

Cooling water availability

Synthesis for 4 potential locations



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Summary

The Ministry of Economic Affairs has asked Deltares to prepare a synthesis report on cooling water. This synthesis report evaluates the expected impacts of climate change on cooling water availability and compliance with CIW temperature criteria for four potential nuclear power plant locations in the Netherlands: Borssele, Terneuzen, Eemshaven and Maasvlakte. The evaluation combines existing modelling results with projected increases in ambient water temperature under different climate scenarios.

The results show that climate change affects thermal conditions at all locations. Increasing background water temperatures lead to a gradual reduction in the available thermal discharge capacity, ultimately resulting in non-compliance with the applicable criteria. The projected timing of non-compliance varies between locations and climate scenarios, with estuarine systems generally showing non-compliance around 2050 for conservative background temperatures and around 2070 for realistic background temperatures, while coastal conditions at Eemshaven may become limiting as early as 2035.

The analysis of this synthesis demonstrates that the results are not only driven by climate change but are also highly sensitive to methodological assumptions. The definition of background temperature and the method used to quantify mixing zone percentage can shift the projected timing of non-compliance by 5 to 20 years.

In addition, the analysis shows that the specific intake and outfall configuration can have a substantial influence on the results. For example at Eemshaven, compliance with the coastal criterion is highly dependent on the design of the outfall (e.g., outfalls higher or lower in the water column) and the interpretation of the CIW criterion. No outfall design was available at the start of the cooling-water availability analysis, nor were any design optimisations assessed. Based on expert judgement, it is estimated that design optimisation of the outfall could delay the moment of non-compliance by a maximum of approximately 10–20 years. Nevertheless, given the shallow waters near the outfall and the cumulative effects of neighbouring cooling water discharges, non-compliance of a cooling water outfall near Eemshaven is therefore expected sooner than at the other potential sites. However, no optimisation of designs has been considered in this synthesis.

Overall, the findings should be interpreted as indicative. The evaluation is intended to provide insight into the relative behaviour of the plant locations under climate change and to identify key sensitivities and constraints. Nevertheless, they aim to provide a basis to support further decision-making by the authorities on the feasibility and location selection for the nuclear power plant developments in The Netherlands.

Below, the summary tables for the different sites are presented, showing the projected year of non-compliance with the estuarine CIW criteria when climate change is taken into account.

Summary Borssele

This table summarises the projected year of non-compliance with the estuarine CIW criteria when climate change is taken into account. It includes all sensitivity tests presented in this report.

Climate scenario	Typical or Maximum criterion	Background temperature	Year of exceedance
SSP245	Typical	Realistic	2100+
		Conservative	2065 - 2070
	Maximum	Realistic	2100+
		Conservative	2055 - 2060
SSP370 (approx.)	Typical	Realistic	2085 - 2090
		Conservative	2055 - 2060
	Maximum	Realistic	2080 - 2085
		Conservative	2050 - 2055
SSP585	Typical	Realistic	2075 - 2080
		Conservative	2055 - 2060
	Maximum	Realistic	2070 - 2075
		Conservative	2050 - 2055

Summary Terneuzen

This table summarises the projected year of non-compliance with the estuarine CIW criteria when climate change is taken into account. It includes all sensitivity tests presented in this report.

Climate scenario	Typical or Maximum criterion	Background temperature	Year of exceedance
SSP245	Typical	Realistic	2090 - 2095
		Conservative	2055 - 2060
	Maximum	Realistic	2080 - 2085
		Conservative	2045 - 2050
SSP370 (approx.)	Typical	Realistic	2070 - 2075
		Conservative	2050 - 2055
	Maximum	Realistic	2070 - 2075
		Conservative	2045 - 2050
SSP585	Typical	Realistic	2065 - 2070
		Conservative	2045 - 2050
	Maximum	Realistic	2060 - 2065
		Conservative	2045 - 2050

Summary Eemshaven (estuarine)

This table summarises the projected year of non-compliance with the estuarine CIW criteria when climate change is taken into account. It includes all sensitivity tests presented in this report.

Climate scenario	Typical or Maximum criterion	Background temperature	Year of exceedance	Year of exceedance Eems location 2 or 3	Year of exceedance Eems location 2 or 3 and no RWE E
SSP245	Typical	Realistic	2085 - 2090	2080 - 2085	2090 - 2095
		Conservative	2070 - 2075		
	Maximum	Realistic	2075 - 2080		
		Conservative	2060 - 2065		
SSP370 (approx.)	Typical	Realistic	2070 - 2075	2065 - 2070	2070 - 2075
		Conservative	2060 - 2065		
	Maximum	Realistic	2065 - 2070		
		Conservative	2055 - 2060		
SSP585	Typical	Realistic	2060 - 2065	2060 - 2065	2065 - 2070
		Conservative	2055 - 2060		
	Maximum	Realistic	2060 - 2065		
		Conservative	2050 - 2055		

Summary Eemshaven (coastal)

This table summarises the projected year of non-compliance with the coastal CIW criteria when climate change is taken into account. It includes all sensitivity tests presented in this report.

Climate scenario	Background temperature	Year of exceedance	Year of exceedance Eems location 2 or 3	Year of exceedance Eems location 2 or 3 and no RWE E
SSP245	Realistic	2030 - 2035	2065 - 2070	2080 - 2085
	Conservative	2020 - 2025	-	-
SSP370 (approx.)	Realistic	2030 - 2035	2060 - 2065	2065 - 2070
	Conservative	2020 - 2025	-	-
SSP585	Realistic	2030 - 2035	2055 - 2060	2060 - 2065
	Conservative	2020 - 2025	-	-

Summary Maasvlakte

This table summarises the projected year of non-compliance with the coastal CIW criteria when climate change is taken into account. It includes all sensitivity tests presented in this report.

Climate scenario	Background temperature	Year of exceedance
SSP245	Realistic	2085 - 2090
	Conservative	2055 - 2060
SSP370 (approx.)	Realistic	2070 - 2075
	Conservative	2050 - 2055
SSP585	Realistic	2065 - 2065
	Conservative	2050 - 2055

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1 Introduction

1.1 Background

The Dutch government is exploring the development of a second nuclear power plant and has identified four potential locations. Deltares has carried out detailed modelling studies to assess the availability of cooling water at each of these sites.

These studies assessed cooling water availability from both an operational perspective (the ability to reliably supply sufficient cooling water for plant operation) and an environmental perspective (the potential impacts of heat discharge on the surrounding water system) for the candidate locations. To support this assessment and provide input for environmental evaluations, Deltares conducted numerical modelling studies to obtain an initial estimate of the cooling water capacity and to explore possible configurations for the cooling water intake and outfall systems. The modelling studies provided an initial assessment under present-day conditions. However, the potential long-term effects of climate change, such as increases in water temperature and their implications for compliance with thermal discharge regulations, were not yet included in the requested scope of these earlier studies.

The Ministry of Economic Affairs and Climate (EZK) has requested Deltares to carry out a synthesis by combining results from the available studies. The aim of this synthesis is to assess the potential effects of different climate scenarios on the future availability of cooling water and the ability of nuclear power plants to comply with environmental (temperature) regulations.

1.2 Objective

The objective of this synthesis is to evaluate the impact of climate change on compliance with the CIW (Committee on Integrated Water Policy) temperature criteria and on the availability of cooling water for the potential nuclear power plant sites.

The synthesis builds on existing modelling studies and evaluates how a range of climate scenarios may affect the thermal conditions of receiving water bodies at the proposed outfall locations. The analysis aims to identify potential constraints and risks, and to support policy development and decision making regarding the siting and operation of a new nuclear power plant.

1.3 Scope and limitations

The scope of this synthesis concerns the assessment on thermal conditions in relation to cooling water availability and the compliance with CIW temperature criteria for the proposed outfall locations at four proposed power plant locations in the Netherlands: Borssele, Terneuzen, Maasvlakte and Eemshaven. The assessment focuses on the interaction between projected increases in background water temperature and thermal plume behaviour and evaluates the implications for compliance with quantitative CIW temperature criteria.

Several assumptions were required in the interpretation of input data, model results and environmental criteria. These include, among others, the definition of ambient water temperature, the selection of representative cross-sections for the mixing zone, and the interpretation of CIW compliance criteria.

The assessment is based on a synthesis of existing modelling studies and is carried out for a selection of climate scenarios to evaluate the potential impacts of climate change on ambient water temperature and the thermal discharge conditions. Three climate scenarios are considered: two based on the IPCC scenarios SSP2-4.5 and SSP5-8.5, and a third scenario derived as the average of these two scenarios to assess sensitivity under intermediate conditions. This derived scenario shows resemblance to IPCC scenario SSP3-7.0 in terms of projected temperature increase and is referred to as such in this report. More favourable climate scenarios (e.g. SSP1-1.9 and SSP1-2.6) are excluded from the analysis. The results should therefore be interpreted as indicative of a range of potential future conditions rather than a complete set of possible climate outcomes.

For each potential location, the assessment in this synthesis is carried out for a single representative intake and outfall configuration, consisting of an open intake combined with a submerged outfall. For Eemshaven, multiple configurations are additionally considered as part of a sensitivity analysis. The configurations are selected to enable a consistent comparison between locations. The synthesis does not aim to assess all possible intake and outfall layout options, nor does it include optimisation of intake and outfall configurations based on the outcomes of this assessment. The potential for design measures to mitigate thermal impacts is therefore not fully explored.

To address the uncertainties, sensitivity analyses have been carried out. These analyses indicate that the outcomes of the assessment, particular the projected timing of non-compliance, can be sensitive to the methodological choices and assumptions applied.

As the synthesis is based on existing modelling studies and preliminary results, the findings should be considered indicative and are intended to support policy development and further analysis, rather than to provide definitive conclusions.

2 Available data and assumptions

For this synthesis, several assumptions and environmental criteria have been applied. This chapter presents the key assumptions, input data and criteria used in the analysis. It describes the selected intake and outfall configurations, the applied climate scenarios, the environmental criteria for thermal discharges, and the approach used to determine background water temperatures.

2.1 Intake and outfall configurations

For each potential location (Borssele, Terneuzen, Maasvlakte and Eemshaven), multiple areas and various intake and outfall configurations were evaluated to determine cooling water availability (see also Deltares, 2024a, 2026a, 2026b, 2026c). To limit the number of variables in the synthesis, a single representative configuration was selected for each location, consisting of an open intake combined with a submerged outfall. For Eemshaven, additional intake and outfall configurations have been assessed as part of a sensitivity analysis to evaluate the impact of configuration choices on the results. An overview of the intake and outfall configuration per location used in this synthesis is presented in Figure 2.4 to Figure 2.4.

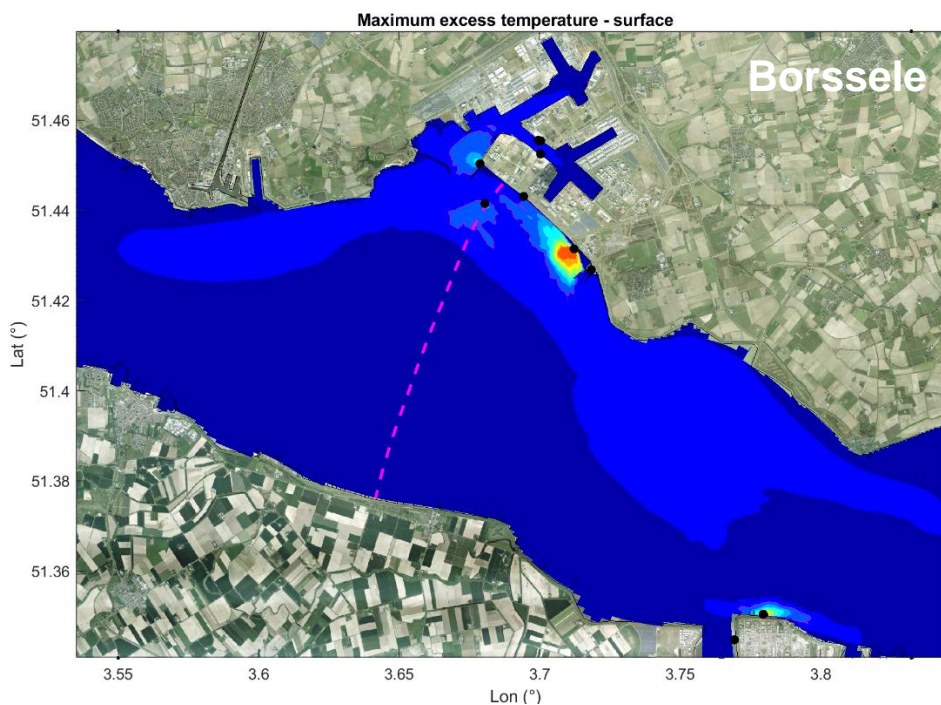


Figure 2.1 Intake and outfall locations (black dots) for Borssele.

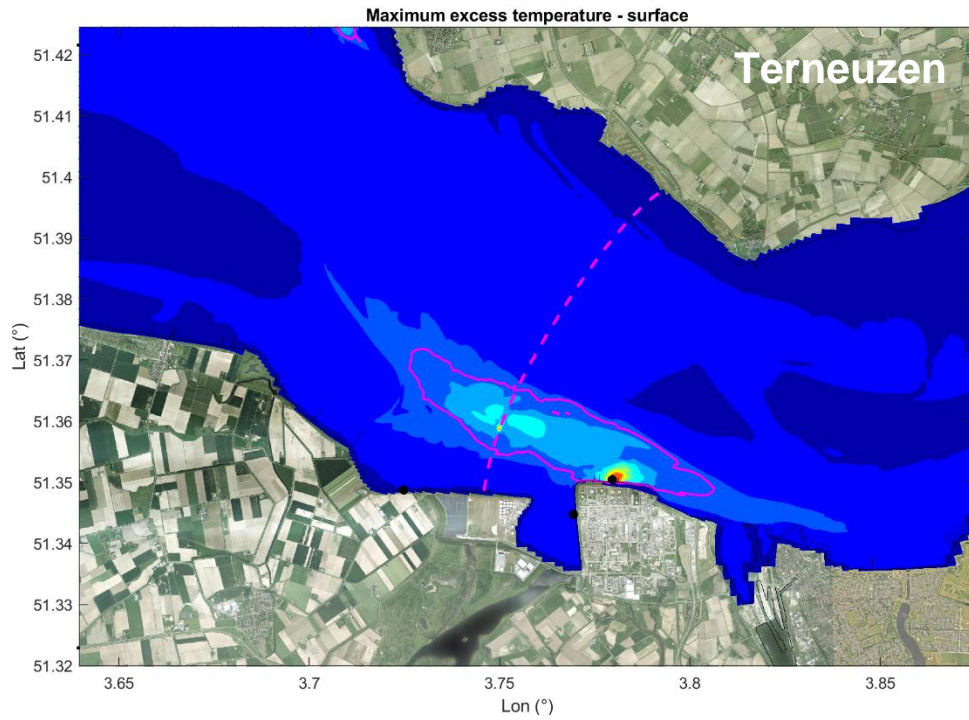


Figure 2.2 Intake and outfall locations (black dots) for Terneuzen.

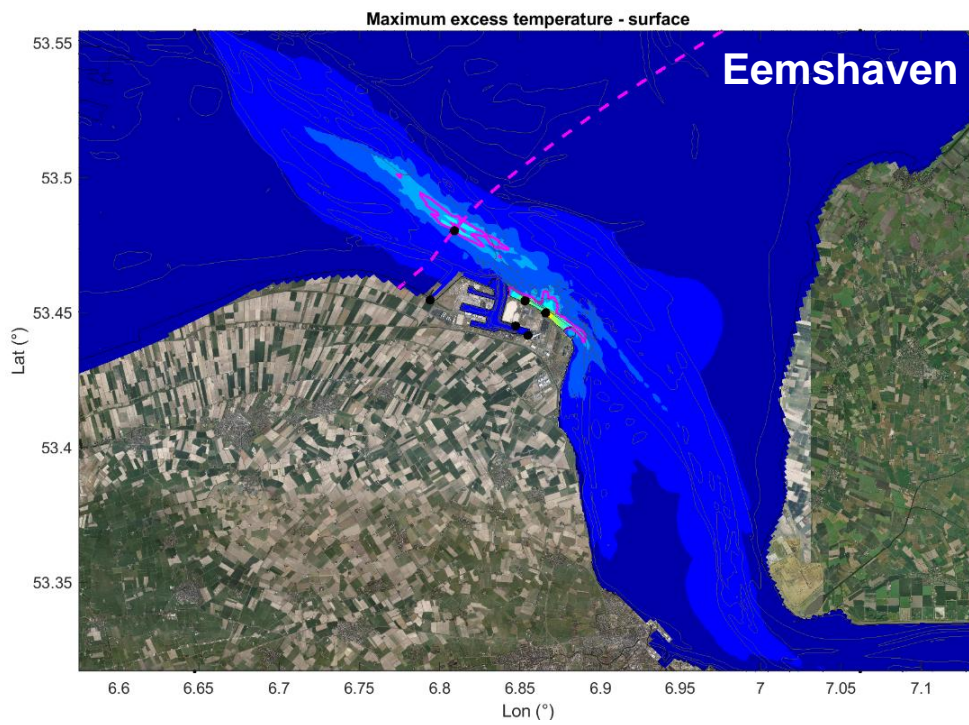


Figure 2.3 Intake and outfall locations (black dots) for Eemshaven.

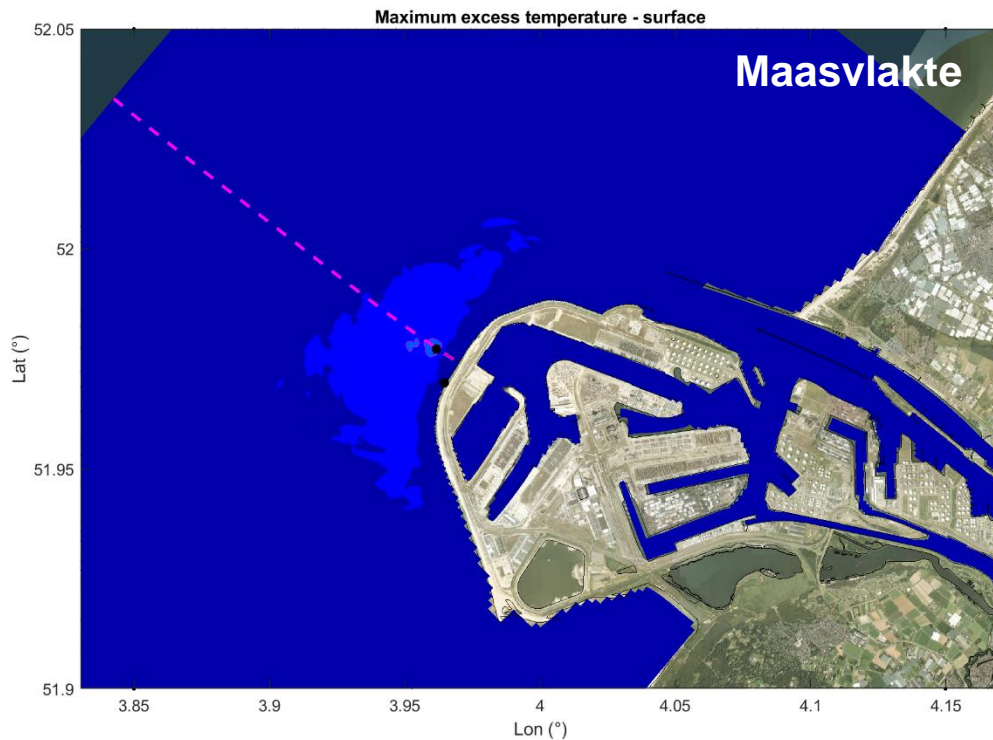


Figure 2.4 Intake and outfall locations (black dots) for Maasvlakte.

2.2 Climate change scenarios and projections

The assessment considers a selection of climate change scenarios to evaluate the potential impact of climate change on cooling water conditions. Two scenarios are based on IPCC pathways:

- SSP2-4.5, which represents moderate global development and climate action leading to intermediate emissions and an estimated global temperature increase of approximately 2.7–3°C by 2100. This scenario reflects a world with partial sustainability efforts and continued fossil fuel use.
- SSP5-8.5, which represents a high-emissions pathway with minimal climate mitigation driven by fossil-fuelled growth. It projects >4°C warming by 2100, making it a worst-case scenario for climate impacts.
- In addition, a scenario is included with projected temperature increases that are intermediate between SSP2-4.5 and SSP5-8.5. This additional scenario resembles IPCC scenario SSP3-7.0 in terms of projected temperature increase, although it does not represent the same underlying socio-economic pathway.

More favourable climate scenarios (e.g. SSP1-1.9 and SSP1-2.6) are excluded from the assessment. The results should therefore be interpreted as indicative of a range of plausible future conditions rather than a complete representation of all possible climate pathways.

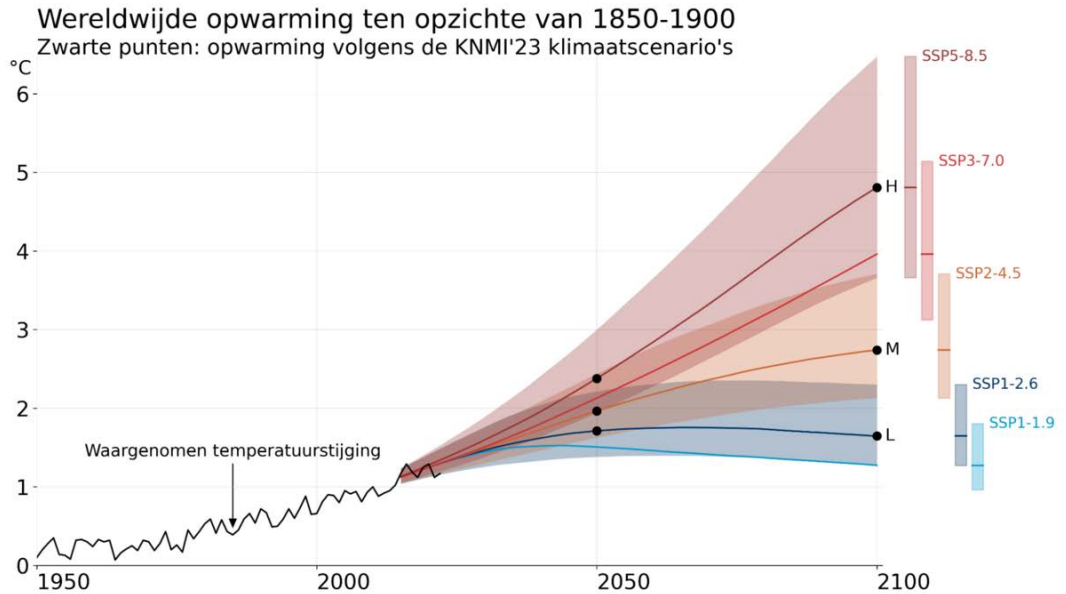


Figure 2.5 Climate scenarios (source: KNMI).

Daily mean seawater temperature projections for the period 2015–2100, based on 16 ensemble members from a tuned version of the EC-Earth3 global climate model, were provided by KNMI and extracted for each potential site (see Figure 2.6 and for further information, Deltares, 2026d). As the environmental criteria are based on 98th-percentile water temperatures, the analysis focuses on projections for the months of July and August, which are typically the warmest months of the year, using data from the nearest available locations. The resulting site-specific projected ambient seawater temperatures under different climate change scenarios are presented in Figure 2.7.

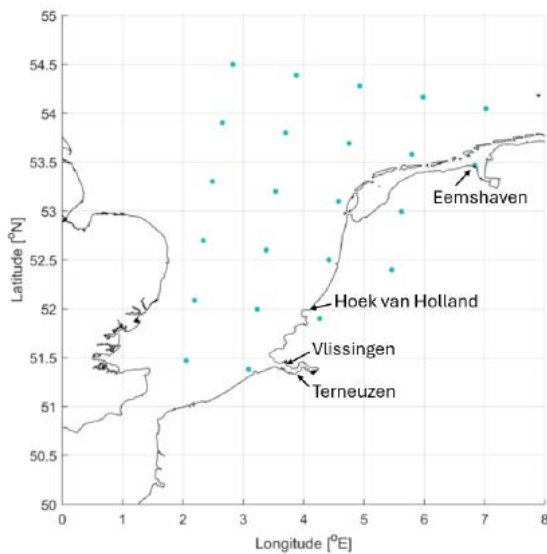


Figure 2.6 North Sea - KNMI seawater temperature data locations (Source: KNMI).

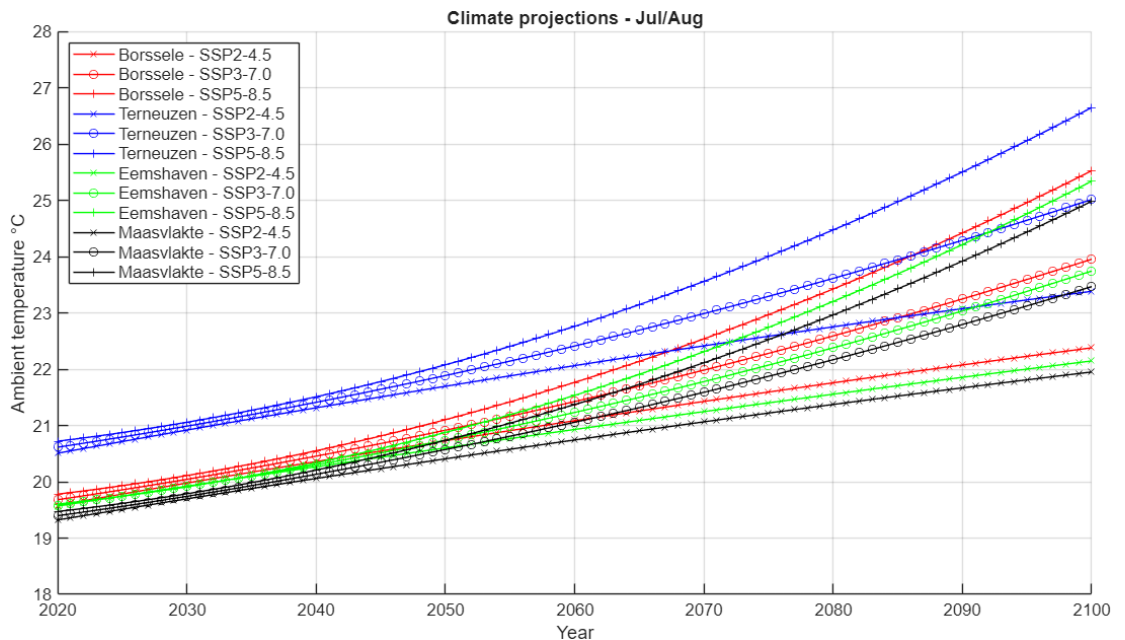


Figure 2.7 Ambient seawater temperature projections under different climate change scenarios per location for the months July and August.

2.3 Environmental Criteria

An overview of the applicable environmental criteria for each location is presented in earlier studies, including the report ‘*Voorstel regelgevend kader warmtelozingen centrales Borssele en Maasvlakte*’, Deltares (2023).

In the present assessment, the focus is on the temperature criteria as defined by CIW (2004), which were evaluated in the numerical modelling studies. These criteria are as follows, subdivided into the different applicable water body classifications:

- Estuarine waters – mixing zone:
 - The maximum permitted extent of the mixing zone (defined by the 25°C temperature contour) may cover no more than 25% of the cross-sectional area of the water body. This criterion must be met at least 98% of the time.
- Estuarine waters – temperature increase:
 - The average temperature of the water body may not increase by more than 2°C and/or increase above 25°C for at least 98% of the time.
- Coastal waters – mixing zone:
 - The 25°C temperature contour of the thermal plume should not reach the seabed.

The following classification of water types apply per location:

- Borssele: estuarine
- Terneuzen: estuarine
- Maasvlakte: coastal
- Eemshaven: mixed (coastal and estuarine)

It should be noted that the Ems-Dollard estuary has characteristics of both estuarine and coastal waters. Based on KRW classifications, the transition between these two water bodies is located close to the Eemshaven (Figure 2.8). This implies that multiple criteria apply within the Eemshaven area. The area northwest of Eemshaven is evaluated against the coastal criterion, whereas the area around and southeast of Eemshaven is evaluated against the estuarine criterion.



Figure 2.8 Boundary coastal / estuarine water body. (Source KRW).

2.4 Background temperature

In the original assessments of the cooling water availability per location, application of the environmental criteria requires quantification of the background water temperature near the project site. The CIW criteria define the background temperature as the temperature recorded at the boundary of the water body and require the highest 98th-percentile temperature as the regulatory background temperature.

For example, for the Western Scheldt the temperature measured at the border between The Netherlands and Belgium was used as a conservative background temperature, corresponding to the measurement station at Bath. Based on 20 years of data retrieved from the RWS Waterinfo portal¹, the 98th-percentile water temperature at this location is 22.5°C. Accordingly, the mixing zone is defined as the area in which the temperature increase exceeds 2.5°C above background conditions (25°C – 22.5°C), see Deltares (2024a). It is noted however that temperatures recorded at this more inland location are clearly higher than closer to sea and at the project location.

In this synthesis, the 98th-percentile water temperature was determined *locally* at each project site, resulting in a more representative and local background temperature at the different sites. Additionally, a sensitivity analysis was performed using the background temperature at the boundary of the water body, in line with the CIW definition.

2.4.1 Borssele and Terneuzen

For Borssele and Terneuzen, the local 98th-percentile water temperatures are derived based on the analysis measurements from multiple stations in the Western Scheldt, see Figure 2.9. Based on this analysis the following local 98th-percentile temperatures are applied: respectively 20.9°C for Borssele and 21.3°C for Terneuzen. For more details about the background temperature, see Deltares (2024b).

¹ <https://waterinfo.rws.nl/>

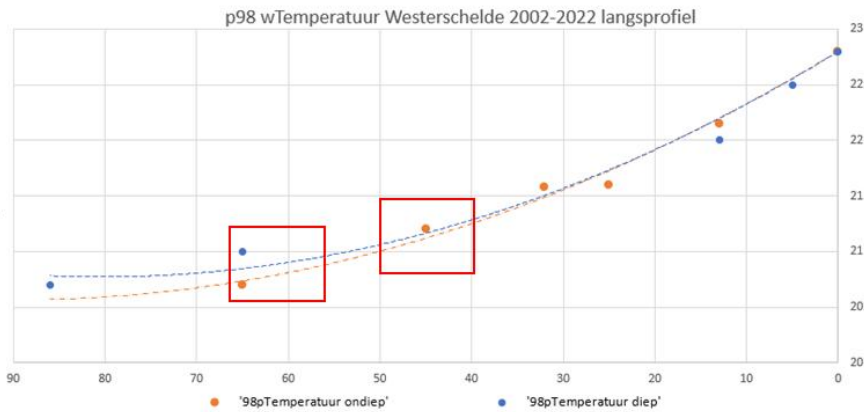


Figure 2.9 Computed 98th-percentile temperatures in the Western Scheldt. The left red box indicates the Borssele project area. The right red box indicates the Terneuzen project area.

2.4.2 Eemshaven

For Eemshaven, the selection of a representative 98th-percentile background water temperature is not straightforward based on the available data for the Ems–Dollard estuary. Ideally, a representative measurement location should be situated within the current-carrying part of the estuary, at or near the boundary of the waterbody, outside the influence of existing thermal plumes from cooling water discharges included in the assessment, and based on measurements with a high temporal resolution (e.g. 10-minute intervals) over a sufficiently long and recent period.

Based on these criteria, the station ‘Eemshaven Stroommeetpaal’ was selected as the most representative measurement location, as it is located close to the project site. The 98th-percentile water temperature derived from 6 years of data corresponds to 21.5 °C, which is consistent with the value applied in previous cooling water studies. The selection of the background temperature is subject to uncertainty due to spatial variability and the influence of existing discharges and is therefore further evaluated in the sensitivity analysis.

Table 2.1 Computed 98th-percentile background temperatures for stations near the Eemshaven (source: www.waterinfo.rws.nl).

Station	Start date	End date	frequency	existing outfalls	98th perc. [°C]
Bocht van Watum	20-1-2000	11-12-2023	Weeks		22.016
Bocht van Watum noord	20-1-2000	11-12-2009	Weeks		21.308
Delfzijl	1-1-2000	31-12-2001	Day		21.6
Eemshaven	1-1-2000	22-8-2022	10 min.	+	22.7
Eemshaven stroommeetpaal	1-1-2017	31-12-2023	10 min.	+	21.5
Groote Gat noord	20-1-2000	11-12-2023	Weeks		23.1572
Huibertgat oost	20-1-2000	11-12-2023	Weeks		21.123
Stroommeetpaal Eemshaven	14-1-2024	13-1-2025	10 min.	+	21.6



Figure 2.10 Available temperature measurements stations near the Eemshaven (source: www.waterinfo.rws.nl)

2.4.3 Maasvlakte

For the Maasvlakte, the analysis of the 98th-percentile water temperature is based on the available data from measurement locations north of the Maasvlakte, close to Hoek van Holland in the Nieuwe Waterweg, see Figure 2.11. Because the plant considered for the Maasvlakte is located offshore, west of the Maasvlakte, deriving a representative local background temperature is not straightforward. Since for Maasvlakte the coastal criterion applies for which near-bed temperatures are considered, the 98th-percentile temperatures closest to the seabed of stations HOEKVHLRTOVR and HOEKVHLD were used (respectively 20.7 °C and 20.9 °C). In this assessment, these temperatures were rounded off and a 98th-percentile temperature of 21 °C was therefore applied, representing the seawater temperature at the considered outfall location.



Figure 2.11 Locations of ambient water temperature measurements (www.waterinfo.rws.nl).

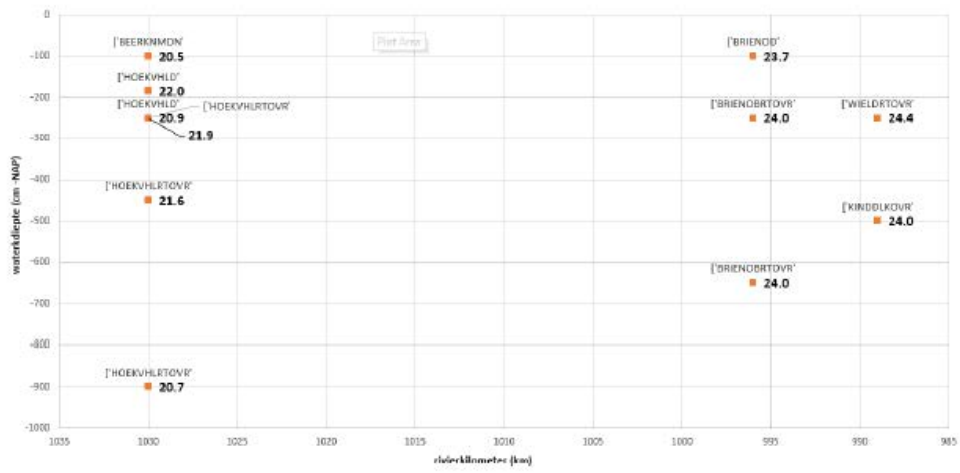


Figure 2.12 Computed 98th-percentile water temperature at different locations near the Maasvlakte (www.waterinfo.rws.nl).

3 Methodology and results

This chapter presents the methodology and results of the assessment of cooling water availability and compliance with CIW temperature criteria under projected climate change conditions. The analysis combines modelled thermal plume behaviour with projected increases in ambient water temperature to evaluate the evolution of thermal impacts over time.

First, the methodological approach for assessing compliance with both estuarine and coastal criteria is described. This includes the derivation of key indicators such as the extent of the mixing zone and near-bottom temperature conditions. Second, the results are presented for each proposed location, indicating the projected timing of non-compliance under different climate scenarios.

3.1 Methodological Approach

3.1.1 Assessment of Estuarine criterion

For this synthesis, the excess temperature due to the thermal discharge, modelled using Delft3D, was adopted from the previous modelling studies (Deltares 2024a, 2026a, 2026b, 2026c). In this analysis the computed 98th-percentile background temperatures from the local measurements and projected climate-induced temperature increases are added to the plume dispersion to derive the expected (future) absolute summer temperatures at the project sites including cooling water discharges.

To compare the modelling results with the environmental criteria of CIW (2004) of the estuarine mixing zone, the percentage of the cross-sectional area where the total water temperature exceeds 25°C is determined. The CIW criterion does not specify which cross-sectional area should be used. In this analysis, all the gridlines are used as potential cross-sections (Figure 3.1). Dry areas are excluded from the total cross-sectional area.

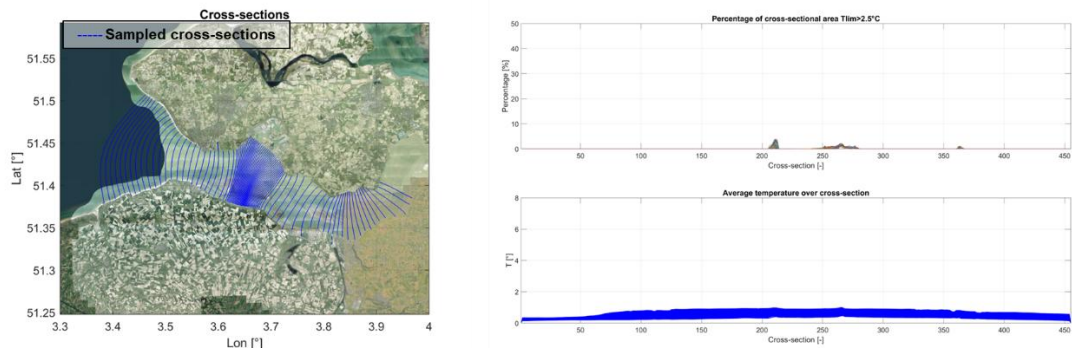


Figure 3.1 Gridlines used as cross-sections for Borssele.

For each model output timestep (30 minutes), the percentage of the cross-sectional area where the water temperature exceeds 25°C is calculated for all cross-sections (Figure 3.2). From this, the maximum exceedance per timestep (t) is determined. To obtain a realistic representation of exceedance, the dynamic behaviour of the thermal plume needs to be taken into account. Therefore, the time-averaged value of the maximum cross-sectional percentage (P) is used as the primary indicator in this synthesis (in the schematic example the *mean* of $P_{max,t1}$, $P_{max,t2}$, $P_{max,t3}$ and $P_{max,t4}$). This approach filters out short-term fluctuations and results in a robust estimate of the sustained spatial extent of the thermal plume.

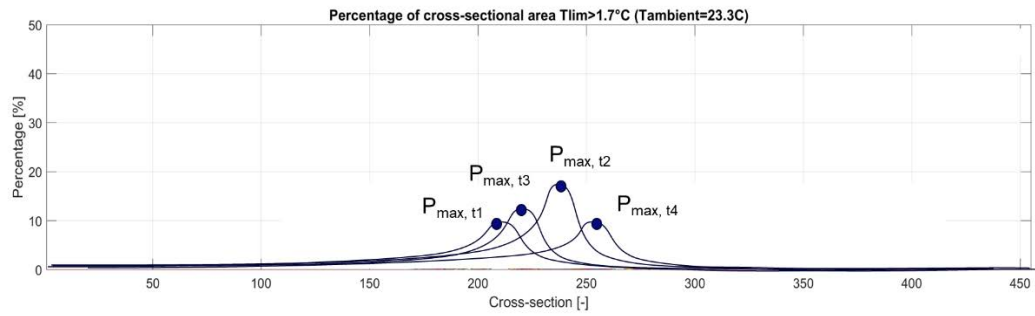


Figure 3.2 Schematic representation of the computed (maximum) percentage of the cross-sectional area covered by the mixing zone for four different output timesteps.

As part of the sensitivity analysis (see next chapter), a conservative approach is also applied. In this case, the *maximum* percentage across all cross-sections and all timesteps is used. This represents a worst-case scenario, where such a percentage only occurs once, briefly in a simulation (in the schematic example this is the *maximum* of $P_{\max, t1}$, $P_{\max, t2}$, $P_{\max, t3}$ and $P_{\max, t4}$).

Projected climate-induced increases in background temperature are subsequently added to the modelled plume dispersion, after which the results are reassessed against the environmental criteria. Figure 3.3 represents intermediate results from the cooling water synthesis, illustrating how an increase in background temperature (T_{ambient}) leads to a corresponding increase in the percentage of the cross-sectional area where the water temperature exceeds 25 °C. Each background temperature results in a different typical maximum percentage of the cross-sectional area covered by the mixing zone that at some point exceeds the 25% criterion.

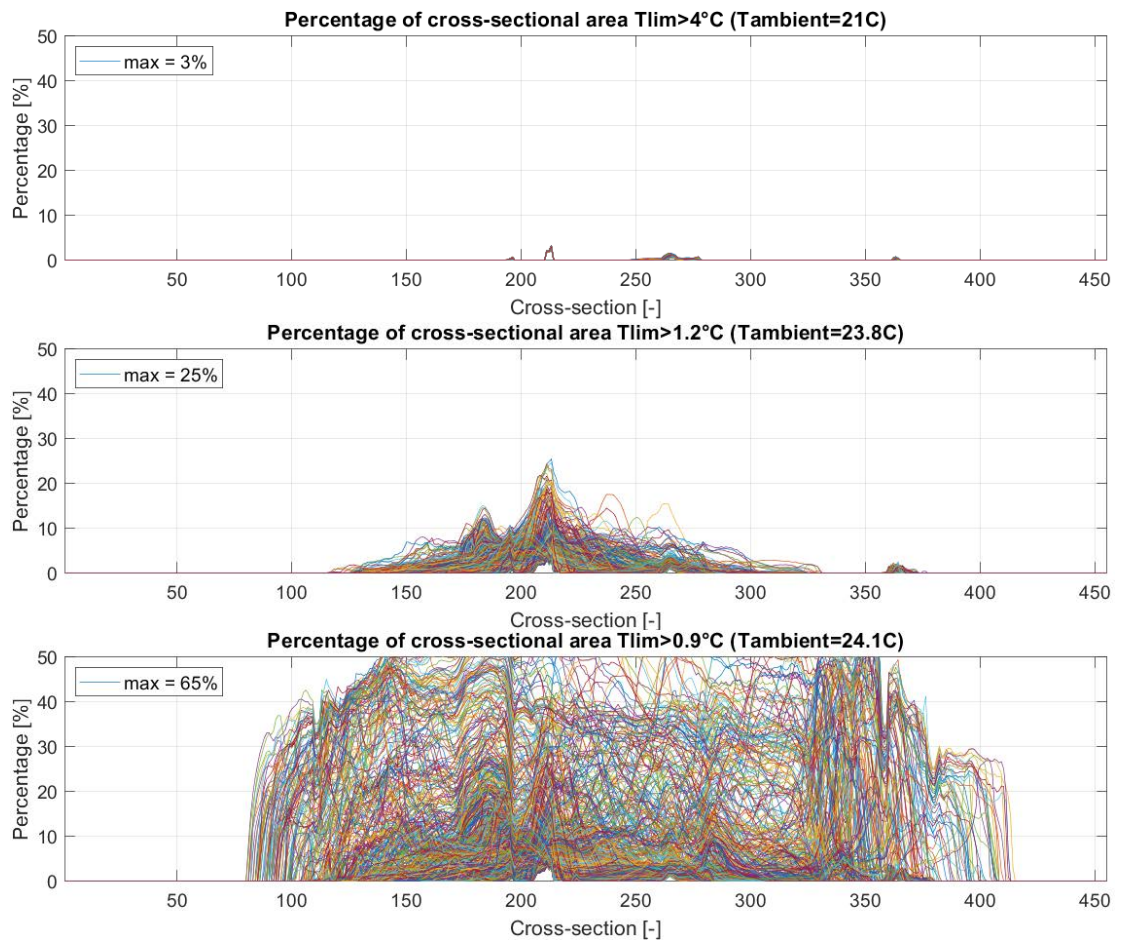


Figure 3.3 Intermediate results of the cooling water synthesis with increased background temperature.

This analysis results in a relationship between the ambient water background temperature and the maximum percentage of the cross-sectional area exceeding the 25°C threshold (Figure 3.4). The corresponding average cross-sectional temperature was also computed using the same method.

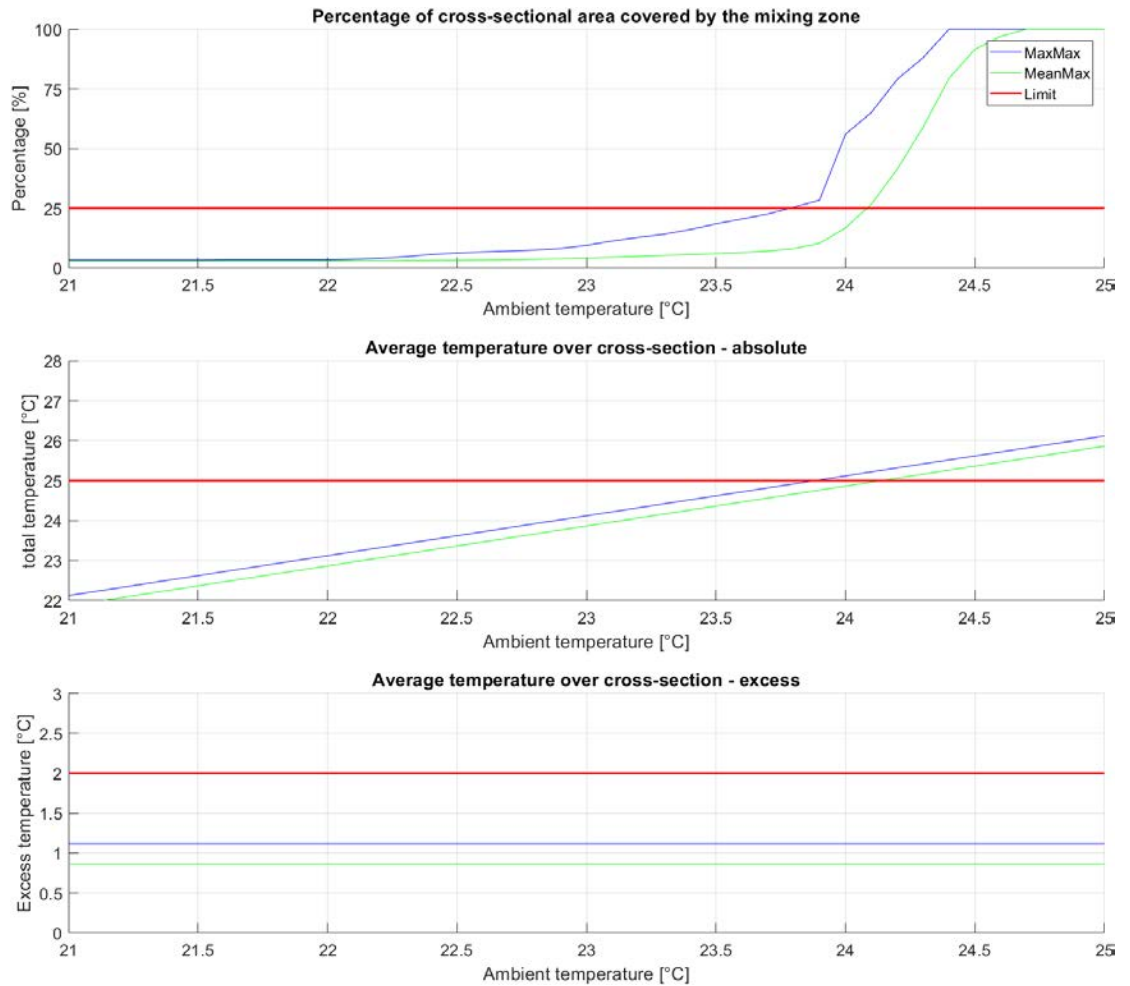


Figure 3.4 Example of the relation between the (maximum) cross-sectional area covered by the mixing zone (top plot), the absolute (middle plot) and excess (lower plot) ambient temperature (increase).

By combining these relationships with the selected climate scenarios, the percentage of the cross-sectional area covered by the mixing can be expressed as a function of time. An example of this relationship is presented in Figure 3.6, where the red line indicates the threshold value of 25%. This approach forms the basis for determining the projected timing of non-compliance under the different climate scenarios.

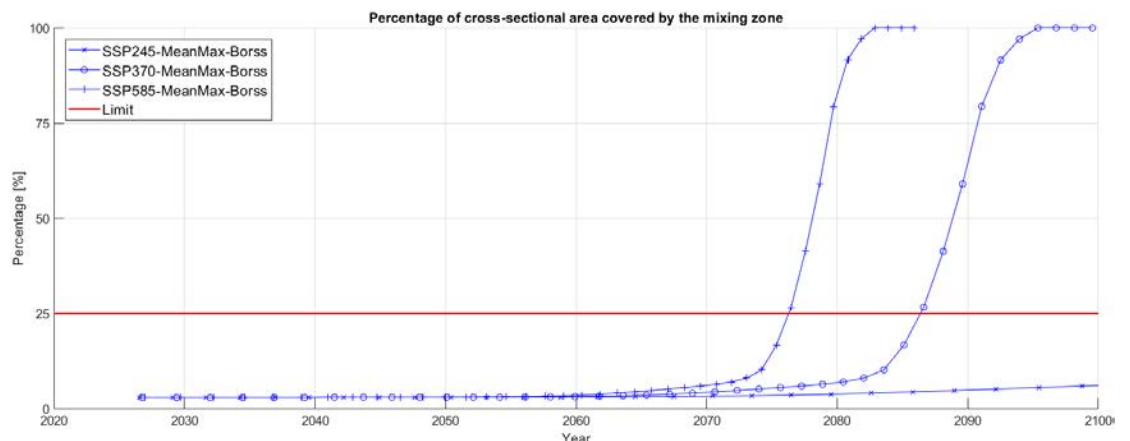


Figure 3.5 Example of the relation of the different climate scenarios and the (maximum) percentage of the cross-sectional area covered by the mixing zone.

3.1.2 Assessment of Coastal criterion

For coastal waters, the CIW mixing zone criterion requires that the 25 °C temperature contour of the discharge plume does not reach the seabed. To assess compliance under increasing background temperatures (i.e. due to climate change), the expected maximum near-bottom temperature is calculated for different background temperatures. An example is presented in Figure 3.6. The red line indicates the threshold value of 25 °C. By combining this relationship with the selected climate scenarios, the near-bottom temperature can be expressed as a function of time, allowing the timing of non-compliance to be determined. When the near-bottom temperature exceeds the threshold value of 25 °C, non-compliance of the intake and outfall configuration is expected. Due to the indicative nature of this assessment, the moment of non-compliance is sometimes indicated by a period of 5 years rather than the exact year. It is noted that no alternative outfall configurations or design optimisations were considered to reduce seabed impacts. The results therefore reflect the selected configuration only.

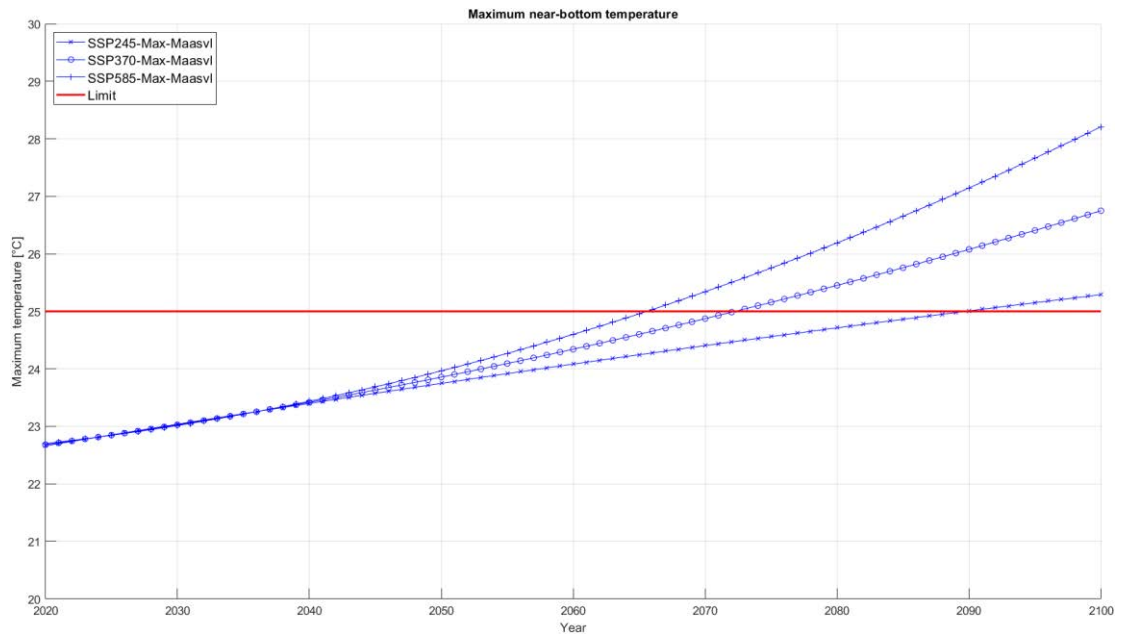


Figure 3.6 Example of the relation between time (climate change) and the maximum temperature near the bottom.

3.2 Results for the different locations

3.2.1 Borssele

Based on the approach, specified assumptions and interpretation of the CIW criteria as described in Section 3.1, non-compliance with the most critical estuarine criterion at Borssele is projected to occur around 2075 under SSP5-8.5 worst-case scenario, around 2085 under SSP3-7.0, and after 2100 under SSP2-4.5. The estuarine criterion for the maximum cross-sectional area covered by the mixing zone is more critical compared to the average temperature increase criterion.

Compared to the other locations, Borssele shows relatively late onset of non-compliance, which is mainly related to the comparatively lower background temperatures and more favourable hydrodynamic conditions that promote plume mixing.

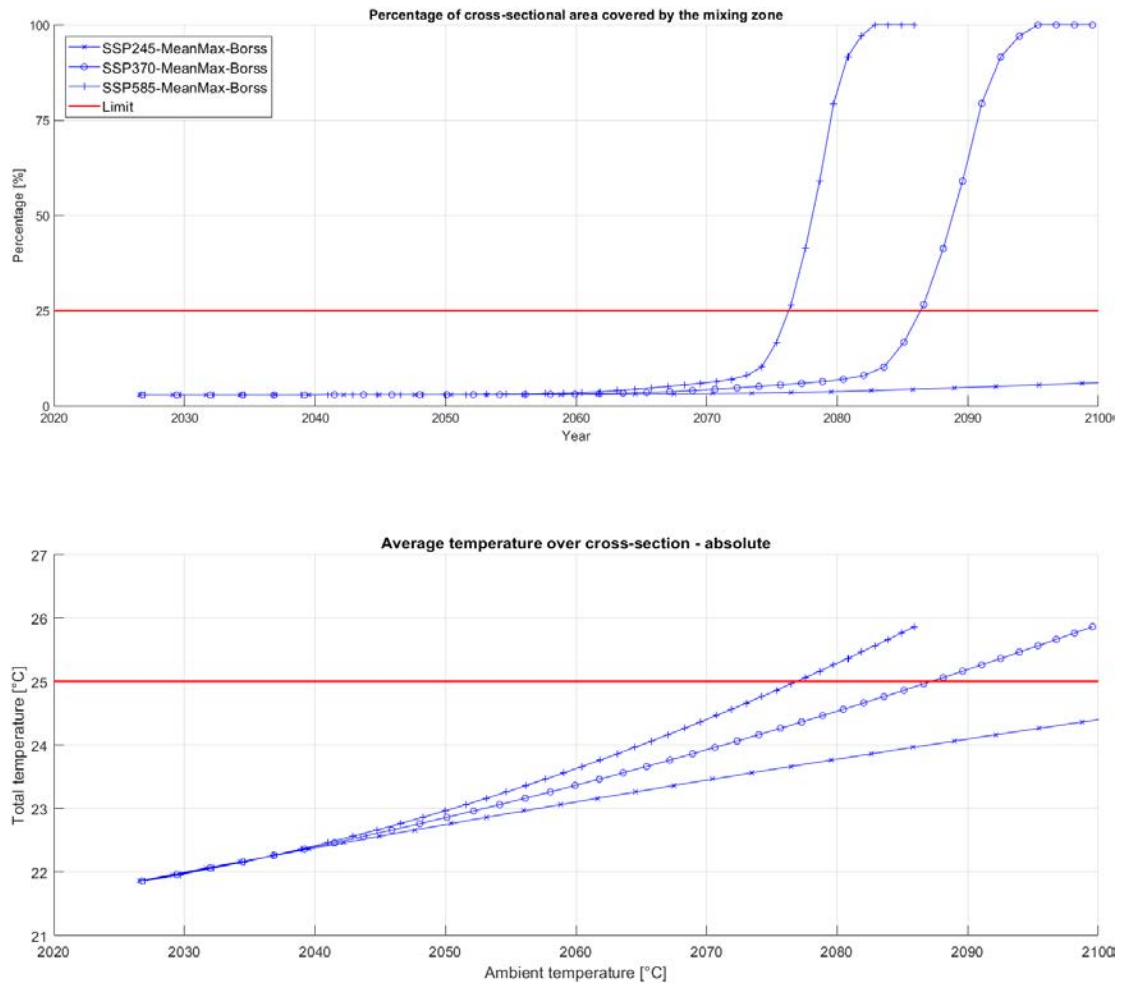


Figure 3.7 Relationship between climate scenarios, mixing zone extent, and average temperature for Borssele. Red lines indicate threshold values.

3.2.2 Terneuzen

At Terneuzen, non-compliance with the CIW estuarine criterion is projected to occur around 2065 (SSP5-8.5), 2075 (SSP3-7.0), and 2095 (SSP2-4.5).

This corresponds to an approximately 10-year earlier onset of non-compliance compared to Borssele. The earlier onset of non-compliance can be attributed to higher background water temperatures and less favourable mixing conditions in the Western Scheldt at this location.

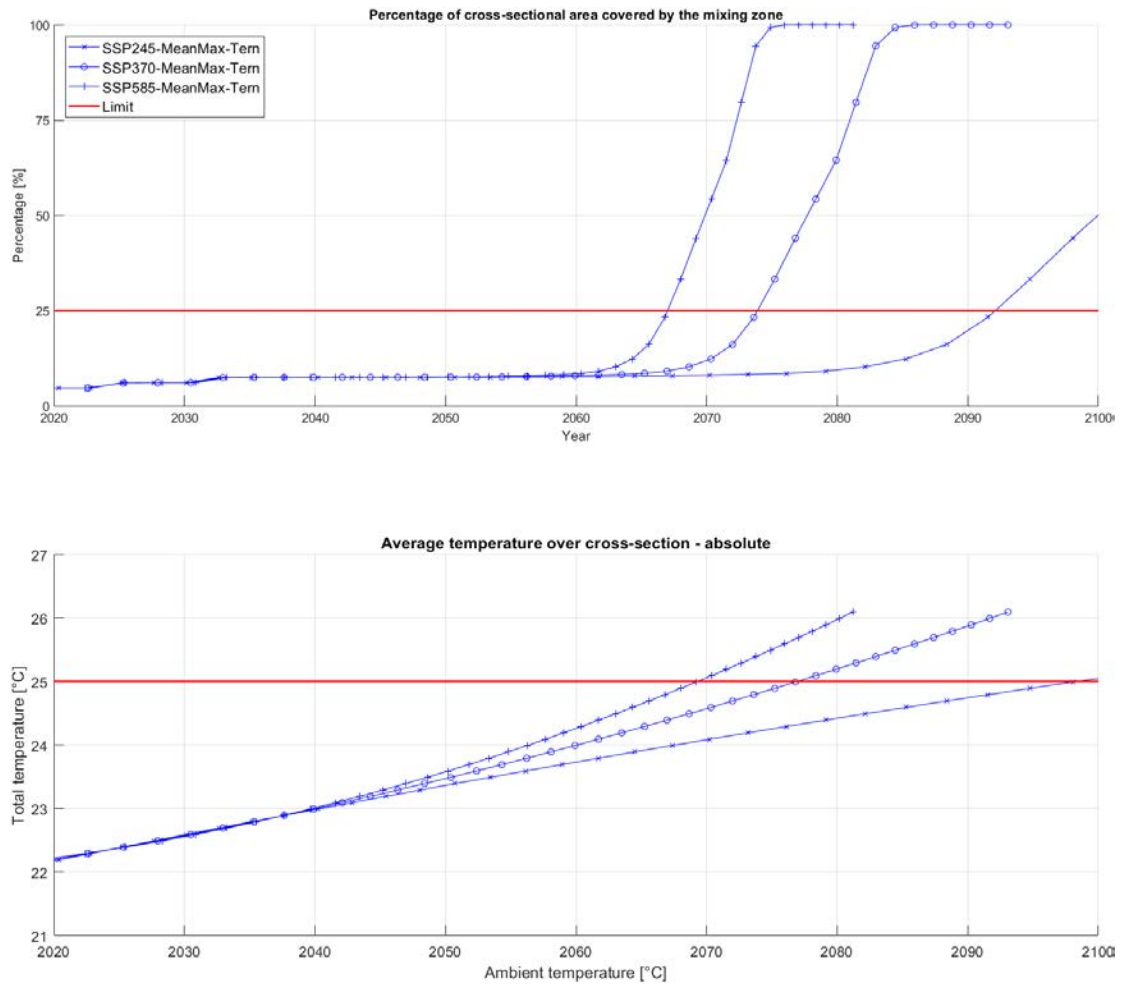


Figure 3.8 Relationship between climate scenarios, mixing zone extent, and average temperature for Terneuzen. Red lines indicate threshold values.

3.2.3 Eemshaven (Estuarine criterion)

It is noted that the Ems–Dollard system is classified as a mixed estuarine–coastal environment. For part of the study area (inside the pink polygon, see Figure 3.9) the estuarine criterion applies while outside this zone, the coastal criterion applies.

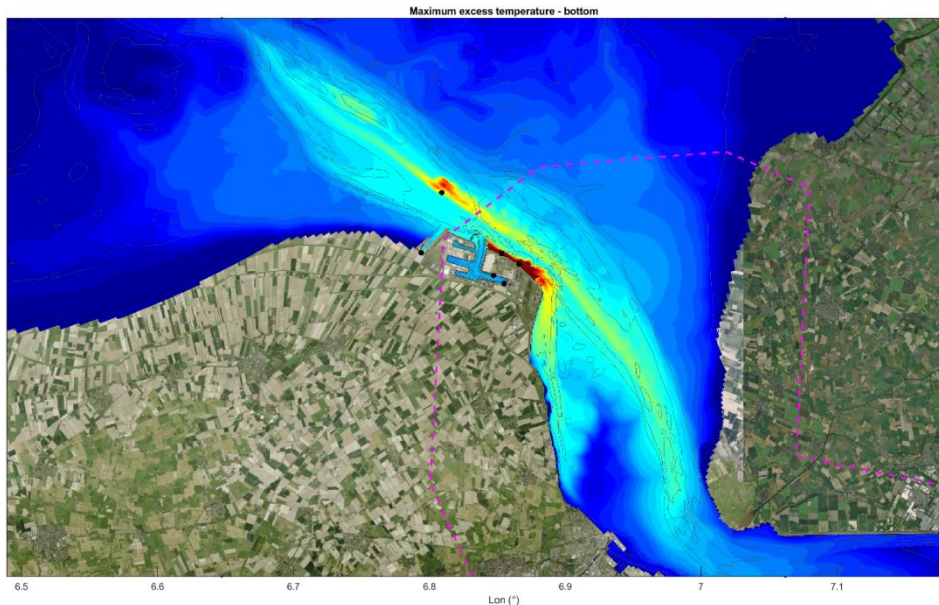


Figure 3.9 Study area of the Eemshaven proposed site indicated with pink polygon. The black dots represent the new and existing intake and outfall locations of the various plants.

For the estuarine part of the Eemshaven area, non-compliance with the CIW criterion is projected to occur around 2065 (SSP5-8.5), 2070 (SSP3-7.0), and 2090 (SSP2-4.5), see Figure 3.10.

This corresponds to an earlier onset of approximately 5 years compared to Terneuzen. The relatively early non-compliance is mainly driven by higher background temperatures and site-specific hydrodynamic conditions in the Ems–Dollard estuary.

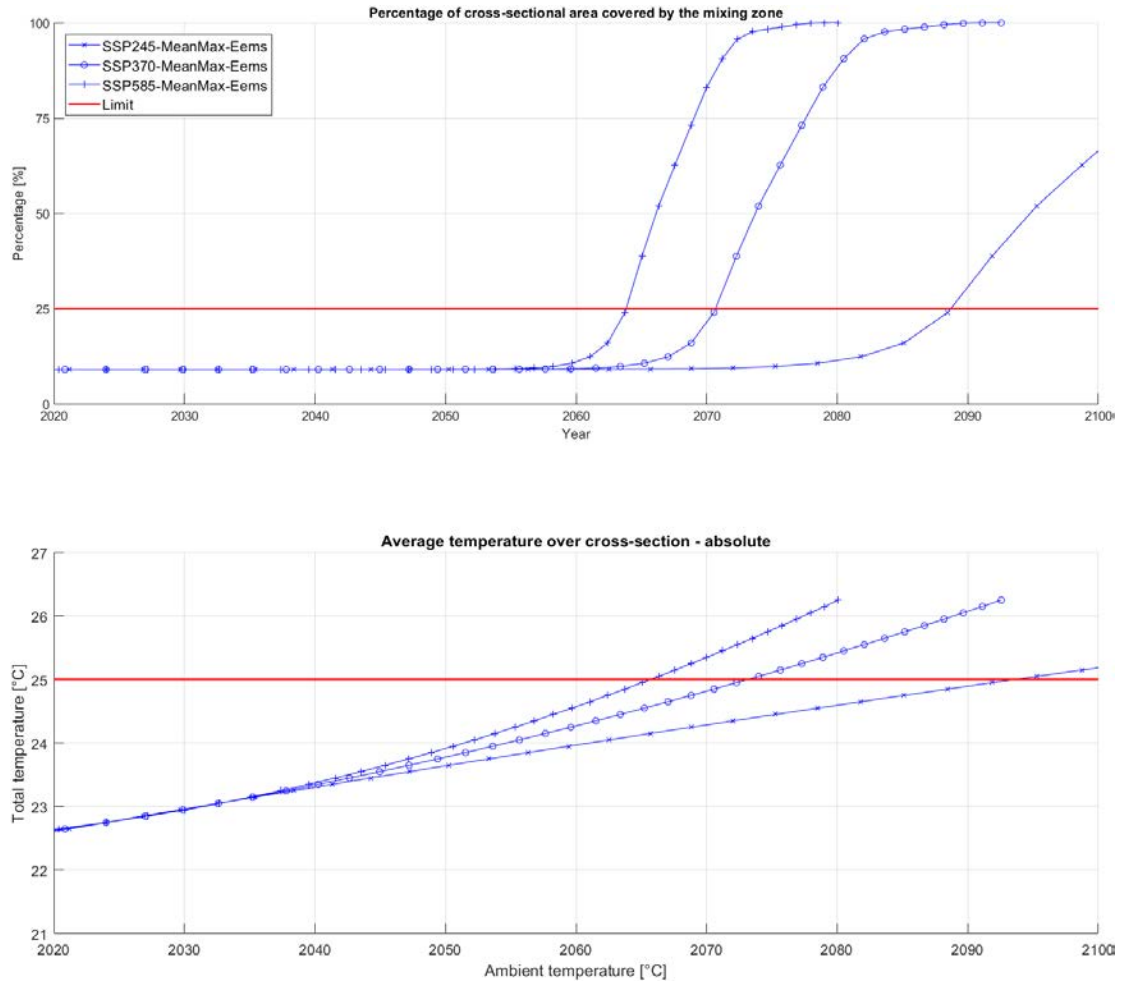


Figure 3.10 Relationship between climate scenarios, mixing zone extent, and average temperature for Eemshaven. Red lines indicate threshold values.

Coastal criterion

For the coastal part of the Eemshaven area, non-compliance with the seabed criterion (i.e. 25 °C temperature contour of the discharge plume not reaching the seabed) is projected to occur substantially earlier than under the estuarine criterion, namely between approximately 2030 and 2040 for all scenarios, see Figure 3.11.

Compliance with the coastal criterion is strongly dependent on the design and configuration of the outfall (e.g. discharge depth and orientation), as well as on the interpretation of the CIW criterion. In the present assessment, no alternative discharge configurations or design optimisations were considered.

Based on expert judgement, optimisation of the outfall design could potentially delay the moment of non-compliance by approximately 10–20 years. However, given the relatively shallow water depths near Eemshaven and the cumulative thermal load from neighbouring discharges, non-compliance is expected to occur earlier at this location than at the other proposed sites.

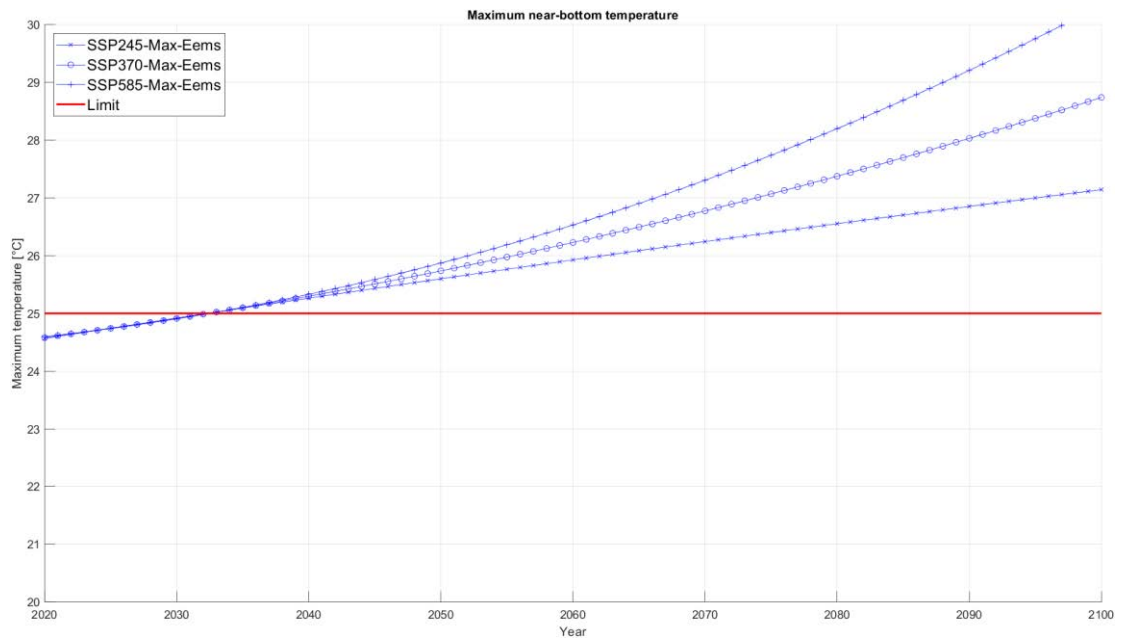


Figure 3.11 Relationship between climate scenarios and maximum near-bottom temperature for Eemshaven. Red lines indicate threshold values.

3.2.4 Maasvlakte

For Maasvlakte, non-compliance with the CIW estuarine criterion is projected to occur around 2065 (SSP5-8.5), 2070 (SSP3-7.0), and 2090 (SSP2-4.5), see Figure 3.12, which is comparable to the results for the estuarine case of Eemshaven.

Similar to Eemshaven, compliance with the coastal criterion is expected to be sensitive to the design of the outfall. However, in contrast to Eemshaven, the Maasvlakte benefits from deeper water conditions, which may provide greater opportunities for optimising the discharge configuration and mitigating thermal impacts at the seabed.

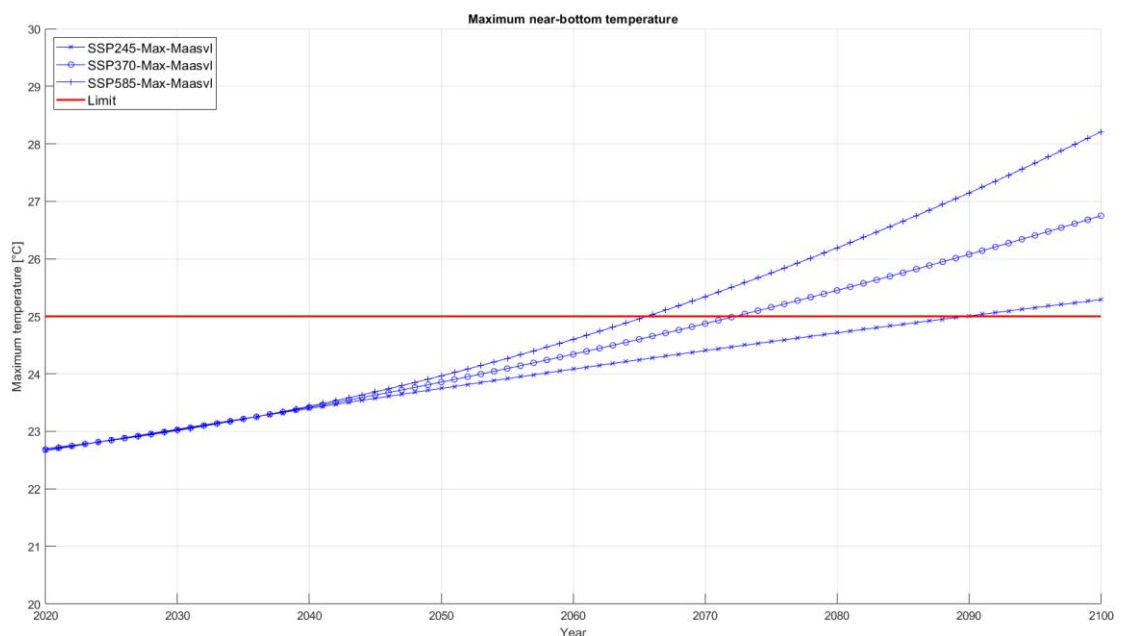


Figure 3.12 Relationship between climate scenarios and maximum near-bottom temperature for Maasvlakte. Red lines indicate threshold values.

4 Sensitivity Tests

To enable a consistent comparison of the cooling water availability across the four locations, several assumptions needed to be made in this synthesis. These assumptions were considered realistic; however, to assess their influence on the results a sensitivity analysis was performed.

In this chapter, the sensitivity analysis is presented, assessing the influence of key assumptions applied in this synthesis. The sensitivity analysis focused on the following aspects:

- The use of local background water temperature instead of the temperature at the boundary of the water body. It should be noted that upstream (more inland) temperatures are typically higher due to limited mixing and freshwater influence, which can lead to more conservative estimates of non-compliance when applied in the assessment.
- The use of a *typical* (time-averaged) maximum percentage of the cross-sectional area occupied by the mixing zone, rather than the *absolute* maximum percentage.
- The intake and outfall design considered in the assessment (particularly relevant for Eemshaven).
- The use of either the full cross-sectional width of a channel or only the main navigation channel (relevant for Terneuzen).

4.1 Ambient temperature and typical or maximum percentage

This section evaluates the sensitivity of the results to the choice of background temperature and the method used to quantify the extent of the mixing zone.

4.1.1 Borssele

Figure 4.1 illustrates the sensitivity of the results for Borssele. The original results are shown in blue. The black line represents the results obtained when the absolute maximum mixing zone extent is considered (i.e. a conservative approach in which exceedance occurring only once in the simulation is considered). The pink and green lines show the results when the background temperature is defined at the upstream boundary of the water body (location at Bath), using respectively the maximum and mean values.

The results demonstrate that the choice of mixing zone representation has a clear effect on the timing of non-compliance. Using the conservative maximum extent leads to earlier non-compliance by approximately 5–10 years compared to the baseline approach. Applying a more conservative definition of background temperature, based on the upstream boundary, results in an even larger shift, leading to earlier non-compliance by approximately 10–20 years.

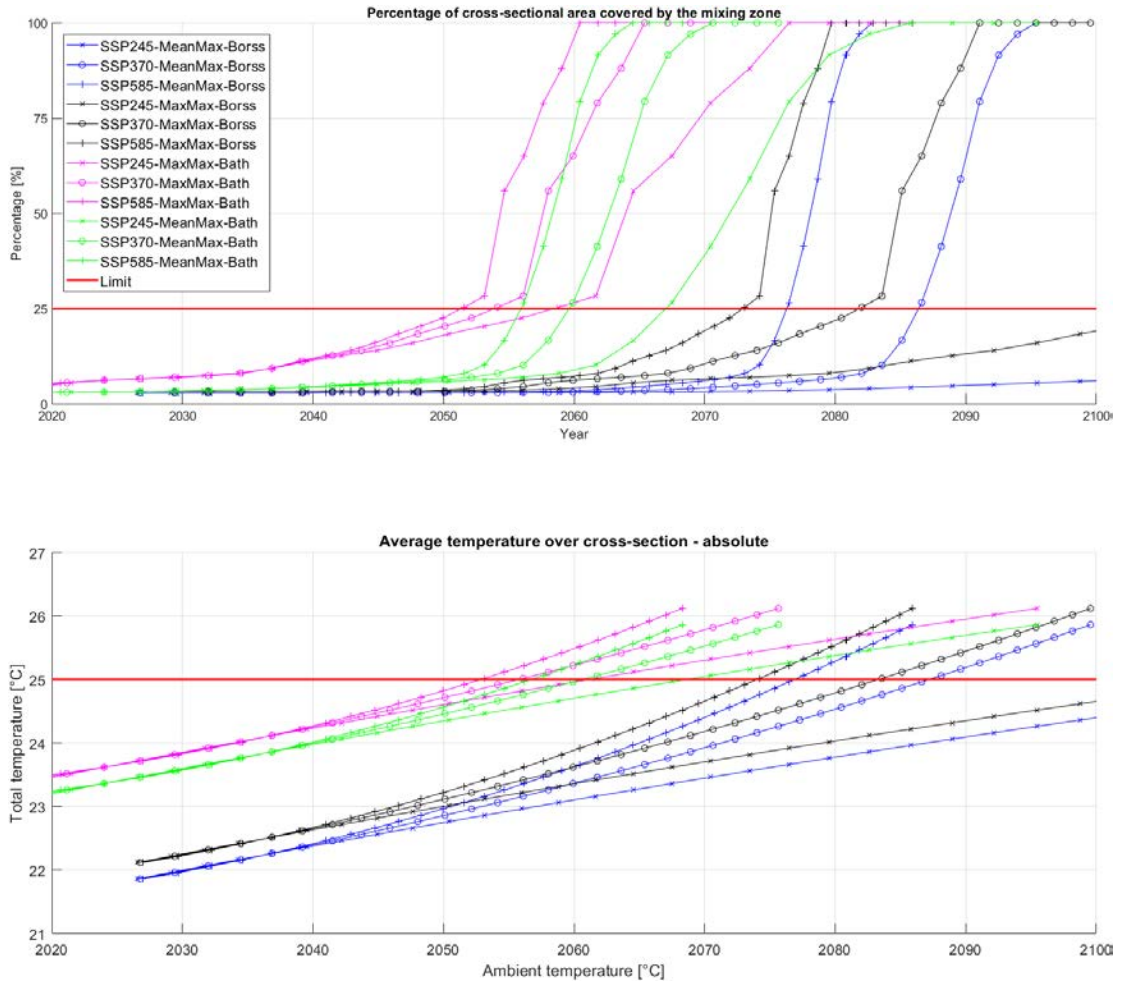


Figure 4.1 Sensitivity of mixing zone extent and average cross-sectional temperature to background temperature assumptions and climate scenarios for Borssele. Red lines indicate threshold values.

4.1.2 Terneuzen

Figure 4.2 presents the sensitivity analysis for Terneuzen, using the same set of assumptions. The results for Terneuzen show a similar pattern to Borssele. The use of the absolute maximum mixing zone extent leads to an earlier onset of non-compliance by approximately 5–10 years. When the upstream temperature is used instead of the locally derived temperature, non-compliance occurs approximately 10–20 years earlier.

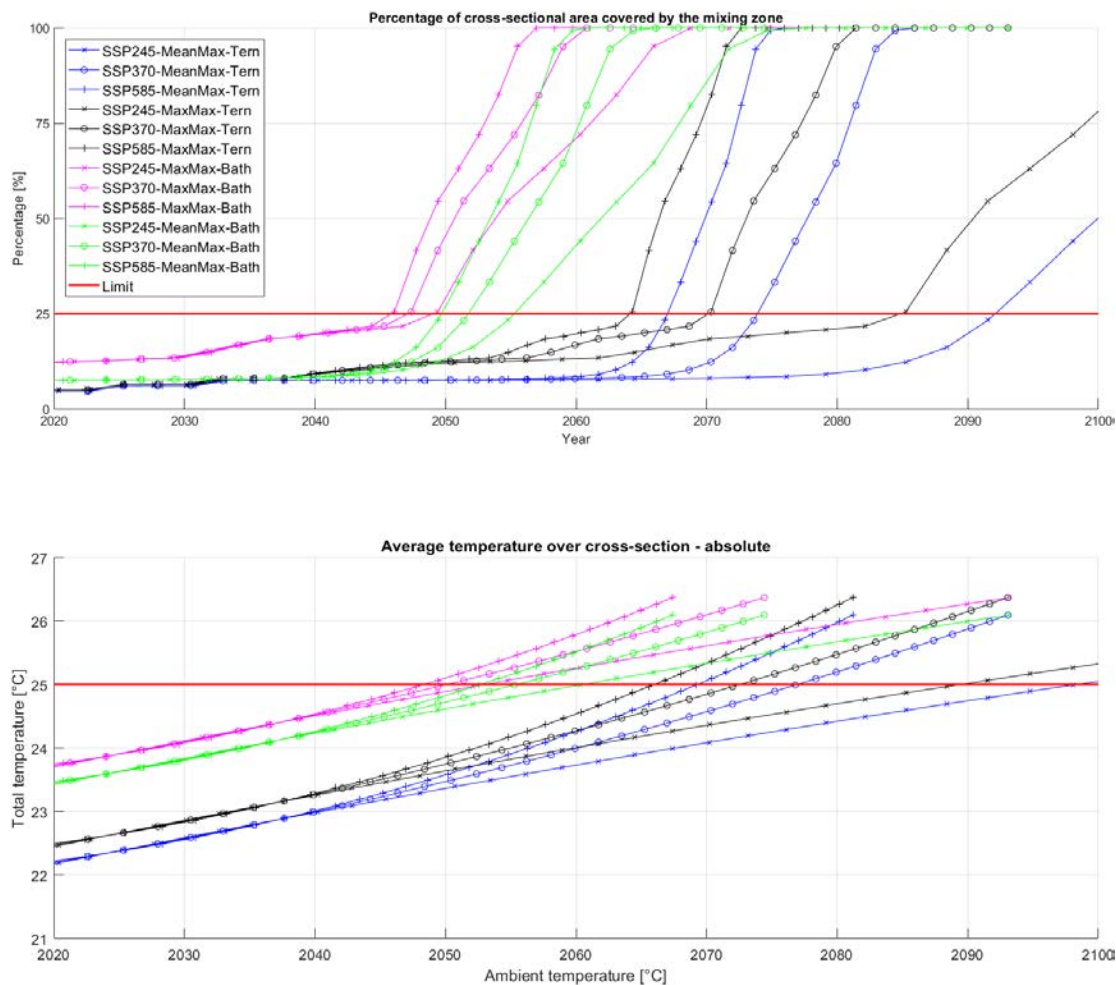


Figure 4.2 Sensitivity of mixing zone extent and average cross-sectional temperature to background temperature assumptions and climate scenarios for Terneuzen. Red lines indicate threshold values.

4.1.3 Eemshaven (estuarine)

For the estuarine part of Eemshaven, Figure 4.3 shows the sensitivity of the results to the same assumptions. The behaviour is consistent with the results for the Western Scheldt locations. Using the absolute maximum mixing zone extent results in non-compliance occurring approximately 5–10 years earlier. Applying upstream boundary temperatures results in non-compliance occurring approximately 10–20 years earlier. This indicates that the choice of background temperature and exceedance metric has a comparable influence across estuarine systems.

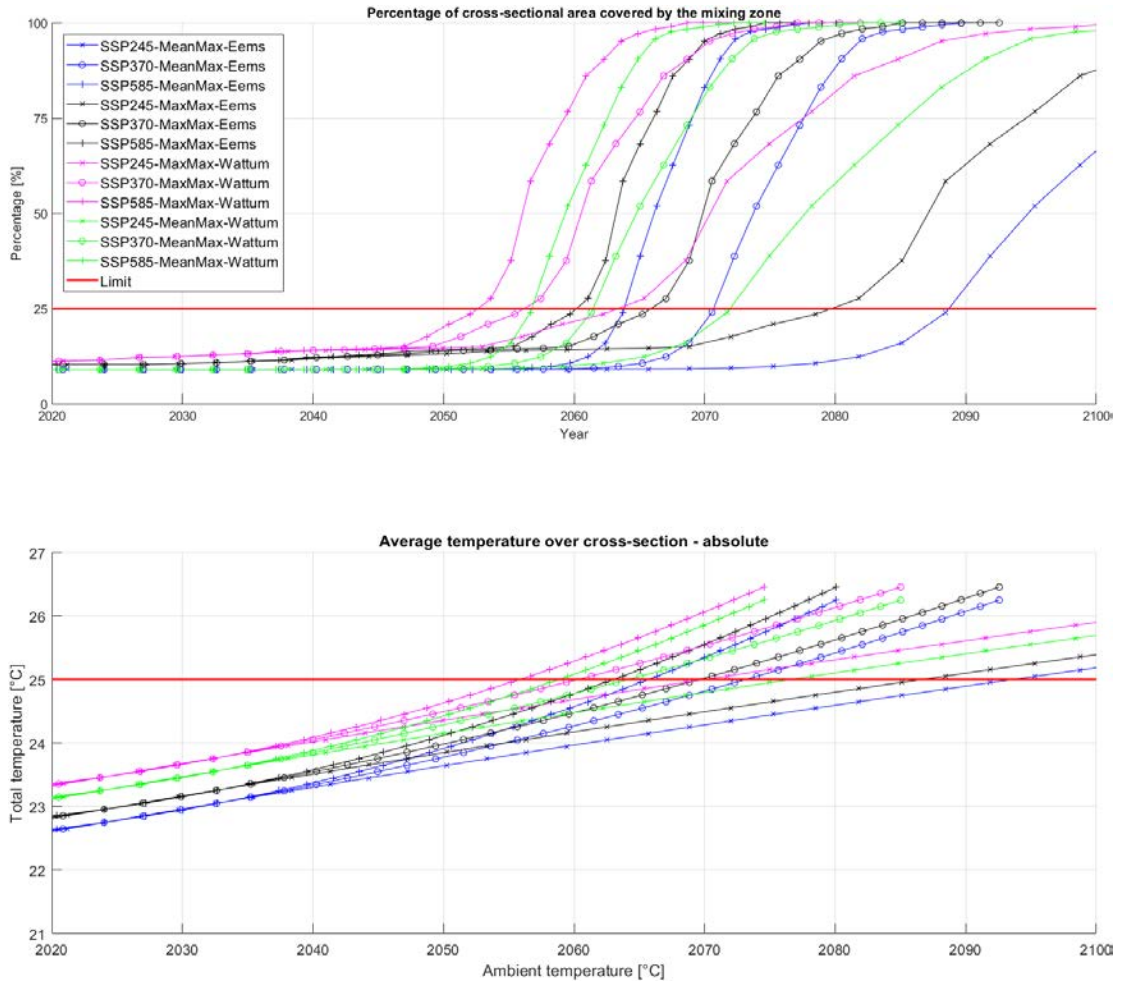


Figure 4.3 Sensitivity of mixing zone extent and average cross-sectional temperature to background temperature assumptions and climate scenarios for Eemshaven (estuarine criterion). Red lines indicate threshold values.

4.1.4 Eemshaven (coastal)

For the coastal criterion at Eemshaven, the sensitivity is dominated by the choice of background temperature. Figure 4.4 shows the baseline results (blue) and the results obtained when the upstream temperature at Wattum is applied (pink).

In this case, the use of upstream boundary temperatures increases the 98th-percentile background temperature to approximately 22°C, compared to approximately 21.5°C in the baseline approach. Although the temperature difference is relatively small (around 0.5°C), it leads to substantially more critical conditions with respect to compliance with the coastal criterion. This shift results in an exceedance already in the present date. However, compliance with the coastal criterion is strongly dependent on the design and configuration of the outfall. As no design optimisation has been considered, the results should be interpreted as indicative for the selected configuration.

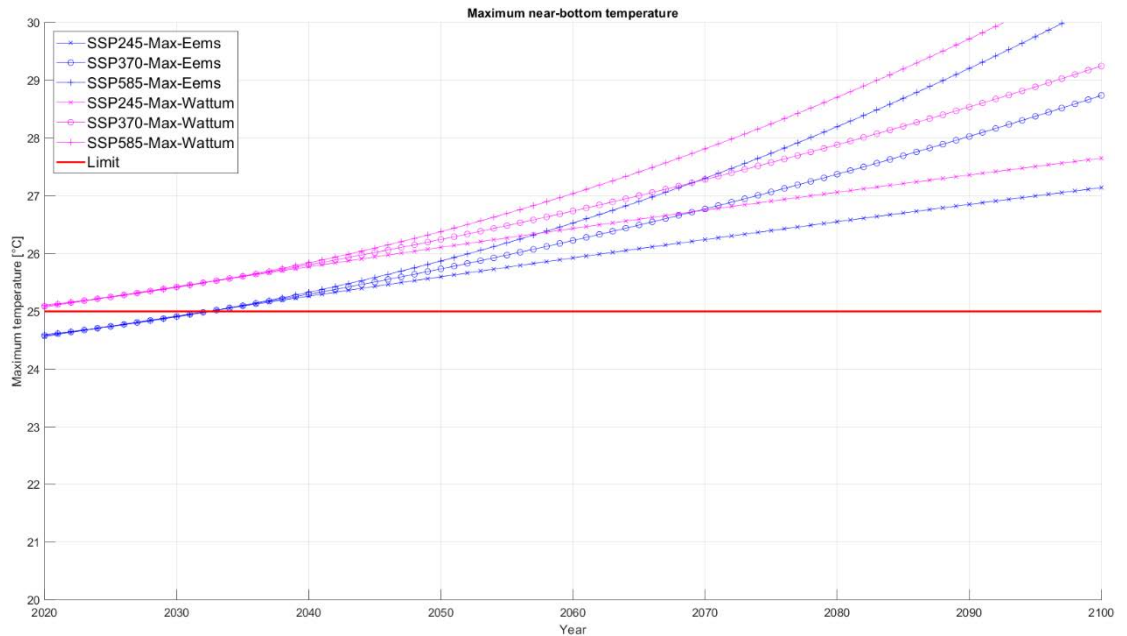


Figure 4.4 Maximum near-bottom temperature over time for different climate scenarios and background temperature assumptions for Eemshaven (coastal criterion). The red line indicates the threshold.

4.1.5 Maasvlakte

Figure 4.5 shows the sensitivity of the results for Maasvlakte to the choice of background temperature. The blue lines represent the baseline results, while the pink lines show the results obtained when upstream temperatures at Hoek van Holland are applied.

The results indicate that increasing the background temperature from approximately 21°C to 22°C, as implied by the upstream approach, results in non-compliance by approximately 10–20 years earlier. Similar to Eemshaven, the results for Maasvlakte are sensitive to the design of the outfall, particularly for the coastal criterion, although the greater water depth may offer opportunities for optimisation.

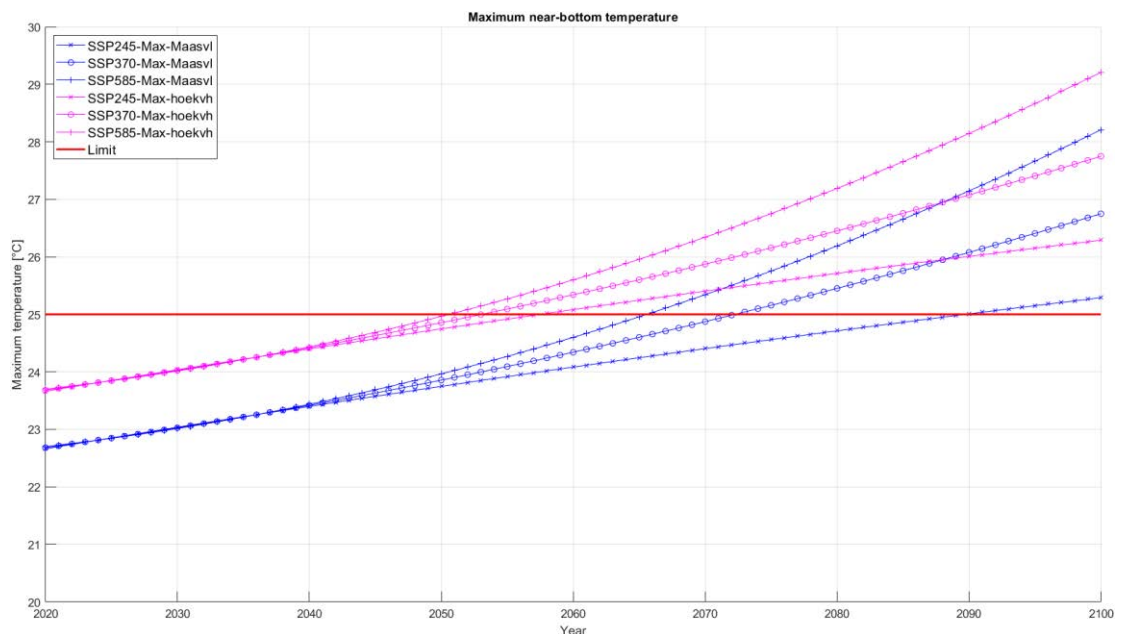


Figure 4.5 Maximum near-bottom temperature over time for different climate scenarios and background temperature assumptions for Maasvlakte. The red line indicates the threshold.

4.2 Intake/outfall location (Eemshaven)

This section evaluates the influence of alternative intake and outfall configurations at Eemshaven, as well as the effect of different operational scenarios for existing facilities. As the future configuration is uncertain, multiple scenarios are considered, including alternative locations east of the Eemshaven port entrance (Locations 2 or 3) and cases with and without operation of the RWE Eemshaven power plant (Location 2), see also Figure 4.6.



Figure 4.6 Overview of the existing plants in the Eemshaven area. RWE Magnum (1), RWE Eemshaven (2) and ENGIE Eemshaven (3).

The results for the different cases, for both the estuarine and coastal criterion, are presented below.

Eemshaven Location 1 (original)

Estuarine criterion

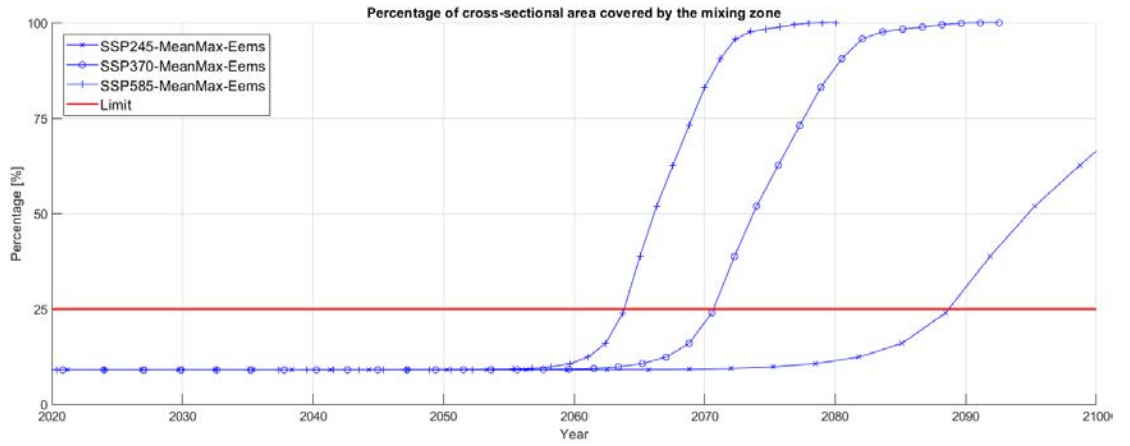


Figure 4.7 Relationship between climate scenarios and mixing zone extent for Eemshaven Location 1 (Deltares reference: Case 7). The red line indicates the threshold.

Coastal criterion

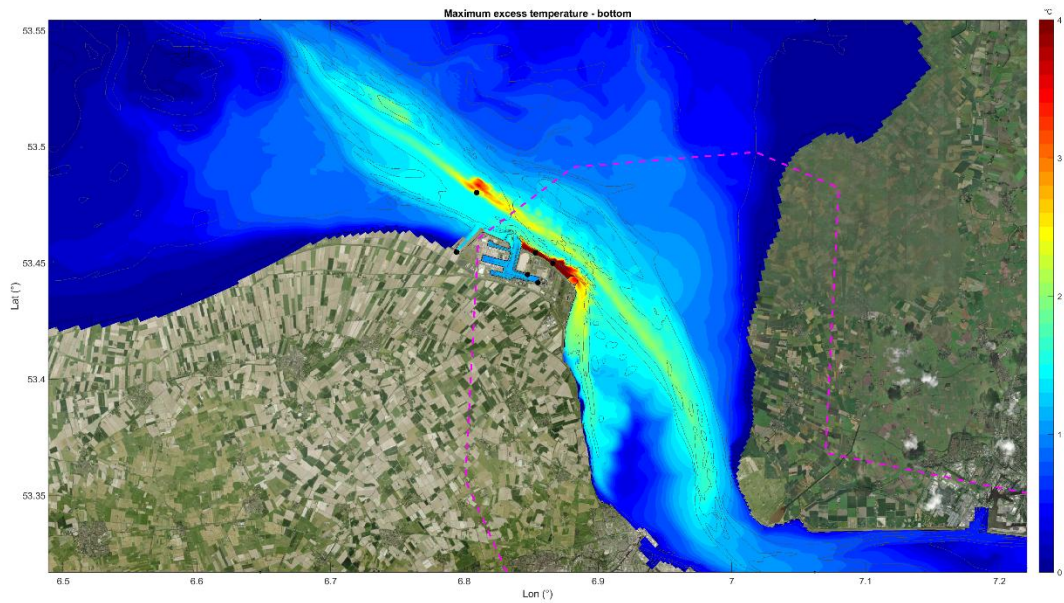


Figure 4.8 Maximum near-bottom excess temperatures for Eemshaven Location 1 (Deltares reference: Case 7). The magenta line indicates the areas for which the estuarine and coastal criterion apply.

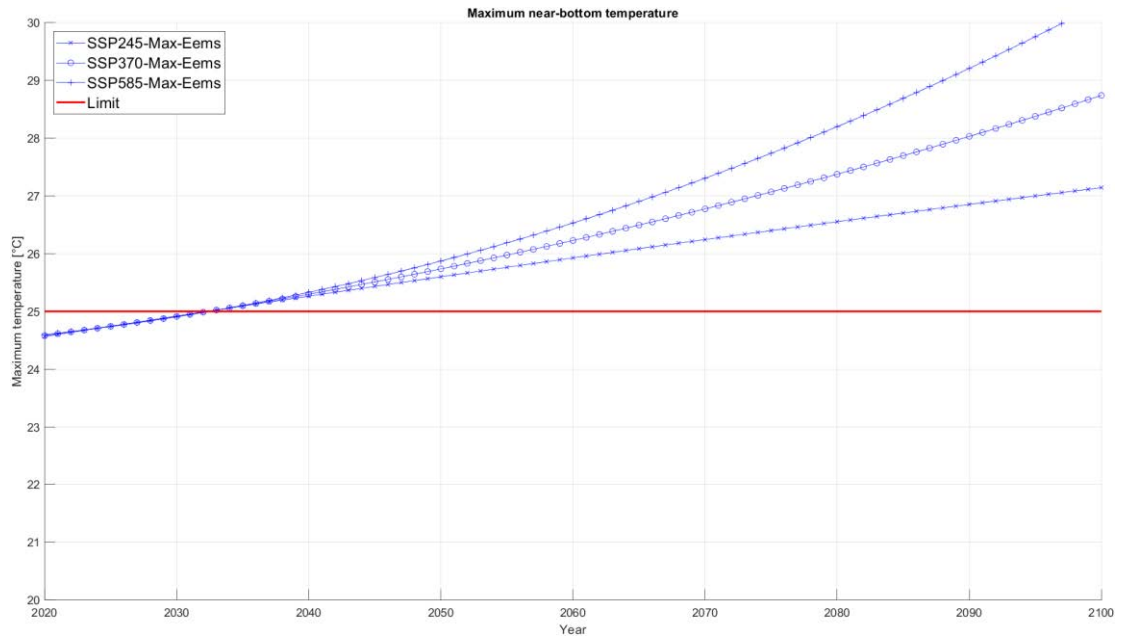


Figure 4.9 Maximum near-bottom temperature over time for different climate scenarios for Eemshaven Location 1 (Deltares reference: Case 7). The red line indicates the threshold.

Eemshaven Location 2 or 3

Estuarine criterion

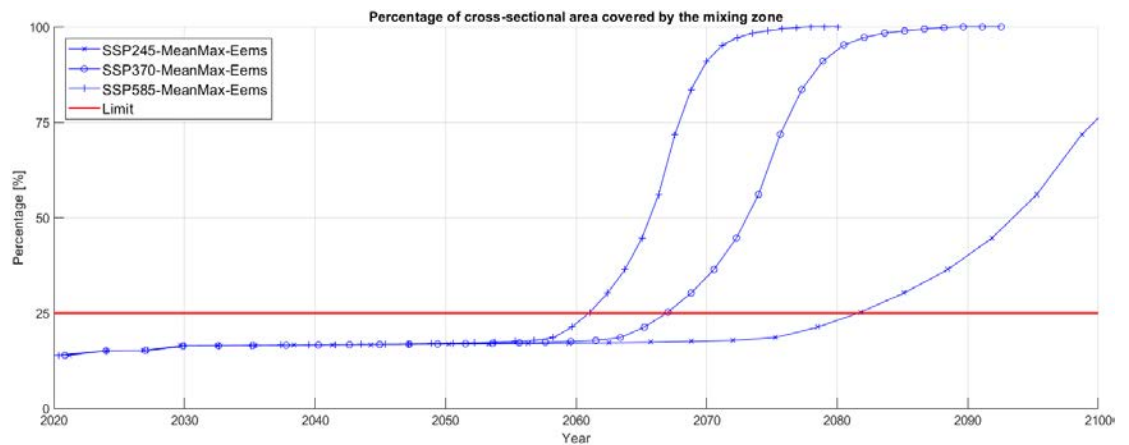


Figure 4.10 Relationship between climate scenarios and mixing zone extent for Eemshaven Location 2/3 (Deltares reference: Case 8). Red lines indicate threshold values.

Coastal criterion

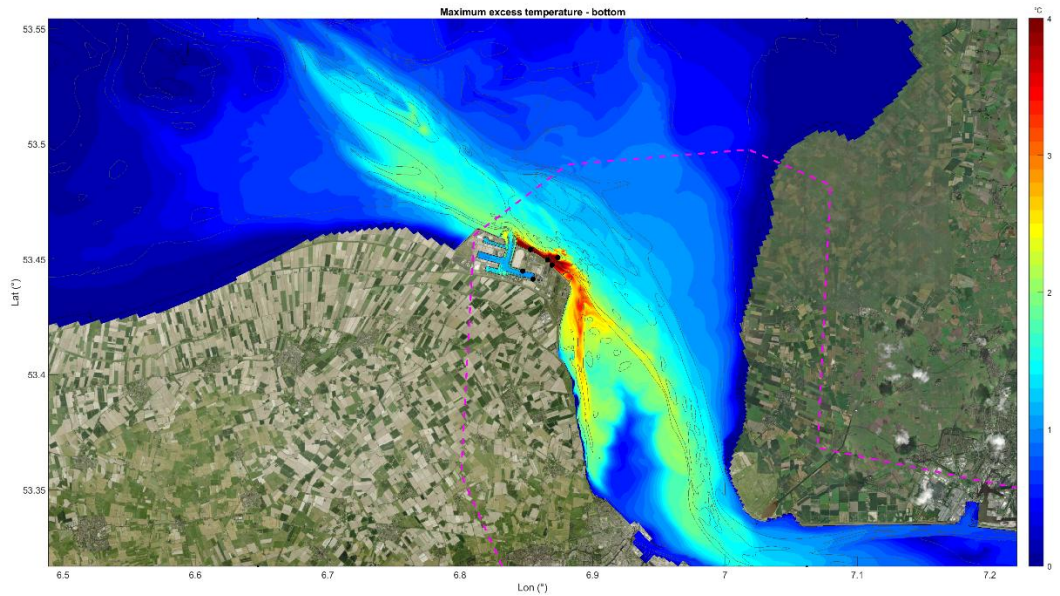


Figure 4.11 Maximum near-bottom excess temperatures for Eemshaven Location 2/3 (Deltares reference: Case 8). The magenta line indicates the areas for which the estuarine and coastal criterion apply.

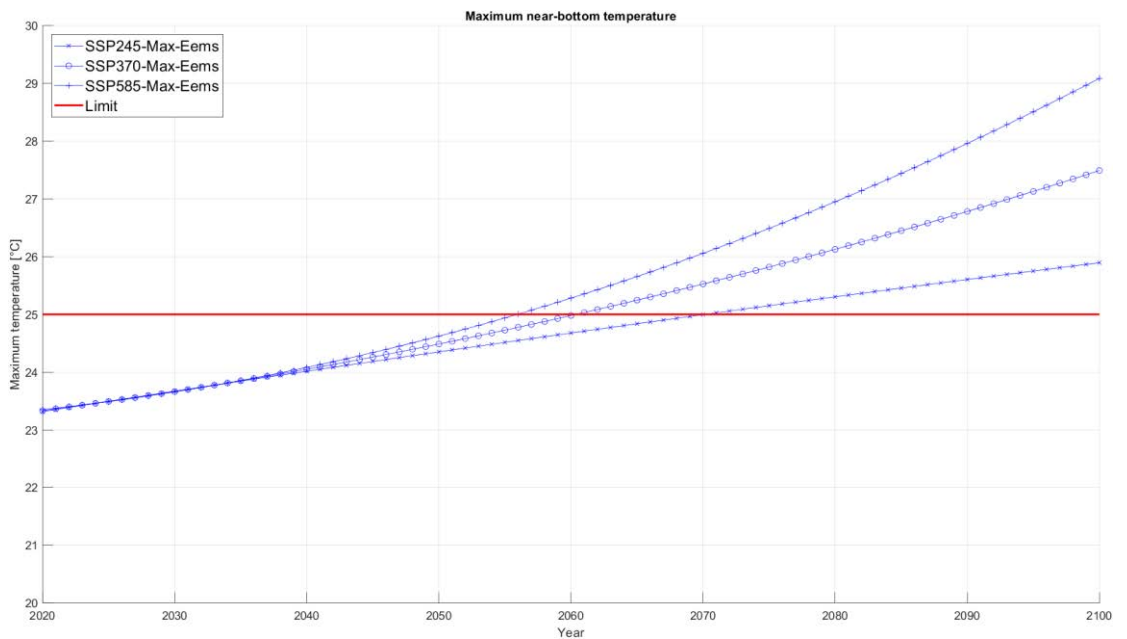


Figure 4.12 Maximum near-bottom temperature over time for different climate scenarios for Eemshaven Location 2/3 (Deltares reference: Case 8). The red line indicates the threshold.

Eemshaven Location 2 or 3 without RWE Eemshaven

Estuarine criterion

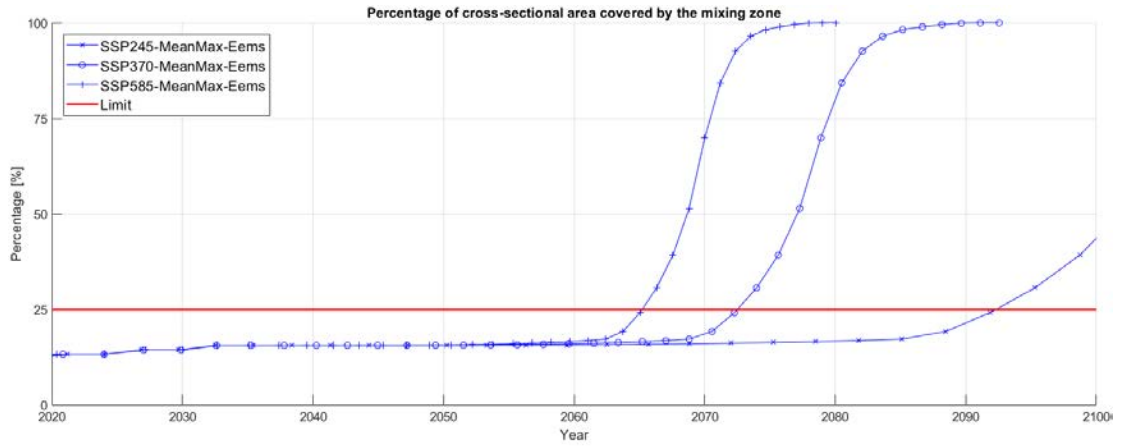


Figure 4.13 Relationship between climate scenarios and mixing zone extent for Eemshaven Location 2/3, excluding RWE (Deltares reference: Case 9). Red lines indicate threshold values.

Coastal criterion

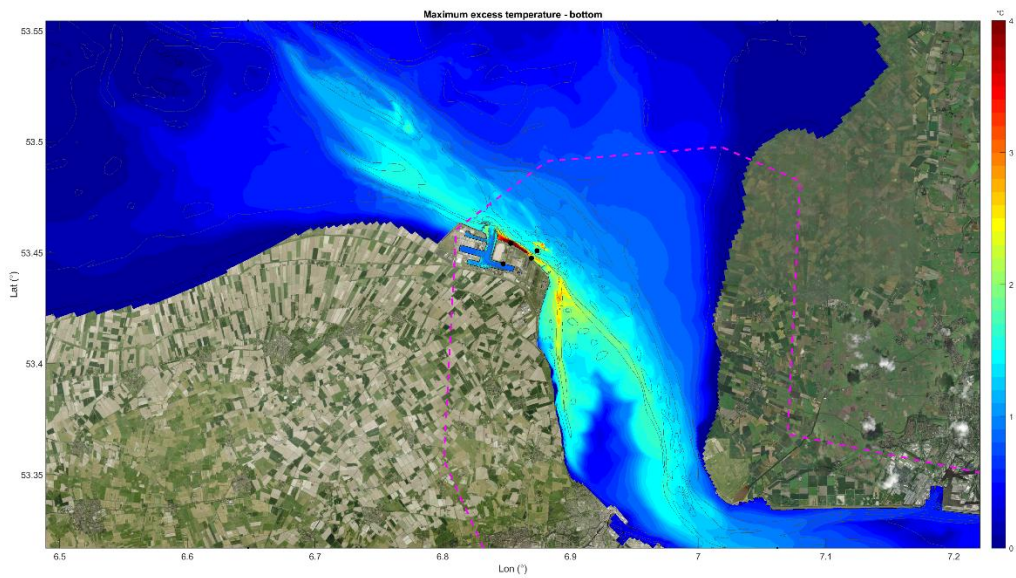


Figure 4.14 Maximum near-bottom excess temperatures for Eemshaven Location 2/3, excluding RWE. (Deltares reference: Case 9). The magenta line indicates the areas for which the estuarine and coastal criterion apply.

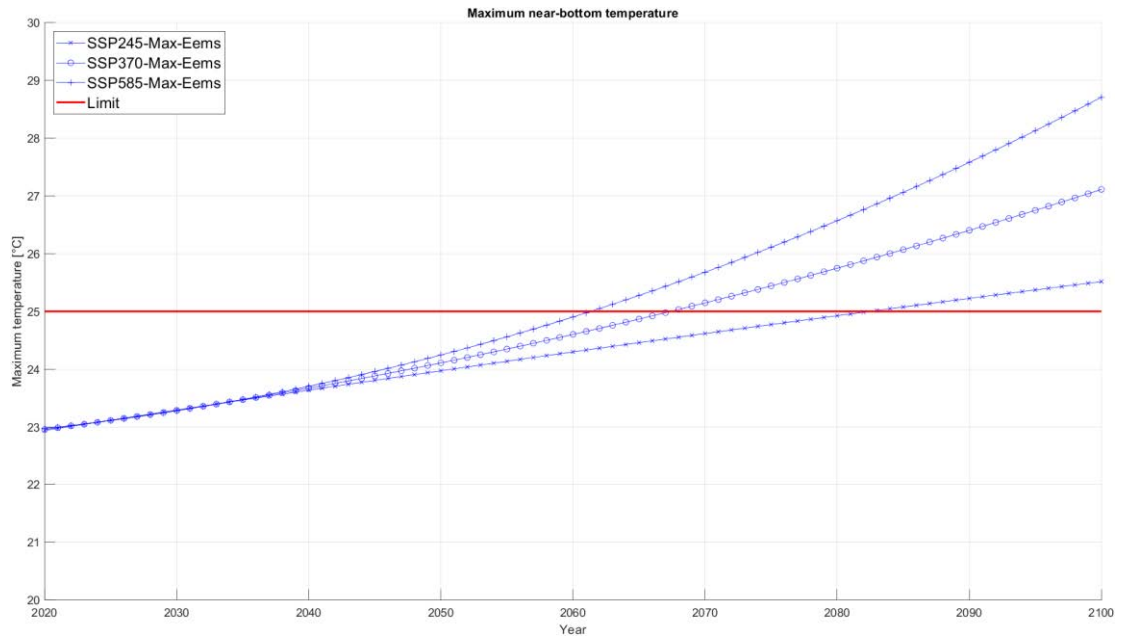
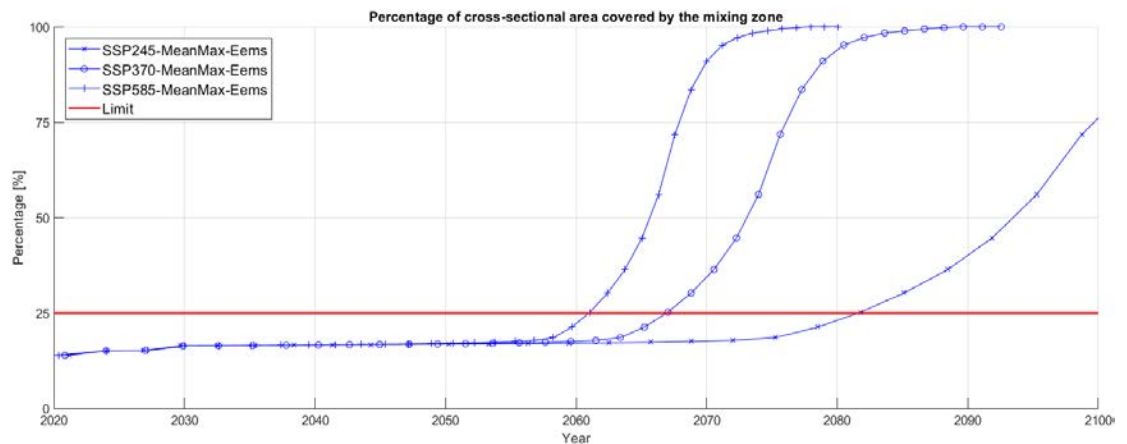


Figure 4.15 Maximum near-bottom temperature over time for different climate scenarios for Eemshaven Location 2/3, excluding RWE (Deltares reference: Case 9). The red line indicates the threshold.

The results show that the intake and outfall configuration has a noticeable impact on compliance with the estuarine criterion. Configurations located east of Eemshaven generally result in non-compliance occurring approximately 5 years earlier than for the western configuration. In contrast, excluding the RWE power plant delays non-compliance by approximately 5–10 years (Figure 4.16).

For the coastal criterion, the effect is reversed. Eastern configurations lead to significantly later non-compliance in the coastal area west of Eemshaven, with delays of approximately 20–40 years compared to the western configuration (Figure 4.17 and Figure 4.18). This highlights the strong influence of discharge location and surrounding hydrodynamics on coastal thermal impacts.



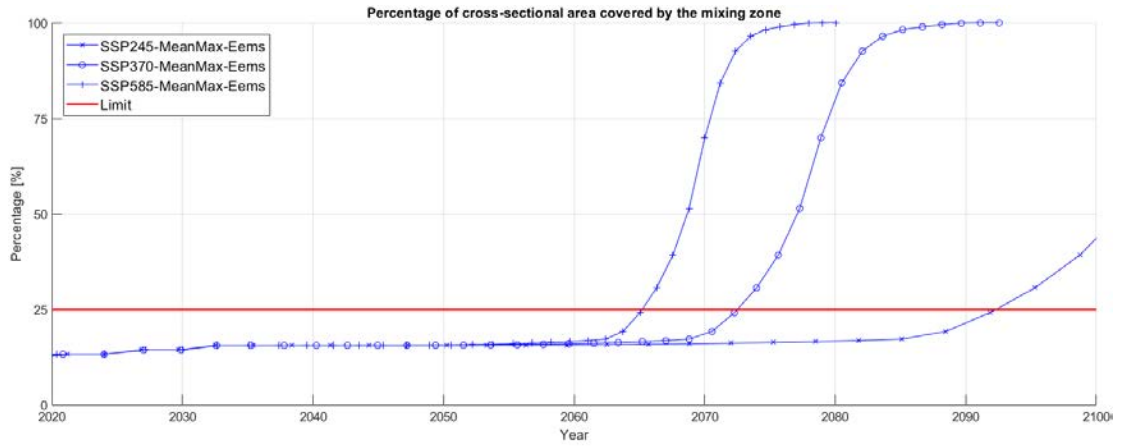


Figure 4.16 Percentage of mixing zones Top: Eemshaven design 2 or 3, Bottom Eemshaven design 2 or 3 without RWE E.

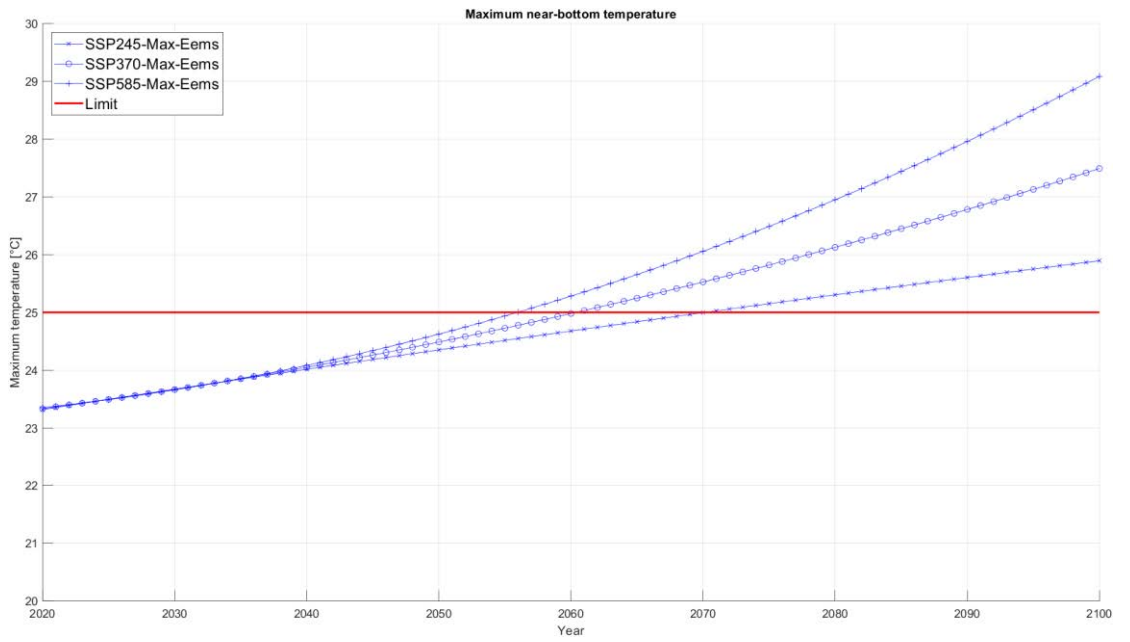


Figure 4.17 Maximum near-bottom temperature for Eemshaven design 2 or 3.

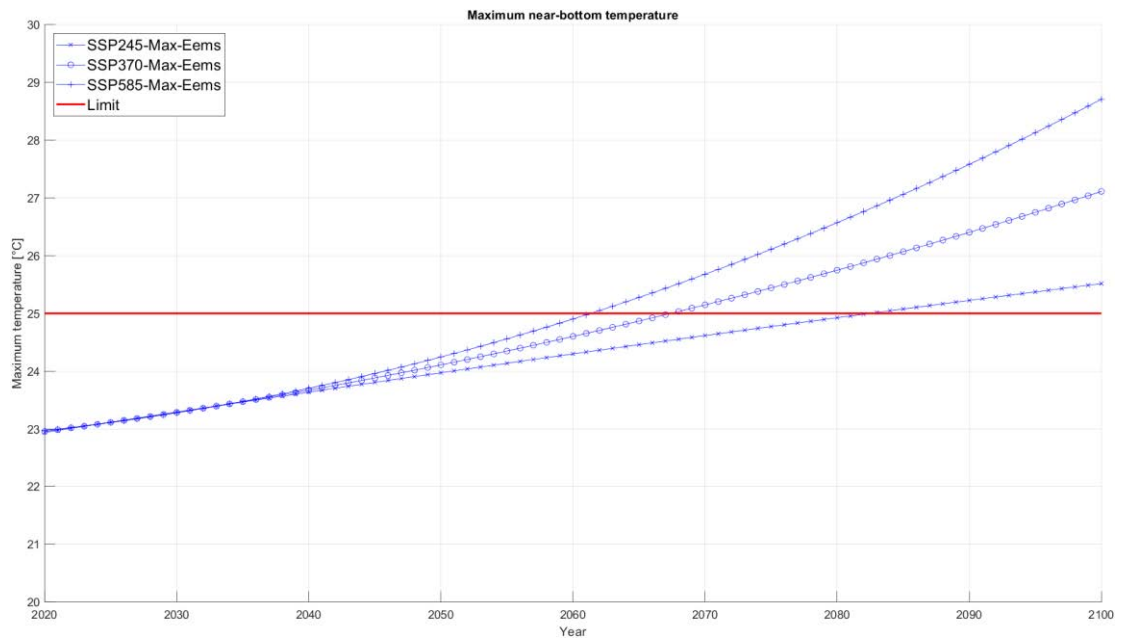


Figure 4.18 Maximum near-bottom temperature for Eemshaven design 2 or 3 without RWE E.

4.3 Cross-sectional area (Terneuzen)

The sensitivity of the results to the definition of the cross-sectional area was investigated for Terneuzen by comparing the full estuarine width with the main navigation channel only (Figure 4.19).

The results indicate that restricting the analysis to the main channel leads to an earlier onset of non-compliance, by approximately 5–10 years. This reflects the reduced cross-sectional area available for mixing, resulting in higher relative plume coverage.

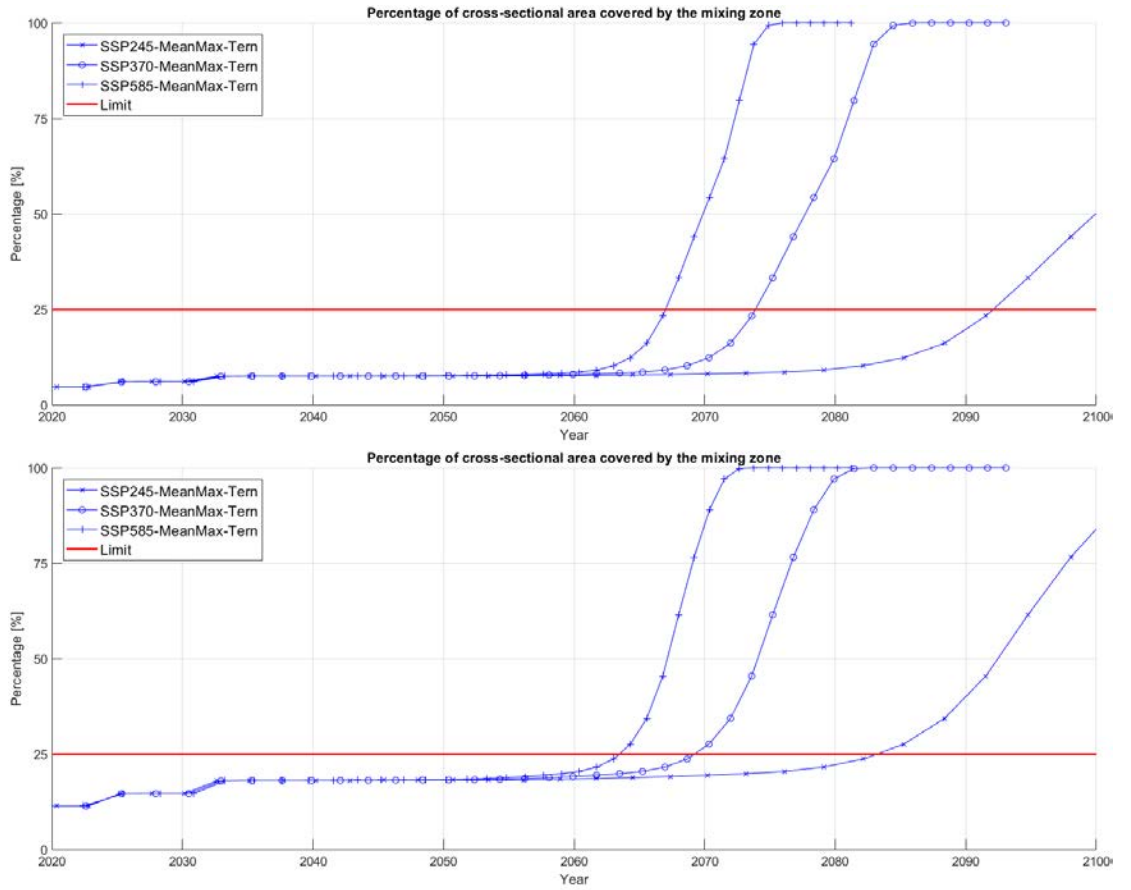


Figure 4.19 Top: Full cross-sectional area of total estuarine width, Bottom: Only cross-sectional area of the main channel.

5 Conclusions

5.1 General conclusions

This synthesis shows that climate change has a significant impact on cooling water availability and compliance with CIW temperature criteria at all considered locations. Under projected climate scenarios, all sites are expected to experience decreasing thermal cooling capacity, eventually leading to non-compliance with the applicable criteria.

Based on the analysis, the following preliminary conclusions are made:

- **Borssele:** Non-compliance with the CIW estuarine criterion is expected around 2075 (SSP5-8.5), 2085 (SSP3-7.0) and after 2100 (SSP2-4.5).
- **Terneuzen:** Non-compliance with the CIW estuarine criterion is expected around 2065 (SSP5-8.5), 2075 (SSP3-7.0) and 2095 (SSP2-4.5), approximately 10 years earlier than for Borssele.
- **Eemshaven (estuarine criterion):** Non-compliance with the CIW estuarine criterion is expected around 2065 (SSP5-8.5), 2070 (SSP3-7.0) and 2090 (SSP2-4.5), approximately 5 years earlier than for Terneuzen.
- **Eemshaven (coastal criterion):** Non-compliance with the coastal criterion is expected substantially earlier than under the estuarine criterion, namely between 2030 and 2040 for all three considered climate scenarios. It should be noted that compliance and interpretation with the coastal CIW criterion is sensitive to the design and configuration of the outfall, which has not been optimised in this assessment. Given the shallow waters near the outfall and the cumulative effects of neighbouring cooling water discharges, non-compliance of a cooling water outfall near Eemshaven is therefore expected sooner than at the other potential sites.
- **Maasvlakte:** Non-compliance with the CIW estuarine criterion is expected around 2065 (SSP5-8.5), 2070 (SSP3-7.0) and 2090 (SSP2-4.5). Similar to Eemshaven, compliance with the coastal criterion may be sensitive to the outfall design; however, deeper water conditions may provide more flexibility for optimisation.

It is further noted that between approximately 2085 and 2100, ambient water temperatures are expected to exceed 25 °C at all locations under SSP5-8.5, leaving limited or no capacity for any additional thermal discharges.

5.2 Conclusions sensitive tests

Several sensitivity tests were performed to assess the influence of key assumptions, the impact of climate change on cooling water availability and uncertainties in the synthesis approach. Based on these sensitivity tests, the following conclusions can be drawn:

- **Climate scenarios:** Climate change has a large impact on ambient water temperature and compliance with CIW criteria. Differences between climate scenarios SSP5-8.5 and SSP2-4.5 lead to variations of approximately 5 – 30 years in the projected timing of non-compliance. Under SSP5-8.5, ambient background temperatures are expected to reach 25°C approximately 10–15 years after the first occurrence of non-compliance, at which point any cooling water discharge would no longer meet CIW criteria.
- **Background temperature definition:** A less favourable interpretation of the CIW criteria, using upstream boundary temperatures instead of local values, increases the 98th-percentile background temperature by approximately 0.5–2°C. This results in non-compliance occurring approximately 10–20 years earlier.
- **Mixing zone representation:** Using the absolute maximum mixing zone percentage instead of the typical (mean) maximum percentage, non-compliance would typically occur

5–10 years earlier than with the use of a typical (mean) maximum. The use of the typical maximum in combination with the 98th-percentile background temperature is considered a more representative indicator of sustained impacts.

- **Eemshaven – intake/outfall configuration:** For Eemshaven, the selection of which intake and outfall configurations to consider appears to be an important assumption. To quantify the impact of this assumption on the synthesis, several intake and outfall configurations were evaluated. The original configuration was located west of Eemshaven in an area subject to the coastal criterion. As a sensitivity test, an intake and outfall east of Eemshaven (variant Eemshaven 2 or 3) was also assessed. In addition, a situation without the RWE E discharge was considered. From this analysis:
 - For the estuarine criterion, a configuration east of Eemshaven is expected to result in non-compliance occurring typically 5 years earlier compared to the western configuration.
 - Excluding the RWE E provides an additional 5–10 years before non-compliance is reached for the estuarine criteria.
 - For the coastal criterion, a configuration east of Eemshaven is expected to result in non-compliance (*in the coastal area west of the Eemshaven*) occurring typically 20 – 40 years later compared to the western configuration.
- **Terneuzen – cross-sectional definition:** The interpretation of the estuarine criterion is uncertain, particularly regarding the definition of the cross-sectional width (i.e., whether it refers to the full width of the estuary or only the main channel). Applying the main-channel width only results in expected non-compliance occurring 5 –10 years earlier compared to using the full estuarine width.

5.3 Concluding remarks

Overall, the results show that both climate change and methodological assumptions substantially influence the projected timing of non-compliance. The variation introduced by these factors can be of a similar magnitude, highlighting the importance of carefully defining input assumptions and interpretation of the CIW criteria.

The findings provide insight into the sensitivity of different locations and scenarios and should therefore be interpreted as indicative rather than absolute. They are primarily intended to support comparison between locations, identification of key constraints, and to guide further analysis, including the exploration of optimised intake and outfall configurations.

References

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Deltares 2024b, Regelgevend kader koelwater Borssele, 2024, see [Koelwaterstudie Borssele - Deltares | Kernenergie in Nederland](#)

Deltares 2026a, Terneuzen site evaluation cooling water availability, 2026, prepared for Ministry of KGG

Deltares 2026b, Eemshaven site evaluation cooling water availability, 2026, prepared for Ministry of KGG

Deltares 2026c, Maasvlakte site evaluation cooling water availability, 2026, prepared for Ministry of KGG

Deltares 2026d, Evaluation climate projections sea water temperature at Dutch coast, 2026, prepared for Ministry of KGG

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