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VIRIDOR
NEAR-FIELD DISCHARGE MODELLING REPORT – RUNCORN CARBON CAPTURE FACILITY

FINAL

VIRIDOR
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APPENDICES

1. INTRODUCTION

1.1 Background

On behalf of Viridor CC Runcorn Limited (‘Viridor’), Fichtner Consulting Engineers Limited (‘Fichtner’) has commissioned Ramboll UK Limited to develop a near-field surface water dispersion model to assess the impact of a discharge to water from a carbon capture facility (the ‘CC facility’) which Viridor is developing on land adjacent to the Runcorn Energy Recovery Facility (ERF) (the ‘Facility’) on Barlow Way, Runcorn in the north west of England.

The CC facility will capture the carbon dioxide (CO_2) produced by the ERF for sequestration. Process effluents generated by the CC facility will be treated in an on-site water treatment plant for re-use as feedwater for the hybrid cooling towers. However, the hybrid cooling towers will generate a blowdown which will require discharge to the Manchester Ship Canal (MSC).

Given the potential for dilution, advection and dispersion to occur in the receiving environment, a mixing zone model is necessary to determine the impact of the discharge of the blowdown from the hybrid cooling towers on the MSC. This is used to verify that potential Constituents of Concern (CoCs) within the discharge will not present a risk to the environment. For this study the CORMIX model, an industry-standard method for the simulation of plume dynamics in the near-field mixing zone (NMZ), has been primarily used as the basis of assessment.

Uncontaminated surface water run-off, collected from building roofs and areas of hardstanding within the CC facility will be collected in the surface water drainage systems, and has not been considered within this report.

1.2 Modelling Approach

The specific objectives of the hydrodynamic modelling are as follows:

1. describe the modelling approach and work conducted to predict the behaviour of likely discharges from the Facility in the receiving environment;
1. describe the spatial footprint of the near-field results and dilution factors achieved in the NMZ; and
2. describe potential movement of the discharge plume in the far-field in semi-quantitative/qualitative terms.

CORMIX is an industry-standard model used in predicting the likely route and trajectory of wastewater discharges from a point source location. In the NMZ, the characteristics of the discharge govern how the discharge plume is likely to mix with receiving water. The primary forces that typically influence hydrodynamics and the movement of wastewater in the receiving environment beyond the NMZ are flow currents, winds and thermal/density stratification. Waves may also occasionally modify movement and influence the behaviour of the plume.

The wastewater discharge will include a combination of chemical pollutants, such as ammoniacal nitrogen and physical parameters, such as temperature, different from baseline conditions in the receiving environment. As described above, the CoCs in the discharge will be related to blowdown from the hybrid cooling towers.

The near-field modelling work described in this report was conducted to simulate the mixing of wastewater discharges with ambient receiving conditions in the MSC and predict a near-field dilution factor. For the purposes of the assessment, potential impacts are based on a delta increase compared with baseline conditions. The intention is to ascertain the distance from the outfall where dilution in an uncontaminated receiving environment would be sufficient to ensure concentrations of each CoC associated with the Facility are below Environmental Quality Standards (EQS) as described in Section 3.1.

Potential plume movements may vary with water depth. Therefore, CORMIX modelling was performed using a 3D approach to simulate the behaviour of mixing, dilution and dispersion conditions of the wastewater discharge in this particular setting. The modelling approach included multiple sensitivity runs to account for uncertainty in input parameters and to establish how these may impact the overall risk assessment.

1.3 Dispersion Model

CORMIX is an industry-standard mixing zone model which is primarily used to determine detailed wastewater plume characteristics within a region close to a source of discharge (0 - 90 m from an outfall). Beyond 90 m from the outfall, model results are less certain. Whilst CORMIX does not include a sophisticated hydrodynamic model to simulate the unsteady (i.e. time-varying) movement of receiving environments, it has the functionality to model discrete hydraulic effects associated with pipe outfalls and diffusers, typically used to aid wastewater dispersion in situations such as this.

2. CORMIX MODEL APPROACH

2.1 CORMIX Model

Effluent discharge modelling was undertaken using the Cornell Mixing Zone Model (CORMIX) Version 12, a 3D dilution model for the definition of discharge plumes. Consistent with its intended use, the CORMIX model was used to model continuous point source discharges with the role of boundary interaction to predict steady-state mixing behaviour and plume geometry close to the outfall location.

Separate calibration of the results of the model has not been possible because there is insufficient data in the near vicinity of the proposed location for the outfall into the MSC. Therefore, it has not been possible to directly verify the model outputs against available water quality information. However, input data has been used to ensure a conservative approach is taken with respect to the model’s predictions.

Data on the proposed discharge via the existing outfall has been obtained from several sources as presented in Table 2.1. Hydrodynamics, concentrations of selected constituent parameters and dispersion have been evaluated using the following input parameters (a range of representative conditions):

Table 2.1: Modelling Input Parameters

Parameter	Data Used	Source
Outfall (port) location	bankside	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Port alignment	perpendicular to shore	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Number of ports	1	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Port diameter	1,000 mm	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Port angle	0°	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Port height	0 m	BIS Industrial Services Drawing No. PPPD1020062/3/61/00002 (via Viridor)
Average depth of canal in vicinity of outfall	5 - 9 m	Information unavailable - range of depths tested
Depth at discharge	5 - 9 m	Information unavailable - range of depths tested
Average width of canal	58 m	Calculated using GIS
Range of velocities	0.05 - 0.1 m/s	Information unavailable - range of depths tested
Range of wind speeds	3 - 6 m/s	Met Office
Density	1,002 kg/m3	Environment Agency (EA)
Effluent density	1,000 kg/m3 (winter) and 998 kg/m3 (summer)	Fichtner
Manning's roughness (n)	0.018	Conveyance Estimation System

Different effluent flow scenarios were tested - these are discussed in Section 3.5. Further information on all input data is provided in the Section 3 of this report. For the purposes of near-field modelling, ambient flow currents were modelled as unidirectional and steady-state.

3. INPUT DATA

3.1 Effluent Concentrations

Effluent water quality data were provided by Fichtner as presented in Table 3.1:

Table 3.1: Excess Concentrations of CoCs/Physical Parameters in Effluent Discharges

CoC	Units	Effluent Concentration/ Temperature Excess	
		Average Concentrations (long-term)	Maximum Concentrations (short-term)
Antimony	mg/l	0.00014	0.00021
Arsenic	mg/l	0.00013	0.00021
Cadmium	mg/l	0.00021	0.00039
Chromium	mg/l	0.00264	0.00764
Cobalt	mg/l	0.00008	0.00017
Copper	mg/l	0.00130	0.00355
Lead	mg/l	0.00184	0.00502
Manganese	mg/l	0.00075	0.00194
Mercury	mg/l	0.00066	0.00162
Nickel	mg/l	0.00256	0.00812
Thallium	mg/l	0.00018	0.00023
Vanadium	mg/l	0.00011	0.00014
NH_3 (Ammonia)	mg/l	0.04856	0.20086
Temperature	°C	20	20

Table 3.2 presents the relevant water quality standards - annual average concentrations (long term) and maximum allowable concentrations (short term) - for the above constituents, where they are available, as provided by Fichtner:

Table 3.2: Water Quality Standards

CoC	Units	Effluent Concentration/ Temperature Excess	
		Average Concentrations (long-term)	Maximum Allowable Concentrations (short-term)
Antimony	mg/l	-	-
Arsenic	mg/l	0.025	0.025
Cadmium	mg/l	0.0002	0.00044
Chromium	mg/l	0.0006	0.032
Cobalt	mg/l	0.003	0.1
Copper	mg/l	0.0036	0.0036
Lead	mg/l	0.0013	0.014
Manganese	mg/l	0.05	0.05
Mercury	mg/l	0.00007	0.00007
Nickel	mg/l	0.0086	0.034
Thallium	mg/l	-	-
Vanadium	mg/l	0.1	0.1
NH_3 (Ammonia)	mg/l	0.02	0.02
Temperature	°C	-	-

For many of the CoCs, concentrations in the discharge are predicted to be below the relevant water quality standards (highlighted green in Table 3.3). Water quality standards were not available for certain COCs (highlighted yellow in Table 3.3). Therefore, these were not carried forward for CORMIX modelling – only Ammonia and Mercury were modelled.

Table 3.3: Comparison of Predicted Excess Concentrations Against Water Quality Standards

CoC	Units	Effluent Concentration/ Temperature Excess	
		Average Concentrations (long-term)	Maximum Concentrations (short-term)
Antimony	mg/l	0.00014	0.00021
Arsenic	mg/l	0.00013	0.00021
Cadmium	mg/l	0.00021	0.00039
Chromium	mg/l	0.00264	0.00764
Cobalt	mg/l	0.00008	0.00017
Copper	mg/l	0.00130	0.00355
Lead	mg/l	0.00184	0.00502
Manganese	mg/l	0.00075	0.00194
Mercury	mg/l	0.00066	0.00162
Nickel	mg/l	0.00256	0.00812
Thallium	mg/l	0.00018	0.00023
Vanadium	mg/l	0.00011	0.00014
NH_3 (Ammonia)	mg/l	0.04856	0.20086
Temperature	°C	20	20

The modelling was used to determine the distance from the point of discharge into the MSC where the simulated concentrations of each of the unhighlighted CoCs would meet water quality standards. All CoCs were modelled in CORMIX as 'Conservative Pollutants'.

3.2 Compliance Points and Mixing Zones

As effluent discharges, it forms a plume and, where the density of that plume is less than the receiving environment, this rises towards the surface. The plume becomes entrained within the receiving water environment and mixing occurs, diluting the plume as it continues to move. The extent to which this occurs varies dependent on a range of parameters for both the discharge and ambient conditions.

Ramboll understands that a compliance point for effluent discharges from the CC facility has not been provided or previously discussed with the EA. Where dilution in the receiving environment is accepted as a means of achieving environmental water quality standards, compliance points are set some distance from where the effluent plume interacts with the surface. The extent of excess above ambient conditions that are acceptable to avoid impact varies dependent on the CoCs being considered, options for treatment, re-use etc. Nevertheless, the modelling provides calculations of the distances over which dilution may be achieved.

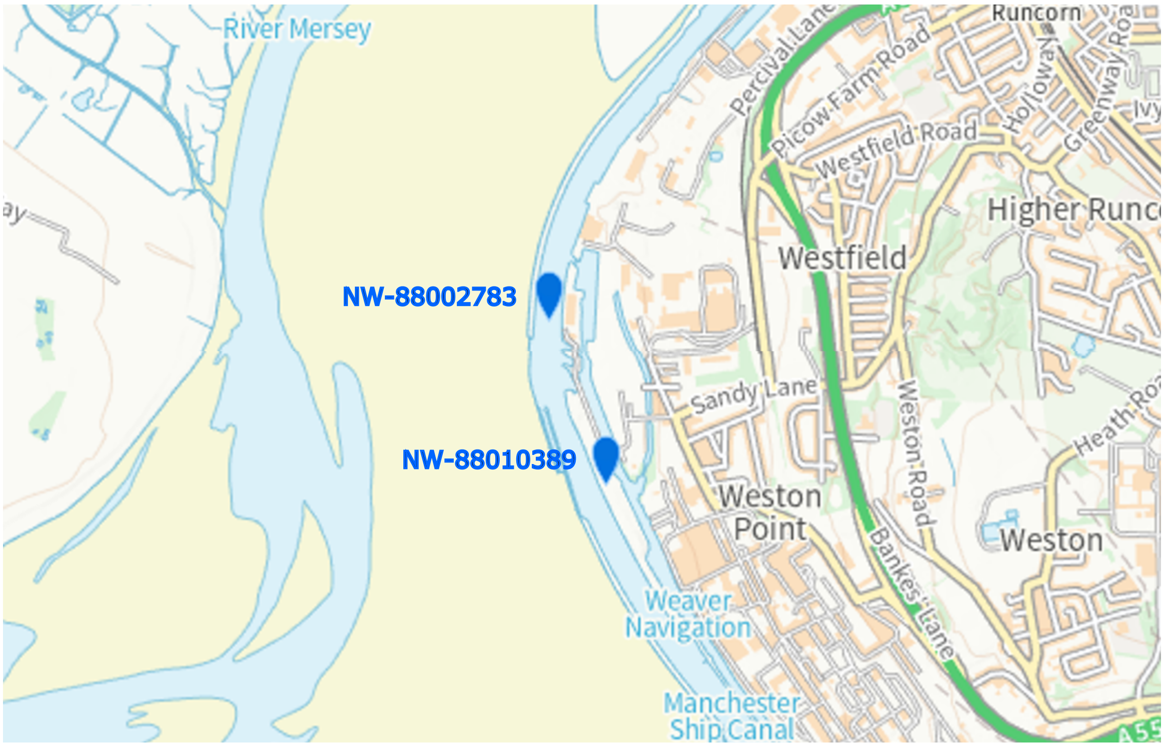
For the purpose of this study, the evaluation of plume characteristics has been done by means of determining:

- At what point plume concentrations within the receiving environment would be below water quality standards; and
- (where applicable) excess concentrations/temperature at 90 m from the outfall.

3.3 Background Water Quality Data

Water quality data is available from the EA's Water Quality Archive[1]. Water quality parameter datasets provided for each location are variable in the number of parameters and regularity of analysis. Most locations have data for temperature, pH and salinity. Some locations also have data for additional parameters such as metals, solvents and pesticides. The locations where data have been obtained (MSC Weston Point Dock, sampling point ID NW-88002783 and Weston Canal Weston Point Runcorn, sampling point ID NW-88010389) are presented in Figure 3.1.

Figure 3-1: EA Water Monitoring Locations



A summary of the EA's data for these two locations is provided in the following sub-sections.

MSC Weston Point Dock

Table 3.4 presents available water data for the MSC Weston Point Dock. Data applicable to the CoCs likely to be present in the discharge from the facility for background water quality are available for lead (data provided for dissolved Pb), NH_3 (ammonia) (data provided for ammoniacal nitrogen as N) and temperature as presented in Table 3.4.

Table 3.4: EA Water Quality Monitoring (NW-88002783)

CoC	Units	Average	Minimum	Maximum
Lead	mg/l	<0.001	<0.001	2.22
NH3 (Ammonia)	mg/l	1.12	<0.03	3.16
Temperature	°C	12.9	3.5	23.4

[1] Environment Agency, *Water Quality Archive*. Available online at: https://environment.data.gov.uk/water-quality (Accessed July 2023).

Weston Canal Weston Point Runcorn

Table 3.5 presents available water data for the Weston Canal Weston Point Runcorn. Data for background water quality are available for mercury (data provided for dissolved Hg), copper (data provided for dissolved Cu), NH_3 (ammonia) (data provided for ammoniacal nitrogen as N) and temperature.

Table 3.5: EA Water Quality Monitoring (NW-88010389)

CoC	Units	Average	Minimum	Maximum
Mercury	mg/l	0.00017	0.00001	0.00515
Copper	mg/l	0.0054	0.0033	0.0162
NH3 (Ammonia)	mg/l	1.34	<0.03	2.58
Temperature	°C	14.3	4.4	27.4

EA data (salinity and temperature) for these locations was also used to estimate ambient density as a non-freshwater uniform average of 1,002 kg/m^3. As would be expected, this is denser than the effluent discharge given the likely temperature difference.

3.4 Outfall Arrangement

Subject to agreement with Inovyn (which also discharges via the same outfall), the discharge would be made via an existing discharge point (or similar arrangement). Based on design drawings provided by Viridor for the existing discharge point, the existing outfall arrangement appears to be a discharge into a flooded chamber that connects via a 1,000 mm pipe below the water level in the MSC into another flooded chamber adjacent to the bank of the MSC before entering the MSC. Therefore, this system allows for mixing of the effluent with water from the MSC prior to discharge into the aquatic environment.

CORMIX cannot fully represent the specific nature of this outfall arrangement so its representation in the model has been simplified, with a view to ensuring conservative assumptions are made. As the outfall pipe is 1,000 mm and is flooded by the backflow, the outfall has been submerged in CORMIX. With very weak ambient flows in the MSC (see Section 3.8), water from the MSC is able to intrude into the outfall (a sub-optimal arrangement for mixing). This nevertheless reflects the nature of the outfall design.

No data was available for other flows via this pipe (e.g. discharges from Inovyn). Therefore, the CORMIX modelling has conservatively only considered the flows associated with the discharge from the CC facility. This is considered a conservative assumption as a low rate of effluent discharge plus ambient intrusion into the pipe are not conducive to mixing.

3.5 Effluent Flows

Discharges from the CC facility would be made at rates between 0.01 m^3/s (average) and 0.015 m^3/s (maximum) based on information provided by Fichtner. These rates of flow were applied when considering average and maximum concentrations of CoCs in the discharge.

3.6 Wind Speed

Wind speeds were varied between 3 metres per second (m/s) and 6 m/s. Sensitivity testing was carried out to see the impact of changes in this parameter (Section 4).

3.7 Bathymetry

No bathymetric data was available for the MSC but it is known that depths vary between 5 – 9 m to allow for navigation. The depth was subject to sensitivity testing as described in Section 4.

3.8 Ambient Flow Velocity

Flow velocities along the MSC are not known. Although likely to be in hydraulic continuity with the downstream limits of the River Weaver, and the Weaver Navigation Channel, flow velocities are expected to be very low. Water levels across the area are kept at a steady height through inflows along the length of the MSC. These inflows include direct rainfall, the River Weaver, other smaller watercourses, groundwater ingress, transfers from other sections of the canal and direct discharges from other industrial sites.

Outflows are understood to be via losses through the bed and banks of the canal as well as overflows located along the length of the linked canal network including at Eastham Locks, more than 10 km to the west of the CC facility, where the MSC meets the estuary of the River Mersey. Leakages at sluices and locks are also understood to be significant and other losses will include direct evaporation and abstractions from adjacent sites. The mechanisms of inflows and outflows will dictate the rate and timing of ambient flows within the canal.

CORMIX cannot model ambient conditions where there is zero flow i.e. a completely stagnant receiving water environment. To be conservative, the model was run with the lowest possible flow rates in the receiving environment with sensitivity tests carried out on ambient flow velocities between 0.01 m/s and 0.2 m/s.

3.9 Manning's 'n'

The Manning's 'n' parameter provides the bed roughness for the CORMIX model. The Conveyance Estimation System (CES) software tool was used to provide a range of roughness suitable for the canal.

The CES provides a comprehensive database of river roughness, integrating diverse information from over 700 references, including photographs (linked to a nationwide river habitat survey) and advice on vegetation cutting and regrowth. The software was developed and maintained by the EA, Scottish Government, Northern Ireland Rivers Agency, HR Wallingford and JBA Project Team.

The canal bed is likely to be characterised largely by silt. The CES tool recommended a 0.018 Manning's 'n' roughness value (lower 0.015, upper 0.022). The model was not considered especially sensitive to roughness parameters.

4. SENSITIVITY TESTING

4.1 Overview

Initial sensitivity testing was completed to understand how the variability of input parameters could affect modelling results. Additional sensitivity testing to determine how variability in the concentrations of CoCs may affect the results is presented in Section 5.

The main input parameters with uncertainty were as follows:

- Average depth of canal = 5 - 9 m;
- Range of ambient velocities = 0.01 - 0.015 m/s;
- Effluent density = 998 kg/m^3 (summer) – 1,000 kg/m^3 (winter); and
- Wind speed = 3 – 6 m/s.

For sensitivity testing, a dummy discharge concentration of a non-specific conservative pollutant was input to the model with a concentration of 1 mg/l. This was then compared with a theoretical water quality standard set at 0.1 mg/l with background concentrations set at 0 mg/l. Input parameters as listed in Section 2.1 and in Section 3 were used for all other parameters. These tests do not use effluent concentrations associated with the potential site discharge and have no bearing on the results described in Section 5 other than to help determine appropriate input parameters where they may be subject to error.

4.2 Base Case

The base case by which other parameters were compared using the following input parameters:

- Average depth of canal = 7 m;
- Ambient velocity = 0.01 m/s;
- Effluent density = 1,000 kg/m^3; and
- Wind speed = 3 m/s.

The results of this initial model run indicated that, due in part to the slow-moving nature of the MSC, mixing through the entire depth of the channel occurs near instantaneously (Coanda Attachment) and there is a strong interaction with the bank and outfall itself. For the base case (Sensitivity Test 1), the concentration of the dummy discharge reaches the theoretical water quality standard of 0.1 mg/l at 7.97 m from the outfall.

4.3 Ambient Depth

Reducing the depth of ambient conditions in the canal from 7 m to 5 m (Sensitivity Test 2), changes the distance for the dummy discharge to reach the theoretical water quality standards from 7.97 m to 12.26 m. Increasing the depth of ambient conditions in the canal from 7 m to 9 m (Sensitivity Test 3), changes the distance for effluent to reach the theoretical water quality standards from 7.97 m to 0.89 m.

4.4 Ambient Velocity

Increasing the rate of ambient velocities in the canal from 0.01 m/s to 0.015 m/s (Sensitivity Test 4), reduces the distance from 7.97 m to 6.4 m.

4.5 Winter/Summer Discharge Rates and Effluent Densities

Reducing the density of the effluent to 998 kg/m^3 to reflect the difference between winter and summer discharge conditions (Sensitivity Test 5) reduces the distance from 7.97 m to 4.69 m.

4.6 Wind Conditions

Increasing the wind speed from 3 m/s to 10 m/s (Sensitivity Test 6) reduces the distance for from 7.97 m to 1.3 m.

4.7 Summary

Table 4.1 presents the results of the various sensitivity tests in terms of the distance to reach the theoretical water quality standard compared to the base case (Sensitivity Test 1) in m and as a percentage of the base case:

Table 4.1: Sensitivity Test Results

Difference	Sensitivity Test 1 (base case)	Sensitivity Test 2 (ambient depth decrease)	Sensitivity Test 3 (ambient depth increase)	Sensitivity Test 4 (ambient velocity increase)	Sensitivity Test 5 (summer density)	Sensitivity Test 6 (wind speed)
m	-	+4.29	-7.08	-1.57	-3.28	-6.67
%	-	154%	11%	80%	59%	16%

With the exception of decreasing the depth of the ambient environment, all of the sensitivity tests result in an improved situation (shorter distance to achieve compliance) relative to the base case. Therefore, it is concluded that the base case provide a conservative assumption and has been adopted for modelling purposes. An allowance for uncertainty in ambient depths is also considered in the analysis of the results.

5. MODEL RESULTS

5.1 Mixing Zone Criteria

The specific model outputs to meet the objectives of this study are to:

1. describe the spatial footprint of the NMZ;
2. find dilution factors achieved within the NMZ;
3. find temperature change within the NMZ; and
4. describe potential movement of the discharge plume in the far-field in semi-quantitative/qualitative terms (where applicable).

5.2 Near-field

The findings from the near-field modelling are presented in Table 5.1 and provide the distances for CoCs to meet the relevant water quality standards (from Table 3.2). Full CORMIX outputs are available upon request (example output is presented in Appendix A).

Table 5.1: Distances to Achieve Compliance with Water Quality Standards

CoC	Units	Average (long-term) Concentration in Discharge	Maximum (short-term) Concentration in Discharge	Water Quality Standard Concentration (Annual EQS - long-term)	Water Quality Standard Concentration (Maximum Allowable - short-term)	Distance to Achieve Compliance (m) long term	Distance to Achieve Compliance (m) short term
Antimony	mg/l	0.00014	0.00021	-	-	-	-
Arsenic	mg/l	0.00013	0.00021	0.025	0.025	-	-
Cadmium	mg/l	0.00021	0.00039	0.0002	0.00044	0.18	-
Chromium	mg/l	0.00264	0.00764	0.0006	0.032	0.34	-
Cobalt	mg/l	0.00008	0.00017	0.003	0.1	-	-
Copper	mg/l	0.00130	0.00355	0.0036	0.0036	-	-
Lead	mg/l	0.00184	0.00502	0.0013	0.014	0.21	-
Manganese	mg/l	0.00075	0.00194	0.05	0.05	-	-
Mercury	mg/l	0.00066	0.00162	0.00007	0.00007	0.53	22.81
Nickel	mg/l	0.00256	0.00812	0.0086	0.034	-	-
Thallium	mg/l	0.00018	0.00023	-	-	-	-
Vanadium	mg/l	0.00011	0.00014	0.1	0.1	-	-
NH3 (Ammonia)	mg/l	0.04856	0.20086	0.02	0.02	0.26	0.50

For the majority of CoCs, input concentrations are already below the relevant water quality standards (green highlighted cells). For those where the concentrations are above water quality standards within the discharge, all achieve compliance with water quality standards within 1 m of the outfall with the exception of the maximum concentration of mercury.

Applying the maximum potential sensitivity increase percentage (Table 4.1, Sensitivity Test 2) to the maximum distance for average conditions (mercury – 0.53 m), results in a potential range of 0.53 m to 0.82 m (i.e. remaining less than 1 m).

5.3 Sensitivity to Changes in Average Concentrations

A further set of sensitivity tests was undertaken to analyse the potential effect of unexpected increases in the concentration of CoCs. This was done by increasing the average concentrations for cadmium, chromium, lead, mercury and ammonia by 25% to see what impact it would have on the distance to achieve compliance. The results of these tests are presented in Table 5.2.

Table 5.2: Sensitivity to Changes in CoCs Concentrations

CoC	Units	Average (long-term) Concentration in Discharge (125%)	Water Quality Standard Concentration (Annual EQS - long-term)	Distance to Achieve Compliance (m)	Difference with Results from Table 5.2 (m)
Cadmium	mg/l	0.0002625	0.0002	0.2	+0.02
Chromium	mg/l	0.0033	0.0006	0.38	+0.04
Lead	mg/l	0.0023	0.0013	0.23	+0.02
Mercury	mg/l	0.000825	0.00007	1.86	+1.33
NH3 (Ammonia)	mg/l	0.0607	0.02	0.29	+0.03

In most cases, the change in distance is negligible. With mercury, where the discharge concentrations are greater relative to water quality standards than for the other CoCs, the distance increases to a greater extent (>1m). However, compliance is still achieved within 2 m of the discharge point. Even if the maximum sensitivity allowance from increasing concentrations of CoCs for mercury is applied (distance to achieve compliance = 1.86 m) to the maximum sensitivity allowance from potential uncertainty in the depth of ambient water (+154%), the resultant distance to achieve compliance (1.86 * 1.54 = 2.86 m) remains very close to the point of discharge.

5.4 Far-field

Based on the results of the near-field modelling, mixing of the plume within the NMZ is considered to be significant and would result in dilution for all of the CoCs such that concentrations would be compliant with water quality standards within 25 m of the discharge point. For the majority, compliance is reached much closer to the discharge point (<1 m). Therefore, consideration of mixing in the far field is not applicable as compliance is reached in the near-field (<90 m from the outfall).

6. SUMMARY AND CONCLUSIONS

On behalf of Viridor, Fichtner has commissioned Ramboll UK Limited to develop a near-field surface water dispersion model to assess the impact of a discharge to water from a CC facility which Viridor is developing on land adjacent to the Facility.

The CC facility will capture the CO_2 produced by the ERF for sequestration. Process effluents generated by the CC facility will be treated in an on-site water treatment plant for re-use as feedwater for the hybrid cooling towers. However, the hybrid cooling towers will generate a blowdown which will require discharge to the Manchester Ship Canal (MSC).

The discharge will include a combination of chemical pollutants, such as ammoniacal nitrogen and physical parameters, such as temperature, different from baseline conditions in the receiving environment, referred to as Constituents of Concern (CoCs). Post-treatment, a comparison of concentrations of these CoCs with the relevant water quality standards indicates that the majority will meet these standards prior to discharge and will not therefore present a risk to the receiving environment.

For those CoCs where the concentrations of pollutants within the effluent are above the relevant water quality standards, the potential impact on receiving waters (tailored to the specific characteristics of the discharge and receiving water) has been assessed to further evaluate the discharge. This has been completed using the CORMIX model, an industry-standard method for the simulation of plume dynamics in the near-field mixing zone (NMZ).

For cadmium, chromium, lead and ammonia, the results of CORMIX modelling (accounting for uncertainty in input parameters) show that water quality standards would be met rapidly within the receiving environment (<1 m from the point of discharge into the MSC). These results do not change significantly even if concentrations are increased by 25%.

For mercury, CORMIX modelling suggest that under average conditions, water quality standards would also be met relatively rapidly upon entering the MSC (<5 m from the point of discharge). Using the short-term, maximum allowable concentrations, the distance to achieve compliance with the water quality standard may increase to approximately 23 m. However, this is well within the usual range of what is considered the Near-field Mixing Zone (NMZ) which, for CORMIX modelling, is usually defined as approximately 90 m from the point of initial mixing.

On the basis of the analysis and modelling completed (including sensitivity testing and the adoption of conservative model parameters), the proposed discharge concentrations are unlikely to result in impacts to the receiving environment because water quality standards would be met within a relatively short distance from the point of discharge into the MSC without further treatment.

APPENDIX A

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CORMIX SESSION REPORT:
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                      CORMIX MIXING ZONE EXPERT SYSTEM
                          CORMIX Version 12.0G
                       HYDRO1:Version-12.0.0.0  December,2020
SITE NAME/LABEL:                Viridor Runcorn ERF
  DESIGN CASE:                  Viridor Runcorn Sens Test 1
  FILE NAME:                    C:\Users\sgaskell\OneDrive -
  Ramboll\Documents\Viridor\CORMIX\VIR MSC Hg Ave A.prd
  Using subsystem CORMIX1:     Single Port Discharges
  Start of session:             06/04/2024--13:34:52
******************************************************************************
SUMMARY OF INPUT DATA:
------------------------------------------------------------------------------
AMBIENT PARAMETERS:
  Cross-section                              = bounded
  Width                           BS         = 58 m
  Channel regularity              ICHREG = 2
  Ambient flowrate                QA         = 4.06 m^3/s
  Average depth                   HA         = 7 m
  Depth at discharge              HD         = 6.99 m
  Ambient velocity                UA         = 0.01 m/s
  Darcy-Weisbach friction factor  F          = 0.0133
    Calculated from Manning's n              = 0.018
  Wind velocity                   UW         = 3 m/s
  Stratification Type             STRCND = U
  Surface density                 RHOAS  = 1002 kg/m^3
  Bottom density                  RHOAB  = 1002 kg/m^3
------------------------------------------------------------------------------
DISCHARGE PARAMETERS:             Single Port Discharge
  Nearest bank                               = left
  Distance to bank                DISTB  = 0 m
  Port diameter                   D0         = 1 m
  Port cross-sectional area       A0         = 0.7854 m^2
  Discharge velocity              U0         = 0.01 m/s
  Discharge flowrate              Q0         = 0.01 m^3/s
  Discharge port height           H0         = 2 m
  Vertical discharge angle        THETA  = 0 deg
  Horizontal discharge angle      SIGMA  = 0 deg
  Discharge temperature (freshwater)         = 20 degC
  Corresponding density           RHO0   = 998.2051 kg/m^3
  Density difference              DRHO   = 3.7949 kg/m^3
  Buoyant acceleration            GP0    = 0.0371 m/s^2
  Discharge concentration         C0     = 0.00066 mg/l
  Surface heat exchange coeff.    KS     = 0 m/s
  Coefficient of decay            KD     = 0 /s
------------------------------------------------------------------------------
DISCHARGE/ENVIRONMENT LENGTH SCALES:
  LQ  = 0.89 m          Lm  = 1.13 m         Lb  = 371.41 m
  LM  = 0.06 m          Lm' = 99999 m         Lb' = 99999 m
------------------------------------------------------------------------------
NON-DIMENSIONAL PARAMETERS:
  Port densimetric Froude number  FR0    = 0.07
  Velocity ratio                  R      = 1.27
------------------------------------------------------------------------------
MIXING ZONE / TOXIC DILUTION ZONE / AREA OF INTEREST PARAMETERS:
  Toxic discharge                            = no
  Water quality standard specified           = yes
  Water quality standard          CSTD   = 0.00007 mg/l
  Regulatory mixing zone                     = yes
  Regulatory mixing zone specification       = distance
  Regulatory mixing zone value               = 200 m (m^2 if area)
  Region of interest                         = 1000 m
******************************************************************************
HYDRODYNAMIC CLASSIFICATION:
  *------------------------*
  | FLOW CLASS   = H3 |
  *------------------------*
  This flow configuration applies to a layer corresponding to the full water
  depth at the discharge site.
  Applicable layer depth = water depth = 6.99 m
```

```
  Limiting Dilution S = (QA/Q0)+ 1.0 = 407.0

*****************************************************************************
MIXING ZONE EVALUATION (hydrodynamic and regulatory summary):

-----------------------------------------------------------------------------
X-Y-Z Coordinate system:
  Origin is located at the BOTTOM below the port/diffuser center:
    0 m from the left bank/shore.
  Number of display steps NSTEP = 10 per module.
-----------------------------------------------------------------------------
NEAR-FIELD REGION (NFR) CONDITIONS :
Note: The NFR is the zone of strong initial mixing.  It has no regulatory
  implication.  However, this information may be useful for the discharge
  designer because the mixing in the NFR is usually sensitive to the
  discharge design conditions.
  Pollutant concentration at NFR edge  c = 0 mg/l
  Dilution at edge of NFR              s = 180.1
  NFR Location:                        x = 77.77 m
    (centerline coordinates)           y = 0 m
                                       z = 6.99 m
  NFR plume dimensions:  half-width (bh) = 154.40 m
                          thickness (bv) = 0.58 m
  Cumulative travel time:       7740.2090 sec.
-----------------------------------------------------------------------------
Buoyancy assessment:
  The effluent density is less than the surrounding ambient water
  density at the discharge level.
  Therefore, the effluent is POSITIVELY BUOYANT and will tend to rise towards
  the surface.
-----------------------------------------------------------------------------
UPSTREAM INTRUSION SUMMARY:
Plume exhibits upstream intrusion due to low ambient velocity or strong
  discharge buoyancy.
  Intrusion length                        =  110.52 m
  Intrusion stagnation point              =  -109.95 m
  Intrusion thickness                     =  0.48 m
  Intrusion half width at impingement     =  154.40 m
  Intrusion half thickness at impingement =  0.58 m

  In this case, the UPSTREAM INTRUSION IS VERY LARGE, exceeding ten (10)
    times the local water depth.
  This may be caused by the small ambient velocity, perhaps in combination
    with the strong buoyancy of the effluent, or alternatively, a strong
    ambient stratification.
  If the ambient conditions are quite unsteady (e.g. tidal), then the
    CORMIX steady-state predictions of the upstream intrusion are probably
    unrealistic.  The plume predictions in the immediate near-field, prior
    to the intrusion layer formation, are acceptable, however.
-----------------------------------------------------------------------------
PLUME BANK CONTACT SUMMARY:
  Plume in bounded section does not contact bank.
*********************** TOXIC DILUTION ZONE SUMMARY ***********************
No TDZ was specified for this simulation.
******************** REGULATORY MIXING ZONE SUMMARY ***********************
An RMZ was specified but its boundary was not encountered within the
  predicted plume region.
In a subsequent analysis, use an ROI that extends further downstream.
But:
The ambient water quality standard was encountered at the following
  plume position:
  Water quality standard                 = 0.00007  mg/l
  Corresponding dilution               s = 9.4
  Plume location:                      x = 0.53 m
    (centerline coordinates)           y = 0 m
                                       z = 6.04 m
  Plume dimension:       half-width (bh) = 0.50 m
******************** FINAL DESIGN ADVICE AND COMMENTS *********************

INTRUSION OF AMBIENT WATER into the discharge opening will occur!
```

For the present discharge/environment conditions the discharge densimetric Froude number is well below unity. This is an UNDESIRABLE operating condition.

To prevent intrusion, change the discharge parameters (e.g. decrease the discharge opening area) in order to increase the discharge Froude number.

In a future iteration, change the discharge parameters (e.g. decrease port diameter) in order to increase the Froude number.

REMINDER: The user must take note that HYDRODYNAMIC MODELING by any known technique is NOT AN EXACT SCIENCE.
Extensive comparison with field and laboratory data has shown that the CORMIX predictions on dilutions and concentrations (with associated plume geometries) are reliable for the majority of cases and are accurate to within about +-50% (standard deviation).
As a further safeguard, CORMIX will not give predictions whenever it judges the design configuration as highly complex and uncertain for prediction.