Ex ante evaluation of nutrients in fresh, coastal and marine waters

with a focus on the Meuse basin

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Summary

This study has been carried out on request of the International Meuse Commission and the Dutch Ministry of Infrastructure and Water Management with the goal to give insight in the total nitrogen and total phosphorus concentrations for the Dutch transboundary water bodies and the fresh, transitional, coastal and marine waters in 2027 for five different scenarios and compare these with the nutrient targets of the Water Framework Directive and the OSPAR Convention. The study used models, which have been developed in the Netherlands and are based on the available data and formats.

The study is an update of the ex-ante evaluation of total nitrogen concentrations in coastal waters of the Meuse catchment, as published in 2015 by Deltares, and an extension of the calculations carried out in 2020 for the National Analysis Water Quality in the Netherlands. The study included a data exchange of water flows, nutrient concentrations, target values and expected reductions for the transboundary waters with Niedersachsen, Nordrhein-Westfalen, Flanders and Wallonia and can be characterized by a positive and active cooperation of all partners.

Different monitoring and analyzing methods used by the different partners play an important role in the encountered differences in concentrations among the partners, especially for total nitrogen.

Differences also exist in the nutrient targets on both sides of the border. Differences in the definition of the targets make it difficult to compare them. In the Netherlands and Flanders summer average concentrations are used, in Germany annual average concentrations are used for the larger transboundary waters and a nitrate concentration for the smaller waters; in Wallonia a 90-percentile of the summer measured values is used.

For almost all waters (including the Meuse river, excluding the Niers and the Roer), the targets of the upstream partners are higher (a factor 2-5) than the Dutch targets. For total phosphorus, the targets are rather comparable between the partners.

Two reference scenarios (A based on the Dutch 2015 data and A+ based on the 2015 data of the upstream countries) are compared with three future scenarios with different transboundary nutrient concentrations (B includes Dutch target values, C includes upstream target values, and D includes expected reductions in 2027) which are all three combined with the expected effects of the intended measures in the Netherlands of the River Basin Management Plan (RBMP) for the 3rd cycle of the Water Framework Directive (WFD).

Reductions of nutrient concentrations for the transboundary waters as expected by the upstream partners in 2027 show to be limited: a 0-5% reduction of both total nitrogen and total phosphorus for Nordrhein-Westfalen, an average reduction of 9% for total nitrogen and 17% for total phosphorus for Flanders and small reductions of 3% for total nitrogen and 2% for total phosphorus for the Meuse River. In scenario A the Dutch targets (which is the basis for scenario B) will be met for only a limited part of the transboundary waters: only 11% of the number of transboundary waters meet the targets for total nitrogen and 33% for total phosphorus. In scenario D this percentage increases to 17% for total nitrogen, but decreases to 31% for total phosphorus.

The nutrient reductions considered in the various WFD Explorer scenarios in all Dutch River Basin Districts (Rhine, Meuse, Scheldt and Ems) including the transboundary waters as a result of the intended measures of the 3rd RBMPs of the WFD also lead to reductions of the nutrient loads discharged into the North Sea. This, in turn, results in decreased nutrient concentrations in the coastal and marine waters. However, the discharged nutrients are diluted quickly in the marine waters. As a result, the impact of the nutrient reductions is largest close to the discharge locations, but is reduced along the coast, and is negligible in the offshore areas.

Although these reductions lead to change in assessment status for a few of the coastal assessment locations in some of the WFD or OSPAR areas, the majority of assessment locations is not affected. Hence, the nutrient reductions in the various scenarios hardly lead to any changes in classification status of the considered areas.

It is recommended to generate a common dataset of the flows and concentrations of the transboundary waters to increase the quality of common evaluations like the present study and support the discussion about the tuning and intercalibration of the targets, as set in the different parts of the Meuse catchment.

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1 Introduction

1.1 Background

End 2019 the International Meuse Commission (IMC) requested an update of the ex-ante evaluation of total nitrogen concentrations in coastal waters of the Meuse catchment for 2021 and 2027, as carried out in 2015 by Deltares (Chrzanowski et al., 2015a and 2015b). In addition, the Dutch Ministry of Infrastructure and Water Management has also indicated that there is a need for an extension of the calculations recently carried out for the National Analysis Water Quality (NAW, an ex-ante evaluation of the effects of the 3rd River Basin Management Plans of the Water Framework Directive (WFD) in the Netherlands (van Gaalen et al., 2020). In the NAW study, the evaluation of the nutrients was limited to the fresh and transitional waters. The Dutch Ministry asks to include also nutrient calculations for the coastal and marine waters for the year 2027. Both questions are combined in this project, to be carried out by Deltares in close collaboration with the upstream countries.

This document is especially made for the IMC. Another document (in Dutch) is made to report to the Dutch Ministry of Infrastructure and Water Management (van den Roovaart et al., 2021, in prep,). Because the North Sea is not only influenced by the Meuse catchment, but also by the other catchments (Ems, Rhine and Scheldt), in several places in this report the information is not restricted to the Meuse catchment. The text about the data exchange (Chapter 3) is restricted to the data of the Meuse catchment.

1.2 Scope and goal of the project

The goal of the project is to calculate total nitrogen and total phosphorus concentrations for all the relevant Dutch transboundary water bodies and the fresh, transitional, coastal and marine waters in 2027 for five different scenarios and compare these with the water quality targets of the WFD and the Convention for the Protection of the Marine Environment of the North-East Atlantic (the ‘OSPAR Convention').

Compared to the 2015 study, this evaluation shows several extensions and improvements:

- Model calculations were carried out not only for total nitrogen, but also for total phosphorus since the N/P ratio is relevant for the coastal and marine waters.
- Updated models were used, both the WFD Explorer (update from version 2.0 to 2.4) and the North Sea Model show more detail in the schematizations used.
- The year 2015 was used as reference year. Scenario calculations were made for the year 2027, the end of the 3rd RBMP cycle.
- Data exchange was not be limited to the Meuse catchment, but also carried out for the Dutch parts and transboundary waters of the Rhine, Scheldt and Ems catchments.
- Concentrations of total nitrogen and total phosphorus were calculated and compared to the water quality targets, both for the fresh water and transitional waters (WFD targets), the coastal (WFD and OSPAR targets) and marine waters (OSPAR targets).
- Scenario calculations were made for all the four Dutch River Basin Districts (Rhine, Meuse, Scheldt and Ems) and the coastal and marine waters. The focus of this report lies on the results Meuse catchment, and coastal and marine waters.

1.3 Reading guide

Chapter 1 shows an introduction to the project and describes the goal of the study. In Chapter 2 the models and the methods used are described. Chapter 3 focuses on the data exchange with the upstream partners. The results of the model calculations are presented in Chapter 4. Finally, in Chapter 5, the discussion, conclusions and recommendations are given. In Chapter 6 the literature references are listed. Detailed additional information is included in the Annexes A-G.

2 Models and methods

2.1 Project approach

In this project two models have been coupled: the WFD Explorer (covering the Dutch transboundary waters and the fresh and transitional waters) and the D3D North Sea Model (covering the Dutch coastal and marine waters). Both models have been developed in the Netherlands and are based on available data and formats. Starting with the WFD Explorer, two reference scenarios were calculated for the year 2027: one based on the Dutch 2015 data (scenario A) and one based on the 2015 data provided by the upstream countries (scenario A+). These references were compared with three scenarios (B, C and D) with different transboundary nutrient concentrations which were combined with the expected effects of the intended measures of the River Basin Management Plans (RBMP) for the 3rd cycle of the WFD. As a second step, the resulting nutrient concentrations and discharges at the WFD Explorer outflow points were used as input for the North Sea Model. Both for the fresh water systems and for the coastal and marine waters, concentrations of total nitrogen and total phosphorus were calculated and compared with the water quality targets as agreed in the WFD and OSPAR assessment frameworks.

2.2 Reference year and scenarios

The year 2015 was used as base year of the project. This year has also been used as base year for the NAW (van Gaalen et al., 2020). As a reference a “no measure” scenario (A) for 2027 is introduced, in the NAW this set of measures is referred to as *NAP5* (5th Nitrate Action Plan) in the NAW. As in the NAW this reference scenario is used to compare with the scenarios B, C and D. The *NAP5* package consists only of measures which are already established policy, so no new measures are added. This is in fact a “no measure” scenario. In this reference scenario the Dutch data of the transboundary rivers are used, as is done in the NAW.

Since it is known from the 2015 study that (sometimes large) differences exist in the flow and nutrient concentration data provided by the different countries, also an alternative reference scenario (A+) is defined. The data for scenario A+ is the same as the A scenario, but for the transboundary waters the data of the upstream partners is used.

For the scenarios B, C and D the so-called “intended measures” set of measures is used, as defined in the NAW. These are the measures which are planned to be carried out and included in the draft RBMPs for the 3rd WFD cycle (2022-2027) by the Dutch waterboards and Rijkswaterstaat. The package “intended measures” includes:

- the national implementation of the 6th Nitrate Action Plan
- the voluntary agricultural measures of the *Deltaplan Agrarisch Waterbeheer* (DAW)
- improvement of Urban Waste Water Plants (UWWTPs)
- hydro morphological and ecological measures.

For all three scenarios B, C and D the same national set of “intended measures” is used, however the input of the transboundary rivers differs. In scenario B it is assumed the nutrient concentrations of the transboundary waters meet the Dutch water quality targets as set by the WFD. In scenario C it is assumed that the nutrient concentrations of the transboundary waters meet the water quality targets defined by the upstream countries. In scenario D the expected concentrations (delivered by the upstream countries) for the year 2027 as a result of the WFD measures in the upstream countries are used.

Summarizing, the reference scenario A, together with the alternative reference A+ and the 3 variants of the transboundary contributions, gives a total of five scenarios:

A **Reference**: prognosis for 2027 including for the Dutch part of the river basins a "no measure" scenario and for the transboundary water bodies the 2015 data measured by the Netherlands;

A+ **Reference**: prognosis for 2027 including for the Dutch part of the river basins a "no measure" scenario and for the transboundary water bodies the 2015 data as measured or modeled by the upstream partners;

B **Dutch targets**: prognosis for 2027 including for the Dutch part of the river basins an "intended measures" scenario and for the transboundary water bodies concentrations meeting the Dutch water quality targets;

C **Upstream targets**: prognosis for 2027 including for the Dutch part of the river basins an "intended measures" scenario and for the transboundary water bodies concentrations meeting the targets of the upstream partners;

D **Realistic**: prognosis for 2027 including for the Dutch part of the river basins an "intended measures" scenario and for the transboundary water bodies realistic expected concentrations in 2027 by the upstream partners as the result of measures planned in the 3rd RBMPs.

2.3 WFD Explorer model

2.3.1 Model structure

It is requested to evaluate the impact of policy measures on manure surplus, nitrate concentrations in groundwater, nutrient load on surface water systems as well as chemical and ecological quality of surface water. In the Netherlands a recently updated set of models is used for the assessment of the Fertiliser Act and the WFD: the National Water Quality Model (LWKM). The model is also used in the NAW and is described in detail in *van der Bolt et al., 2020* (in Dutch). The LWKM is combined with the hydrological calculations made with the National Hydrological Model (NHM), which consists of the sub models:

- MetaSWAP (hydrology, vegetation, unsaturated zone)
- MODFLOW (saturated zone)
- MOZART (regional water systems) and Distribution Model (DM) (national water distribution)

The LWKM is using the following model codes:

- ANIMO (soil quality, soil water quality, nitrate concentration groundwater and nutrient loads to groundwater and surface water)
- MT3DS (underground)
- WFD Explorer (surface water quality; chemical and ecological water quality).

2.3.2 The Water Framework Directive Explorer

The WFD is one of the most important policy directives in Europe for the improvement of water quality and ecology. The WFD Explorer is an analysis tool to support the implementation of the WFD. The tool enables the calculation of the effect of restoration and mitigation measures on the ecological and chemical quality of surface waters. Users will gain insight into the effectiveness of programmes of measures in relation to WFD objectives. Measures can be defined in relation to both point sources, such as wastewater treatment plants, and diffuse sources, such as agriculture and traffic. Likewise, it is possible to calculate the effectiveness of restoration measures such as stream re-meandering or the construction of near-natural riparian zones.

The WFD Explorer is a flexible tool that allows users to easily import or adjust things like their own schematisation of a river basin, emission data and area specific characteristics. The user-friendly interface makes it easy to set up a model structure, perform an analysis and produce reports in an organized and systematic way which can be used in policy briefings, for the communication with stakeholders and as background documentation for reports to the European Commission. For this study the 2.4 version of the model was used.

The WFD Explorer is a lumped, steady state catchment water quality model to quantify catchment nutrient loading after attenuation. It comprises a water balance, a substance balance and an Ecological module (which is not used in this project).

2.3.3 Model scheme

The WFD Explorer consists of three main building blocks that can be used either concurrently or as stand-alone modules (Figure 2-1). The Hydrology module routes the water through the nodal network using the forcing flows from sinks and sources such waste water treatment plants, industry, border crossing streams, etc. as main input. Water quality is subsequently calculated with flow input from the Hydrology module, forcing loads on the nodes, and substance-related retention coefficients. Finally, the Ecology module provides an ecological score per identified water body usually made up of one or more nodes.

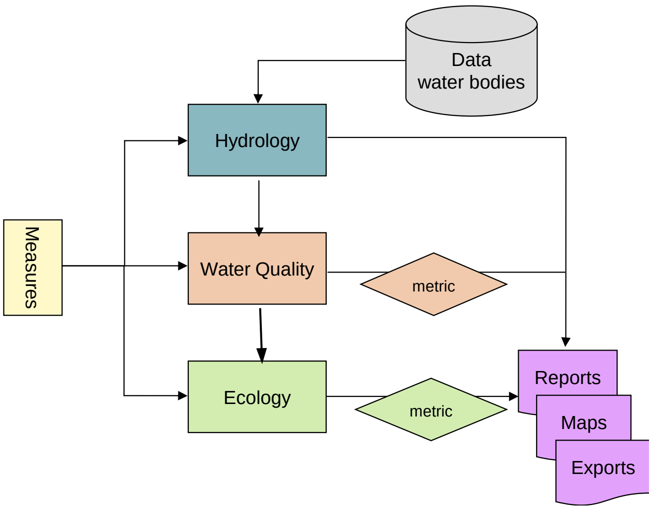


Figure 2-1 Schematic overview of the WFD Explorer

2.3.4 Modelled processes

The Hydrology module routes the water through the nodal network based on a water balance approach without storage terms. For this, the module also needs nodal fractions to correctly divide discharges (bifurcations) and actual flows to meet nodal demands.

This information, given in time-averaged values, should be supplied by a precursor hydraulic or water distribution model.

The Water Quality module uses the flows from the Hydrology module and the nodal forcing loads. In its present implementation only the nutrients total nitrogen and total phosphorus are considered, but the versatility of the underlying software also allows for the computation of other substances. Processes are restricted to a simple first-order disappearance approach. The applied retention coefficients are generally generic in space and time. At present, coefficients are used for the Pleistocene and the Holocene parts of the Netherlands and split up for the summer and winter half years.

2.3.5 Main input and output variables

The WFD Explorer is an instrument which can be applied at multiple scales. This version is hydrological fed by the Dutch National Hydrological Model and receives the following inputs:

1. Spatial schematisation:
   a. Local Surface Waters (LSWs) acting as the principal 2-D rainfall-runoff units;
   b. Distribution Model (DM), a 1-D nodal network for the national waters;
   c. District Water (DW) nodes linking the LSWs to the DM nodes;
2. Flow data:
   a. Routing distribution fractions per individual node per unit time for the discharge situation;
   b. Network routed nodal supplies per unit time (mainly for coping with summer droughts, but also to provide uptake points with sufficient water);
3. Hydrological forcing:
   Sink and source flows per node per unit time: drainage, infiltration, water level conservation, industry, agriculture, drinking water, flushing requirements, etc.

To properly represent the local water network and to properly deal with water quality processes (i.e. to prevent excessive numerical dispersion), the WFD Explorer pre-processor converts 2D-LSW data into multiple nodes, one or more for the network and one representing the aggregated water volume within a LSW. Building the network and necessary conversions into WFD Explorer formats are fully supported by a Windows® GUI.

In its national setup water quality data are currently limited to the nutrients total nitrogen and total phosphorus. These data are derived from the following sources:

1. Load forcing:

   a. Diffuse sources (agriculture) on the LSW aggregation node derived from the ANIMO model;
   b. Industry and WWTPs on the DM and LSW network nodes which are taken from the national Emission Registration (ER) database (www.emissieregistratie.nl);
   c. Wet and dry airborne depositions of nitrogen on all nodes (www.emissieregistratie.nl)
      Again, the pre-processor takes care of the conversions and proper formats for the WFD Explorer.
2. Ecological data:
      The natural reference situation of water bodies is derived from the improved Ex-ante KRW dataset (Van Gaalen et al., 2020). Additional data, such as hydromorphological designs, can be collected from databases operated by the Water Boards.

3. Measures:

   Measures or measure packages can be defined and selected by the user. The effects of these pre-defined measures, for instance in load reductions, are included in the WFD Explorer database.

The WFD Explorer provides the user with the following output:

- EQR scores per water body per biological quality element. The User Interface also facilitates EQR comparisons between different measure packages and consequently provides insight in the effectiveness of such packages;
- Nutrient loads and concentrations at different spatial levels of the water system and hence provides insight into the extent of loads passed over from one location to another. Such functionality is useful for analysing the relations between loads received from neighbouring countries and loads discharged into the North Sea.

2.3.6 Hydrology

The WFD Explorer calculations for all the scenarios are based on a long term 30-year average hydrology, as described in *van der Bolt et al., 2020* (in Dutch).

2.3.7 Transboundary loads nutrients

The transboundary loads are defined with quarterly flows and quarterly concentrations. The transboundary waters are individually schematized. The flows and the concentrations are varied in the different scenarios. The Dutch nitrogen and phosphorus loads are equal to the loads used in the NAW. See *van der Bolt et al., 2020* (in Dutch) for a detailed description of sources.

2.4 Coupling WFD Explorer with North Sea Model

The WFD Explorer results are used as input for the 3D Dutch Continental Shelf Model – Flexible Mesh (DCSM FM, i.e. North Sea Model). By connecting these two models we can calculate the effects of the nutrient reductions in the transboundary rivers on the concentrations in the North Sea. Coupling the WFD Explorer model to the North Sea model involved the following steps:

1 Identification of the locations were the WFD Explorer model domain is discharging into the North Sea.
2 Derive the simulated WFD Explorer total nitrogen and total phosphorus loads at these discharge locations
3 Disaggregate and scale the nutrient loads

These steps are described in more detail in the sections below.

2.4.1 Coupling locations

Figure 2-2 shows the connection of the WFD Explorer and the North Sea Model. The default North Sea Model includes 7 discharge locations along the Dutch coast, whereas the WFD-Explorer contains 15 outflow locations towards the North Sea. Some of these locations overlap, allowing one-to-one coupling. The other WFD-Explorer outflow locations were added to the North Sea Model for this study.

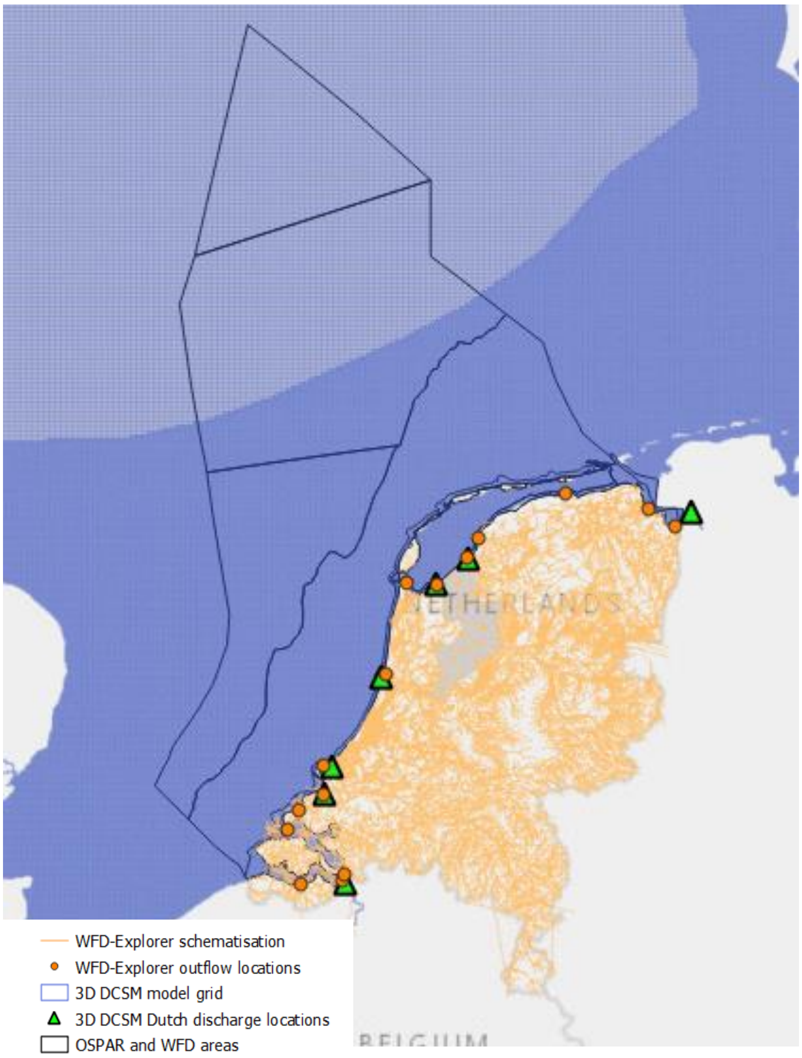


Figure 2-2 Connection points between the WFD Explorer and the North Sea Model. The orange dots represent the outflow points of the WFD Explorer model domain. The green triangles represent the river discharge points in the North Sea Model domain based on measured data. In orange the WFD Explorer schematization and in blue part of the North Sea Model grid is shown. Different shades indicate different grid resolutions. Black outlines show the boundaries of the OSPAR and Water Framework Directive assessment areas included in this study.

2.4.2 Disaggregation and scaling

The WFD Explorer calculates flow rates and nutrient concentrations (total nitrogen and phosphorus) per quarter of a year, which can be converted into nutrient loads per quarter of a year. However, for the North Sea model, daily time series are required for the individual nitrogen fractions nitrate (NO_3), ammonium (NH_4) and particulate organic nitrogen (PON), and the phosphorus fractions phosphate (PO_4) and particulate organic phosphorus (POP). To couple the two models the quarterly loads were therefore distributed over the fractions used in the North Sea model.

The scaling in time and the fraction distribution function were determined based on time series of measured loads. These time series were taken from a database collected and maintained in the context of the OSPAR working group on ecological modelling (ICG-EMO) by Sonja van Leeuwen. The scaling in time (i.e. daily loads) are calculated as follows:

$$\frac{measured\ total\ N\ day_j * WFDE\ \ total\ N\ load\ quarter_i}{measured\ \ total\ N\ quarter_i}$$

or

$$\frac{measured\ total\ P\ day_j\ *\ WFDE\ \ total\ P\ load\ quarter_i}{measured\ \ total\ P\ quarter_i}$$

The resulting series of daily loads are then converted to NO_3, NH_4, PON, PO_4 and POP values by multiplying the daily timeseries with the following ratios:

$$\frac{measured\ NO_3\ load\ quarter_i}{measured\ N\ load\ quarter_i}$$

or

$$\frac{measured\ NH_4\ load\ quarter_i}{measured\ N\ load\ quarter_i}$$

or

$$\frac{measured\ PON\ load\ quarter_i}{measured\ N\ load\ quarter_i}$$

or

$$\frac{measured\ PO_4\ load\ quarter_i}{measured\ P\ load\ quarter_i}$$

or

$$\frac{measured\ POP\ load\ quarter_i}{measured\ P\ load\ quarter_i}$$

For the discharge points for which no measurement data are available, the loads were not scaled over time assuming a constant discharge throughout each quarter of a year and the distribution over the various fractions was based on the seasonal averages of the measured nitrogen and phosphorus fractions for the major rivers, Scheldt, Rhine and Meuse in 2015 (Table 2-1 and Table *2-2*).

Table 2-1 Average nitrogen fraction ratios based on measured concentrations in the major rivers in 2015. These ratios were used to convert the total-N loads of the smaller rivers without measurement data to NO_3, NH_4 and organic nitrogen.

	NO_3	NH_4	PON
Meuse	0.82	0.03	0.15
Rhine	0.82	0.05	0.13
Scheldt	0.74	0.09	0.17
mean	0.80	0.05	0.15

Table 2-2 *Average phosphorus fraction ratios based on measured concentrations in the major rivers in 2015. These ratios were used to convert the total-P loads of the smaller rivers without measurement data to PO_4 and organic phosphorus.*

	PO_4	POP
Meuse	0.78	0.22
Rhine	0.57	0.43
Scheldt	0.31	0.69
mean	0.55	0.45

2.4.3 Measured nutrient loads from the Ems and Scheldt estuary

As the Scheldt and Ems rivers are not included in the WFD Explorer model domain, we based the nutrients loads of these rivers on measured data. Hence, in contrast to the other river loads, which are based on the model results from the WFD Explorer for 2027, the loads of the Ems and Scheldt used for scenario A are equal to the loads that were applied in the standard North Sea model (which were based on measured loads for 2015). For the scenario runs, we directly applied the reduction percentages on the measured nutrient loads.

2.4.4 Validation nutrient loads towards the North Sea

Figure 2-3 shows a comparison between simulated and measured loads, both for total nitrogen and total phosphorus, summed over all WFD Explorer outflow points. Both measured and modelled loads correspond to the year 2015. The simulated total nitrogen and phosphorus loads differ +6% and +15% from their measured counterparts.

When comparing the loads at each of the outflow points (Figure 2-4 and Figure 2-5), we observe that the nitrogen and phosphorus loads of the Meuse river (Haringvliet sluices) are slightly overestimated by the model. For the Rhine outflow points (Maassluis, Lake IJssel east/west), different patterns are found: The modelled nitrogen loads at Maassluis are overestimated, while the phosphorus loads at Maassluis are underestimated. These differences are partially compensated by opposite results at the Lake IJssel outflow points, suggesting a slight bias of the WFD Explorer in its distribution of the Rhine water over its outflow points.

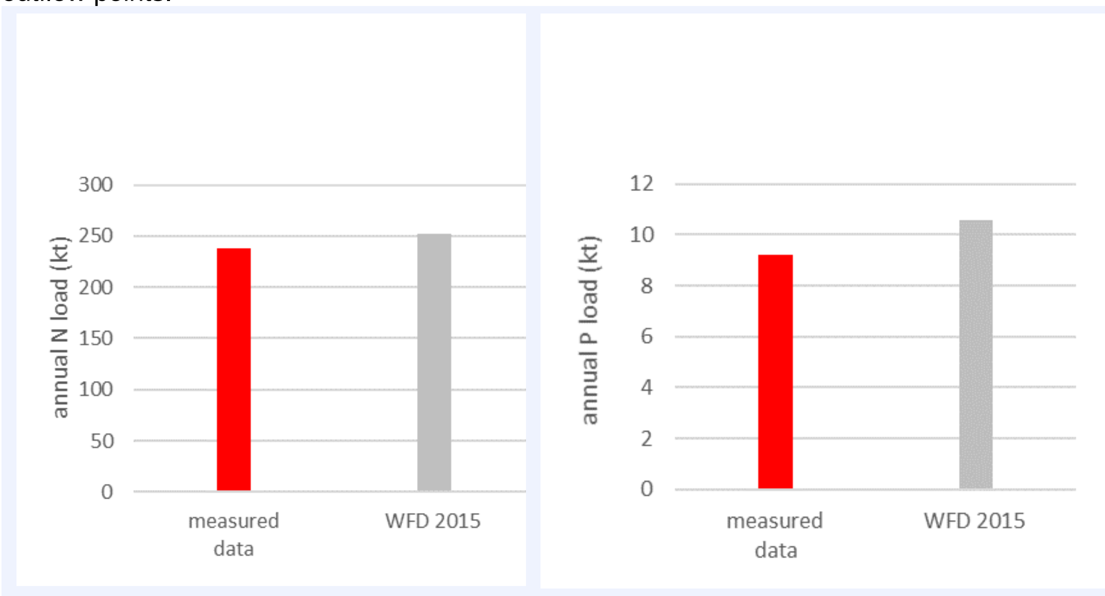


Figure 2-3 Comparison of the measured (red) and simulated total nitrogen (left panel) and phosphorus loads (right panel) summed over all WFD Explorer outflow points.

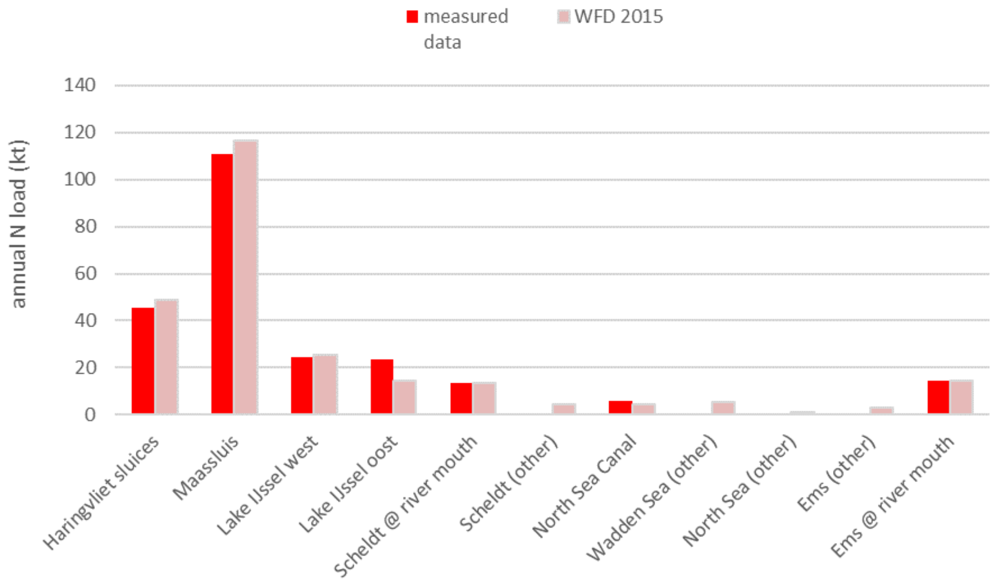


Figure 2-4 Comparison of the measured (red) and simulated (pink) nitrogen loads for each of the WFD-Explorer outflow points.

Figure 2-5 Comparison of the measured (red) and simulated (pink) total phosphorus loads for each of the WFD Explorer outflow points.

2.5 North Sea Model

For the North Sea calculations, the latest model version, the so-called 3D Dutch Continental Shelf Model – Flexible Mesh (3D DCSM-FM, i.e. DSCMv8), was used. This model version is the successor of the 3D southern North Sea model ZUNO, which was used in the previous study on nutrient reductions in 2015 (Chrzanowski et al., 2015).

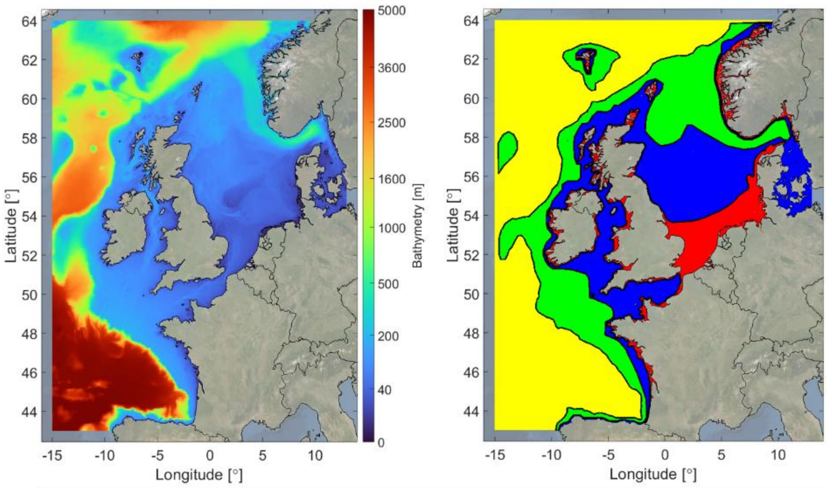
The 3D DCSM-FM hydrodynamic model was developed in recent years as part of Deltares' strategic research program. It is intended to be a versatile model that can be used for all manner of studies and research on the Northwest European Continental Shelf, including the North Sea and adjacent shallow seas, such as the Wadden Sea. It aims to combine state-of-the-art capabilities with respect to modelling of water levels (tide and surge) as well as (residual) transport phenomena, which is crucial for application in water quality and ecological modelling.

2.5.1 Model grid and hydrodynamics

The model domain of 3D DCSM-FM is much larger than the domains of its predecessors. It covers the Northwest European Continental Shelf, specifically the area between 15°W to 13°E and 43°N to 64°N (Figure 2-6). The network consists of approximately 630,000 grid cells. The flexible mesh has coarser grid cells near the open boundaries and in deep waters, whereas the resolution increases toward the shallower waters. Cells in deep oceanic waters have a resolution of 1/10° in longitudinal direction and 1/15° in latitudinal direction, which corresponds to approximately 4 by 4 nautical miles (nm). Along all coasts and in the southern North Sea cell sizes decrease to 0.5 by 0.5 nm, which corresponds to approximately 900 m.

A sigma-layer approach is used for the vertical schematization of the model. This implies that a fixed number of layers, with a thickness depending on local water depth, is present. This results in a high vertical resolution in shallow areas. A total of 20 layers with a uniform thickness of 5% of the water column is applied.

The model bathymetry is based on the gridded dataset by the European Marine Observation and Data Network (EMODnet), a consortium of organizations collecting and distributing European marine data from different sources. For large parts of the Dutch waters, bathymetric information from the detailed Baseline database by the Dutch government is used. For the bed friction, a spatially varying Manning roughness coefficient is used.



Yellow:	1/10° x 1/15°	~ 4.0 nm x 4.0 nm	
Green:	1/20° x 1/30°	~ 2.0 nm x 2.0 nm	→800m isobath
Blue:	1/40° x 1/60°	~ 1.0 nm x 1.0 nm	→200m isobath
Red:	0.75' x 0.5'	~ 0.5 nm x 0.5 nm	→ 50m isobath

Figure 2-6 Bathymetry and grid cell sizes in 3D DCSM-FM.

2.5.2 Open sea boundaries

Water levels

At the northern, western and southern open sea boundaries of 3D DCSM-FM, astronomical water levels are imposed, derived from a harmonic expansion of the amplitudes and phase lags of 31 tidal constituents.

These constituents are retrieved from the global tide model FES2012. The surge at the open boundaries is approximated by addition of an inverse barometer correction (IBC) to the astronomical water levels. This correction is a time- and space-dependent function of the local atmospheric pressure. To account for steric effects, the daily mean water levels from CMEMS are used.

Nutrients, salinity and temperature

For the open sea boundaries, nutrients, temperature and salinity are derived from the Copernicus - Marine environment monitoring service (CMEMS). These daily values at 50 non-uniformly spaced vertical levels are interpolated by Delft3D Flexible Mesh to the appropriate horizontal location and model layers.

2.5.3 Meteorology

For the meteorology, the 3D DCSM-FM model has been coupled to ECMWF’s ERA5 reanalysis dataset. The forcing parameters used are described below.

Momentum flux

To account for the air-sea momentum flux, time- and space-varying wind speeds (at 10 m height) and atmospheric pressure (at MSL) are applied.

Heat-flux

Spatial (both horizontal and vertical) differences in water temperature affect the transport of water through their impact on the water density. Heating of surface water and shallow waters cause temperature gradients that can generate horizontal flow. It can also lead to temperature stratification with accompanying damping of turbulence and hence a reduction in vertical mixing. To include these effects, the transport of temperature is modelled.

Mass-flux

To account for the mass-flux through the air-sea interface, time- and space varying fields of evaporation and precipitation are applied.

2.5.4 River discharges and atmospheric deposition

More than 900 freshwater discharges are considered in the 3D DCSM-FM domain. These are prescribed as depth-averaged, climatological monthly means based on data from the SMHI Pan European hydrological model (E-HYPE). These discharges include varying water temperatures and nutrient concentrations. The seven most important discharges in the Netherlands and three most important German rivers are replaced by gauged discharges with an hourly or daily interval.

Atmospheric deposition

Atmospheric deposition of nitrogen takes place over the whole surface layer, and is included as a spatially explicit forcing function. Its values data are based on model results corresponding to annual means provided by EMEP (European Monitoring and Evaluation Programme under the Convention on Long-range Transboundary Air Pollution).

2.5.5 Initial values and model spin up

After starting the nutrients, temperature and salinity conditions in the 3D DCSM-FM from an external (CMEMS) solution, a spin-up period of one year, forced by realistic meteorological and river discharge values, was applied to reach a dynamic equilibrium.

2.5.6 Water quality processes

At this moment, the 3D DCSM-FMhydrodynamic model is being extended to include all relevant biogeochemical processes for water quality and ecological calculations. Because this model is still in development, in this project we have chosen to use a simplified version.

In this simplified version, we consider all relevant fractions of nitrogen and phosphorus (NH_4, NO_3, PO_4, and the particulate organic fractions PON and POP) as conservative tracers, which are not involved in any biogeochemical process. These nutrients are thus only being discharged and transported. In addition to open sea boundaries and rivers, atmospheric deposition is also taken into account as a nutrient source. Not taken into account biogeochemical processes is an acceptable simplification, since the project is focussed on winter-averaged concentrations, for which biogeochemical process are less relevant. In the recent EUNOSAT project with a comparable focus and context this simplification was shown to be acceptable, by resulting in a good match between modelled nutrient concentrations and measured winter concentrations (R^2=0.84 for DIN and R^2=0.64 for DIP, Blauw et al., 2019). In the current project, the approach is again validated (see Paragraph 2.5.8).

2.5.7 Validation hydrodynamic model

The performance of the 3D DCSM-FM hydrodynamic model has been assessed in detail in the WOZEP project (Zijl et al, 2020). Below a brief overview is given of the validation results.

Water levels were looked at in several Dutch coastal stations. For the studied year (2014) the average total water level RMSE was 6.9 cm. This result is significantly better than that of the previous generation 3D ZUNO-DD model of the southern North Sea (25.6 cm) and due to improvements in both tide and surge.

A comparison of the observed and modelled sea surface temperature from 2006-2013 shows an average RMSE of around 0.4 – 0.5 °C in the southern North Sea. Crucially, the model shows a good representation of inter-annual variation in seasonal temperature stratification. This variation is of importance to correctly predict algal concentrations and oxygen profiles in water quality simulations, but is less relevant for modelling winter nutrient concentrations that are assessed in this study.

In the previous generation 3D ZUNO-DD model, tilting of the southern boundary was needed to achieve a correct representation of residual transport through the English Channel. 3D DCSM-FM has a much larger model domain and thus there is no open boundary in the English Channel. This results in a good representation of this residual transport without the need to artificially adjust the open boundaries, due to a better representation of mainly barotropic phenomena.

2.5.8 Validation water quality model

In Figure 2-7 and Figure 2-8 the modelled winter concentrations for inorganic nitrogen (winterDIN) and inorganic phosphorus (winterDIP) are compared to measured values. Note that this comparison is carried out on basis of results from the ‘standard’ model set up, i.e. the North Sea model based on *measured* nutrient loads for 2015. In all scenarios, these measured loads are replaced by calculated loads on basis of the WFD Explorer model and correspond to the year 2027. For the validation, the winter period was defined as including the months December, January and February.

A regression analysis was carried out to find the relation between the modelled total concentrations of nitrogen and phosphorus and the measured values of winterDIN and winterDIP (see the lines and formulas in Figure 2-7). The results are very similar relations to those obtained in the EUNOSAT project, with slopes of 0.80 for DIN and 0.95 for DIP (Blauw et al 2019). The regression also shows a reasonable goodness of fit, with R^2=0.42 for DIN and R^2=0.48 for DIP. These explained variances are smaller than those found in the EUNOSAT project (see section 2.5.6), although a very similar model was employed. This difference is partly due to the fact that for the measured values a different data set was used (ICES), which includes also the very shallow locations that are relevant for the current study.

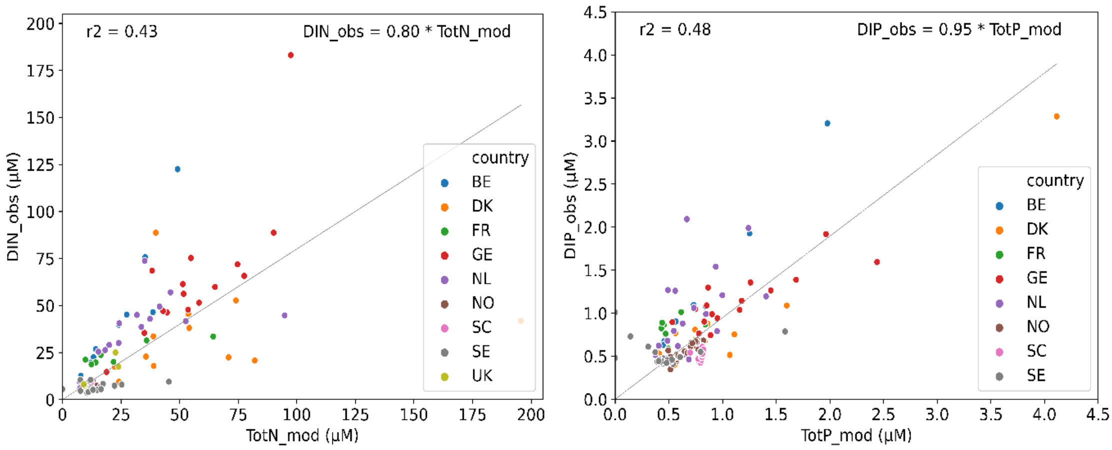


Figure 2-7 Modelled total nitrogen and total phosphorus concentrations versus measured values of winterDIN (left panel) and winterDIP (right panel) Measured values are multi-annual averaged winter concentrations (2009-2014).

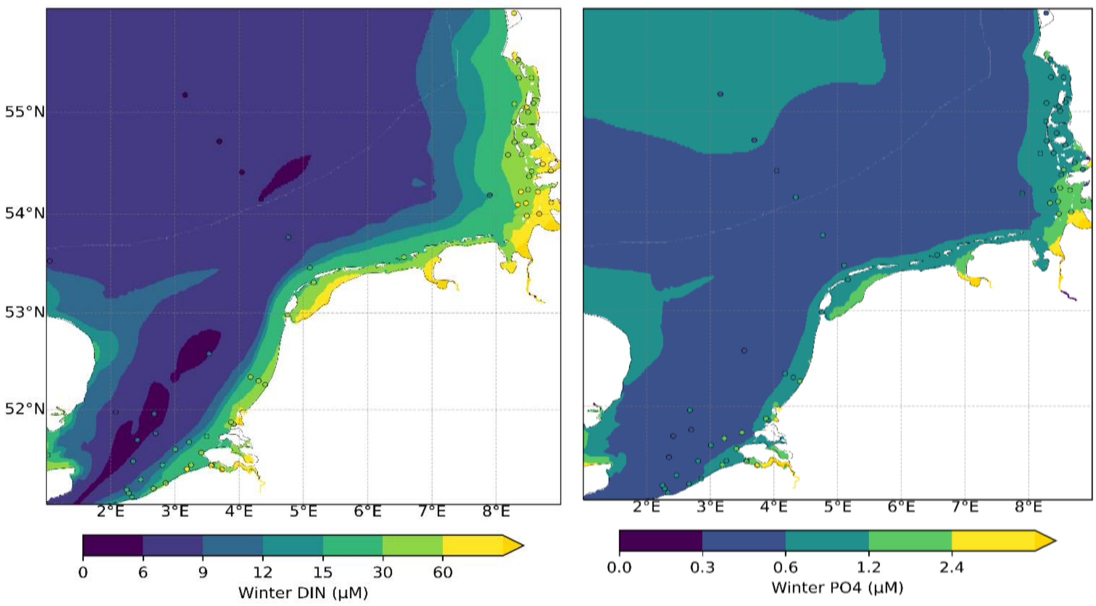


Figure 2-8 Modelled concentrations of winterDIN (right, background color) and winterDIP (left, background color) compared to measured concentrations of winterDIN (colored dots, right) and winterDIP (colored dots, left). Measured values are multi-annual averaged winter concentrations (2009-2014).

2.6 Water Framework Directive and OSPAR assessment methods

2.6.1 Fresh waters

The Water Framework Directive (WFD) applies to all fresh, transitional and coastal waters. With the WFD Explorer the concentrations for the fresh surface water bodies are modelled. These modelled concentrations were assessed following the WFD procedure. In the fresh waters, WFD targets are set for summer average total nitrogen and total phosphorus for each water type. The target levels separate four classes: 'poor', 'bad', 'moderate' and 'good'. Table 2-3 shows an overview of the national proposed target levels per water type (Molen et al., 2018).

Table 2-3 WFD target levels for summer average total nitrogen and total phosphorus for each water type. Target levels separate four classes: 'poor', 'bad', 'moderate' and 'good'.

Water type	Nutrient	Good	Moderate	Bad	Poor
M12	mg P/l	≤ 0.1	0.1 - 0.2	0.2 - 0.4	> 0.4
	mg N/l	≤ 2.0	2.0 - 2.6	2.6 - 3.8	> 3.8
M14, M23, M27	mg P/l	≤ 0.09	0.09 - 0.18	0.18 -0.36	> 0.36
	mg N/l	≤ 1.3	1.3 - 1.9	1.9 - 2.6	> 2.6
M20	mg P/l	≤ 0.03	0.03 - 0.05	0.05 -0.11	> 0.11
	mg N/l	≤ 0.9	0.9 - 1.1	1.1 - 1.4	> 1.4
M21	mg P/l	≤ 0.07	0.07- 0.14	0.14 - 0.28	> 0.28
	mg N/l	≤ 1.3	1.3 - 1.9	1.9 - 2.6	> 2.6
M27	mg P/l	≤ 0.09	0.09 - 0.18	0.18 - 0.36	> 0.36
	mg N/l	≤ 1.3	1.3 - 1.9	1.9 - 2.6	> 2.6
M30, M31	mg P/l	≤ 0.11	0.11 - 0.22	0.22 - 0.33	> 0.33
	mg N/l	≤ 1.8	1.8 - 2.9	2.9 - 4.1	> 4.1
R4, R13, R17	mg P/l	≤ 0.11	0.11 - 0.22	0.22 - 0.33	> 0.33
	mg N/l	≤ 2.3	2.3 - 4.6	4.6 - 6.9	> 6.9
R5, R6, R12, R14, R15, R18	mg P/l	≤ 0.11	0.11 - 0.22	0.22 - 0.33	> 0.33
	mg N/l	≤ 2.3	2.3 - 4.6	4.6 - 6.9	> 6.9
R7, R8, R16	mg P/l	≤ 0.14	0.14 - 0.19	0.19 - 0.42	> 0.42
	mg N/l	≤ 2.5	2.5 - 5.0	5.0 - 7.5	> 7.5
R19, R20	mg P/l	≤ 0.11	0.11 - 0.22	0.22 - 0.33	>0.33
	mg N/l	≤ 2.3	2.3 - 4.6	4.6 - 6.9	>6.9

In this study, the total nitrogen and total phosphorus are compared to the most recent WFD targets defined by the waterboards for each water body (not shown here). These target levels were made available by the Water Information and Data Centre (IHW, 2020).

A correction factor is used to calibrate the model. For a five-year period (2010-2014) the calculated and measured summer average concentrations of total nitrogen and total phosphorus are compared on a water body level. The average of the five-year differences is calculated for each waterbody and used as a factor to correct the model results (see also Loos et al., 2020). These correction factors are applied to all scenario calculations.

The total number of WFD surface water bodies in the Netherlands is 736, almost 2/3 of these in the Rhine catchment (see Table 2-4).

Table 2-4 Number of surface water bodies in the four Dutch catchments.

Catchment area	Number of waterbodies
Ems	20
Meuse	162
Rhine	499
Scheldt	55
total Netherlands	736

2.6.2 Coastal and marine waters

The North Sea model results were compared to the nutrient assessment levels for the coastal- and marine areas in accordance with the WFD and OSPAR Common Procedure (COMP) assessment methods, respectively (Molen et al., 2018, Baretta-Bekker, 2016). In the marine waters, assessment levels are available for both winter mean dissolved inorganic nitrogen (winterDIN), and winter mean dissolved inorganic phosphorus (winterDIP). For the coastal- and transitional waters only winter mean DIN assessment levels are available.

Figure 2-111 gives an overview of the monitoring stations used for the WFD assessment in the transitional and coastal water (up to 1 nautical mile from the coastline). Station names are listed in Annex G.1. We based the corresponding assessment of the modelled concentrations on the following assumptions:

- The WFD applies to transitional waters and the 1-nautical mile zone of the coastal waters; it does not apply to further offshore/marine waters.
- The coastal and transitional WFD areas are only assessed for winterDIN, because no relation has been found between winterDIP and ecology in these waters.
- For the WFD assessment the winter period is defined as the months December - February.
- When salinity is equal to 30 psu or higher the assessment level for winterDIN is 33 µM (= 0.46 mg N/l).
- At salinities lower than 30 psu the assessment level is normalized to a salinity of 30 psu to account for the high fraction of the fresh water (Prins et al. 2015). Hence, when the salinity is lower than 30 psu we applied the following equation to determine the salinity normalized assessment level:

$$DIN\ ass.level\ (mg\ N/l)\ =\ 2.59 - 0.071\ *\ Salinity$$

- The correction for salinity was applied in all coastal and transitional WFD areas.

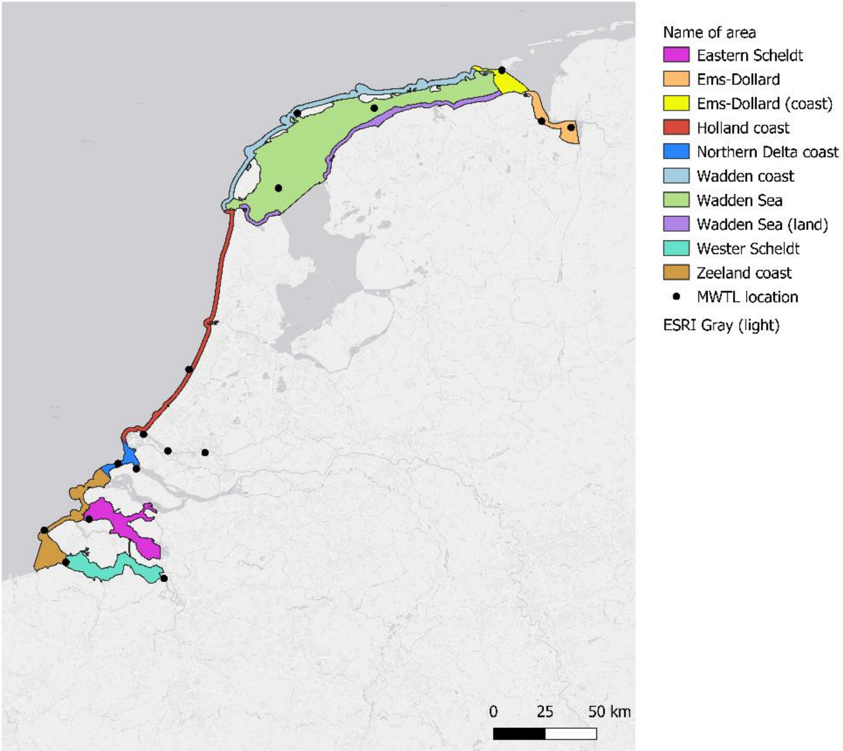


Figure 2-11 WFD assessment areas and monitoring stations (Waterkwaliteitsportaal, 2019).

Figure 2-12 gives an overview of the Dutch monitoring stations used for the OSPAR assessment. Station names are listed in Annex G.2.We based the corresponding assessment of the modelled concentrations on the following assumptions, as described by Baretta-Bekker (2016):

- In this study, only the Dutch OSPAR assessment areas are considered.
- For OSPAR there assessment levels for both DIN and DIP exist.
- For the OSPAR assessment the winter period is defined as the months November - February.
- The assessment levels differ per assessment area. This differentiation is related to salinity. See for an overview of the assessment levels at a salinity of 30 psu or higher.
- When salinity is lower than 30 psu the assessment level is corrected to account for the higher fresh water contribution. In the OSPAR COMP, the winter mean nutrient concentrations are normalised using mixing diagrams (see OSPAR, 2013, Annex-6a). As deriving mixing diagrams was outside the scope of this study, we followed a similar approach as for the WFD, normalising the assessment level instead of the nutrient concentration, by assuming a constant background concentration at a salinity of 34.5 psu In this study the normalization of the assessment level to salinity at 30 psu was carried out as follows:

$$DIN\ ass. level\ (mg\ N/l)\ =\ 2.28 - 0.062\ *\ Salinity$$

$$DIP\ ass.\ level\ (mg\ P/l)\ =\ 0.0609 - 0.0012\ *\ Salinity$$

- These salinity corrections are solely applied to the OSPAR area ‘Coastal Waters’ at salinities <30 psu.

Table 2-5 WinterDIN and winterDIP assessment levels of the OSPAR areas considered in this study (Baretta-Bekker, 2016).

Assessment area	Ass. Level winterDIN (mg N/l)	Ass. level winterDIP (mg P/l)
Wadden Sea	0.098	0.0217
Western Scheldt	0.42	0.0248
Coastal waters	0.42	0.0248
Dogger Bank	0.21	0.0248
Southern Bight	0.21	0.0248
Oyster Grounds	0.21	0.0248
Ems-Dollard	0.42	0.0248

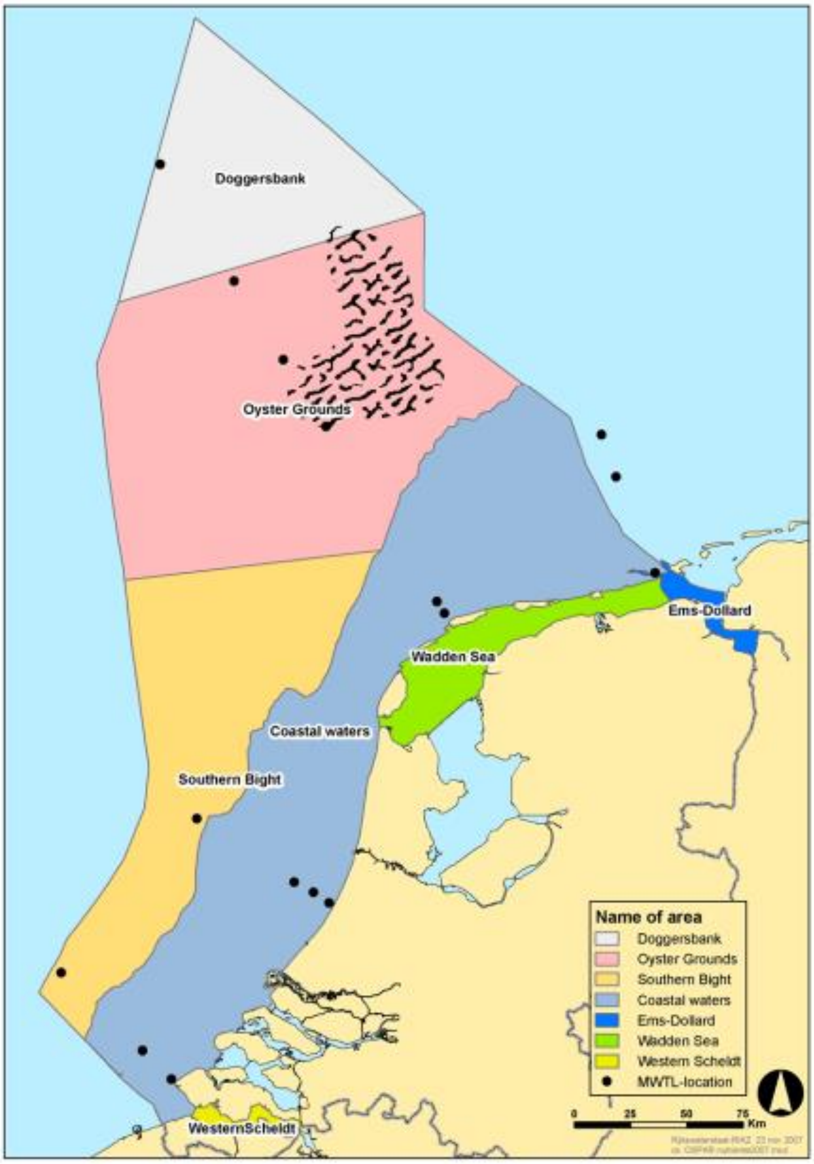


Figure 2-12 Dutch OSPAR assessment areas and monitoring stations indicated with black dots (source, Baretta-Bekker, 2016).

3 Data exchange partners

In this study, not only the transboundary waters in the Meuse catchment have been included in the modelling exercise, but the transboundary waters in all Dutch catchments. For this report to the IMC, the focus has been laid on the Meuse catchment. In this chapter and the corresponding figures, tables and Annexes (B, C, D, E and F) only the transboundary waters in the Meuse catchment are presented. In the report of this project for the Dutch Ministry of Infrastructure and Water Management, the data of all the Dutch catchments and data exchanged with the upstream partners will be presented.

Compared to the 2015 study, the updated WFD Explorer contains more individually schematized transboundary waters in the Meuse catchment (2015 study: 13, this study: 36).

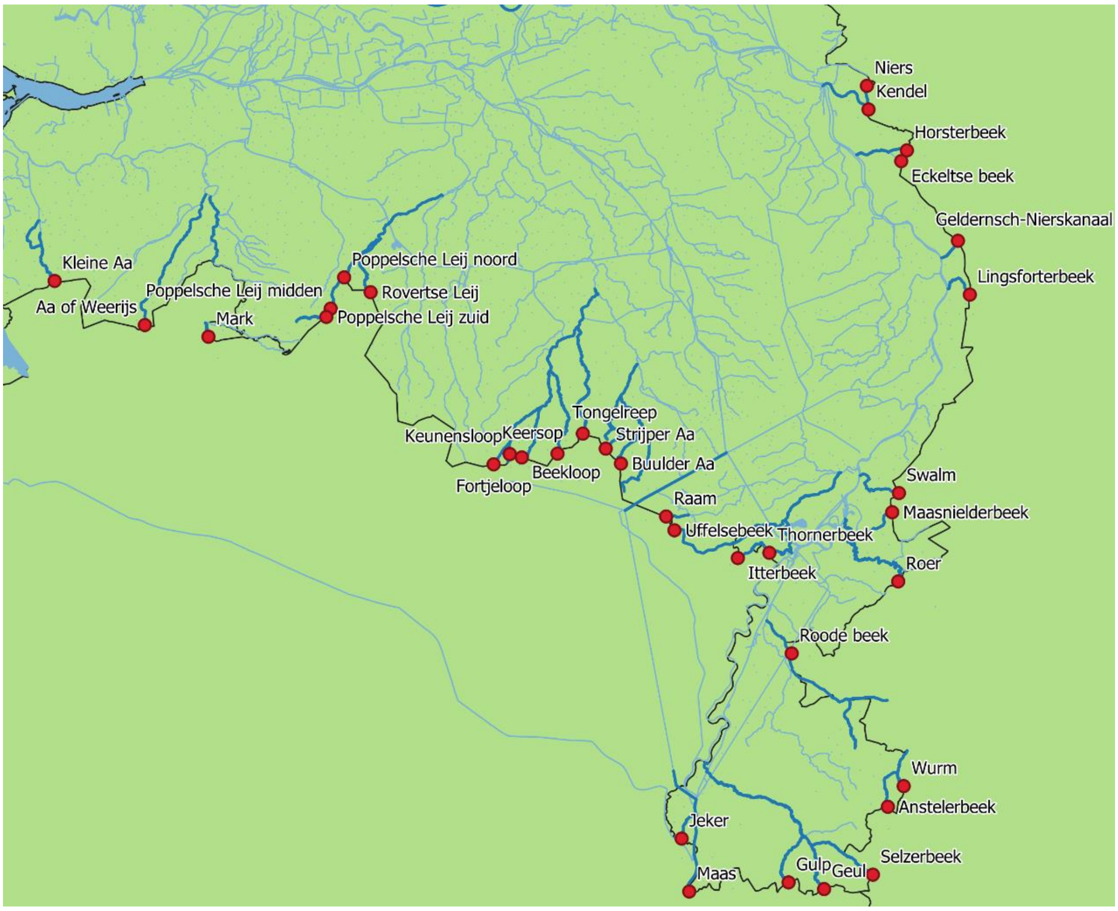


Figure 3-1 Locations and (Dutch) names of the transboundary waters in the Meuse catchment

Although most of the new added waters are small or very small, they all have a WFD surface water body status in the Netherlands and are therefore relevant to include in this evaluation. Figure 3-1 shows the location and (Dutch) names of the 36 transboundary waters in the Meuse catchment. In Annex A the locations of the transboundary water of the Ems, Rhine and Scheldt River are given.

By means of an Excel spreadsheet and a map with the location of the transboundary surface water bodies, the quarterly average flows and concentrations of total nitrogen and phosphorus as used in the NAW have been shared with the foreign water managers.

They were asked to check this data and add their own measurement data or modeled data to this spreadsheet. In addition, we requested the foreign WFD targets for total nitrogen and total phosphorus (scenario C), and the expected reduction percentages for total nitrogen and total phosphorus in 2027 compared to 2015 (scenario D). The foreign data is also used for the scenario A+. A total overview of both the Dutch data and the data provided by the foreign partners for the Meuse catchment is included in the Annexes B, C, D, E and F.

The exchange of data was characterized by a positive and active cooperation of all partners: Nordrhein-Westfalen (NRW), Flanders (FL) and Wallonia (WL). Due to the short time frame of the project, only data that was (more or less) readily available could be provided by the partners. We must be aware that all partners are very busy with the national RBMP processes. Besides this, most of the work is more or less hampered by the COVID-19 crises measures.

In the following paragraphs we will elaborate on the exchanged data per foreign water manager.

3.1 Nordrhein-Westfalen

This concerns 13 transboundary waters (see Annex B).

Flow rates 2015
For all but one of the transboundary waters from NRW quarterly or yearly average discharges were supplied. These discharges sometimes deviate strongly from the values in the NAW for the smaller waters. For the largest waters, the Roer and the Niers, the deviation is respectively only 5% and 4%. For the water bodies for which yearly data has been supplied, the ratio from the data from the NAW has been used to convert the annual average values to quarterly average values. No flow rates were supplied for the Maasnielderbeek and for this water body the Dutch data was used for the A+ scenario.

Total nitrogen 2015
Quarterly averaged measured total nitrogen concentrations were supplied for seven waters. These measured concentrations deviate on average 14% from the values from the NAW, where the values are sometimes higher and sometimes lower. For the Roer and the Niers a concentration of respectively 1% and 16% lower was measured compared to the values from the NAW. The data has been taken from the NAW for the waterbodies for which no data has been supplied.

Total phosphorus 2015
Quarterly averaged measured total phosphorus concentrations have been supplied for all waters. These measured concentrations deviate on average 41% from the values from the NAW, whereby the values are sometimes higher and sometimes lower. For the Roer and the Niers the measured concentration was respectively 22% and 113% higher than the values from the NAW.

Foreign targets
For the Roer and the Niers, the two largest transboundary waters from NRW, a management target for annual averaged total nitrogen of 2.8 mg/l applies to protect the North Sea, for all waters a target of 11.3 mg N/l for nitrate applies. For the annual average total phosphorus, a target of 0.1 (ten waters) or 0.15 mg/l (three waters) applies for the transboundary waters.

Reduction percentages 2027 compared to 2015
Reduction percentages for both total nitrogen and total phosphorus have been supplied for all waters. These percentages all show either no reduction (0%) or a reduction of 5%.

Expected concentrations in 2027
Expected concentrations have been supplied which are calculated from the measured values for 2015 and the reduction percentages for 2027.

3.2 Flanders

This concerns 21 transboundary waters (see Annex B). Due time constraints, Flanders only provided data for the transboundary Flanders waterbodies, so thus not on the smaller rivers. Also, only yearly data could be provided instead of quarterly data.

Flow rates 2017
For ten of the larger transboundary waters modelled yearly averaged discharges have been supplied. These values are modelled for 2017. Missing data is taken from the NAW.

Total nitrogen 2017
For eleven waters, measured annual averaged nitrogen concentrations for 2017 have been supplied. These measured concentrations deviate on average 24% from the values from the NAW values, where the values are sometimes slightly higher and but usually significantly lower. The ratio from the data from the NAW has been used to convert the annual average values to quarterly average values. For the other waters, except the Scheldt, the data has been taken from the NAW.

Total phosphorus 2017
Measured annual averaged phosphorus concentrations for 2017 were supplied for eleven waters. These measured concentrations deviate on average by 43% from the values from the NAW, sometimes higher and sometimes lower. The ratio from the data from the NAW has been used to convert the annual average values to quarterly averaged values. For the missing waters the data has been taken from the NAW.

Foreign standards
The targets for total nitrogen and phosphorus have been supplied for thirteen of the larger cross-border waters in Flanders. A target for summer averaged total nitrogen of 4.0 mg/l applies to all these waters, the target for the summer averaged total phosphorus concentration is 0.14 mg/l.

Reduction percentages 2027 compared to 2017
For eight waters reduction percentages for 2027, compared to the modelled values for 2017, have been provided for total nitrogen and total phosphorus. For some waters the reduction percentages are positive and thus mean an increase in the expected concentrations. The average expected decrease in the total nitrogen concentration is 9%, the average expected decrease in the phosphorus concentration is 17%. Since concentrations from Flanders are also from 2017 these are used to calculate the reduction. For waters where no reduction percentages have been supplied, the average of all obtained reduction percentages in transboundary waters from Flanders has been used.

Expected concentrations in 2027
The expected flow-weighted summer average concentrations for 2027 have been supplied for those waters for which the modelling was done and the validation results for total nitrogen and total phosphorus were positive. The expected concentrations used in the scenario D are calculated from the modelled 2017 data and the reduction percentages for 2027.

3.3 Wallonia

This concerns only two, but important, transboundary waters: the Geul and the Meuse river (see Annex B).

Flow rates 2015
Quarterly averaged flows have been supplied for both waters from Wallonia. For the Geul these are measured values which are on average 6% lower than the values from the NAW. The values for the Meuse have been modeled and the average is 5% higher.

Total nitrogen 2015
Measured quarterly averaged total nitrogen concentrations have been supplied for both the Geul and the Meuse, these are on average 5 and 8% respectively lower than the values from the NAW.

Total phosphorus 2015
Measured quarterly averaged total phosphorus concentrations were supplied for both the Geul and the Meuse, these are on average 22 and 12% higher, respectively, than the values from the NAW.

Foreign standards
The foreign target for total nitrogen is 7.74 mg/l for both the Geul and the Meuse; the target for total phosphorus in these waters is 0.2 and 0.5 mg/l respectively. These targets apply to the 90th percentile of the measurements.

Reduction percentages 2027 compared to 2015
For the Geul, the concentrations of total nitrogen and phosphorus are expected to remain the same in 2027 compared to 2015. For the Meuse, there is an expected reduction of 3 and 2% respectively for total nitrogen and phosphorus.

Expected concentrations in 2027
No expected concentrations for 2027 have been provided.

3.4 Arguments for the use of the A+ scenario

The overview of the exchanged 2015 discharges and concentrations shows that, despite the positive cooperation in the project, the data received from the partners show some gaps (not covering all the transboundary waters used in the Dutch model), are not all available on a quarterly basis and partly relate to a different range of years. Combining discharges and concentrations from different years is usually not recommended in water quality modelling. Structural differences seem to exist in analyzing methods between partners, an example is the difference of measuring total nitrogen or taking the sum of the different measured components (N-Kj, NO_3 and NO_2).
Therefore, these data can't be used to construct a complete scenario A, as was the original idea in the project. It was decided to use the available Dutch dataset for the scenario A. Besides this, it was agreed with NRW, FL and WL to use their data, supplemented with Dutch data for the missing water bodies, for the extra reference scenario: A+.

3.5 Overview targets

Table 3-1 gives an overview of the different targets for the transboundary waters set by the Netherlands, NRW, FL and WL. NRW only uses targets for total nitrogen for the larger waters (Niers and Roer), for these waters the NRW yearly average of 2.8 mg/l is in range with the NL 2.3 summer average.

For the other waters, NRW uses the targets of the Nitrate Directive: 11.3 mg/l N (50 mg/l nitrate), almost a factor 5 higher than the NL target. For total phosphorus, the differences between NRW and NL are small: NL 0.11 mg/l summer average and NRW 0.1-0.15 mg/l yearly average.

For FL no targets are set for the (very) small waters. For these waters, Flanders uses the targets of the Nitrate Directive: 11.3 mg/l N (50 mg/l nitrate), like NRW does. For the other transboundary waters (small rivers and brooks), the FL targets that are set for these waters are less strict than the NL targets: 70% for total nitrogen and 30% for total phosphorus (all summer averages). In Flanders big rivers have a standard of 2.5 mg/l N summer average, but these are no transboundary waters with the Netherlands and so not included in Table 3-1.

The WL target concentrations are also higher than the NL targets: about three times as high for total nitrogen and three (Meuse) to two (Geul) times as high for total phosphorus, but not easy to compare because these targets are defined as 90 percentiles. To calculate the reduction in scenario C, the targets have been compared to the 90 percentiles of the Dutch measurement data from 2015. When the targets were higher than the 90 percentiles, the percentage exceedance has been calculated and the average quarterly concentrations of the concerning waters is decreased by this percentage.

Table 3-1 Water quality targets for the transboundary waters for total nitrogen, nitrate nitrogen and total phosphorus set by NL, NRW, FL and WL.

name NL	water-manager	target NL (mg/l)			target foreign (mg/l)			
		total nitrogen	total phosphorus	period	total nitrogen	nitrate nitrogen	total phosphorus	period
Eckeltsche Beek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Horsterbeek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Geldernsch-Nierskanaal	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Lingsforterbeek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Niers	NRW	2.3	0.11	summer avg	2.8		0.15	yearly avg
Kendel	NRW	2.3	0.11	summer avg		11.3	0.15	yearly avg
Swalm	NRW	2.3	0.11	summer avg		11.3	0.15	yearly avg
Maasnielderbeek - Bosbeek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Roer	NRW	2.3	0.11	summer avg	2.8		0.1	yearly avg
Wurm	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Selzerbeek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Roode Beek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Anstelerbeek	NRW	2.3	0.11	summer avg		11.3	0.1	yearly avg
Mark	FL	2.3	0.11	summer avg	4		0.14	summer avg
Aa of Weerijs	FL	2.3	0.11	summer avg	4		0.14	summer avg
Kleine Aa	FL	2.3	0.11	summer avg	4		0.14	summer avg
Dommel	FL	2.3	0.11	summer avg	4		0.14	summer avg
Beekloop	FL	2.3	0.11	summer avg		11.3		
Keersop	FL	2.3	0.11	summer avg		11.3		
Fortjeloop	FL	2.3	0.11	summer avg		11.3		
Keunensloop	FL	2.3	0.11	summer avg		11.3		
Strijper Aa	FL	2.3	0.11	summer avg		11.3		
Buulder Aa	FL	2.3	0.11	summer avg		11.3		
Poppelsche Leij midden	FL	2.3	0.11	summer avg		11.3		
Poppelsche Leij noord	FL	2.3	0.11	summer avg		11.3		
Poppelsche Leij zuid	FL	2.3	0.11	summer avg	4		0.14	summer avg
Rovertsche Leij	FL	2.3	0.11	summer avg	4		0.14	summer avg
Tongelreep	FL	2.3	0.11	summer avg	4		0.14	summer avg
Raam	FL	2.3	0.11	summer avg	4		0.14	summer avg
Uffelsebeek	FL	2.3	0.11	summer avg	4		0.14	summer avg
Itterbeek	FL	2.3	0.11	summer avg	4		0.14	summer avg
Thornerbeek	FL	2.3	0.11	summer avg	4		0.14	summer avg
Gulp	FL	2.3	0.11	summer avg	4		0.14	summer avg
Jeker	FL	2.3	0.11	summer avg	4		0.14	summer avg
Geul	WL	2.3	0.11	summer avg	7.74		0.2	90percentile
Maas	WL	2.5	0.14	summer avg	7.74		0.5	90percentile

3.6 Overview reductions

An overview of expected reductions as a result of the national RBMPs by NRW, FL and WL is given in Table 3-2. NRW exchanged estimated reductions in the year 2027 of 0% or 5% compared to 2015. Most of the waters show a 5% reduction, both for total nitrogen and for total phosphorus.

From FL model output was obtained for most of the waters. For a set of small waters, no reductions were calculated and for these waters (in consultation with FL), the average reduction of the other waters in FL has been used: 7% reduction for total nitrogen and 3% for total phosphorus. For a small set of waters, higher reductions are expected: 4 for total nitrogen (reductions up to 26%) and 5 for total phosphorus (up to 47%).

For a few waters an increase of concentrations is expected due to agricultural inputs, which in some areas could increase with limited measured: the Tongelreep (total nitrogen +1%), the Uffelsebeek (total nitrogen +4%, total phosphorus +15%) and the Itterbeek (total phosphorus +7%). The reductions received from FL were given as reduction in 2027 compared to the year 2017.

The expected reductions from WL are small: 0% for the Geul (for both total nitrogen and total phosphorus) and for the Meuse 3% for total nitrogen and 2% for total phosphorus.

Tabel 3-2 Expected reduction percentages of total nitrogen and total phosphorus in 2027 compared to 2015 (for FL compared to 2017).

name NL	water-manager	reduction percentage 2027		
		total nitrogen	total phosphorus	note
Eckeltsche Beek	NRW	5%	5%	
Horsterbeek	NRW	5%	0%	
Geldernsch-Nierskanaal	NRW	5%	5%	
Lingsforterbeek	NRW	5%	5%	
Niers	NRW	5%	5%	
Kendel	NRW	5%	0%	
Swalm	NRW	5%	5%	
Maasnielderbeek - Bosbeek	NRW	0%	0%	
Roer	NRW	5%	0%	
Wurm	NRW	5%	5%	
Selzerbeek	NRW	0%	5%	
Roode Beek	NRW	5%	0%	
Anstelerbeek	NRW	5%	5%	
Mark	FL	12%	28%	relative to modelled summer average 2017
Aa of Weerijs	FL	0%	38%	relative to modelled summer average 2017
Kleine Aa	FL	9%	14%	estimated by average reduction Flanders
Dommel	FL	26%	47%	relative to modelled summer average 2017
Beekloop	FL	9%	14%	estimated by average reduction Flanders
Keersop	FL	9%	14%	estimated by average reduction Flanders
Fortjeloop	FL	9%	14%	estimated by average reduction Flanders
Keunensloop	FL	9%	14%	estimated by average reduction Flanders
Strijper Aa	FL	9%	14%	estimated by average reduction Flanders
Buulder Aa	FL	9%	14%	estimated by average reduction Flanders
Poppelsche Leij midden	FL	9%	14%	estimated by average reduction Flanders
Poppelsche Leij noord	FL	9%	14%	estimated by average reduction Flanders
Poppelsche Leij zuid	FL	9%	14%	estimated by average reduction Flanders
Rovertsche Leij	FL	9%	14%	estimated by average reduction Flanders
Tongelreep	FL	-1%	31%	relative to modelled summer average 2017
Raam	FL	9%	14%	estimated by average reduction Flanders
Uffelsebeek	FL	-4%	-15%	relative to modelled summer average 2017
Itterbeek	FL	12%	-7%	relative to modelled summer average 2017
Thornerbeek	FL	18%	4%	relative to modelled summer average 2017
Gulp	FL	9%	14%	estimated by average reduction Flanders
Jeker	FL	6%	10%	relative to modelled summer average 2017
Geul	WL	0%	0%	
Maas	WL	3%	2%	

3.7 Scenario input

The total overview of input data for the WFD Explorer calculations is included in Annex F: this table shows both the dataset for scenario A and the calculated reductions in the scenarios B, C and D compared to scenario A.

When the concentration in scenario A is already below the target concentration in B or C, a 0% reduction is used. Since the expected reductions for scenario D are relative to scenario A+, the calculated reductions for scenario D (relative to scenario A) as given in Annex F can differ from the reductions as given in table 3-2.

Yearly averages and summer averages are converted info quarterly data, based on the relative distribution through the year of the scenario A dataset.

3.8 Comparing reductions and targets

Table 3-3 gives a comparison of the NL targets (scenario B) with scenario A and the expected reduction in 2027 (scenario D). What we see is that only 4 waters meet the NL targets for total nitrogen in scenario A. For total phosphorus, the number is higher: 12 of the 38 waters already meet the targets in scenario A. Looking at the comparison with the concentrations in scenario D, we do see some (small) improvements of the concentrations compared to scenario A, but only resulting in meeting the target in two extra water bodies for total nitrogen and one less for phosphorus.

Table 3-3 Overview of the NL targets compared to the concentrations in scenario A and scenario D for the transboundary waters (red: above the NL target, green: below the NL target).

name NL	water-manager	total nitrogen summer average (mg/l)			total phosphorus summer average		
		target NL	scenario A	scenario D	target NL	scenario A	scenario D
Eckeltsche Beek	NRW	2.3	7.00	6.65	0.11	0.11	0.17
Horsterbeek	NRW	2.3	7.00	6.65	0.11	0.10	0.06
Geldernsch-Nierskanaal	NRW	2.3	4.70	5.08	0.11	0.16	0.23
Lingsforterbeek	NRW	2.3	13.75	13.06	0.11	0.18	0.14
Niers	NRW	2.3	7.62	5.54	0.11	0.07	0.16
Kendel	NRW	2.3	7.00	12.35	0.11	0.11	0.02
Swalm	NRW	2.3	6.12	6.03	0.11	0.10	0.13
Maasnielderbeek - Bosbeek	NRW	2.3	1.19	1.19	0.11	0.10	0.04
Roer	NRW	2.3	3.17	3.01	0.11	0.08	0.13
Wurm	NRW	2.3	4.45	4.18	0.11	0.13	0.15
Selzerbeek	NRW	2.3	1.58	1.58	0.11	0.21	0.10
Roode Beek	NRW	2.3	15.91	15.11	0.11	0.10	0.07
Anstelerbeek	NRW	2.3	10.13	8.65	0.11	0.20	0.16
Mark	FL	2.3	5.99	2.83	0.11	0.28	0.13
Aa of Weerijs	FL	2.3	3.80	2.02	0.11	0.18	0.06
Kleine Aa	FL	2.3	3.99	2.42	0.11	0.33	0.24
Dommel	FL	2.3	4.64	3.01	0.11	0.21	0.15
Beekloop	FL	2.3	1.79	1.63	0.11	0.08	0.07
Keersop	FL	2.3	4.07	3.70	0.11	0.07	0.06
Fortjeloop	FL	2.3	4.07	3.70	0.11	0.07	0.06
Keunensloop	FL	2.3	1.79	1.63	0.11	0.09	0.07
Strijper Aa	FL	2.3	5.23	4.76	0.11	0.45	0.39
Buulder Aa	FL	2.3	4.32	3.93	0.11	0.34	0.29
Poppelsche Leij midden	FL	2.3	5.78	5.26	0.11	0.19	0.16
Poppelsche Leij noord	FL	2.3	5.78	5.26	0.11	0.19	0.16
Poppelsche Leij zuid	FL	2.3	5.78	5.26	0.11	0.19	0.16
Rovertsche Leij	FL	2.3	5.78	2.30	0.11	0.19	0.14
Tongelreep	FL	2.3	2.57	2.22	0.11	0.17	0.11
Raam	FL	2.3	3.90	3.48	0.11	0.14	0.29
Uffelsebeek	FL	2.3	3.49	4.11	0.11	0.26	0.15
Itterbeek	FL	2.3	5.14	3.83	0.11	0.13	0.23
Thornerbeek	FL	2.3	4.27	2.81	0.11	0.24	0.13
Gulp	FL	2.3	6.20	5.64	0.11	0.16	0.14
Jeker	FL	2.3	6.55	6.56	0.11	0.50	0.53
Geul	WL	2.3	4.17	4.17	0.11	0.20	0.20
Maas	WL	2.5	3.65	3.55	0.14	0.21	0.21

3.9 Total sum of transboundary loads per scenario

Table 3-4 shows the reduction in total load of the sum of all transboundary waters compared to the scenario A. In scenario B this reduction will be 30-35% for both total nitrogen and total phosphorus. For scenario C the reduction is expected to be minimal with 5% for total nitrogen and 3% for total phosphorus. For scenario D the reduction will be about 5% for total nitrogen and 2% for total phosphorus.

Table 3-4 Reduction of total load of total nitrogen and total phosphorus of the transboundary waters in the Meuse district in scenario B, C and D compared to scenario A.

substance	change in total transboundary loads (%)		
	scenario B	scenario C	scenario D
total nitrogen	-35%	-5%	-5%
total phosphorus	-33%	-3%	-2%

4 Results

4.1 Fresh waters

4.1.1 Results on a national scale

The calculations with the WFD Explorer for the five scenarios generate concentrations of total nitrogen and total phosphorus per quarter for the fresh and transitional water bodies). The summer average concentrations per waterbody are compared with the targets set for the WFD by the Dutch waterboards and Rijkswaterstaat, following the WFD classification using the classes “poor”, “bad”, “moderate” and “good”. The results for the five scenarios on a national level are shown in Figure 4-1 and Table 4-1.

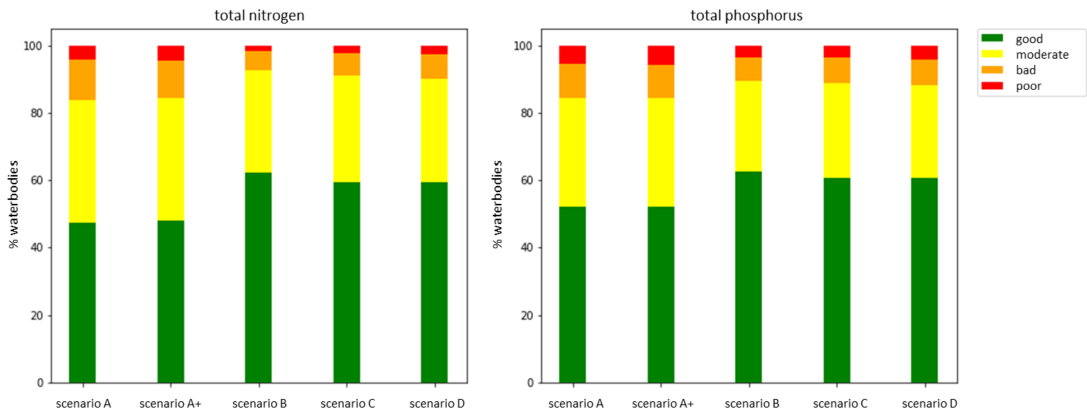


Figure 4-1 Percentage of surface water bodies in the different classes per scenario.

Table 4-1 Percentage of surface water bodies in the different classes per scenario.

substance	judgment	scenario A	scenario A+	scenario B	scenario C	scenario D
total nitrogen	good (%)	47.5	48.2	62.4	59.4	59.4
total nitrogen	moderate (%)	36.2	36.3	30.4	31.9	31.0
total nitrogen	bad (%)	12.3	11.2	5.5	6.4	7.2
total nitrogen	poor (%)	4.0	4.3	1.7	2.3	2.5
total phosphorus	good (%)	52.1	52.2	62.7	60.8	60.7
total phosphorus	moderate (%)	32.6	32.3	26.9	28.3	27.6
total phosphorus	bad (%)	10.0	10.0	6.9	7.4	7.5
total phosphorus	poor (%)	5.4	5.5	3.5	3.5	4.1

When we compare the results of the A and the A+ scenario, we see only minor differences for total nitrogen (up to 1.1% in category “bad”) and almost no differences for total phosphorus.

Comparing the scenarios B, C and D with the A and A+ scenario, we see no surprises considering the applied scenarios, both for total nitrogen as for total phosphorus. In all three scenarios B, C and D, the Dutch 3rd RBMP measures are included, compared to the A and A+ scenarios. The only differences between the scenarios B, C and D are the concentrations of the transboundary waters. In scenario B we see the highest improvement of the waterquality compared with A and A+ (for total nitrogen 15% more waterbodies in category “good” and for total phosphorus 10%). In scenario B for the transboundary waters the Dutch target values are used.

For scenario C we also see an improvement of the percentages waterbodies falling in the category “good” compared to A and A+, allthough the differences are smaller than in the scenario B: for total nitrogen 10% more waterbodies in category “good” and for total phosphorus 8%. The explanation for this is that the target values of the upstream countries are in for most waters less strict than the Dutch ones. Comparing the scenario D with the A and A+ scenarios, we see almost no differences with scenario C. Since for most transboundary waters the upstream countries assumed expected reductions up to the level of the (upstream) target values.

4.1.2 Results on a catchment scale

The results for the five scenarios on a catchment level are shown in Figure 4-2 and Table 4-2. As this report is written for the IMC, the focus will be on the results in the Meuse catchment. Figure 4-3 gives an extract of Figure 4-2, only for the Meuse catchment. Nevertheless, it is interesting to compare the results in the Meuse catchment with the other catchments.

Table 4-2 Percentage of surface water bodies in the different classes per scenario per catchment

substance	scenario	judgment	Ems	Meuse	Rhine	Scheldt
total nitrogen	A	good (%)	63.2	23.4	55.0	45.7
total nitrogen	A	moderate (%)	21.1	43.4	34.4	37.0
total nitrogen	A	bad (%)	5.3	23.4	8.6	15.2
total nitrogen	A	poor (%)	10.5	9.7	2.0	2.2
total nitrogen	A+	good (%)	63.2	24.8	55.2	47.8
total nitrogen	A+	moderate (%)	21.1	43.4	34.8	34.8
total nitrogen	A+	bad (%)	5.3	20.7	8.1	13.0
total nitrogen	A+	poor (%)	10.5	11.0	1.8	4.3
total nitrogen	B	good (%)	78.9	51.7	65.2	63.0
total nitrogen	B	moderate (%)	5.3	37.2	29.6	26.1
total nitrogen	B	bad (%)	15.8	8.3	3.6	10.9
total nitrogen	B	poor (%)		2.8	1.6	
total nitrogen	C	good (%)	78.9	39.3	64.9	60.9
total nitrogen	C	moderate (%)	5.3	46.2	28.7	28.3
total nitrogen	C	bad (%)	15.8	9.7	4.5	10.9
total nitrogen	C	poor (%)		4.8	1.8	
total nitrogen	D	good (%)	78.9	42.1	64.0	60.9
total nitrogen	D	moderate (%)	5.3	38.6	30.3	23.9
total nitrogen	D	bad (%)	15.8	13.1	4.1	15.2
total nitrogen	D	poor (%)		6.2	1.6	
total phosphorus	A	good (%)	52.6	35.9	54.0	84.8
total phosphorus	A	moderate (%)	26.3	43.4	31.5	10.9
total phosphorus	A	bad (%)	10.5	14.5	9.3	2.2
total phosphorus	A	poor (%)	10.5	6.2	5.2	2.2
total phosphorus	A+	good (%)	52.6	37.2	54.0	82.6
total phosphorus	A+	moderate (%)	26.3	41.4	31.7	10.9
total phosphorus	A+	bad (%)	10.5	14.5	9.3	2.2
total phosphorus	A+	poor (%)	10.5	6.9	5.0	4.3
total phosphorus	B	good (%)	63.2	59.3	60.8	91.3
total phosphorus	B	moderate (%)	15.8	33.8	27.2	6.5
total phosphorus	B	bad (%)	10.5	5.5	7.7	2.2
total phosphorus	B	poor (%)	10.5	1.4	4.3	
total phosphorus	C	good (%)	63.2	50.3	61.2	89.1
total phosphorus	C	moderate (%)	15.8	40.7	26.8	8.7
total phosphorus	C	bad (%)	10.5	7.6	7.7	2.2
total phosphorus	C	poor (%)	10.5	1.4	4.3	
total phosphorus	D	good (%)	63.2	51.7	60.8	87.0
total phosphorus	D	moderate (%)	15.8	37.2	27.2	6.5
total phosphorus	D	bad (%)	10.5	7.6	7.7	4.3
total phosphorus	D	poor (%)	10.5	3.4	4.3	2.2

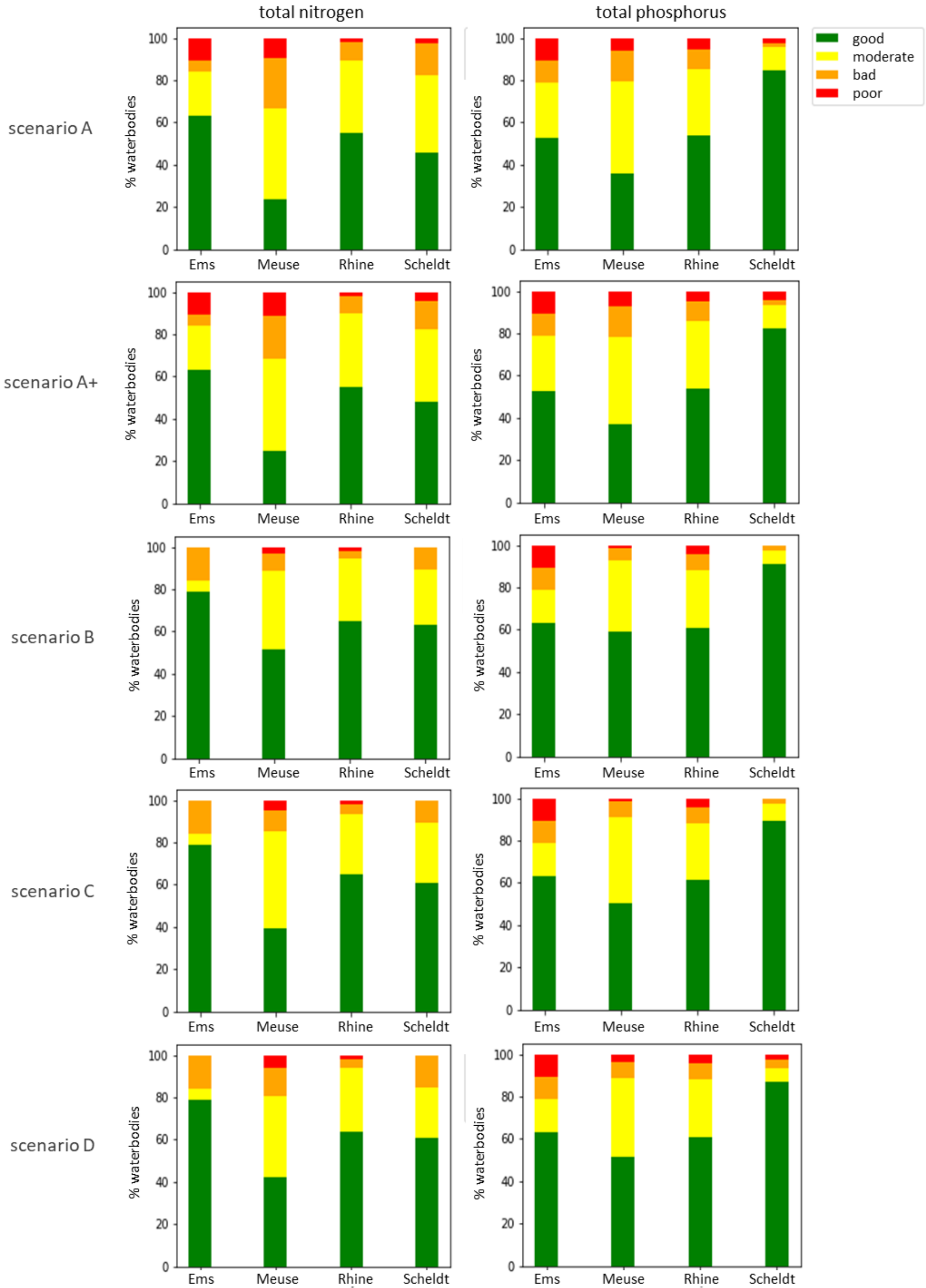
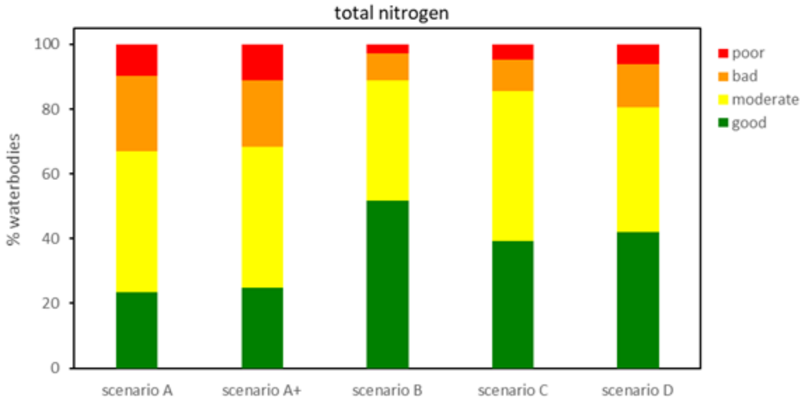


Figure 4-2 Percentage of surface water bodies in the different classes per scenario per catchment.



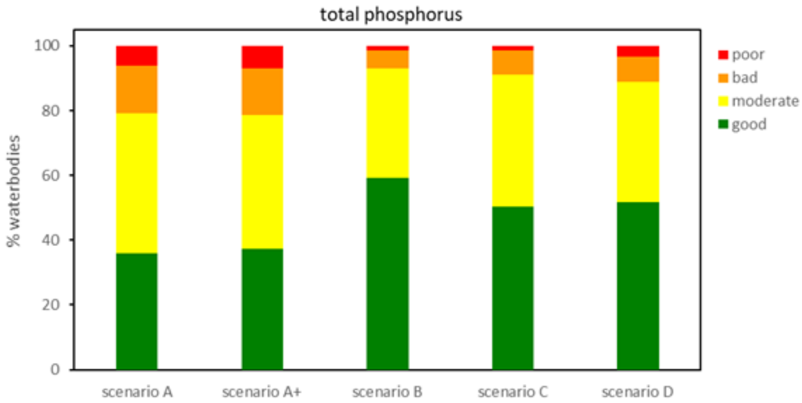


Figure 4-3 Percentage of surface water bodies in the different classes for total nitrogen and total phosphorus per scenario in the Meuse catchment.

Starting with scenario A, we can conclude the Meuse catchment has the lowest score of the category “good”, both for total nitrogen as for total phosphorus. The main reason for this is the high level of agricultural activities in the (Dutch part of) the Meuse catchment compared to the other Dutch catchments.

The differences between A and A+ for the Meuse catchment are small, less than 2% difference in the category “good”. Also, for the other catchments the differences between A and A+ are very small.
Comparing the A/A+ and the B/C/D scenarios in the Meuse catchment, we see the same results as for the national figures, but more extreme: both for total nitrogen and total phosphorus the scenario B shows a higher percentage of water bodies in the category “good” compared with the A and A+ scenarios (for total nitrogen more than twice as high: from 24% to 52% “good” and for total phosphorus almost twice as high: from 37% to 59%). As in the national figures, the percentages in scenario C are higher than in A and A+ (total nitrogen 39% “good” and total phosphorus 50%), but not as high as in scenario B. The rather high difference in the percentages “good” between scenario B and C (12% for total nitrogen and 9% for total phosphorus) show the impact of the differences between the Dutch and upstream targets for the transboundary waters. The scenario D lies between B and C (total nitrogen 50% “good” and total phosphorus 52%), which means that in the Meuse catchment the upstream partners expect not to fully meet the own targets by 2027 when applying the “intended measures”.

It is important to realize that for all partners the intended measures are based on the draft RBMPs and not on the final RBMPs or programmes of measures.

4.1.3 Transboundary waters

In Figure 4-4 and Table 4-3 we zoom in to the assessment results of the transboundary waters and compare these with the other (not transboundary) water bodies. Please take note that in the Ems catchment and in the Scheldt catchment there are no (Ems) or only a few transboundary waters (Scheldt), so this result in large fluctuations between the scenarios of the percentages in the different classes. Figure 4-5 gives an extract of Figure 4-4, only for the Meuse catchment.

When we look at the scenario A in the Meuse catchment, the first remarkable thing is that the percentage of waterbodies in the category “good” is lower for the transboundary waters than for the other waters, both for total nitrogen (10% lower) and total phosphorus (17% lower).

For the A+ scenario, the differences between the transboundary and other waters are much smaller. We see that the not transboundary waters are almost the same for A and A+, as can be expected. The large differences are found for the transboundary waters. For these waters the percentage “good” in A+ is higher than for A (8% for total nitrogen and 11% for total phosphorus), indicating the data of the upstream countries in the Meuse catchment show a significant better water quality compared to the Dutch dataset. This might be the result of differences in monitoring or analysing techniques.

We also see that, when the quality of the transboundary waters is improved (compared to the A and A+ scenarios), as is the case in the scenarios B, C and D, we also see a structural improvement of (a part of) the more downstream waterbodies. The highest increase is seen in scenario B: for total nitrogen an increase from 25% to 53% “good” and for total phosphorus an increase from 39% to 57% “good”. This shows that an improvement of the water quality of the transboundary waters in the Meuse catchment leads to a significant improvement of the water quality in the whole catchment.

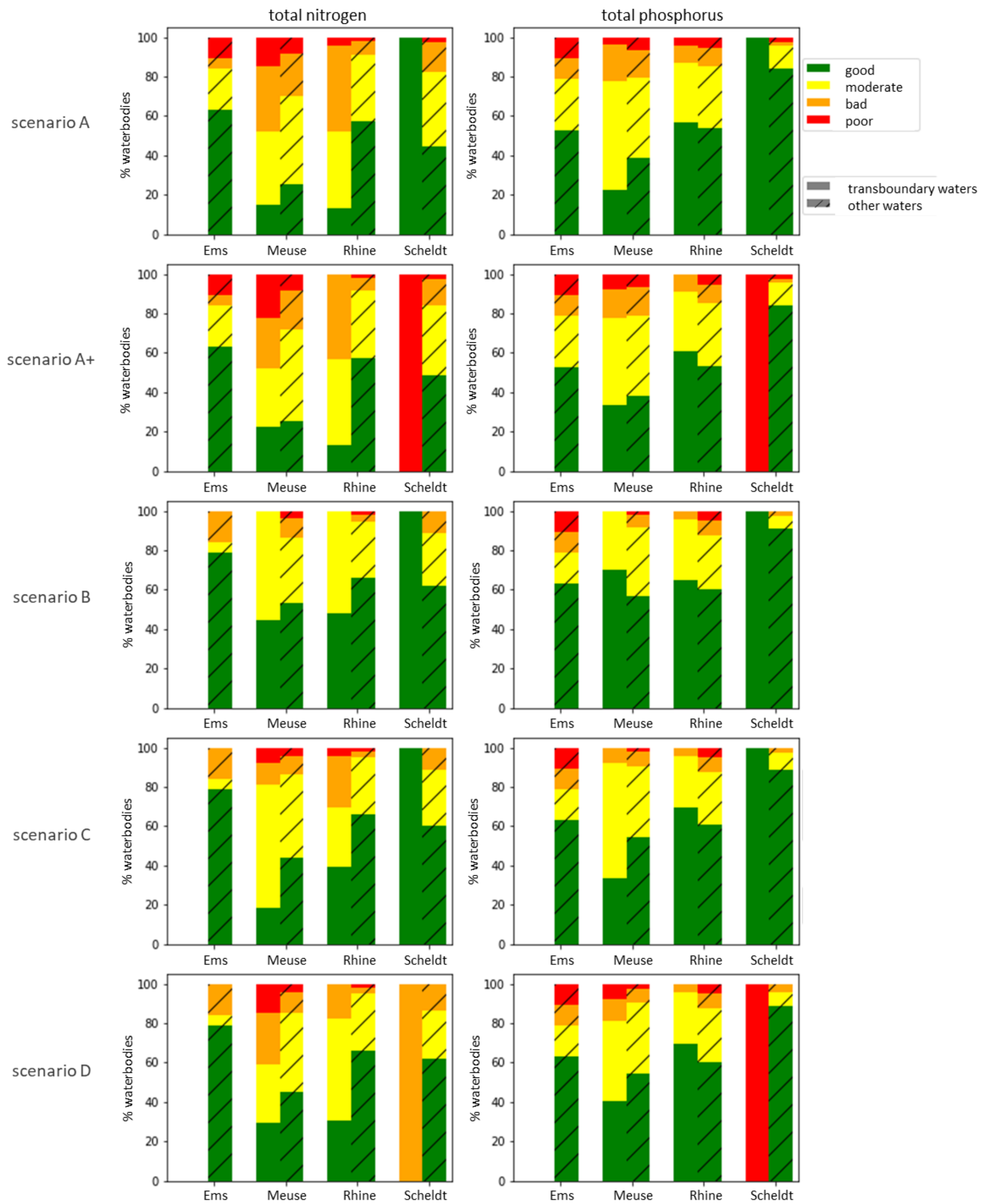
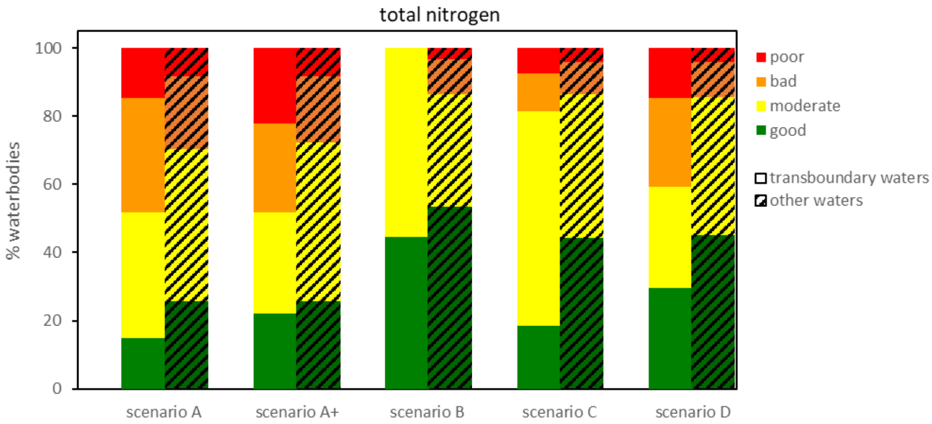


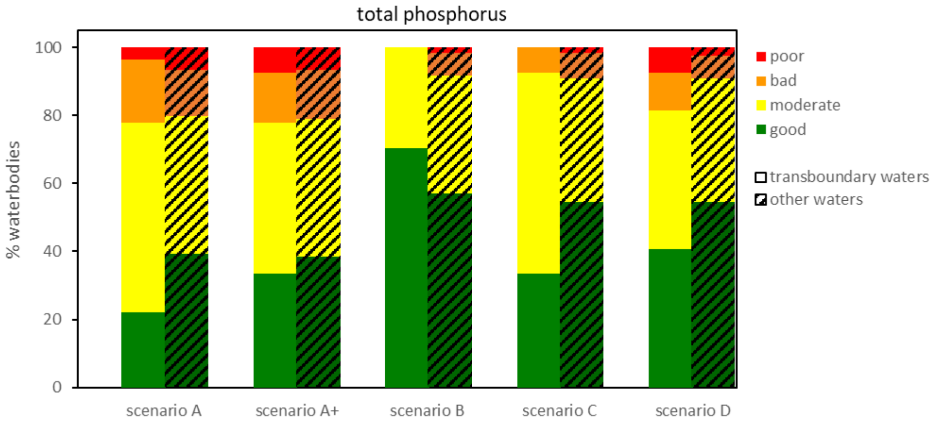
Figure 4-4 Percentage of surface water bodies in the different classes per scenario per catchment and split up in transboundary water bodies and other water bodies (striped bars).

Table 4-3 Percentage of surface water bodies in the different classes per scenario per catchment and split up between transboundary water bodies and other water bodies.

substance	scenario	judgment	Ems (transboundary waters)	Ems (other waters)	Meuse (transboundary wate	Meuse (other waters)	Rhine (transboundary water	Rhine (other waters)	Scheldt (transboundary wate	Scheldt (other waters)
total nitrogen	A	good (%)		63.2	14.8	25.4	13.0	57.3	100.0	44.4
total nitrogen	A	moderate (%)		21.1	37.0	44.9	39.1	34.1		37.8
total nitrogen	A	bad (%)		5.3	33.3	21.2	43.5	6.7		15.6
total nitrogen	A	poor (%)		10.5	14.8	8.5	4.3	1.9		2.2
total nitrogen	A+	good (%)		63.2	22.2	25.4	13.0	57.5		48.9
total nitrogen	A+	moderate (%)		21.1	29.6	46.6	43.5	34.4		35.6
total nitrogen	A+	bad (%)		5.3	25.9	19.5	43.5	6.2		13.3
total nitrogen	A+	poor (%)		10.5	22.2	8.5		1.9	100.0	2.2
total nitrogen	B	good (%)		78.9	44.4	53.4	47.8	66.1	100.0	62.2
total nitrogen	B	moderate (%)		5.3	55.6	33.1	52.2	28.4		26.7
total nitrogen	B	bad (%)		15.8		10.2		3.8		11.1
total nitrogen	B	poor (%)				3.4		1.7		
total nitrogen	C	good (%)		78.9	18.5	44.1	39.1	66.3	100.0	60.0
total nitrogen	C	moderate (%)		5.3	63.0	42.4	30.4	28.6		28.9
total nitrogen	C	bad (%)		15.8	11.1	9.3	26.1	3.3		11.1
total nitrogen	C	poor (%)			7.4	4.2	4.3	1.7		
total nitrogen	D	good (%)		78.9	29.6	44.9	30.4	65.9		62.2
total nitrogen	D	moderate (%)		5.3	29.6	40.7	52.2	29.1		24.4
total nitrogen	D	bad (%)		15.8	25.9	10.2	17.4	3.3	100.0	13.3
total nitrogen	D	poor (%)			14.8	4.2		1.7		
total phosphorus	A	good (%)		52.6	22.2	39.0	56.5	53.8	100.0	84.4
total phosphorus	A	moderate (%)		26.3	55.6	40.7	30.4	31.6		11.1
total phosphorus	A	bad (%)		10.5	18.5	13.6	8.7	9.3		2.2
total phosphorus	A	poor (%)		10.5	3.7	6.8	4.3	5.3		2.2
total phosphorus	A+	good (%)		52.6	33.3	38.1	60.9	53.6		84.4
total phosphorus	A+	moderate (%)		26.3	44.4	40.7	30.4	31.8		11.1
total phosphorus	A+	bad (%)		10.5	14.8	14.4	8.7	9.3		2.2
total phosphorus	A+	poor (%)		10.5	7.4	6.8		5.3	100.0	2.2
total phosphorus	B	good (%)		63.2	70.4	56.8	65.2	60.5	100.0	91.1
total phosphorus	B	moderate (%)		15.8	29.6	34.7	30.4	27.0		6.7
total phosphorus	B	bad (%)		10.5		6.8	4.3	7.9		2.2
total phosphorus	B	poor (%)		10.5		1.7		4.5		
total phosphorus	C	good (%)		63.2	33.3	54.2	69.6	60.8	100.0	88.9
total phosphorus	C	moderate (%)		15.8	59.3	36.4	26.1	26.8		8.9
total phosphorus	C	bad (%)		10.5	7.4	7.6	4.3	7.9		2.2
total phosphorus	C	poor (%)		10.5		1.7		4.5		
total phosphorus	D	good (%)		63.2	40.7	54.2	69.6	60.3		88.9
total phosphorus	D	moderate (%)		15.8	40.7	36.4	26.1	27.3		6.7
total phosphorus	D	bad (%)		10.5	11.1	6.8	4.3	7.9		4.4
total phosphorus	D	poor (%)		10.5	7.4	2.5		4.5	100.0	

Figure 4-5 Percentage of surface water bodies in the different classes per scenario for the Meuse catchment and split up in transboundary water bodies and other water bodies (striped bars).





4.2 Coastal and marine waters

4.2.1 Reductions in discharges into the North Sea

Figure 4-6 and Figure 4-77 show the effects of the nutrient reductions due to measures and/or foreign inputs on the total nitrogen and total phosphorus discharges towards the North Sea. As compared to scenario A, the decreases in the total nitrogen discharge from all four catchments (Rhine, Meuse, Scheldt and Ems) is 4.1% (scenario A+), 6.9% (scenario B), 11.0% (scenario C), and 8.5% (scenario D). In contrast to total nitrogen, the total phosphorus discharge into the North Sea increases with 6.6% in scenario A+ and 0.6% in scenario D as compared to scenario A. The other scenarios show decreases in the total phosphorus discharge of 6.6% (scenario B) and 8.3% (scenario C). The total phosphorus load in scenario D is equal to that of scenario A, but is 5.6% reduced as compared to scenario A+.

Figure 4-8 and Figure 4-9 show that most discharge locations follow the same pattern, with scenario C showing the highest reduction. Only at the discharge location of the Meuse (Haringvliet sluices), reductions are highest in scenario B.

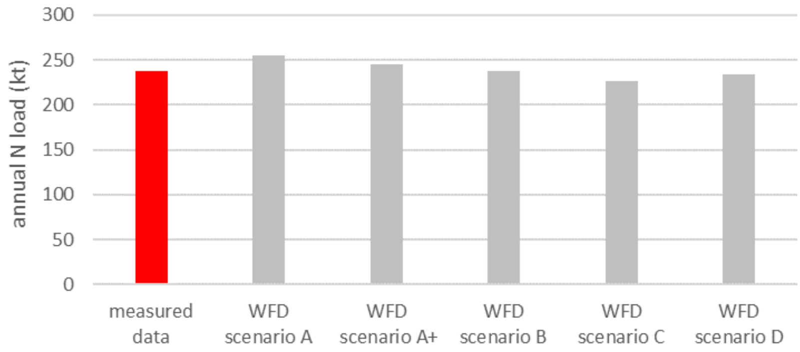


Figure 4-6 Comparison of the measured (red) and simulated (grey) total nitrogen loads summed over all the outflow points.

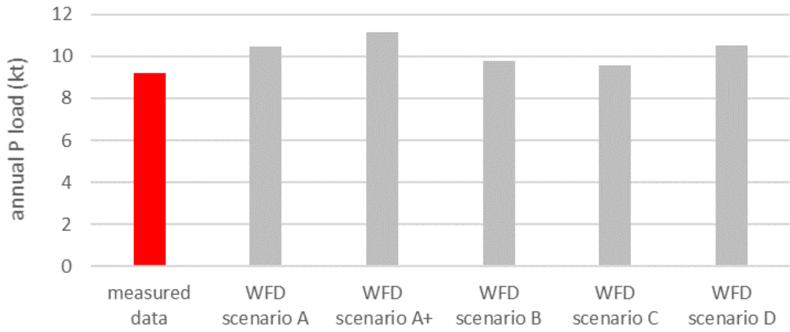


Figure 4-7 Comparison of the measured (red) and simulated (grey) total phosphorus loads summed over all the outflow points.

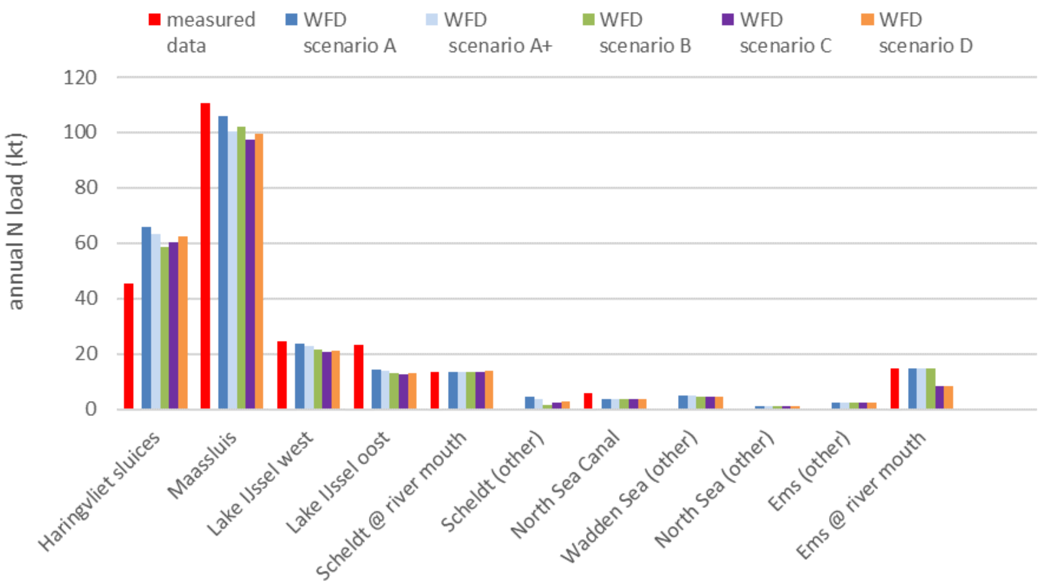


Figure 4-8 Comparison of the measured (red) and simulated (other colors) total nitrogen loads for each of the WFD Explorer outflow points.

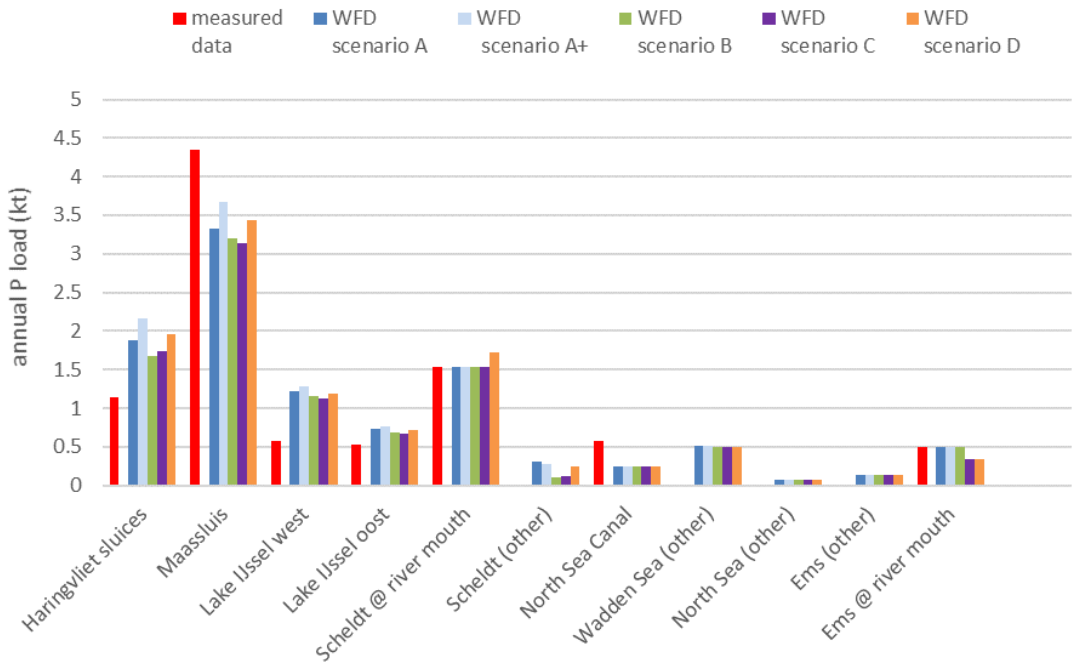


Figure 4-9 Comparison of the measured (red) and simulated (other colors) total phosphorus loads for each of the WFD Explorer outflow points.

4.2.2 Classification WFD-areas

Figure 4-1010 shows the spatial differences per scenario of the modelled winterDIN concentrations as compared to scenario A. The shown differences are the absolute differences in winter concentrations, averaged over the months December, January and February. Locally, at the discharge locations, winter concentrations show clear decreases in all scenarios. These differences are all closely related to (and explained by) the differences in nutrient discharges as calculated with the WFD-Explorer (see section 4.2.1). In scenario B, the largest reduction occurs at the discharge location of the Meuse (Haringvliet sluices). In scenario D, the largest reduction occurs in the Ems-Dollard estuary.

Figure 4-11 shows the classification of the modelled winter concentrations based on the WFD assessment levels. The classification is shown for all scenario runs, and is in all these maps carried out per gridcel. Only a few differences appear between scenario A and the other scenarios, and these differences only cover small parts of the areas.

In Table 4-4 the modelled DIP winter concentrations, assessment levels and classification status are summarized. In scenario A, the modelled values are below the assessment level in six of the areas. Modelled nitrogen concentrations in the other four areas are above assessment level. This is very similar to the results from the standard model (which were based on measured loads for 2015), apart from WFD-area ‘Holland coast’. The other scenario runs hardly show any differences in the classification as compared to scenario A, except for scenario C. In that scenario the modelled winterDIN concentration is below the assessment level, leading to a good status in seven WFD areas.

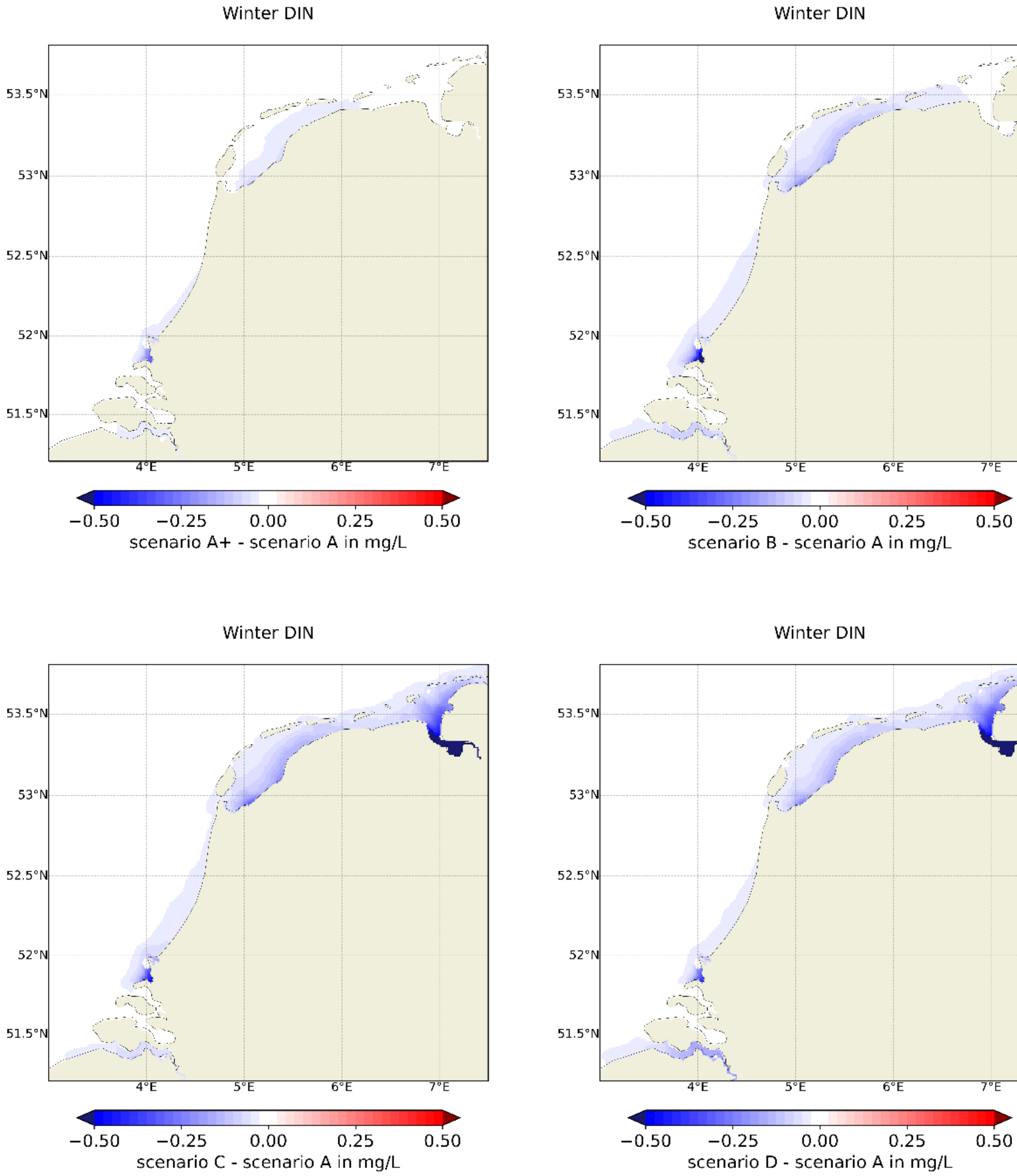
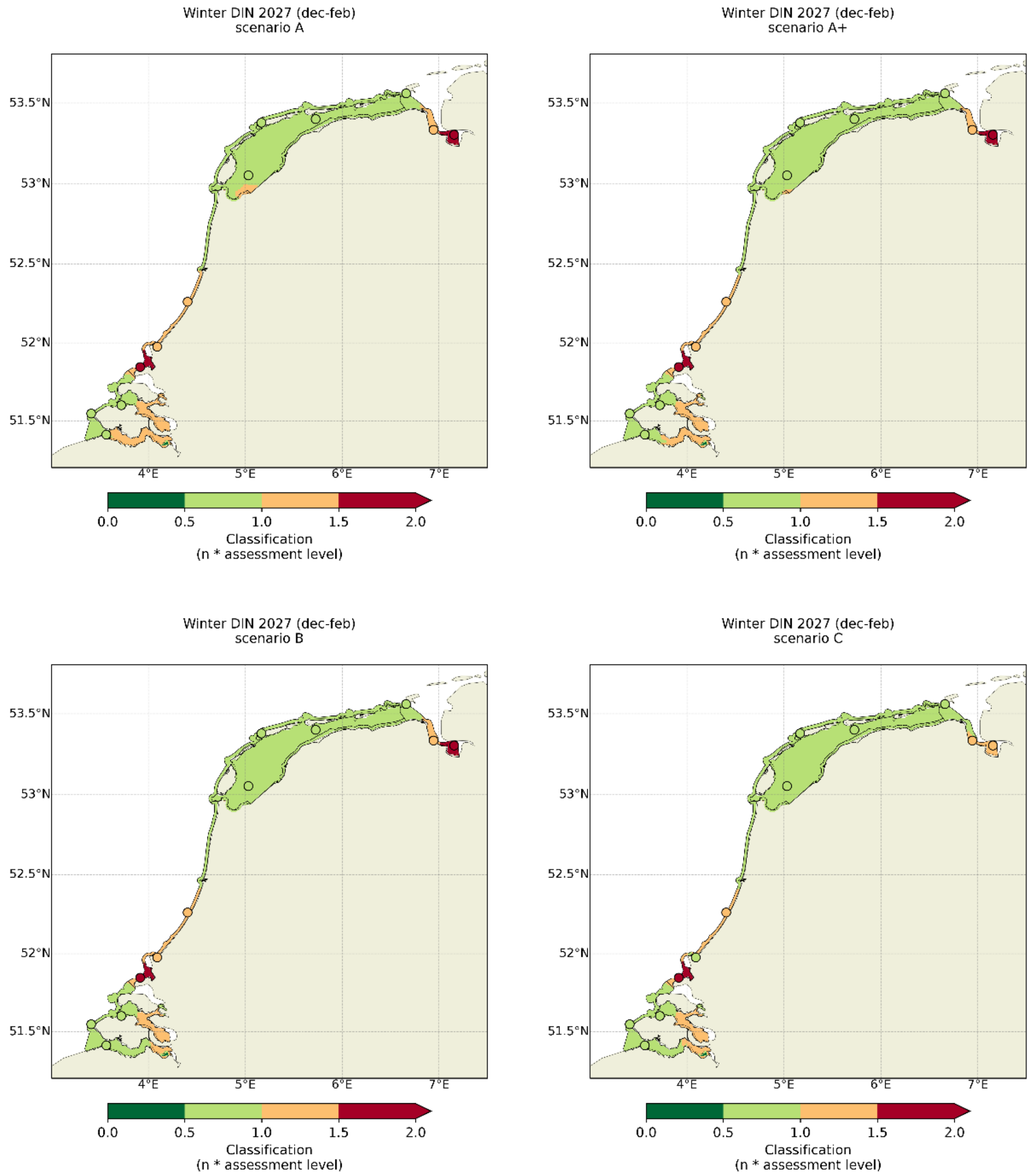


Figure 4-10 Absolute difference in modelled concentrations winterDIN (Dec-Feb) as compared to scenario A, for scenario A+ (upper left panel), scenario B (upper right panel), scenario C (lower left panel) and scenario D (lower right panel). Differences are calculated as Concentration$_{scenario}$ – Concentration$_{scenario\ A}$ in mg/l.


Winter DIN 2027 (dec-feb)
scenario A
Winter DIN 2027 (dec-feb)
scenario A+
Winter DIN 2027 (dec-feb)
scenario B
Winter DIN 2027 (dec-feb)
scenario C
53.5°N
53°N
52.5°N
52°N
51.5°N
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)

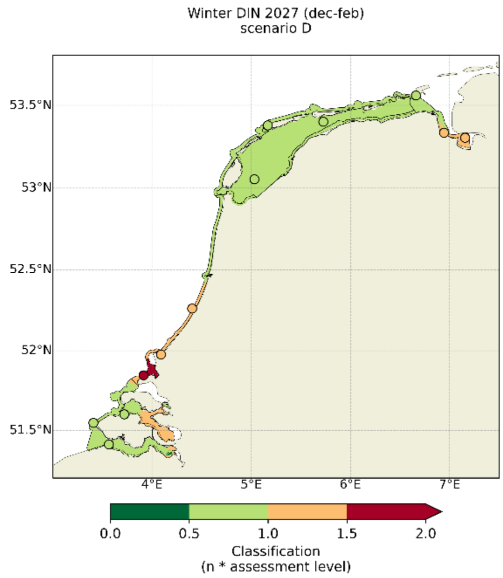


Figure 4-11 Classification of the modelled concentrations of winterDIN in the Dutch WFD areas per scenario. Classification is carried out per gridcell, the colored dots are the classification locations. Green colors indicate that winterDIN concentrations are below the WFD assessment level.

Table 4-4 Modelled concentrations of winterDIN (mg N/l) and assessment levels (mg N/l) in the WFD areas per classification location for the standard model (based on measured loads for 2015), and each scenario (based on simulated loads for 2027). Green colors indicate that the concentrations are below the assessment level.

Assessment area	Monitoring station	Ass. level[1]	Standard	scenario A	scenario A+	scenario B	scenario C	scenario D
Ems-Dollard (coast)	HUIBGOT	0.54	0.38	0.46	0.44	0.43	0.41	0.41
Ems-Dollard	BOCHTVWTM	1.36	1.75	1.95	1.94	1.93	1.39	1.38
	GROOTGND	1.81	2.83	2.98	2.98	2.97	1.99	1.99
Holland coast	NOORDWK2	0.53	0.52	0.59	0.57	0.56	0.55	0.56
Nieuwe Waterweg	BEERKNMDN	2.05	2.20	2.18	2.07	2.08	2.00	2.05
Northern Delta coast	GOERE2	0.98	1.06	1.73	1.67	1.54	1.60	1.64
Eastern Scheldt	WISSKKE	0.46	0.31	0.35	0.34	0.33	0.33	0.33
Wadden coast	BOOMKDP	0.46	0.32	0.36	0.34	0.34	0.33	0.33
Wadden Sea	DANTZGT	0.93	0.75	0.74	0.71	0.68	0.66	0.67
	DOOVBWT	0.79	0.73	0.74	0.71	0.68	0.66	0.67
Wester Scheldt	VLISSGBISSVH	0.48	0.39	0.47	0.46	0.43	0.44	0.41
Zeeland coast	WALCRN2	0.46	0.27	0.30	0.30	0.28	0.29	0.29

[1]Salinity normalized assessment levels.

Legend
Above assessment level
Below assessment level

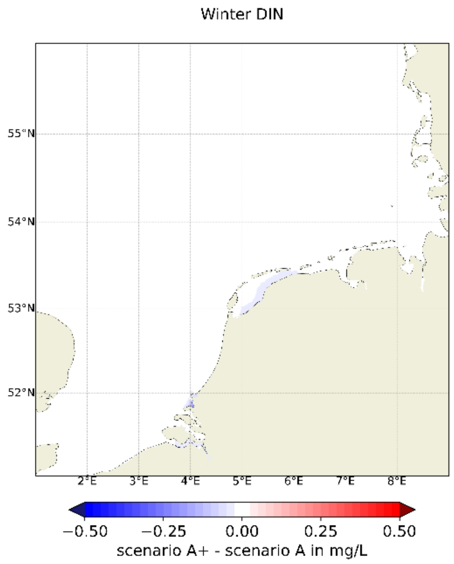
4.2.3 Classification OSPAR-areas

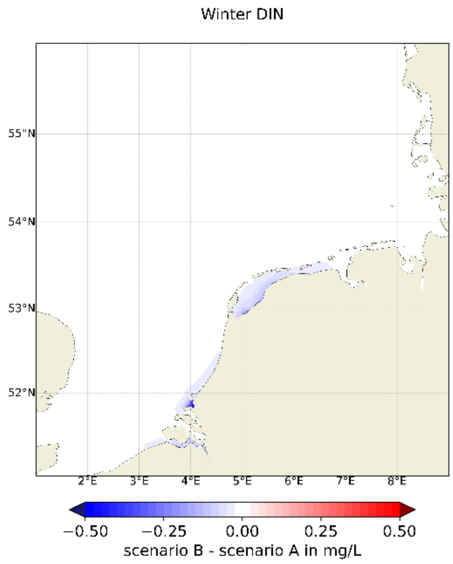
Concentrations and classifications of WinterDIN

Figure 4-1212 shows the spatial differences per scenario of the modelled winterDIN concentrations as compared to scenario A. These results are very similar as those shown for the WFD areas (Figure 4-10) but for the OSPAR assessment framework the winter concentrations are averaged over the months November, December, January and February. Like before, winter concentrations locally show clear decreases in scenarios A+, B and C. These differences are all closely related to (and explained by) the differences in nutrient discharges as calculated with the WFD-Explorer (see section 4.2.1).

Figure 4-13 shows the classification of the modelled winter concentrations based on the OSPAR assessment levels. The classification is shown for each of the scenario runs, and is in all these maps carried out per gridcell. Only a few differences appear between scenario A and the other scenarios, and these differences only cover small parts of the areas.

In Table 4-5 the modelled DIN winter concentrations, assessment levels and classification status are summarized. In scenario A, the modelled values are below the assessment level in all three estuaries. In the offshore areas and in part of the area ‘Coastal Waters’ the modelled concentrations are below the assessment level. Except for three locations, this is similar to the results of the standard model (which were based on measured loads for 2015). The other scenario runs hardly show any difference in classification as compared to scenario A.





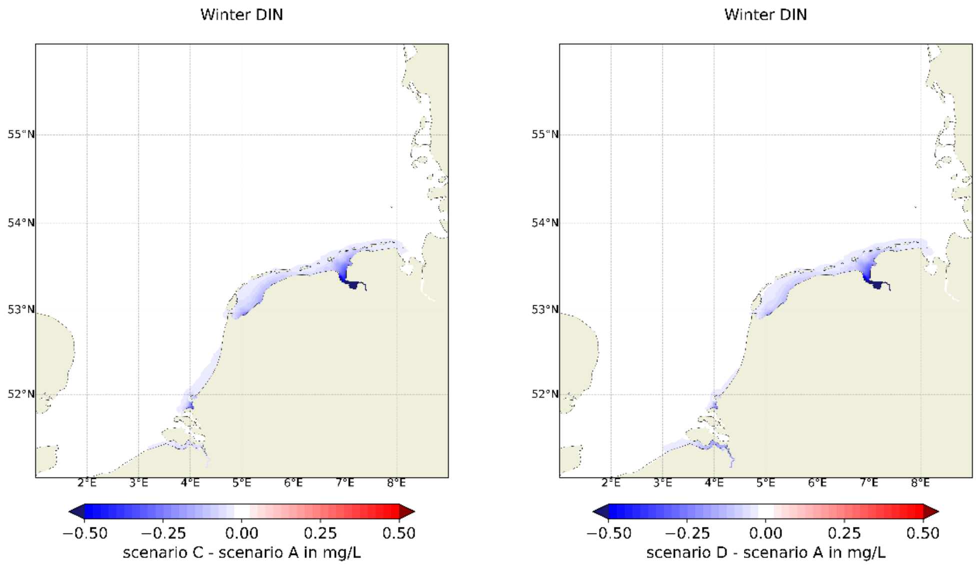
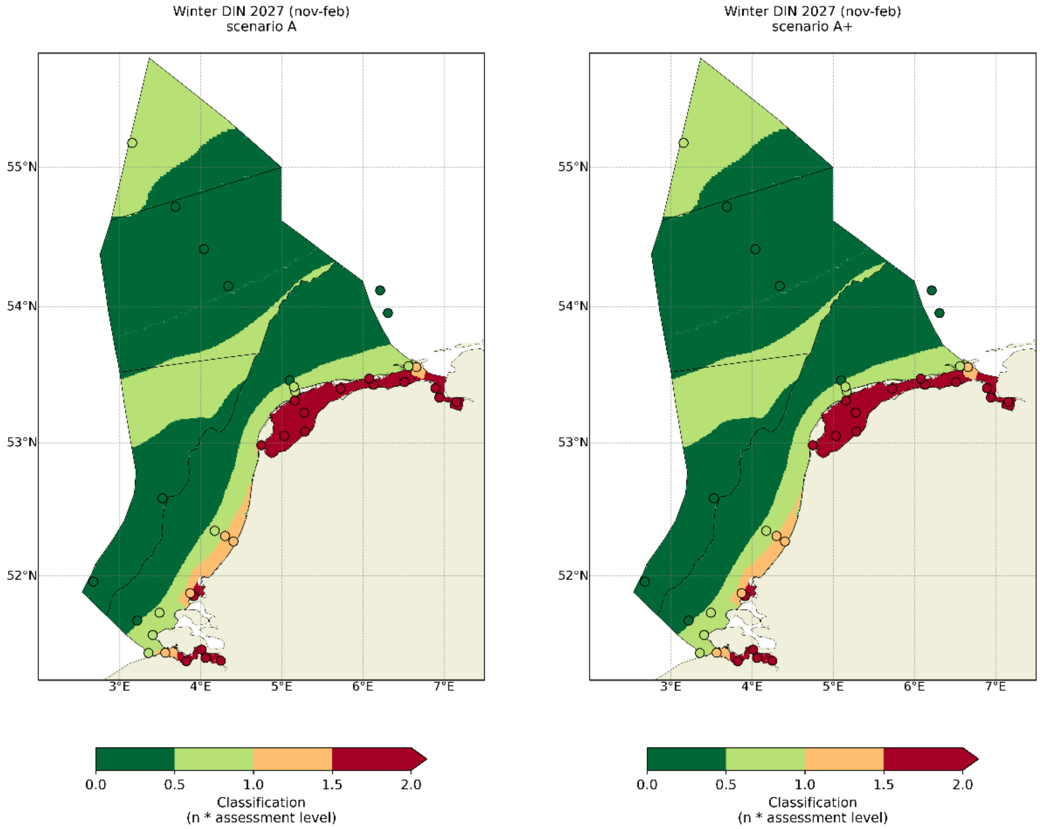
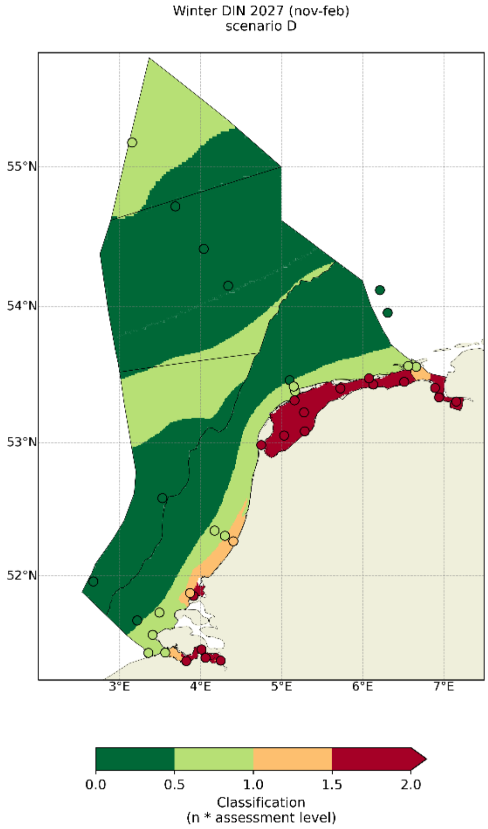
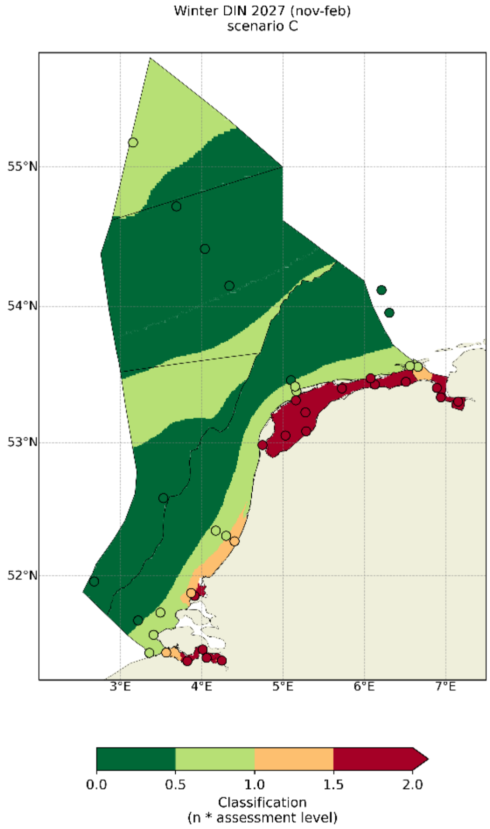


Figure 4-12 Absolute difference in modelled concentrations winterDIN (Nov-Feb) as compared to scenario A, for scenario A+ (upper left panel), scenario B (upper right panel), scenario C (lower left panel) and scenario D (lower right panel). Differences are calculated as Concentration$_{scenario}$ – Concentration$_{scenario\ A}$ in mg/l.





Winter DIN 2027 (nov-feb)
scenario D
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)



Winter DIN 2027 (nov-feb)
scenario C
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)

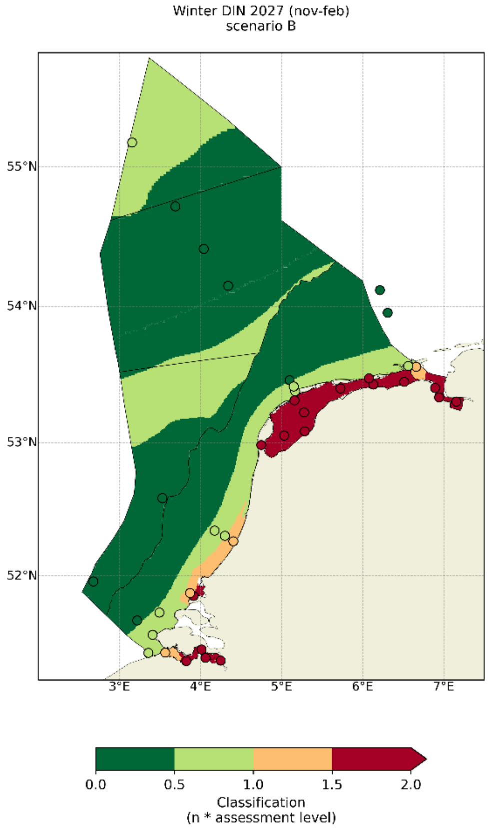


Figure 4-33 Classification of the modelled concentrations of winterDIN in the Dutch OSPAR areas per scenario. Classification is carried out per gridcell, the colored dots are the classification locations. Green colors indicate that winterDIN concentrations are below the OSPAR assessment level.

Table 4-5 Modelled concentrations of winterDIN (mg N/l) and assessment levels (mg N/l) in the OSPAR areas per classification location for the standard model (based on measured loads for 2015), and each scenario (based on simulated loads for 2027). Green colors indicate that the concentrations are below the assessment level.

Assessment area	Monitoring station	Ass. level[1]	Standard	scenario A	scenario A+	scenario B	scenario C	Scenario D
Coastal waters	GOERE2	0.83	1.00	1.49	1.44	1.33	1.37	1.42
	GOERE6	0.50	0.57	0.75	0.74	0.68	0.70	0.73
	NOORDWK10	0.42	0.40	0.44	0.42	0.42	0.41	0.42
	NOORDWK2	0.46	0.48	0.53	0.51	0.50	0.50	0.50
	NOORDWK20	0.42	0.27	0.29	0.28	0.27	0.27	0.28
	ROTTMPT3	0.46	0.35	0.41	0.40	0.39	0.38	0.38
	ROTTMPT50	0.42	0.13	0.13	0.13	0.13	0.13	0.13
	ROTTMPT70	0.42	0.12	0.12	0.12	0.12	0.12	0.12
	SCHOUWN10	0.42	0.23	0.25	0.25	0.24	0.24	0.24
	TERSLG10	0.42	0.20	0.21	0.20	0.20	0.20	0.20
	TERSLG4	0.42	0.26	0.28	0.27	0.27	0.27	0.27
	BOOMKDP	0.42	0.31	0.33	0.32	0.32	0.31	0.31
	WALCRN2	0.42	0.27	0.30	0.30	0.29	0.29	0.29
	WALCRN20	0.42	0.19	0.20	0.20	0.19	0.20	0.19
Wadden Sea	BLAUWSOT	0.10	0.73	0.68	0.66	0.63	0.61	0.62
	DANTZGT	0.10	0.68	0.66	0.64	0.61	0.60	0.60
	DOOVBOT	0.10	1.20	1.00	0.97	0.91	0.88	0.90
	DOOVBWT	0.10	0.71	0.70	0.68	0.65	0.63	0.65
	MARSDND	0.10	0.45	0.47	0.45	0.44	0.43	0.44
	VLIESM	0.10	0.36	0.38	0.37	0.36	0.36	0.36
	ZOUTKPLG	0.10	0.45	0.62	0.59	0.58	0.57	0.57
	ZOUTKPLZGT	0.10	0.40	0.46	0.44	0.43	0.42	0.42
	ZUIDOLWOT	0.10	0.47	0.68	0.66	0.64	0.61	0.61
Wester Scheldt	HANSWGL	0.42	1.09	1.22	1.18	1.13	1.15	1.05
	LAMSWDBI59	0.42	1.23	1.35	1.32	1.27	1.29	1.18
	SCHAARVODD	0.42	1.58	1.68	1.64	1.61	1.62	1.51
	TERNZBI20	0.42	0.68	0.83	0.79	0.73	0.75	0.70
	VLISSGBISSVH	0.42	0.39	0.47	0.45	0.43	0.43	0.41
	WIELGN	0.42	0.33	0.39	0.37	0.36	0.36	0.35
Ems-Dollard	BOCHTVWTM	0.42	1.61	1.81	1.81	1.79	1.31	1.31
	BOCHTVWTND	0.42	1.40	1.59	1.59	1.57	1.17	1.17
	GROOTGND	0.42	2.56	2.73	2.72	2.71	1.85	1.85
	HUIBGOT	0.42	0.39	0.45	0.44	0.43	0.41	0.40
Southern Bight	NOORDWK70	0.21	0.08	0.08	0.08	0.08	0.08	0.08
	WALCRN70	0.21	0.09	0.09	0.09	0.09	0.09	0.09
Oyster grounds	TERSLG100	0.21	0.08	0.08	0.08	0.08	0.08	0.08
	TERSLG135	0.21	0.09	0.09	0.09	0.09	0.09	0.09
	TERSLG175	0.21	0.10	0.10	0.10	0.10	0.10	0.10
Dogger Bank	TERSLG235	0.21	0.11	0.11	0.11	0.11	0.11	0.11

[1]Assessment levels for 'Coastal Waters' are normalized to 30 psu.

Legend	
Red	Above assessment level
Green	Below assessment level

Concentrations and classification WinterDIP

Figure 4-444 shows the spatial differences per scenario of the modelled winterDIP concentrations as compared to scenario A. Like the figures for winterDIN, the shown differences are the absolute differences in winter concentrations, averaged over the months November, December, January and February. Again, concentrations locally show clear decreases in scenarios B and C. However, in contrast to winterDIN, the winterDIP concentrations show an increase in scenario A+ and D. The differences compared to scenario A are all closely related to (and explained by) the differences in nutrient discharges as calculated with the WFD-Explorer (see section 4.2.1).

Figure 4-15 shows the classification of the modelled DIP winter concentrations based on the OSPAR assessment levels. The classification is shown for all of the scenario runs, and is in all these maps carried out per gridcell. Only a few differences appear between scenario A and the other scenarios, and these differences only cover small parts of the areas.

In Table 4-6, the modelled DIP winter concentrations, assessment levels and classification are summarized. In scenario A, the modelled values are above the assessment levels in all three estuaries. In the offshore areas and in part of the area ‘Coastal Waters’ the modelled concentrations are below the assessment levels. Except for two locations, this is similar to the results of the standard model (which were based on measured loads for 2015). The other scenario runs show no difference in classifications as compared to scenario A.

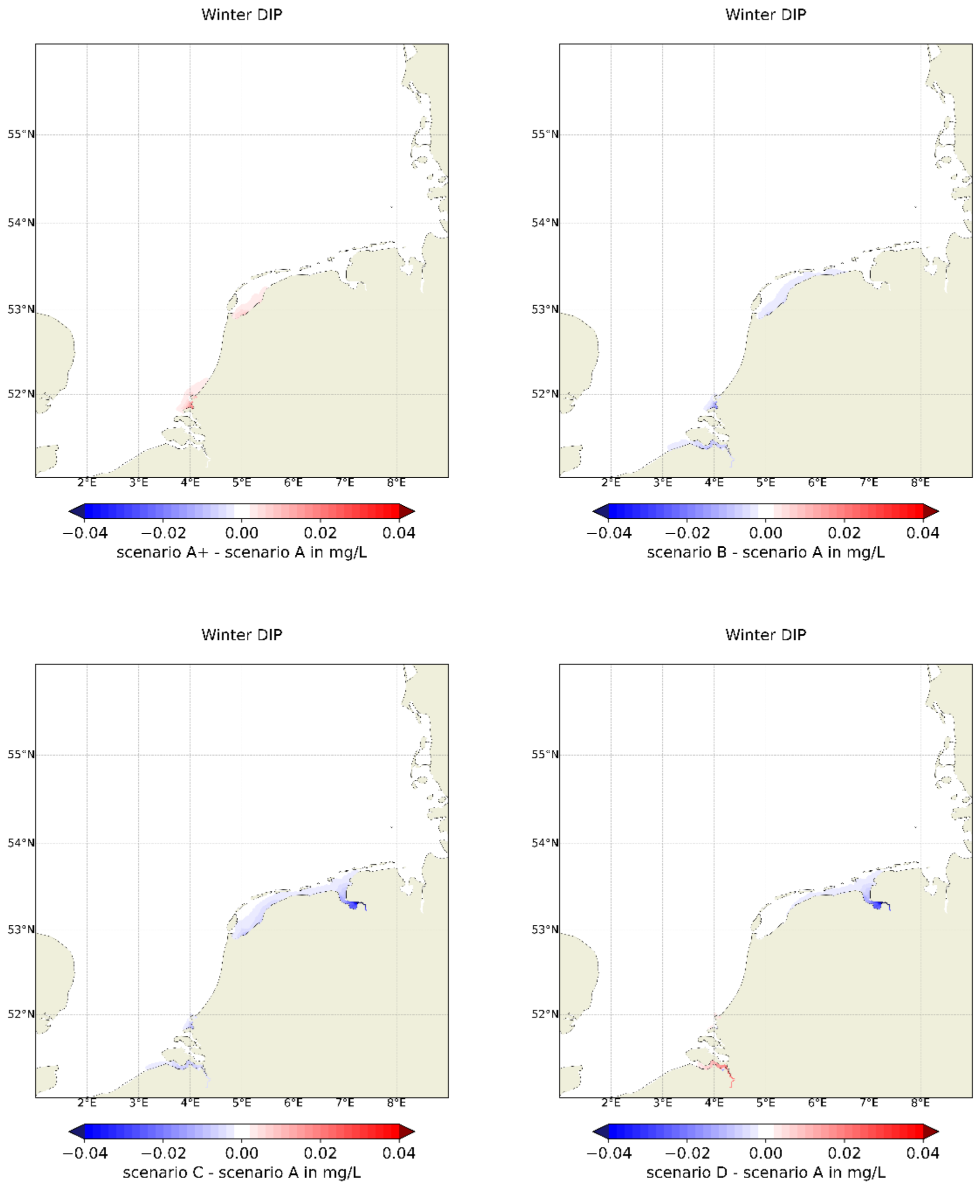
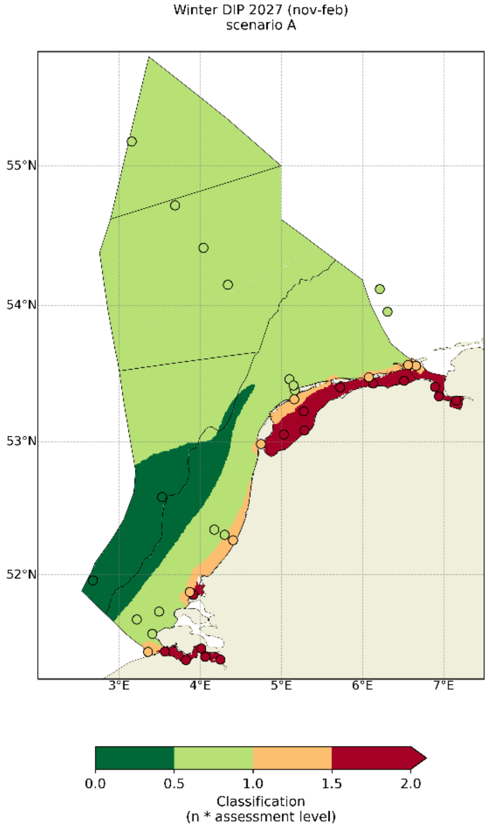
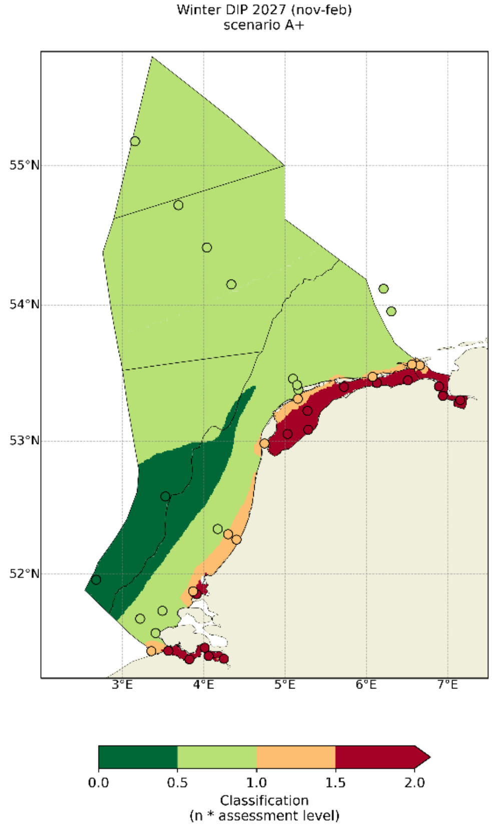
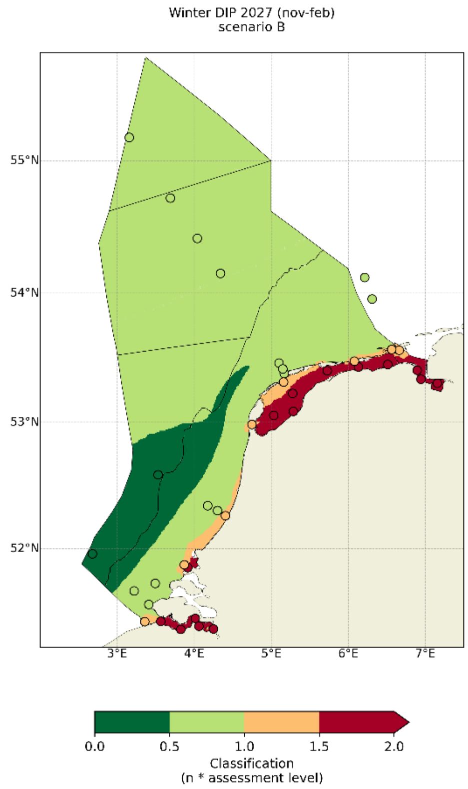
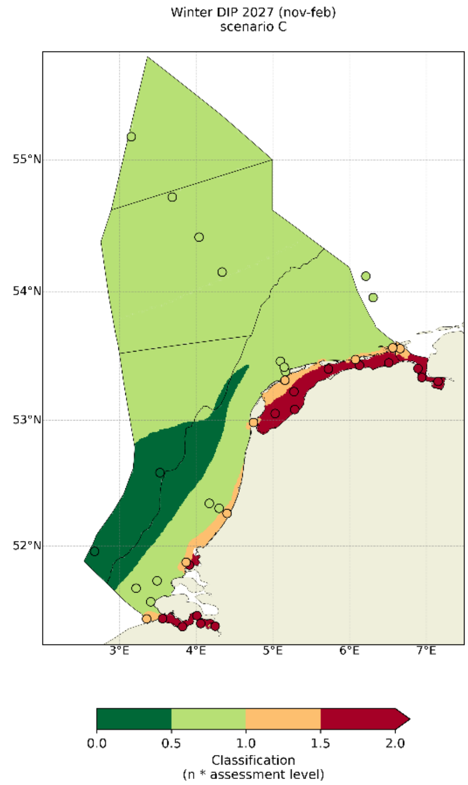


Figure 4-44 Absolute difference in modelled concentrations winterDIP (Nov-Feb) as compared to scenario A, for scenario A+ (upper left panel), scenario B (upper right panel), scenario C(lower left panel) and scenario D (lower right panel). Differences are calculated as Concentration$_{scenario}$ – Concentration$_{scenario\ A}$ in mg/l.


Winter DIP 2027 (nov-feb)
scenario A
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)


Winter DIP 2027 (nov-feb)
scenario A+
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)


Winter DIP 2027 (nov-feb)
scenario B
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)


Winter DIP 2027 (nov-feb)
scenario C
55°N
54°N
53°N
52°N
3°E
4°E
5°E
6°E
7°E
0.0
0.5
1.0
1.5
2.0
Classification
(n * assessment level)

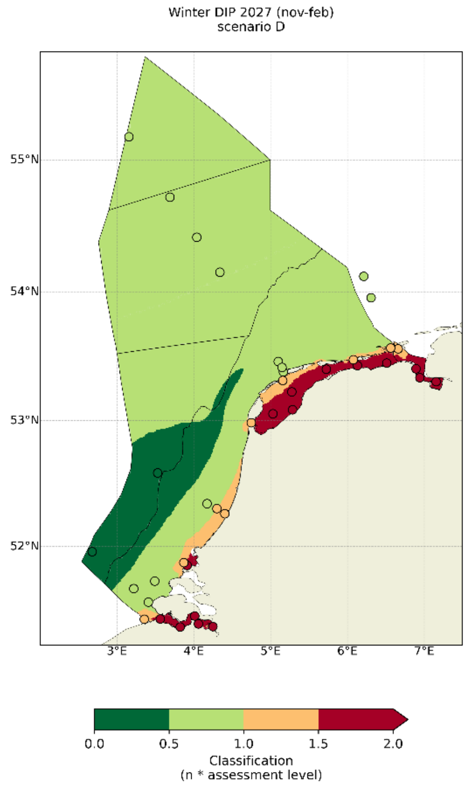


Figure 4-15 Classification of the modelled concentrations of winterDIP in the Dutch OSPAR areas per scenario. Classification is carried out per gridcell, the colored dots are the classification locations. Green colors indicate that WinterDIP concentrations are below the OSPAR assessment level.

Table 4-6 Modelled concentrations of winterDIP (mg N/l) and assessment levels (mg N/l) in the OSPAR areas per classification location for the standard model (based on measured loads for 2015), and each scenario (based on simulated loads for 2027). Green colors indicate that the concentrations are below the assessment level.

Assessment area	Monitoring station	Ass. level[1]	Standard	scenario A	scenario A+	scenario B	scenario C	scenario D
Coastal waters	GOERE2	0.033	0.039	0.061	0.070	0.055	0.057	0.063
	GOERE6	0.027	0.027	0.035	0.039	0.033	0.033	0.037
	NOORDWK10	0.025	0.024	0.025	0.026	0.023	0.024	0.025
	NOORDWK2	0.026	0.028	0.028	0.030	0.026	0.027	0.028
	NOORDWK20	0.025	0.018	0.019	0.019	0.018	0.018	0.019
	ROTTMPT3	0.026	0.021	0.029	0.029	0.028	0.028	0.028
	ROTTMPT50	0.025	0.014	0.014	0.014	0.014	0.014	0.014
	ROTTMPT70	0.025	0.016	0.016	0.016	0.016	0.016	0.016
	SCHOUWN10	0.025	0.017	0.018	0.018	0.017	0.017	0.018
	TERSLG10	0.025	0.015	0.016	0.016	0.015	0.015	0.016
	TERSLG4	0.025	0.019	0.019	0.020	0.019	0.019	0.019
	BOOMKDP	0.025	0.021	0.022	0.023	0.021	0.021	0.022
	WALCRN2	0.025	0.019	0.021	0.022	0.020	0.021	0.022
	WALCRN20	0.025	0.015	0.016	0.016	0.016	0.016	0.016
Wadden Sea	BLAUWSOT	0.022	0.034	0.046	0.047	0.044	0.043	0.045
	DANTZGT	0.022	0.031	0.045	0.045	0.043	0.042	0.043
	DOOVBOT	0.022	0.048	0.067	0.070	0.063	0.062	0.066
	DOOVBWT	0.022	0.034	0.047	0.049	0.045	0.044	0.046
	MARSDND	0.022	0.027	0.030	0.032	0.029	0.029	0.030
	VLIESM	0.022	0.023	0.025	0.026	0.024	0.024	0.025
	ZOUTKPLG	0.022	0.023	0.049	0.049	0.047	0.046	0.046
	ZOUTKPLZGT	0.022	0.023	0.032	0.032	0.031	0.030	0.031
	ZUIDOLWOT	0.022	0.024	0.052	0.052	0.050	0.049	0.049
Wester Scheldt	HANSWGL	0.025	0.128	0.136	0.135	0.128	0.129	0.148
	LAMSWDBI59	0.025	0.147	0.154	0.153	0.147	0.148	0.169
	SCHAARVODD	0.025	0.196	0.201	0.200	0.195	0.196	0.222
	TERNZBI20	0.025	0.074	0.085	0.083	0.076	0.077	0.090
	VLISSGBISSVH	0.025	0.035	0.041	0.041	0.038	0.038	0.043
	WIELGN	0.025	0.027	0.032	0.032	0.029	0.030	0.033
Ems-Dollard	BOCHTVWTM	0.025	0.074	0.093	0.093	0.092	0.080	0.080
	BOCHTVWTND	0.025	0.065	0.083	0.083	0.082	0.072	0.072
	GROOTGND	0.025	0.119	0.134	0.134	0.133	0.109	0.109
	HUIBGOT	0.025	0.022	0.031	0.031	0.030	0.029	0.029
Southern Bight	NOORDWK70	0.025	0.011	0.011	0.011	0.011	0.011	0.011
	WALCRN70	0.025	0.012	0.012	0.012	0.012	0.012	0.012
Oyster grounds	TERSLG100	0.025	0.014	0.014	0.014	0.014	0.014	0.014
	TERSLG135	0.025	0.016	0.016	0.016	0.016	0.016	0.016
	TERSLG175	0.025	0.018	0.018	0.018	0.018	0.018	0.018
Dogger Bank	TERSLG235	0.025	0.019	0.019	0.019	0.019	0.019	0.019

[1]Assessment levels for 'Coastal Waters' are normalized to 30 psu.

Legend
- Above assessment level (red)
- Below assessment level (green)

5 Discussion, conclusions and recommendations

5.1 Fresh waters

5.1.1 Differences in data between partners

As described in Chapter 3, different monitoring and analyzing methods used by the different parties in combination with the use of different years (both for flows and concentrations) may lead to differences in perceived concentrations and loads, especially for total nitrogen. To assess the impact of these differences on the WFD classifications, the two sets of measured values were used in the reference scenarios A and A+.

The use of different target definitions makes it difficult to compare the target values: NRW uses year averages, NL and FL summer averages and WL 90 percentile values. For this study the concentrations and the targets have been converted into quarterly concentrations.

Another difference is that the flows and concentrations of the Meuse River on the Dutch side of the border are measured, but the Walloon data is the result of modeling.

Not all the transboundary waters on the Dutch side which are designated as WFD surface water bodies have a comparable WFD status in the upstream countries. For the transboundary waters in upstream countries without a WFD status, often less data or no data could be made available within the short time frame of the study. In that case, the Dutch data for flows and concentrations was used in the A+ scenario. Because the waters without a WFD status are always (very) small waters, the impact of this on the total loads to the North Sea is limited.

5.1.2 Comparing water quality targets between the partners

The Dutch targets are in the same range as the targets of NRW, both for total nitrogen and for total phosphorus. For total phosphorus the Dutch and the FL targets are also quite comparable, but for the smaller waters the total nitrogen target concentration of FL is almost twice as high as compared to the Dutch targets (4 and 2.4 mg/l summer average). The targets in WL are defined as 90 percentile values and therefore not directly comparable with the Dutch summer average values.

5.1.3 Comparing load reduction between scenarios

The reduction in total load of all transboundary waters in the Meuse catchment as compared to scenario A is highest for scenario B (30-35% for both total nitrogen and total phosphorus) and much lower for scenario C (< 1% for total nitrogen and total phosphorus). This is due to the higher target values in FL and WL. For scenario D the expected reduction is limited with 3% for total nitrogen and 2% for total phosphorus.

5.1.4 Comparing percentage of water bodies with good water quality between scenarios

Although the differences of flows and concentrations between the same transboundary waters in scenarios A and A+ are often quite large for individual waters, the overall differences in percentage water bodies in category “good” between these scenarios on a national level are minimal (<1%). This is partly caused by the fact that the percentage of transboundary waters compared to all waters (transboundary waters and non-transboundary waters) is rather small and by the fact that the differences of the flows and concentrations fluctuate in both directions (sometimes the Dutch data are higher, sometimes lower).

When zooming in at the Meuse catchment, we see that for scenario A+ data the transboundary waters show a much higher percentage of water bodies in the category "good" than is the case for scenario A, mainly because the upstream data show lower concentrations than the Dutch data.

When comparing the reference scenarios A/A+ with scenarios B/C/D in the Meuse catchment, we see a large improvement of the percentage of water bodies in the category "good" (total nitrogen from 24% to 52% and total phosphorus from 37% to 59%) for scenario B, a smaller improvement for scenario C (total nitrogen 39% "good" and total phosphorus 50%) and a moderate improvement for scenario D (total nitrogen 50% "good" and total phosphorus 52%).

It is interesting to see that, when the quality of the transboundary waters is improved (compared to the scenarios A and A+), as is the case for all projected scenarios B, C and D, we observe a structural improvement of the more downstream waterbodies.

It is important to realise that an increase of the percentage of water bodies in the category "good", as shown in the scenarios B, C and D not automatically results in a much lower input of nutrient loads into the coastal waters. A lot of the transboundary and connected downstream water bodies are relatively small and the loads to the North Sea will mainly be determined by the input via the upstream parts of the Rhine and the Meuse rivers rather than by the smaller WFD waterbodies in the Dutch part of the catchments.

5.2 Coastal and marine waters

In reference scenario A the modelled winterDIN concentrations are below the assessment level in six of the WFD areas (Ems-Dollard coast, Eastern Scheldt, Wadden coast, Wadden Sea, Wester Scheldt, and Zeeland coast), and in three of the OSPAR-areas (Southern Bight, Oyster grounds, and Dogger Bank), see Table 4-4 and Table 4-5. The modelled winterDIP concentrations are below the assessment level in these same three OSPAR-areas, see Table 4-6. The winter DIP concentrations in the OSPAR area 'Coastal waters' are also below the assessment level in most (but not all) of the classification locations. For the WFD areas DIP assessment levels do not exist.

The modelled winterDIN concentration in the four remaining WFD areas (Ems-Dollard, Holland coast, Nieuwe Waterweg and Northern Delta coast) are *above* the assessment level. This is also the case for the winterDIN and winterDIP concentrations in the three remaining OSPAR-areas (Wadden Sea, Wester Scheldt, and Ems-Dollard).

The classification results from scenario A+ are equal to those of scenario A, apart from that of the winterDIP concentration at the OSPAR assessment location Noordwijk10. Apparently, the differences in measured data between Dutch and upstream partners hardly lead to differences in classification status of the marine and coastal waters.

Furthermore, a few differences occur between the reference scenarios A and A+ on the one hand, and the standard model on the other hand. These differences are due to the autonomous developments in nutrient loading that were assumed for 2027 in all scenarios (but were not considered in the standard model which was based on measured loads for 2015), in combination with the WFDE model inaccuracy (i.e. differences between measured and modelled discharges, see section 2.4.4).

5.2.1 Effectivity of scenarios

The modelled winterDIN concentrations in the marine and coastal areas are highest in scenario A and decrease most in scenario C. In contrast, the winterDIP concentrations are highest in scenario A+ but still decrease most in scenario C. The decreases in marine concentrations are in line with the reductions in the total amount of nutrients discharged (section 4.2.1). From a spatial point of view, the decrease is largest along the coast, close to the discharge locations, and is negligible in the offshore areas. This is simply the effect of dilution of the river/discharge plumes with North Sea water.

Close to the outflow location of the Meuse catchment (the Haringvliet sluices), scenario B shows a larger reduction than scenario C. This is a direct result of the local discharges of the Meuse catchment which are smaller in scenario C than in scenario B. Nutrient concentrations at all other outflow locations, however, follow a different pattern, with larger reductions in scenario C than in scenario B. Apparently, the Meuse catchment behaves different than the other catchments, but the impact of this difference on the coastal and marine areas is small and visible only close to its outflow location.

Although the discharged nutrients and the modelled concentrations in the coastal and marine areas change across the scenarios, this hardly leads to a change in classification status of these areas. Only the WFD area ‘Nieuwe Waterweg’ changes from 'red’ (above the assessment level) to ‘green’ (below the assessment level) in scenario C. In the other areas, the concentrations are too high above the assessment level, or the reductions are too small to make an area change class.

Yet, in some of the individual classification locations the concentrations do change enough to make them fall into a different class. For example, location ‘Noordwijk 10’ does change class in scenarios B and C, but this is just one out of fourteen classification locations for the OSPAR-area ‘Coastal Waters’. Also location ‘Huibertsgat Oost’ changes class in scenario C, but this is just one out of four classification locations in the OSPAR area ‘Ems-Dollard’. These local changes are not enough to make the whole area change status.

5.2.2 WFD vs OSPAR

Some areas are part of both the WFD and the OSPAR framework. This is for instance the case for the Wadden Sea, Wester Scheldt and Ems-Dollard. Surprisingly, both the Wadden Sea and the Wester Scheldt are 'green’ according to the WFD-classification (i.e. DIN concentrations are below the assessment level), while they are ‘red’ according to the OSPAR classification (i.e. concentrations are above the assessment level).

These differences are explained by the differences in both classification frameworks. Differences exist with respect to the assessment level, the definition of the winter period, the number of classification locations per area, and the application of a salinity correction. Especially the salinity correction seems to be an important factor explaining the differences in classification of the Wester Scheldt and Wadden Sea. This salinity correction is based on a linear relation between salinity and winterDIN. However, a linear relation is not always found, especially in the estuaries, and its application in those areas is problematic (Prins et al., 2015).

In addition to the salinity correction, also several other issues have been encountered in the assessment of nutrient and chlorophyll values in the North Sea, leading to incoherent threshold values between locations, areas, and/or countries. The European Commission has asked EU member states to improve on this so future assessment reports will give a good overview of the level of eutrophication in the North Sea.

The JMP EUNOSAT project (Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data) has developed a new common method for monitoring and assessment of eutrophication in the North Sea (Enserink et al, 2019). This method is currently being finetuned and tested. It will avoid overlap with the WFD framework by considering the WFD assessment results as leading.

5.2.3 Assessment levels rivers vs marine/coastal waters

Just like the previous study in 2015, this study shows that it is possible that nutrient concentrations in the river (mouth) are below the assessment level, while in the coastal area where they are discharged, they are above the assessment level. This is for instance the case for the winterDIN concentrations in the WFD areas Holland coast and Nieuwe Waterweg which are classified as ‘red’, while the nearby total nitrogen concentrations in the Rhine are classified as ‘green’.

This seeming contradiction is discussed in Prins et al. (2015). In their report it is shown that the relation between the assessment levels for nitrogen in the North Sea and in the rivers is poor. The total-N concentrations in the growing season in the Rhine is (almost) below the assessment level, which is less the case for the total-N concentrations in the winter, while the winter-DIN concentrations in the North Sea are still above their assessment level.

5.3 Conclusions

The following conclusions can be drawn from this study:

- The current study provides more insight in the effects of measures taken in the 3rd River Basin Management cycle of the WFD regarding the total nitrogen and total phosphorus concentrations in the downstream part of the Meuse catchment and the effects on the coastal and marine waters.
- The exchange of data was characterized by a positive and active cooperation of all partners: Nordrhein-Westfalen (NRW), Flanders (FL) and Wallonia (WL). Due to the short time frame of the project, only data could be achieved that was (more or less) readily available for the partners. We must consider that all partners have been very busy with the national RBMP processes this year, what leaves limited time left for extra activities like this project. Besides this, for all of us most of the work is hampered by the COVID-19 crises measures.
- For 36 transboundary waters in the Meuse catchment data exchange with the upstream partners has taken place. Large differences exist between the Dutch data and the data of the upstream partners regarding the flows and concentrations of total nitrogen and total phosphorus in the transboundary waters, especially for the smaller waters.
- For the (very) small transboundary waters in the Meuse catchment differences in flows up to a factor 10 can be seen. For the larger water bodies, like the Meuse, the Roer and the Niers, differences in yearly flows are limited to 5%. Without a further analysis it can’t be concluded which data has a better quality.
- For most of the (very) small transboundary waters in upstream countries which don’t have a WFD status, less data or no data could be provided from the upstream partners within the limited time available for this study. For about half of the transboundary waters, no flow data is available from the upstream partners. For a quarter of the transboundary waters, measured flows are available, for the other quart modelled flows.
- Different monitoring and analyzing methods used by the different partners might play an important role in the differences in concentrations between the partners, especially for total nitrogen. The difference between measuring total nitrogen or taking the sum of the different measured components (N-Kj, NO_3 and NO_2) may lead to a difference of 10% in year average concentrations. Another explanation of the differences in flows and concentrations is the use of different monitoring years.

- Both in the Dutch data and the upstream data, not for all transboundary waters matching flow and nutrient concentration data for the reference year 2015 are available.
- Average differences in the Dutch and upstream total nitrogen concentrations of the transboundary waters in the Meuse catchment are about 20% for the smaller waters (differences in two directions: upstream concentrations higher or lower than the Dutch data), but for all the larger waters the concentrations of the upstream partners are lower than the Dutch concentrations (Meuse -8%, Niers -16% and Roer -1%). For total phosphorus, the average differences between the Dutch and upstream concentrations are larger (15-45% for the different partners), also in two directions. For the larger waters, the total phosphorus concentrations of the upstream partners are not lower, but higher than the Dutch concentrations (Meuse +12%, Niers +113% and Roer +22%).
- Differences also exist in the nutrient targets on both sides of the border. Differences in the definition of the targets make it difficult to compare them. In the Netherlands and Flanders summer average concentrations are used, in Germany year average concentrations for the larger transboundary waters and a nitrate concentration for the smaller waters and in Wallonia a 90-percentile of the summer values is used.
- For almost all waters (excluding the Niers and the Roer), the targets of the upstream partners are higher (a factor 2-5) than the Dutch targets, also including the Meuse river. For total phosphorus, the targets are rather comparable between the partners.
- Reductions of nutrient concentrations for the transboundary waters as expected by the upstream partners in 2027 as the result of the RBMPs show to be limited: a 0-5% reduction of both total nitrogen and total phosphorus for NRW, an average reduction of 9% for total nitrogen and 17% for total phosphorus for FL (and an increase of maximal 4% for total nitrogen and 15% for total phosphorus instead of a reduction for 3 waters) and small reductions of 3% for total nitrogen and 2% for total phosphorus for the Meuse River.
- In scenarios C (upstream targets) and D (expected reductions) the Dutch targets will be met for only a limited part of the transboundary waters (11% for total nitrogen and 33% for total phosphorus).
- The reduction in total load of the sum of all transboundary waters in the Meuse catchment compared with the A scenario is the highest in scenario B (30-35% for both total nitrogen and total phosphorus) and much lower for scenario C (< 1% for total nitrogen and total phosphorus), mainly caused by the higher target values in FL and WL. For scenario D the expected load reduction will be limited to 3% for total nitrogen and 2% for total phosphorus.
- On a national scale the percentage of water bodies with a good status in the Netherlands (excluding the coastal waters) is about 50%, both for total nitrogen and total phosphorus, showing no differences between the A and the A+ scenarios. In the scenarios including the Dutch 3rd RBMP measures, this percentage increases to 63% in scenario B and 60% in the scenarios C and D, again both for total nitrogen and total phosphorus.
- Zooming in from the national level to the catchment level, we see the percentage of water bodies with a good status for the scenarios A and A+ in the Meuse catchment is the lowest of the four Dutch catchments: ca. 25% for total nitrogen and 37% for total phosphorus. The main background for this is the high level of agricultural activities in the Meuse catchment.
- When comparing the A/A+ and the B/C/D scenarios in the Meuse catchment, we see for scenario B a large improvement of the percentage of water bodies with a good status (total nitrogen from 24% to 52% and total phosphorus from 37% to 59%), a smaller improvement in scenario C (total nitrogen 39% and total phosphorus 50%) and scenario D falls between B and C (total nitrogen 50% and total phosphorus 52%).
- When the quality of the transboundary waters is improved (compared to the A and A+ scenarios), as is the case in the scenarios B, C and D, we also see a structural improvement of (a part of) the more downstream waterbodies.

- An increase of the percentage of water bodies with a good status, as shown in the scenarios B, C and D does not automatically result in a much lower input of nutrient loads into the coastal waters. A lot of the transboundary and connected downstream water bodies are relatively small and/or not closely connected to the main rivers while the nutrient loads to the North Sea will mainly be determined by the input via the Rhine and the Meuse rivers.
- The nutrient reductions considered in the various WFD Explorer scenarios also lead to reductions of the nutrient loads discharged into the North Sea. This, in turn, results in decreased nutrient concentrations in the coastal and marine waters. However, the discharged nutrients are diluted quickly. As a result, the impact of the nutrient reductions is largest close to the discharge locations, but is reduced along the coast, and is negligible in the offshore areas.
- Close to the outflow location of the Meuse catchment (the Haringvliet sluices), scenario B shows a larger reduction than scenario C. This is a direct result of the local discharges of the Meuse catchment which are smaller in scenario C than in scenario B. Nutrient concentrations at all other outflow locations, however, follow a different pattern, with larger reductions in scenario C than in scenario B. Apparently, the Meuse catchment behaves different than the other catchments, but the impact of this difference on the coastal and marine areas is small and visible only close to its outflow location.
- Some overlap exists between the WFD and the OSPAR assessment frameworks. Both frameworks cover the areas Wadden Sea, Western Scheldt and Ems-Dollard. In some cases, differences in assessment status appear, even when based on the same model results. These differences are explained by the differences in these frameworks with respect to the assessment levels, the definition of the winter period, the number of classification locations per area, and the application of a salinity correction. Currently, a new common method for monitoring and assessment of eutrophication in the North Sea is being developed, which will address various issues in the old OSPAR framework and will avoid overlap with the WFD framework by considering the WFD assessment results as leading.
- Just like the previous study in 2015, this study shows that it is possible that nutrient concentrations in the river (mouth) are below the assessment level, while in the coastal area where they are discharged, they are above the assessment level. This is for instance the case for the winterDIN concentrations in the WFD areas ‘Holland coast’ and ‘Nieuwe Waterweg’ which are classified as ‘red’, while the nearby total nitrogen concentrations in the Rhine are classified as ‘green’. This seeming contradiction has been discussed in Prins et al. (2015), where it is shown that the relation between the assessment levels for nitrogen (winterDIN) in the North Sea and in the rivers (growing season total-N) is poor indeed.

5.4 Recommendations

- It is recommended to generate a common dataset of the flows and concentrations for the transboundary waters, preferably for a longer period of time. In an ideal situation, this dataset would be the result of the cooperation of all partners (NRW, FL, WL, NL), including the Dutch waterboards in the Meuse catchment. In this exercise also attention should to be given to the different monitoring and analyzing methods used by the different parties involved. This dataset would increase the quality of common evaluations like the present study and support the discussion about the (need for) tuning and intercalibration of the targets, as set in the different parts of the Meuse catchment.
- Although there is a lot of cooperation between the Netherlands and the upstream partners, both on the national level within the River Committees and on a regional and local level, still differences exist in the nutrient fresh water target values between the partners. It is recommended to have attention for this.

6 References

Chrzanowski, C., Cleij, P. Van den Roovaart, J., Thiange, C., Troost, T. (2015a). Evaluation of total nitrogen concentrations in coastal waters of the Meuse catchment for 2021 and 2027. Deltares report 1220521-ZSW-0005. Delft

Chrzanowski, C., Van den Roovaart, J., Van ‘t Hoff, L., Lebecque, T., 2015b. IMC - Evaluation of nutrients in Meuse catchment - Discussion document for chemistry group. Memo 1220521-000-ZWS-0004. 21st August 2015.

Baretta-Bekker, H., 2016. Application COMP. OSPAR Comprehensive Procedure to the Dutch marine waters.

Bolt, F.J.E. van der, T. Kroon, P. Groenendijk, L.V. Renaud, J. van den Roovaart, G.M.C.M. Janssen, S. Loos, P. Cleij, A. van der Linden, en A. Marsman, 2020. Het landelijk waterkwaliteitsmodel; Uitbreiding van het Nationaal Water Model met waterkwaliteit ten behoeve van berekeningen van nutriënten. Wageningen, Wageningen Environmental Research, Rapport 3005. ISSN 1566-7197.

Blauw A. et al. (2019). JMP EUNOSAT - ACTIVITY 1 Coherence in assessment framework of chlorophyll a and nutrients. DG ENV/MSFD SecondCycle/2016, (Activity 1 Report), 86.

EmissieRegistratie (National Emission Registration, the Netherlands): www.emissieregistratie.nl

Enserink L., Blauw A., van der Zande D., M. S. (2019). Summary report EU project Joint Monitoring Programme of the Eutrophication of the North Sea with Satellite data (JMP EUNOSAT).

Gaalen, F. van, Tiktak, A., Franken, R., 2015. Waterkwaliteit nu en in de toekomst. Tussentijdse rapportage ex ante evaluatie van de Nederlandse plannen voor de Kaderrichtlijn Water. PBL report 1765.

Gaalen, F. van, L. Osté & E. van Boekel, 2020. Nationale analyse waterkwaliteit. Onderdeel van de Delta-aanpak Waterkwaliteit, Den Haag: Planbureau voor de Leefomgeving

Groenendijk, P., Renaud, L.V., Roelsma, J., 2005. Prediction of Nitrogen and Phosphorus leaching to groundwater and surface waters; Process descriptions of the Animo4.0 model. Wageningen, Alterra–Report 983, 114 pp.

IHW, Water Information and Data Centre, 2020. National collection WFD targets, may 2020, file doelen-2020.csv

Klein, J. de, 2008. From ditch to delta, nutrient retention in running waters. Thesis, Wageningen University.

Kroes, J.G., Van Dam, J.C., Groenendijk, P., Hendriks, R.F.A., Jacobs, C.M.J., 2008. SWAP version 3.2. Theory description and user manual. Alterra-report 1649, 262 pp, Alterra, Research Institute, Wageningen, The Netherlands.

Loos, S., Troost, T.A., Goorden, N., Thiange, C., Weeber, M., Los, F.J., 2014. Stikstof scenario studie met KRW-Verkenner en koppeling met het Noordzee model. Deltares report 1208815-000.

Molen, D.T. & Pot, R. & Evers, C.H.M. & Herpen, F.C.J. & Nieuwerburgh, L.L.J. & Loon, Willem M.G.M. & et.al,. (2018). Referenties en maatlatten voor natuurlijke watertypen voor de kaderrichtlijn water 2021-2027.

OSPAR Convention : https://www.ospar.org/convention/text

OSPAR, 2013 Agreement 2013-8. Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area. Supersedes Agreements 1997-11, 2002-20 and 2005-3

Prins T.C., 2007. Stikstofnormen K&O wateren. Ministerie van Verkeer en Waterstaat, Rijkswaterstaat.

Prins, T.C., Troost, T.A., Los, F.J., Blauw, A.N., 2015 Discussiepunten bij de normstelling voor nutriënten voor OSPAR, KRW en KRM. Deltares report 1220097.

Roovaart, J. van den, T. Troost, A. van der Linden, W. Altena, 2021. Ex ante evaluatie van de effecten van voorgenomen maatregelen op de nutriënten in de Nederlandse zoete, kust- en mariene wateren. Deltares rapport 11205267-005-ZWS-0003 (in voorbereiding)

Water Framework Directive Explorer: www.krwverkenner.nl

Waterkwaliteitsportaal, 2019. Bronbestanden publiek december 2019, bestand 4.monitoringsprogramma_owl_20191212.csv. https://www.waterkwaliteitsportaal.nl/WKP.WebApplication/General/DownloadFile?path=CustomReports/December2019Publiek/Bestanden/

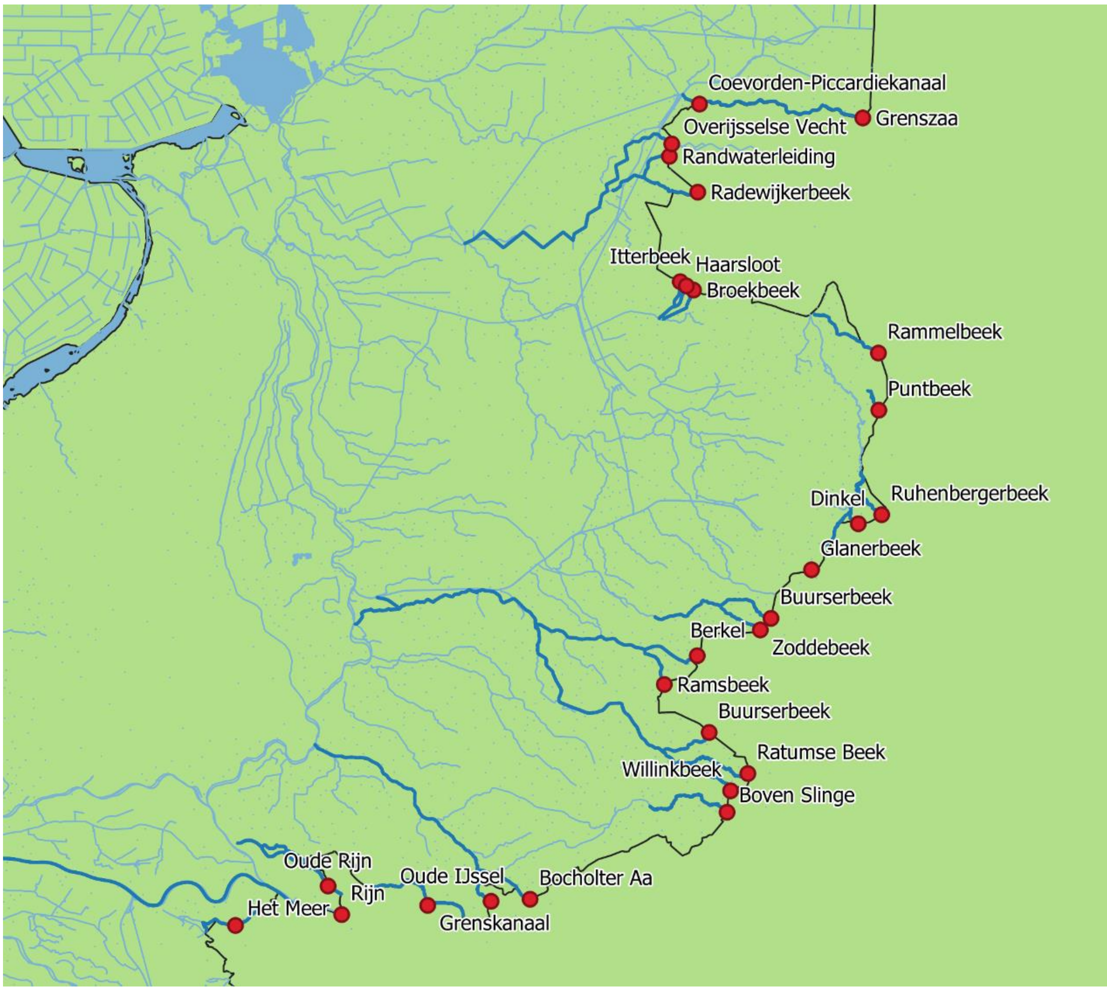
Waterkwaliteitsportaal (Database Water Quality Portal, the Netherlands): http://www.waterkwaliteitsportaal.nl/

Zijl F., Laan, S.C., van Duren, L.A., 2020. Potential ecosystem effects of large upscaling of offshore wind in the North Sea; First interim report model scenarios; Deltares draft report 11203731-004-ZKS-0006

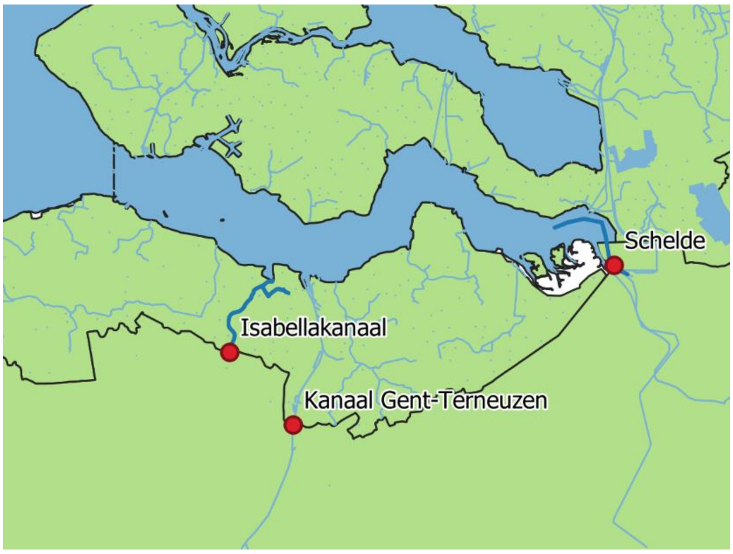
A Locations of transboundary waters per catchment

A.1 Locations of transboundary waters Ems catchment

A.2 Locations of transboundary waters Rhine catchment



A.3 Locations of transboundary waters Scheldt catchment



B Details transboundary waters Meuse catchment

Legend

watermanager foreign	
Nordrhein-Westfalen	NRW
Flanders	FL
Wallonia	WL

watermanager NL	
Rijkswaterstaat	RWS
Waterschap Limburg	WL
Waterschap Brabantse Delta	WBD
Waterschap De Dommel	WDD

coordinate system
EPSG:28992 - Amersfoort/RD New

Name NL	WFD-name NL	WFD-code NL	name foreign	WFD-name foreign	WFD-code foreign	watermanager		coordinates	
						NL	foreign	X	Y
Eckeltsche Beek	Eckeltsebeek	NL60_ECKELTBK	Spanische Ley	Spanische Ley	DE_NRW_2856_6712	WL	NRW	203942	403940
Horsterbeek	Eckeltsebeek	NL60_ECKELTBK	Hülmer Leitgraben	Horster Beek	DE_NRW_28566_2608	WL	NRW	204690	405361
Geldernsch-Nierskanaal	Gelderns Nierskanaal	NL60_GELDEKAN	Nierskanal	Nierskanal	DE_NRW_2854_3470	WL	NRW	211444	393393
Lingsforterbeek	Lingsforterbeek	NL60_LINGSFBK	Leitgraben	Leitgraben	DE_NRW_2852_5101	WL	NRW	213020	386260
Niers	Niers	NL60_NIERS	Niers	Niers	DE_NRW_286_7972	WL	NRW	199395	413910
Kendel	Niers	NL60_NIERS	Kendel	Kendel	DE_NRW_28698_0	WL	NRW	199613	410774
Swalm	Swalm	NL60_SWALM	Schwalm	Schwalm	DE_NRW_284_11934	WL	NRW	203634	359998
Maasnielderbeek - Bosbeek	Maasnielderbeek Bovenloop	NL60_MSNL_BOV	Buschbach	Buschbach	DE_NRW_282992_4170	WL	NRW	202749	357458
Roer	Roer	NL60_ROER	Rur	Rur	DE_NRW_282_21841	WL	NRW	203542	348299
Wurm	Worm	NL60_WORM	Wurm	Wurm	DE_NRW_2828_26286	WL	NRW	204268	321202
Selzerbeek	Selzerbeek	NL60_SELZERBK	Senserbach	Senserbach	DE_NRW_28142_6254	WL	NRW	200196	309481
Roode Beek	Rode Beek Brunssum	NL60_RODEBRUN	Rodebach	Rodebach	DE_NRW_281822_3995	WL	NRW	189450	338768
Anstelerbeek	Anselderbeek	NL60_ANSELDBK	Amstelbach	Amstelbach	DE_NRW_28286_5744	WL	NRW	202172	318467
Mark	Boven Mark	NL25_13	Mark	Mark (Maas)	VL11_145	WBD	FL	112271	380688
Aa of Weerijs	Aa of Weerijs	NL25_34	Aa of Weerijs	Weerijsebeek	VL05_148	WBD	FL	103856	382234
Kleine Aa	Molenbeek	NL25_59	Kleine Aa	Kleine Aa - Wildertse beek	L111_1102	WBD	FL	91923	388078
Dommel	Boven Dommel	NL27_BO_1_2	Dommel	Dommel	VL05_136	WDD	FL	158459	365211
Beekloop	Keersop/ Beekloop	NL27_BO_3_2	Beekloop		L217_5465	WDD	FL	153737	364713
Keersop	Keersop/ Beekloop	NL27_BO_3_2	Elzenloop		L217_5465	WDD	FL	152133	365162
Fortjeloop	Keersop/ Beekloop	NL27_BO_3_2	Fortjeloop		L217_5465	WDD	FL	150011	363802
Keunensloop	Keersop/ Beekloop	NL27_BO_3_2	Keunensloop		L217_5465	WDD	FL	152155	365155
Strijper Aa	Groote Aa/ Buulder Aa	NL27_KD_1_2	Beverbeek		L217_5464	WDD	FL	164843	365872
Buulder Aa	Groote Aa/ Buulder Aa	NL27_KD_1_2	Kranjesbeek		L217_5464	WDD	FL	166853	363900
Poppelsche Leij midden	Nieuwe Leij-Pop.L-Rov.L-Voortsestroom	NL27_L_1_2	Poppelsche Leij midden		L217_5456	WDD	FL	128447	384410
Poppelsche Leij noord	Nieuwe Leij-Pop.L-Rov.L-Voortsestroom	NL27_L_1_2	Poppelsche Leij noord		L217_5456	WDD	FL	130224	388547
Poppelsche Leij zuid	Nieuwe Leij-Pop.L-Rov.L-Voortsestroom	NL27_L_1_2	Ossevenneloop	Leyloop	L107_600	WDD	FL	127873	383314
Rovertsche Leij	Nieuwe Leij-Pop.L-Rov.L-Voortsestroom	NL27_L_1_2	Rovertsche Leij	De Aa (Ravels)	L107_601	WDD	FL	133732	386583
Tongelreep	Tongelreep	NL27_T_1_2	Warmbeek	Warmbeek	VL17_147	WDD	FL	161814	367866
Raam	AEF-bovenloopjes Midden-Limburg	NL60_AEF_ML	Raam	Lozerbroekbeek	L111_1086	WL	FL	172829	356896
Uffelsebeek	Haelense Beek en Uffelsebeek	NL60_HAELUFFE	Abeek	Abeek	VL11_133	WL	FL	173934	355069
Itterbeek	Itterbeek en Thornerbeek	NL60_ITTETHOR	Itterbeek	Itterbeek I	VL05_137	WL	FL	182319	351391
Thornerbeek	Itterbeek en Thornerbeek	NL60_ITTETHOR	Thornerbeek	Itterbeek II	VL05_138	WL	FL	186492	352082
Gulp	Gulp	NL60_GULP	Gulp	Gulp	L107_893	WL	FL	189033	308456
Jeker	Jeker	NL60_JEKER	Jeker/Le Geer	Jeker II	VL05_140	WL	FL	174884	314256
Geul	Geul	NL60_GEUL	Gueule			WL	WL	193739	307573
Maas	Bovenmaas	NL91BOM	Meuse			RWS	WL	175890	307247

C Discharges transboundary waters Meuse catchment

name NL	water-manager	discharge NL 2015 (m3/s)				discharge foreign 2015 (m3/s)						difference
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	avg. 2015	note	
Eckeltsche Beek	NRW	0.20	0.07	0.04	0.11					0.10	WKDB MQ4Z (2015-2018)	-7%
Horsterbeek	NRW	0.13	0.05	0.03	0.07					0.04	WKDB MQ4Z (2015-2018)	-46%
Geldernsch-Nierskanaal	NRW	2.97	1.16	1.61	2.05	1.1693	0.3974	0.3052	0.6357		measurements 2015	-68%
Lingsforterbeek	NRW	0.39	0.17	0.17	0.30					0.21	WKDB MQ4Z (2015-2018)	-18%
Niers	NRW	11.30	7.38	5.50	7.38	11.662	6.8844	4.5879	7.3154		measurements 2015	-4%
Kendel	NRW	0.12	0.07	0.06	0.08					0.12	WKDB MQ4Z (2015-2018)	45%
Swalm	NRW	2.14	2.10	1.97	2.65	2.2843	1.5962	1.4929	1.6733		measurements 2015	-20%
Maasnielderbeek - Bosbeek	NRW	0.01	0.01	0.01	0.01							
Roer	NRW	29.24	14.34	12.21	19.79	25.811	14.27	12.275	19.74		measurements 2015	-5%
Wurm	NRW	2.50	2.00	2.00	2.50					3.34	WKDB MQ4Z (2015-2018)	49%
Selzerbeek	NRW	0.21	0.14	0.14	0.16					0.32	WKDB MQ4Z (2015-2018)	94%
Roode Beek	NRW	0.16	0.10	0.07	0.10					0.77	WKDB MQ4Z (2015-2018)	612%
Anstelerbeek	NRW	0.01	0.01	0.01	0.01					0.12	WKDB MQ4Z (2015-2018)	1110%
Mark	FL	5.03	1.98	1.46	3.27					0.688	modelled 2017	-77%
Aa of Weerijs	FL	1.95	0.64	0.58	1.37					0.581	modelled 2017	-49%
Kleine Aa	FL	0.46	0.04	0.04	0.46					0.739	modelled 2017	196%
Dommel	FL	2.44	1.70	1.35	1.70					1.067	modelled 2017	-41%
Beekloop	FL	0.10	0.05	0.05	0.08							
Keersop	FL	0.04	0.03	0.02	0.02							
Fortjeloop	FL	0.06	0.04	0.03	0.03							
Keunensloop	FL	0.15	0.08	0.05	0.08							
Strijper Aa	FL	0.14	0.06	0.03	0.08							
Buulder Aa	FL	0.07	0.03	0.02	0.04							
Poppelsche Leij midden	FL	0.05	0.05	0.04	0.03							
Poppelsche Leij noord	FL	0.08	0.06	0.05	0.04							
Poppelsche Leij zuid	FL	0.09	0.07	0.05	0.05							
Rovertsche Leij	FL	0.50	0.39	0.27	0.23							
Tongelreep	FL	1.22	0.85	0.67	0.85					1.107	modelled 2017	23%
Raam	FL	0.40	0.23	0.18	0.27					0.165	modelled 2017	-39%
Uffelsebeek	FL	0.65	0.40	0.31	0.43					0.861	modelled 2017	92%
Itterbeek	FL	0.28	0.21	0.15	0.22					0.312	modelled 2017	45%
Thornerbeek	FL	0.31	0.22	0.18	0.23					0.742	modelled 2017	216%
Gulp	FL	0.52	0.41	0.30	0.38							
Jeker	FL	2.00	1.00	1.00	2.00					2.259	modelled 2017	51%
Geul	WL	1.98	1.05	0.87	1.34	2.36	0.83	0.47	1.28	108.735	measured values	-6%
Maas	WL	503.25	188.64	86.01	205.77	538.66	199.54	85.91	213.58		modelled values	5%

D Concentrations total nitrogen transboundary waters Meuse catchment

name NL	water-manager	NL total nitrogen 2015 (mg/l)				foreign total nitrogen 2015 (mg/l)						difference
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	avg. 2015	note	
Eckeltsche Beek	NRW	12	8.3	5.7	8.6							
Horsterbeek	NRW	12	8.3	5.7	8.6							
Geldernsch-Nierskanaal	NRW	7.17	5.43	3.97	4.97	7.25	6.30	4.40	5.00		measurements 2015	7%
Lingsforterbeek	NRW	10	12.17	15.33	10.9							
Niers	NRW	7.45	7.63	7.6	6.23	6.63	6.52	5.15	5.92		measurements 2015	-16%
Kendel	NRW	12	8.3	5.7	8.6	14.00	15.00	11.00	15.00		measurements 2015	59%
Swalm	NRW	7.35	6.5	5.73	6.37	8.15	6.80	5.90	6.53		measurements 2015	6%
Maasnielderbeek - Bosbeek	NRW	7.76	1.1	1.28	0.73							
Roer	NRW	3.85	3.63	2.7	3.1	3.93	3.33	3.00	2.93		measurements 2015	-1%
Wurm	NRW	5.2	4.95	3.95	5	3.70	4.20	4.60	4.80		measurements 2015	-9%
Selzerbeek	NRW	2	1.55	1.6	1.4							
Roode Beek	NRW	14.3	15.07	16.75	17.5							
Anstelerbeek	NRW	9.6	9.25	11	6.5	12.00	11.00	7.20	5.90		measurements 2015	-1%
Mark	FL	10.8	7.67	4.3	6.63					3.22	measurements 2017 summer average	-46%
Aa of Weerijs	FL	5.52	4.52	3.08	6.42					2.02	measurements 2017 summer average	-47%
Kleine Aa	FL	6.18	4.3	3.68	7.03					2.66	measurements 2017 summer average	-33%
Dommel	FL	6.3	4.7	4.58	4.87					4.07	measurements 2017 summer average	-12%
Beekloop	FL	4.54	1.95	1.63	2.52							
Keersop	FL	6.9	4.28	3.86	4.54							
Fortjeloop	FL	6.9	4.28	3.86	4.54							
Keunensloop	FL	4.54	1.95	1.63	2.52							
Strijper Aa	FL	9.01	4.39	6.07	4.55							
Buulder Aa	FL	5.91	3.17	5.46	6.89							
Poppelsche Leij midden	FL	13.06	6.25	5.31	6.2							
Poppelsche Leij noord	FL	13.06	6.25	5.31	6.2							
Poppelsche Leij zuid	FL	13.06	6.25	5.31	6.2							
Rovertsche Leij	FL	13.06	6.25	5.31	6.2					2.53	measurements 2017 summer average	-56%
Tongelreep	FL	4.01	2.77	2.37	2.63					2.20	measurements 2017 summer average	-14%
Raam	FL	5.47	3.63	4.17	4.13					3.82	measurements 2017 summer average	-2%
Uffelsebeek	FL	6.47	3.4	3.57	4.27					3.95	measurements 2017 summer average	13%
Itterbeek	FL	8.43	6.37	3.9	5.57					4.35	measurements 2017 summer average	-15%
Thornerbeek	FL	3.8	4.9	3.63	3					3.43	measurements 2017 summer average	-20%
Gulp	FL	7.7	6.7	5.7	4.9							
Jeker	FL	9.25	6.7	6.4	9.1					6.98	measurements 2017 summer average	7%
Geul	WL	5.23	4.7	3.63	4.67	5.46	4.43	3.5	4		measurements 2015	-5%
Maas	WL	4.1	3.8	3.5	3.92	3.85	3.56	3.01	3.63		measurements 2015	-8%

E Concentrations total phosphorus transboundary waters Meuse catchment

name NL	water-manager	NL total phosphorus 2015 (mg/l)				foreign total nitrogen 2015 (mg/l)						difference
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	avg. 2015	note	
Eckeltsche Beek	NRW	0.06	0.06	0.16	0.08	0.07	0.21	0.14	0.14		measurements 2018	53%
Horsterbeek	NRW	0.06	0.04	0.16	0.08	0.11	0.09	0.03	0.08		measurements 2018	-8%
Geldernsch-Nierskanaal	NRW	0.09	0.11	0.2	0.18	0.15	0.38	0.09	0.19		measurements 2018	40%
Lingsforterbeek	NRW	0.1	0.13	0.23	0.14	0.38	0.1	0.2	0.1		measurements 2018	29%
Niers	NRW	0.08	0.06	0.08	0.07	0.16	0.07	0.26	0.13		measurements 2015	113%
Kendel	NRW	0.06	0.05	0.16	0.07	0.11	0.01	0.04	0.07		measurements 2015	-34%
Swalm	NRW	0.06	0.11	0.08	0.12	0.23	0.14	0.14	0.11		measurements 2015	69%
Maasnielderbeek - Bosbeek	NRW	0.6	0.1	0.1	0	0.02	0.02	0.05	0.02		measurements 2016	-86%
Roer	NRW	0.1	0.05	0.1	0.1	0.08	0.16	0.11	0.08		measurements 2015	22%
Wurm	NRW	0.09	0.08	0.17	0.08	0.12	0.19	0.13	0.09		measurements 2018	28%
Selzerbeek	NRW	0.06	0.13	0.29	0.1	0.11	0.10	0.12	0.11		measurements 2016	-24%
Roode Beek	NRW	0.08	0.13	0.07	0.05	0.10	0.03	0.10	0.05		measurements 2016	-15%
Anstelerbeek	NRW	0.1	0.2	0.2	0.1	0.15	0.17	0.18	0.06		measurements 2015	-9%
Mark	FL	0.57	0.32	0.23	0.3					0.19	measurements 2017 summer average	-33%
Aa of Weerijs	FL	0.28	0.22	0.13	0.24					0.09	measurements 2017 summer average	-47%
Kleine Aa	FL	0.38	0.39	0.27	0.43					0.28	measurements 2017 summer average	-15%
Dommel	FL	0.31	0.25	0.17	0.26					0.28	measurements 2017 summer average	33%
Beekloop	FL	0.08	0.06	0.1	0.08							
Keersop	FL	0.12	0.03	0.11	0.13							
Fortjeloop	FL	0.13	0.03	0.11	0.12							
Keunensloop	FL	0.08	0.07	0.1	0.08							
Strijper Aa	FL	0.72	0.26	0.64	0.24							
Buulder Aa	FL	0.15	0.21	0.47	0.41							
Poppelsche Leij midden	FL	0.15	0.18	0.2	0.08							
Poppelsche Leij noord	FL	0.15	0.19	0.18	0.1							
Poppelsche Leij zuid	FL	0.15	0.19	0.18	0.09							
Rovertsche Leij	FL	0.15	0.19	0.19	0.1					0.16	measurements 2017 summer average	-16%
Tongelreep	FL	0.16	0.14	0.2	0.1					0.16	measurements 2017 summer average	-7%
Raam	FL	0.25	0.18	0.1	0.14					0.34	measurements 2017 summer average	143%
Uffelsebeek	FL	0.25	0.35	0.17	0.26					0.13	measurements 2017 summer average	-49%
Itterbeek	FL	0.14	0.14	0.11	0.12					0.21	measurements 2017 summer average	70%
Thornerbeek	FL	0.21	0.24	0.24	0.11					0.14	measurements 2017 summer average	-42%
Gulp	FL	0.08	0.15	0.17	0.15							
Jeker	FL	0.33	0.52	0.48	0.25					0.59	measurements 2017 summer average	18%
Geul	WL	0.21	0.18	0.21	0.16	0.15	0.24	0.29	0.25		measurements 2015	22%
Maas	WL	0.12	0.15	0.27	0.22	0.14	0.13	0.29	0.29		measurements 2015	12%

F Concentrations used in scenario A and reduction in scenarios B, C and D compared to A for total nitrogen and total phosphorus for the Meuse catchment

name NL	water-manager	scenario A								scenario B		scenario C		scenario D	
		total nitrogen (mg/l)				total phosphorus (mg/l)				change (%)		change (%)		change (%)	
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	total nitrogen	total phosphorus	total nitrogen	total phosphorus	total nitrogen	total phosphorus
Eckeltsche Beek	NRW	12.00	8.30	5.70	8.60	0.06	0.06	0.16	0.08	-67%	0%	0%	0%	-5%	3%
Horsterbeek	NRW	12.00	8.30	5.70	8.60	0.06	0.04	0.16	0.08	-67%	0%	0%	0%	-5%	83%
Geldernsch-Nierskanaal	NRW	7.17	5.43	3.97	4.97	0.09	0.11	0.20	0.18	-51%	-29%	0%	-31%	-4%	58%
Lingsforterbeek	NRW	10.00	12.17	15.33	10.90	0.10	0.13	0.23	0.14	-83%	-39%	0%	-33%	-5%	261%
Niers	NRW	7.45	7.63	7.60	6.23	0.08	0.06	0.08	0.07	-70%	0%	-61%	0%	-15%	93%
Kendel	NRW	12.00	8.30	5.70	8.60	0.06	0.05	0.16	0.07	-67%	0%	0%	0%	11%	90%
Swalm	NRW	7.35	6.50	5.73	6.37	0.06	0.11	0.08	0.12	-62%	0%	0%	0%	5%	267%
Maasnielderbeek - Bosbeek	NRW	7.76	1.10	1.28	0.73	0.60	0.10	0.10	0.00	0%	0%	0%	-50%	0%	-97%
Roer	NRW	3.85	3.63	2.70	3.10	0.10	0.05	0.10	0.10	-27%	0%	-16%	0%	-3%	-18%
Wurm	NRW	5.20	4.95	3.95	5.00	0.09	0.08	0.17	0.08	-48%	-12%	0%	-5%	-32%	27%
Selzerbeek	NRW	2.00	1.55	1.60	1.40	0.06	0.13	0.29	0.10	0%	-48%	0%	-31%	0%	74%
Roode Beek	NRW	14.30	15.07	16.75	17.50	0.08	0.13	0.07	0.05	-86%	0%	-5%	0%	-5%	19%
Anstelerbeek	NRW	9.60	9.25	11.00	6.50	0.10	0.20	0.20	0.10	-77%	-45%	0%	-33%	19%	39%
Mark	FL	10.80	7.67	4.30	6.63	0.57	0.32	0.23	0.30	-62%	-60%	-33%	-49%	-53%	-52%
Aa of Weerijs	FL	5.52	4.52	3.08	6.42	0.28	0.22	0.13	0.24	-39%	-37%	0%	-20%	-47%	-67%
Kleine Aa	FL	6.18	4.30	3.68	7.03	0.38	0.39	0.27	0.43	-42%	-67%	0%	-58%	-39%	-27%
Dommel	FL	6.30	4.70	4.58	4.87	0.31	0.25	0.17	0.26	-50%	-48%	-14%	-33%	-35%	-29%
Beekloop	FL	4.54	1.95	1.63	2.52	0.08	0.06	0.10	0.08	0%	0%	0%	0%	-9%	-14%
Keersop	FL	6.90	4.28	3.86	4.54	0.12	0.03	0.11	0.13	-43%	0%	0%	0%	-9%	-14%
Fortjeloop	FL	6.90	4.28	3.86	4.54	0.13	0.03	0.11	0.12	-43%	0%	0%	0%	-9%	-14%
Keunensloop	FL	4.54	1.95	1.63	2.52	0.08	0.07	0.10	0.08	0%	0%	0%	0%	-9%	-14%
Strijper Aa	FL	9.01	4.39	6.07	4.55	0.72	0.26	0.64	0.24	-56%	-76%	0%	0%	-9%	-14%
Buulder Aa	FL	5.91	3.17	5.46	6.89	0.15	0.21	0.47	0.41	-47%	-68%	0%	0%	-9%	-14%
Poppelsche Leij midden	FL	13.06	6.25	5.31	6.20	0.15	0.18	0.20	0.08	-60%	-42%	0%	0%	-9%	-14%
Poppelsche Leij noord	FL	13.06	6.25	5.31	6.20	0.15	0.19	0.18	0.10	-60%	-41%	0%	0%	-9%	-14%
Poppelsche Leij zuid	FL	13.06	6.25	5.31	6.20	0.15	0.19	0.18	0.09	-60%	-41%	-31%	-24%	-9%	-14%
Rovertsche Leij	FL	13.06	6.25	5.31	6.20	0.15	0.19	0.19	0.10	-60%	-42%	-31%	-26%	-60%	-28%
Tongelreep	FL	4.01	2.77	2.37	2.63	0.16	0.14	0.20	0.10	-11%	-35%	0%	-18%	-14%	-36%
Raam	FL	5.47	3.63	4.17	4.13	0.25	0.18	0.10	0.14	-41%	-21%	0%	0%	-11%	109%
Uffelsebeek	FL	6.47	3.40	3.57	4.27	0.25	0.35	0.17	0.26	-34%	-58%	0%	-46%	18%	-42%
Itterbeek	FL	8.43	6.37	3.90	5.57	0.14	0.14	0.11	0.12	-55%	-12%	-22%	0%	-25%	82%
Thornerbeek	FL	3.80	4.90	3.63	3.00	0.21	0.24	0.24	0.11	-46%	-54%	-6%	-42%	-34%	-44%
Gulp	FL	7.70	6.70	5.70	4.90	0.08	0.15	0.17	0.15	-63%	-31%	-35%	-13%	-9%	-14%
Jeker	FL	9.25	6.70	6.40	9.10	0.33	0.52	0.48	0.25	-65%	-78%	-39%	-72%	0%	6%
Geul	WL	5.23	4.70	3.63	4.67	0.21	0.18	0.21	0.16	-45%	-44%	0%	-15%	0%	0%
Maas	WL	4.10	3.80	3.50	3.92	0.12	0.15	0.27	0.22	-32%	-33%	0%	0%	-3%	-2%

G Assessment areas and monitoring stations

G.1 WFD

Overview of the monitoring stations used for the WFD assessment for the estuaries and Dutch coastal water bodies (Waterkwaliteitsportaal, 2019).

Assessment area	Watertype	Station	Station name
Ems-Dollard	Coastal water	HUIBGOT	Huibertgat Oost
Ems-Dollard	Transitional water	BOCHTVWTM	Bocht van Watum
	Transitional water	GROOTGND	Groote Gat noord
Haringvliet West	Transitional water	HARVSS	Haringvlietsluizen[a]
Holland coast	Coastal water	NOORDWK2	Noordwijk-2
Nieuwe Maas	Transitional water	BRIENOD	Brienenoord[a]
Nieuwe Waterweg	Transitional water	BEERKNMDN	Caland-Beerkanaal midden
	Transitional water	MAASSS	Maassluis[a]
Northern Delta coast	Coastal water	GOERE2	Goeree-2
Eastern Scheldt	Coastal water	WISSKKE	Wissenkerke
Wadden coast	Coastal water	BOOMKDP	Boomkensdiep
Wadden Sea	Coastal water	DANTZGT	Dantziggat
	Coastal water	DOOVBWT	Doove Balg west
Wester Scheldt	Transitional water	SCHAARVODDL	Schaar van Oude Doel
	Transitional water	VLISSGBISSVH	Vlissingen boei SSVH
Zeeland coast	Coastal water	WALCRN2	Walcheren-2

[a] Station not included in North Sea model domain.

G.2 OSPAR

Overview of the Dutch monitoring stations used for the OSPAR assessment (Baretta-Bekker, 2016).

Assessment area	Station	Station name
Coastal waters	GOERE2	Goeree-2
	GOERE6	Goeree-6
	NOORDWK10	Noordwijk-10
	NOORDWK2	Noordwijk-2
	NOORDWK20	Noordwijk-20
	ROTTMPT3	Rottumerplaat 3 km uit de kust
	ROTTMPT50	Rottumerplaat 50 km uit de kust
	ROTTMPT70	Rottumerplaat 70 km uit de kust
	SCHOUWN10	Schouwen 10 km uit de kust
	TERSLG10	Terschelling 10 km uit de kust
	TERSLG4	Terschelling 4 km uit de kust
	BOOMKDP	Boomkensdiep
	WALCRN2	Walcheren 2 km uit de kust
	WALCRN20	Walcheren 20 km uit de kust
Wadden Sea	BLAUWSOT	Blauwe Slenk oost
	DANTZGT	Dantziggat
	DOOVBOT	Doove Balg oost
	DOOVBWT	Doove Balg west
	MARSDND	Marsdiep noord
	VLIESM	Vliestroom
	ZOUTKPLG	Zoutkamperlaag
	ZOUTKPLZGT	Zoutkamperlaag zeegat
	ZUIDOLWOT	Zuid Oost Lauwers oost
Wester Scheldt	HANSWGL	Hansweert geul
	LAMSWDBI59	Lamswaarde Boei 59
	SCHAARVODD	Schaar van Oude Doel
	TERNZBI20	Terneuzen boei 20
	VLISSGBISSVH	Vlissingen boei SSVH
	WIELGN	Wielingen Boei W2
Ems-Dollard	BOCHTVWTM	Bocht van Watum
	BOCHTVWTND	Bocht van Watum noord
	GROOTGND	Groote Gat noord
	HUIBGOT	Huibertgat-Oost
Southern Bight	NOORDWK70	Noordwijk-70
	WALCRN70	Walcheren 70 km uit de kust
Oyster grounds	TERSLG100	Terschelling 100 km uit de kust
	TERSLG135	Terschelling 135 km uit de kust
	TERSLG175	Terschelling 175 km uit de kust
Dogger Bank	TERSLG235	Terschelling 235 km uit de kust

H Overview reductions of discharges to the North Sea

Overview of the computed reductions in the WFD-Explorer total nitrogen loads relative to scenario A. Outflow locations of small rivers were grouped.

WFD-Explorer outflow location	Scenario A+ % reduction	Scenario B % reduction	Scenario C % reduction	Scenario D % reduction
Haringvliet sluices	3.5	10.9	8.5	4.9
Maassluis	5.3	3.5	8.1	5.9
Lake IJssel west	3.6	9.2	13.0	10.2
Lake IJssel oost	3.4	9.7	13.2	10.5
Scheldt @ river mouth	0.0	0.0	0.0	-1.0[a]
Scheldt (other)	21.9	60.4	48.0	34.8
North Sea Canal	0.5	2.6	3.3	3.1
Wadden Sea (other)	0.1	3.2	3.4	3.3
North Sea (other)	8.0	14.3	10.4	15.1
Ems (other)	0.0	3.6	3.6	3.6
Ems @ river mouth	0.0	0.0	42.3	42.3

[a] For scenario D an increase of 1% is anticipated for the Scheldt.

Overview of the computed reductions in the WFD-Explorer total phosphorus loads relative to scenario A. Outflow locations of small rivers were grouped.

WFD-Explorer outflow location	Scenario A+ % reduction	Scenario B % reduction	Scenario C % reduction	Scenario D % reduction
Haringvliet sluices	-15.3	11.3	7.8	-3.7
Maassluis	-10.5	3.9	5.6	-3.3
Lake IJssel west	-4.6	5.2	8.1	2.7
Lake IJssel oost	-4.5	5.4	8.3	3.0
Scheldt @ river mouth	0.0	0.0	0.0	-13.0[a]
Scheldt (other)	10.7	68.2	61.4	21.0
North Sea Canal	-0.1	2.4	2.4	2.3
Wadden Sea (other)	0.0	4.0	4.1	4.0
North Sea (other)	2.6	5.7	4.8	5.6
Ems (other)	0.0	4.5	4.5	4.5
Ems @ river mouth	0.0	0.0	31.3	31.3

[a] For scenario D an increase of 13% is anticipated for the Scheldt.

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