Annex 5B

# Detailed Results of CORMIX Modelling

*CONTENTS*

# 1 MODEL SETUP

## 1.1 PROPOSED EFFLUENT CHARACTERISTICS

The assumed characteristics of the effluent for Sha Tau Kok Sewage Treatment Works (STKSTW) are presented below.

***Table 1.1 Effluent Characteristics of the STKSTW***

| Determinand | Existing STKSTW | Expanded STKSTW |
|---|---|---|
| **Normal Effluent Discharge** | | |
| Flow Rate ($m^3$/day) | 1,660 | 10,000 |
| Salinity (mg/L) | 0.1 | 0.1 |

This exercise aims to provide indication on the near field mixing behavior of the effluent plume from the sewage treatment works so that can be properly captured in the far field water quality modelling exercise using Delft3D WAQ. To ensure conservative assessment, the Delft3D WAQ model simulation would only take into account the vertical profile of the saline effluent discharged from the submarine outfall. The horizontal dispersion predicted by the near field model would be omitted in the far field water quality model and all loading would be distributed only to the grid cell where the outfall is located.

## 1.2 DESIGN OF SUBMARINE OUTFALL

The design specifications of the existing and proposed outfalls are shown below in *Table 1.2*.

***Table 1.2 Design of the Existing Outfall and the Proposed Outfall***

| Parameter | Information |
|---|---|
| **Outfall of the Existing STKSTW** | |
| Diffuser | No; Single port discharge |
| Diameter of discharge port | 250 mm |
| Configuration of discharge port | Single port |
| Location of outfall from the nearest coastline | The outfall is located about 200 m away from the coastline. |
| Discharge Depth | 2 m |
| **Outfall of the Expanded STKSTW** | |
| No. of discharge ports in the diffuser | 22 |
| Diameter of discharge port | 125 mm |
| Configuration of discharge port | A total of 11 risers are each 3.5 m separated from each other. There are 2 ports for each riser, each pointing horizontally and located 0.5 m above seabed. Two ports on the same riser are facing 180° with one another. The diffuser line is 45° to the tidal current. |
| Location of diffuser from the nearest coastline | The outfall is located about 200 m away from the coastline. |
| Discharge Depth | 7.2 m |

## 1.3 INPUT VALUES FOR NEAR FIELD MODELLING

The input parameters for near field modelling are summarized below. All the hydrodynamic conditions adopted were derived from the corresponding Delft3D FLOW scenarios.

*Table 1.3 Discharge Parameters Inputs for CORMIX Modelling*

| Parameter | Existing STKSTW | Expanded |
|---|---|---|
| Discharge Type | Refers to *Table 1.2* above | |
| Total discharge flow rate | 1,660 $m^3$/day | 10,000 $m^3$/day |
| Effluent Salinity | 0.1 mg/L | 0.1 mg/L |

*Table 1.4 Ambient Condition Inputs for CORMIX Modelling*

<table>
<tr><th colspan="2" rowspan="3">Parameter</th><th colspan="2">Scenarios</th></tr>
<tr><th>D10 / D50 / D90</th><th>W10 / W50 / W90</th></tr>
<tr><th>Dry season</th><th>Wet season</th></tr>
<tr><td colspan="4">Existing STKSTW</td></tr>
<tr><td rowspan="5">Ambient Conditions</td><td>Ambient Velocity (1)</td><td>D10: 0.0026 m/s<br>D50: 0.0131 m/s<br>D90: 0.0284 m/s</td><td>W10: 0.0020 m/s<br>W50: 0.0134 m/s<br>W90: 0.0291 m/s</td></tr>
<tr><td>Water Depth at discharge outfall</td><td colspan="2">2 m</td></tr>
<tr><td>Average Surface (1) Water Density</td><td>1022.67 kg/m³</td><td>1019.29 kg/m³</td></tr>
<tr><td>Average Bottom (1) Water Density</td><td>1023.01 kg/m³</td><td>1020.66 kg/m³</td></tr>
<tr><td>Ambient Wind Speed</td><td colspan="2">2 m/s<br>(CORMIX's recommended value for conservative design condition)</td></tr>
<tr><td colspan="4">Expanded STKSTW</td></tr>
<tr><td rowspan="5">Ambient Conditions</td><td>Ambient Velocity (1)</td><td>D10: 0.0140 m/s;<br>D50: 0.0391 m/s;<br>D90: 0.0862 m/s.</td><td>W10: 0.0165 m/s;<br>W50: 0.0444 m/s;<br>W90: 0.0908 m/s.</td></tr>
<tr><td>Water Depth at discharge outfall</td><td colspan="2">10 m</td></tr>
<tr><td>Average Surface (1) Water Density</td><td>1021.53 kg/m³</td><td>1019.02 kg/m³</td></tr>
<tr><td>Average Bottom (1) Water Density</td><td>1027.76 kg/m³</td><td>1020.74 kg/m³</td></tr>
<tr><td>Ambient Wind Speed</td><td colspan="2">2 m/s<br>(CORMIX's recommended value for conservative design condition)</td></tr>
</table>

**Note:**

(1) The water density is derived from simulated temperature and salinity from the baseline scenario of the Delft3D FLOW modelling of the corresponding scenario at the outfall locations. Ambient velocity and current direction is also derived from simulation results of Delft3D Flow modelling.

(2) Based on the results of far-field hydrodynamic simulation, the ambient current is close to 45° to the proposed outfall alignment. As such, all CORMIX simulations for the proposed outfall are carried out with 45° ambient current flow.

## 1.4 MODELLING SCENARIOS

The near field dispersion was modelled for combinations of different vertical density profile and ambient current velocity for each outfall locations. Based on the input information above, total of six (6) model runs were carried out for each season as listed below.

*Table 1.5 Summary of Near-field Model Scenarios*

| Scenario ID | Plant | Seasons | Percentile of Current Velocity |
|---|---|---|---|
| D10-1 | Existing STKSTW | Dry Season | 10th |
| D50-1 | | Dry Season | 50th |
| D90-1 | | Dry Season | 90th |
| W10-1 | | Wet Season | 10th |
| W50-1 | | Wet Season | 50th |
| W90-1 | | Wet Season | 90th |
| D10-3 | Expanded STKSTW | Dry Season | 10th |
| D50-3 | | Dry Season | 50th |
| D90-3 | | Dry Season | 90th |
| W10-3 | | Wet Season | 10th |
| W50-3 | | Wet Season | 50th |
| W90-3 | | Wet Season | 90th |

## 2 MODELLING PREDICTIONS

The predicted vertical profiles of effluent plume at the edge of near field region by the CORMIX modelling under various scenarios are presented below in *Table 2.1*.

The modelling results of near field dispersion predicted under the existing STKSTW outfall are presented as follows. As shown in *Table 2.1*, the distance from the discharge port to the edge of mixing zone is predicted to decrease as the ambient current velocity increase. As a results of relatively low water depth, low effluent density, high jet velocity (about 10 cm/s from the port), all effluent plumes are predicted to reach the water surface at the edge of near field region. However, the effluent plume tends to be thicker vertically and spread across the water column vertically under the $10^{th}$-percentile flow condition. The same pattern is observed in both seasons for the existing STKSTW outfall. For near field dispersion of effluent from the proposed outfall, part of the predictions show the same trend as the predictions for the existing STKSTW outfall. As shown in *Table 2.1*, the distance from the discharge port to the edge of mixing zone is predicted to decrease as the ambient current velocity increase. Unlike the cases for the existing outfall, the effluent plume cannot reach the water surface (plume trapped) in wet season for discharge from the proposed outfall. The higher water depth and the density gradient in wet season are considered the major reason for predicted plume trapped in wet season. The effluent plume from the proposed outfall is predicted to locate at the lower portion of the water column (deeper) and the plume thickness is also higher as the ambient current velocity increase. It is expected that the increase in advection and entrainment as the ambient velocity increase leads to thicker plume and decrease in buoyance of the effluent plume (lower plume depth). In comparison, the effect of advection and entrainment is much less significant for discharge from the existing outfall, as a result of very low ambient current velocity (generally one-third of the current velocity at the proposed outfall) and the lack of diffuser (which enhance entrainment by increasing surface area of the effluent plume).

The near field dispersion modelling prediction would be incorporated in the Delft3D WAQ far field modelling as required in paragraph 4 of Appendix D-1 of the EIA Study Brief. Based on the combined results of prediction for discharge from the existing outfall, the top plume level would be 2 m above the seabed level (i.e. water surface) and the bottom plume level would be 1.76 m above the seabed level in dry season. Since in the Delft3D WAQ simulation the whole water column is divided in the 5 layers with relative thickness of 1:2:2:3:2 (from surface to bottom layer), the predicted effluent plume for discharge from the existing outfall in dry season should be put in the surface layer of the water column. Similarly, the average effluent plume is predicted to locate between 1.876 m to 2 m above the seabed for discharge from the existing outfall in wet season and that also corresponds to the surface layer of the Delft3D WAQ model. For the discharge from the proposed outfall in dry season, the average plume would be located between 3.68 m to 7.15 m above seabed level, which is about the upper half of the water column. The pollution loading from effluent would therefore be allocated to the first 3 layers of the water column in the Delft3D WAQ model. In wet season, the average effluent plume from discharge from the proposed outfall would be located between 3.616 m to 5.02 m above seabed level, which corresponds to $4^{th}$ layer of the water column (count from the surface) in the Delft3D WAQ model.

*Table 2.1 Vertical and Horizontal Extent of Effluent Plume at the Edge of Zone of Initial Mixing*

| Plant | Scenarios | Probability | Distance from Discharge Port to the Edge of Near Field Region (m) | Top Level above seabed of Effluent Plume at the Edge of Near Field Region (m below water surface) | Bottom Level above seabed of Effluent Plume at the Edge of Near Field Region (m below water surface) | Effluent Plume Thickness at the Edge of Near Field Region (m) |
|---|---|---|---|---|---|---|
| Existing STKSTW | D10-1 | 0.2 | 841.38 | 2.00 | 1.01 | 0.99 |
| | D50-1 | 0.6 | 84.49 | 2.00 | 1.95 | 0.05 |
| | D90-1 | 0.2 | 14.61 | 2.00 | 1.94 | 0.06 |
| | W10-1 | 0.2 | 401.55 | 2.00 | 1.60 | 0.40 |
| | W50-1 | 0.6 | 36.27 | 2.00 | 1.96 | 0.04 |
| | W90-1 | 0.2 | 5.02 | 2.00 | 1.90 | 0.10 |
| Expanded STKSTW | D10-3 | 0.2 | 1011.08 | 7.15 | 6.52 | 0.63 |
| | D50-3 | 0.6 | 2.57 | 7.15 | 3.58 | 3.57 |
| | D90-3 | 0.2 | 15.37 | 7.15 | 1.14 | 6.01 |
| | W10-3 | 0.2 | 168.31 | 6.31 | 5.68 | 0.62 |
| | W50-3 | 0.6 | 103.94 | 4.84 | 3.56 | 1.28 |
| | W90-3 | 0.2 | 65.00 | 4.29 | 1.72 | 2.57 |
| Existing STKSTW | | | Dry weighted average | 2.00 | 1.760 | 0.240 |
| | | | Wet weighted average | 2.00 | 1.876 | 0.124 |
| Expanded STKSTW | | | Dry weighted average | 7.15 | 3.680 | 3.470 |
| | | | Wet weighted average | 5.02 | 3.616 | 1.408 |