



Nutan Bidyut
Bangladesh Limited
(NBBL)

Thermal Plume Modelling using CORMIX for NBBL's Bhola Combined Cycle Power Plant Discharge

Final Report

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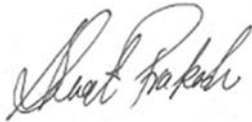
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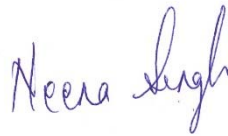
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Acronyms and Abbreviations

Name	Description
BPDB	Bangladesh Power Development Board
°C	degrees Celsius
m ³ /s	cubic meters per second
ERM	Environmental Resource Management, Inc.
IFC	International Finance Corporation
kg/m ³	kilogram per cubic meter
m	meter
m/s	meter per second
NBBL	Nutan Bidyut Bangladesh Limited
ppt	parts per thousand
USEPA	United States Environmental Protection Agency

1. INTRODUCTION AND BACKGROUND

The primary purpose of this study conducted by ERM India Private Limited (ERM) was to estimate the size and configuration of the thermal plume resulting from the cooling water discharge from a proposed 225 megawatt combined cycle power plant under construction by Nutan Bidyut Bangladesh Limited (NBBL). The United States Environmental Protection Agency (USEPA)-approved near-field model, CORMIX (Version 11.0), was chosen for this study. CORMIX has been applied to many similar cases (<http://www.cormix.info/>) and is recognized by the USEPA as an appropriate model for computing trajectories, dilution rates, and mixing zone dimensions. This report summarizes the application of the CORMIX model to the cooling water discharge.

The plant, referred to as "Bhola II", is located near Burhanuddin in Bangladesh, covering an area of ~29 acres. It is currently under construction alongside the existing Bangladesh Power Development Board (BPDB) power plant, referred to as "Bhola I". The cooling water blowdown at Bhola II is proposed to be routed to a guard pond, where it will be mixed with other water sources and fed to the effluent treatment plant, before ultimately being discharged to the Dehular Khal. The cooling water blowdown is designed to be at or marginally above (<1°C) the ambient temperature of the Khal.

Approximately 72 meters from the Bhola II discharge, the existing Bhola I plant has a discharge to the Khal of similar configuration. Though by design, Bhola II will discharge at or marginally above the ambient water temperature, modelling was conducted to consider the cumulative impacts of the Bhola I and Bhola II discharges for a theoretical temperature increase of 3.5°C above ambient from each discharge. The CORMIX module used is CORMIX3 for Buoyant Surface Discharges. ERM modeled the extent of the thermal plume for worst-case discharge conditions, which consists of the cooling water blowdown. It is worth noting that, due to the lack of some detailed information regarding the discharges, the Bhola I and Bhola II discharges were modeled identically for consistency and simplicity; any actual differences in design and configuration from what was assumed for modelling may result in a different thermal plume than what is presented here. The locations of Bhola I and Bhola II on the Dehular Khal are shown in Figure 1.1.

Figure 1.1 Bhola I and Bhola II on the Dehular Khal in the Bhola District of Bangladesh, India



Source: Google Earth, 2019

2. CORMIX APPLICATION TO NBBL'S DISCHARGE

A typical CORMIX application requires three (3) types of data as inputs:

- A description of the effluent (i.e., its flow and temperature);
- The dimensions, location, and configuration of the discharge structure; and
- The properties and characteristics of the receiving waterbody—in this case, the Dehular Khal (i.e., width, depth, flow rate, and temperature).

Since the study was focused on the Bhola II discharge, and limited information was known about the Bhola I discharge, only the Bhola II discharge was modeled. It was then assumed that an identical thermal plume would occur 72 meters from the location of the Bhola II discharge for the purpose of performing an overlap analysis.

2.1 Model Input Parameters

NBBL provided the information used as input to CORMIX in the form of reports, drawings, maps, and electronic files. These are presented in the following sections.

2.1.1 Properties of the Effluent

Effluent characteristics for the Bhola II thermal discharge, as provided by NBBL, are presented in Table 2-1.

Table 2-1: Effluent Properties

Parameter	Value
Discharge flow (m ³ /s)	0.19
Initial temperature differential (°C)	+3.5

2.1.2 Configuration of the Discharge Structure

Key design parameters of the selected discharge structure, as provided by NBBL, are presented in Table 2-2.

Table 2-2: Design Elements of the Discharge Structure

Parameter	Value
Discharge type	Surface channel (CORMIX3)
Discharge configuration	Flush
Horizontal angle (relative to receiving waterbody)	75°
Channel width (m)	0.55
Channel depth (m)	0.30

The horizontal angle and channel depth were estimated using maps and photographs of the discharge.

2.1.3 Characteristics of the Dehular Khal at the Discharge Location

CORMIX requires a number of parameters that characterize ambient conditions, including water depth, temperature, salinity, and currents.

Bathymetry data were available from a survey performed for NBBL by Development Survey Consultant (DCS) on 7 October 2018. The average water depth in the area was estimated to be ~3 m. The CORMIX user manual suggests that the difference between depth at the discharge and average depth in the region of interest is not to be modeled as greater than 30%. Therefore, for this application it was assumed that the average depth and the depth at the discharge location are both equal to 3 m to improve model stability. For this application, it was also assumed that the bottom of the Khal was not sloped near the entrance of the discharge channel.

Flow data were available from the Environmental Impact Assessment (EIA) conducted by ERM for Bhola I in August 2012, which identifies the minimum flow in the Dehular Canal to vary from 62 to 124 m³/s, based on a feasibility study conducted by BPDB. Both ends of this range were modeled, as well as a near-zero [5 m³/s] value to represent an extreme low current scenario, simulating near-stagnant conditions.

It should be noted that the Dehular Khal is a tidal stream and is known to demonstrate frequent variations, stagnation and reversing of the flow based on the tide. Hence, the thermal discharge from the Plant is likely to disperse in either directions. In the Khal section along the Plant, the general flow vectors are in southwest to northeast direction and northeast to southwest direction. For the purposes of this study, it was assumed that the Dehular Khal flows from southwest to northeast, and that the Bhola II discharge is upstream of the Bhola I discharge. Being a tidal canal, the flow in the Khal may stagnate or flow in reverse under certain conditions. An extreme low current scenario was considered to simulate near-stagnant conditions, but a reversed flow scenario creates the potential for recirculation and was not considered for this analysis. However, based on the output of the model, similar results can be assumed in a reverse flow condition.

Average monthly temperature, salinity, and density data used in the model were provided by NBBL from a sampling event dated 16 April 2016, as part of the baseline studies for the Environmental and Social Impact Assessment conducted by ERM for Bhola II. The width of the Khal was estimated to be 60 m with a slight meander based on the most recent morphological stream information from a January 2019 Google Earth® image.

2.2 Scenario Information

The International Finance Corporation (IFC) standard requires that the temperature change relative to ambient not be more than 3°C beyond 100 m from the discharge point. The thermal plume from NBBL's discharge was evaluated against this standard. A summary of the CORMIX modelling input parameters that are constant for all scenarios are presented in Table 2-3.

Table 2-3: CORMIX3 Input Data

Parameter	Value
Discharge type	Surface channel (CORMIX3)
Discharge configuration	Flush
Horizontal angle (relative to waterbody)	75°
Channel width	0.55 m
Channel depth	0.3 m
Effluent flow rate	0.19 m ³ /s
Effluent salinity	0.081 ppt
Effluent density	993.92 kg/m ³
Waterbody type (bounded/unbounded)	Bounded
Bounded width	60 m
Bed roughness (Manning's or Chezy coefficient)	Manning's: 0.01
Average water depth	3 m
Water depth at discharge structure	3 m
Bottom slope at discharge structure	0°
Ambient temperature	32°C
Ambient salinity	0.081 ppt
Ambient density	995.09 kg/m ³
Wind speed	1 m/s

For the purpose of the modelling study a total of three (3) scenarios were used to model the thermal plume under varying ambient flow conditions. Flow data were available from the Environmental Impact Assessment (EIA) conducted by ERM for Bhola I in August 2012, which identifies the minimum flow in the Dehular Canal to vary from 62 to 124 m³/s, based on a feasibility study conducted by BPDB. Both ends of this range were modeled, as well as a near-zero [5 m³/s] value to represent an extreme low current scenario, simulating near-stagnant conditions.

The ambient flow values for each CORMIX modelling scenario are presented in Table 2-4.

Table 2-4: CORMIX3 Input Data Varying by Scenario

Parameter	Scenario 1	Scenario 2	Scenario 3
Ambient flow rate (m ³ /s)	5	62	124

3. RESULTS AND CONCLUSIONS

3.1 CORMIX Model Results

Table 3-1 summarizes the extent of the various resulting plumes (3°C temperature rise or reduction) in multiple dimensions, as characterized by three (3) indicators:

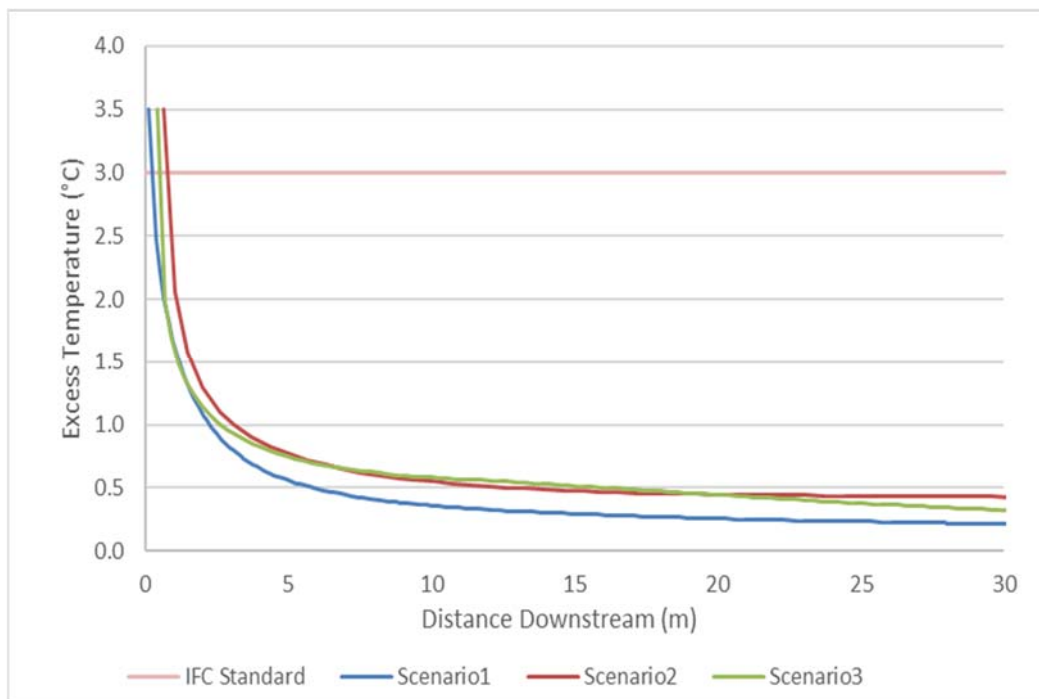
- Length of the plume (centerline);
- Width of the plume; and
- Depth of plume.

Table 3-1: Mixing Zone Dimensions Based on Plume Centerline for Each Scenario

Scenario	Plume length (m)	Width (m)	Thickness (m)
1	0.37	9.60	0.75
2	1.03	3.10	0.52
3	0.68	1.90	0.65

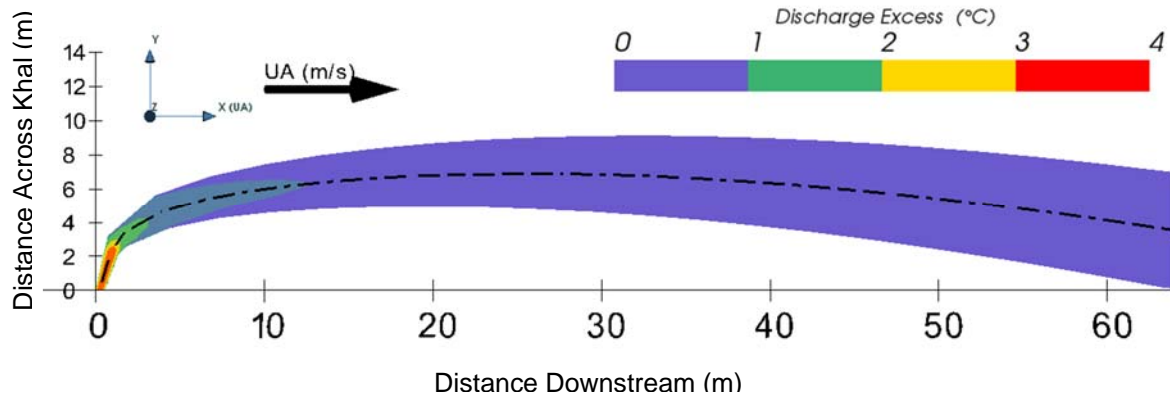
In all of the three (3) modelling scenarios, the IFC standards were met within ~1 m downstream. The excess temperatures downstream along the centerline of the plume for each scenario are presented in Figure 3.1.

Figure 3.1: Excess Temperature with Downstream Distance for Scenarios 1-3



The centerline temperature is the maximum at each transect and temperatures decrease away from the centerline. The detailed plume behavior for the worst case downstream scenario (Scenario 2) is presented in Figure 3.2.

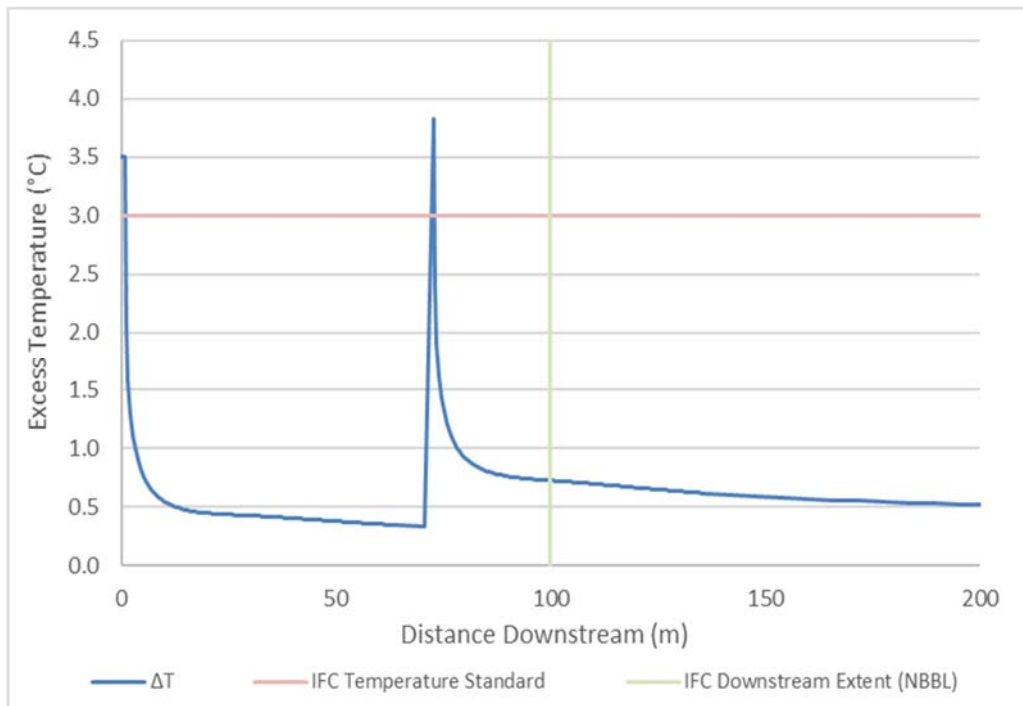
Figure 3.2: Thermal Plume for the Worst Case Downstream Scenario (Scenario 2)



3.1.1 Overlap Analysis

An overlap analysis was performed using the worst case downstream scenario (Scenario 2) results. The Bhola I discharge is located approximately 72 m downstream from the modeled Bhola II discharge. For the purposes of performing an overlap analysis, and as CORMIX can only consider a single discharge per model simulation, it was assumed that a plume identical to that produced by the Bhola II discharge would occur approximately 72 m downstream from the Bhola I discharge. The excess temperature with downstream distance for both discharges is presented in Figure 3.3 **Error! Reference source not found.**, with the Bhola I discharge occurring at 0 m and the Bhola II discharge occurring at 72 m. However, it is again worth noting that ERM assumed the Bhola I and Bhola II discharges to be identical in this study; in actuality, the two (2) may differ in their design and result in a smaller or larger combined plume. A more detailed analysis could be conducted to better understand complex processes resulting from this overlap in the Khal; however, this simplified assessment shows there is no overlap in plumes, suggesting a more complex model that allows multiple discharges is not necessary.

Figure 3.3: Overlap Analysis of Excess Temperature with Downstream Distance



3.2 Conclusion

All of the three (3) scenarios modeled meet the IFC standard of less than 3°C change within 100 m from either discharge. The farthest distance that either individual plume travels in any direction and in any scenario before meeting less than a 3°C change is 9.6 m across the Khal.

The overlap analysis demonstrates that the IFC standard of less than 3°C change within 100 m is met when considering the cumulative impacts of the Bhola I and Bhola II discharges. The excess temperature 100 m downstream from the Bhola II discharge is approximately 0.72°C.

3.3 Recommendations

- To verify that the Bhola II discharge meets the IFC standard, regular and frequent monitoring of the discharge could be conducted to record and confirm that the discharge temperature is at or marginally above the ambient water temperature as designed.
- To confirm that recirculation is not occurring in the case of a reverse flow scenario, monitoring could be conducted at the intake and compared to the upstream water temperature; however, if the discharge temperature is at the ambient water temperature as designed, this is not likely necessary.

4. REFERENCES

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