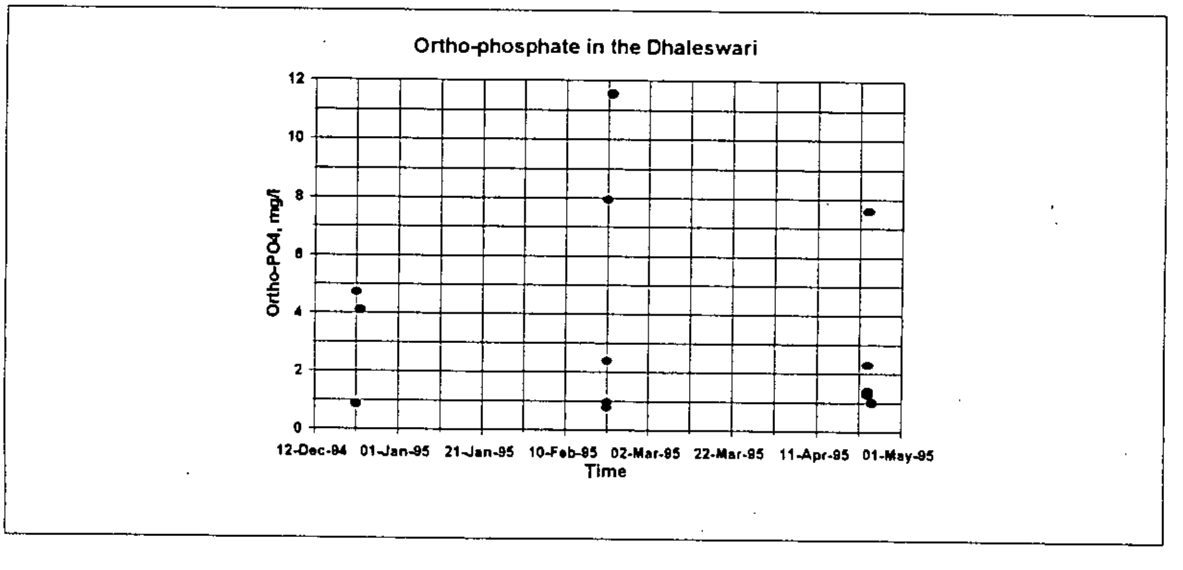


Figure 4.10 PO4 in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95

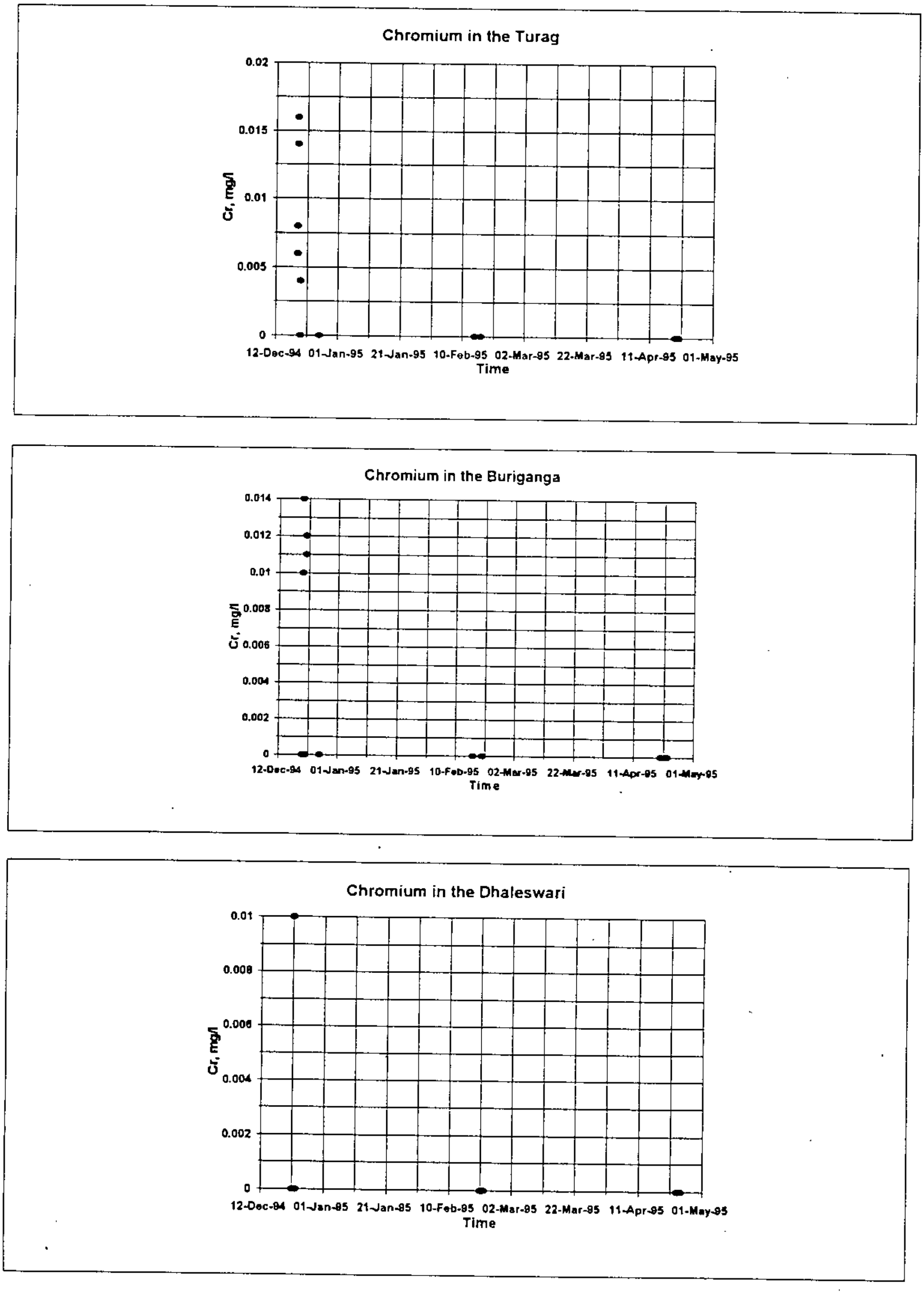


Figure 4.11 Cr in the Turag,Buriganga and Dhaleswari during the Dry season Dec'94 to Apr'95

Table 4.7 Summary of Water Quality Data Analyses for the Turag, Buriganga and Dhaleswari (Testing done at the DOE lab)

Water Quality Parameter	Turag			Buriganga			Dhaleswari		
	Min. value	Max. value	Data Range mostly vary within	Min. value	Max. value	Data Range mostly vary within	Min. value	Max. value	Data Range mostly vary within
DO	0.1	8.2	0.1-5.0	0.1	17.2	0.1-4.0	2.8	22.7	4.0-8.0
BOD_5	1	150	-	2.5	430	-	1	200	-
COD	4	382	-	8	540	-	4	530	-
NH_3-N_2	0	14.53	-	0	15.2	-	0	0.11	-
NH_4-N_2	0	109	-	0	114	-	0	0.76	-
E.Coli	75	7500	-	10	55000	-	4	4000	-
T.Coli	25	20000	-	125	80000	-	50	6500	-
TSS	9	80	-	10	42	-	10	35	-
NO_3-N_2	0	6.7	-	0	8.9	-	0	4.58	-
Ort-PO_4-P	0.06	5.36	-	0.45	15.22	-	0.78	11.54	-
Cr	0	0.016	-	0	0.014	-	0	0.01	-

Note: All values in Table 4.7 are in mg/l, except E.Coli and T.Coli which are in Nos./100 ml

Figure 4.2 indicates that BOD_5 values in the Buriganga were mostly within 25 to 200 mg/l according to the test results of samples from February, 1995 and April, 1995 field campaigns. Figure 4.3 indicates that COD values in the Buriganga were mostly within 50 to 450 mg/l according to the test results of samples from February, 1995 and April, 1995 field campaigns. Figure 4.6 indicates that the number of E.Coli in the Buriganga were within 10,000 per 100 ml (except one very high value) according to the test results of samples from February, 1995 and April, 1995 field campaigns. Much higher values of E.Coli (15,000 to 25,000 Nos./100 ml) were observed from the samples of December, 1994 field campaign. Similar comment is applicable in the case of Total Coliforms (Figure 4.7). Concentration of TSS in the Buriganga mostly varies, according to Figure 4.8, between 15 to 25 mg/l. Concentration of Chromium is generally low in the Buriganga, having high values around 0.01 to 0.014 mg/l (found only from samples of December, 1994 field campaign).

With possible exceptions, river water nowadays is not used directly for drinking. However, as a source of irrigation water, bathing, and washing of household items river water is still practised widely in Bangladesh. In consideration of the relevance of the water quality parameters measured/tested (and as historical data collected from the DOE which are described later on) during the present study, the Environmental Quality Standards (EQS) of relevant parameters set out by the DOE (DOE, 1991) for fishing, recreational and irrigation water are shown in Table 4.8.

Table 4.8 EQS of Some Relevant Water Quality Parameters (DOE, 1991)

Parameter	Recreational	Fishing	Irrigation
Alkalinity (total), mg/l	NYS	70-100	NYS
Ammonia (NH_3), mg/l	2	0.025	3
Ammonical Nitrogen (as N), mg/l	NYS	1.2	15
BOD, mg/l	3	6	10
Chloride (as Cl), mg/l	600	600	600
COD, mg/l	4	NYS	NYS
Chromium, mg/l	NYS	0.05	NYS
Coliform (total), Nos./100 ml	200	5000	1000
Coliform (faecal), Nos./100 ml	NYS	NYS	10
DO, mg/l	4-5	4-6	5
Nitrate (as N), mg/l	NYS	NYS	NYS
pH	6 - 9.5	6.5 - 8.5	6.0 - 8.5
SS, mg/l	20	25	NYS

Note: NYS - Standard not yet set

It is seen from Table 4.8 that the EQS are not yet complete. Comparing these available set of standards with pertinent data (Tables 4.3 to 4.6 and Figures 4.1 to 4.11), it is found that as sources of recreational, fishing and irrigation water, the Buriganga and the Turag rivers hardly satisfy the EQS set out by the DOE. Occasional high concentrations of DO or low concentrations of other parameters are mainly the result of fresh water inflow to these rivers, especially during spring tide period, and local rainfall.

Table 4.9 to Table 4.11 show comparison of test results obtained from different laboratories. Reviewing Tables 4.9 to 4.11, it is apparent that there exists almost no match among the results of different laboratories. The gross differences among the results reflect that there may be some problems in testing samples for water quality parameters in the laboratories. The differences might be due to improper preservation of samples, quality of the chemicals for testing, lack of skill, use of faulty instruments/apparatus, etc. The differences in test results may pose problem in application of this data in water quality modelling. This issue needs to be considered when similar studies are carried out in future.

Table 4.9 Comparison of Results of Water Quality Parameters obtained from Different Laboratories

(Sampling carried out during 8-22 February, 1995)

Sample Identification	NO_3 as N_2 (mg/l)		Ortho-PO_4 as P (mg/l)		Cr (mg/l)	
	BUET	DOE,Dhaka	BUET	DOE, Dhaka	BUET	DOE, Dhaka
S-7*	2.0	0.00	3.16	10.7	0.827	0.11
S-8*	0.3	0.00	7.92	4.54	0.062	0.00
S-9*	4.5	0.00	7.12	8.97	0.145	0.00
S-10*	0.0	0.00	7.92	3.42	0.067	0.004
KASHIPUR K*	0.0	0.00	2.64	5.87	0.008	0.004
DHOLAI K*	1.3	0.00	9.52	5.01	0.067	0.004
BURI-1B	0.0	0.08	0.88	0.53	0.001	0.00
BURI-1S	0.0	0.02	1.03	0.34	0.00	0.00
BURI-2	0.0	1.8	0.68	0.20	0.008	0.00
BURI-3B	0.0	0.04	0.88	0.25	0.00	0.00
BURI-3S	0.0	0.94	0.32	0.71	0.00	0.00
BURI-4	0.0	0.28	1.53	0.49	0.01	0.00
BURI-5S	0.0	1.12	0.44	0.84	0.00	0.00
BURI-5B	0.0	0.8	1.16	1.2	0.012	0.00
BURI-6S	0.0	0.00	0.62	0.75	0.019	0.00
BURI-6B	0.0	0.34	0.57	10.5	0.00	0.00
BURI-7S	0.0	0.00	0.20	8.0	0.002	0.00
BURI-7B	0.0	0.78	0.18	0.87	0.019	0.00
BURI-8S	0.0	2.4	0.01	7.5	0.00	0.00
BURI-8B	0.0	0.89	0.02	8.4	0.00	0.00
BURI-9S	0.0	1.97	0.02	0.78	0.009	0.00
BURI-9B	0.0	2.18	0.00	0.97	0.002	0.00
BURI-10S	0.0	0.21	0.03	2.4	0.00	0.00
BURI-10B	0.0	2.48	0.05	7.95	0.00	0.00
BURI-11	0.0	4.58	0.02	11.54	0.00	0.00

Notes: S - sample collected from 1 m below water surface, B - sample collected from 1 m above river bed

* - wastewater sample

Table 4.10 Comparison of Test Results of Water Quality Parameters obtained from Different Laboratories

(Sampling done during 13-27 April, 1995)

Sample Name	BOD			COD			NH_3-N_2			NH_4-N_2			E.Coli		
	DOE,Dhk	DOE,Ctg	SWMC	DOE,Dhk	DOE,Ctg	SWMC	DOE,Dhk	DOE,Ctg	SWMC	DOE,Dhk	DOE,Ctg	SWMC	DOE,Dhk	DOE,Ctg	SWMC
S-7	140	190		200	368		0.73	70		0.77	117.51	80	800	480	
S-8	10	210		30	158.4		79.04	11		83.72	21.06	16.2	10	590	
S-9	90	220		70	396		10.94	24.2		11.96	46.23	105	70	630	
S-10	120	180		220	260		15.2	32		16.1	54.07	80	50	720	
Dholai Khal	50			272			21.88			23.18		95	170		
Kashipur K.	30			78			1.14			1.21		6.4	70		
PSTP O.F.	20			120			0.6			0.64		19.2	150		

Note: 1. Concentration of all the parameters is in mg/l except E.Coli and T.Coli, which are in Nos./100 ml

2. Testing of parameters at SWMC were done using a Filter Photometer

Legend: DOE, Dhk: Laboratory of the Department of Environment, Dhaka Division

DOE, Ctg: Laboratory of the Department of Environment, Chittagong Division

SWMC : Laboratory of the Surface Water Modelling Centre

Table 4.11 Comparison of Test Results of Water Quality Parameters obtained from Different Laboratories

(Sampling done during 13-27 April, 1995)

Sample Name	Total Coliform			TSS			NO_3-N_2			Ortho-P04 - P			Cr		
	DOE Dhk	DOE Ctg	SWMC	DOE Dhk	DOE Ctg	SWMC	DOE Dhk	DOE Ctg	SWMC	DOE Dhk	DOE Ctg	SWMC	DOE Dhk	DOE Ctg	SWMC
S-7	1500	980		55	415		1.98	1.13	<0.5	1.08	20	2.4	0.18	0.001	
S-8	80	1080		160	503		2.34	1.22	<0.5	6.4	13	1.6	0	0.001	
S-9	110	1070		80	527		0.99	2.01	<0.5	3.1	18	3	0	0.0023	
S-10	200	1180		184	270		1.26	1.89	<0.5	3.21	22	3.6	0	0.002	
Dholai Khal	250			350			0		<0.5	7.65		3.6	0		
Kashipur K.	220			35			0		<0.5	6.01		1.2	0		
PSTP O.F.	180			34			0		<0.5	4.08		3	0		

Note: 1. Concentration of all the parameters is in mg/l except E.Coli & T. Coli, which are in Nos./100 ml

2. Testing of parameters at SWMC were done using a Filter Photometer

Legend: DOE, Dhk: Laboratory of the Department of Environment, Dhaka Division

DOE, Ctg: Laboratory of the Department of Environment, Chittagong Division

SWMC : Laboratory of the Surface Water Modelling Centre

4.2 Historical Data Collected by the DOE

The Department of Environment has been maintaining three water quality monitoring stations on the Turag and Buriganga rivers. These are located at:

- The outfall of the Hazaribagh main drain,
- The outfall of the Pagla Sewage Treatment Plant,
- Chandni Ghat near water intake point of the DWASA.

It should be noted that the first monitoring station is located, according to the schematisation of river network in the present study, on the Turag river. However, the DOE mentioned this river as the Buriganga. For uniformity, this location will be mentioned to be situated on the Turag throughout this study.

In the first two locations, samples are also collected from the drains before it reaches the river. In the river, samples are collected at different distances from the bank (or outfall), having different depths, along a specific cross-sectional line.

Historical data between the year 1980 to 1994 were collected to evaluate the current status and the pollution trend of the Turag and Buriganga rivers. The DOE collects samples from these points on an intermittent basis, having shorter interval in the dry period and longer intervals in the monsoon. pH, Chloride, Total Alkalinity, Total Suspended Solids (TSS), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) are analysed for each sample by the DOE on a regular basis. Occasionally, they analyse samples for Chemical Oxygen Demand (COD), Ammonia, Coli-colonies, Chromium and some other parameters. Table A.1 to Table A.5 (APPENDIX A) show values of the abovementioned 10 parameters for the period of 1980-1994. Figure B.1 to Figure B.17 (APPENDIX B) show the trend of pollution in the Turag and Buriganga, for this period, with respect to these 10 parameters. As the DOE collects samples at each location (except the two drains) at different depths and distances from the bank, minimum and maximum values of the parameters from every sampling programme are shown in the Tables and Figures. Tables 4.12 to 4.16 summarise the status of pollution with respect to these 10 parameters.

Table 4.12 Analysis of Water Quality Parameters - Chandnighat (DOE)

Parameter	Minimum Value	Maximum Value	Data Range mostly vary between
pH	5.7	7.9	6.75 - 7.75
Chloride (mg/l)	1.2	110	10 - 50
Total Alkalinity (mg/l)	23	196	50 - 175
Total Suspended Solids (mg/l)	7	180	25 - 75
Dissolved Oxygen, DO (mg/l)	1.5	7.1	4.5 - 7.0
BOD_5 at 20°C (mg/l)	0.09	50	1 - 5
COD (mg/l)	0	104	*
Ammonia (mg/l)	0	0	*
Coli-colonies (Nos./100 ml)	1,350	13,500	*
Chromium (mg/l)	0	0.03	*

Note: * - Data set too little to make such comment

Table 4.13 Analysis of Water Quality Parameters - Hazaribagh (DOE)

Parameter	Minimum Value	Maximum Value	Data Range mostly vary between
pH	6.1	8.4	6.75 - 7.75
Chloride (mg/l)	2	3,350	10 - 100
Total Alkalinity (mg/l)	24	760	50 - 200
Total Suspended Solids (mg/l)	5	1,108	10 - 100
Dissolved Oxygen, DO (mg/l)	1.4	11.9	4 - 7
BOD_5 at 20°C (mg/l)	0.3	210	1 - 10
COD (mg/l)	0	198	*
Ammonia (mg/l)	0	0.4	*
Coli-colonies (Nos./100 ml)	19.5	9,500	*
Chromium (mg/l)	0	0.63	*

Note: * - Data set too little to make such comment

Table 4.14 Analysis of Water Quality Parameters - Pagla STP outfall (DOE)

Parameter	Minimum Value	Maximum Value	Data Range mostly vary between
pH	6.6	7.9	7.0 - 7.4
Chloride (mg/l)	5	51	5 - 40
Total Alkalinity (mg/l)	24	204	50 - 150
Total Suspended Solids (mg/l)	23	164	30 - 60
Dissolved Oxygen, DO (mg/l)	4.9	7.4	5.75 - 6.75
BOD_5 at 20^oC (mg/l)	1	4.4	2 - 4
COD (mg/l)	NA	NA	-
Ammonia (mg/l)	NA	NA	-
Coli-colonies (Nos./100 ml)	NA	NA	-
Chromium (mg/l)	NA	NA	-

Note: NA - Data not available for the period of analysis

Table 4.15 Analysis of Water Quality Parameters - Hazaribagh main drain (DOE)

Parameter	Minimum Value	Maximum Value	Data Range mostly vary between
pH	5.2	12	7.0 - 8.5
Chloride (mg/l)	6	10,200	50 - 3000
Total Alkalinity (mg/l)	50	3,000	50 - 1250
Total Suspended Solids (mg/l)	16	5,025	50 - 1500
Dissolved Oxygen, DO (mg/l)	0	7.3	0 - 0.25
BOD_5 at 20^oC (mg/l)	0	1,090	50 - 400
COD (mg/l)	0	12,800	200 - 2500
Ammonia (mg/l)	0.2	150	*
Coli-colonies (Nos./100 ml)	0	4,000	*
Chromium (mg/l)	0.7	21	*

Note: * - Data set too little to make such a comment

Table 4.16 Analysis of Water Quality Parameters - Pagla STP main drain (DOE)

Parameter	Minimum Value	Maximum Value	Data Range mostly vary between
pH	6.6	8.2	7.3 - 7.7
Chloride (mg/l)	6	55	10 - 50
Total Alkalinity (mg/l)	52	208	100 - 170
Total Suspended Solids (mg/l)	22	108	40 - 60
Dissolved Oxygen, DO (mg/l)	0.9	5.9	4.5 - 6.0
BOD_5 at 20°C (mg/l)	1.6	250	100 - 150
COD (mg/l)	46.8	780	*
Ammonia (mg/l)	NA	NA	-
Coli-colonies (Nos./100 ml)	300	80,000	*
Chromium (mg/l)	NA	NA	-

Note: NA - Data not available for the period of analysis,* - Data set too little to make such a comment

As mentioned earlier, there is only one monitoring station of the DOE in the Turag, and two monitoring stations in the Buriganga at Chandnighat and Pagla. Two of the monitoring stations are located near the wastewater outfalls (Hazaribagh and Pagla). Water quality data from only these three stations may not be representative to assess the pollution in the Turag and Buriganga. However, comparison of the EQS (Table 4.8) with the DOE data (Tables 4.12 to 4.14) indicates that there did not exist considerable problem in the two rivers for the period of analysis (1980-94). Only, concentrations of Total Alkalinity and Suspended Solids violated the EQS to some extent. These findings hardly conform with the findings from data procured during this study.

The concentrations of DO near Hazaribagh and Chandnighat have hardly gone below the critical level of 4 mg/l, especially since 1989. These results contradict with the findings of other studies carried out by different researchers which have been mentioned earlier. Also, the DO concentrations in the Turag and Buriganga measured during this study mostly varied between 0.1 to 4.0 mg/l, indicating the rivers unsuitable for aquatic life in the dry season.

4.3 Data Collected by the Pagla Sewage Treatment Plant Authority

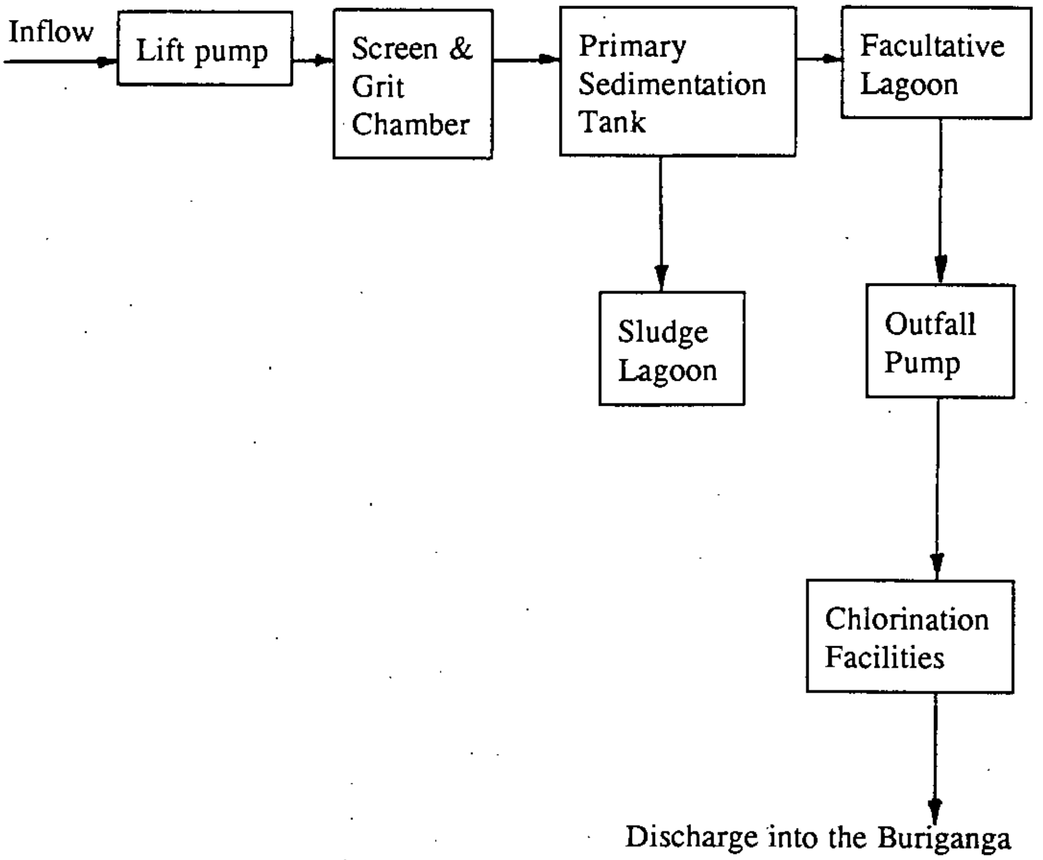
The Pagla Sewage Treatment Plant (PSTP), under the Dhaka Water and Sewerage Authority (DWASA), is the only sewage treatment plant in Bangladesh. After a renovation done by the JICA in March 1992, PSTP started its operation with expanded and new facilities. The sewered area being served by the PSTP has been shown in Figure 2.5. Relevant information regarding the PSTP are given below:

Designed Population	1,150,000 persons (Considering total population of the city in 1987 as 4,320,000)	
Sewerage System	Separate System	
Treatment System	For Sewage:	Primary Sedimentation Tank + Facultative Lagoon
	For Sludge:	Sludge Lagoon (Digestion + Drying in the Sun)
Outfall River	The Buriganga	
Designed Sewage	Daily Average:	96,000 m^3/day
	Daily Maximum:	120,000 m^3/day

Designed Water Quality:

Parameter	Influent Sewage Quality (mg/l)	Primary Tank Removal Rate (%)	Sedimentation Effluent Water Quality (mg/l)	Facultative Lagoon Removal Rate (%)	Effluent Water Quality (mg/l)	Total Removal Rate (%)
BOD	200	40	120	59	50	75
SS	200	60	80	25	60	70

Treatment Process:



The authority of the PSTP has been keeping, since its renovation, daily records of sewage flow. Occasional test results of BOD and TSS of wastewater samples are also recorded. Samples are taken from both the untreated and treated seawge. The treated sewage from the PSTP is discharged into the Buriganga river. Post-chlorination is done infrequently, mostly at times when cholera or any other fatal intestinal disease is reported.

All the data from the PSTP during the period between March 1992 to April 1995 were collected, checked and processed. Afterwards these were incorporated in the MIKE 11. Figure 4.12 and Figure 4.13 show BOD and SS concentrations in the treated and untreated sewage (effluent and influent), loadings of BOD and SS to the Buriganga from March, 1992 to April, 1995, and variations of BOD and SS loadings to the Buriganga due to varying volume of flow of treated wastewater. Relationships have been established between the flow of wastewater and the loadings of BOD and SS to the Buriganga using 'best fit curve' method using a software named 'GRAPHER'. To establish the relationships, it was assumed that the volume of influent and effluent wastewater is the same. Then, from the

BOD and SS concentrations in the effluent and the volume of effluent wastewater, loadings were calculated. The relationships are as follow:

$$L = 0.050933 \times Q + 450.025, \; Q > 0$$

$$S = 0.04476 \times Q + 314.895, \quad Q > 0$$

where, L = BOD loading in kg/d,

S = SS loading in kg/d, and

Q = Effluent flow in m^3/d

From the Figure 4.12 and Figure 4.13, it can be concluded that the PSTP has been operating quite satisfactorily since its renovation. It should be noted that there was a period of transition from March 1992 to October 1992, when the effluent quality of the PSTP did not meet the designed criteria in terms of BOD and SS. One of the factors could be that the facultative lagoon was not sufficiently matured in that period so that removal of the designed BOD and SS were not possible within a detention time of 7 days.

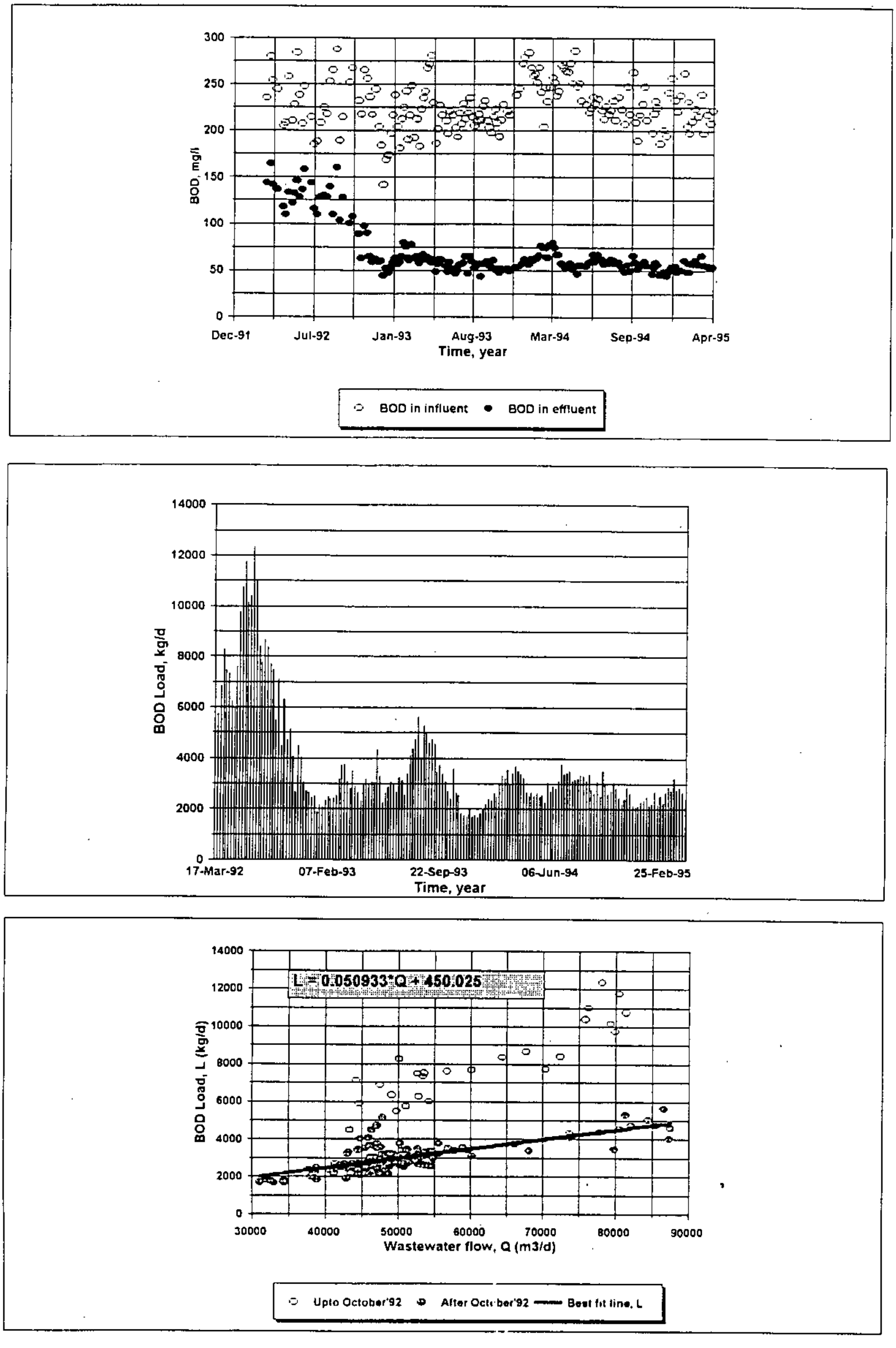
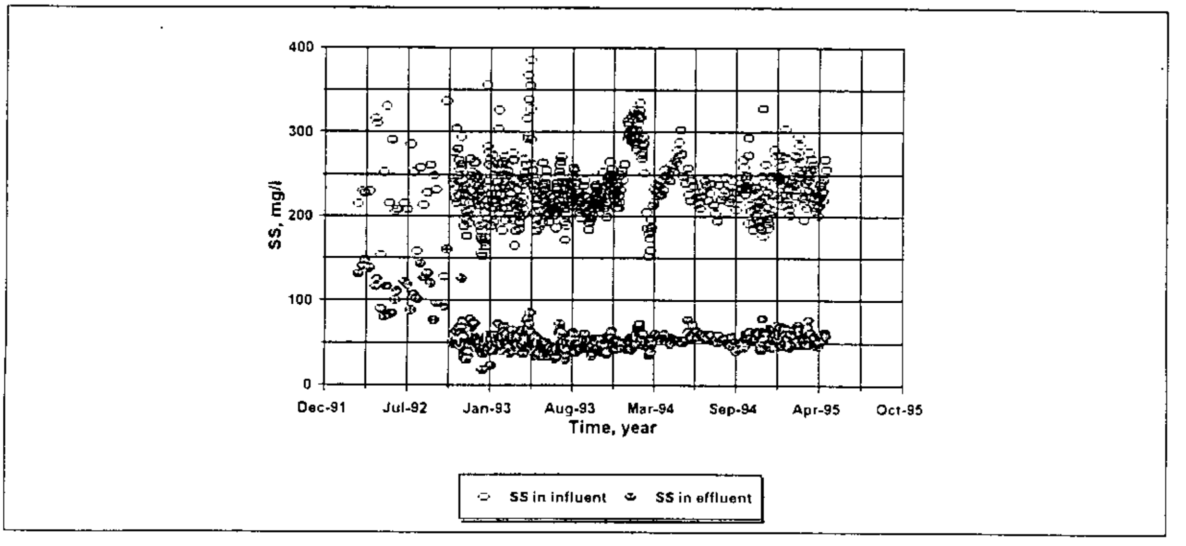
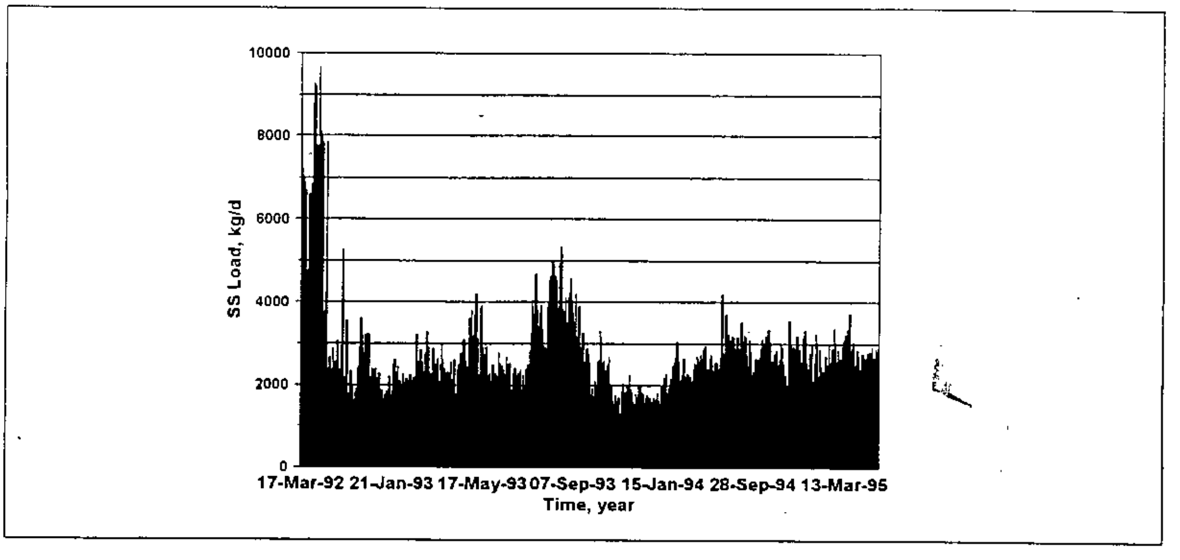


Figure 4.12 BOD removal status and Loadings to the Buriganga from the Pagla STP





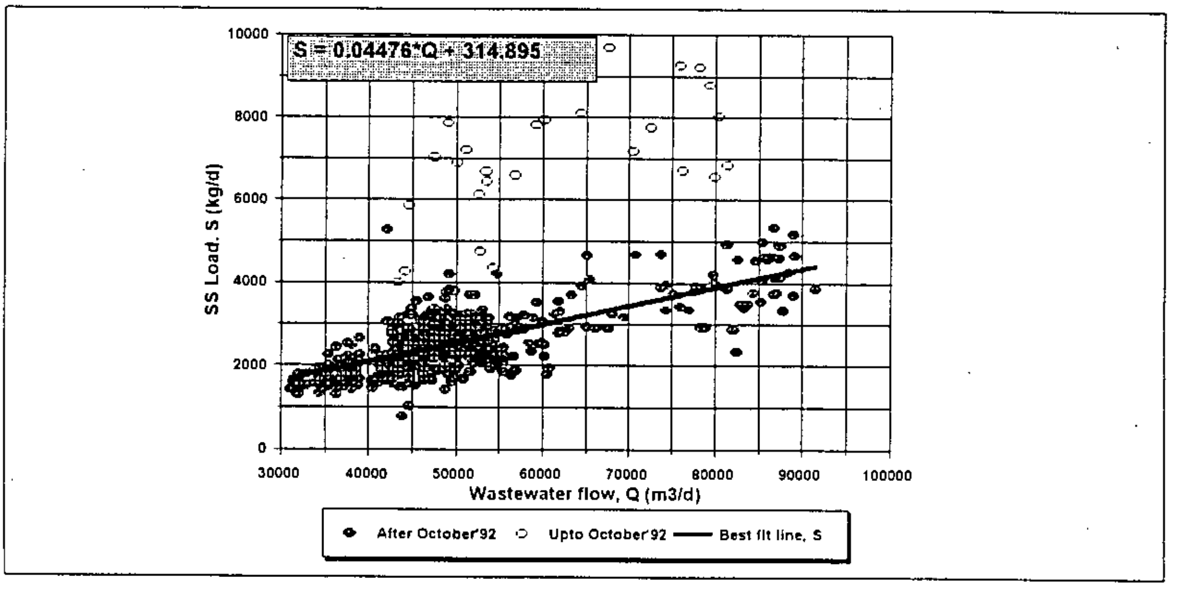


Figure 4.13 Suspended solids (SS) removal status and Loadings to the Buriganga from the Pagla STP

CHAPTER 5

ASSESSMENT OF POLLUTION LOADS

Assessment of the impacts of pollutants in a river mainly depends on the sources of pollution discharging into the river, and the river hydraulics. These items were addressed in the study with the latest information/data. Following sections provide detailed descriptions on the sources and severity of pollution reaching the Turag-Buriganga-Dhaleswari river system.

5.1 Point Sources

The major point sources contributing towards the pollution of the Buriganga may be divided broadly into three groups:

Group 1. Sluice Gates along the Dhaka Integrated Flood Protection (DIFP) Embankment.

Group 2. City Drains along the Buriganga including the Dholai Khal.

Group 3. Outfalls from the PSTP and the Kashipur Khal.

It must be noted at this point that there are many non-point (diffused) sources falling into the Turag-Buriganga-Dhaleswari river system, originating either from industries or from domestic wastes. As it is really difficult to compute pollution loadings separately from all these non-point sources, contribution from these sources on a lump sum basis are taken into account when computing the waste loadings from the major outfalls mentioned above. A detail description of the three major polluting sources is given below.

Group 1:

There are 11 sluice gates (one of which was incomplete at the initiation of this study) along the DIFP embankment, among which S-1 to S-3 sluices drain into the Tongi Khal. These three sluices drain irrigation drainage water through some small khals, namely Diabari and

Abdullapur Khal (Figure 2.4). These canals are barely affected by any kind of wastes. Therefore, no pollution loadings were estimated through these sluices.

Sluice S-4 drains Mirpur 12, Pallabi and adjoining low-lying areas through Degun Khal which is also connected with Diabari, Abdullapur and Baunia Khals (Figure 2.4). Although no visible effects were identified during field visits, water quality modelling revealed possible pollution of the water body, indicating the Degun khal to be a carrier of domestic wastes of the region. However, field measurement is required to verify this assumption.

Sluice S-5 drains Mirpur Section A, B and C through a branch of the Kalyanpur khal (Figure 2.4). No visible effects of pollution were evident during the field visits. Some additional loadings had been defined through this sluice after being invoked by water quality model. This loading estimate should also be verified through field measurement.

Sluice S-4 and S-5 falls within the MODS Zone IV. This MODS zone had no sewerage facility when this study was initiated in 1995. However, in recent times, sewerage drains are being installed in this zone. If MODS Zone IV were sewered throughout and wastewater (sewage) is then directed to the Degun Khal, then the water quality in the Turag will experience a definite deterioration.

Sluice S-6 drains stormwater from a drainage area comprising Mohammadpur, Darussalam, Kalyanpur and adjoining areas through Kalyanpur khal and a part of Ramchandrapur Khal (Figure 2.4). Also, bathroom wash from these areas is discharged through this sluice. There is also a pumping station which operates during high-flow period in the Buriganga river, when gravity flow through this sluice is not possible. Pollutant loadings through this sluice was also established through studying the water quality model. As, during field visits, wastewater flowing through this sluice did not show any deteriorated colour and no bad odour could be smelt, this sluice was not included in the programme of 'direct flow measurement' of wastewater. The loading assumed at this sluice is needed to be verified by field measurement.

Sluice S-7 is the most polluted sluice among the ten sluice gates. The tannery wastes from

Hazaribagh tannery area are mostly discharged through this sluice gate, along with domestic wastes from the neighbouring unsewered areas through Kantasur Khal (Figure 2.4). Also, a part of the Ramchandrapur Khal drains through this sluice. Wastewater-carrying drains from a number of areas ultimately discharge through this sluice. These areas are: Rayer Bazar, Nimtala, Sultanganj, Zigatala, Charakghata, Nawabganj, Gajmahal, Kantasur and West Dhanmondi. Extremely odorous wastewater having a very dark colour is discharged through this sluice. Before falling into the Turag, tannery wastes are first dumped into a ditch named 'Nimtala Beel'.

Through Sluice S-8, wastewater from the unsewered (or partially sewered) Borhanpur, Kanipara and Battala Majar Area are drained. Also, a small portion of the tannery waste is drained through this sluice. Characteristics of the wastewater, in terms of colour and odour, through this sluice are similar to the wastewater through sluice S-7. However, the rate of flow here is much less than that of through S-7.

Sluice S-9 drains wastewater from the unsewered (or partially sewered) areas, viz. Pilkhana, Enayetganj, Ganaktuli, Azimpur, Bhagalpur and Nawabganj. Sluice S-10 drains wastewater from Shahidnagar, Balughat and Amligola.

Flows of wastewater through Sluice S-7 to S-10 were measured and samples were collected for analyses in the laboratory for 'wet loading' estimates.

Sluice S-11 was not in operation during the field visits conducted in this study. Recently, it has been opened after the completion of its construction. However, no relevant information could be collected regarding the sluice. Moreover, as this sluice gate was not in operation during the period for which the water quality model was developed, it did not deem necessary to include this in the model as a point source. However, proper attention should also be paid to this sluice gate if it drains wastewater to the Turag.

Group 2:

There are 41 drains, including the Dholai Khal, along the Buriganga which carry wastewater (and stormwater) and fall into the Buriganga (Technoconsult - personal communication). The drains span from Postagala-Shashanghat to Babubazar. Some of the outlets of these drains are made of Iron pipe, some with RCC pipe; some of these are Brick drains and the rest are natural earthen canal, e.g. the Dholai Khal. Table C.1 (APPENDIX C) shows the location and description of the drains. Precise measurement of wastewater flows from all these drains was not possible for many technical reasons. Only in the Dholai Khal, flows were measured and samples were collected for 'wet loading' estimates. For the rest 40 drains, 'dry loading' estimates were carried out. In the water quality model, loadings from the 40 City drains has been considered as point source of pollution.

The Dholai Khal, locally also known as the Sutrapur Khal, is the most polluted point source falling into the Buriganga. About 40% of the total pollutants falling into the Buriganga is discharged from the Dholai Khal. Previously, Manda Khal (Debdulai Khal) and Gerani Khal contributed to the Dholai Khal, as has been found in a drawing by the 'Technoconsult'. Manda Khal, at the other end, was joined with the Gazaria Khal, which falls into the Balu river. However, during the field visits, it was found that the Manda Khal has no connection with the Dholai Khal beyond a market place situated near the Dayaganj Road side. It is because, recently the Manda Khal and the adjoining low-lying areas at that location were filled up to create new habitats. Gerani Khal still exists and is connected with the Dholai Khal. The areas being drained by the Dholai Khal, unfortunately, is not possible to identify properly. It has been mentioned in the Supplementary Report of FAP-8A (JICA, 1991) that in 1987, the UNDP/UNCHS conducted a feasibility study on the improvement of the Dholai Khal as an Old Dhaka Area Development Project. However, it was virtually impossible to get hold of the report on the then ongoing Environmental Improvement Project (EIP) of the Dhaka City Corporation. Verbal communication revealed that there was a component in the EIP concerning the Dholai Khal, namely 'Dholai Khal Stormwater Drainage', which was 53% of the whole EIP. From field visits and relevant sources, it could be gathered that the Dholai Khal-Gerani Khal system drains part of Narinda, Saidabad, Farashganj, and adjoining areas of the Hrishikesh Das Road and S.K.Das Road. There is no plan for a treatment plant for the the wastewater of the Dholai Khal.

Group 3:

A comprehensive description on the PSTP has already been given in the preceding chapter.

The severity of pollution caused by the pollutants released from the PSTP is quite insignificant in comparison with the other two major sources, viz. Sluice S-7 and the Dholai Khal. Although the PSTP was designed to serve a sewage flow of 96,000 m^3/day on an average and a maximum flow of 120,000 m^3/day, it was found from the PSTP data that it never ran close to the average flow at 96,000 m^3/day. Normally, it operates at 55-60% of its average capacity.

Kashipur Khal: This point source of pollutant was identified during the field visits. Originating from Baburail and Panchabati, two small khals join to make the Kashipur Khal, which falls into the side channel of the Dhaleswari. Recently, this khal has become tremendously polluted mainly from disharges from small industries and textile dyeing mills.

5.2 Non-point Sources

Besides the major point sources of pollution, there are numerous indistinct sources which discharge into the Turag-Buriganga-Dhaleswari river sytem. They are either of domestic origin or of industrial origin. Some are combined wastes from domestic and industrial sources.

Wastewater of mainly domestic origin from these non-point sources are discharged into the Turag-Buriganga reach from Lalbagh to Babubazar area. Within this area, there are some noteworthy places like Islambag, Shahidnagar, Rasulpur and Kamrangir Char which are very thickly populated without any sewerage facility. In turn, considerable amount of pollutants are being released into the rivers, rendering the river water highly polluted which is visible from the deteriorated colour in the dry period. Also, the pungent smell from the river within the vicinity of the area strongly points out the high pollution of the river. It should be noted that beyond Lalbagh - upstream of the Buriganga, wastewaters are disposed of into the Turag through the sluice gates, and beyond Babubazar wastewaters are released through 41 drains/khals into the Buriganga, as has been mentioned in the preceding section.

Wastewaters of combined origin are mainly discharged from densely populated Zinzira and

Keraniganj areas which are also unsewered. Domestic and industrial wastes are discharged through many drains into the Buriganga. Besides, areas beyond Postagola along the Buriganga viz. Jurain, Pagla, Fatulla and Shyambazar contribute pollutants of domestic and industrial origin into the Buriganga. Wastewater of mainly industrial origin are discharged from industries situated in the Shyambazar and Fatulla areas. Major portion of these industries are 'textile dyeing' industries. Also, there are vegetable oil refinery, fish processing industry, brickfields, steel re-rolling mills, etc.

Wasteloads from innumerable indistinct origins can-not be measured precisely in the field through direct flow measurement technique. Therefore, loadings from these non-point sources have been taken into account by increasing the loadings of nearby point sources which will be discussed later.

5.3 Estimation of Pollution Loadings

Since, it is not possible to compute loadings from all the points of wastewater effluent through measurement of flows directly, it is necessary to estimate the total loadings, arising out of contributing areas, which may be discharged into the nearby stream.

Two methods were employed to compute and compare the pollutant loadings, viz. 'Dry Method' and 'Wet Method'. In dry method, sub-catchments (zones), which may contribute wastewater to the rivers, were sorted out using information from three different studies. These were; FAP-8A final report (JICA, 1991), NEMPCP final report (Browder, 1992) and Drainage Network Map of the DIFP authority (DRG.NO.DIFP/L/002/B). Unit loading figures for BOD, COD, Nitrogen, Phosphorus, TSS and Chromium were obtained from literature (Browder, 1992 & Henze). Sub-catchment wise total population and unsewered population were also obtained from relevant studies and maps (Browder, 1992; JICA, 1991 and DWASA).

In general, the loading arising out of domestic sources can be estimated by:

Total domestic load = Per capita waste production x Number of inhabitants x Percentage of Population unsewered

The waste produced per capita varies with the standard and type of living. Besides the physiological excreted amounts of pollutants, the pollution load from kitchen, bathroom, washing of clothes, street cleansing and storm waters can also be considered in the per capita waste production estimates. To account for the loadings due to industrial wastes, per capita pollution loads can be increased by an arbitrary percentage when only small industrial plants are considered. Moreover, Nitrogen, Phosphorus and Chromium loadings need to be increased due to fertilizer use and atmospheric fallout. Thus, the total loading may be estimated by:

Total loading = Per capita waste production x Number of inhabitants x Percentage of population unsewered + Contribution from small industries + Contribution from fertilizer + Atmospheric fallout

It should be pointed out here that there exists considerable differences between the values of per capita waste production rate given by Henze and Browder. Henze assumed higher values than those given by Browder. No distinct reason is evident from these studies. One possibility could be that the per capita figures given by Henze include the impact of street cleansing and storm water runoff. In dry season, these processes hardly exist in Bangladesh. Table D.1 to Table D.3 (APPENDIX D) show detail break-up of pollution loading estimates in dry method along with all the relevant information.

In the wet method, loadings were calculated from the measured rate of flow through drains/khals and concentration of specific parameter determined through laboratory analyses. The locations of the wastewater outfalls were identified and selected for flow measurement during several field visits, as shown in Table D.4 (APPENDIX D). At all the wastewater drains, direct measurements of wastewater flow rate were conducted (except for the PSTP drain, flow rate of which was collected from the PSTP authority). Two measurement campaigns were carried out in the months of February and April, 1995. At the Dholai Khal and the Kashipur Khal, suitable cross-sections were chosen. Then, a 'VALEPORT' current meter was employed to measure the velocity of flow. Due to difficulties, velocities at the four Sluice gates could not be measured by the current meter. At those locations, floats were used to estimate the surface velocities which were adjusted accordingly. Cross-sections were estimated from the water depths at the upstream and downstream of the sill levels and the widths of the sluices. Then, loading for each parameter was computed by the following equation:

Loading = Flow Discharge x Concentration

Afterwards, different dry loadings and wet loadings for BOD were compared to assess the extent of agreement among the loadings computed using different data. It was found that there were reasonable agreement between dry and wet loadings when wet loadings were computed using flow and concentrations from the field data collection campaign of February, 1995. However, wet loadings based on the April, 1995 data did not match with those of dry loadings. Table 5.1 shows comparison of BOD loadings in the two methods. Table 5.2 shows the location and the amount of BOD loadings used in the WQ model. Figure 5.1 shows the BOD loadings used in the WQ model and their percentile distribution.

Table 5.1 Comparison of BOD Loadings

I.

Method of Study	Contributing Zones/WW drains	Zoning done by	Total BOD load (kg/d)	
			Feb., 1995	Apr., 1995
Wet	S-7 to S-10 plus Dholai Khal	DIFP (& SWMC)	60,489	16,736
Dry	A to C	NEMPCP	59,531	

Flow through the Sluices S-7 to S-10 and from the Dholai Khal were measured in situ during February and April, 1995 and samples of wastewater collected during the flow measurement were tested at the DOE Lab, Dhaka.

(Table 5.1 Contd.)

II.

Method of Study	Contributing Zones/WW drains	Zoning done by	Total BOD load (kg/d)
Dry	DA plus DB	FAP-8A	58,371
Dry	S-3 to City Drains	DIFP (& SWMC)	54,760

Percent of aréa and population unsewered for S-8 and S-9 are extremely low as has been found by consulting the Sewerage Network Map of DWASA. These data are hardly acceptable. If these percentages are increased to 46% (averaging percentage of unsewered contributing areas for S-7, S-10, S-11 and City Drains), the total BOD loading from S-3 to City Drains becomes 57,787 kg/d, when the difference in loadings becomes insignificant.

III.

Method of Study	Contributing Zones/WW drains	Zoning done by	Total BOD load (kg/d)
Dry	H, I and J	NEMPCP	42,441
Dry	S-3 to S-5	DIFP	39,904

Population unsewered as found by NEMPCP estimate is 1,697,642 persons, whereas it is 1,596,150 persons for S-3 to S-5. The difference in loading is evident from the difference in population unsewered.

(Table 5.1 Contd.)

IV.

Sluice Gate No.	Wet Method BOD (kg/d)		Dry Method BOD (kg/d) Zoning by DIFP
	Feb.,1995	Apr.,1995	
S-7	29,462	10,886	3,493
S-8	587	194	1,846
S-9	4,493	1,664	221
S-10	1,236	1,140	1,363

If BOD loading from Hazaribagh tanneries, 17,600 kg/d estimated by the BKH Consulting Engineers, is added to the figure obtained from the Dry method, loading through S-7 stands to be 21,093 kg/d.

It seems from the above figures that actual wastewater drainage areas for S-8 and S-9 should be different from what has been estimated by consulting the DIFP stormwater drainage areas.

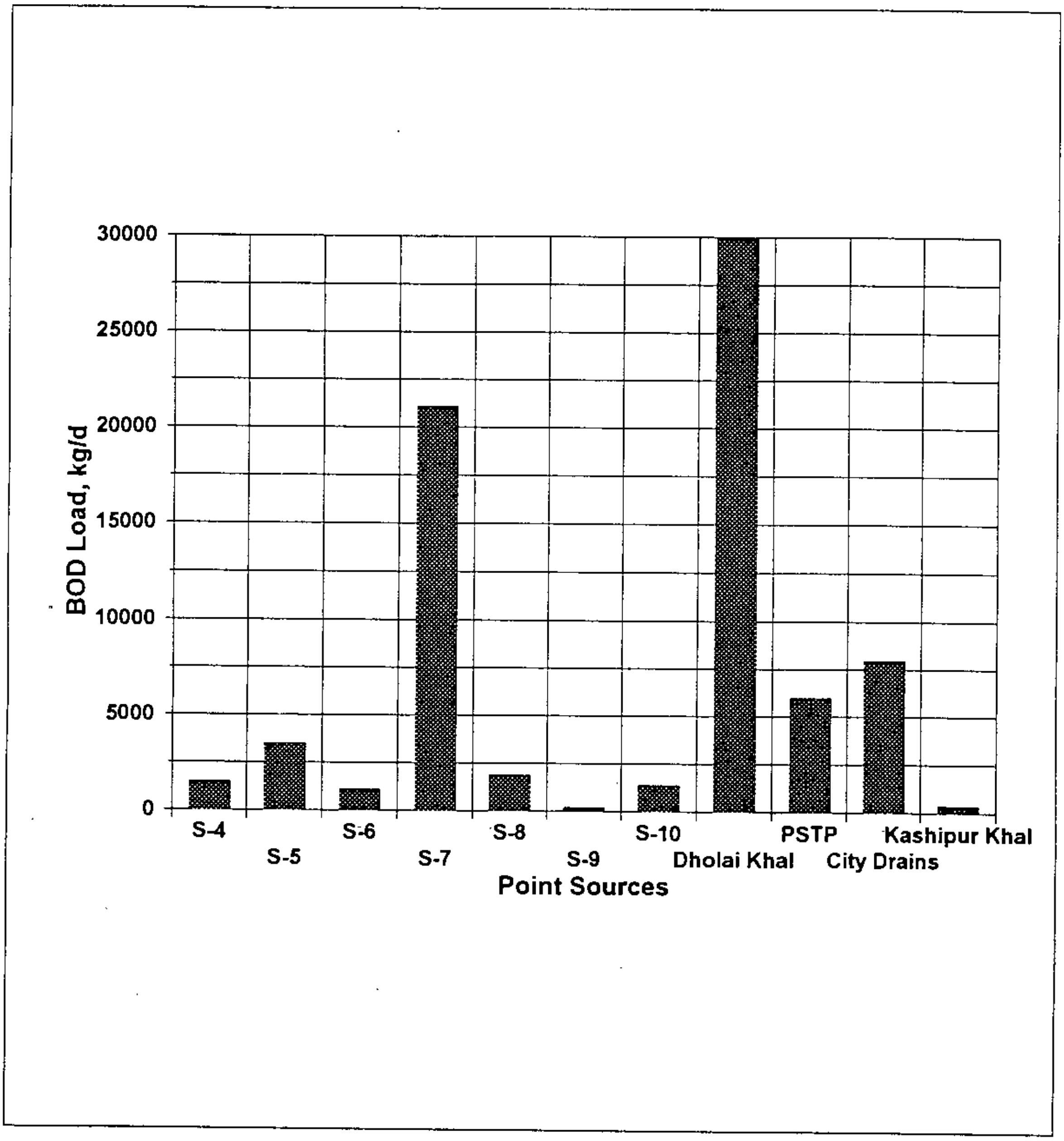
Table 5.2 Name, Position and Amount of BOD Loadings

Name of WW Outfalls	Entering into: River/Channel	Chainage (km)	Loading (kg/d)	Method of Estimate/Remarks
Sluice No. S-4	Turag	58.500	1,469	5% of Dry Load
Sluice No. S-5	Turag	63.000	3,482	65% of Dry Load
Sluice No. S-6¤	Turag	66.000	1,080	Rough Estimate
Sluice No. S-7	ARTCHNTG4	2.500	21,082	Wet. 28% lower
Sluice No. S-8	ARTCHNTG4	6.500	1,857	Dry
Sluice No. S-9	ARTCHNBG1	1.500	220	Dry
Sluice No. S-10	ARTCHNBG1	2.500	1,382	Wet. 12% higher
Dholai Khal	Buriganga	28.500	29,980	Wet. 20% higher
Pagla STP O.F.	Buriganga	32.750	PSTP, DWASA data	
City Drains@	Buriganga	27.500	7,949	Dry
Kashipur Khal	ARTCHNDH2	6.500	363	Wet

¤ BOD Loading from Sluice No.6 is estimated on the basis of necessity of water quality model calibration. It seemed during the calibration that some loadings were being missed so that computed DO near about Turag 67.00 did not improve with any effort. Thereafter, a BOD loading of nearly 1000 kg/d was applied through this sluice. However, it is only suggestive and needs to be verified through field measurement.

@ City Drains along the Buriganga extends from a Chainage 25.500 to 30.500. There are 41 Drains (Technoconsult - personal communication) within this 5 km stretch. To avoid complexity of describing loadings in the model from too many points -which is also not technically feasible , the estimated dry loading from the area covering these drains has been applied at a single point.

Reviewing Table 5.2, it is found that the total BOD loading to the Turag-Buriganga-Dhaleswari is approximately 73,000 kg/d (considering the PSTP loading to be nearly 4000 kg/d). Of the total amount, the Turag receives approximately 31,000 kg/d and the Buriganga receives 42,000 kg/d. The total BOD loading from the two major industrial clusters (Hazaribagh and Fatulla, Table 2.1) is 21,450 kg/d, which is less than 30% of the total BOD loading of 73,000 kg/d. The need of more sewage treatment facility is apparent from these figures. In addition, industrial wastes need to be treated prior to disposal to reduce the input of toxic substances as well as heavy metals.



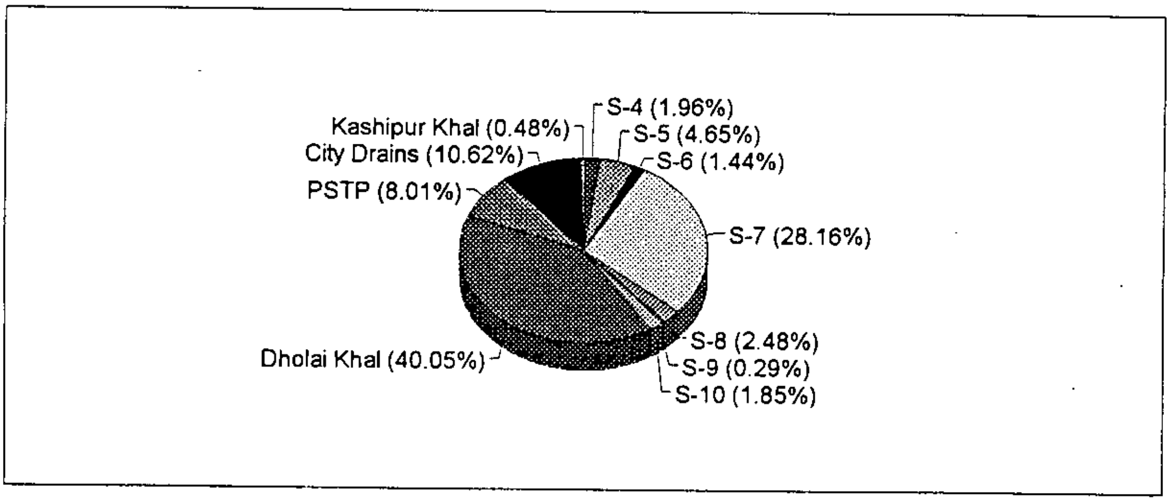
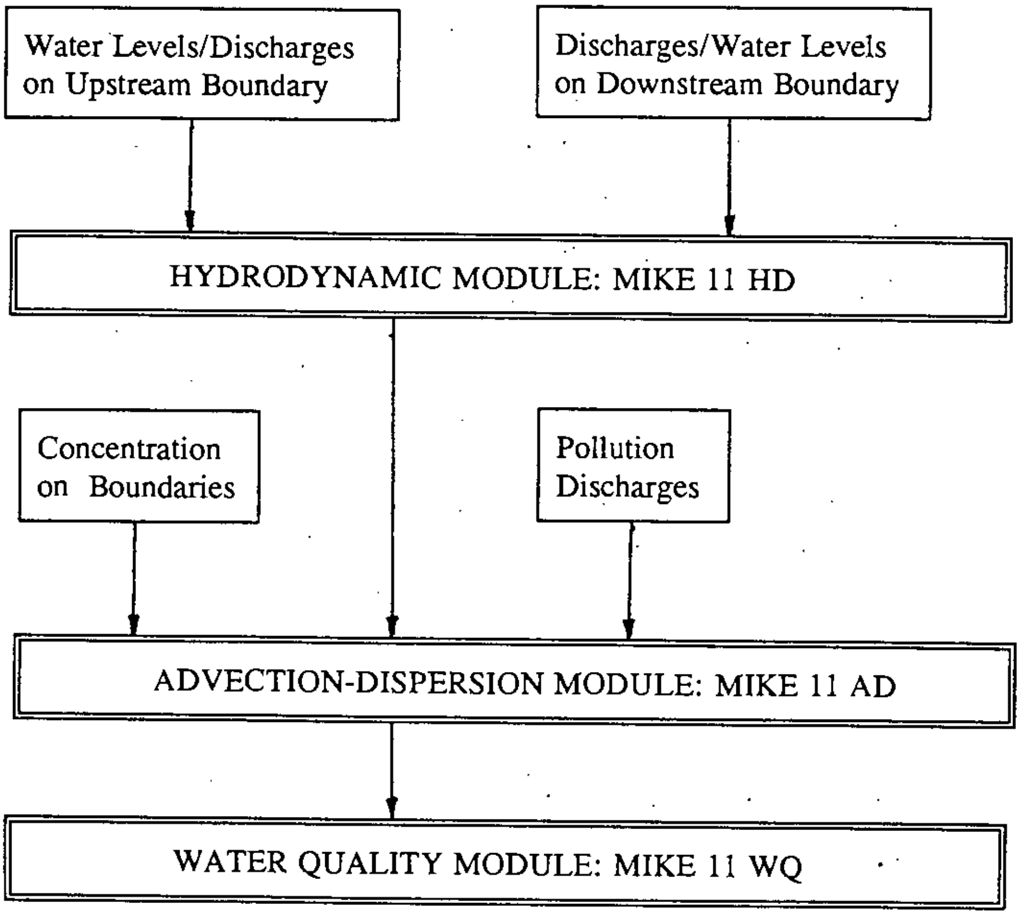


Figure 5.1 **BOD Loadings from Point Sources to the Turag-Buriganga-Dhaleswari rivers and their Percentile Distribution**

CHAPTER 6

MODELLING STRATEGY

The water quality modelling approach consists of the integrated Advection-Dispersion (AD) and Water Quality (WQ) modules in the MIKE 11. The two modules simultaneously describe the discharge, transport and effects of pollutants in the river system. The AD module works based on the hydrodynamic description of water levels and flows calculated by the Hydrodynamic (HD) module in MIKE 11. The conceptual flow diagram shown below describes the integration of the MIKE 11 modules and the input parameters needed for water quality modelling.



The hydrodynamics of rivers depends, for monsoon period, on the hydrological input, i.e. catchment runoff due to rainfall for which the Rainfall Runoff module (NAM) of MIKE 11 is to be used when needed.

6.1 The MIKE 11 Modules

The hydrodynamic module of MIKE 11 is based upon the equation of the conservation of mass and momentum (the Saint Venant equation). However, in order to save computer time, MIKE 11 has the options of using the diffusive or the kinematic wave approximation, if the fully dynamic description is not required. For simulation of very long time series, a quasi-steady flow model can be applied. In parts of the river system model (e.g., the upper steeper reaches and at flood plains), simplified equations can be used, while the full equations can be applied to other reaches at the same time. The differential equations sovled in the hydrodynamic module are:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q_L$$

$$\frac{\partial}{\partial x}[\alpha \frac{Q^2}{A}] + \frac{\partial Q}{\partial t} + gA.\frac{\partial h}{\partial x} + \frac{g/Q/Q}{M^2AR^{3/4}} = 0$$

where,

Q	=	discharge (m^3/s)
A	=	cross-sectional area (m^2)
q_L	=	source/sink discharge per unit length (m^2/s)
h	=	water level (m)
M	=	Manning's number ($m^{1/3}/s$)
R	=	resistance radius (m)

The hydrodynamic model is sovled in a space staggered computational grid using an efficient numerical solution procedure (Abbott, 1979). Special equations are included for flows over weirs, embankments, culverts etc. Any configuration of channels can be accommodated (including loops) taking into account lateral discharges, free overflow and submerged flow over weirs (with automatic switching), flooding and drying of low lying areas and quasi two-dimensional flow conditions on floodplains.

The transport-dispersion module of MIKE 11 is based upon the advective-dispersive transport equation for dissolved or suspended material. The module requires input from the hydrodynamic module in term of discharges and water levels in time and space. The partial differential eqution reads:

$$\frac{\partial AC}{\partial t} + \frac{\partial T}{\partial x} = -F.A.C + q_L.C_L$$

$$T = QC - AD.\frac{\partial C}{\partial x}$$

where,

C	=	concentration (arbitrary unit)
T	=	horizontal transport component
F	=	linear decay coefficient (s^{-1})
C_L	=	source concentration
D	=	dispersion coefficient (m^2/s)

It is implicity assumed in the above two equations that the discharge, area, and source/sink discharge satisfy the low continuity equation and that the solute is inert in the sense that it does not create hydraulic gradients. Moreover, it is assumed that the solute under consideration is completely mixed over the cross-section and is conservative or subject to a first order reaction (linear decay). However, other reaction orders can be included by use of the Water Quality Module.

The transport-dispersion equation is sovled numerically using an implicit finite differnce scheme, which in principle is unconditionally stable and has no numerical dispersion (Olesen, et al, 1989). A correction term has been introduced in order to eliminate the third order truncation error. This corection term makes it possible to simulate dispersion of concentration profiles with very steep fronts (Leonard, 1979).

The Water Quality Module of MIKE 11 consists totally of five partial differential equations describing (DHI, 1995):

1) oxygen concentration
2) concentration of BOD
3) ammonium/ammonia concentration
4) nitrate concentration
5) temperature

The differential equations are solved using a fourth order Runga-Kutta method (Press, 1986).

The water quality module describes the oxygen conditions, which normally constitute the prime environemntal parameter influencing the ecological state of polluted rivers.

Factors influencing the oxygen conditions are degradations of organic matter, respiration, nitrification (oxygen consuming), photosynthesis and exchange of oxygen with the atmosphere. Another important factor influencing these processes is water temperature which is also included in the model.

The differential equation describing the oxygen concentration is

$$
\begin{aligned}
\frac{d}{dt}(C\{O_2\}) = & + K_2 (C_m - C\{O_2\}) && \text{(reaeration)} \\
& - R && \text{(respiration)} \\
& + P && \text{(photosynthesis)} \\
& - B && \text{(bottom respiration)} \\
& - K_3 C\{BOD\} && \text{(BOD-degradation)} \\
& - Y K_4 (C\{NH^+_4\}^{nl}) && \text{(nitrification)}
\end{aligned}
$$

where, K_2 is reaeration cosntant, C_m oxygen saturation cosntant, K_3 degradation constant, Y oxygen consumption per nitrification unit and nl reaction order of denitrification.

The BOD cocnentration is described by:

$$\frac{d(C\{BOD\})}{dt} = - K_3\, C\{BOD\} \quad \text{(CBOD decay)}$$
$$+ \text{Resuspension} \quad \text{(suspension)}$$
$$- \text{Sedimentation} \quad \text{(sedimentation)}$$

Resuspension occurs where the velocity (u) exceeds a critical value (v). The resuspension is assumed to be cosntant in time. At flow velocities smaller than the critical value, sedimentation will occur, described with a first order reaction mechanism.

The differential equation describing the ammonium/ammonia reactions is:

$$\frac{d(C\{NH4^+\})}{dt} = + Y_2\, K_3\, C\{BOD\} \quad \text{(CBOD decay)}$$
$$- K_4\, C\{NH_4^+\}^{n1} \quad \text{(nitrification)}$$
$$- 0.066\,(P\text{-}R) \quad \text{(uptake by plants)}$$
$$- 0.109\, K_3\, C\{BOD\} \quad \text{(uptake by bacteria)}$$

The BOD decay term equals the BOD decay term in the oxygen and CBOD balances, except for the yield factor Y_2. Y_2 is the amount of ammonium that is released at the BOD decay. K_4 is the nitrification rate, P the photosynthesis rate and R the respiration rate.

The reactions influencing the nitrate concentration are given by:

$$\frac{d(C\{NO_3^-\})}{dt} = + K_4\, C\{NH_4^+\}^{n1} \quad \text{(nitrification)}$$
$$- K_6\, C\{NO_3^-)^{n2} \quad \text{(denitrification)}$$

in which, K_6 is the denitrification rate and n2 is the order of denitrification.

The temperature (T) is modelled by:

$$\frac{dT}{dt} = (Rad_{in} - Rad_{out})^{*} f_r$$

where, Rad_{in} describes the absorbed radiation with a sinus curve and Rad_{out} describes the emitted radiation (constant). The term f_r is a factor to adjsut the units.

6.2 Rainfall Runoff Model-NAM

As the HD model was calibrated for the period of December 1994 to April 1995, it was not felt necessary to include the NAM output, i.e., the catchment runoff. The reason behind was that rainfall during that period was almost nil, contributing little or no runoff to the rivers being considered for the HD model calibration.

6.3 Hydrodynamic Model-HD

6.3.1 Setup

The basic hydrodynamic (HD) model setup used for the Buriganga-Lakhya river system was adopted from the verified North Central Region Model (NCRM) developed by the SWMC. The NCRM was verified for the period of April, 1993 to October, 1993 (SWMC, 1995). From that HD model set up, according to the schematisation for the present purpose, a new set up was made and run, involving some techniques with change in calibration parameters to account for the calibration for the dry season.

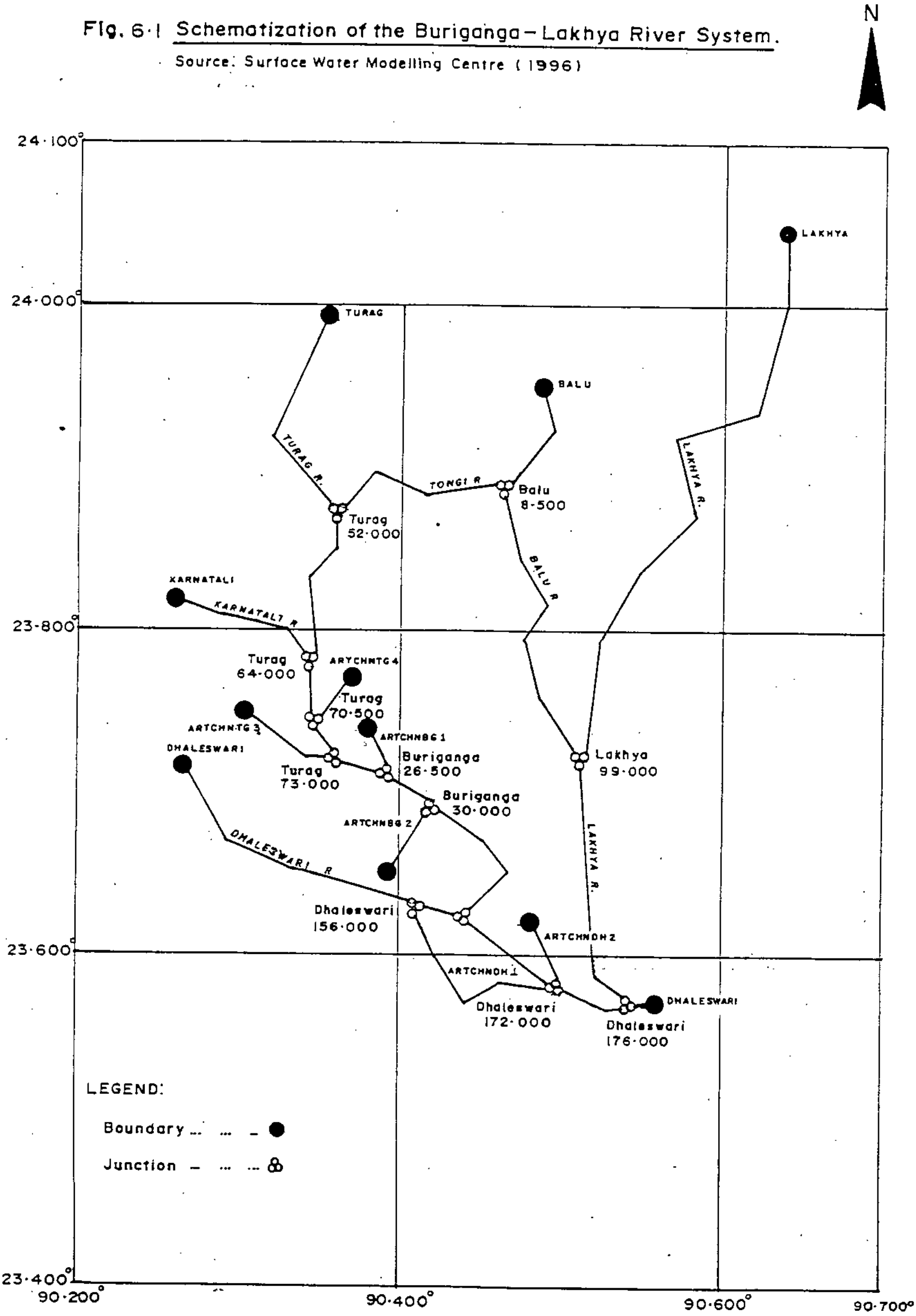
The present river network adopted for the water quality modelling was chosen in such a way that the boundaries would not be directly affected by pollution discharges. It helped in describing boundary concentrations of necessary water quality parameters without much difficulties (Figure 2.1). Table 6.1 describes the river network and Figure 6.1 shows schematisation of the Buriganga-Lakhya river system.

6.3.2 Hydrometric Data Collection and Processing

For the calibration of the hydrodynamic (HD) model, water level and discharge data are required. Figure 2.1 shows the existing stations from which data were collected. Two new gauging stations were installed by SWMC in the month of July, 1994 at Kodda on the

Fig. 6·1 Schematization of the Buriganga – Lakhya River System.

Source: Surface Water Modelling Centre (1996)



Turag and at Savar on the Karnatali. Those two are, among a total of eight, boundary stations for the Buriganga-Lakhya river system. Five water level readings, at an interval of

Table 6.1 River/Channel Description as per Schematisation

River Name	Topo ID	Chainage U/S	Chainage D/S	U/S Connection		D/S Connection	
				River	Chainage	River	Chainage
Balu	1989-90	0	30.000			Lakhya	99.000
Buriganga	1989-90	23.000	40.000	Buriganga	23.000	Dhaleswari	164.000
Tongi_K	DUL-1991	1.000	15.000	Turag	52.000	Balu	8.500
Lakhya	1989-90	48.000	120.000			Dhaleswari	176.000
Turag	SWH-1989	30.000	37.000			Turag	37.000
Turag	SWH-1989	37.001	75.000	Turag	37.000	Buriganga	23.000
Karnatali	DUL-1991	1.000	11.400			Turag	64.000
Dhaleswari	1988-89	135.000	178.000				
ARTCHN-BG1	FICTI-TOUS	0	4.500			Buriganga	26.500
ARTCHN-BG2	FICTI-TOUS	0	7.000			Buriganga	30.000
ARTCHN-TG3	FICTI-TOUS	0	30.000			Turag	73.000
ARTCHN-TG4	FICTI-TOUS	0	6.500			Turag	70.500
ARTCHN-DH1	FICTI-TOUS	0	19.500	Dhaleswari	156.000	Dhaleswari	172.000
ARTCHN-DH2	FICTI-TOUS	0	10.000			Dhaleswari	172.000

three hours, were being recorded daily and fortnightly discharge observations were carried out at those two stations. As both the Buriganga and the Lakhya are tidal during the dry season, a special programme was also carried out for tidal discharge measurements at Mill

Barrack, which is a BWDB water level station. Those tidal discharge measurements were carried out for an improved calibration of the Buriganga-Lakhya river system. A total of 11 tidal discharge observations were carried out from December, 1994 to May, 1995. First three observations in December, 1994 to January, 1995 were made by the BWDB (Hydrology). Rest 8 observations were made by SWMC facilities. All other stations are regular BWDB hydrological stations. Table 6.2 shows the list of hydrometric stations.

After receiving the field data, they were checked for errors or inconsistencies using standard procedure. In case of unexpected deviations, BWDB (Hydrology) was contacted for clarification.

Rating curves were constructed for two new stations, viz. Savar (SWMC) and Kodda (SWMC) using the HIS module of MIKE 11. Rating curve for Kalatia (70) had been constructed earlier for the NCRM. Time series of discharges for those stations were then generated from water levels using HIS. Tidal discharge at Mill Barrack were computed from field data using a computer program developed at the SWMC.

6.3.3 Updating and Calibration

The HD model was updated by giving new run with the data for the period between December 15, 1994 to April 30, 1995 (except January, 1995). Generated discharges from rating curves for the two new SWMC stations were used as boundaries, viz. Kodda on the Turag and Savar on the Karnatali. Generated discharge from rating curve, as mentioned earlier, was used at Kalatia on the Dhaleswari. Tidal water level of Kalagachia (71) obtained from auto gauge paper chart from the BWDB (Hydrology) was used as the downstream boundary. It is worthy to mention here that the HD model could not include the result for January, 1995 and other months excepting the period mentioned above because paper chart of tidal water levels of Kalagachia for those months could not be collected from the BWDB (Hydrology). In addition, tidal discharge at Mill Barrack (42) observed and computed by SWMC, were used for comparison.

Table 6.2 List of Hydrometric Stations

Sl. No.	River	Station	Owner	Type	Status of Station
01	Lakhya	177 Lakhpur	BWDB	WL	U/S boundary
02	Haridhoa	274 Narsingdi	BWDB	WL	Not used
03	Balu	7 Pubail	BWDB	WL	U/S boundary
04	Lakhya	179 Demra	BWDB	Q	Comparison
05	Balu	7.5 Demra	BWDB	Q	Comparison
06	Tongi Khal	299 Tongi	BWDB	WL	Comparison
07	Turag	Kodda	SWMC	Q	U/S boundary
08	Karnatali	Savar	SWMC	Q	U/S boundary
09	Dhaleswari	70 Kalatia	BWDB	WL	U/S boundary
10	Ichamati	0.0 Ichamati	Interpolated WL between 91.9L - Baruria Transit and 93.5L Mawa		Not used
11	Dhaleswari	71Kalagachia	BWDB	WL	D/S boundary
12	Turag	302 Mirpur	BWDB	Q	Comparison
13	Buriganga	42 Mill-Barrack	BWDB/SWMC	WL/Q	Comparison
14	Buriganga	43Hariharpara	BWDB	WL	Comparison
15	Dhaleswari	71A Rekabi Bazar	BWDB	WL	Comparison

The verified NCRM HD model did not cover the dry season calibration, i.e., no calibration was done for the period of November, 1993 to March, 1994. As a consequence, information with respect to the dry season tidal behaviour of the Buriganga-Lakhya river system was not available. Therefore, considerable effort had to be devoted in getting a reasonable tidal calibration of the Buriganga-Lakhya river system. To do so, in the first place, a number of minor channels (artificial channels) had to be included in the main schematisation of the HD model set up, which are denoted by a prefix ARTCHN as shown in Table 6.1. These channels exist physically within the model area and act as storage volumes for the flood water coming from the Meghna river via the lower boundary at Kalagachia. During ebbing, flood water previously intruded into these channels runs back towards the Meghna, leaving the channels almost dry. As the actual information regarding those channels (cross-section, length etc.) were not known, the lengths and cross-sections of those channels were estimated from maps and adjusted until a good agreement could be found with respect to the tidal discharge simulation at Mill Barrack on the Buriganga. In the second place, it was seen during HD computation that the Haridhoa and the Ichamati dried up several times, which subsequently created numerical instability during the advection-dispersion (AD) computation. Therefore, those two channels were excluded from the schematization. Table 6.1 shows the connection of rivers/channels as per the latest changes being made during the HD calibration. Resistance number (Manning's M which is the inverse of Manning's 'n') was also needed to be changed during the calibration. Figure E.1 to Figure E.7 (APPENDIX E) show the comparison between observed and simulated water levels/tidal discharges at Mill Barrack. At all other locations, comparison of water levels are within acceptable limit. Therefore, those figures are not included.

6.4 Water Quality Model (WQM)

The water quality model of MIKE 11 consists of several modules describing different aspects of water quality in areas influenced by human activities. Depending on the actual water quality problem someone wants to investigate, any or all of the following modules can be chosen from MIKE 11:

BOD/DO/COLI module	(Standard WQ)
EU	(Eutrophication)
BOD/DO/PHOS module	(WQ including Phosphorus)
HM	(Heavy Metal)

For the present study, the Standard WQ module consisting only of BOD/DO description has been used.

The BOD/DO model deals with the basic aspects of river water quality in areas influenced by human activities, e.g. oxygen depletion and ammonia levels as a result of organic matter loadings. The state variables in the BOD/DO model are Dissolved oxygen (DO), Water Temperature, Organic matter (expressed as dissolved, suspended and deposited BOD_5), Ammonia/Ammonium and Nitrate. Figure 6.2 shows the physical representation of the phenomena involved in the BOD-DO model.

The BOD/DO model can be applied at six different levels of complexity. The appropriate level is determined from a consideration of the study requirements and data availability.

6.4.1 The Buriganga Water Quality Model Setup

Setup of the WQ model consists of choosing a WQ 'Model Level', defining 'Boundaries'(Open or Closed) and Initial Conditions of 'State Variables' (Commonly called as Components, e.g. DO, Temperature). Table 6.3 show the setup of the Buriganga-Lakhya WQ model.

'Model Level 5' of the Water Quality Module of MIKE 11 was considered for the simulation of the water quality model. 'Level 5' takes into consideration five state variables, namely, DO, Temperature, and BOD suspended, BOD dissolved and BOD sedimented. Moreover, it considers the Immediate and Delayed Oxygen Demand. Model Level 5 was chosen because very thick wastewater released from the Dholai Khal and some of the Sluice gates were supposed to be sedimented and were likely to exert a delayed demand for oxygen. All BOD loadings introduced into the model were considered as the 'dissolved' BOD. Other two components of BOD's were considered to be 'zero'. It is worthy to be mentioned that if accurate measurement of the three fractions of BOD are not available, the total BOD can be specified either as Dissolved or as Suspended BOD. DO concentration at the boundaries were considered to be constant (for a specific period of time) which were the saturation concentration at an average temperature of the period in question. The average temperatures were computed from the recorded temperatures of the SWMC field campaigns. Those average temperatures were also considered to be constant and were used at the boundaries. A minimal BOD of 1 mg/l was applied at all the boundaries.

Fig. 6·2

Water Quality Model Applications

Source: Danish Hydraulic Institute, Denmark

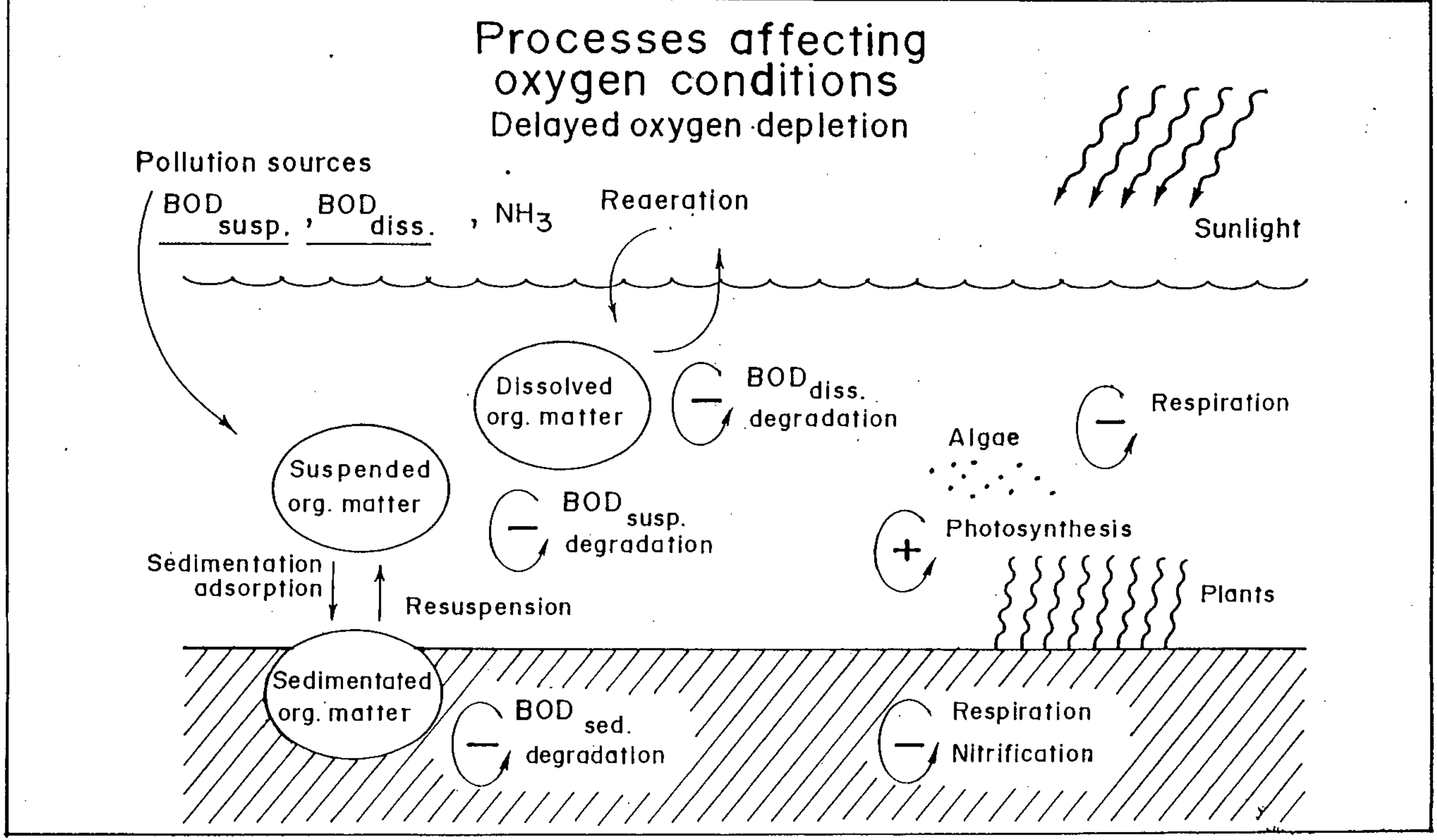


Table 6.3 Water Quality Model Setup

Component	Boundary Value	Initial Value
DO	8.77	6.0
TEMPERATURE	21.6	20.0
BOD SUS.	0.0	0.0
BOD DIS.	1.0	1.0
BOD SED.	0.0	0.0

Boundary Conditions

Open Concentration Boundary		Kmix	Closed Boundary	
River	Chainage, km		River	Chainage, km
Turag	30.00	1.00	ARTCHNBG1	0.00
Lakhya	48.00	1.00	ARTCHNBG2	0.00
Dhaleswari	135.00	1.00	ARTCHNDH2	0.00
Dhaleswari	178.00	100.00	ARTCHNTG3	0.00
Karnatali	1.00	1.00	ARTCHNTG4	0.00
Balu	0.00	1.00		

6.4.2 Calibration

The Water Quality Model (WQM) was calibrated for the period of 19th to 26th of December, 1994. As the Advection-Dispersion (AD) model was not calibrated, some of the parameters affecting the AD phenomena needed to be calibrated during the water quality calibration, e.g. Dispersion Coefficient, Kmix.

The water quality model calibration started with all 'default' water quality (WQ) parameters given in the 'Model level 5'. Thereafter, many 'runs' were required to achieve an acceptable level of simulation. As the Buriganga-Lakhya river system is complex, reach-wise AD and WQ parameters were needed. It is to be noted that default values of WQ parameters are some pre-defined values which had been found to be applicable in many WQ problems. However, these may need to be changed depending on the nature of the problem.

The WQM was calibrated for DO only. As the temperature seldom varied by more than 1^0C in a day, no calibration was required. The other parameter namely, dissolved BOD could not be calibrated because there was only one or two values of BOD_{total} available per location in a day. Moreover, those values were not used for comparison because of differences in data. Table 6.4 shows the finalized AD and WQ parameters for the acceptable level of simulation with respect to DO. All other 'Default Water Quality Parameters' are given in Table 6.5. Figure F.1 to Figure F.4 (APPENDIX F) show the simulated and observed DO after calibration.

Table 6.4 AD and WQ Parameters Calibrated (Other than Defaults)

AD Parameters (Global)

Parameter	Value
Dispersion factor	100
Exponent	1
Minimum Dispersion Coefficient	0
Maximum Dispersion Coefficient	1000

Global values are replaced in the following locations:

River	Chainage	Dispersion Coefficient
Turag	30.00	200
Turag	75.00	200
Buriganga	23.00	50
Buriganga	30.00	50

(Table 6.4 Contd.)

WQ Parameters (Global)

Parameter	No. / Value	Recommended Range
Reaeration Expression No.	2	-
Respiration of Plants and Animals at 20°C (g $O_2/m^2/d$)	2	1.0 - 5.0
Maximum O_2 Production by Photosynthesis (g $O_2/m^2/d$)	1.75	1.75 - 7.0
Displacement of Maximum O_2 Production (hours)	-1.0	-

Global values are replaced at the following locations:

River	Chainage, km	Parameter	No./Value
Dhaleswari	176	Reaeration Expression No.	3
Dhaleswari	178	-do-	3
ARTCHNBG1	0.00	-do-	1
ARTCHNBG1	4.50	-do-	1
ARTCHNBG1	0.00	Respiration of Plant & Animal	1
ARTCHNBG1	4.50	-do-	1
ARTCHNBG1	0.00	Maximum O_2 Production by Photosynthesis	0.01
ARTCHNBG1	4.50	-do-	0.01

6.4.3 Discussion on Calibration phase

Like all other model, WQM requires good boundary conditions for the state variables. Time series of DO, Temperature and BOD were not available at the boundaries. Thus, the DO of saturation concentration at a specific temperature, the constant temperature averaged over some days and a minimum BOD of 1 mg/l were considered as reasonable estimates. In the second place, BOD loadings were of practical importance in getting the right level of DO. As it was hardly possible to arrive at the exact loading figures even by using both the

Table 6.5 Default Water Quality Parameters used in the Water Quality Model

Parameter	Default Value
1st Order decay rate of Dissolved BOD at 20°C (1/d)	0.25
Temperature coefficient for the decay of Dissolved BOD	1.024
1st Order decay rate of Suspended BOD at 20°C (1/d)	0.10
Temperature coefficient for the decay of Suspended BOD	1.024
Half-saturation Oxygen Concentration (Michaelis-Menten) (g $O_2/m^3)^2$	2.00
Sediment Oxygen Demand at 20°C (g $O_2/m^2/d$)	0.50
Temperature coefficient for the Sediment Oxygen Demand	1.024
Adsorption of Dissolved Organic Matter (1/d)	36.00
Resuspension of Organic Matter (BOD) (g BOD/m^2/d)	0.50
Sedimentation rate of Organic Matter (BOD) (m/d)	0.80
Critical Flow Velocity (m/s)	1.00
Critical Concentration of Organic Matter in Bed (g BOD/m^2)	0.00
1st Order decay rate for Sediment BOD (1/d)	0.75
Temperature coefficient for the decay of Sediment BOD	1.024
Maximum absorbed Solar Radiation (kJ/m^2/d)	5000
Displacement of Maximum Solar Radiation from 12 noon (hr)	1
Emitted Heat Radiation (kJ/m^2/d)	1600

dry and wet method depending on the at hand data and information, those were to be adjusted to some extent (Table 5.2). In that regard, the measured DO data together with the dynamic longitudinal profile of DO were of practical help.

Although, the calibration of the model with respect to DO is found to be satisfactory, there are some shortcomings which must be taken into consideration. In the first place, the HD calibration could be improved further if actual topographical description of the 'artificial channels' were available. It was found during the HD calibration that the 'artificial channels' played the vital role in getting the right shape and amplitude of tidal discharges. Moreover, observed (which were not available) half-hourly or hourly water levels at

Lakhpur (177) on the Lakhya in conjunction with some observed tidal discharges near by Demra (for comparison) could improve the overall HD calibration for the Buriganga-Lakhya river system. In the second place, the AD model could not be calibrated due to lack of any kind of observation made on a conservative substance, e.g. salinity. Therefore, the true description of advection-dispersion phenomena in terms of AD parameters were not known/calibrated before proceeding with the WQ calibration.

More intensive field measurement for the wet loading estimates could be of practical help in justifying the loadings which were finally considered to be applied in the WQ computation. No field measurement plan was taken up to estimate loadings further upstream of Hazaribagh along the Turag and downstream of PSTP outfall along the Buriganga-Dhaleswari. Therefore, loadings had to be assumed at those stretches of rivers from the dry loading estimate.

A one-dimensional modelling approach had been chosen for the entire system. Thus, it had been implicitly assumed that there were perfect vertical mixing and no lateral dispersion of pollutants in the rivers. This simplification is liable to produce slightly different results than the actual condition. However, it is evident from the measurements that a serious water quality problem exists during the dry season in the Turag and Buriganga rivers, the Buriganga being the worst. Only the Dhaleswari remains in the acceptable condition considering the critical DO level as 4 mg/l.

6.4.4 Verification of the Water Quality Model

After a successful calibration of a model with one set of data, it is necessary to verify the model with another set of data. However, mainly due to lack of time as well as data and resources, the verification process could not be completed in this study. The model may be further modified through a comprehensive verification process which will provide more reliable results.

CHAPTER 7

MODEL APPLICATION : IMPACT ASSESSMENT

In the preceding chapters, effort was given to address the status of pollution in the Buriganga in light of past studies, analyses of data/information collected during this study , and data collected by different organisations. This is generally the standard approach for studying the pollution problem in a river. However, as the assimilative capacity of a river is largely dependent on the hydrological feature of the domain and on the hydrodynamics of the river, it is not possible to draw an inference on the improvement or worsening of pollution in the river without a simultaneous analyses of water quality monitoring and hydrometric data. This is specially important when river water quality is to be studied under varying river hydrodynamics and pollution loads entering into the river. Analytical approach to address this situation is time consuming and tedious. Use of a mathematical model with the help of powerful computer offers as an alternative of proven efficacy.

7.1 Investigation of Impacts of Pollution

The BOD/DO module of MIKE 11 can be applied for restoration purposes for rivers where the water is of inferior quality to sustain a diverse biological community. With this module, a number of different scenarios can be simulated. For example, oxygen depletion in a river due to outlet of urban and industrial sewage; high ammonia levels as a results of high loadings of ammonia from industrial or municipal sewage and/or indirectly due to a release of ammonia from BOD decay; immediate and delayed oxygen demand due to storm sewer overflow. The following section describes the impact of pollutants, under different scenarios or possible management alternatives.

7.2 Alternative Scenario Study

The calibrated model with the existing pollutant loadings may be considered as the "base condition". This model has been used to assess the impacts of variable pollutant loading conditions. Following each run, the model output has been compared with the calibrated model results or the "base condition". In the base condition, the minimum DO levels of the three rivers are as follows:

Turag	1.95 mg/l at Chainage 75.000
Buriganga	0.23 mg/l at Chainage 30.000
Dhaleswari	3.79 mg/l at Chainage 164.00

During this study a number of probable alternative scenarios have been considered along with a few hypothetical management alternatives. The model was applied for both the probable as well as hypothetical management alternatives to assess their probable impact on the water quality of the river system.

Scenario 1:

For a number of years, different international organization such as the World Bank, the Asian Development Bank, etc. as well as the Government of Bangladesh have discussed the possibilities and options to improve the existing conditions at the Hazaribagh Tannery area. One of the major options considered with emphasis is complete relocation of the tanneries from Hazaribagh to another location outside of the Greater Dhaka city. Thus, Scenario 1 addresses such option by considering only the effect of domestic wastes of that area disposing into the river system through Sluice S-7 and the pollutant load resulting from the tanneries being set to zero. The pollutant load from the tanneries was estimated to be 17,600 kg/day (BKH, 1994).

The model predicts an immediate increase in minimum DO level in the Turag river to 2.75 mg/l. However, no appreciable rise of DO have been predicted in the Buriganga and the Dhaleswari rivers by the model. The minimum DO levels in these two rivers have been predicted to be 0.26 mg/l and 3.80 mg/l, respectively. This indicates that relocation of Hazaribagh tannery area alone may not improve the DO levels in the Turag-Buriganga-Dhaleswari river system. However, the heavy metal pollution caused by the direct disposal of tannery effluents will be drastically reduced following the relocation.

Scenario 2:

The Asian Development Bank has proposed to construct a treatment plant at the Hazaribagh area to treat the domestic as well as industrial effluents prior to disposal. However, since the model predicts that complete removal of tanneries alone may not improve the DO level of the river system, a scenario has been considered where the effluents from the Sluice S-7, the City Drains and the Dholai Khal be treated separately with a 60% BOD removal efficiency prior to disposal.

The model indicates that the DO level may not improve appreciably in the Turag with a minimum value of 1.25 mg/l. However, improvement in the DO levels in the Buriganga and the Dhaleswari have been predicted to be slightly better, with minimum DO levels of 2.97 mg/l and 4.11 mg/l, respectively.

Scenario 3:

A situation has been considered in this option when all the wastewater, entering into the Turag-Buriganga river system, have been diverted to a treatment plant located near the junction of the Buriganga and Dhaleswari, at Hariharpara. The treatment plant is assumed to operate on a 60% BOD removal efficiency, and treated wastewater is being released into the Dhaleswari river at chainage 164.00. The PSTP has been considered to operate in its usual mode.

Since all the treated wastewater was assumed to be disposed of at the Dhaleswari, it is expected that the DO condition will deteriorate from the base run. The model correctly simulates the condition by showing a minimum DO level of 2.57 mg/l in the Dhaleswari which is lower than the base run of 3.79 mg/l. However, the model predicts a marked rise in the minimum DO level in the Turag to 5.27 mg/l from 1.95 mg/l in the base run, and a moderate increase in the Buriganga to a level of 2.57 mg/l from 0.23 mg/l in the base run.

Scenario 4:

In this scenario, it has been assumed as in Scenario-3 that all the wastewater entering into the Turag-Buriganga river system, have been diverted to a treatment plant and the treatment plant is assumed to operate on a 60% BOD removal efficiency. However, the treated wastewater in this case has been assumed to be released into the Dhaleswari river at chainage 176.00, near Rekabi Bazar (confluence of the Dhaleswari-Lakhya rivers) instead of chainage 164.00. The PSTP is considered to operate in its usual mode.

The simulated result indicates that the Turag and the Buriganga do not violate the critical level of DO, i.e. minimum DO levels in these rivers remain above 4 mg/l with values of 5.27 mg/l and 5.14 mg/l, respectively. However, as all the treated wastewaters are assumed to be released in the Dhaleswari at chainage 176.00, minimum DO level goes below 4 mg/l in this river (3.64 mg/l) as expected.

Scenario 5:

In this option, the effect on the river water quality was investigated assuming the Pagla Sewage Treatment Plant operating in its 100% loading condition. It has been mentioned earlier that the PSTP normally runs at 55%-65% of its full capacity. The BOD loading in such a condition has been calculated from the Wastewater Flow - Loading relationship established earlier (Chapter 4).

However, as per model results, conditions in the three rivers do not seem to vary considerably from the base condition with minimum DO levels in the Buriganga, Turag and Dhaleswari being 0.26 mg/l, 1.95 mg/l and 3.57 mg/l, respectively.

Scenario 6:

The Zinzira and Keraniganj areas generate considerable amount of point and non-point loads to the Buriganga which can not be precisely estimated. Thus, in this scenario, an additional amount of 2,000 kg/day of BOD loading was assumed to be applied at Chainage 28.000 at the Buriganga.

No significant decrease in DO level was predicted by the model due to this increased loading. Minimum DO levels in the Buriganga, Turag and Dhaleswari rivers are 0.22 mg/l, 1.88 mg/l and 3.78 mg/l, respectively which are slightly lower than in the base run.

Scenario 7:

In this option, no BOD loading has been considered from Sluice S-7, the second most severe polluting outfall, discharging into the Turag.

It has been found that the minimum DO level in the Turag rose to 3.05 mg/l from 1.92 mg/l in the base condition. However, effects in the Buriganga and the Dhaleswari are minimal, having DO levels of 0.28 mg/l and 3.81 mg/l, respectively.

Scenario 8:

The Dholai Khal is found, during load estimation, to contribute the highest amount of BOD load to the Buriganga river. The aesthetic condition of the khal itself suffices immediate attention from respective authorities. A series of solutions have been considered over the years including diverting the flow to a treatment plant effectively nullifying the BOD load to the Buriganga from this source. Thus, this scenario involves a sensitivity run of the calibrated model with Dholai Khal BOD load set to zero, keeping all other loads same as the base condition.

The model predicts an increase in minimum DO level in the Buriganga from 0.23 mg/l to 1.7 mg/l due to this changed loading condition. However, this apparent increase in DO level is well below the minimum DO required for survival of aquatic life (4.0 mg/l).

Scenario 9:

In this scenario, the calibrated model has been used for another sensitivity run considering the third major BOD loading, discharging through the City Drains, set to zero.

The model result shows that increase of DO levels in the Buriganga and Dhaleswari is not remarkable, having minimum DO levels of 0.32 mg/l and 3.84 mg/l, respectively. Only, the minimum DO level in the Turag has risen to 2.33 mg/l.

Scenario 10:

As it has been found in the preceding scenarios that withdrawal of any of the major polluting outfalls alone does not improve the condition of the Turag-Buriganga rivers, all the loadings from the Sluice S-7, Dholai Khal and City drains have been withdrawn in this option.

The simulated outcome of this option is remarkable. In the three rivers, minimum DO levels crossed the critical DO level of 4 mg/l, viz. 4.23 mg/l in the Buriganga, 4.57 mg/l in the Turag and 4.11 mg/l in the Dhaleswari. The reason of the lower DO level in the Dhaleswari in comparison with the other two rivers can be attributed to the effect of the wastewater discharge from Kashipur Khal, which discharges a BOD load of approximately 400 kg/day into the Dhaleswari.

Table 7.1 provides a summary of the minimum DO levels in the Turag-Buriganga-Dhaleswari river system under alternative scenarios. Figure 7.1 shows the minimum DO levels in the Turag-Buriganga-Dhaleswari rivers under alternative scenarios. Figures G.1 to G.11 (APPENDIX G) show DO profiles under the alternative scenarios.

7.3 Discussion

A series of realistic as well as hypothetical management alternatives were considered through ten different scenarios using the calibrated model. Except for the Scenario-10 where all three major point source BOD loads were considered to be zero, the DO levels in the river system do not improve beyond the minimum DO level of 4.0 mg/l required for survival of aquatic life in any of the nine different scenarios. The Sluice S-7, Dholai Khal and the City Drains wastewater when disposed of at Dhaleswari 164.000 following treatment for removal of BOD with 60% removal efficiency, the model predicts an improved DO level in the Turag but not in the Buriganga and the Dhaleswari (Scenario-3).

Table 7.1 Minimum DO in the Turag-Buriganga-Dhaleswari under Alternative Scenarios

SCENARIO	TURAG		BURIGANGA		DHALESWARI	
	Chainage, km	DO, mg/l	Chainage, km	DO, mg/l	Chainage, km	DO, mg/l
Base Run	75.000	1.95	30.000	0.23	164.000	3.79
1	70.500	2.75	30.000	0.26	164.000	3.80
2	75.000	1.25	30.000	2.97	176.000	4.11
3	75.000	5.27	40.000	2.57	164.000	2.57
4	75.000	5.27	28.250	5.14	176.000	3.64
5	75.000	1.95	30.000	0.26	164.000	3.57
6	75.000	1.88	30.000	0.22	164.000	3.78
7	75.000	3.05	30.000	0.28	164.000	3.81
8	75.000	2.39	27.000	1.70	176.000	4.11
9	75.000	2.33	30.000	0.32	164.000	3.84
10	75.000	4.57	26.50	4.23	176.000	4.11

On the other hand, if the treated effluent from the above point sources are disposed of at Dhaleswari 176.000 instead of 164.000, the Dhaleswari minimum DO level is predicted to fall slightly below 4.0 mg/l whereas, the Buriganga and the Turag minimum DO levels seem to improve appreciably (Scenario-4).

The model also indicates that even if the Hazaribagh tannery area is entirely relocated, the DO level in the Buriganga may not improve appreciably (Scenario-1). However, other pollutants, such as the heavy metal levels, may drop considerably following the relocation.

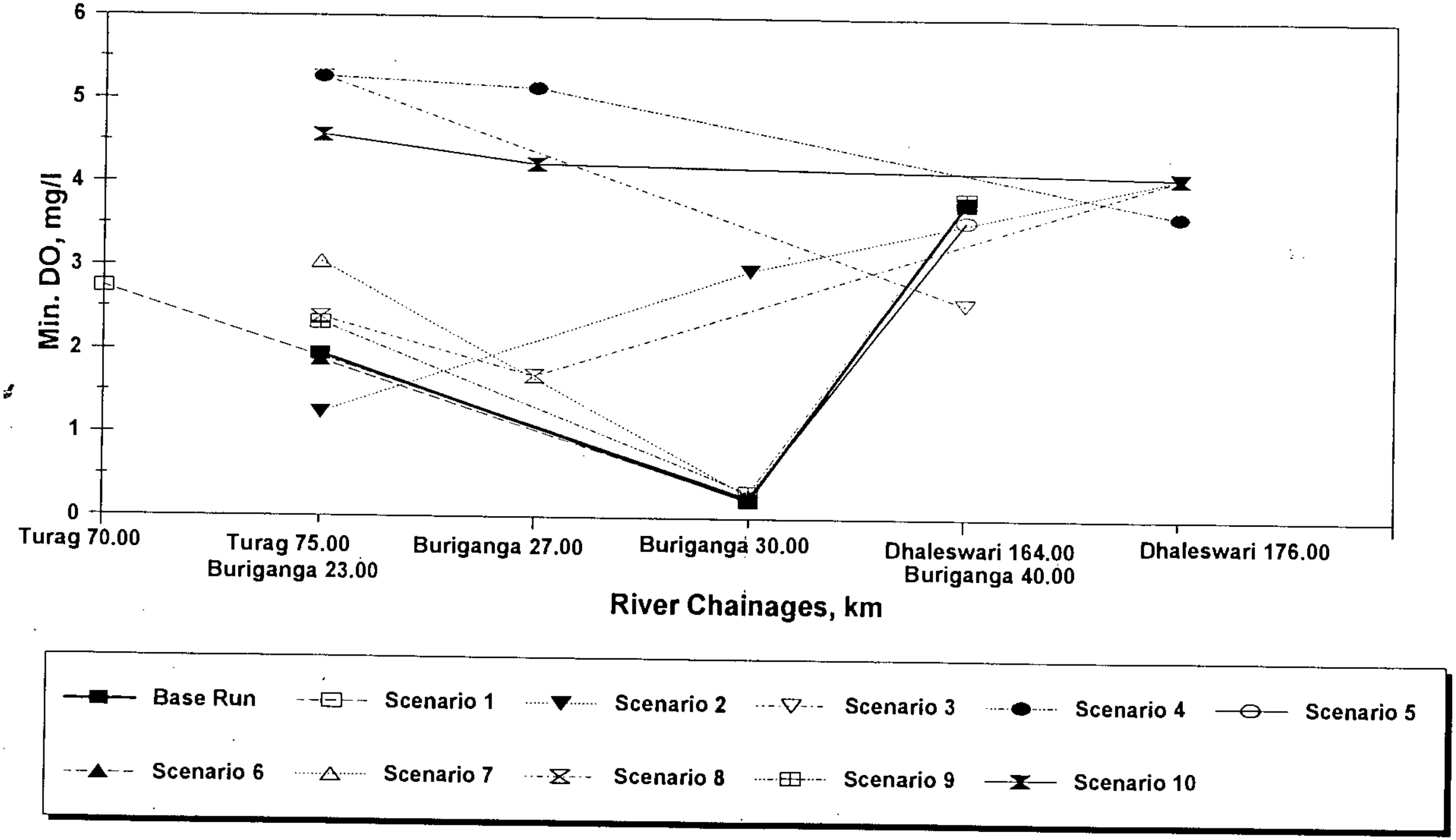


Figure 7.1 Minimum DO levels in the Turag, Buriganga and Dhaleswari rivers

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Untreated domestic sewage containing primarily biodegradable materials are being disposed indiscriminately in the Buriganga river system as well as almost all the surface waterbodies in Bangladesh. These pollutants constantly deplete one of the most important water quality parameters required for the survival of aquatic life, namely the Dissolved Oxygen (DO). A series of investigative studies have been conducted to assess the pollution status of the Buriganga river system. These studies have one common conclusion indicating a deteriorating DO level of the river system. Thus, an extensive data collection and sampling programme have been conducted in this study to assess the present status of pollution of the Buriganga. These samples were tested at three different laboratories namely, BUET, DOE and SWMC. A water quality model (developed using MIKE 11) was applied to the river system after calibration of the model using the collected data. The load estimates for the point and non-point sources were performed in wet and dry methods using the data collected during the study and by different organisations/agencies such as Pagla Sewage Treatment Plant of DWASA, JICA, DIFPA, etc. A series of different scenarios have been considered by varying the BOD loading conditions to study the management alternatives for improvement of the Buriganga river system water quality with respect to DO. The major conclusions of the above study have been presented in the following section.

8.1 Conclusions

The results of the sampling programme strengthen the previous study findings that the water quality of the Buriganga river system is deteriorating at an alarming rate to sustain the aquatic life. This is indicated by the very low DO levels during the dry season, as has been indicated by the data collected during the study from December, 1994 to April, 1995. However, gross differences in test results of same samples at various laboratories in Bangladesh limits the use of these data for sensitive policy issues. These differences may be attributed to the approach adopted by laboratories in sample preservation, quality of chemicals used, testing method applied or qualification or expertise of the technicians.

Thus, application of these data require judgement and expertise of the user and the nature of the study.

Considerable amount of data is essential for calibration of any water quality model. Due to lack of time and resources, the data collection programme was limited to three different periods in a dry season only. In order to get the most out of the available data and to complete the calibration process within the time period, a series of small duration runs for the December, 1994 were performed. The calibrated model matches the field data of diurnal DO variation reasonably well.

The model when applied for the dry period, with the estimated point source BOD loads, indicates that the DO levels in the Turag and the Buriganga river may not be in a position to sustain the aquatic life. The Dhaleswari, although not as polluted as the other two rivers, may also have a DO level inadequate for aquatic life.

A series of management alternative scenario simulations using the calibrated model indicate that a single treatment plant for one major point source of pollutants such as the Dholai Khal or the Hazaribagh tannery area may not be adequate for the improvement of the minimum DO level of the Buriganga river system. However, the heavy metal loads to this surface water system may improve appreciably following the relocation of the Hazaribagh tannery area outside the Greater Dhaka city. The model also predicts a dramatic improvement of the minimum DO level in the Buriganga river system if all the major pollutant sources are treated for biodegradable materials and disposed of at a location further downstream of the Dhaleswari river. Since, the calibration and verification process have been severely restricted by the limited data and resources, the findings of this study through the model may only be used as an initial basis for future management plan.

8.2 Recommendations

Availability of appropriate amount of data required for calibration and verification of a water quality model almost always restrict its use. Thus, it is recommended that continuous hydrometric and water quality data be monitored/collected at important locations of the river system. Since, reliability of a model result depends on the quality of data, a uniform sampling technique and standard testing procedure need to be followed at the leading laboratories in Bangladesh. This may be achieved through coordination among the appropriate authorities running these laboratories.

Although considerable effort was devoted for the assessment of pollution loads, there are some areas where further investigation is required to facilitate future modelling works. These areas include Keraniganj, Zinzira, Islambagh, Shahid Nagar, Rasulpur and Kamrangir Char.

Due to lack of data, time and resources, the verification process could not be completed in this study. Thus, the model may be further modified through a comprehensive verification process which will provide a more reliable result.

A one-dimensional model may not be adequate for a complex river system such as the Buriganga, where a multi-dimensional model may be appropriate. Development of such a tool requires considerably more data and expertise than in the one-dimensional model. Thus, involvement of data collection authorities will increase enormously.

As a planning tool, mathematical models are now widely recognised having proven efficiency. With the advent of very fast computing facilities, it has become very easy to study alternatives to optimise many physical problems. Therefore, use of mathematical models can be incorporated in planning sectors to assess measures to be taken up to minimise a physical problem like pollution in the rivers of Bangladesh.

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APPENDIX A

HISTORICAL WATER QUALITY DATA OF THE DOE

Table A.1 Data Record of Water Quality Parameters (1980-1994)

Source : The Department of Environment, Dhaka

Station : Chandni Ghat on the Buriganga

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
08-Jan-80	7.7	7.9	13.5	16	172	180	12	16	5.1	5.8	1.3	4	0	0	0	0	1500	12000		
12-Feb-80	7.4	7.6	25	27	172	180	19	23	2.8	4.2	1.1	2.1	0	0	0	0	2200	5200		
14-Mar-80	7.1	7.4	41	42	160	196	31	32	6.2	6.6	3.2	3.7	0	0			5200	6200		
04-Apr-80	6.8	7.1	37.5	38.5	152	180	29	33	1.5	3	1.1	2.2	0	0	0	0	6000	9000		
16-Jun-80	6.3	6.5	6.5	8	24	56	41	45	3.1	4.1	1.6	2	0	0	0	0	1350	13300		
09-Jul-80	7.5	7.6	6	6	32	68	25	61	3.8	4.1	1.6	2	0	0	0	0	4500	6000		
06-Aug-80	7	7.1	2.5	2.5	56	64	7	180	4.4	6.1	1.8	4.1	0	0	0	0	12900	13500		
06-Sep-80	7.1	7.4	2	2	60	68	31	49	6.1	7.1	3.9	4.9	0	0	0	0	5000	6500		
06-Apr-83	6.6	6.75	97	110	127	153	96.5	103.5	2.75	3	21	25								
05-May-83	7.3	7.45	34.5	35	98	99	56	75.5	3.1	3.3	20	23								
20-Jun-83	6.15	6.2	15	15	63	69	42.5	46	4.75	4.8	4.3	4.35								
05-Jul-83	7.2	7.5	21	21.5	52	58	36	44	1.7	1.9	30	31								
03-Aug-83	5.7	5.95	1.5	3.5	53	54	57.5	65.5	6.05	6.25	0.75	0.85								
04-Sep-83	7.25	7.25	3.5	3.5	53	67	21.5	36.5	6.35	6.7	4.85	5.3								
03-Jan-84	7.15	7.2	43	45	152	156	71.5	74	4.55	4.65	1.65	1.9								
07-Feb-84	6.85	7.1	64	64.5	163	169	64.5	65	3.2	3.3	0.09	0.09								
06-Mar-84	7.7	7.85	84	85	160	170	108.5	114	5.85	6.45	1.75	1.9								
03-Apr-84	7.2	7.3	33	34	170	171	56	59	5.75	5.9	3.95	4.15								
07-May-84	7.1	7.15	25.5	26	124	128	62.5	64	3.1	3.3	1.05	1.55								
03-Jun-84	6.85	6.85	24	24	46	48	48	50	2.8	3.35	1	1.5								
05-Jul-84	7.15	7.25	13	14	54	55	46.5	49	4.55	4.75	4.2	4.2								
02-Aug-84	6.95	6.95	14.5	16	82	132	29	30.5	4.8	5	1.2	1.2								
01-Sep-84	6.1	6.1	9.75	10	96	101	46	50	4.55	5.35	3.35	4.05	91.5	104						
11-Oct-84	7.45	7.45	8	20.5	55	56	66.5	74	4.25	4.9	1.95	2.3	18.75	20.25						
03-Nov-84	7.15	7.25	11.9	14.25	63	71.3	38.5	39	5.45	5.65	4.6	4.8	5	5						
10-Dec-84	7.2	7.3	28	33	110	124	52	54	5.9	6.45	5.15	5.75								

All units in mg/l, except Coli-colonies/100 ml

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
01-Jan-85	7.45	7.6	23.5	31	140	144	76.5	79	5.2	5.4	2.3	2.35	9.5	10						
03-Feb-85	7.15	7.2	35.5	36.5	154	158	85.5	98	2.5	3.05	1.09	1.95	16	20						
02-Mar-85	6.1	6.1	57.5	63.5	142	150	113	114	2.85	3	1.8	1.95	23.5	25.5						
02-Apr-85	6.05	6.15	37	52.5	144	153	79	81	3.1	3.15	2	2	24	28						
07-May-85	6.25	6.45	21.5	25	143	148	73.5	77	4.9	5.15	3.05	3.25	23.5	29						
02-Jun-85	6.8	7.1	19	22.5	146	152	78	79.5	5.5	5.8	2.45	3.55	22	27						
05-Aug-85	6.85	6.85	6	6.25	46	47	19.5	30.5	4.5	4.65	1.55	1.8								
04-Sep-85	6.1	6.2	5.75	5.75	33	37	20.5	25.5	4.9	5	2.75	3								
08-Oct-87	6.8	7	1.2	2.3	84	90	38	46	4.8	5.3	1.8	2.1								
14-Jan-88	6.8	7	8	12	90	94	45	55	5	6	2.1	8.2	44.2	51						
24-Feb-88	6.8	7.1	30	38	148	152	107	114	5	6.2	3	3.2	50.7	57						
04-May-88	6.75	7	43.5	46.5	122	126	74	114	1.7	4	3.5	50								
25-Jun-88	6.8	6.9	12.5	15.5	36	40	32	39	5.1	5.2	1.7	2								
05-Jul-88	6.8	6.9	11.5	12.5	24	36	15	22	4.9	5.1	1	1.8								
11-Aug-88	7.1	7.2	7.8	8	46	50	22	25												
06-Nov-88	7.2	7.3	9	12	42	46	25	26	6	6.5	1.6	2.1								
01-Dec-88	7.3	7.3	9	10	23	25	28	30	4.7	5	1	1.2								
10-Jan-89	7.2	7.4	16	18	136	140	48	57	4.7	4.9	2.3	2.8								
11-Feb-89	7.2	7.4	35	36	176	180	40	50	5	5.2	0.2	1								
14-Mar-89	7.3	7.4	35	37	172	176	33	50	4.9	5.1	0.9	1.1								
05-Apr-89	7.2	7.3	35	38	172	180	35	38	5	5.2	0.8	1								
10-May-89	7.3	7.4	36	39	168	172	50	52	4.9	5.1	1.5	1.8								
07-Jun-89	7.1	7.2	27	31	124	132	49	51	5	5.3	1.1	1.9								
02-Jul-89	7	7.2	14	16	52	64	50	55	5.5	5.9	0.9	1.2								
05-Sep-89	7.1	7.3	25	29	56	68	33	36	6.3	6.8	1.9	2.1								
08-Nov-89	7.3	7.4	28	31	80	96	30	32	6	6.3	2.4	3.5								
06-Mar-90	7.5	7.6	40	44	128	148	45	47	6	6.2	2.1	2.5								
04-Apr-90	7.4	7.6	46	50	144	152	49	52	6.1	6.4	2.4	2.7								
06-May-90	7.3	7.4	48	52	160	168	47	50	6.2	6.6	1.9	2.3								
02-Jun-90	7.2	7.4	45	49	144	156	44	46	6	6.3	2	2.3								
06-Aug-90	7	7	26	28	80	92	77	80	6.7	7	1.7	2.2								
04-Sep-90	7.1	7.2	27	29	92	100	52	55	5.9	6.2	1.7	2								

All units in mg/l, except Coli-colonies/100 ml

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
07-Nov-90	7.3	7.5	30	32	96	112	46	50	6	6.3	1.8	2.4								
03-Dec-90	7.3	7.4	19	22	92	108	25	28	6	6.3										
08-Jan-91	7.3	7.4	24	28	112	118	28	66	6.7	6.9										
09-May-91	7	7.2	25.5	31	112	114	30	33	5.4	5.7	3.1	3.3								
08-Jun-91	6.7	7	5	7	40	42	40	47	5.1	5.6	2.8	3								
11-Jul-91	6.6	6.8	5	8	40	44	52	53	5.2	5.5	2.5	2.8								
01-Apr-92	7.4	7.5	15.5	17	60	68	23	25	5.9	6.2	2.3	2.8								
06-Jun-92	7.5	7.5	13.5	15.5	126	140	32	35	5.9	6.3	2.3	2.7								
04-Jul-92	7.1	7.3	13	14.5	120	124	45	46	5.9	6.1	2.4	2.9								
06-Aug-92	6.9	7	12.5	13.5	112	116	48	54	6.1	6.4	1.9	2.3								
24-Sep-92	7.2	7.5	14	15	116	128	48	52	6	6.2	1.9	2.2								
05-Oct-92	7.3	7.6	16	18.5	124	136	58	61	5.5	6	2.7	3.5								
11-Nov-92	7.5	7.7	20	21	92	100	28	32	5.3	5.8	3	3.5							0	0
12-Dec-92	7.5	7.6	21	21.5	100	104	20	24	5.7	6.1	2.4	2.8							0	0
21-Apr-93	7.4	7.6	20	21.5	104	112	28	32	5.5	5.8	3.2	3.7								
27-Jun-93	7	7.3	14	15	108	116	38	42	6	6.6	2.8	3.2								
04-Jul-93	6.7	6.8	17.5	18.5	72	80	55	61	6.2	6.6	2	2.9								
08-Aug-93	6.7	7.1	13.5	14.5	48	68	55	58	6.2	6.6	3.2	3.5								
07-Sep-93	6.6	7	13	13.5	52	64	46	50	5.5	5.7	2.5	3.1							0.01	0.03
04-Oct-93	7.1	7.2	15	15.5	68	72	46	50	5	5.3	1.8	2.9								
03-Nov-93	7	7.1	17.5	19.5	82	88	40	44	5.6	5.9	2.8	3.2								
02-Mar-94	6.9	7.3	19	21	88	96	26	31	4.4	4.8	1.8	2.2								
06-Jun-94	7.2	7.4	15	16	154	156	35	38	4.3	4.6	1.1	1.2								
04-Jul-94	6.9	7.2	10	12	58	62	40	45	6.4	6.8	2.4	3								
02-Aug-94	6.9	7.2	10	14	46	50	42	47	6	6.4	3.3	3.6								
03-Oct-94	7.1	7.2	16	20	58	64	30	34	5.7	5.9	3.8	4.2								
13-Dec-94	7.4	7.6	16	17.5	64	68	38	44	3.2	4	3	3.5								

All units in mg/l, except Coli-colonies/100 ml

Table A.2 Data Record of Water Quality Parameters (1980-1994)

Source: The Department of Environment, Dhaka

Station : Hazaribagh on the Buriganga

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
09-Jan-80	7.7	7.8	8	9	172	180	11	15	6.8	11.9	1.7	7.4			0	0	700	1400		
10-May-80	7.5	7.8	12	14.5	112	120	6	30	5.8	6.2	2.1	3.1			0	0	1000	8000		
14-Jun-80	6.5	6.8	9.5	18	44	48	8	10	3	4.1	1.7	3	0	0	0.1	0.4	1000	1300		
10-Jul-80	7.1	7.3	2	2.5	56	60	19	38	5.2	6.2	3	4	0	0	0	0	2000	3800		
06-Aug-80	7.4	7.7	2.5	3	56	68	5	45	5.9	6.2	3.6	4.4	0	0	0	0	4000	9500		
05-Jan-83	6.9	7.15	10.5	10.5	182	183	23	28	6.75	6.9	1.1	1.55					19.5	102.5		
03-Feb-83	7.1	7.1	27.5	265	172	173	81	81	5.05	6	2.9	5.35					68	72		
09-Mar-83	6.9	7.05	84	86	174	176	102	103	3.45	3.7	3.5	4								
12-Apr-83	6.65	6.75	125	135	177	183	102	105.5	5.9	6.1	5.45	5.55								
12-May-83	7.1	7.15	190	220	154	156	163	171.5	3.9	4.2	2.5	3.51								
22-Jun-83	6.3	6.55	445	450	83	185	96	107.5	2.2	2.6	3.5	4								
21-Jul-83	6.2	6.2	3.5	3.5	52	54	30	30.5	6.4	6.7	0.95	2.2								
17-Aug-83	6.55	6.65	15	15.5	53	57	33	44	6.75	7.1	0.45	1.62								
11-Sep-83	7.05	7.05	5	6	56	61	34	34.5	8.4	8.7	1.4	1.5								
05-Oct-83	6.9	6.9	7	7.5	57	57	26.5	27	1.4	1.45	21.5	24.5								
10-Nov-83	7	7.1	14	17	56	62	30.5	34	7.3	7.4	1.2	1.3								
07-Dec-83	7.35	7.45	27.5	30.5	103	116	49.5	51.5	6.8	6.85	1.9	1.95								
04-Jan-84	7	7.2	70	72	122	160	73	80	4.3	5.1	2.2	2.8								
09-Feb-84	7.1	7.3	53	56	154	166	74	77	7.4	7.5	5.8	6.6								
13-Mar-84	7	7.2	83	211	150	158	94	104	6.9	8.1	1.1	1.9								
07-Apr-84	7.4	7.5	38	45	140	154	61	64	6	7.3	1.3	1.8								
19-May-84	7.2	7.6	15	19	44	50	35	40	7.2	8.5	3.5	6.2								
05-Jun-84	7	7.2	15	17	42	48	43	53	4.3	4.7	3.7	4.1								
07-Jul-84	7.1	7.4	8	24	34	44	43	55	6.2	7.2	1.4	2.2								
05-Aug-84	7.1	7.2	6	11	32	46	30	32	3.4	4.1	1.3	1.6								
12-Sep-84	7	7.1	14	18	44	48	31	52	4	4.8	0.4	1.8								
07-Oct-84	7	7.3	6	8	40	194	13	33	7	7.4	4.1	4.5	5.5	11			1400	1800	0.01	0.63

All units in mg/l, except Coli-colonies/100 ml

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
08-Nov-84	7.2	7.4	7	8	64	70	36	45	5.9	10.9	0.5	2.3	7	10					0.31	0.62
09-Dec-84	7.2	7.4	15	29	120	144	66	80	6.2	6.6	5.1	6.1	22	29						
03-Jan-85	7.5	8.4	40	3350	128	760	92	1108	6.3	7	1.1	2.9	6	13					0.04	0.13
06-Feb-85	7.1	7.4	31	35	148	156	81	86	5.1	5.3	2	2.3	18	25	0.04	0.16				
04-Mar-85	6.6	6.8	45	52	136	142	111	124	3.3	3.9	2.1	2.7	7	11						
04-Apr-85	6.1	7.1	50	55	136	148	74	86	7.2	7.7	3	3.4	12	16						
08-May-85	6.1	6.8	51	63	130	240	60	70	4.5	5.7	1.3	2.8	11	14						
03-Jun-85	6.7	7.5	43	54	144	260	66	72	6.2	6.5	1.6	1.9	11	18						
14-Aug-85	6.9	7.1	13	15	42	46	121	152	5.1	6	2.3	3								
13-Oct-87	6.9	7.1	11.5	13.5	84	92	40	49	6.4	6.8	2.2	2.4	46	46						
08-Feb-88	6.8	7.1	17	60	63	70	122	127	5.8	6.4			49.2	198						
09-May-88	7.3	7.9	56	56.5	110	114	96	176	4.3	5.3	2.1	2.6								
06-Jun-88	6.8	6.9	4	9	36	46	46	61	3.7	4.6	0.8	3.6								
07-Aug-88	6.9	7.1	4.5	5	26	54	15	20	6.6	8.1	0.3	2.2								
15-Oct-88	7	7.1	6	9	60	64	20	22	7	7.1	1	1.4								
27-Nov-88	7.1	7.2	8	9	64	72	47	50	5	6.5	1.7	1.8								
12-Dec-88	7.1	7.2	8	10	64	72	38	40	6.3	6.6	1.5	2.1								
21-Jan-89	7.2	7.4	6	9	60	68	36	47	6.2	7.5	1.7	1.9								
20-Feb-89	7.3	7.4	8	14	64	76	93	101	5.8	6	1.2	1.5								
10-Apr-89	7.4	7.4	10	18	68	80	45	48	5.3	5.6	1.4	1.7								
27-Jun-89	7.1	7.3	12	22	92	104	40	47	5.7	5.9	1.7	2.2								
25-Jul-89	7.1	7.2	34	37	56	72	25	27	6.1	6.5	1.8	2.1								
09-Sep-89	7.3	7.4	46	50	64	76	31	33	6.6	6.9	1.9	2.2								
11-Nov-89	7.3	7.5	48	52	72	88	29	30	6.2	6.4	1.8	2.5								
17-Feb-90	7.5	7.6	59	63	140	152	40	44	6.3	6.5	2	2.3								
08-Mar-90	7.4	7.5	62	65	140	156	44	48	6.2	6.3	2	2.3								
10-Apr-90	7.7	7.8	67	70	152	168	51	53	6.2	6.5	2	2.1								
10-May-90	7.4	7.5	63	68	164	176	50	55	6.1	6.4	1.8	2.1								
03-Jun-90	7.2	7.4	60	64	156	164	48	50	6	6.3	2	2.3								
15-Jul-90	7	7	40	43	60	72	60	63	6.3	6.6	2.3	2.8								
11-Aug-90	7	7.2	27	30	84	88	70	73	6.3	6.6	2	2.3								
09-Sep-90	7.2	7.4	28	32	84	100	49	53	6.2	6.5	1.7	2								

All units in mg/l, except Coli-colonies/100 ml

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli-colonies		Chromium	
14-Oct-90	7.3	7.4	32	35	96	112	50	53	6	6.3	1.1	1.9								
20-Dec-90	7.2	7.4	28	32	88	92	32	34	6.1	6.4										
05-Jan-91	7.3	7.5	32	38	96	100	11	25	6	6.3										
08-May-91	7.2	7.3	100	110	196	204	42	45	2	2.3	190	210								
09-Jun-91	6.7	7.2	70	72	160	168	50	52	5.3	5.6	1.5	2.2								
07-Aug-91	7.3	7.5	65	68	178	210	62	65	5.5	5.8	1.7	2.4								
18-Apr-92	7.3	7.5	34	36	168	184	38	44	6	6.2	2.7	3.2								
08-Jun-92	7.4	7.5	33	36	180	188	37	41	6.1	6.4	2.7	3.1								
05-Jul-92	7.2	7.4	31	34	152	168	50	52	5.8	6	2.7	3.4								
17-Aug-92	7.2	7.3	30	33	148	160	49	52	6.4	6.7	2.7	3.1								
05-Oct-92	7.3	7.6	36	39	184	204	51	57	5.7	6.2	3.4	4								
13-Nov-92	7.6	7.7	38	40	192	196	34	38	5.3	5.7	3.1	3.7							0	0
03-Dec-92	7.6	7.7	36	41	188	204	24	26	6.2	6.5	3	3.8							0	0
27-Apr-93	7.5	7.7	19.5	21	220	232	36	40	5.4	5.8	2.8	3.3								
30-Jun-93	6.7	6.8	22	25	28	32	36	40	6.4	6.7	0.4	2	26	36					0	0
06-Jul-93	6.4	6.5	27.5	30	24	30	52	60	5.8	6.2	1.9	2.1								
24-Aug-93	6.8	7.2	20.5	22	24	30	60	63	6.6	6.8	1.6	2								
06-Oct-93	6.8	6.9	22.5	25	40	46	49	54	5.7	5.9	2.5	3	8	10					0	0
20-Nov-93	7.1	7.2	27	27.5	42	50	37	40	5.4	5.6	2.2	2.5							0	0
03-Mar-94	7.2	7.4	24	28	112	124	33	36	5.6	5.8	2.6	3.3								
03-Jun-94	7.1	7.3	31	33	124	132	38	42	6.2	6.5	2.2	2.6							0	0
03-Jul-94	6.8	7.1	25	27	64	70	44	49	7	8	2.5	3							0	0
01-Aug-94	7.1	7.3	18	22	72	76	47	52	6.1	6.5	3.4	3.8								
07-Sep-94	7.1	7.2	15.5	18	76	82	40	43	6	6.5	3.1	3.5								
06-Oct-94	7.1	7.2	18	21	78	82	35	38	6.2	6.7	3.2	3.8								
10-Dec-94	7.3	7.5	20	23	74	82	44	46	3.3	3.8	2.9	3.3								

All units in mg/l, except Coli-colonies/100 ml

Table A.3 Data Record of Water Quality Parameters (1988-1993)

Source : The Department of Environment, Dhaka

Station : Pagla on the Buriganga

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli		Chromium	
09-Aug-88	7.1	7.2	5	5.5	54	58	24	30												
16-Oct-88	7	7.1	7	8	80	88	40	53	5.9	6.3	2	2.2								
15-Nov-88	7.1	7.2	12	14	140	190	70	72	5.1	5.3	1.9	2								
07-Dec-88	7.3	7.4	26	30	24	36	52	54	5.2	5.5	2.3	4.1								
17-Jan-89	7.3	7.4	20	21	84	88	42	43	6.1	6.7	2.8	3.2								
08-Feb-89	7.2	7.2	27	29	200	204	42	50	4.9	5	1.1	2.6								
18-Mar-89	7.3	7.4	36	37	172	188	42	50	5	5.1	2.8	3								
27-Apr-89	7.3	7.4	39	40	182	200	28	32	5.6	5.9	2.6	2.8								
15-May-89	7.4	7.4	38	42	180	184	42	44	5	5.3	2.4	2.6								
08-Jun-89	7.1	7.3	29	32	136	140	33	36	5.1	5.5	1.5	1.8								
05-Jul-89	7	7.1	12	14	60	72	40	47	5.1	5.5	1.1	1.4								
19-Feb-90	7.4	7.5	36	39	120	136	36	39	6.1	6.3	1	1.3								
11-Mar-90	7.4	7.5	39	42	128	140	38	44	6	6.3	2.5	2.8								
16-Apr-90	7.3	7.4	45	49	144	156	47	52	6	6.2	1.4	2.6								
20-May-90	7.3	7.4	47	51	156	168	44	45	6.2	6.4	1.9	2.2								
09-Jun-90	7.2	7.3	44	48	136	148	48	50	6.1	6.4	1.8	2.2								
13-Aug-90	6.9	7	26	29	52	60	62	70	6.3	6.5	1.8	2.2								
11-Sep-90	7.1	7.2	26	30	56	68	50	52	6.1	6.6	1.5	1.8								
22-Oct-90	7	7.2	30	33	64	76	47	49	6.7	7	1.2	1.6								
13-Nov-90	7.1	7.3	31	34	68	80	42	45	6.7	7	1.2	1.6								
17-Dec-90	7.2	7.3	29	30	68	72	27	30	6	6.2										
20-May-91	6.6	6.8	5.5	6	42	48	41	44	6	6.6	2.1	2.4								
21-Aug-91	7.1	7.3	7	7.5	50	54	23	26	6.3	6.6	2	2.5								
17-Nov-91	6.9	7	8	9.5	44	50			6	6.4	2	2.5								
03-Dec-91	6.9	7.2	9	10.5	50	56			6	6.3	3	3.5								
09-Jul-92	7	7.2	12	13	112	120	40	42	6	6.2	3	3.8								
25-Aug-92	7	7.3	11	12.5	108	120	44	48	6.1	6.5	3	3.5								

All units in mg/l, except Coli-colonies/100 ml

Date	pH		Chloride		T.Alkalinity		T.S.S.		D.O.		B.O.D.		C.O.D.		NH3		Coli		Chromium	
14-Sep-92	7.2	7.3	12	13.5	120	128	49	52	6	6.4	2	2.3								
25-Oct-92	7.3	7.6	10	11	116	132	30	35	5.3	5.8	3.8	4.2								
25-Nov-92	7.4	7.5	11.5	12	136	140	27	30	6.2	6.5	4	4.4								
05-Dec-92	7.5	7.6	11	12.5	136	148	24	28	5.6	5.8	3.4	3.8								
25-Apr-93	7.3	7.5	16.5	18	144	156	36	38	5.1	5.4	3.4	3.8								
14-Jun-93	6.9	7.1	15.5	17	132	140	47	56	5.7	5.9	3.3	3.8								
20-Jul-93	6.7	6.8	12.5	14	104	116	85	98	6.4	6.7	3.2	3.8								
21-Aug-93	6.6	7.9	10	11	48	84	60	164	6	6.5	3.5	3.9								
29-Sep-93	7	7.2	12.5	13.5	80	92	47	52	7.2	7.4	2.8	3.4								

All units in mg/l, except Coli-colonies/100 ml

Table A.4 Data Record of Water Quality Parameters (1980-1994)

Department of Environment, Dhaka

Station : Hazaribagh Main Drain

Date	pH	Chlorid	T.Alk	T.S.S.	D.O.	B.O.D	C.O.D.	NH3	Coli-colonies	Chromium
09-Jan-80	7.85	7750	140	2525	0	18	2736	120	0	
10-May-80	7.9	2750	890	1119		80	2100	150	100	
14-Jun-80	5.9	38	52	40	0	60	890	30	200	
10-Jul-80	6.8	6	64	56	3	0.4	300	0.2	100	
06-Aug-80	7.7	9.5	60	16	3.8	1.9	65	55	4000	
05-Jan-83	7.8	250	1580	5025	0	55			1322	
03-Feb-83	8.5	4600	1300	2327	0	65			1240	
09-Mar-83	7.7	1160	149	1800	0	70				
12-Apr-83	7.3	4950	1760	105	0	65				
12-May-83	8.5	500	252	257	0	50				
22-Jun-83	7.3	2150	506	800	0	50				
21-Jul-83	5.9	19	52	34	1.9	30				
17-Aug-83	6.5	42	56	35	1.3	35				
11-Sep-83	7.85	18	114	68	0	38				
05-Oct-83	7.1	12	52	58	0.7	25.5				
10-Nov-83	6.9	77	98	104	0	40				
07-Dec-83	8.1	160	236	1828	1.5	37				
04-Jan-84	8.1	1060	1740	1106	1	36				
09-Feb-84	8	9750	3000	232	7.3	0.6				
13-Mar-84	7.7	4140	174	1198	1.6	18				
07-Apr-84	8.4	4950	1700	2788	0	31				
19-May-84	5.2	275	2100	2092	0	34				
05-Jun-84	6.2	59	82	138	0.9	0.3				
07-Jul-84	6.4	500	260	51	2.5	30				
05-Aug-84	6.8	31	138	62	1.6	0.4				
12-Sep-84	6.8	38	142	32	1.8	5.4				
07-Oct-84	7.2	26	194	46	2.5	21	134		1900	1.15

All units in mg/l, except Coli-colonies/100 ml

Date	pH	Chlorid	T.Alk	T.S.S.	D.O.	B.O.D	C.O.D.	NH3	Coli-colonies	Chromium
08-Nov-84	8.5	34.5	50	204	0	3.6	45			0.7
09-Dec-84	8.3	500	1080	1206	0	40	115			
03-Jan-85	8.3	7150	1090	1316	0.4	3.9	2304			1.77
06-Feb-85	7.9	5200	1380	792	0	160	1210	1.16		
04-Mar-85	7.6	6350	1390	1894	0	135	8			
04-Apr-85	6.8	64	280	316	0	42	752			
08-May-85	6.7	710	128	292	0	200	619			
03-Jun-85	6.8	580	148	318	0	100	668			
14-Aug-85	8.1	126	142	528	0	40				
13-Oct-87	8.1	21.5	390	47	0	120				
08-Feb-88	8	1420	248	186	0		413.3			
09-May-88	8.3	2300	1360	828	0	250	4160			
06-Jun-88	8.4	470	290	205	0	240	2240			
07-Aug-88	8.3	50	80	70	5.8	0.7				
15-Oct-88	8.4	2875	728	300	0	430	4320			
27-Nov-88	8.1	2975	550	350	5	400	3600			
12-Dec-88	7.2	2950	1200	400	0	260	2340			
21-Jan-89	7.85	2300	300	300	0	290	4000			
20-Feb-89	8.5	2425	320	1750	0	330				
10-Apr-89	8.4	2375	330	500	0	330	2230			
27-Jun-89	7.8	2325	128	325	0	120	1872			
25-Jul-89	7.85	10200	2000	320	0	130	2160			
09-Sep-89	8.4	300	240	200	0	120	694			
11-Nov-89	7.85	490	560	412	0	140	1250			
17-Feb-90	7.85	530	540	442	0	190	1275			
08-Mar-90	7.8	510	590	490	0	150	1450			
10-Apr-90	7.85	540	570	216	0	170				
10-May-90	7.85	550	550	440	0	160				
03-Jun-90	7.85	510	520	580	0	180				
15-Jul-90	7.85	460	240	502	0	160				
11-Aug-90	7.85	470	255	390	0	150	12800			
09-Sep-90	7.85	490	530	930	0	140				

All units in mg/l, except Coli-colonies/100 ml

Date	pH	Chlorid	T.Alk	T.S.S.	D.O.	B.O.D	C.O.D.	NH3	Coli-colonies	Chromium
14-Oct-90	7.85	500	550	502	0	160	10800			
20-Dec-90	7.85	470	520	870	0					
05-Jan-91	12	510	580	602	0					
08-May-91	8	260	540	588	0	290				
09-Jun-91	8	110	470	962	0	420	1660			
07-Aug-91	8.1	120	440	402	0	110				
18-Apr-92	8.5	3375	570	690	0		1800			
08-Jun-92	9	9622	60	620	0	250	1750			
05-Jul-92	8.5	3025	530	945	0	140	1662			
17-Aug-92	8.5	2950	520	1510	0	130	1600			
06-Sep-92	8.5	3050	550	1260	0	140	2050			
05-Oct-92	8.5	3250	710	1210	0	220	1560			1.6
13-Nov-92	8.5	3350	690	750	0	150	1200			1.1
03-Dec-92	8.5	3375	700	1824	0	150	1800			1.8
27-Apr-93	8.5	3200	800	260	0	440	1500			
06-Jul-93	8.2	2825	1040	245	0	102				
24-Aug-93	8.6	2050	1040	290	0	120				
06-Oct-93	8.5	950	1280	1425	0	1090	2880			20.5
20-Nov-93	8.5	930	1220	1212	0	386	1010			21
03-Mar-94	8.5	93	1120	288	0	410				
03-Jun-94	8.5	192	1150	360	0	410				20
03-Jul-94	8.3	980	1080	360	0	150				19
01-Aug-94	8.3	950	1020	360	0	120	350			
07-Sep-94	8.5	925	1010	570	0	310	1200			
06-Oct-94	8.5	9300	1040	810	0	160	1210			
10-Dec-94	8.5	950	1020	360	0	250	1200			

All units in mg/l, except Coli-colonies/100 ml

Table A.5 Data Record of Water Quality Parameters (1988-1993)

Source : The Department of Environment, Dhaka

Station : Main Drain of Pagla STP

Date	pH	Chlor	T.Alk	T.S.S	D.O.	B.O.	C.O.D	Ammonia	Coli	Chromium
15-Nov-88	7	13	136	76	5	2	46.8			
07-Dec-88	7.5	38	52	54	5	4				
17-Jan-89	8.2	55	128	54	5.1	3.7			80000	
08-Feb-89	7.2	29	208	52	4.3	10				
18-Mar-89	7.4	42	196	80	3.2	90			2000	
27-Apr-89	7.3	44	208	40	3.3	100				
15-May-89	7.5	37	200	46	4.9	120				
08-Jun-89	7.4	27	160	40	5	70				
05-Jul-89	7.3	17	84	52	5	99				
19-Feb-90	7.5	42	140	50	5.2	70				
11-Mar-90	7.7	46	144	52	4.7	120				
16-Apr-90	7.6	54	164	99	5.3	140				
20-May-90	7.7	53	172	100	5.8	150				
09-Jun-90	7.6	50	140	56	5.8	140				
13-Aug-90	7.3	31	100	72	5	130				
11-Sep-90	7.5	33	108	60	5.9	120				
22-Oct-90	7.5	36	112	50	5.9	140				
13-Nov-90	7.5	35	116	52	0.9	250	780			
17-Dec-90	7.5	33	100	32	4.1					
20-May-91	7	6.5	60	46	4.9	1.6				
21-Aug-91	7.5	6	62	50	4.8	120				
17-Nov-91	7.3	7.5	56		5.2	140				
03-Dec-91	7.3	11	58		5.8	110				
09-Jul-92	7.4	15.5	124	45	5.9	110			300	
25-Aug-92	7.6	14.5	132	52	5.8	120				
14-Sep-92	7.7	15.5	112	54	5.8	1.9				
25-Oct-92	7	13.5	136	40	4.1	140				

All units in mg/l, except Coli-colonies/100 mg/l

Date	pH	Chlor	T.Alk	T.S.S	D.O.	B.O.	C.O.D	Ammonia	Coli	Chromium
25-Nov-92	7.6	15.5	148	42	5.9	110	150			
05-Dec-92	7.7	16	164	22	5.5	170				
25-Apr-93	7.6	21.5	168	42	4.5	130				
14-Jun-93	7.4	16	164	54	5.5	150				
20-Jul-93	6.6	13.5	100	108	5.9	120			18000	
21-Aug-93	6.7	10.5	92	65	5.6	110			15000	
29-Sep-93	7.3	14	100	55	3.4	150			18000	

All units in mg/l, except Coli-colonies/100 mg/l

APPENDIX B

FIGURES SHOWING STATUS OF POLLUTION (DOE)

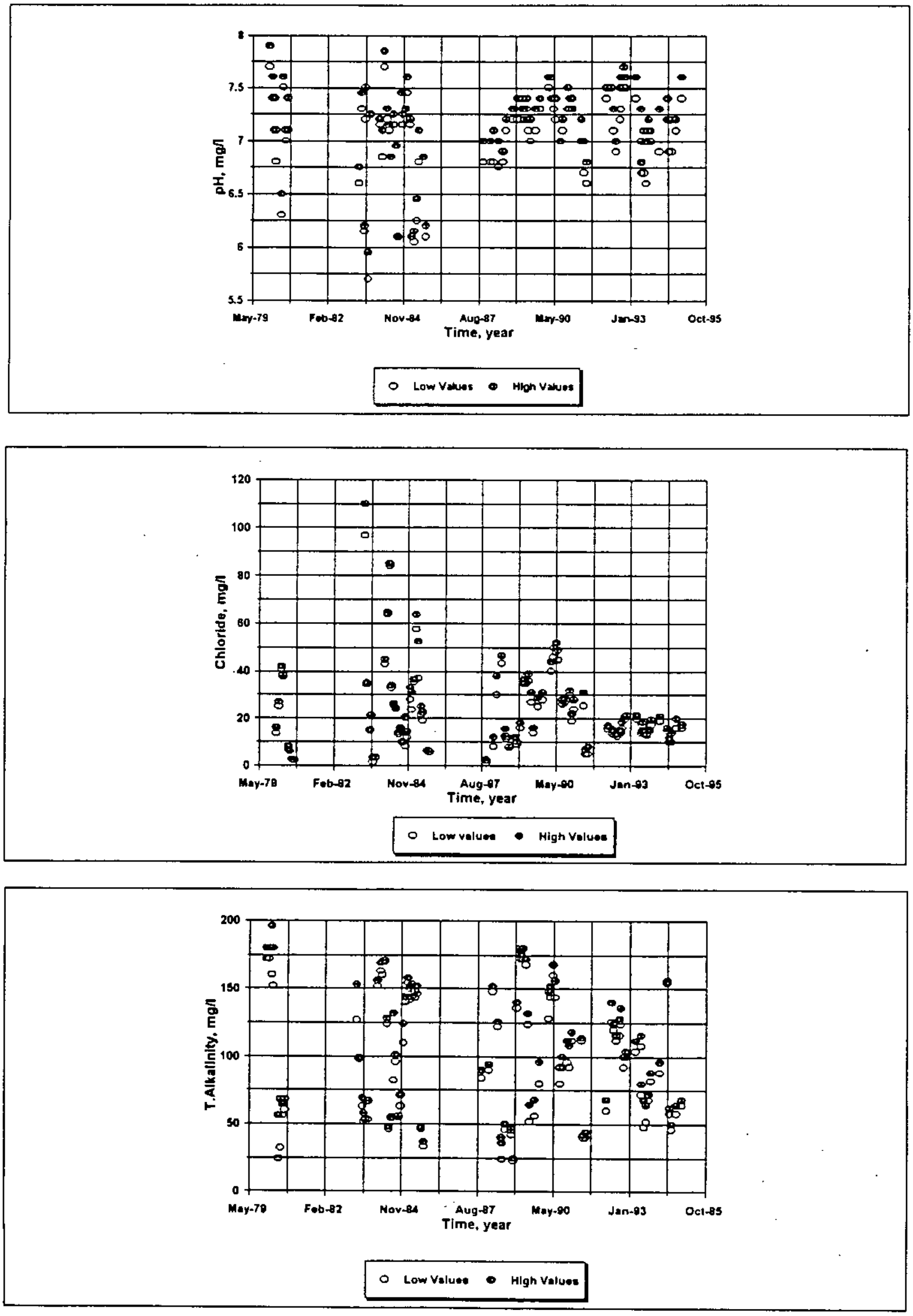


Figure B.1 Trend of pH, Chloride and T.Alkalinity near Chandnighat in the Buriganga (DoE)

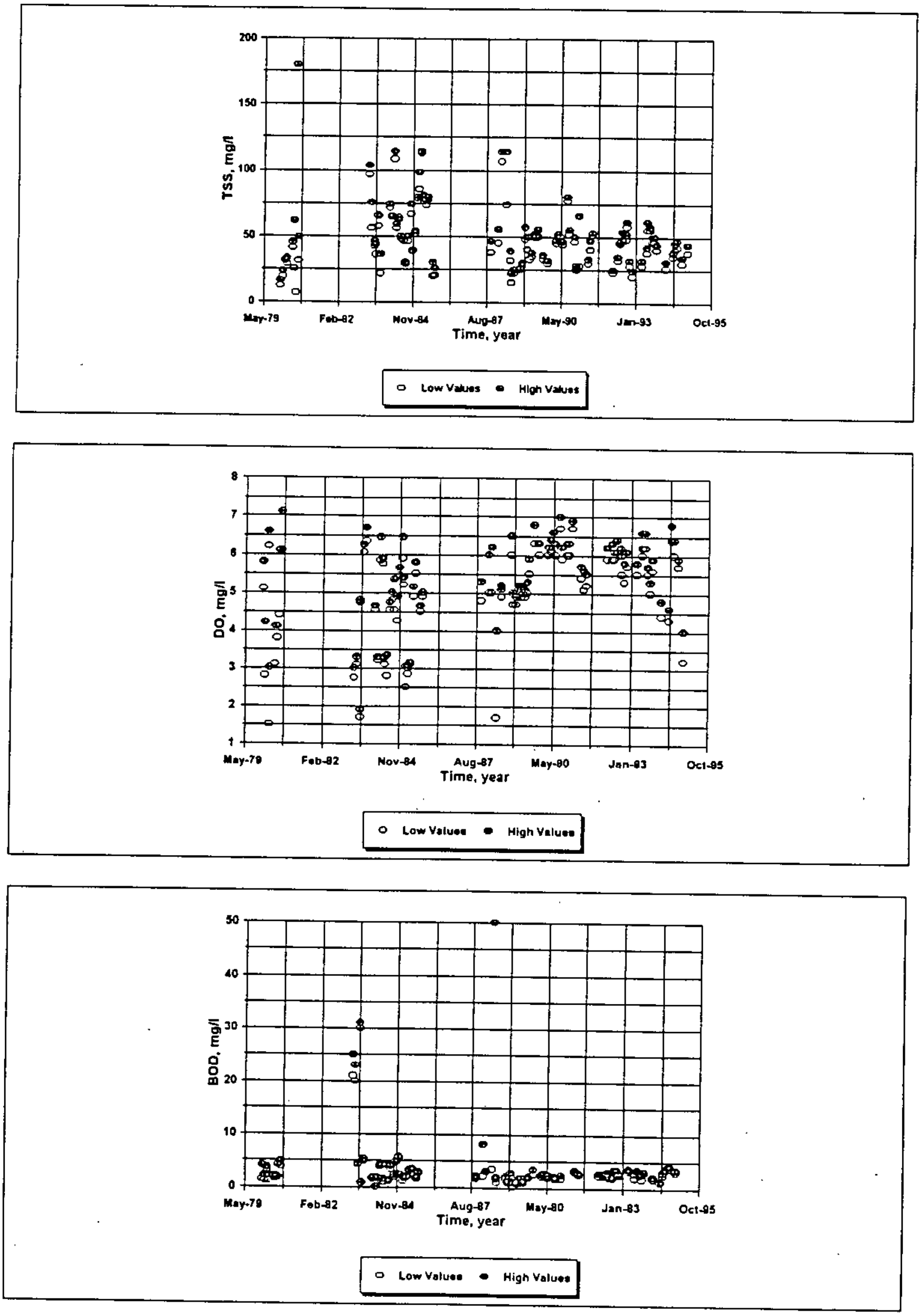
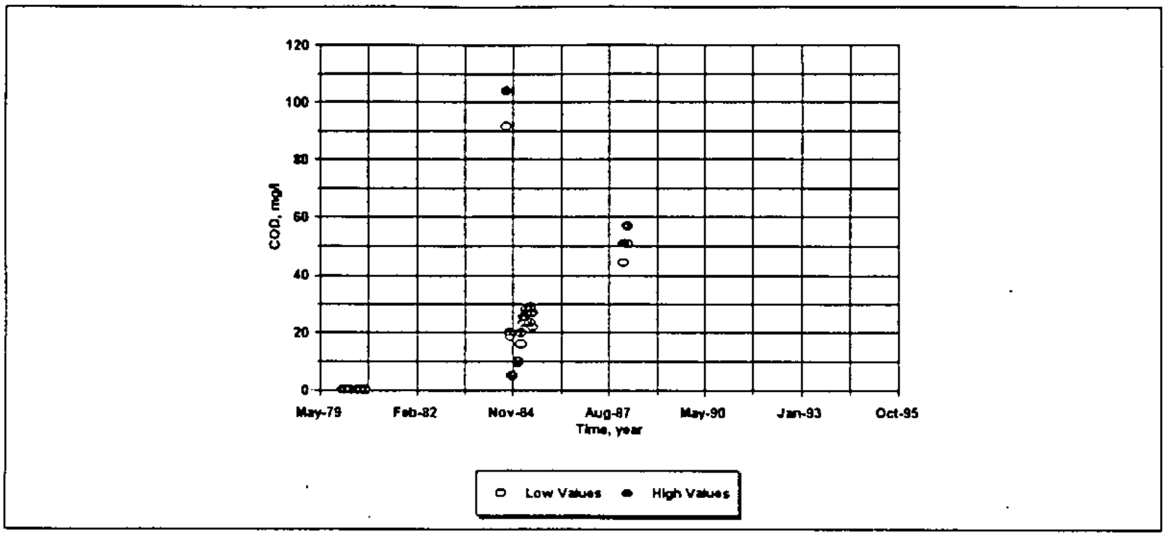
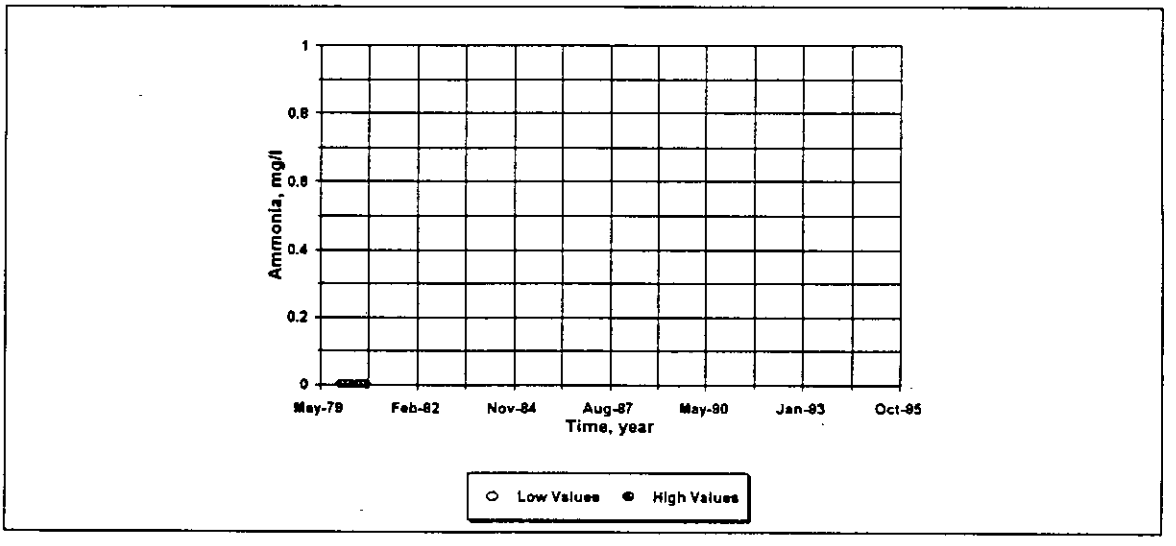


Figure B.2 Trend of TSS, DO and BOD near Chandnighat in the Buriganga (DoE)





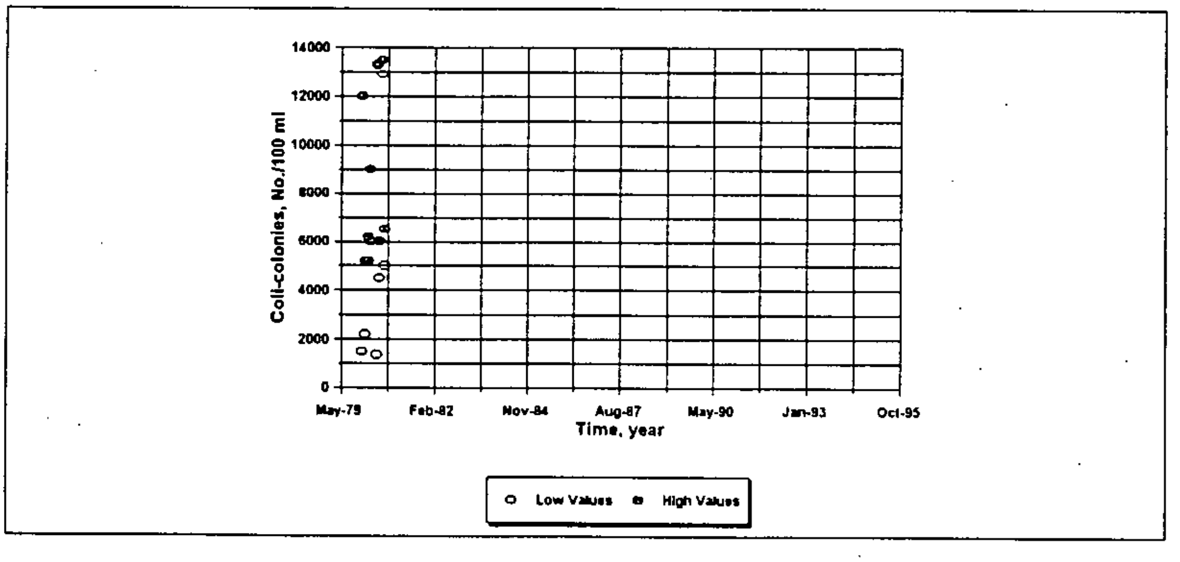


Figure B.3 Trend of COD, Ammonia and Coli-colonies near Chandnighat in the Buriganga (DoE)

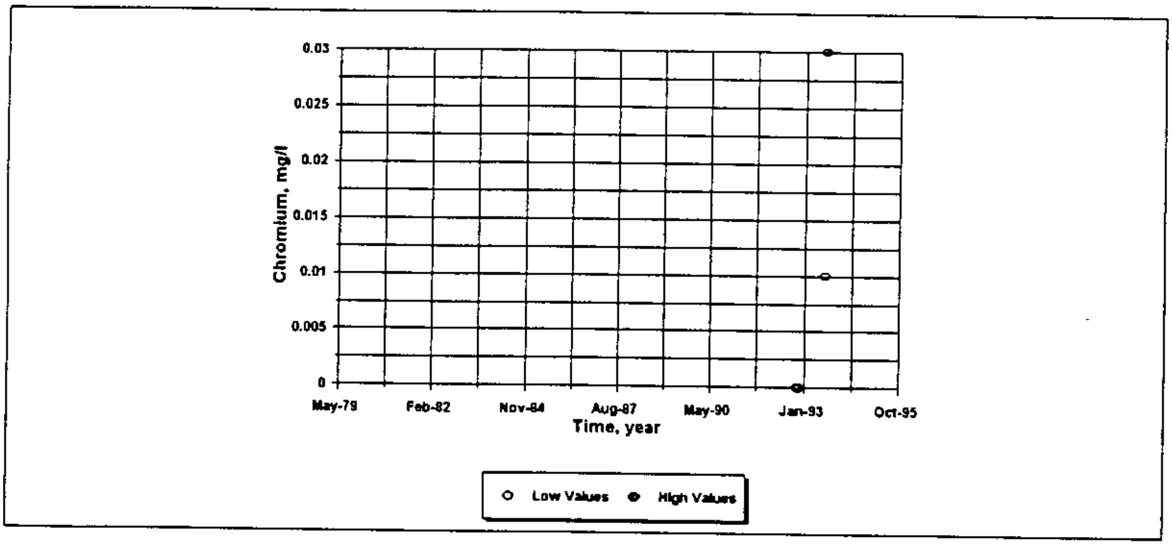
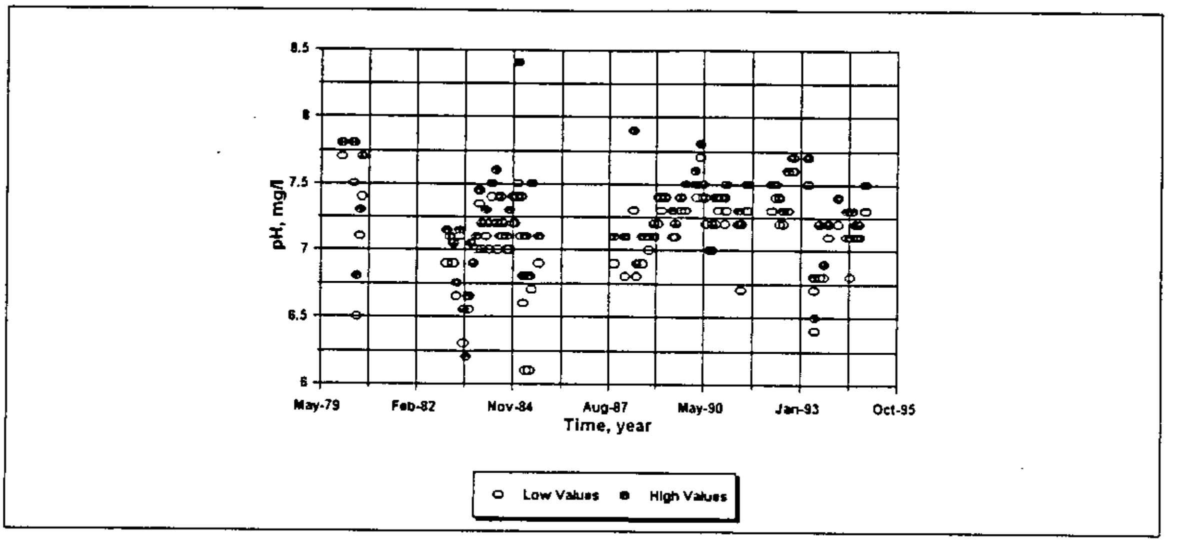
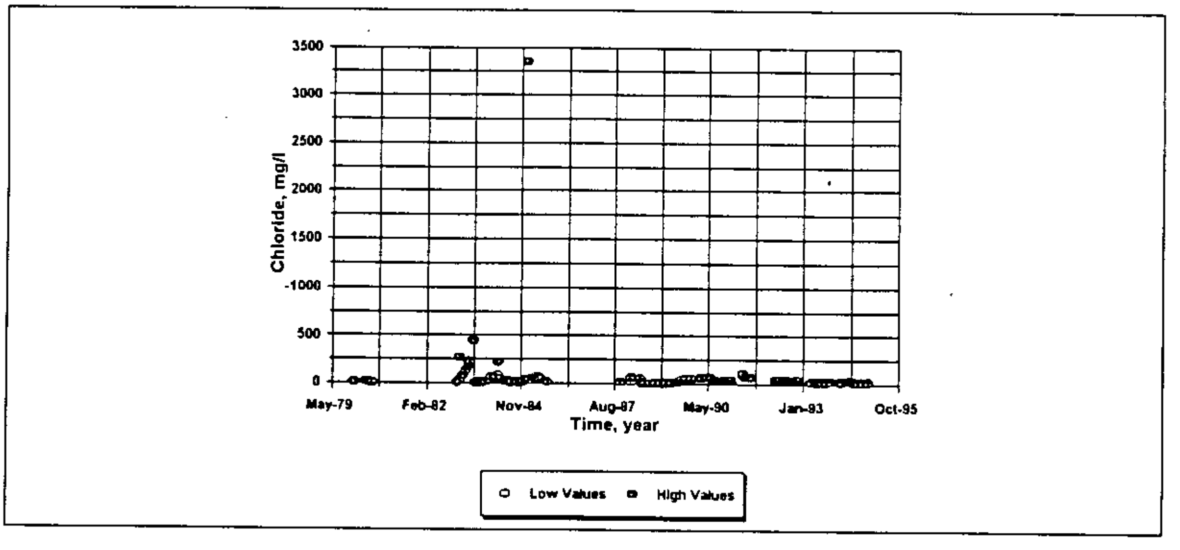


Figure B.4 Trend of Chromium near Chandnighat in the Buriganga (DoE)





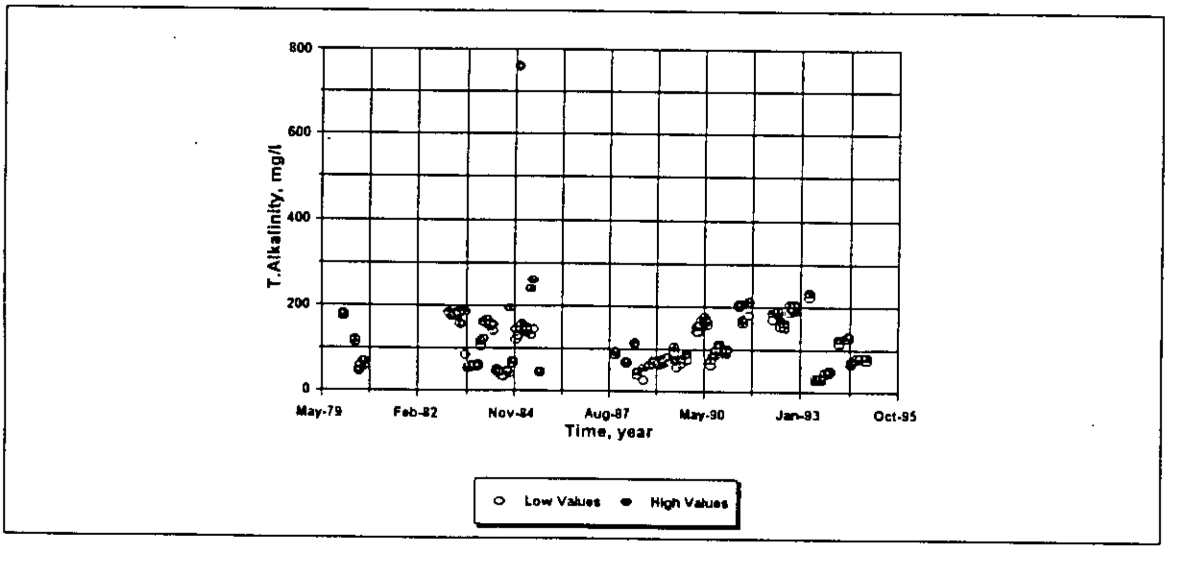
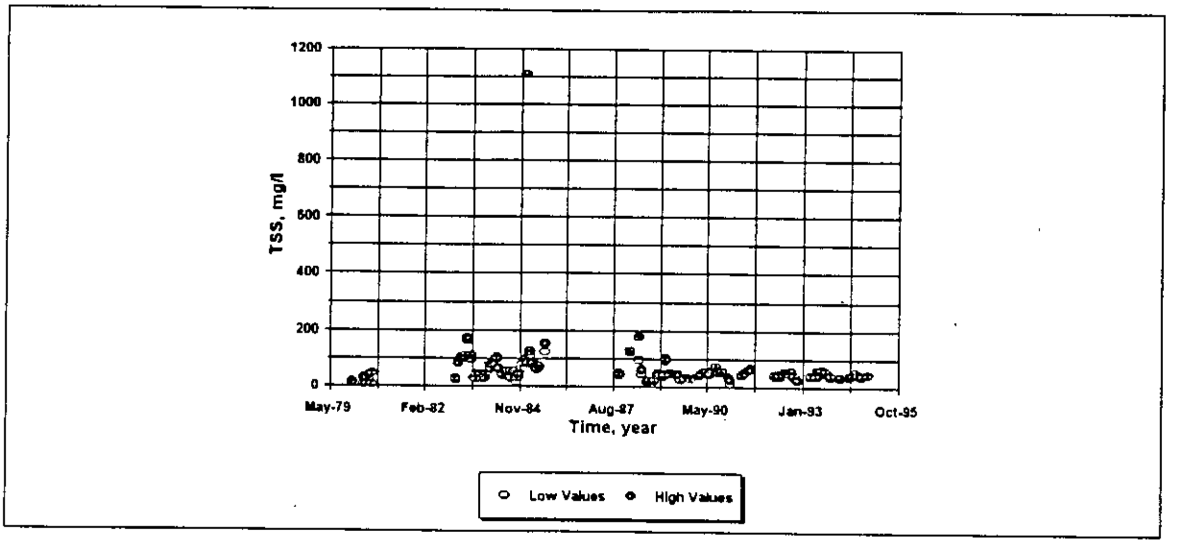
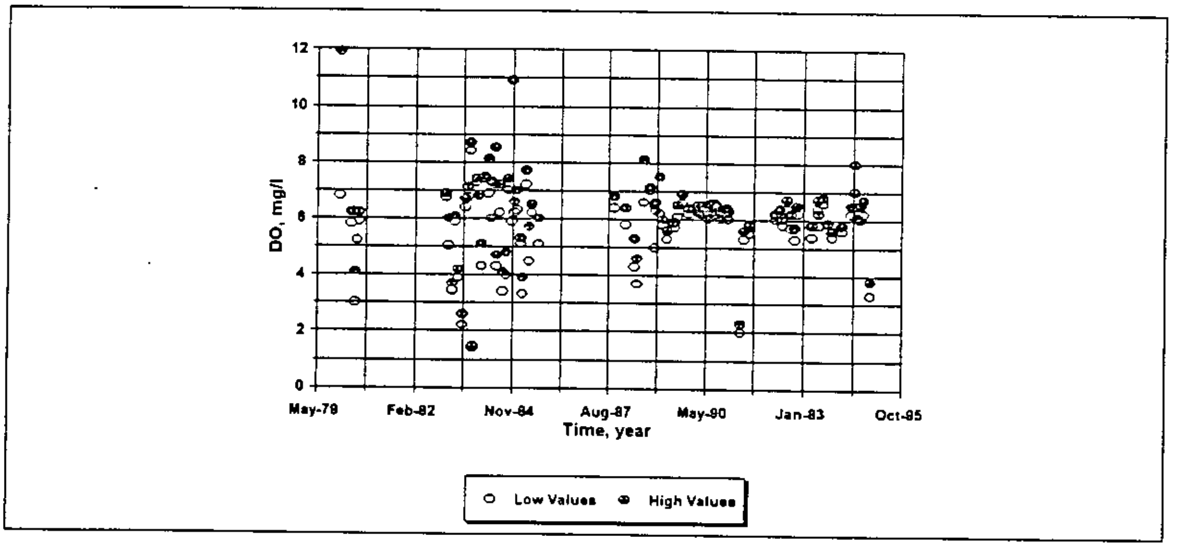


Figure B.5 Trend of pH, Chloride and T.Alkalinity near Hazaribagh in the Turag (DoE)





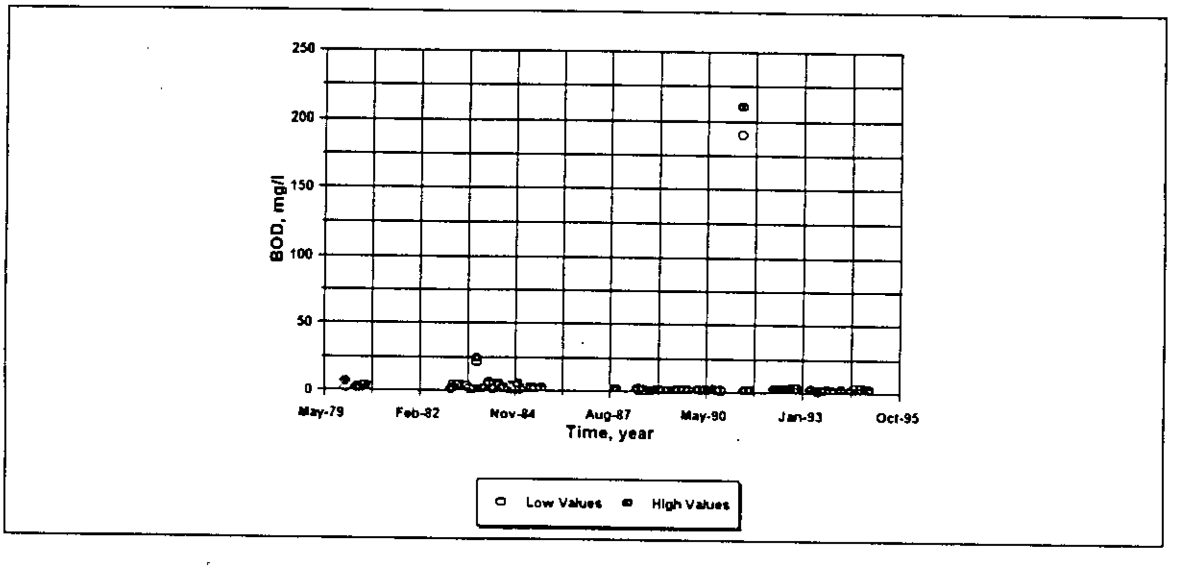


Figure B.6 Trend of TSS, DO and BOD near Hazaribagh in the Turag (DoE)

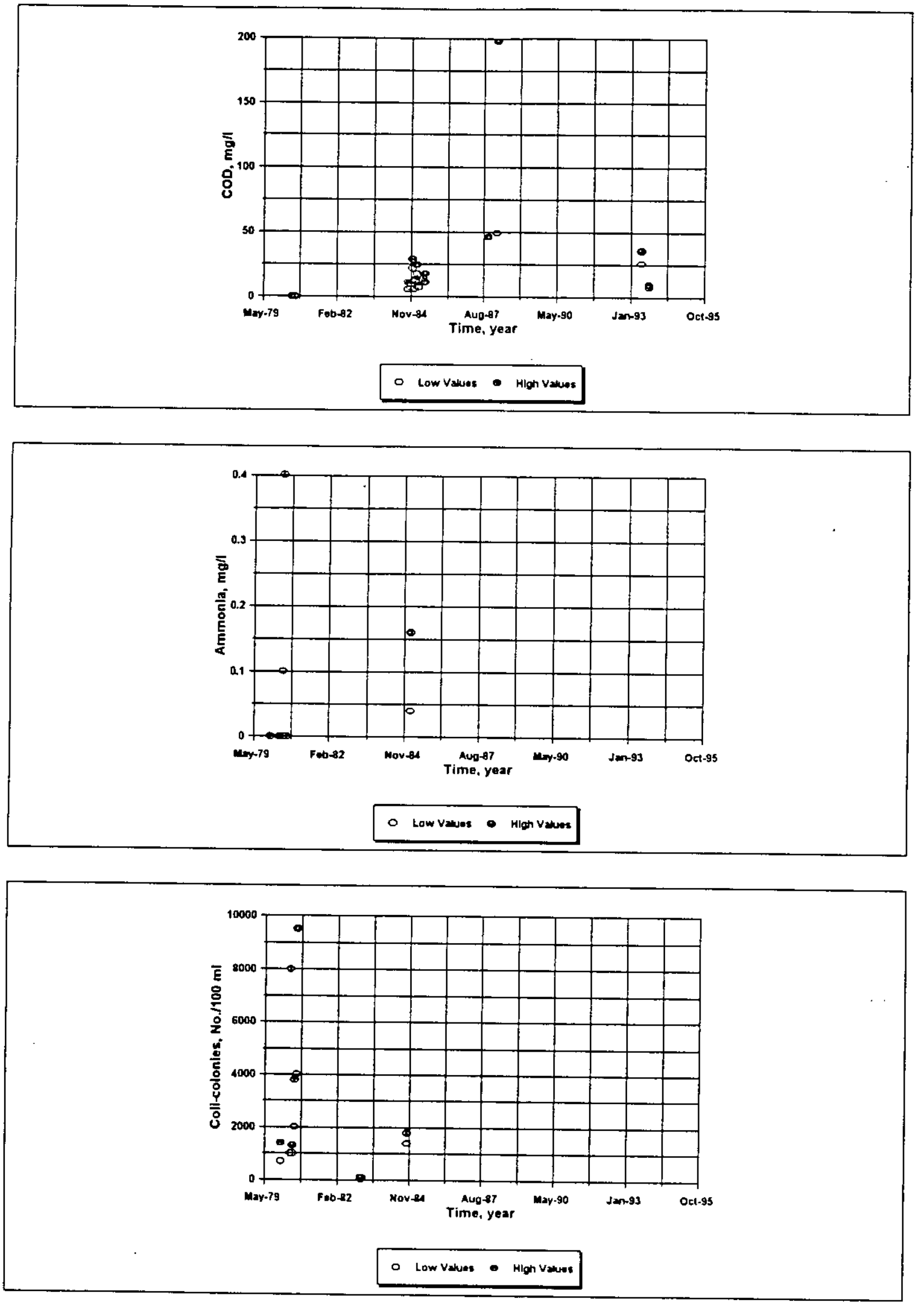


Figure B.7 Trend of COD, Ammonia and Coli-colonies near Hazaribagh in the Turag (DoE)

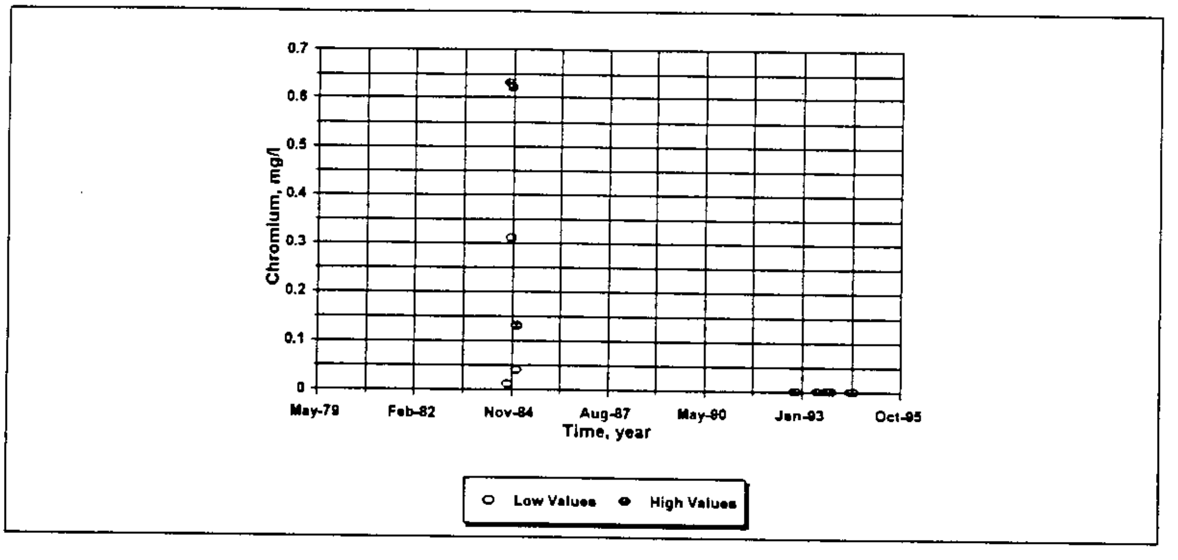


Figure B.8 Trend of Chromium near Hazaribagh in the Turag (DoE)

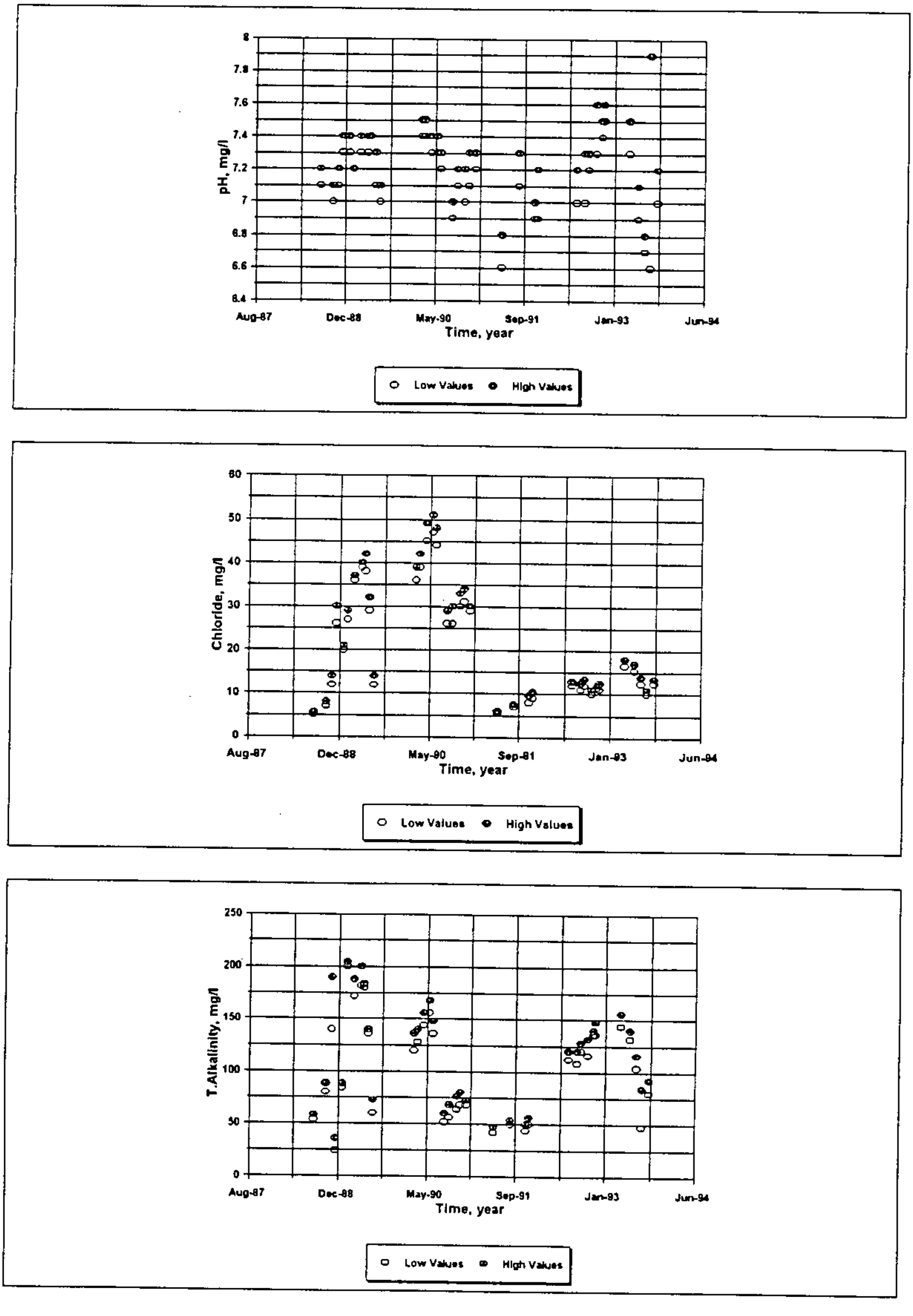
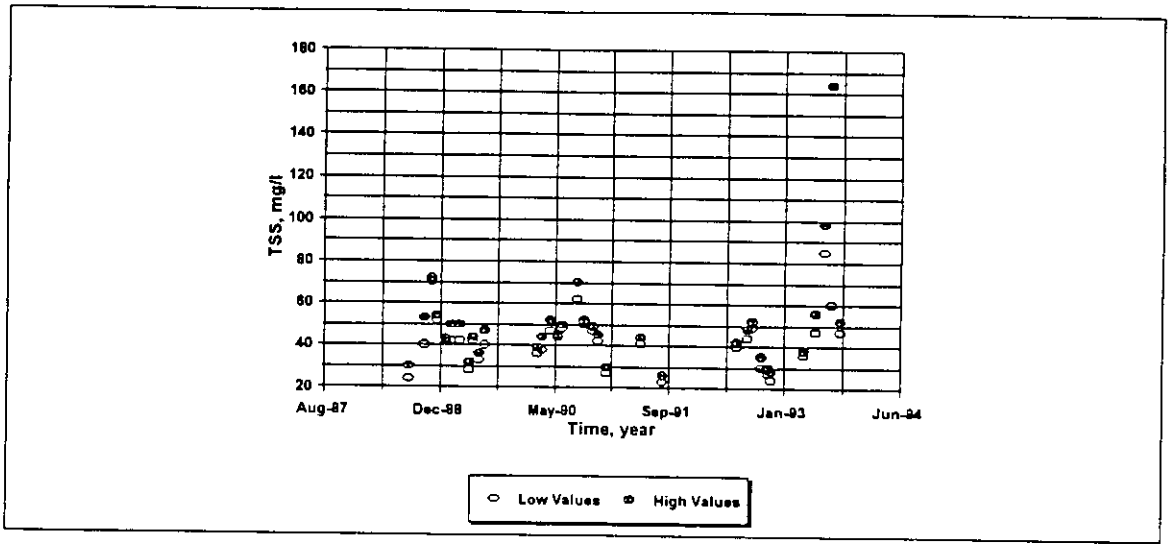
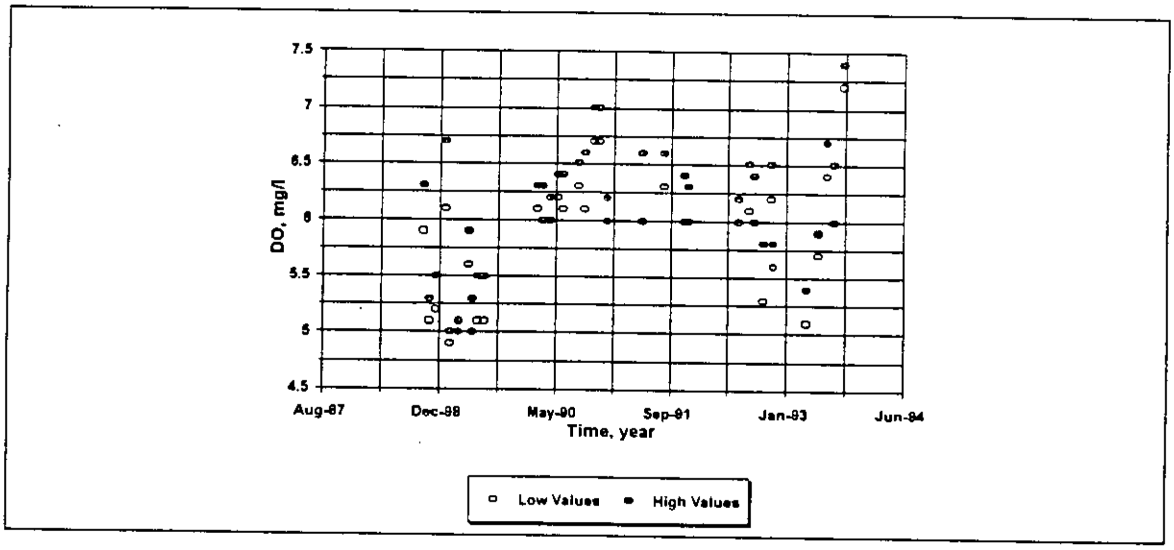


Figure B.9 Trend of pH, Chloride and T.Alkalinity near PSTP outfall in the Buriganga (DoE)





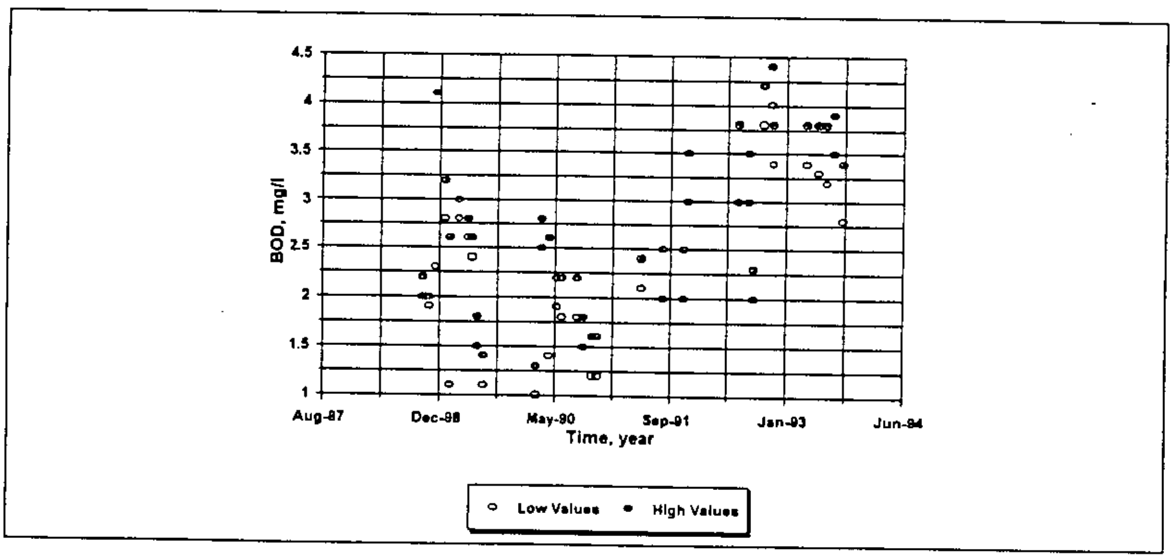
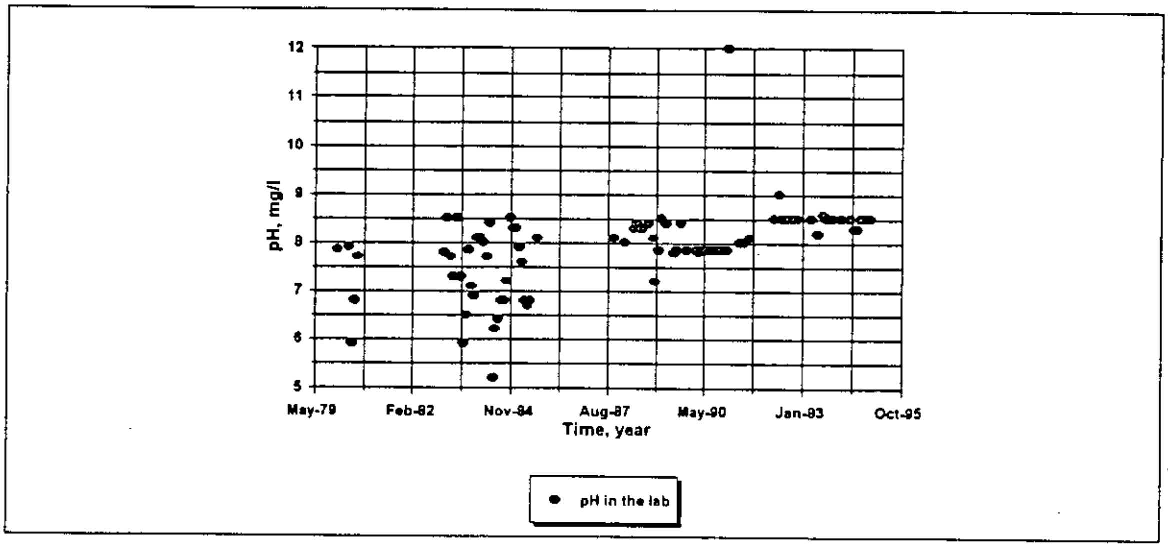
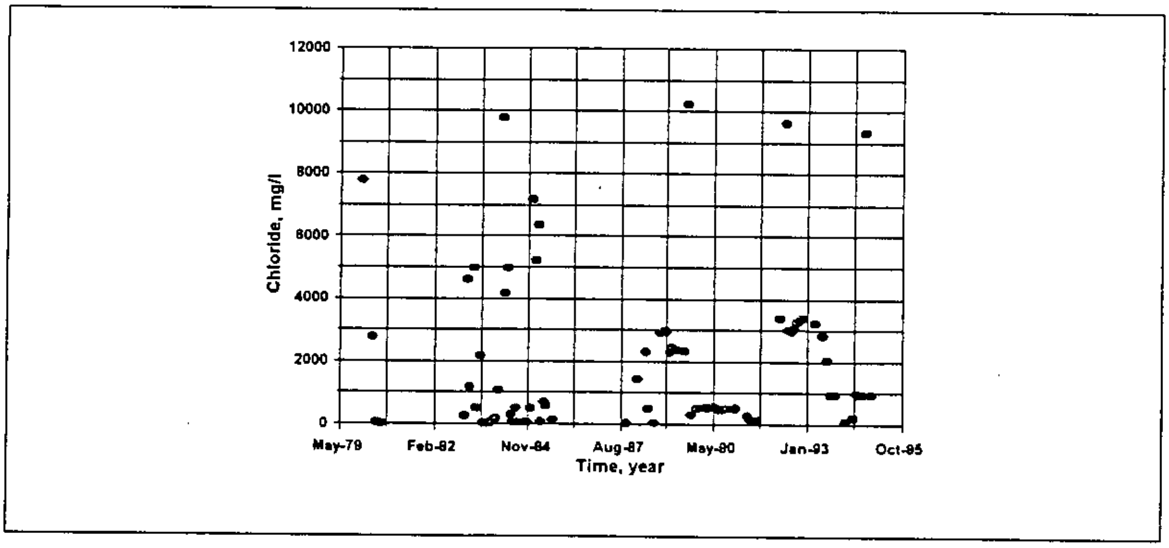


Figure B.10 Trend of TSS, DO and BOD near PSTP outfall in the Buriganga (DoE)





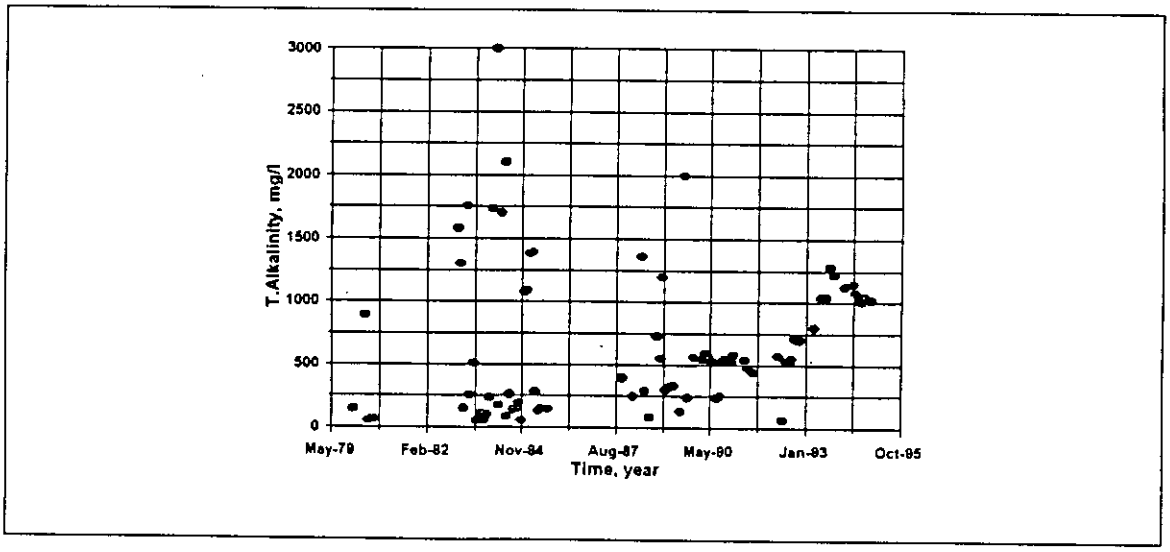
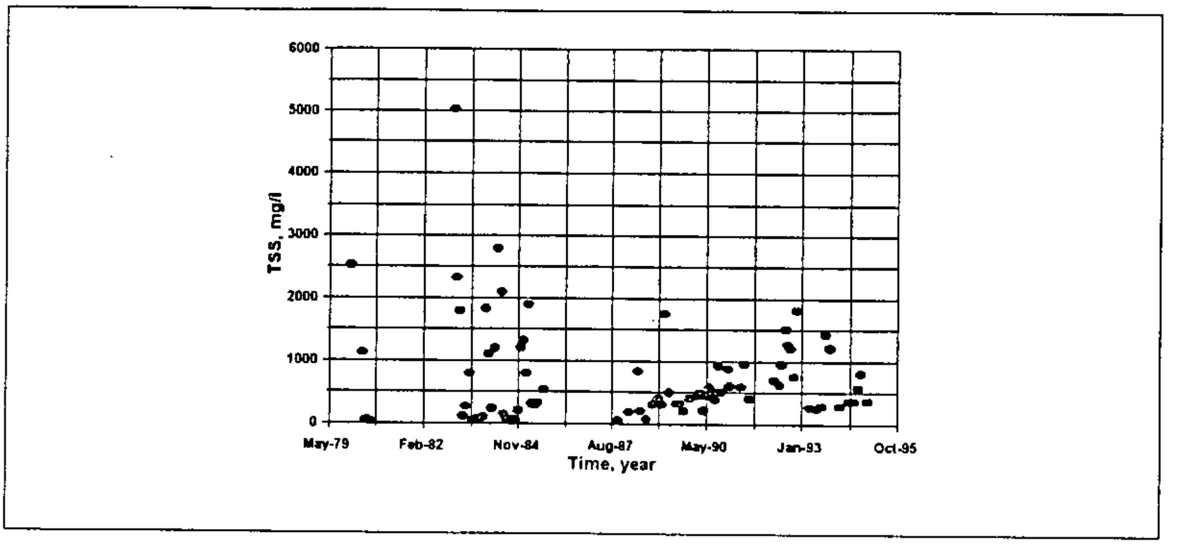
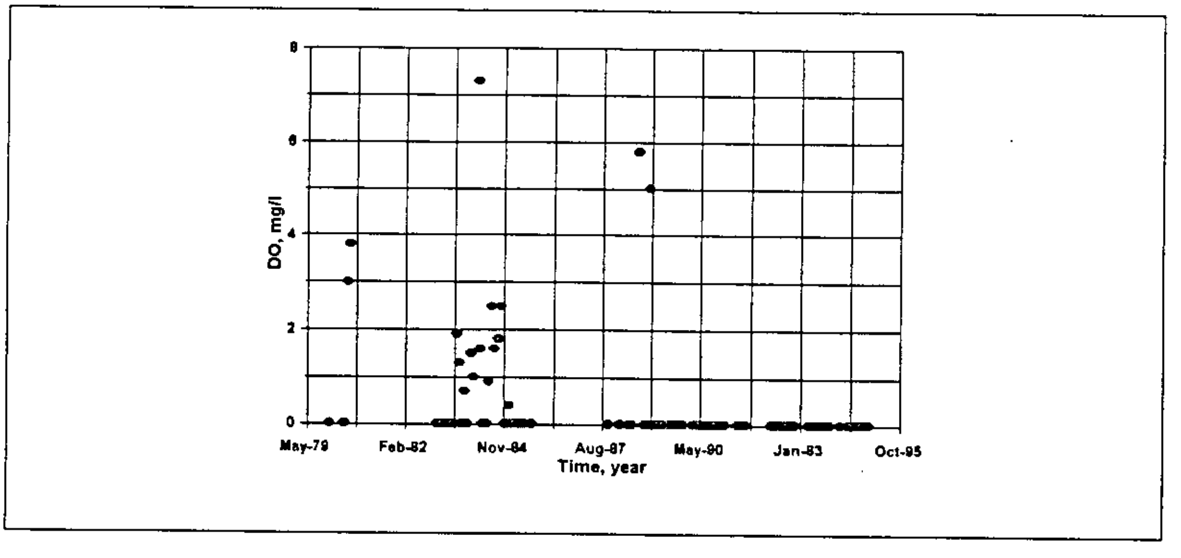


Figure B.11 Trend of pH, Chloride and T.Alkalinity in the Main drain of Hazarihagh (DoE)





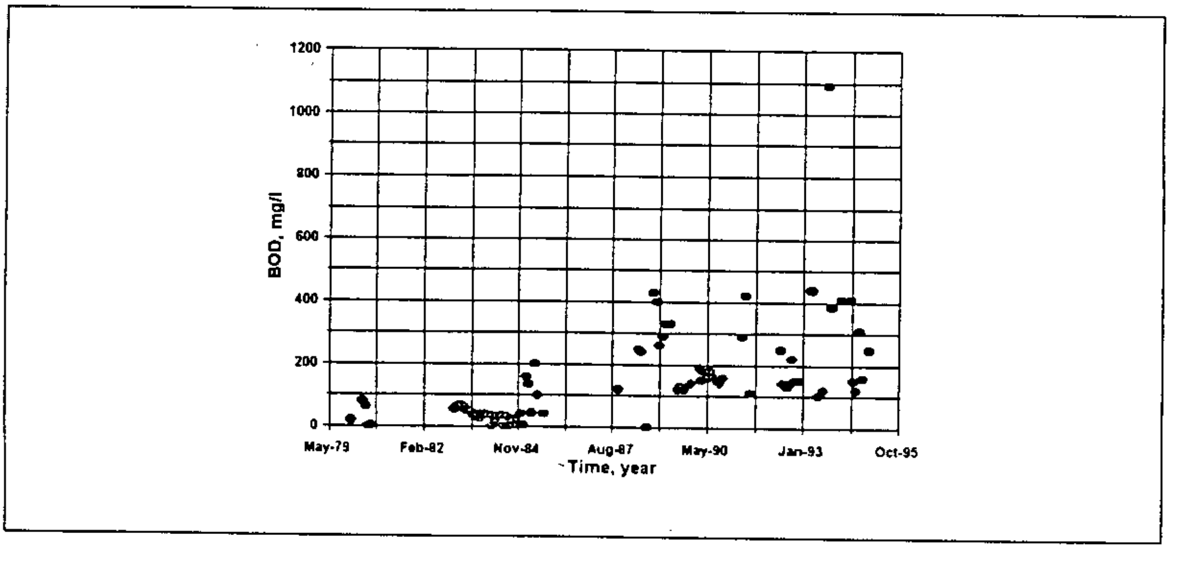
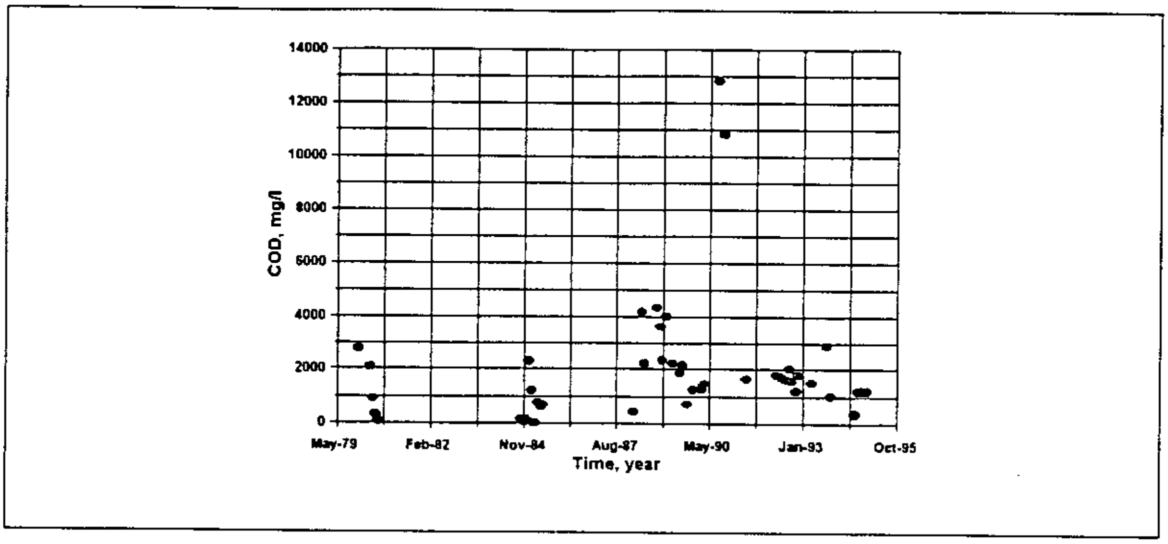
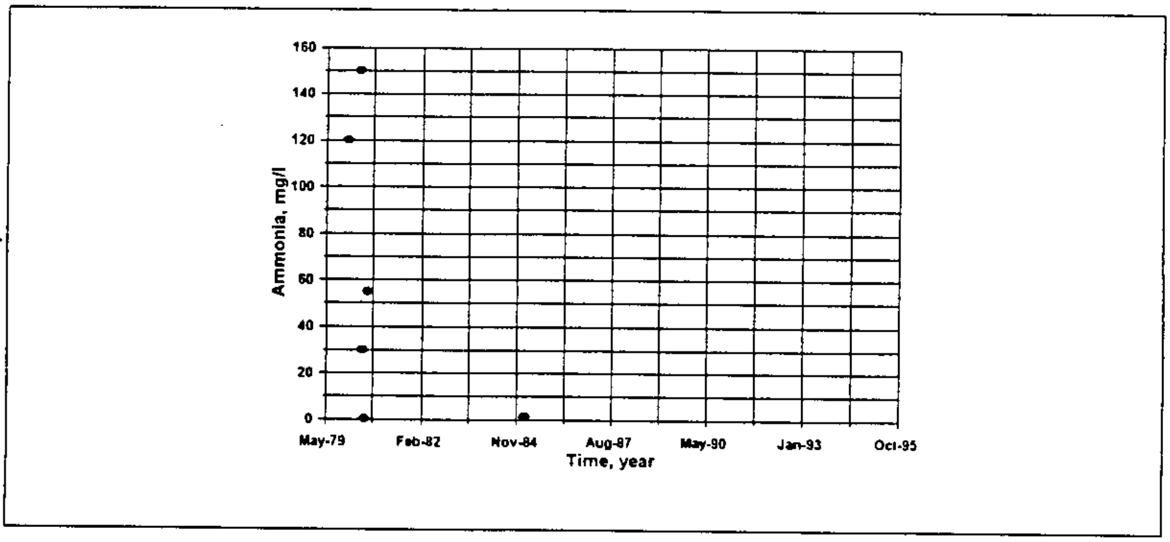


Figure B.12 Trend of TSS, DO and BOD in the Main drain of Hazaribagh (DoE)





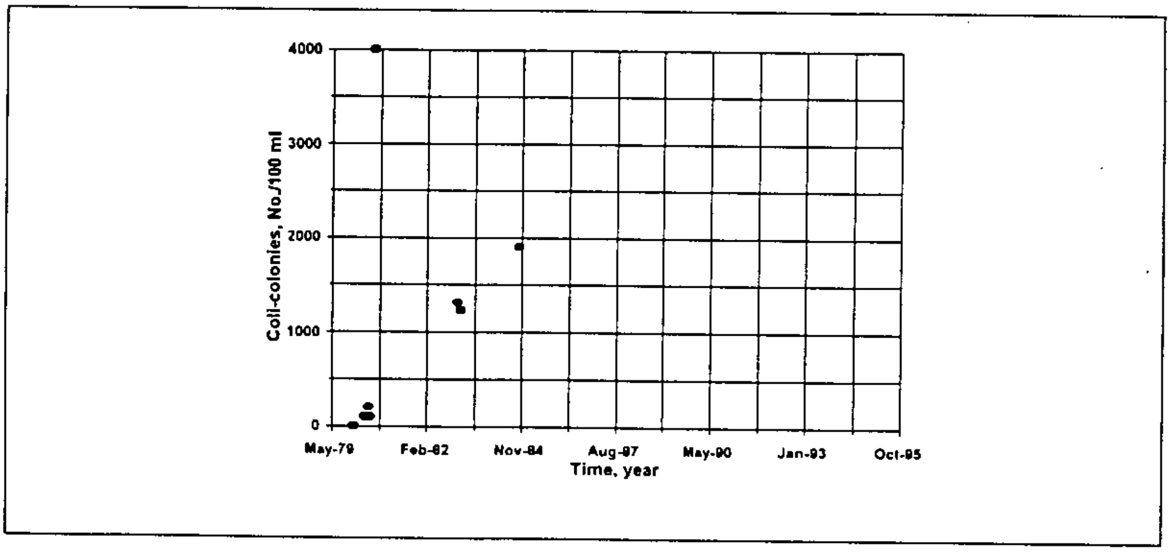


Figure B.13 Trend of COD, Ammonia and Coli-colonies in the Main drain of Hazarihagh (DoE)

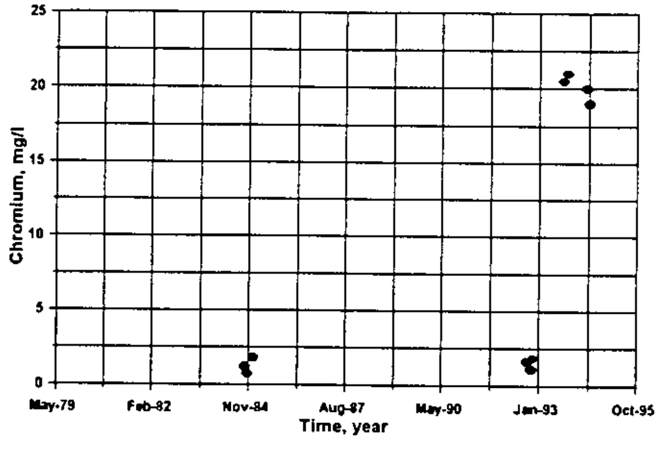
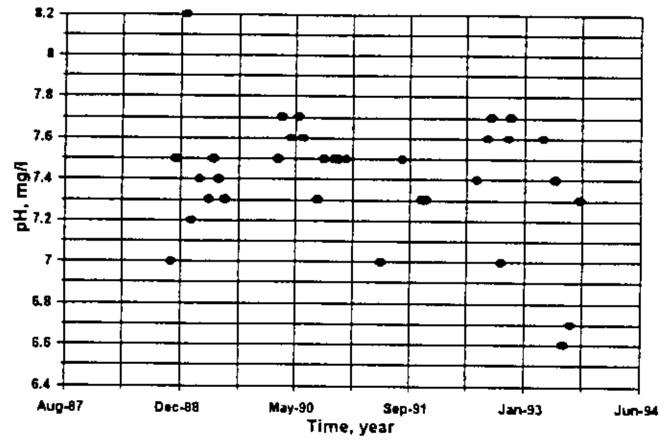
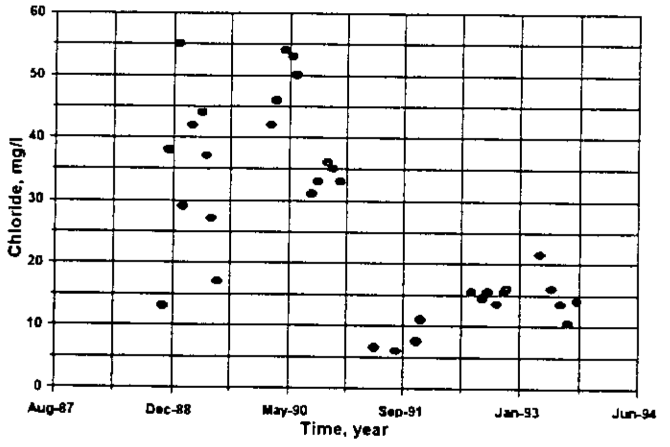


Figure B.14 Trend of Chromium in the Main drain of Hazaribagh (DoE)





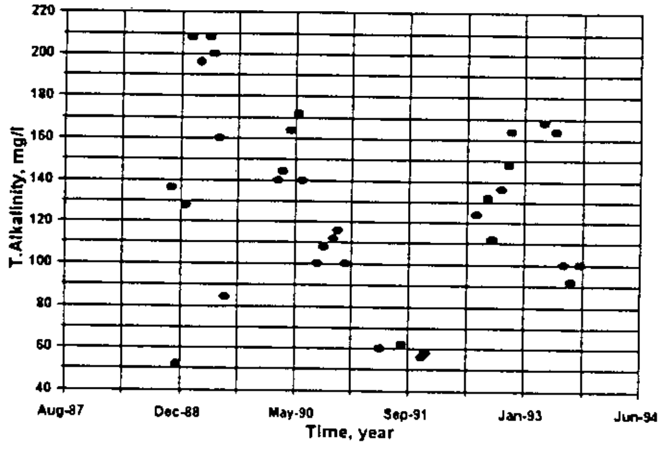
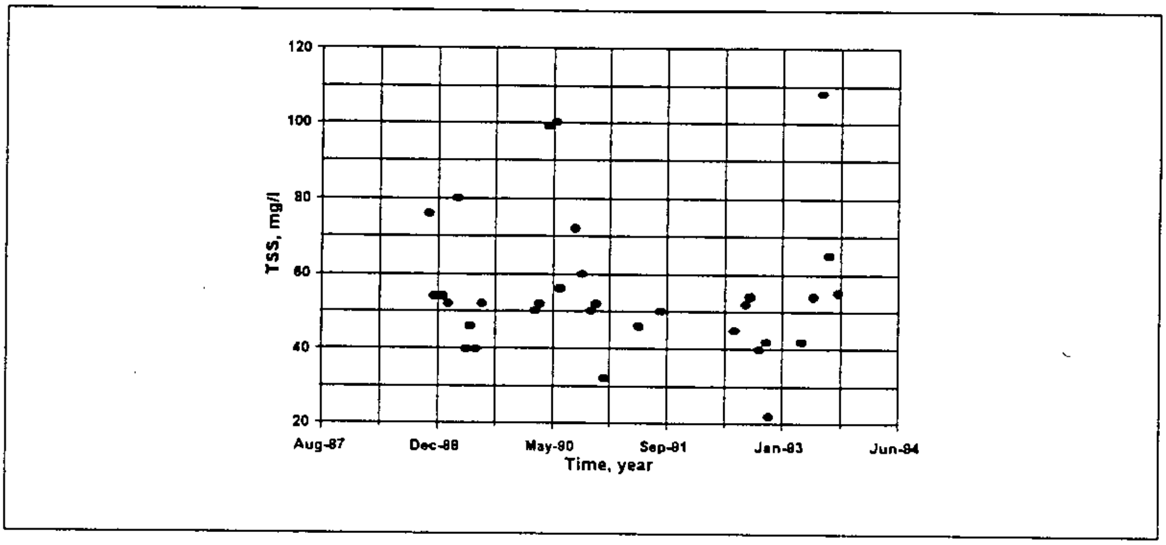
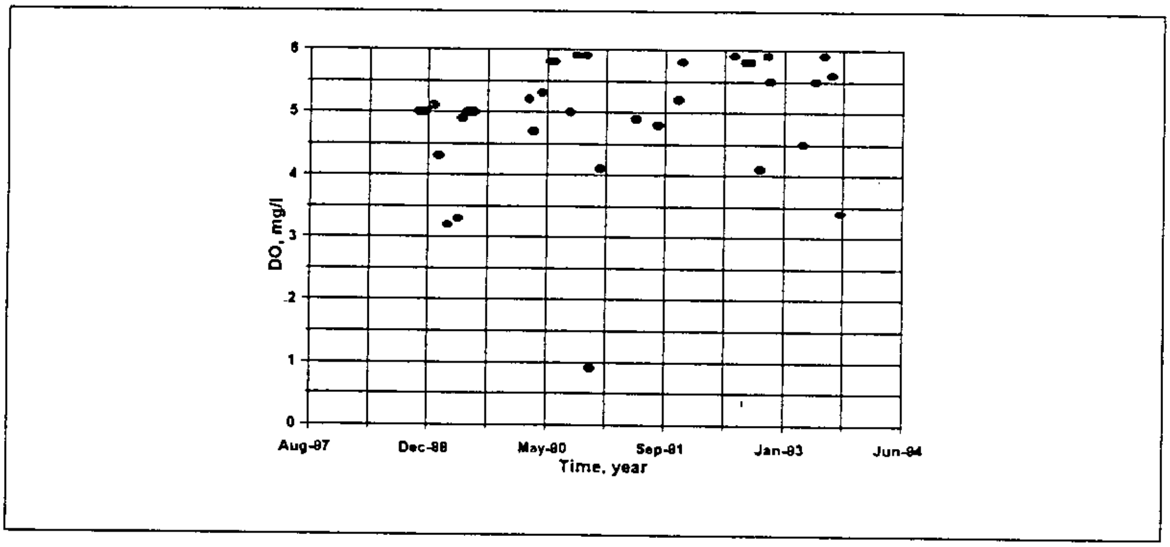


Figure B.15 **Trend of pH, Chloride and T.Alkalinity in the Main drain of PSTP (DoE)**





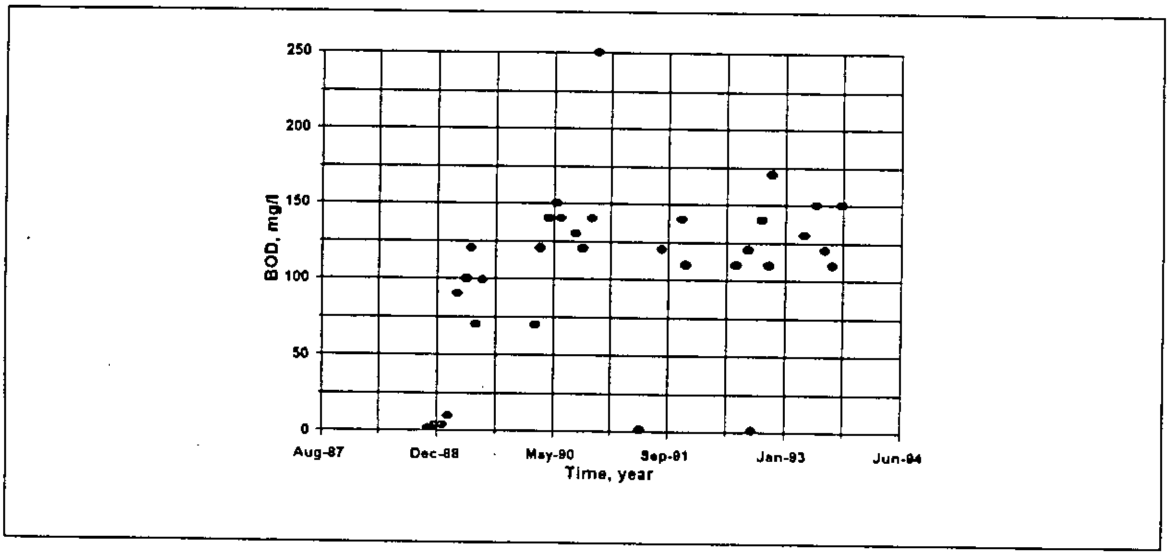
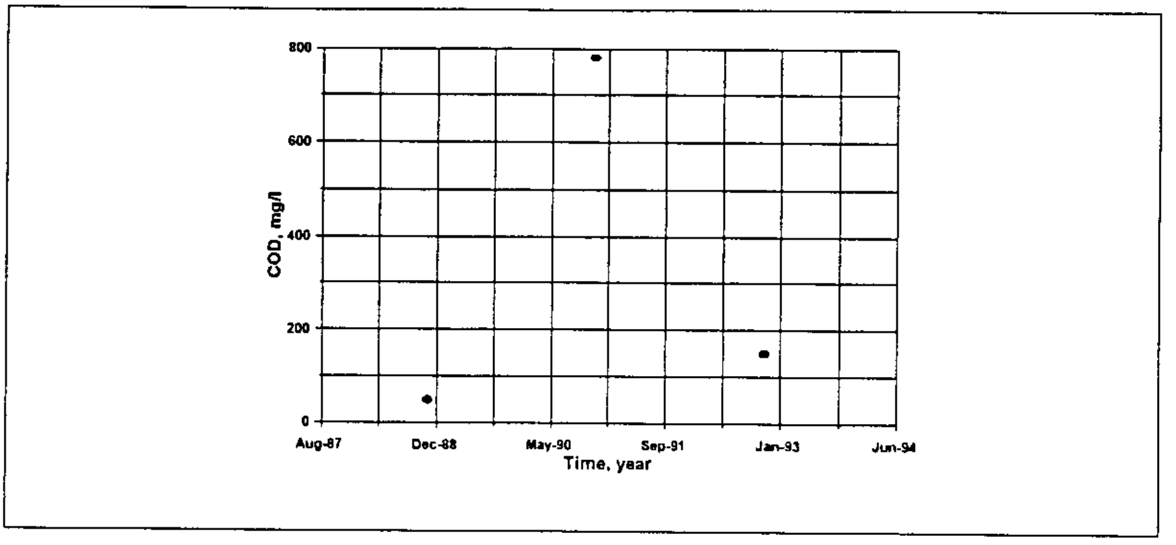


Figure B.16 Trend of TSS, DO and BOD in the Main drain of the PSTP (DoE)



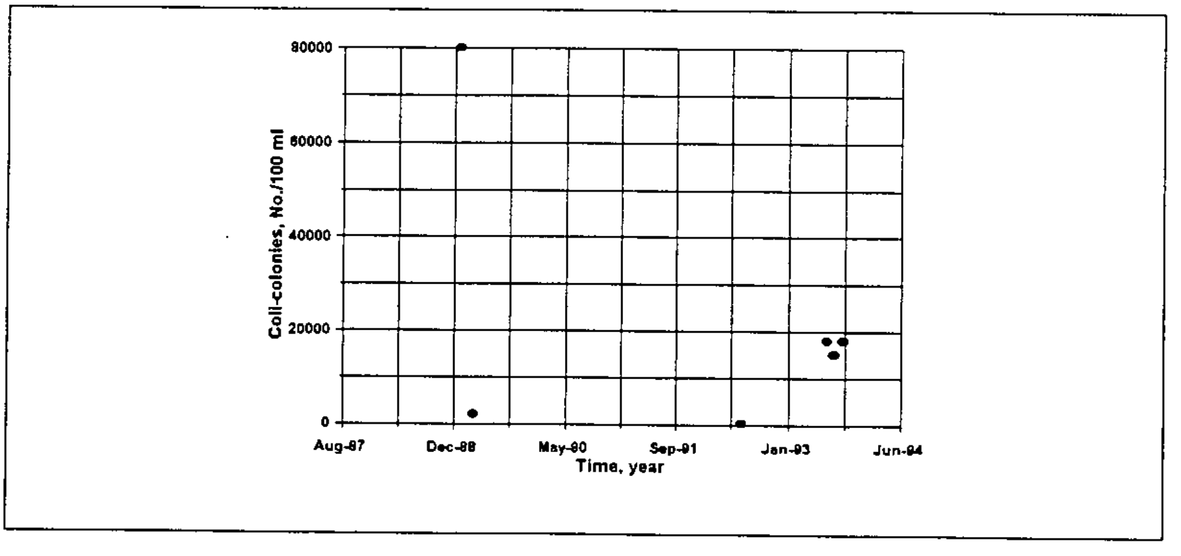


Figure B.17 Trend of COD and Coli-colonies in the Main drain of the PSTP (DoE)

APPENDIX C

DESCRIPTION OF CITY DRAINS OF DHAKA CITY

Table C.1 Description of the Outlets of the Local Drains That Fall Into the Turag-Buriganga

Source: Technoconsult - Personal Communication

Sl. No.	Name of Drain	Location	Type of Outlet			Size (mm) of Outlet	Remarks
			Pipe	Brick Drain	Natural Drain		
01	Postagola - Sashanghat Drain	Postagola area, Sashanghat to Buriganga. CH. 439m from Friendship Bridge.	Iron Pipe	-	-	370 mm dia	Carrying storm water & waste water.
02	Postagola - Sashanghat Drain	Bank Colony to Buriganga River CH. 505m.	R C C Pipe	-	-	750 mm dia	Carrying storm water & waste water.
03	Postagola - Sashanghat Drain	Postagola Bank Colony to Buriganga River CH. 563.45m.	R C C Pipe	-	-	750 mm dia	Carrying storm water & waste water.
04	Postagola-Dhaka Cotton Mill Drain	Postagola-Dhaka Cotton Mill to Buriganga River CH. 702m.	R C C Pipe	-	-	400 mm dia	Carrying storm water & waste water.
05	Postagola-Dhaka Cotton Mill Drain	Postagola-Dhaka Cotton Mill to Buriganga River CH. 794.65m.	-	Brick Drain	-	750 mm wide	Carrying storm water & waste water.
06	Faridabad (Archingate) Dhopa ghat Drain (Crossing N C Goswami Road).	Dhopaghat to Buriganga River CH. 1091.20m.	-	Brick Drain	-	320 mm wide	Carrying storm water & waste water.
07	Faridabad N C Goswami Road Drain.	Faridabad to Buriganga River (N C Goswami Rd Crossing) CH. 1245.60m.	-	Brick Drain	-	200 mm wide	Carrying storm water & waste water.
08	Faridabad N C Goswami Road Drain	Faridabad to Buriganga River CH. 1338.92 m.	-			620 mm dia	Carrying storm water & waste water.
09	Goshaibari Drain	Goshaibari Bazar to Buriganga River CH. 1497.70 m.	-	Brick Drain	-	220 mm wide	Carrying storm water & waste water.
10	Alamganj Khal	Faridabad Madrasha to Buriganga River via Alamganj Rd crossing CH. 1555.51 m.	-		Khal	1500 mm wide	Carrying storm water & waste water.

Sl. No.	Name of Drain	Location	Type of Outlet			Size (mm) of Outlet	Remarks
			Pipe	Brick Drain	Natural Drain		
11	Mill Barrak (C S D Godown) Drain	C S D to Buriganga River CH. 1829.00 m.	-	Brick Drain	-	470 mm wide	Carrying storm water & waste water.
12	Mill Barrak Drain	Mill Barrak mosque to Buriganga River CH. 2015.20 m.	-	Brick Drain	-	600 mm wide	Carrying storm water & waste water.
13	Mill Barrak Drain	Mill Barrak area to Dholai Khal	-	Brick Drain	-	400 mm wide	Carrying storm water & waste water.
14	Dholai Khal	Narinda to Buriganga River CH. 2187.00 m.	-		Khal	30000 mm wide	Carrying storm water & waste water.
15	Ultinganj Lane Drain	Farashganj (Ultinganj) to Buriganga River CH. 2318.38 m.	-	Brick Drain	-	200 mm wide	Carrying storm water & waste water.
16	Ultinganj Lane Drain	Farashganj (Ultinganj) to Buriganga River CH. 2465.12 m.	-	Brick Drain	-	270 mm wide	Carrying storm water & waste water.
17	Farashganj Drain	Farashganj to Buriganga River CH. 2631.58 m.	-	Brick Drain	-	240 mm wide	Carrying storm water & waste water.
18	Shambazar Drain	Shambazar to Buriganga River CH. 2691.00 m.	R C C Pipe	-	-	330 mm dia	Carrying storm water & waste water.
19	Shambazar Drain	Shambazar to Buriganga River CH. 2770.22 m.	-	Brick Sewer	-	900 mm dia	Carrying storm water & waste water.
20	Shambazar Drain	Shambazar to Buriganga River CH. 2795.47 m.	R C C Pipe	-	-	400 mm dia	Carrying storm water & waste water.
21	Shambazar Drain	Shambazar to Buriganga River CH. 2847.22 m.	R C C Pipe	-	-	300 mm dia	Carrying storm water & waste water.
22	Shambazar Drain	Shambazar to Buriganga River CH. 2869.92 m.	R C C Pipe	-	-	400 mm dia	Carrying storm water & waste water.
23	Shambazar Drain	Shambazar to Buriganga River CH. 2891.17 m.	-	Brick Drain	-	400 mm wide	Carrying storm water & waste water.

Sl. No.	Name of Drain	Location	Type of Outlet			Size (mm) of Outlet	Remarks
			Pipe	Brick Drain	Natural Drain		
24	Shambazar Drain	Shambazar to Buriganga River CH. 2940.27 m.	-	Brick Drain	-	750 mm wide	Carrying storm water & waste water.
25	Shambazar Lalkuthi Drain	Shambazar (Lalkuthi) to Buriganga CH. 2971.42 m.	-	Brick Drain	-	700 mm wide	Carrying storm water & waste water.
26	Lalkuthi Drain	Lalkuthi to Buriganga River CH. 2988.97 m.	R C C Pipe	-	-	400 mm dia	Carrying storm water & waste water.
27	Lalkuthi Drain	Lalkuthi to Buriganga River CH. 3104.60 m.	-	Brick Drain	-	750 mm wide	Carrying storm water & waste water.
28	Sadarghat Drain	Sadarghat to Buriganga River CH. 3328.01 m.	-	Brick Drain	-	500 mm wide	Carrying storm water & waste water.
29	Simpson Road (Sadarghat) Drain	Simpson Road to Buriganga River CH. 3374.16 m.	R C C Pipe	-	-	900 mm dia	Carrying storm water & waste water.
30	Simpson Road (Sadarghat) Drain	Simpson Road to Buriganga River CH. 3420.88 m.	R C C Pipe	-	-	230 mm dia	Carrying storm water & waste water.
31	Wiseghat Drain	Wiseghat to Buriganga River CH. 3500.08 m.	R C C Pipe	-	-	600 mm dia	Carrying storm water & waste water.
32	Wiseghat Drain	Wiseghat to Buriganga River CH. 3522.90 m.	R C C Pipe	-	-	230 mm dia	Carrying storm water & waste water.
33	Wiseghat Drain	Wiseghat to Buriganga River CH. 3589.55 m.	R C C Pipe	-	-	250 mm dia	Carrying storm water & waste water.
34	Wiseghat Nawabbari Drain	Ahasanulla Road to Buriganga River CH. 3600.65 m.	R C C Pipe	-	-	230 mm dia	Carrying storm water & waste water.
35	Ahasan Manjil Drain	Ahasan Manjil to Buriganga River CH. 3640.75 m.	R C C Pipe	-	-	230 mm dia	Carrying storm water & waste water.
36	Badamatali Ghat Drain	Badamtali to Buriganga River CH. 3790.88 m.	R C C Pipe	-	-	230 mm dia	Carrying storm water & waste water.

Sl. No.	Name of Drain	Location	Type of Outlet			Size (mm) of Outlet	Remarks
			Pipe	Brick Drain	Natural Drain		
37	Badamatali Ghat Drain	Badamtali to Buriganga River CH. 3836.18 m.	-	Brick Sewer	-	900 mm dia	Carrying storm water & waste water.
38	Badamatali Ghat Drain	Badamtali to Buriganga River CH. 3875.18 m.	-	Brick Sewer	-	600 mm dia	Carrying storm water & waste water.
39	Badamatali Ghat Drain	Badamtali to Buriganga River CH. 3943.68 m.	-	Brick Sewer	-	600 mm dia	Carrying storm water & waste water.
40	Babubazar Drain	Badamtali to Buriganga River CH. 4086.58 m.	-	Brick Sewer	-	1300 mm dia	Carrying storm water & waste water.
41	Babubazar Drain	Badamtali to Buriganga River CH. 4099.73 m.	-	Brick Drain	-	500 mm wide	Carrying storm water & waste water.

APPENDIX D

BREAK-UP OF DRY AND WET LOADING ESTIMATES

Table D.1 Estimate of Pollution Loads in Dry Method (Ref. JICA, 1991)

Unit Loading Values

Domestic			Percentage Increase for Industry			Use of Fertilizer			Atmospheric Fallout		
BOD(1)	35.62	g/c.d	BOD(1)			BOD(1)			BOD(1)		
BOD(2)	25	g/c.d	BOD(2)			BOD(2)			BOD(2)		
COD	79.45	g/c.d	COD	10	g/c.d	COD			COD		
Nitrogen	10.96	g/c.d	Nitrogen	5	g/c.d	Nitrogen	0.1644	g/km2.d	Nitrogen	0.0822	g/km2.d
Phosphorus	1.37	g/c.d	Phosphorus	5	g/c.d	Phosphorus	0.0137	g/km2.d	Phosphorus	0.0082	g/km2.d
Chromium	0.0137	g/c.d	Chromium			Chromium			Chromium	8.2E-05	g/km2.d
TSS(1)	54.79	g/c.d	TSS(1)			TSS(1)			TSS(1)		
TSS(2)	25	g/c.d	TSS(2)			TSS(2)			TSS(2)		

Total Estimated Loadings

Zone	Area (km2)	Agr. Area (km2)	Population	%Sewerd	%Unsewd	Drains to	BOD (kg/d)	COD (kg/d)	Nitrogen (kg/d)	Phosphoru (kg/d)	Chromium (kg/d)	TSS (kg/d)
DA(1)	33		2135000	19	81	Dholai K,	61599.45	151136.5	19901.36	2487.67	23.6921	94751.09
DA(2)	33		2135000	19	81	Buriganga	43233.75					43233.75
DB(1)	26.7		605500	0	100	Ibrahim K.	21567.91	52917.67	6968.096	871.012	8.295352	33175.35
DB(2)	26.7		605500	0	100	-Turag	15137.5					15137.5
TB(1)	5.1		98000	0	100	Haider K	3490.76	8564.71	1127.784	140.973	1.3426	5369.42
TB(2)	5.1		98000	0	100	-Tongi K	2450					2450
TA(1)	7.7		173750	0	100	Tongi K	6188.975	15184.88	1999.516	249.9394	2.380376	9519.763
TA(2)	7.7		173750	0	100	-Turag	4343.75					4343.75
SB(1)	30.5		298750	0	100	Turag	10641.48	26109.26	3438.018	429.7521	4.092878	16368.51
SB(2)	30.5		298750	0	100		7468.75					7468.75
KA(1)	4.5		94368	0	100	Buriganga,	3361.388	8247.291	1085.987	135.7484	1.292842	5170.423
KA(2)	4.5		94368	0	100	Dhaleswari	2359.2					2359.2
DC(1)	82		2761500	19	81	Balu	79675.35	195486.4	25741.27	3217.659	30.64437	122555.1
DC(2)	82		2761500	19	81		55920.38					55920.38
SC(1)	10.9		105750	0	100	Karnatali	3766.815	9242.021	1216.972	152.1215	1.448776	5794.043
SC(2)	10.9		105750	0	100		2643.75					2643.75
KB(1)	21.1		440382	0	100	Dhaleswari	15686.41	38487.18	5067.918	633.4897	6.033235	24128.53
KB(2)	21.1		440382	0	100		11009.55					11009.55

Table D.1 (Contd)

Notes: Areas depicted here are `built-up areas' as described in the above reference

From built-up areas given for 1991 and 2010, areas for 1995 have been calculated on a linear growth basis.

From the total areas, a fraction of loading should be assigned to Agricultural areas. At present, it has not been considered.

Population figures have been calculated from the given population for 1990 and 2010 on a linear growth basis.

BOD(1), TSS(1): unit loading values obtained from Henze.

BOD(2), TSS(2): unit loading values obtained from Browder (1992)

All other unit loading values are from Henze.

Table D.2 Estimate of Pollution Loads in Dry Method (Ref. Technoconsult, 1994)

Unit Loading Values

Domestic			Percentage Increase for Industry			Use of Fertilizer			Atmospheric Fallout		
BOD(1)	35.62	g/c.d	BOD(1)			BOD(1)			BOD(1)		
BOD(2)	25	g/c.d	BOD(2)			BOD(2)			BOD(2)		
COD	79.45	g/c.d	COD	10	g/c.d	COD			COD		
Nitrogen	10.96	g/c.d	Nitrogen	5	g/c.d	Nitrogen	0.1644	g/km2.d	Nitrogen	0.0822	g/km2.d
Phosphorus	1.37	g/c.d	Phosphorus	5	g/c.d	Phosphorus	0.0137	g/km2.d	Phosphorus	0.0082	g/km2.d
Chromium	0.0137	g/c.d	Chromium			Chromium			Chromium	8.2E-05	g/km2.d
TSS(1)	54.79	g/c.d	TSS(1)			TSS(1)			TSS(1)		
TSS(2)	25	g/c.d	TSS(2)			TSS(2)			TSS(2)		

Total Estimated Loadings

Zone	Area (km2)	Agr. Area (km2)	Population	%Sewerd	%Unsewd	Drains to	BOD (kg/d)	COD (kg/d)	Nitrogen (kg/d)	Phosphoru (kg/d)	Chromium (kg/d)	TSS (kg/d)
S-1(1) + S-1(2)	2.38 2.38		80074 80074	0 0	100 100	Tongi K	2852.236 2001.85	6998.067	921.4918	115.1865	1.09714	4387.254 2001.85
S-1(1) + S-2(2)	16.58 16.58		557824 557824	0 0	100 100	Tongi K	19869.69 13945.6	48751.03	6419.44	802.43	7.64219	30563.18 13945.6
S-3(1) • S-3(2)	5.7 5.7		219455 219455	0 0	100 100	Turag	7816.987 5486.375	19179.27	2525.489	315.6861	3.006534	12023.94 5486.375
S-4(1) • S-4(2)	30.19 30.19		1162342 1162342	0 0	100 100	Turag	41402.62 29058.55	101582.9	13376.23	1672.029	15.92409	63684.72 29058.55
S-5(1) $ S-5(2)	5.96 5.96		214353 214353	0 0	100 100	Turag	7635.254 5358.825	18733.38	2466.775	308.3468	2.936637	11744.4 5358.825
S-7(1) # S-7(2)	1.64 1.64		232880 232880	40 40	60 60	Turag	4977.111 3493.2	12211.53	1607.99	200.9987	1.914274	7655.697 3493.2
S-8(1) # S-8(2)	2.6 2.6		369200 369200	80 80	20 20	Turag	2630.181 1846	6453.247	849.7509	106.2189	1.011608	4045.694 1846
S-9(1) # S-9(2)	0.52 0.52		73840 73840	88 88	12 12	Turag	315.6217 221.52	774.3896	101.9701	12.74627	0.121393	485.4832 221.52
S-10(1) # S-10(2)	0.96 0.96		136320 136320	60 60	40 40	Turag	1942.287 1363.2	4765.475	627.5083	78.43854	0.747034	2987.589 1363.2
S-11(1) # S-11(2)	1.68 1.68		238560 238560	57 57	43 43	Buriganga	3653.928 2564.52	8965.049	1180.5	147.5625	1.405357	5620.402 2564.52

Zone	Area (km2)	Agr. Area (km2)	Population	%Sewerd	%Unsewd	Drains to	BOD (kg/d)	COD (kg/d)	Nitrogen (kg/d)	Phosphoru (kg/d)	Chromium (kg/d)	TSS (kg/d)
City # Drains	3.6 3.6		511200 511200	58 58	42 42	Buriganga	7647.756 5367.6	18764.06	2470.814	308.8517	2.941445	11763.63 5367.6

Table D.2 (Contd)

Notes: + Population has been estimated taking into account of an average density of population/km2 as obtained from Zone I, as given in the NEMPCP Final Report (Browder, 1992)

* Population has been estimated taking into account of an average density of population/km2 as obtained from Zone J , as given in the NEMPCP Final Report (Browder, 1992)

$ Population has been estimated taking into account of an average density of population/km2 as obtained from Zone H , as given in the NEMPCP Final Report (Browder, 1992)

Population has been estimated taking into account of an average density of population/km2 as obtained from Zones A and B, as given in the NEMPCP Final Report (Browder, 1992)

No sub-catchment area was defined for the City Drains zone in the above reference. It has been worked out consulting Sewerage Network Map obtained from P & D Sewer Division (DWASA)

Percentage of sewered and unsewered area has been demarcated from the same map. The map is not fully clear. Therefore, percentage of sewered and unsewered population may need to be revised.

From the total areas, a fraction of loading should be assigned to Agricultural area, especially from S-1 to S-5. At present, it has not been considered.

BOD(1), TSS(1): unit loading values obtained from Henze.

BOD(2), TSS(2): unit loading values obtained from Browder (1992)

All other unit loading values are from Henze.

Table D.3 Estimate of Pollution Loads in Dry Method (Ref. JICA, 1989)

Unit Loading Values

Domestic			Percentage increase for industry			Use of Fertilizer			Atmospheric Fallout		
BOD(1)	35.62	g/c.d	BOD(1)			BOD(1)			BOD(1)		
BOD(2)	25	g/c.d	BOD(2)			BOD(2)			BOD(2)		
COD	79.45	g/c.d	COD	10	g/c.d	COD			COD		
Nitrogen	10.96	g/c.d	Nitrogen	5	g/c.d	Nitrogen	0.1644	g/km2.d	Nitrogen	0.0822	g/km2.d
Phosphorus	1.37	g/c.d	Phosphorus	5	g/c.d	Phosphorus	0.0137	g/km2.d	Phosphorus	0.0082	g/km2.d
Chromium	0.0137	g/c.d	Chromium			Chromium			Chromium	8.2E-05	g/km2.d
TSS(1)	54.79	g/c.d	TSS(1)			TSS(1)			TSS(1)		
TSS(2)	25	g/c.d	TSS(2)			TSS(2)			TSS(2)		

Total Estimated Loadings

Zone	Area (km2)	Agr. Area (km2)	Population	%Sewerd	%Unsewd	Drains to	BOD (kg/d)	COD (kg/d)	Nitrogen (kg/d)	Phosphoru (kg/d)	Chromium (kg/d)	TSS (kg/d)
A(1)	7.25		704937	28	72	Buriganga	18079.1	44357.74	5840.939	730.1174	6.953499	27808.92
A(2)	7.25		704937	28	72		12688.87					12688.87
B(1)	7.24		1344008	27	73	Buriganga	34947.7	85745.49	11290.8	1411.35	13.44142	53755.88
B(2)	7.24		1344008	27	73		24528.15					24528.15
C(1)	10.92		1101924	19	81	Buriganga	31792.93	78005.14	10271.56	1283.945	12.22805	48903.28
C(2)	10.92		1101924	19	81		22313.96					22313.96
D(1)	7.46		438374	26	74	Balu	11555.01	28350.65	3733.159	466.6448	4.444236	17773.7
D(2)	7.46		438374	26	74		8109.919					8109.919
E(1)	13.93		123787	0	100	Balu	4409.293	10818.36	1424.542	178.0677	1.695883	6782.29
E(2)	13.93		123787	0	100		3094.675					3094.675
F(1)	13.7		1140364	22	78	Balu	31683.42	77736.45	10236.18	1279.523	12.18593	48734.82
F(2)	13.7		1140364	22	78		22237.1					22237.1
G(1)	17.64		406116	30	70	Balu	10126.1	24844.76	3271.509	408.9387	3.894654	15575.77
G(2)	17.64		406116	30	70		7107.03					7107.03
H(1)	17.6		632988	22	78	Turag	17586.69	43149.59	5681.854	710.2317	6.764111	27051.5
H(2)	17.6		632988	22	78		12343.27					12343.27
I(1)	31.42		1057106	13	87	Turag	32759.08	80375.63	10583.71	1322.963	12.59965	50389.39
I(2)	31.42		1057106	13	87		22992.06					22992.06
J(1)	7.69		296072	4	96	Turag	10124.24	24840.2	3270.909	408.8637	3.89394	15572.91
J(2)	7.69		296072	4	96		7105.728					7105.728

Table D.3 (Contd)

Notes: Population given in the above reference has been increased by a linear growth rate of 34%.

Population may need to be increased by growth rate up to 38% (JICA, 1991).

A(1) means zone a for which, unit loading figures have been used as given by BOD(1), TSS(1) etc.

BOD(1), TSS(1): unit loading values obtained from Henze,

BOD(2), TSS(2): unit loading values obtained from Browder (1992).

All other unit loading values are from Henze.

Table D.4 Estimate of Pollution Loads in Wet Method (SWMC, 1996)

Raw Data

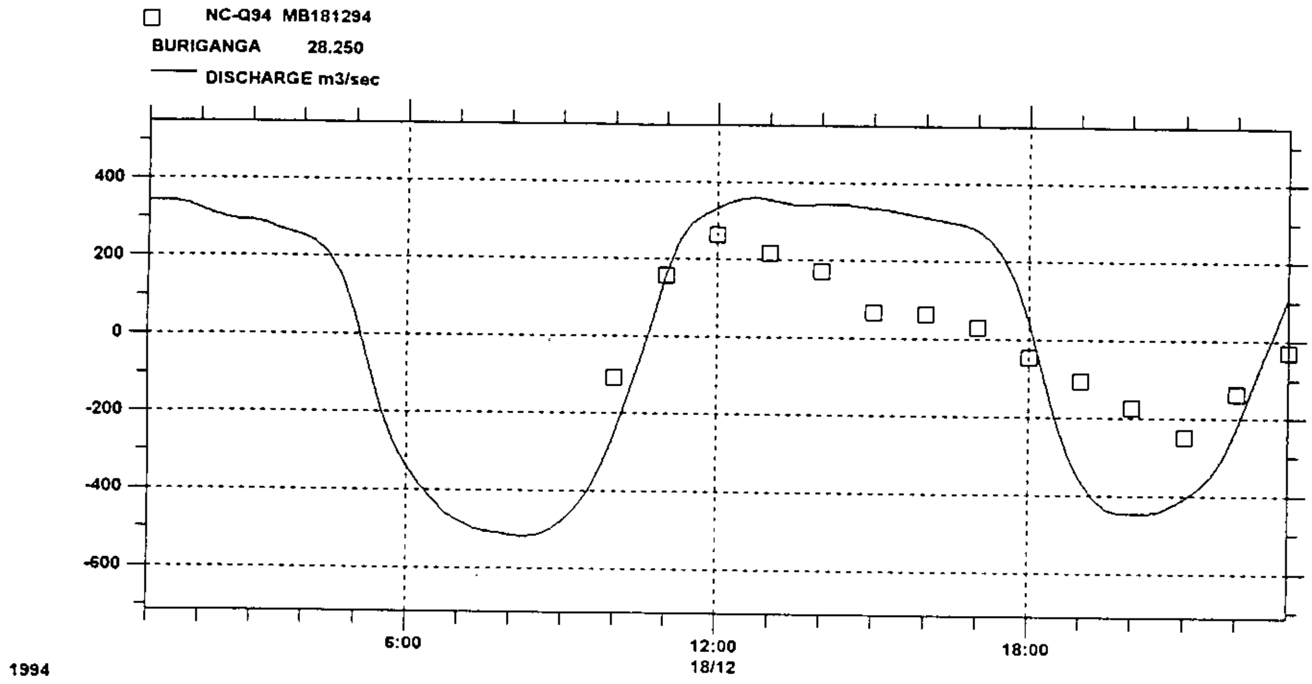
Location	Date	BOD (mg/l)	COD (mg/l)	$NH3-N_2$ (mg/l)	$NH4-N_2$ (mg/l)	NO_3-N_2 (mg/l)	Ortho-PO4 - P (mg/l)	Cr (mg/l)	TSS (mg/l)	Flow (m3/s)	Drains to
S-7	08.02.95	310	416	10.71	80.3	0	3.16	0.827	110	1.1	Turag
	26.04.95	140	200	0.73	0.77	1.98	1.08	0.18	55	0.9	
S-8	08.02.95	136	192	8.1	60.8	0	7.92	0.062	60	0.05	Turag
	26.04.95	10	30	79.04	83.72	2.34	6.4	0	160	0.225	
S-9	08.02.95	260	323	4.8	36	0	7.12	0.145	300	0.2	Turag
	26.04.95	90	70	10.94	11.96	0.99	3.1	0	80	0.214	
S-10	12.02.95	130	256	5.73	43	0	7.92	0.067	195	0.11	Turag
	26.04.95	120	220	15.2	16.1	1.26	3.21	0	184	0.11	
Dholai Khal	13.02.95	220	374	6.8	51	0	9.52	0.067	270	1.3	Buriganga
	16.04.95	50	272	21.88	23.18	0	7.65	0	350	0.66	
Kashipur Khal	11.02.95	20	105	1.29	9.7	0	2.64	0.008	80	0.21	Dhaleswari
	15.04.95	30	78	1.14	1.21	0	6.01	0	35	2.7	
PSTP Outfall	-	-	-	-	-	-	-	-	-	-	Buriganga
	18.04.95	20	120	0.6	0.64	0	4.08	0	34	0.58542	

Table D.4 (Contd.)

Computed Loadings

Location	Date	BOD (kg/d)	COD (kg/d)	NH_3-N_2 (kg/d)	NH_4-N_2 (kg/d)	NO_3-N_2 (kg/d)	Ortho-PO_4-P (kg/d)	Cr (kg/d)	TSS (kg/d)	Flow (m3/s)	Drains to
S-7	08.02.95	29462.4	39536.64	1017.878	7631.712	0	300.33	78.60	10454.4	1.1	Turag
	26.04.95	10886.4	15552	56.7648	59.8752	153.9648	83.98	14.00	4276.8	0.9	
S-8	08.02.95	587.52	829.44	34.992	262.656	0	34.21	0.27	259.2	0.05	Turag
	26.04.95	194.4	583.2	1536.538	1627.517	45.4896	124.42	0	3110.4	0.23	
S-9	08.02.95	4492.8	5581.44	82.944	622.08	0	123.03	2.51	5184	0.2	Turag
	26.04.95	1664.064	1294.272	202.2762	221.1356	18.3047	57.32	0	1479.16 8	0.21	
S-10	12.02.95	1235.52	2433.024	54.45792	408.672	0	75.27	0.64	1853.28	0.11	Turag
	26.04.95	1140.48	2090.88	144.4608	153.0144	11.97504	30.51	0	1748.74	0.11	
Dholai Khal	13.02.95	24710.4	42007.68	763.776	5728.32	0	1069.29	7.53	30326.4	1.3	Buriganga
	16.04.95	2851.2	15510.53	1247.685	1321.816	0	436.23	0	19958.4	0.66	
Kashipur Khal	11.02.95	362.88	1905.12	23.40576	175.9968	0	47.90	0.15	1451.52	0.21	Dhaleswari
	15.04.95	6998.4	18195.84	265.9392	282.2688	0	1402.01	0	8164.8	2.7	
PSTP Outfall	-	-	-	-	-	-	-	-	-	-	Buriganga
	18.04.95	1011.61	6069.64	30.35	32.37		206.37	0	1719.73	0.595	

APPENDIX E
PLOTS OF HYDRODYNAMIC MODEL CALIBRATION



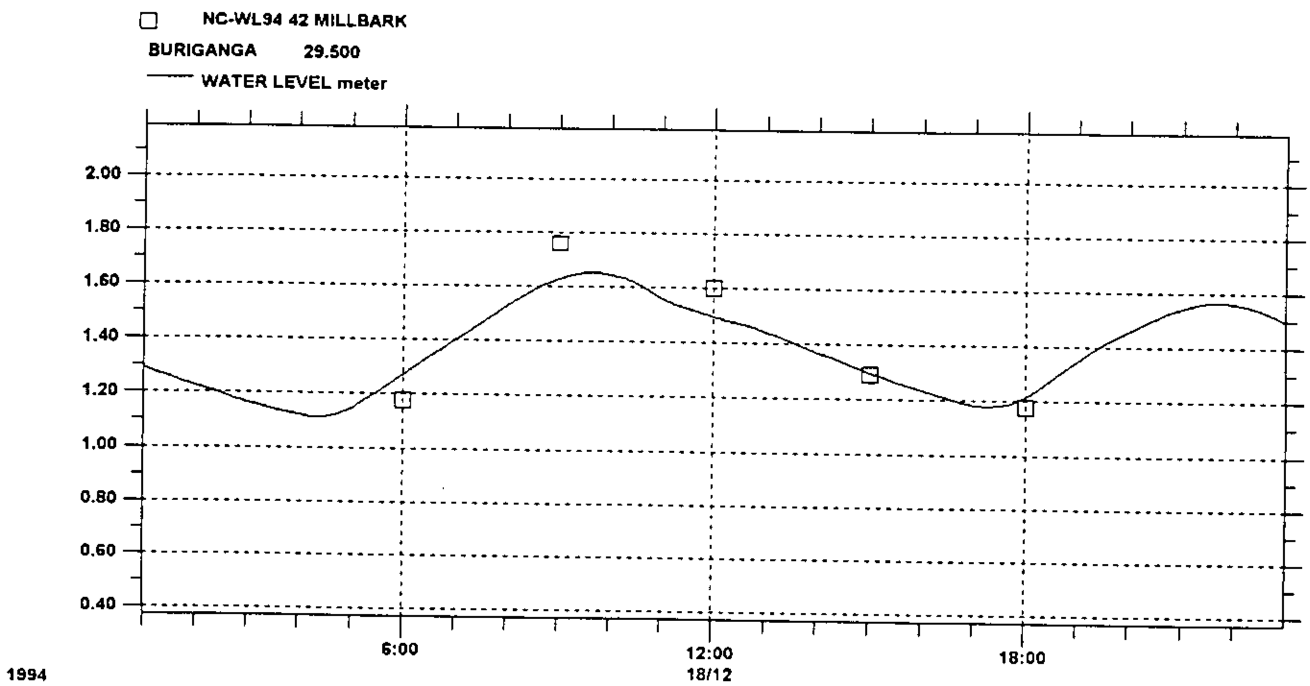
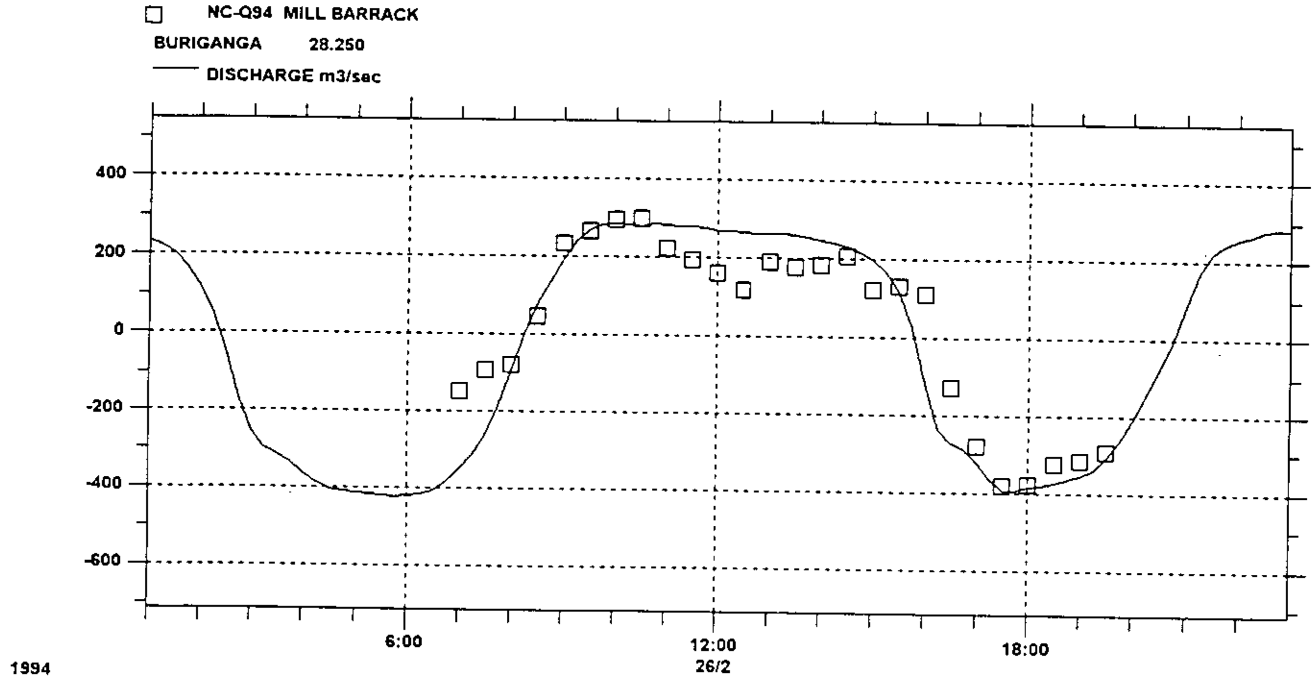


Figure E.1	Comparison of Observed and Simulated Water level & Discharge Calibration of the Hydrodynamic Model River name, Location name and Chainages are shown on Plot

DATA FILE : HDTST.RDF
RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

MIKE 11



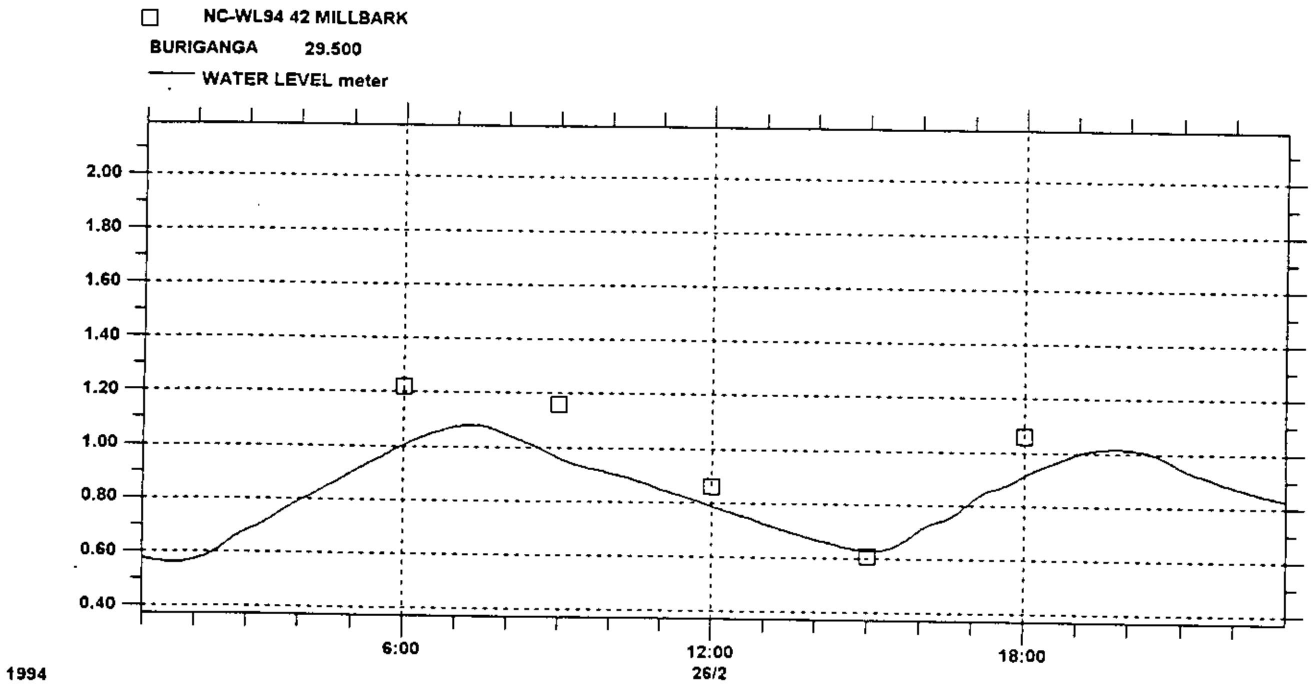


Figure E.2	Comparison of Observed and Simulated Water level & Discharge Calibration of the Hydrodynamic Model River name, Location name and Chainages are shown on Plot

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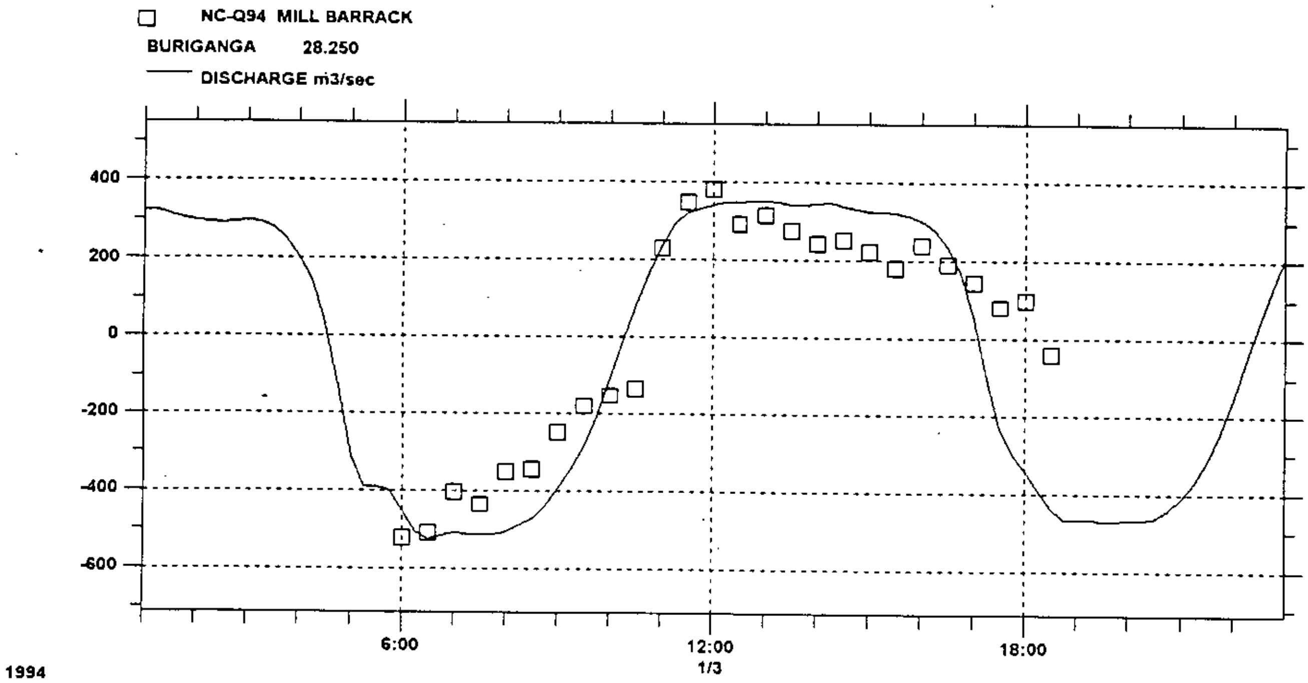
RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

MIKE 11



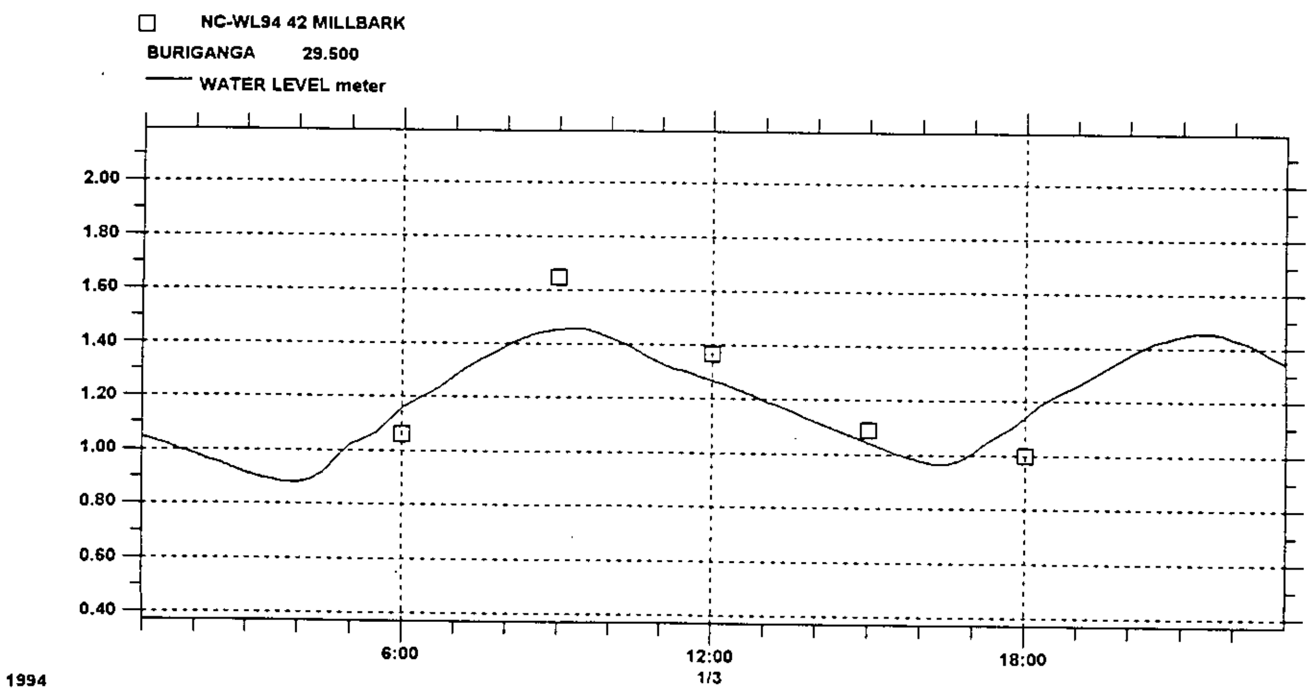


Figure E.3	Comparison of Observed and Simulated Water level & Discharge Calibration of the Hydrodynamic Model River name, Location name and Chainages are shown on Plot

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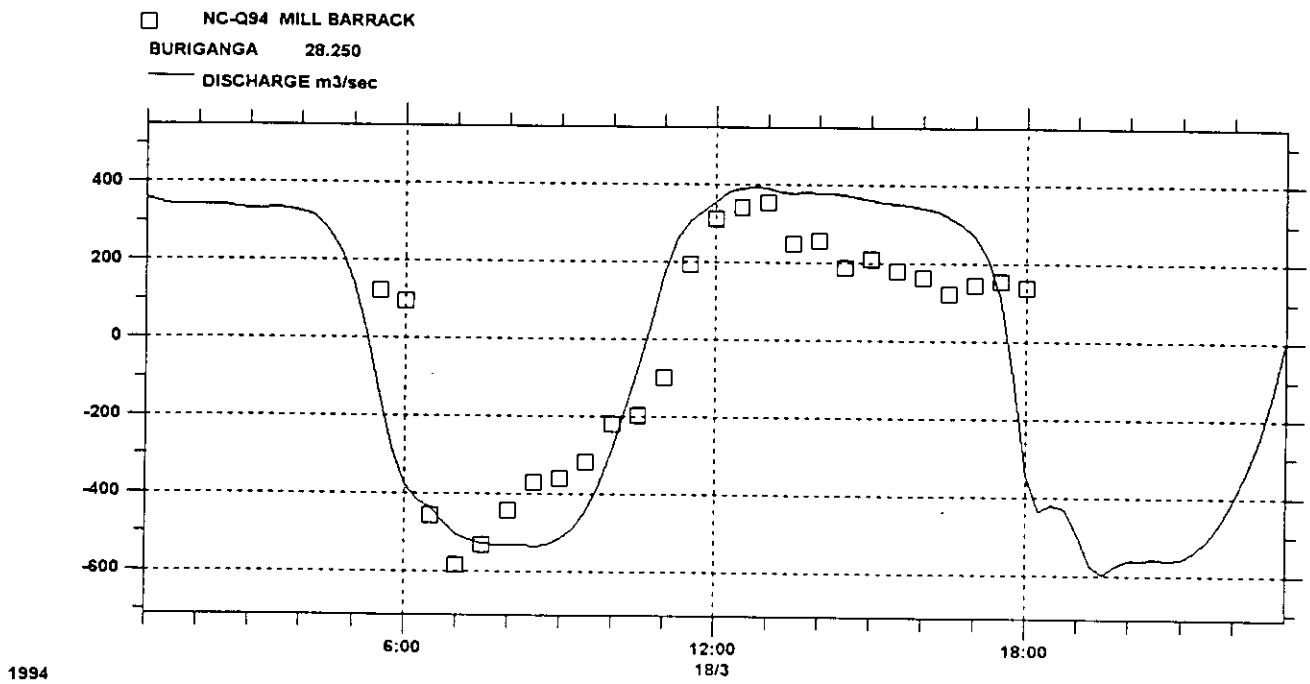

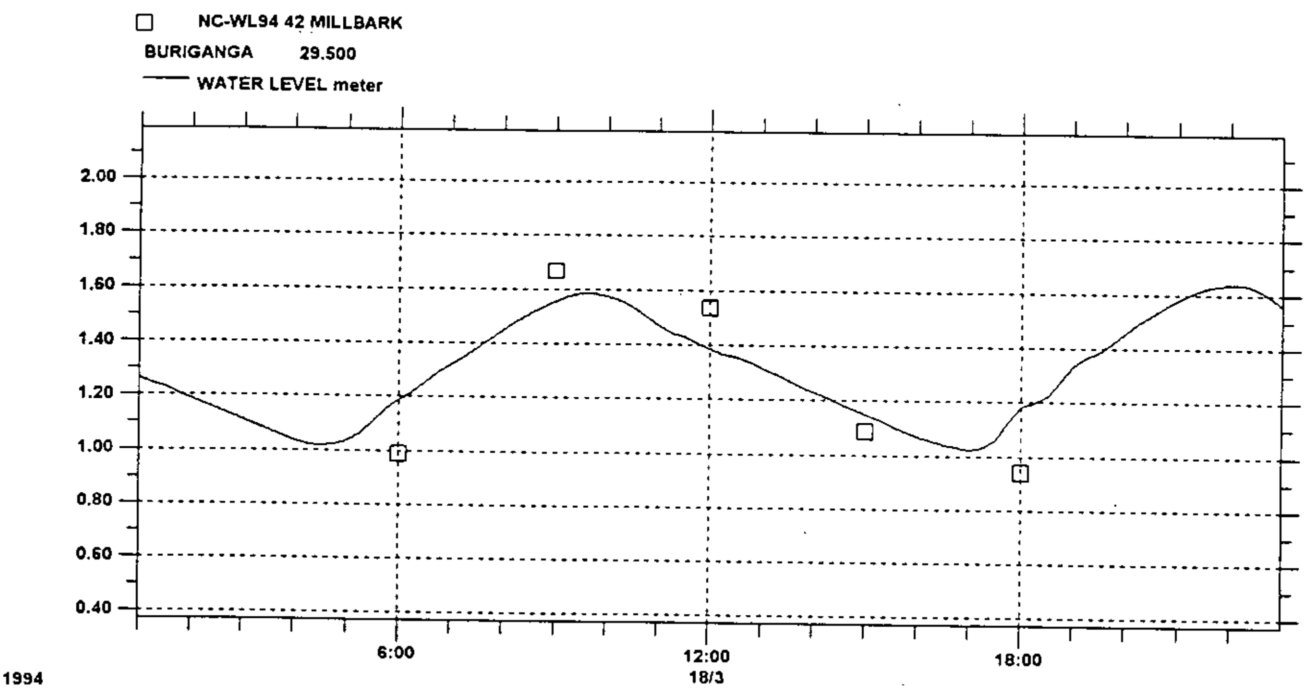

Figure E.4

Comparison of Observed and Simulated Water level & Discharge
Calibration of the Hydrodynamic Model
River name, Location name and Chainages are shown on Plot

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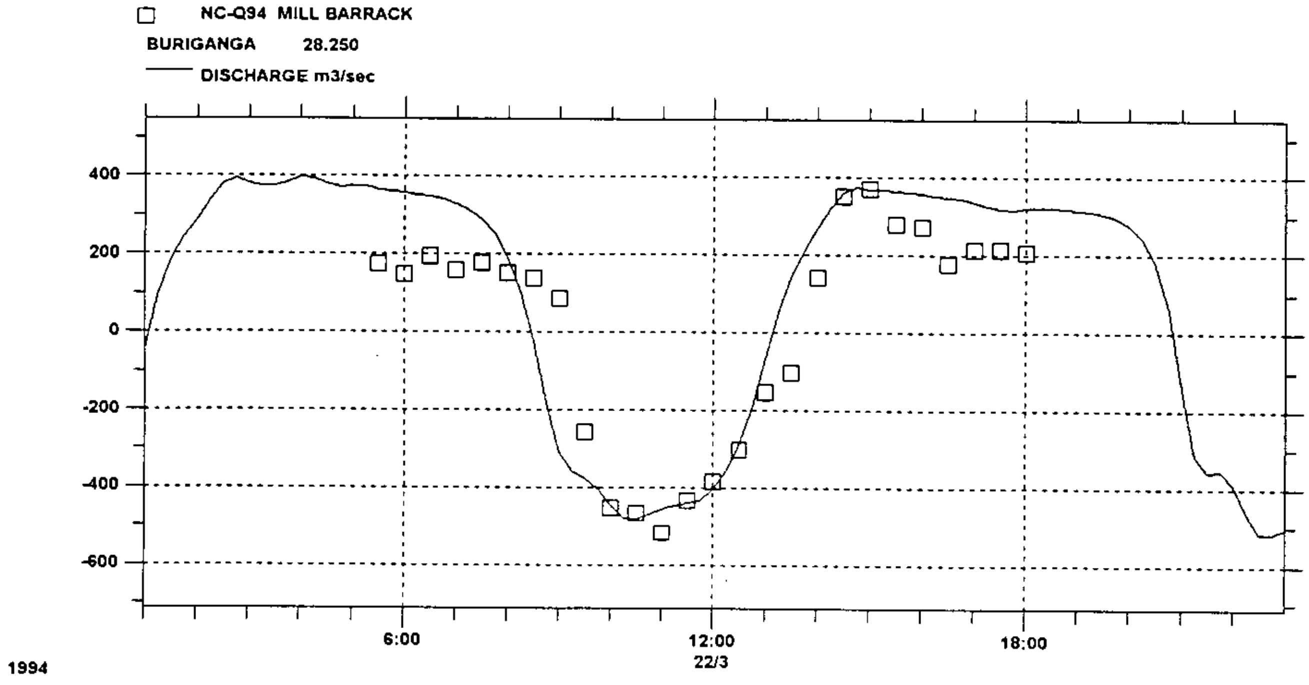
RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

MIKE 11



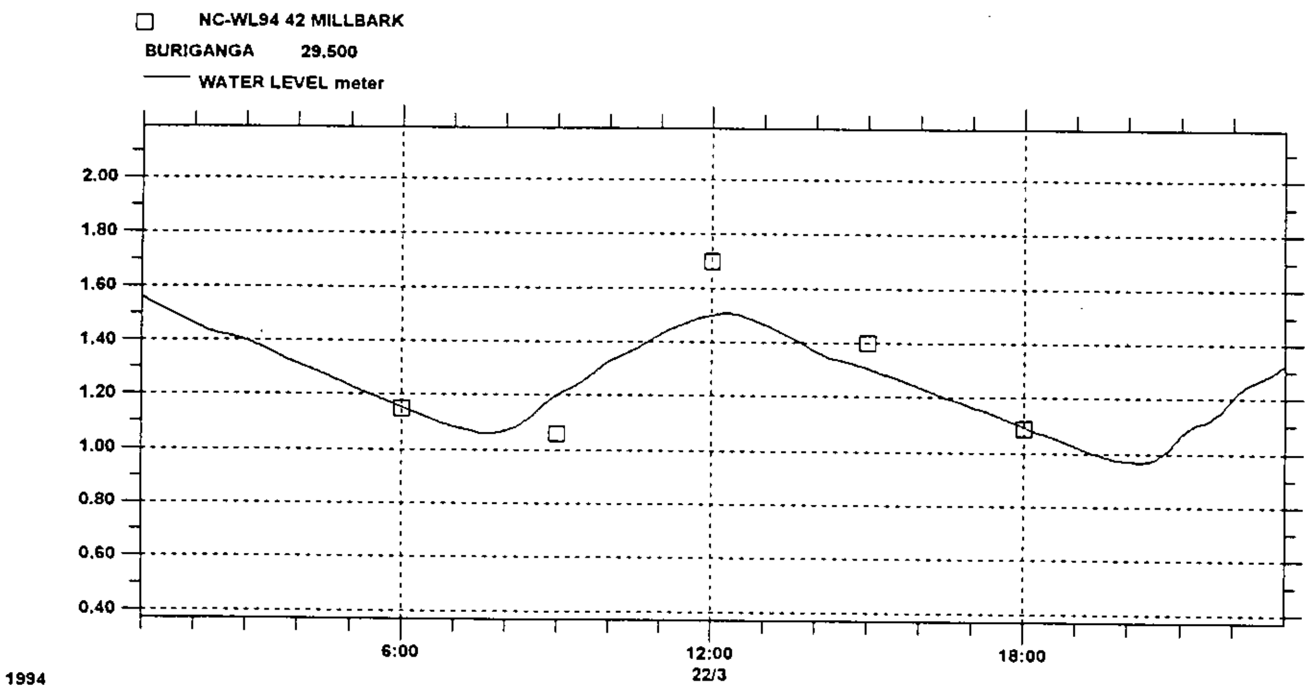


Figure E.5	Comparison of Observed and Simulated Water level & Discharge Calibration of the Hydrodynamic Model River name, Location name and Chainages are shown on Plot

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RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

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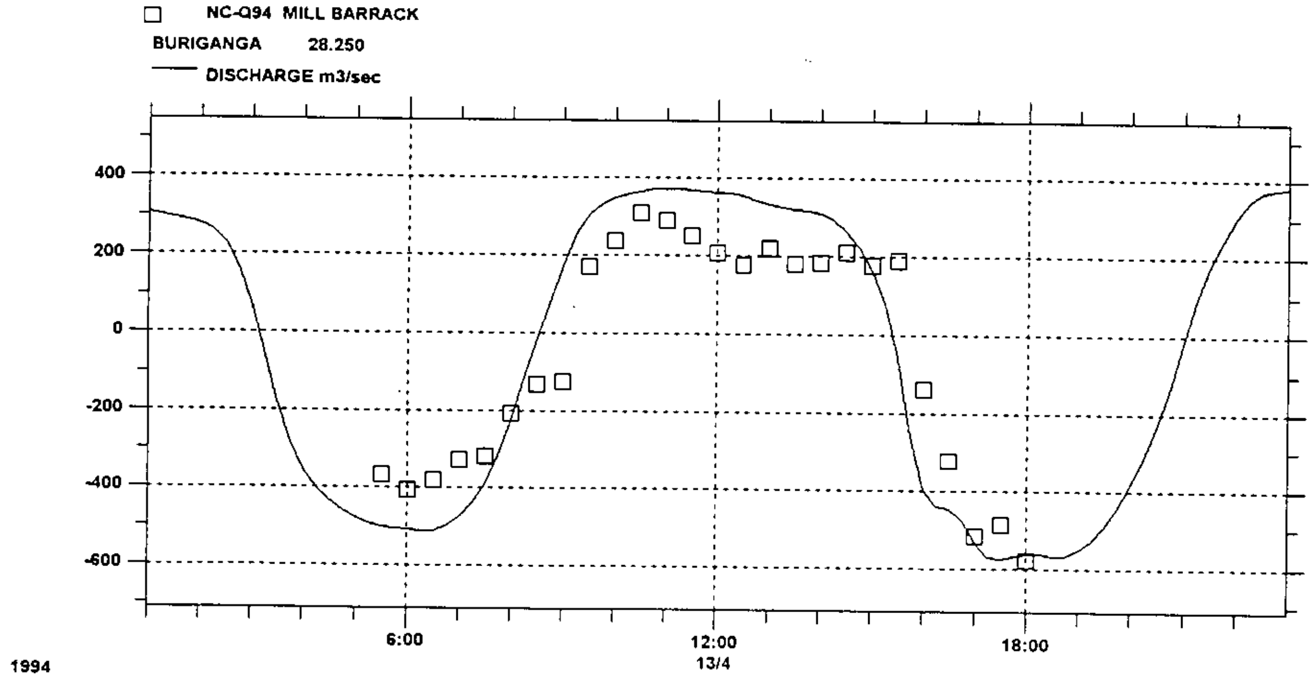

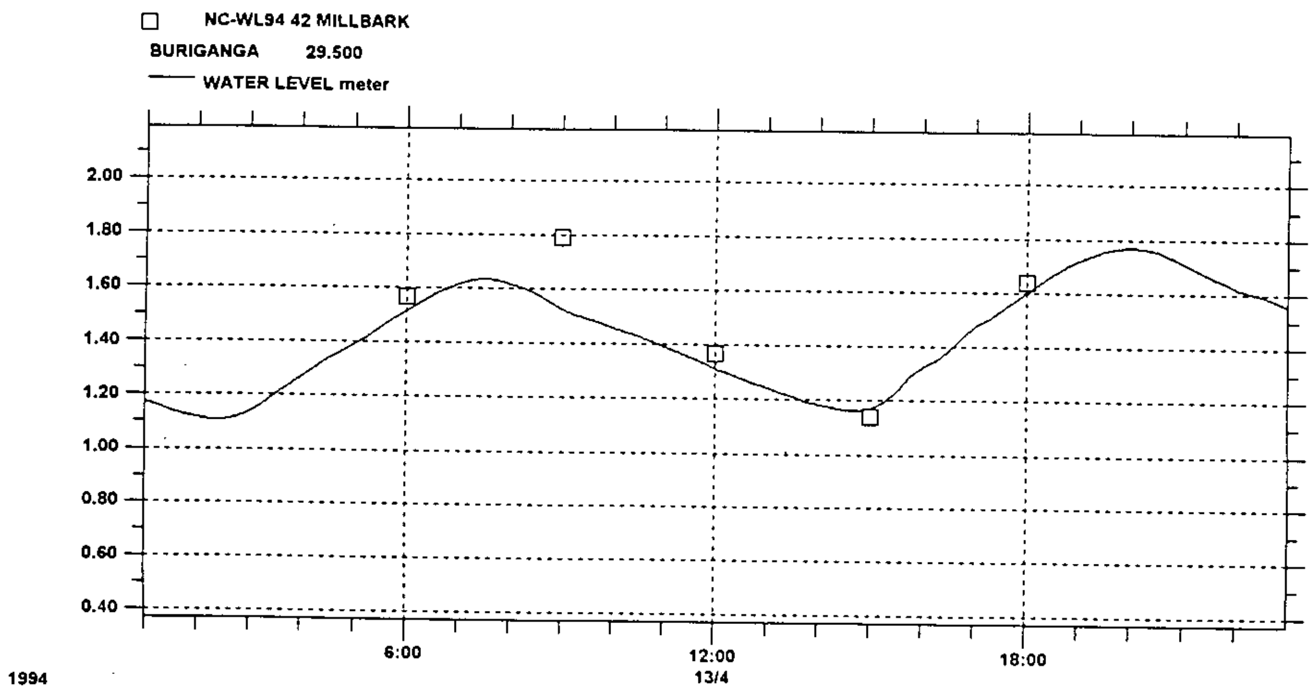

Figure E.6	Comparison of Observed and Simulated Water level & Discharge Calibration of the Hydrodynamic Model River name, Location name and Chainages are shown on Plot

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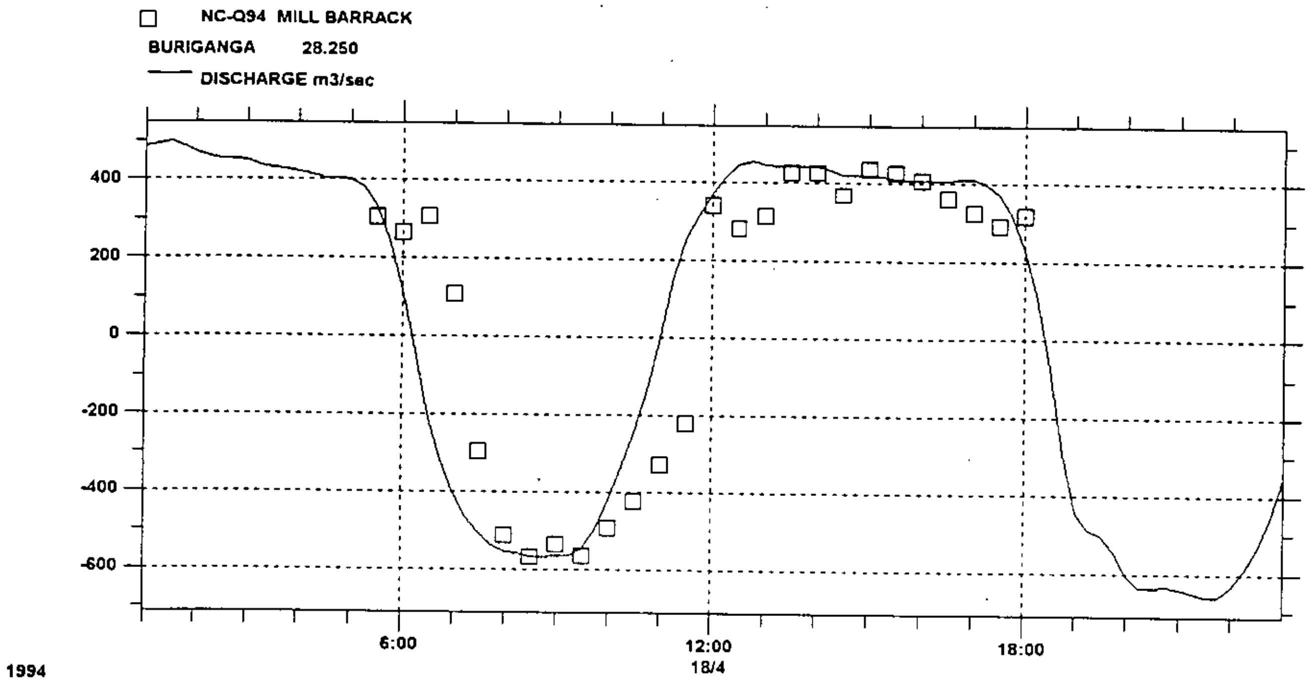
RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

MIKE 11



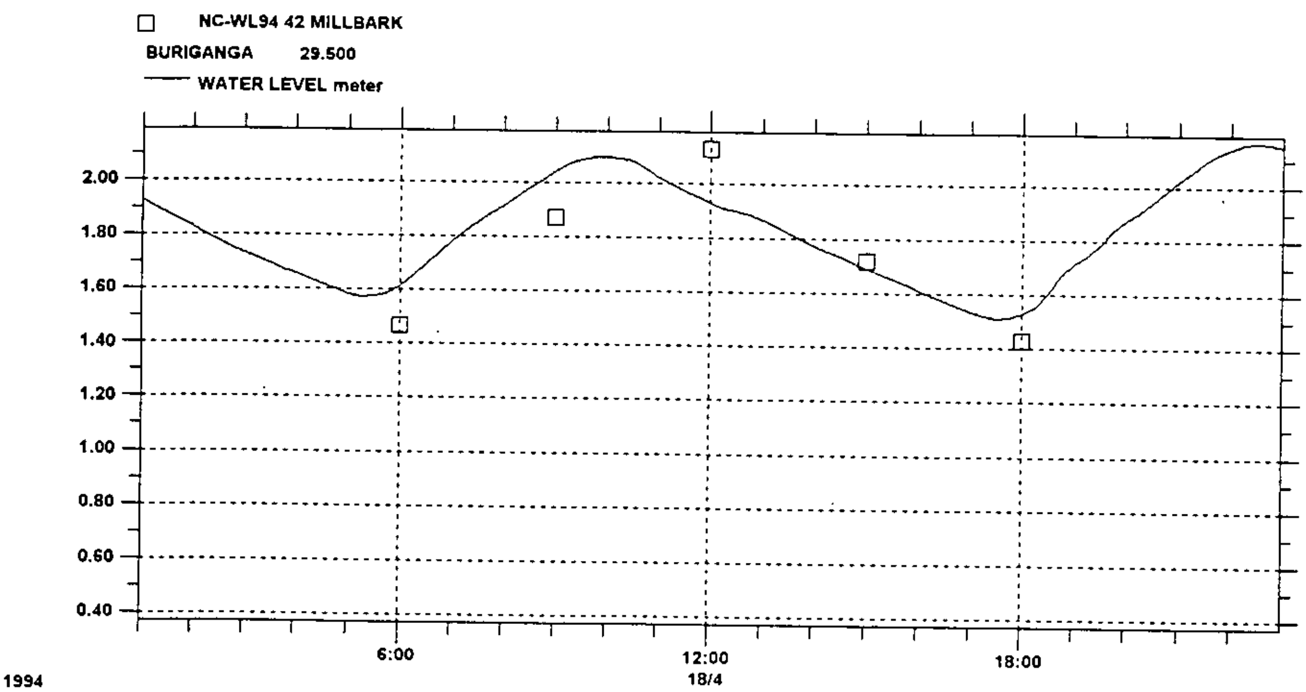


Figure E.7 Comparison of Observed and Simulated Water level & Discharge
Calibration of the Hydrodynamic Model
River name, Location name and Chainages are shown on Plot

DATA FILE : HDTST.RDF
RESULT FILE : HDTST.RRF

BOUNDARY FILE : HDFIN.BSF
CALCULATED : 17-APR-1996, 16:21

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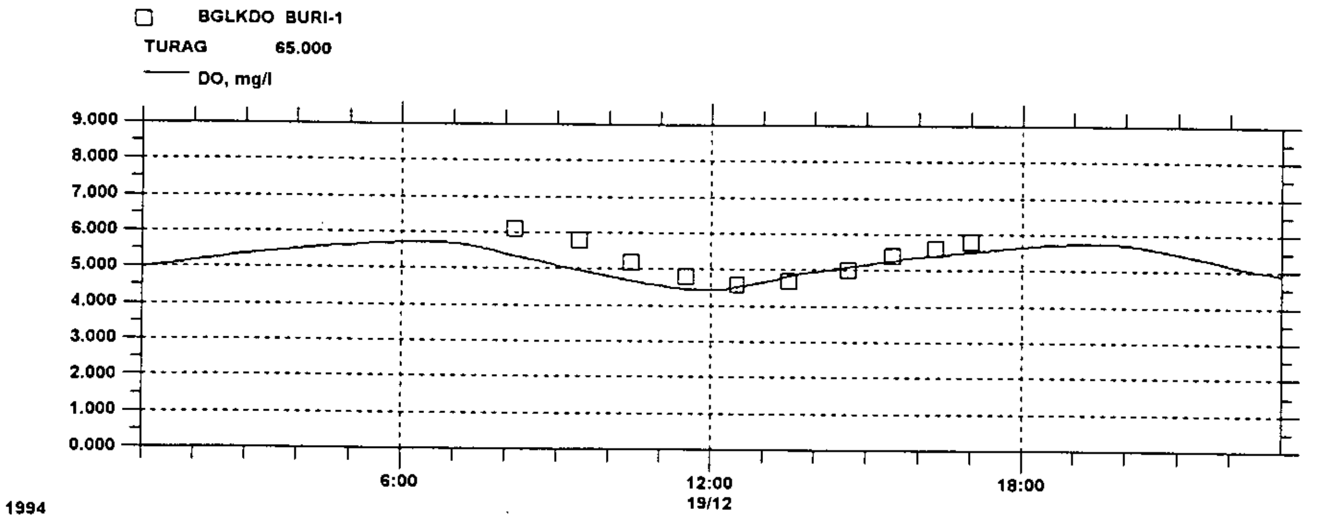
APPENDIX F

PLOTS OF WATER QUALITY MODEL CALIBRATION



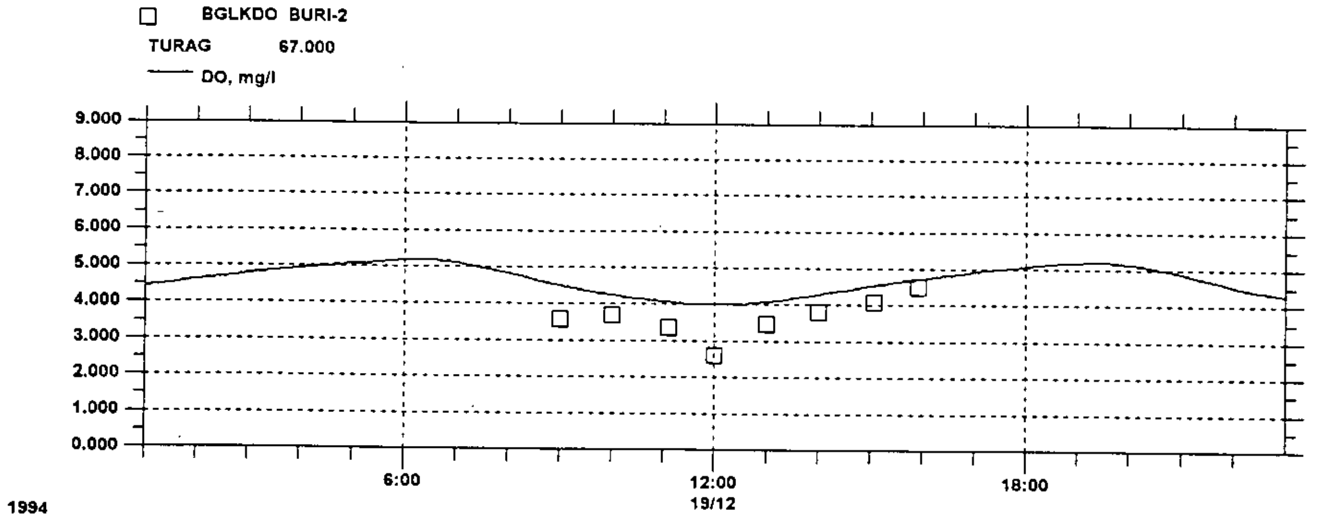


Figure F.1	Comparison of Observed and Simulated DO Calibration of the Water Quality Model River name, Location name and Chainages are shown on Plot

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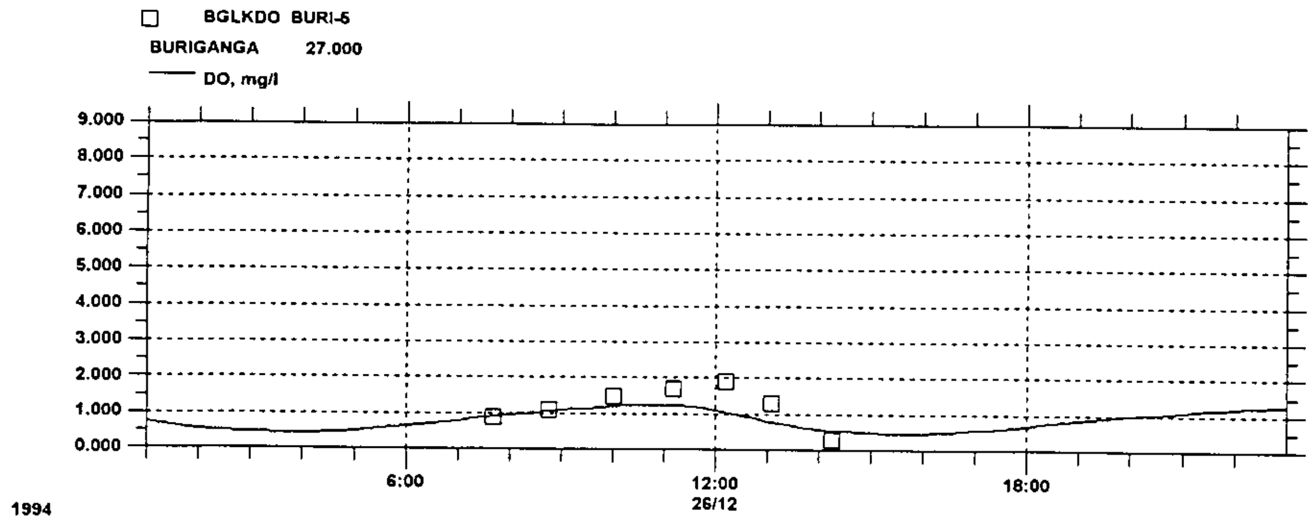
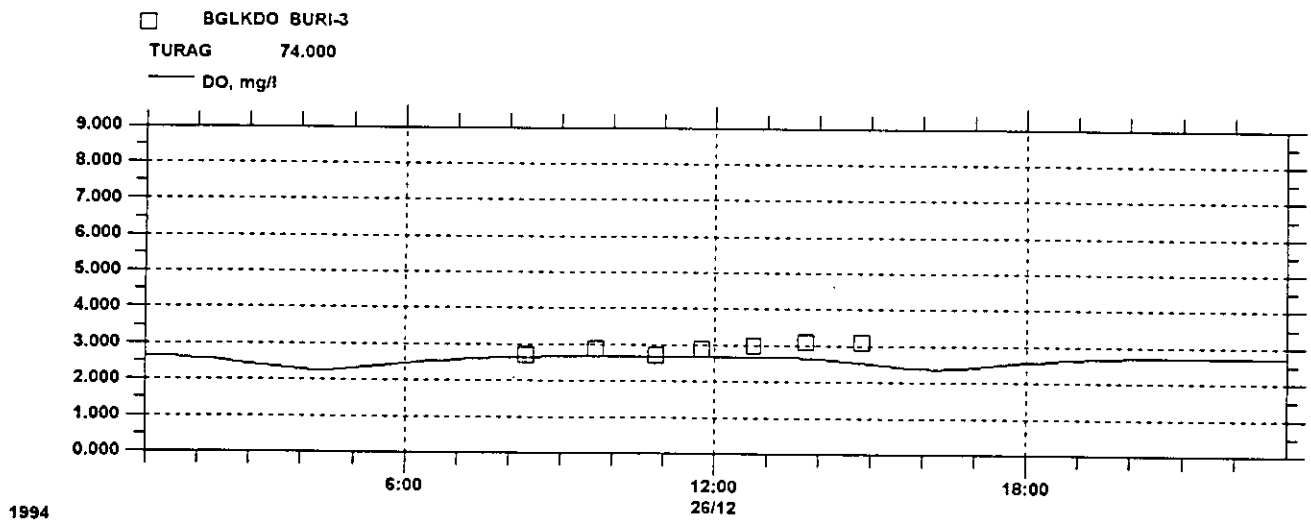
RESULT FILE : WQ_CDEC.TRF

BOUNDARY FILE : WQ_DOSB.BSF
CALCULATED : 30-APR-1996, 08:47

MIKE 11





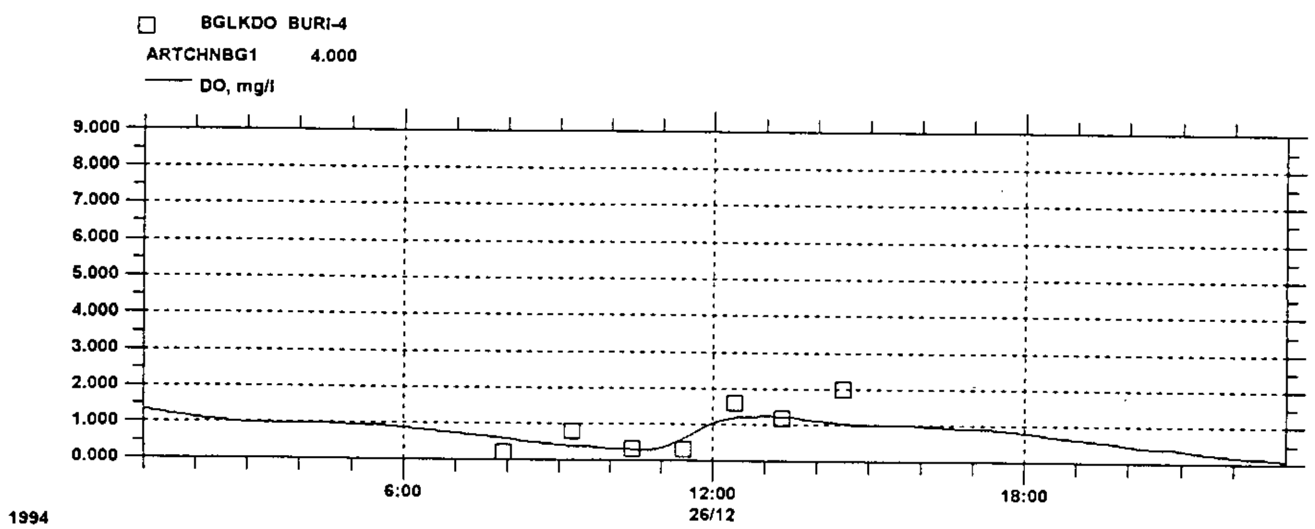


Figure F.2	Comparison of Observed and Simulated DO Calibration of the Water Quality Model River name, Location name and Chainages are shown on Plot

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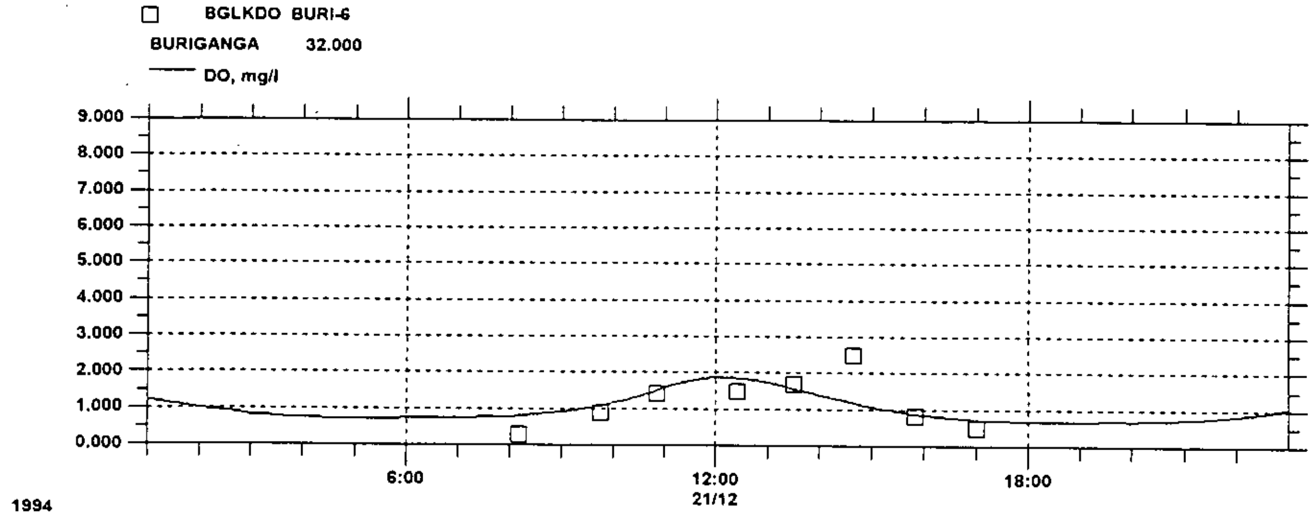
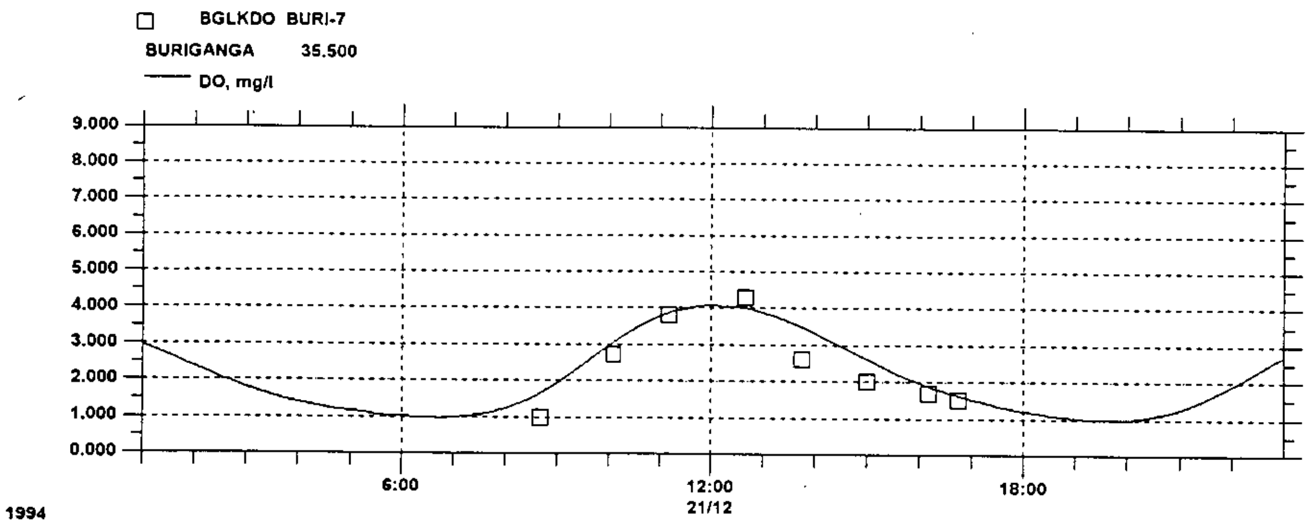
RESULT FILE : WQ_CDEC.TRF

BOUNDARY FILE : WQ_DOSB.BSF
CALCULATED : 30-APR-1996, 08:47

MIKE 11





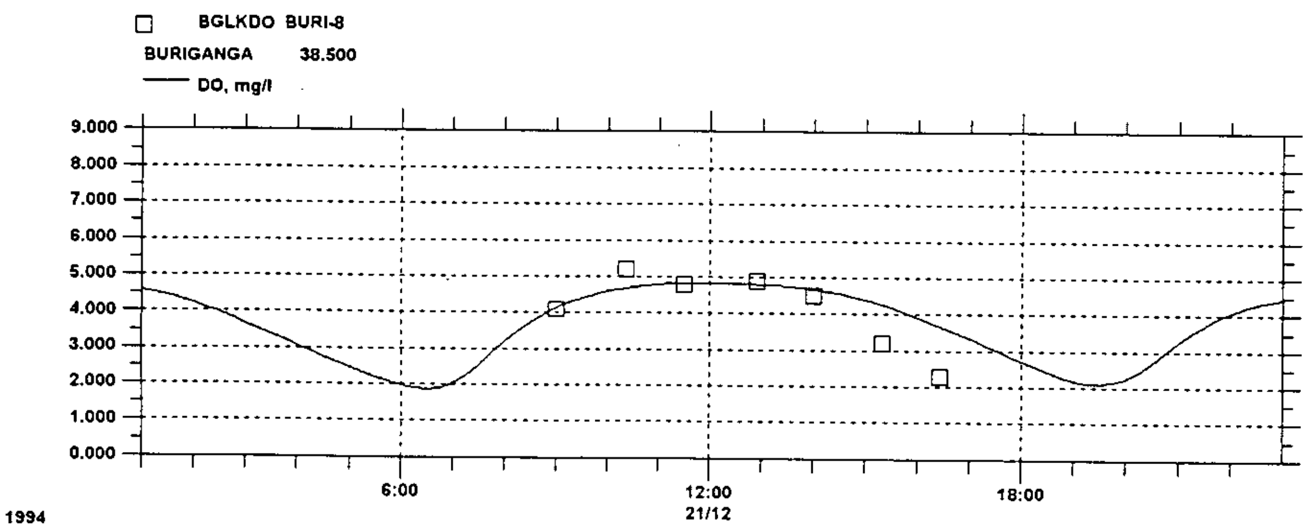


Figure F.3	Comparison of Observed and Simulated DO Calibration of the Water Quality Model River name, Location name and Chainages are shown on Plot

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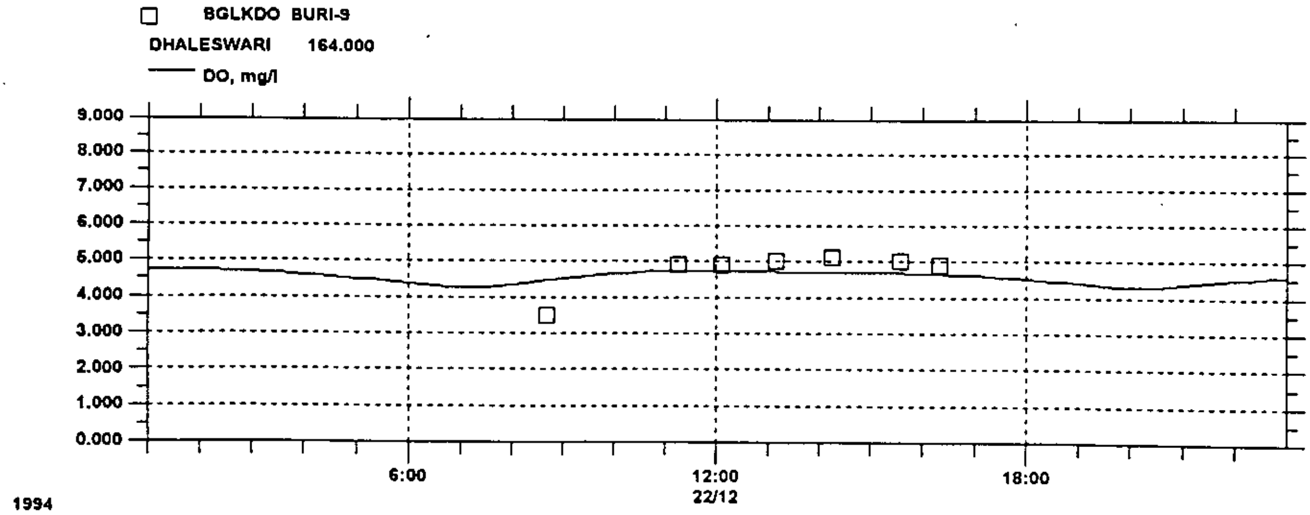
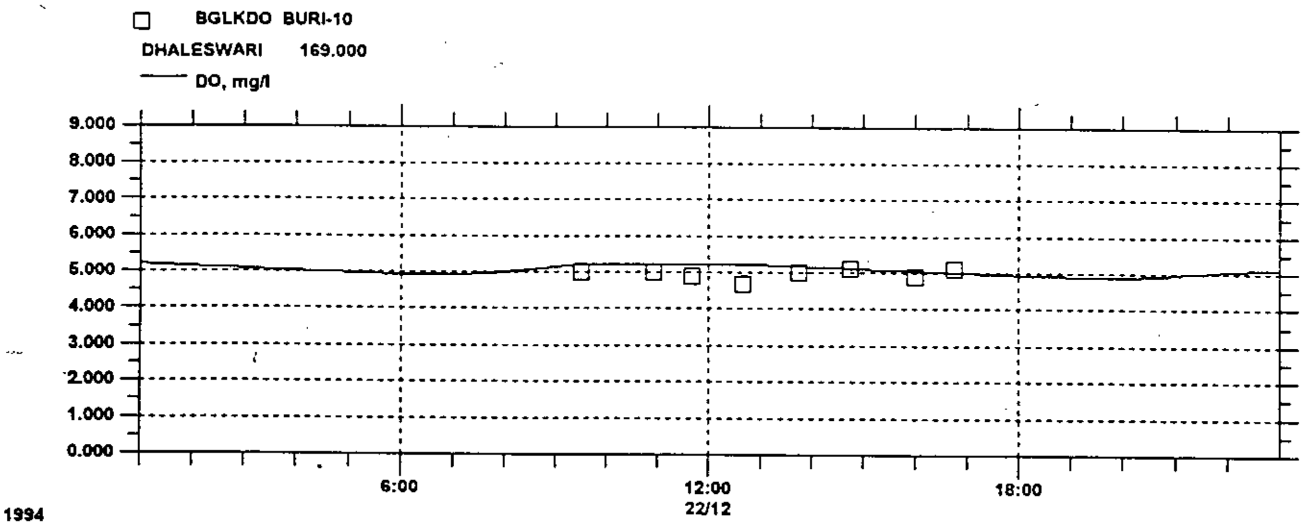
RESULT FILE : WQ_CDEC.TRF

BOUNDARY FILE : WQ_DOSB.BSF
CALCULATED : 30-APR-1996, 08:47

MIKE 11





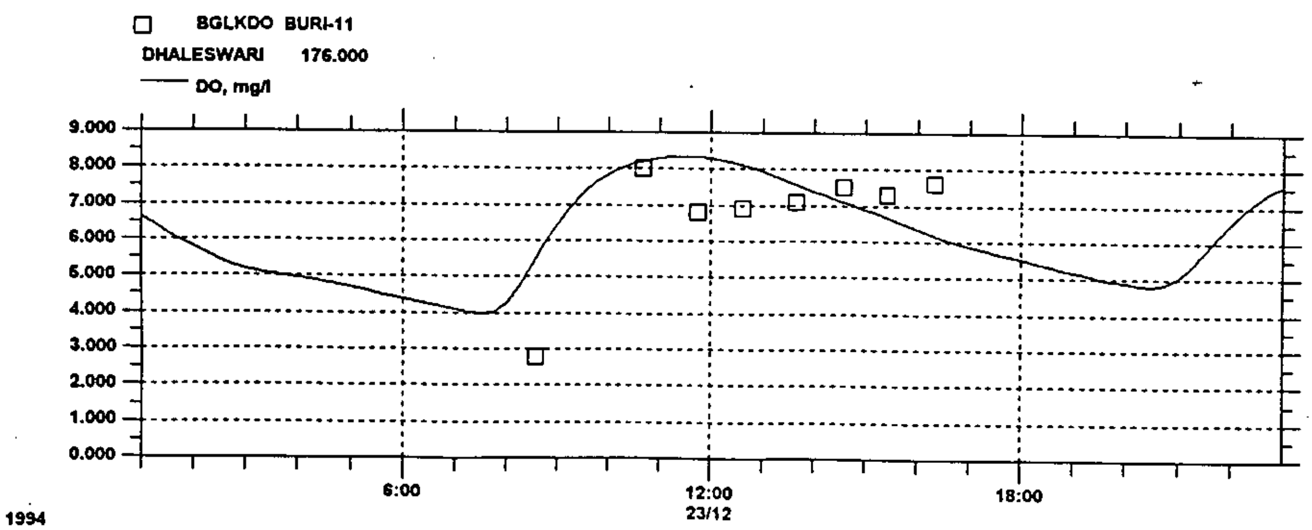


Figure F.4	Comparison of Observed and Simulated DO Calibration of the Water Quality Model River name, Location name and Chainages are shown on Plot

DATA FILE : HDTST.RDF
RESULT FILE : WQ_CDEC.TRF

BOUNDARY FILE : WQ_DOSB.BSF
CALCULATED : 30-APR-1996, 08:47

MIKE 11

APPENDIX G

DO PROFILES UNDER ALTERNATIVE SCENARIOS

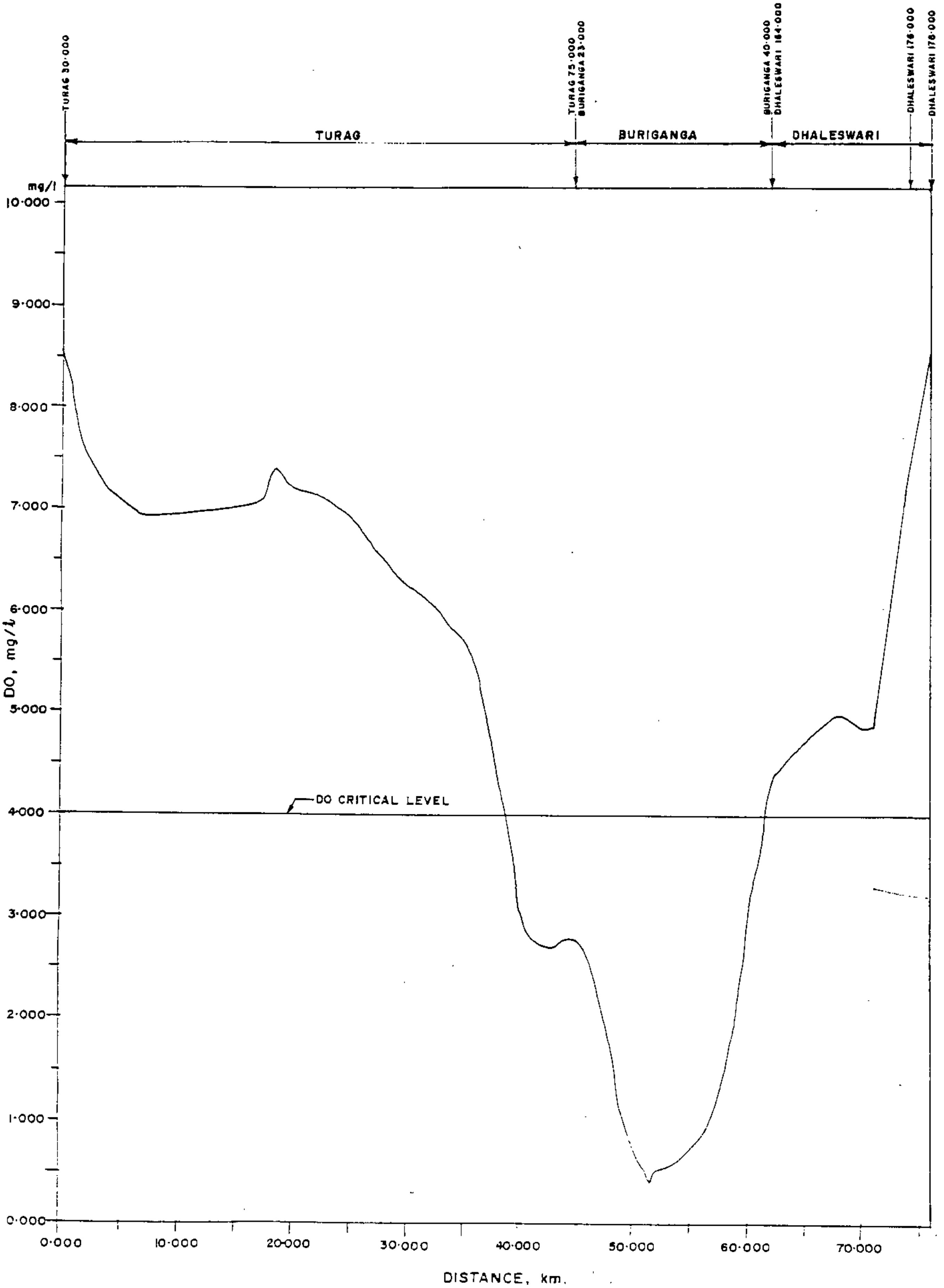


Figure G·1	Dissolved Oxygen Profile along the Turag – Buriganga – Dhaleswari Rivers **BASE CONDITION**

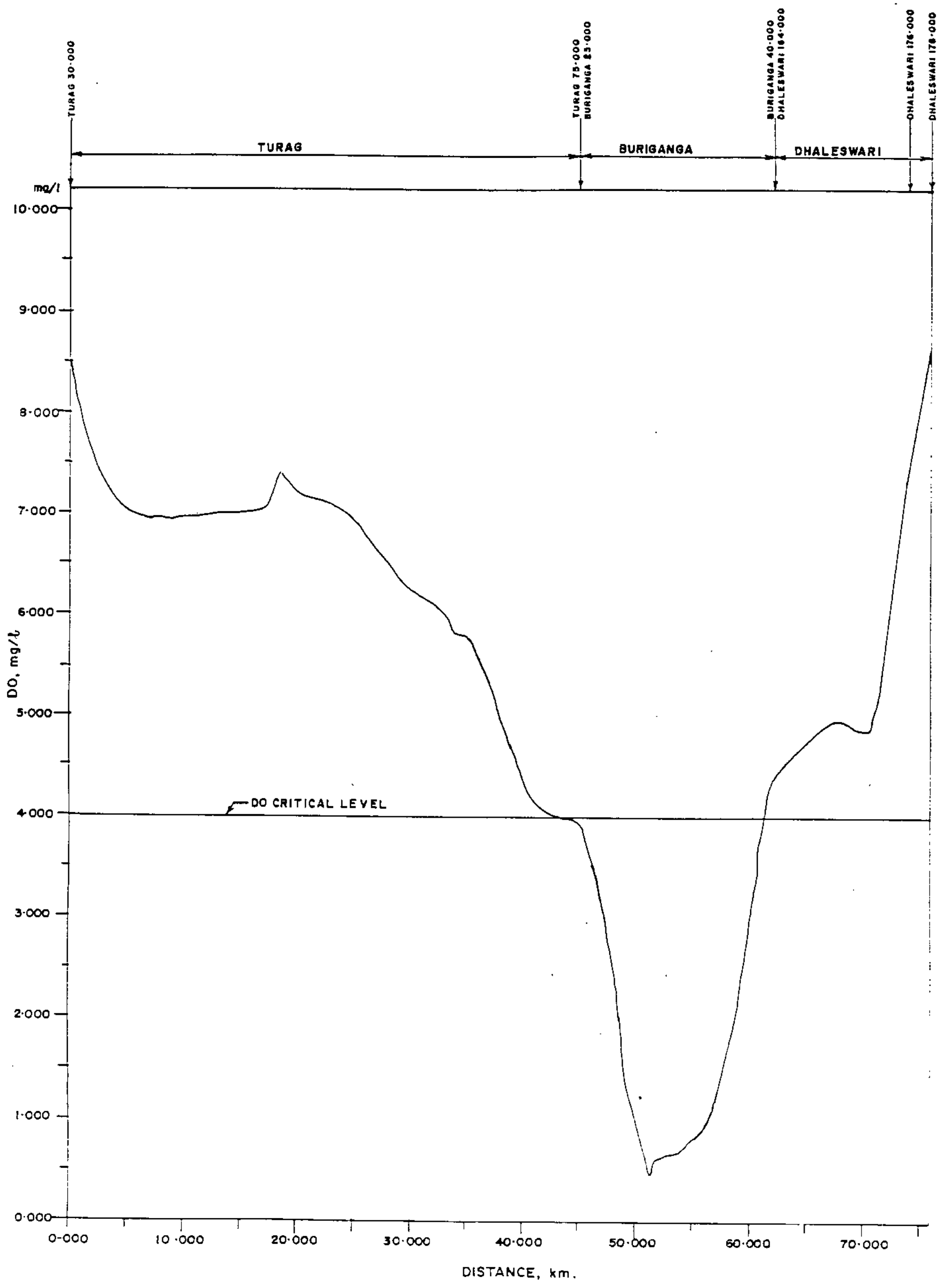


Figure G·2	Dissolved Oxygen Profile along the Turag – Buriganga – Dhaleswari Rivers **Scenario I**

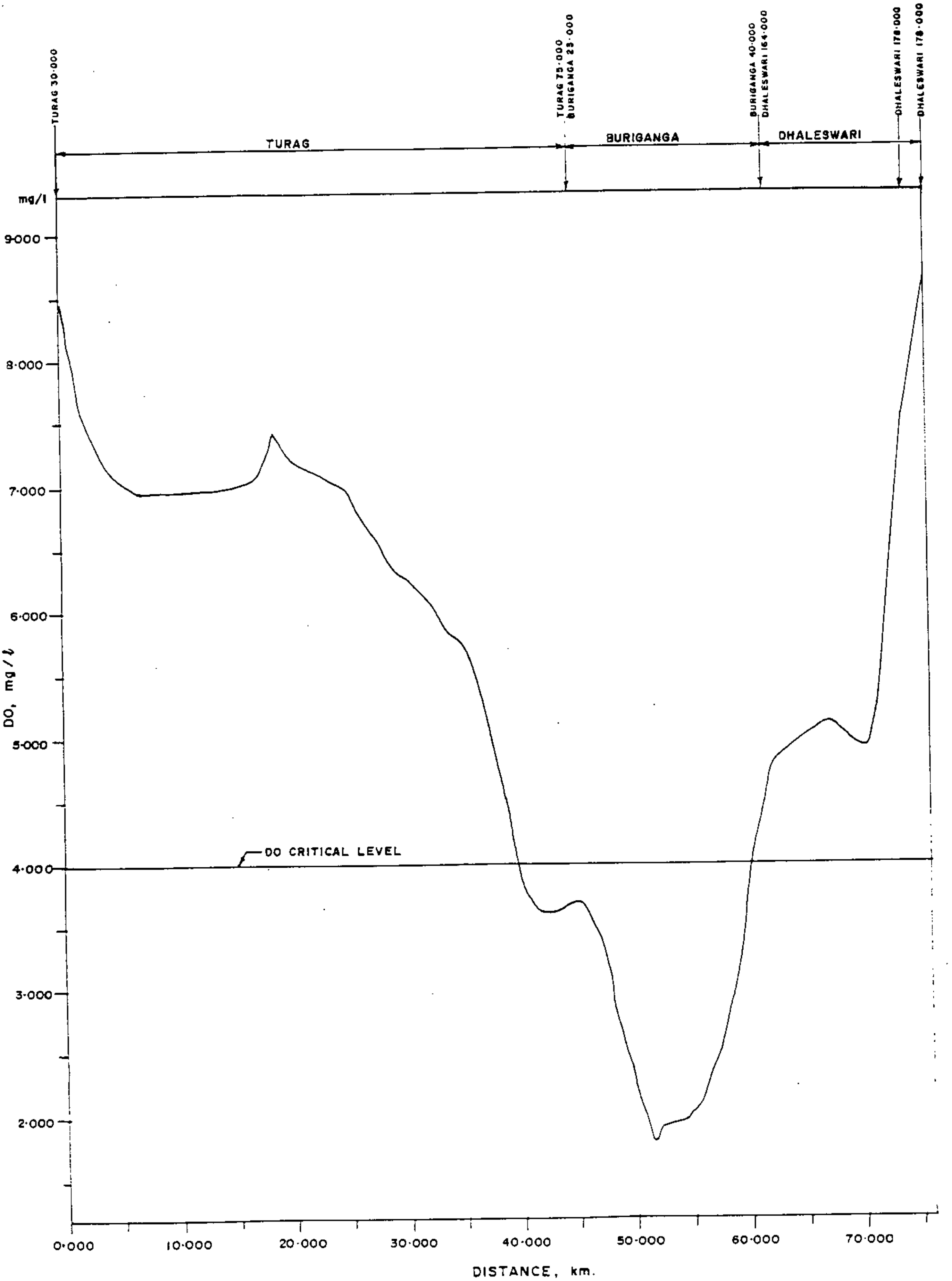


Figure G-3	Dissolved Oxygen Profile along the Turag - Buriganga - Dhaleswari Rivers **Scenario 2**

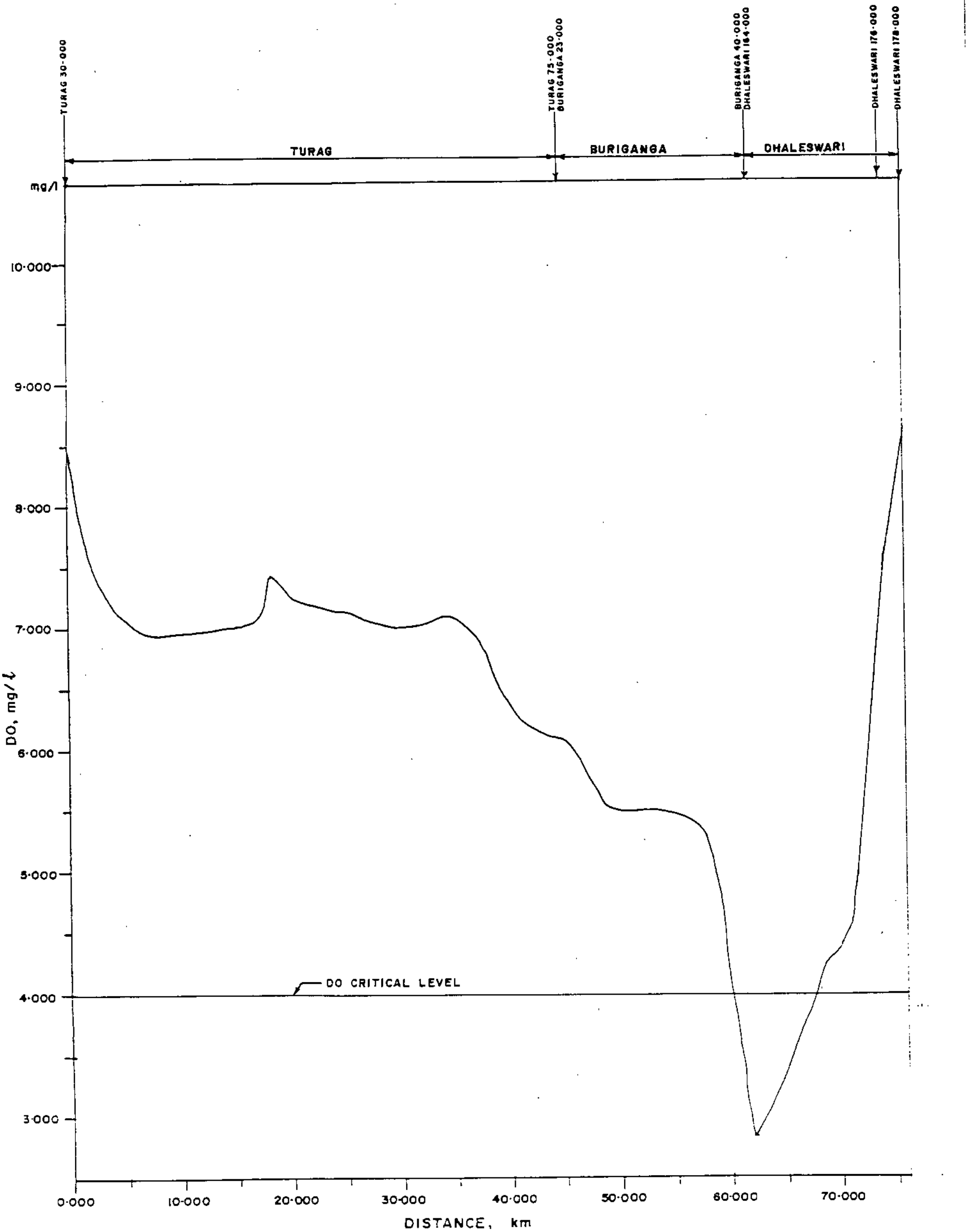


Figure G·4	Dissolved Oxygen Profile alog the Turag – Buriganga – Dhaleswari River **Scenario 3**

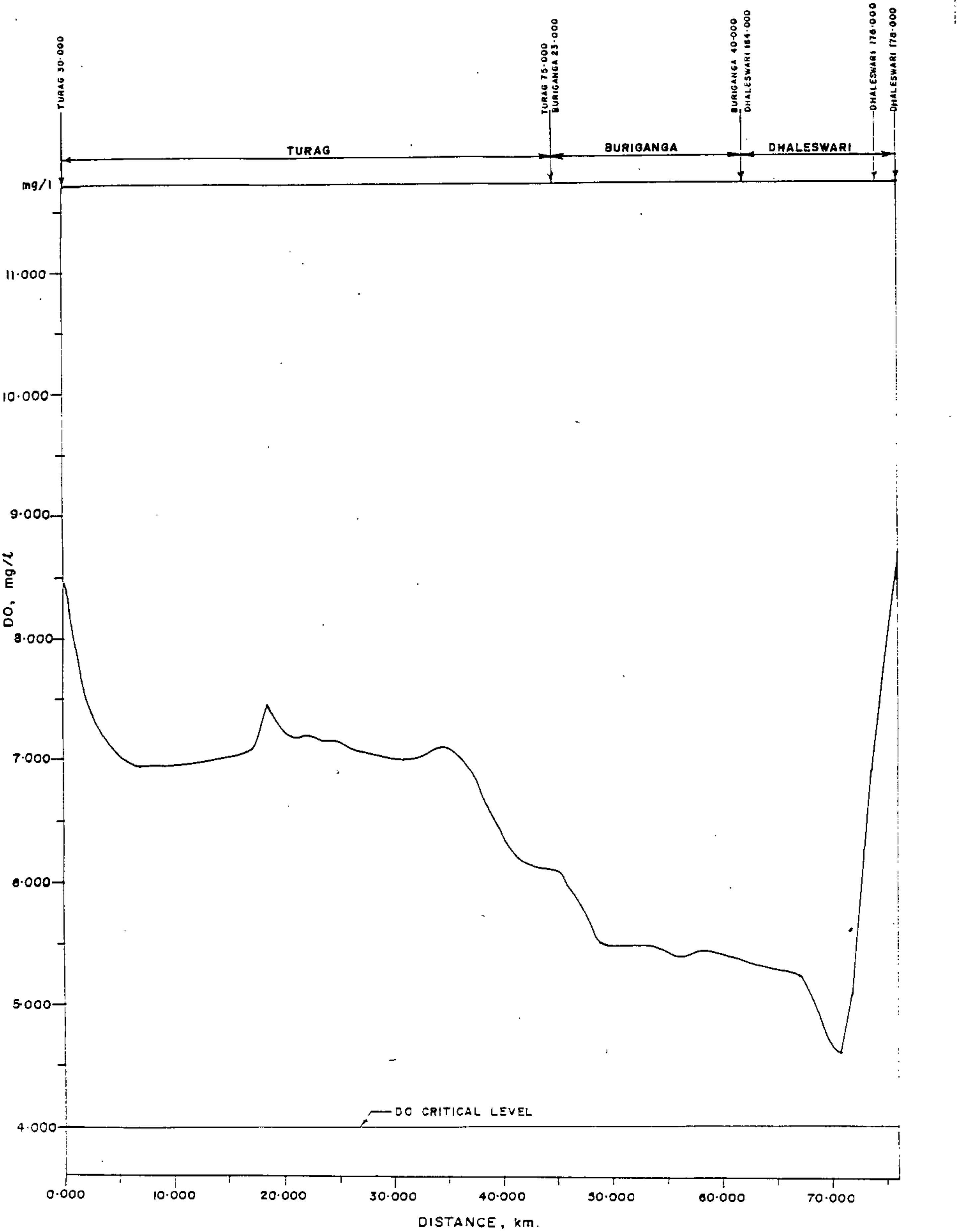


Figure G·5	Dissolved Oxygen Profile along the Turag – Buriganga – Dhaleswari Rivers **Scenario 4**

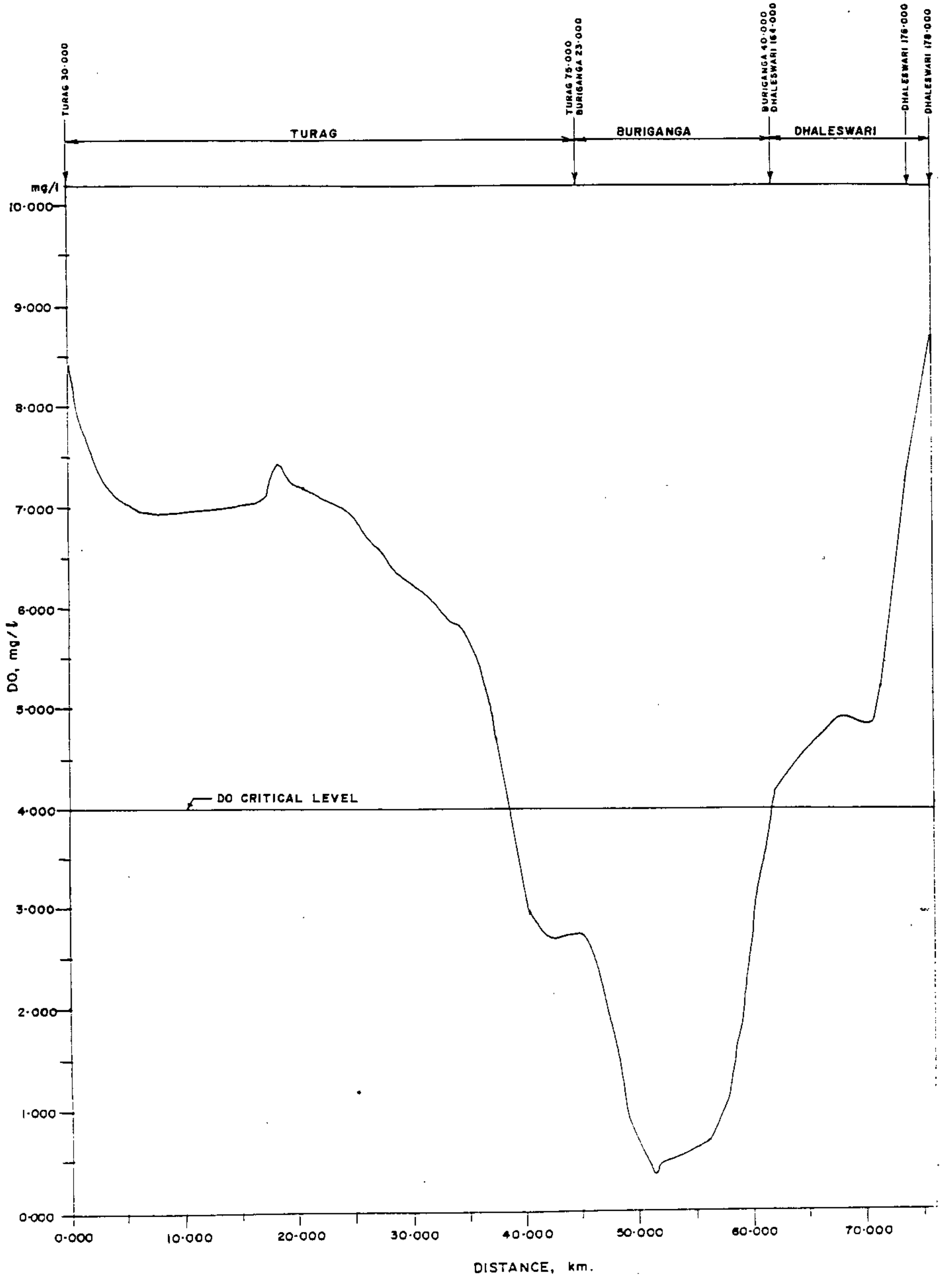


Figure G·6	Dissolved Oxygen Profile along the Turag – Buriganga – Dhaleswari Rivers **Scenario 5**

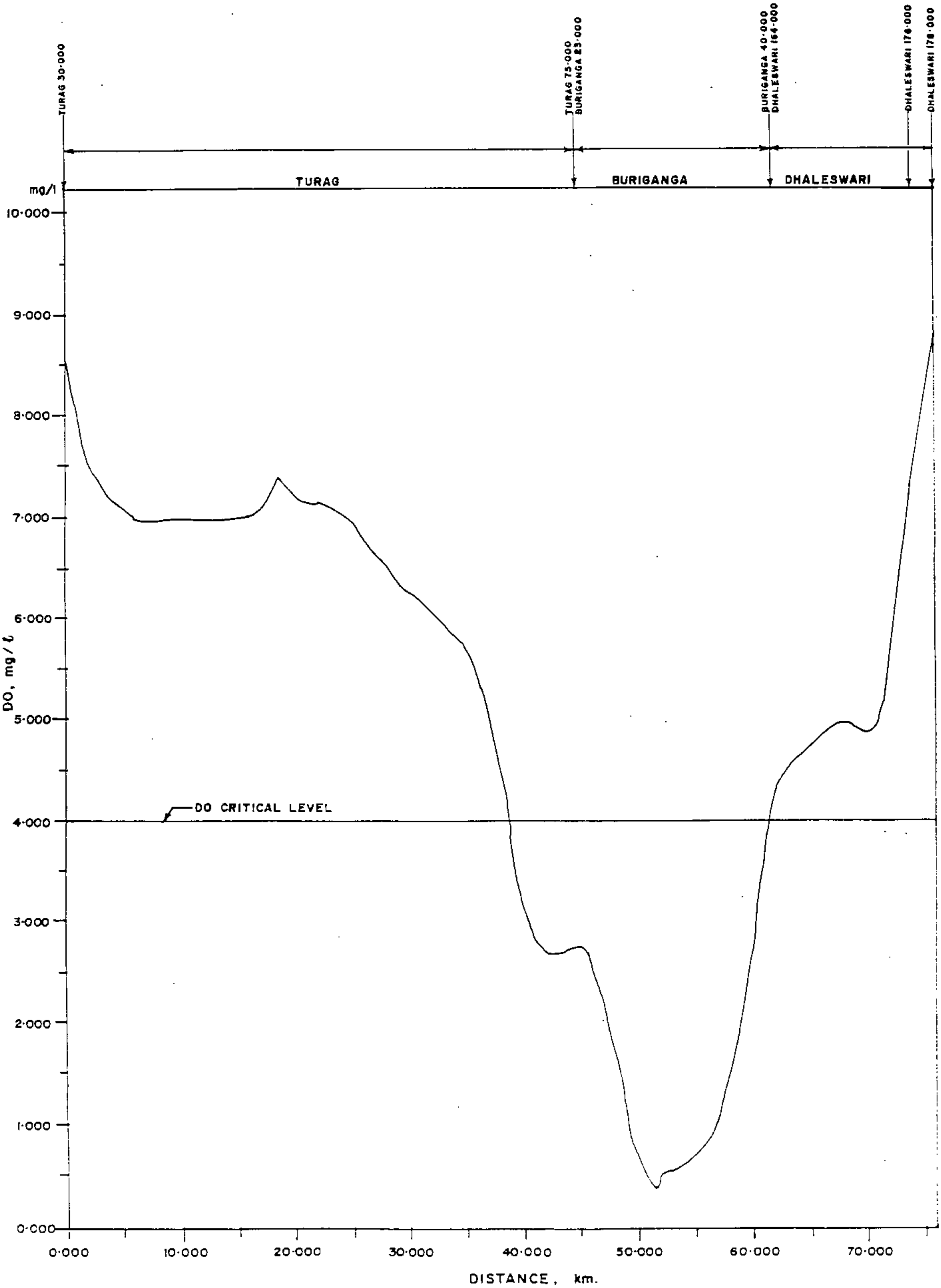


Figure G·7	Dissolved Oxygen Profile along the Turag – Buriganga – Dhaleswari River **Scenario 6**

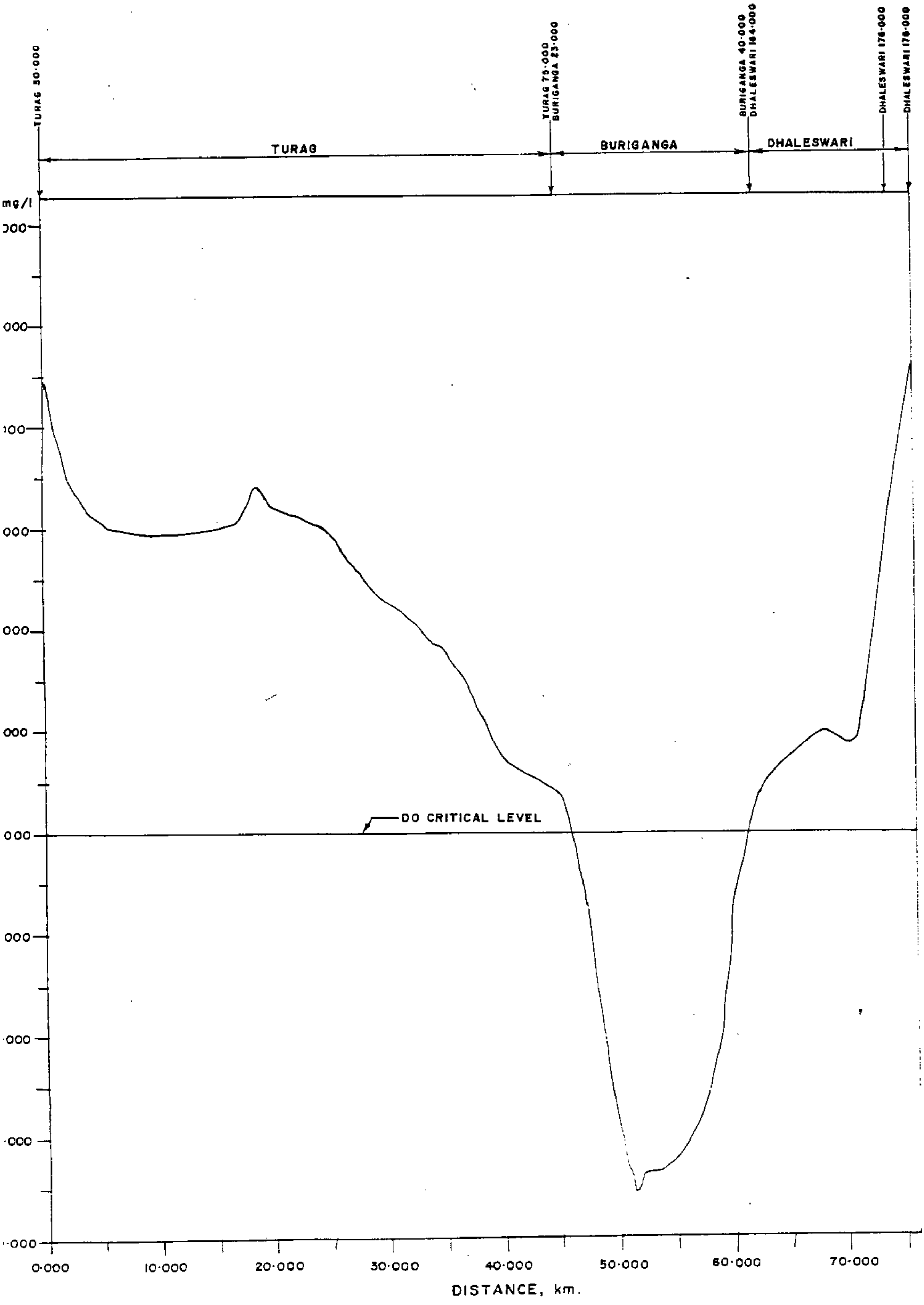


Figure G·8	Dissolved Oxygen Profile along the Turag-Buriganga-Dhaleswari Rivers **Scenario 7**

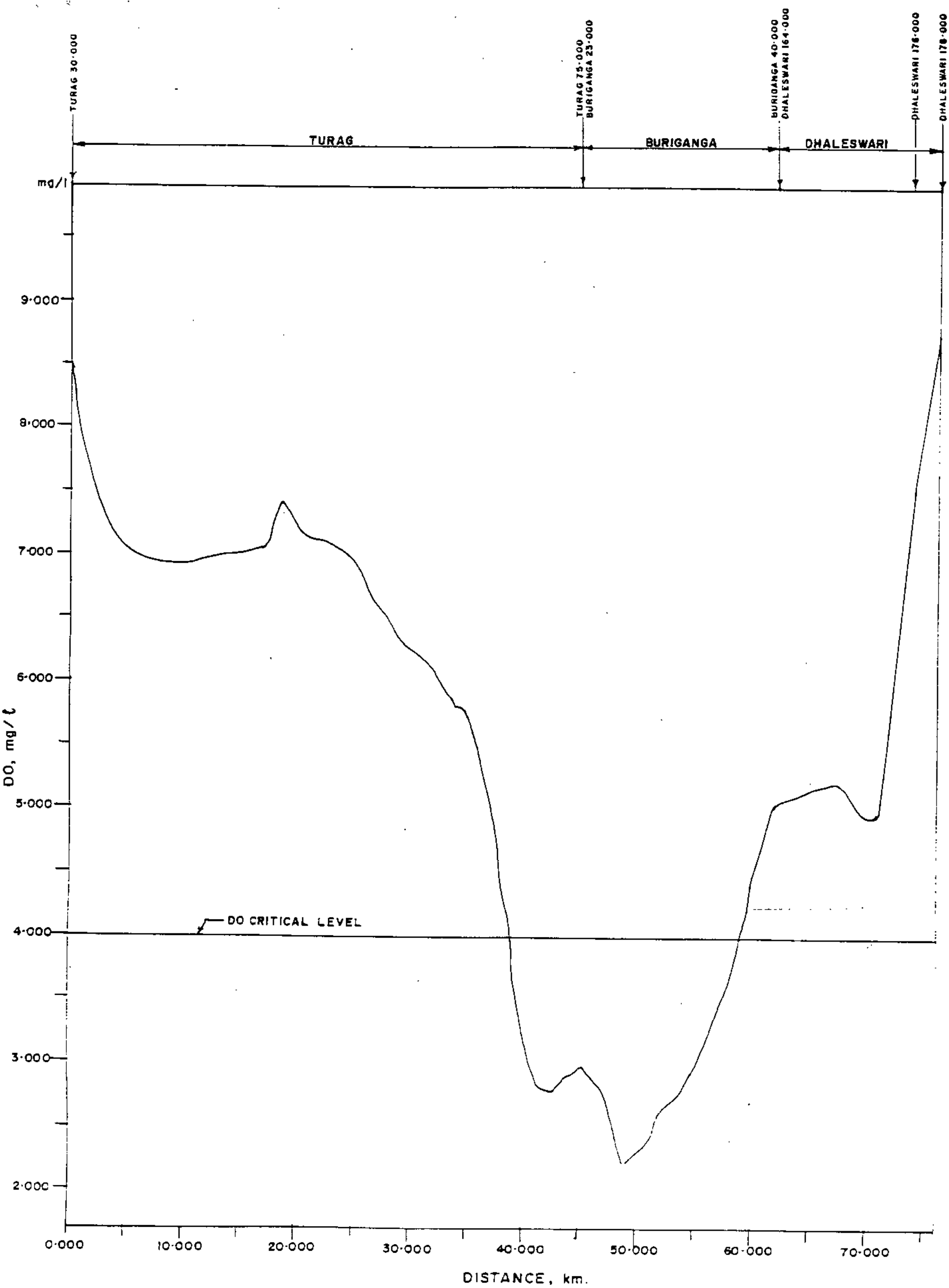


Figure G·9	Dissolved Oxygen Profile along the Turag, Buriganga, Dhaleswari Rivers. **Scenario 8**

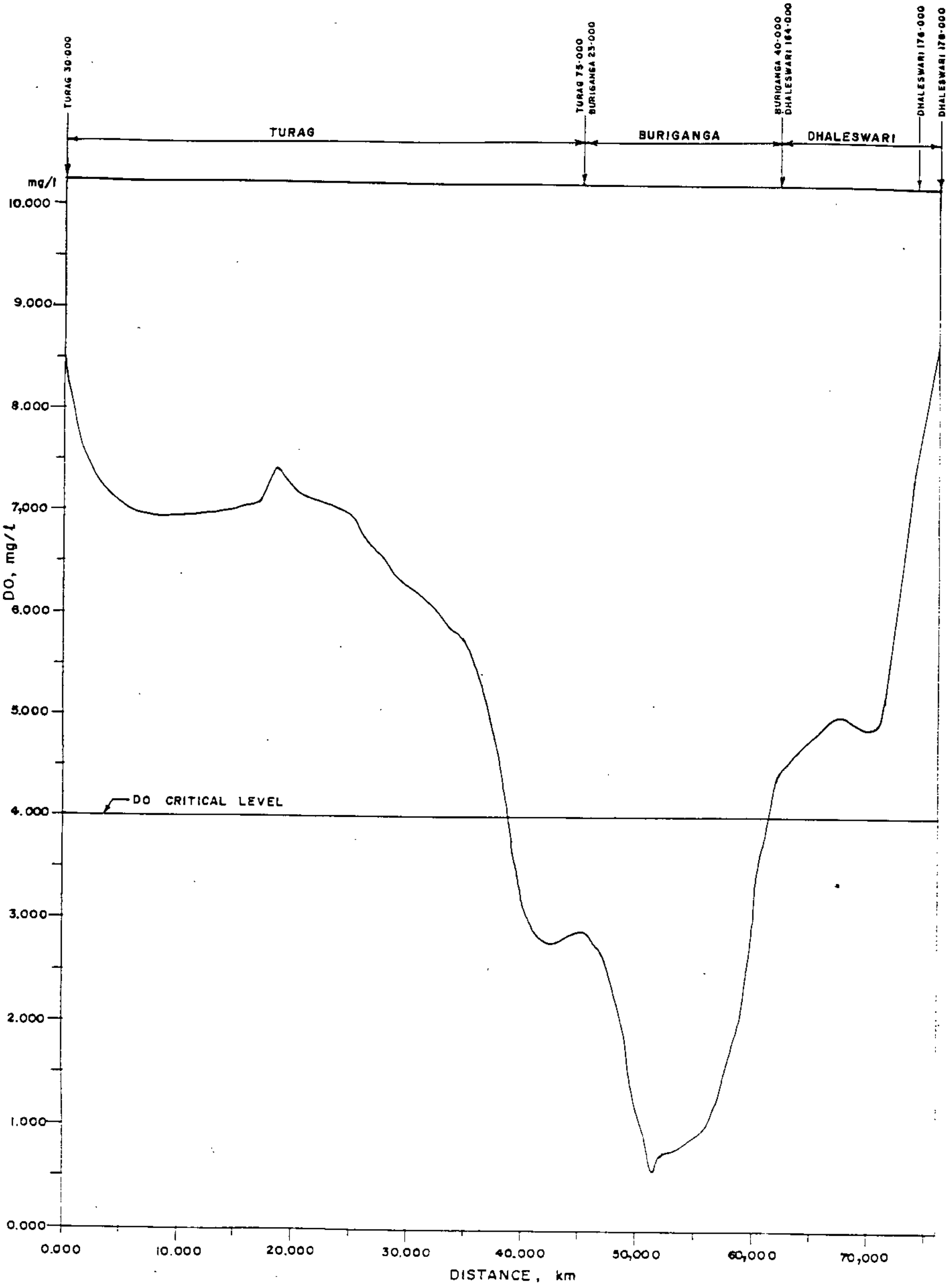


Figure G·10	Dissolved Oxygen Profile along the Turag–Buriganga–Dhaleswari Rivers **Scenario 9**

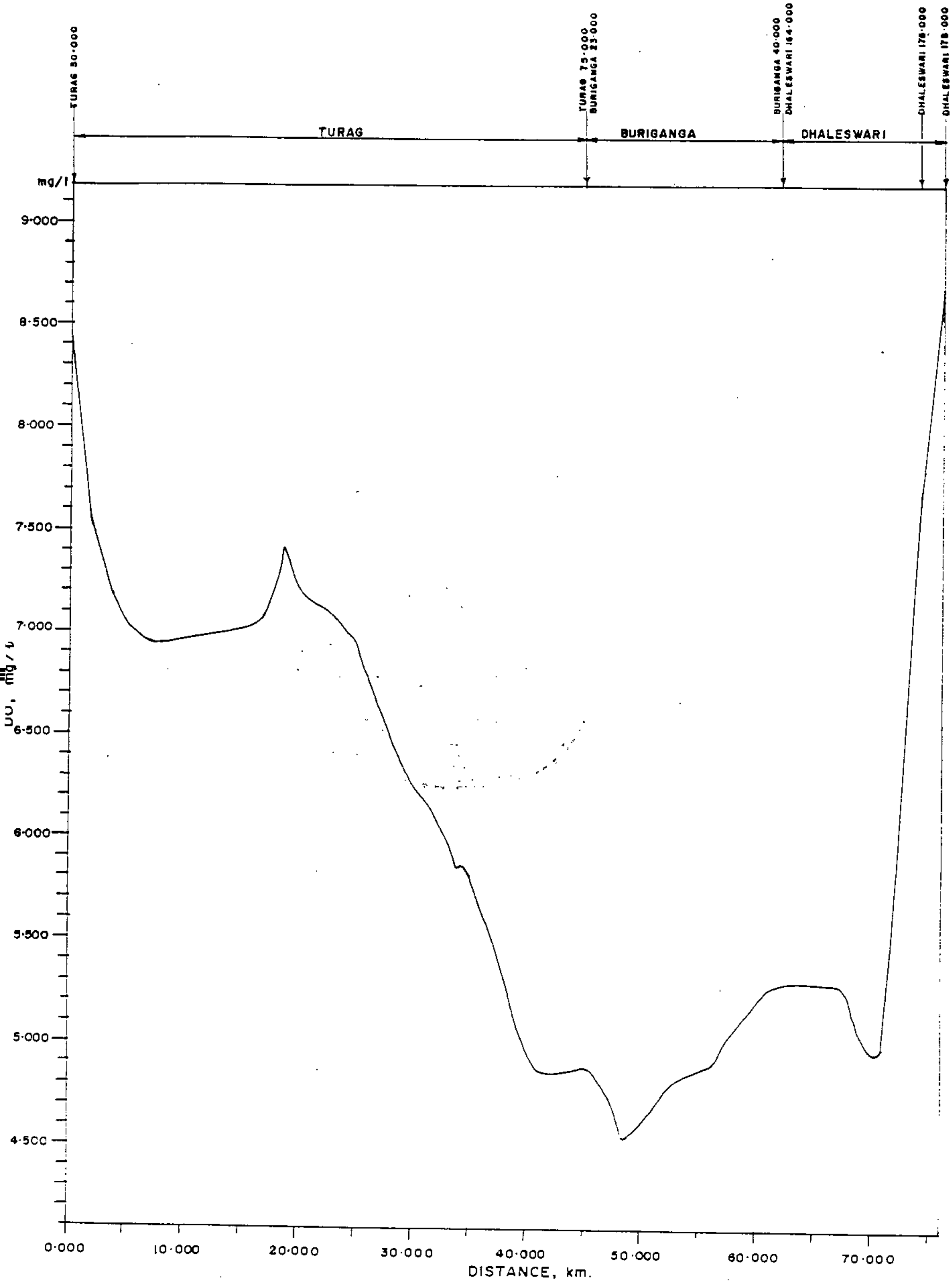


Figure G·11 Dissolved Oxygen Profile along the Turag–Buriganga–Dhaleswari Rivers
Scenario 10