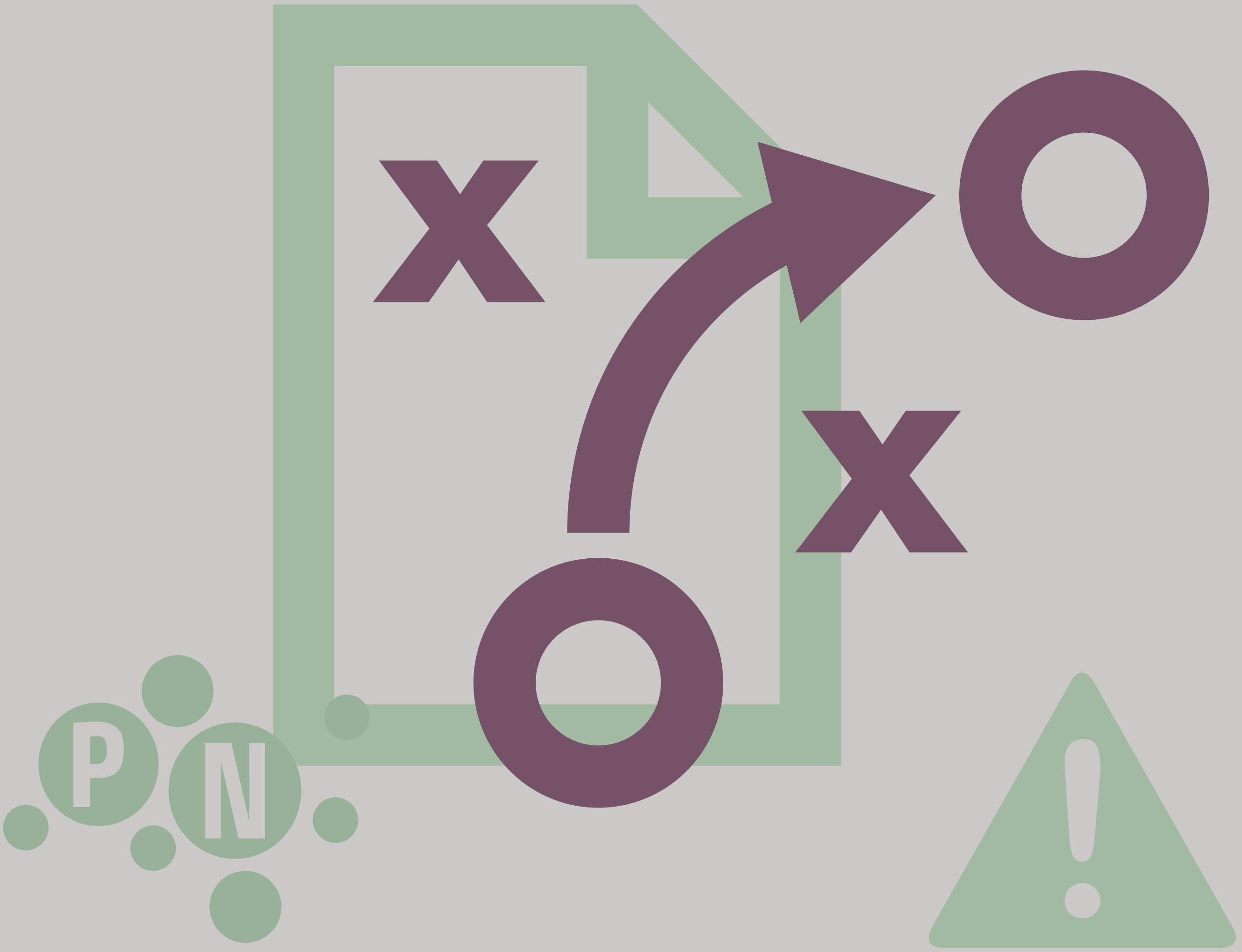
PLC-7

Applied methodology for the PLC-7 assessment

Baltic Marine Environment
Protection Commission

Monitoring assessment

2021



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Introduction

The PLC guidelines include e.g. guidance on sampling methodology, how to calculated load from points sources and other sources, quantification of inputs from unmonitored areas, quantifying uncertainty on flow and inputs, how are source apportionment calculated etc. for PLC assessment.

Contracting Parties (the nine member countries of HELCOM) were requested to report applied methodologies for the PLC assessment by filling in a questionnaire. When countries have used methods described in the PLC guidelines, they could refer to these, otherwise they should provide a short description of the methodology. Countries forwarded the information during 2017 and 2018 and made some few updates during early 2019. Based on these inputs an applied methodology report for PLC 6 was elaborated. Contracting Parties were requested to make updates of description of their methodologies, so they comply with what was used for the PLC 7 periodic assessment. The present report is an updated version of the "Applied methodology report for PLC 6"[1]

The report contains the reported methodology sorted by country. The following methods were included in the questionnaire on PLC-6 assessment methodology:

1. Calculation of flow and loads (rivers, direct point sources):
2. Inputs from unmonitored areas:
3. Source apportionment (load and source-oriented approach):
4. Retention:
5. Transboundary inputs:
6. Uncertainty on flow, loads, unmonitored and total inputs and on sources

The report includes an overview of the reported methodologies and a summary with remarks and discussion on the applied methodologies including the comparability of the results from the used national methods and some identified shortages.

It also includes an annex with details on the models used by the Contracting Parties as a standardized overview on main in-data and out-data, resolution of these data and model resolution. The annex is elaborated by Michal Pohl, Swedish Agency for marine water and management (SWAM), based on inputs from PLC-7 IG members.

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[1] Svendsen, L.M (ed.) 2019. Applied methodology for the PLC-6 assessment. HELCOM 59 p.

Overview on country methodologies

The table below provides an overview of the methodologies used by HELCOM Contracting Parties (besides EU). “Yes” in each cell indicates if a country reports and/or follows the principles/methodology described in the PLC guidelines. “No” indicates that a national method is applied or that the information is not reported.

After the overview table follows a chapter with summary remarks about the method applied. The chapter includes some identified shortages and need for improvement as indicated in *paragraphs with italic letters*.

The report also includes one chapter per country with the input elaborated by each country.

	Flow/Load	Unmonitored areas	Source apportionment	Retention	Transboundary inputs	Uncertainty on inputs & sources
Denmark	Yes. Daily flow and daily concentration (linear interpolation). Chemical and hydrological stations are coinciding. All point sources >30 PE calculated based on monitoring flow and concentrations (sampling frequency depends on PE) Scattered dwelling: estimated based on statistic of number of scattered dwelling, type of wastewater collection/treatment and coefficient of annual TN and TP losses for category. Storm waters: losses relate to statistics and amount of rain Content of TP in 1 PE reduced gradually since 1990.	Yes National model estimates flow, diffuse losses of TN and TP (including scattered dwelling). Modelled run off in 1*1 km grid are aggregate to 3351 catchments of 1.5 to 30 km^2 polygons, and modelled monthly diffuse losses are calculated on the 3351 catchments to estimated losses from the unmonitored areas. Diffuse losses for TN based on (soil type, % cultivation, degree of drainage, monthly 10*10 grid precipitation, air temperature nitrogen surplus) and TP (based on soil type, % cultivation, regional baseflow index BFI, monthly 10*10 km grid precipitation and % meadows) Point sources inputs (also monitored in unmonitored areas) added.	Yes. Load and source-oriented approach according to guidelines. Load oriented – agriculture estimate from loads. Minus other sources taking into account retention. Source oriented: Diffuse losses estimated with models (as for unmonitored areas). Atm. dep: calculated on inland surface waters based on monitored deposition on land (of TN and TP).	Yes Calculated for all large lakes individually with a national model. Retention estimates for nearly 6,000 small ponds and lakes based on results from 16 monitored lakes), for streams wider than 2 m and for restored wetlands.	Not relevant for Denmark.	Yes. Follow the Danish examples in the guideline.
Estonia	Yes. Daily flow daily concentration (linear interpolation). Point sources quarterly reported flow and concentrations.	Yes. National model (EstModel) divides Estonia in three catchments and eight sub-basins. Average specific run-off per catchment based on monitored part of the catchment based	Partly. Source oriented approach based on simple coefficients from the EstModel.	Partly Retention in surface water is calculated using Michaelis-Menten equation approach (Michaelis & Menten, 1993). Retention on diffuse load is estimated as, where the value of the	Yes. Narva River (border) assumed 1/3 of total load is Estonian.	Not quantified and reported.

		on the simple coefficient-based model		retention coefficient of the surface water is related to the estimated residence time of the nutrients in the waterbody. Retention on point sources are calculated by point source and by parameter (TN and TP) related to the time it takes for the point source loads to reach the monitoring station and the time the retention of the point source load attain half of the maximum value of the retention coefficient.		
Finland	Yes Load: mean monthly concentration multiplied by mean monthly flow and summed up. Flow proportional sampling. Point sources monitored.	Yes By extrapolation from monitored areas.	Yes Load and source-oriented approach according to guide-lines. Natural background inputs and diffuse load based on monitoring 45 catchments. SOILN-N for TN estimates and ICECREAM model for TP loads from agricultural land. These results are extrapolated for whole Finland with various models.	Yes National statistical modelling with mass balance approach using incoming and outflowing load in a sub-catchment, and load from point sources, agriculture, forestry, scattered dwellings, natural leaching and atmospheric deposition of N on lakes. Retention is assumed negligible in unmonitored areas.	Yes Based on monitored inputs of the rivers Torne and Vuoksi River and modelled nutrient inputs of the Seleznevka River.	Not quantified and reported.
Germany	Yes. Load: Daily flow and daily concentration (linear interpolation) or mean monthly flow and monthly concentration depending on the Federal State.	Yes. Annual reporting: Based on area proportion method based on the entire monitored area. PLC 7 – periodic reporting: Using the MoRE model to calculate pathway specific	Yes. Source oriented approach using results of the empirical based emission MoRE model. Calculations are pathway oriented.	Is reported The MoRE model provides riverine retention based on the MONERIS retention coefficients for TN and TP (Behrendt & Opitz (1999)).	Reported Based on agree proportions of total TN (3.7 %) and TP (8.5 %) load in Oder.	Estimated based on expert judgement.

	Direct point sources based on continuous flow measurements and non-continuous concentration.	loads (coming from point and diffuse sources) and flow from unmonitored areas (summed up for the entire unmonitored area).				
Latvia	Yes Load: mean monthly concentration multiplied by mean monthly flow and summed up. Point source load quantified based on monitoring results.	Yes By extrapolation from monitored areas.	Yes. Source oriented approach based on land-use and simple export coefficients.	Yes. Follows Behrendt & Opitz (1999) with retention coefficient for TN and TP depending on discharge, areas on surface waters in the catchment.	Yes. Monitored monthly concentrations and extrapolated discharges. Daugava loads divided between RU and BY taking into account catchments areas (guidelines).	Not quantified and reported for total loads. Estimates for monitoring stations using Harmels et al (guideline) formula.
Lithuania	Yes: Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point source load monitored? Periodic reporting: Load and flow are modelled with SWAT model (set up for entire Lithuania).	Yes. Using areas proportion method using Minija River concentrations and flows. Periodic reporting: SWAT to model flow and load from unmonitored areas.	Yes National model using average data 2007-2014. SWAT-model use environmental data, climate, point source discharge, agricultural activities etc.) – all sources simulated, but atmospheric deposition is monitored. Results re-scaled to mirror the reported annual, which were calculated from monitoring results.	Yes. Using SWAT model – calculate retention on all pollutants and sources – and include processes in river channels as sedimentation, resuspension, turn-over of nutrients, diffusion.	Yes. Modelling, but for Sventoji area proportion. The models do not cover catchment in other countries and are therefore not working very well. But, Belarussian based on monthly concentrations and daily flow monitored. Inputs through Matrosovka channel is calculated by flow proportional coefficient based on measured data in the channel. Also modelling transboundary inputs from Lithuania to Latvia.	Not quantified and reported.
Poland	Yes, partly	Yes.	Yes. Load-oriented approach:	Yes.	Yes	Not quantified and reported

	Flow based on daily flow measurements. Nutrient concentration measured monthly. Load calculated as product of monthly flow and monthly concentration. Point sources- larger point sources need at least one measurement required – calculate load of the day and multiply with 365. For smaller WWTP (typical < 2000 PE) without monitoring 4.0 kg N/year per PE and 0.61 kg P/y per PE are used and assuming 65 % and 35 % reduction coefficients for TN and TP, respectively. Industries: Only data for plants in PRTR register. Used questionnaire to get information to several industrial plants. Information lacking rom several plants, load are underestimated. Scattered dwellings: TN and TP load 4.4 kg/n and 0.8 kg P per person, statistics on number of not connected person and coefficient of TN and TP entering surface waters according to HARP guidelines.	Use the area proportion methodology. The proportion between the unmonitored and monitored area of each river was used to calculate the load from unmonitored parts of river. The load from point sources located at unmonitored catchments was added to load in each catchment. For BAPLAND the load was extrapolated from 7 monitored rivers using the same proportion method.	It is assumed that retention coefficient of nutrients from different sources are not equal. Sources have been divided in two groups: one group with the source discharging directly to surface waters (point sources and atmospheric deposition, the other group diffuse sources including scattered dwelling. overflows and natural background losses. Applying two scenarios. In scenario 1 retention coefficients for all sources in both groups, and scenario 2 all retention in group 1 is zero. Average of the two scenarios are used. Natural background losses: The losses are clearly separated from managed forestry and wastelands. 0.02 mg P/l is used for natural background concentration, while the nitrogen concentration depends on soil permeability from 0.15 mg N/l (highly permeable) to 0.60 mg N/l (poorly permeable) soils. For atmospheric deposition in natural background catchments a fixed literature value is applied (1.2 kg N/ha) Agricultural land: Monitoring in each catchment of nitrates and phosphates – monitored in a country wise groundwater and tile drainage water monitoring program	Retention coefficients in monitored rivers is calculated based on the mass-balance methodology. Retention in unmonitored part of a river catchment was calculated as proportional to the share of the unmonitored area of the entire catchment of that river catchment – but is only applied on the sources in the unmonitored part of a catchment	From Slovakia: Based on monitored concentration and flows received from Slovakia. From Ukraine: For on rivers based on monitored from other rivers based on the proportion af catchment I Ukraine and using a unit load From Belarus: More or less as from Ukraine. Czech Republic: Polish monitoring at the border covering 75 % of the catchment in Czech Republic. Remaining contribution from CZ are not quantified. Germany: Load from Germany estimated based on fixed ratios of Oder total loads (3.7 % TN and 8.5 % TP).	

	Storm waters: Using HARP guidelines Using paved urban areas connected to combined sewer system, TN and specific TN and TP discharges from paved urban areas (14 kg N/ha and 1.2 kg TP/ha) Aquaculture sources: No fish feed data available. Use of standard units loads of 60 kg/N on fish and 9 kg/tons fish.		(nitrate and phosphate) in mainly agricultural areas. Data only available for Vistula and Oder catchment. Flow from agricultural land: Load= average concentration time average flow multiplied by a correction factor to take into account other N and P compounds, and other correction done (se section 2.5 from Poland). For some minor catchment also used MONERIS modelling to estimate agricultural sources. Forestry and unmanaged land: Use of slope, permeability of soils, estimated N and P concentration in precipitation, flow weighted concentration from managed forestry.0,038 mg p/l was used for all soil types, while nitrogen concentration depends on soil permabilty from 0.31 mg N/l high permeable to 1.22 mg/l for poor permeability Direct atmospheric deposition: Based on monitoring from 22 monitoring stations TN and TP in precipitation and calculated for inland surface waters Scattered dwellings: Se column "Flow/load" Number of persons not connected to WWTP are			

			estimated. It is assumed that 90 % of total N and P loads generated discharged from in untreated areas is generated by people in such areas and using 4 kg N and 0.61 kg P per PE. The share of TN and TP reaching surface wasters are estimated by making an agricultural fertilizer balance. <u>Urban surface run off and combined sewer overflow</u>: Estimate some standard concentration in the flow from urban surface run off divided in some categories based om extensive US surveys. A tentative figure of 5 % of total N and P load discharged to combined sewers has been used for estimating combined sewer overflows. Source in monitored and unmonitored areas are estimated with exactly same methodology.			
Russia	Yes Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point sources based on continuous monitoring (min 12 times per year).	Yes. Estimated using HYPE and FyrisNP model.	Yes. For big catchments using Institute of Limnological Loading Model. Model includes annual load, load from point sources, diffuse load from agriculture, diffuse emissions from land surface not affected by agriculture and atm. dep. HYPE og FyrisNP model used to assess source contribution in Leningrad region and smaller	Yes. Follows Behrendt & Opitz (1999) method: See Russia formulas no. 5-6-7-8. Requires annual load from the catchment direct load to the lake, hydraulic load to the lake, lake percentage in the catchment, specific run-off.	Yes. Based on agree proportions used for PLC5.5.	Not quantified and reported.

			catchments in the watershed of Gulf of Finland. Point source load: state statistical data. Natural and anthropogenic load (excluding agriculture) specific concentrations in runoff from urban areas (scattered dwellings areas), natural background areas and mixed area taking into area and runoff of each of these types. For small catchments load from scattered dwelling are estimated using a Swedish Environmental Protection Agency method. Atmospheric: TN zero, TP 3.2 kg/km^2. Agriculture diffuse loads: Formula 3 take into account N and P content I plough layer, organic and mineral fertilizer applied, field areas (per enterprise), coefficient related to uptake of organic and mineral fertilizer, nutrient outflow from plough layer, distance from agricultural areas to receiving surface waters, soils types, soil texture, land use structure, status of applying BAT. Background load: Take into account coefficient for mass exchange with			

			atmosphere, % lake area and retention factor.			
Sweden	Yes. Daily flow and daily concentration (from linear interpolation of monthly concentrations). Point sources monitored loads. Smaller point sources estimated based on treatment methodology and number of person equivalents.	Yes. Main rivers (38) monitored to the mouths. Minor rivers and coastal areas are estimated with area-specific load estimated from similar rivers in the area.	Yes. <u>Source oriented</u>: TN and TP loads to lakes and rivers calculated for 39,600 sub-catchments. Several models used. Inputs from point sources and diffuse sources. Diffuse source estimated by land use area multiplied by specific runoff and concentration in runoff for the land use. Concentration for agricultural land calculated by the NLeCC – includes SOILNDB for N and ICECREAMDB for P (using fertilizer, atm. dep., crop yield, catch crops, buffer zones, agricultural practices, weather data, crop rotation, soil type, soil P, soil slope). Specific concentration for land use forest, wetlands, alpine and open land based on representative data based on monitoring campaigns. <u>Stormwater</u>: runoff coefficients from statistics. <u>Scattered dwellings:</u> Number of population not connected, load per person, reductions efficiencies of applied techniques.	Yes. National models using SMED-HYPE model in the 39,600 sub-catchments. Take into account river and lake nutrient processes. SMED-HYPE is built upon HYPE – but use the land use leaching and local river retention.	Not reported in PLC-7. Load from Norwegian and Finnish catchments calculated from Corine Land Cover and land use not including anthropogenic land use sources.	Not reported

			Atm. dep. MATCH model (N) and monitoring (P). Load oriented approach Retention form SMED-HYPE in 39,600 subcatchments. Calculated at river mouths using total loads from the annual reporting.			

Summary remarks and discussion on the applied methodologies

This chapter includes summary remarks on the reported methodologies and some comments to the applied methodologies including the comparability of the results from the used national methods. Some identified shortages and needs for improvement are indicated in the *paragraphs with italic letters*.

Calculation of flow and loads (rivers, direct point sources)

Two methodologies are mainly applied for rivers load:

- Calculated from daily means of flow and daily concentration (daily concentration applied by interpolation)
- Calculated from mean monthly flow and mean monthly concentration

If countries are monitoring water level continuously (as recommended in the PLC guidelines) and take chemical samples monthly, it should be considered to use daily flow and daily concentrations for load calculation to make data more consistent and comparable. Monthly mean methods are overall underestimating loads. Why use monthly means of flow when more frequent sampling is available?

For wastewater treatment plants and industries, the method(s) of load estimates depends on both the size of these point sources (big sources higher sampling frequency) and the traditions in the countries. Some countries use daily mean and daily concentration for load calculation for point sources with at least 12 annual samples, other countries use monthly or even annual mean concentration and flow.

Some countries are sampling point sources don to 30 PE, for other countries plants are more than 1000 EP before sampling are required. Further, data for some industries are not available in all countries.

There is a need for further harmonizing load calculation methods for both riverine loads and especially for loads from wastewater treatment plants and industries. At present data from these sources – and particularly from minor sources – are not fully comparable and consistent, and certainly not all discharges are included from all point source in some countries.

For scattered dwellings countries apply country specific losses pr. PE and some countries take into account treatment category for scattered dwelling. The applied methodology is quite unclear or not specified for stormwaters e.g. how the amount of precipitation (and intensity of precipitation) is taken into account and how concentration of chemical compounds have been estimated/assumed. The removal percentages are not specified for many countries, and how it is quantified is often not specified.

There is a need to clarify TN and TP per PE for scattered dwelling, how any treatment is taken into account, how the number of scattered dwellings are quantified, methods used for quantifying inputs from stormwaters, and the completeness of the quantification, including flow quantification. Further it should be harmonised how removal percentages are quantified. These sources (particularly for TP) are of increasing importance and they are the wastewater sources with the highest uncertainty on the quantified inputs. There is a need to further harmonize the definitions, methodologies and the completeness in quantifying these sources.

For marine fish farms consumption of feed (fish production) and food conversion rates are used when available. For freshwater fish farm food consumption (fish production), food conversion rates and any treatment is used (if available), but at least one country uses monitoring in inlets and outlets to estimate net loads from fish farms. Further, national/regional statistics might be used.

There is a need for further clarification regarding N and P content in food, food conversion rates, determining losses from fish production within inland water fish farms, how any treatment etc. is taken into account, and if all fish plants are included in the reporting/ assessment. Inputs from aquaculture might be the point source with the most incomparable and inconsistent inputs, and there is a need of further harmonization of TN and TP input quantification methods, and to ensure that all aquaculture activities are included in the assessment, and the necessary data to calculate load from fish farms are available/collected.

For other types of aquaculture there seems to be no reporting.

Inputs from unmonitored areas

Inputs are estimate by overall two methods:

- Area proportion
- Specific modelling

The area proportion methods are divided in two sub-methods:

- Upscaling the monitored part of the catchment to the mouth by simple area proportion
- Using discharge weighted concentration from the monitored part of the river or from neighbouring catchment with corresponding characteristics (as land use, soils types, agricultural practices etc.) to estimate unmonitored part of the rivers and/or unmonitored rivers. Some countries use discharge weighted concentration from only some selected rivers on all unmonitored part of the catchment – others are dividing the catchment area in the country in some regions and sub-regions

Some countries use specific model based on soil type characteristics, land use and some specific agricultural practices parameters, modelled flow, quantified point sources losses or simple modelled coefficients etc. to estimate diffuse and/or total inputs from unmonitored areas.

It is not clear how some countries take into account inputs from points sources in unmonitored areas. Is it correct to assume corresponding proportion of point sources in unmonitored areas as in monitored areas? Do countries have information on point sources in unmonitored areas – then it is only the diffuse part that needs to be monitored/estimated.

When the proportion of unmonitored area are low (e.g. less than 5-10%) by taking into account the point sources in unmonitored areas, using area proportion/discharge weighted concentration from monitored areas should provide comparable results (if the monitoring result are comparable). When the proportion of unmonitored area are higher, it is recommendable to use more extensive modelling and take into account specific characteristics of the unmonitored area. Overall, if information on point sources is available in unmonitored areas (e.g. point actually are monitored), this information should be used.

For countries/catchments with more than 5-10% unmonitored areas the applied methodology is not fully consistent and comparable between countries.

More detailed information on the applied models by countries are in annex 1.

Source apportionment (load- and source-oriented approach)

Load oriented approach:

- Most countries follow overall the methodology of the PLC guideline estimating anthropogenic diffuse losses as the remaining part of the monitored load after subtracting input from point source, scattered dwellings, storm waters, and natural background losses and taking into account retention in inland surface waters
- Most countries take into account retention on sources. Some countries are estimating different retention coefficient form different sources, and are also estimating different retention coefficient in monitored and unmoored areas

The load-oriented approach accumulates the uncertainty on the anthropogenic diffuse sources. If some of the point sources are not quantified, and if e.g. inputs from scattered dwellings and/or storm waters are not quantified then the estimated anthropogenic diffuse losses (which usually is seen as an estimate of the inputs from agricultural sources) will be over-estimated. The estimate is also dependent on how natural background losses are estimated e.g. if they are calculated for the entire catchment. The estimated anthropogenic diffuse sources are also depended on how retention is calculated and taken into account.

Further, it is quite obvious that it is important to take into account how inputs from unmonitored areas are quantified and included in the source quantification of the load-oriented approach.

It should be considered to use flow normalized loads for the source apportionment to reduce variability in the diffuse sources.

Although the load-oriented approach use more harmonized methodology than the source oriented approach, further efforts are needed e.g. on quantifying some of the diffuse sources including natural background, scattered dwellings and stormwaters, atmospheric deposition and how unmonitored areas and retention are quantified and taken into account, to make results more comparable and consistent.

Source oriented approach:

- Many countries use rather comprehensive models to estimate diffuse sources entering into surface waters (e.g. SOIL-N, ICECREAM, SWAT, MoRE, NLeCC, MATCH, other specific developed national models). Models range from empirical (EstModel) to physio-chemical process-oriented modelling
- Some countries have not fully performed the source-oriented approach
- Some countries model each sources/pathways separately, other countries model mainly diffuse sources aggregated. Some countries apply the same methodology quantifying sources in monitored and unmonitored areas, other countries have different methods in monitored and unmonitored areas
- The size of modelling units varies, some countries use small units (few square kilometres), estimating both flow and different diffuse source for each unit, while other countries model only for large units and are aggregating several sources
- Retention is generally taken into account – some countries in each modelling unit and directed to each source/pathway, and other countries apply a more aggregated approach
- Some countries include inputs from scattered dwelling and stormwaters together with other diffuse sources
- Atmospheric deposition on inland surface waters is taken into account (and modelled) by some countries. One country also takes into account atmospheric inputs on the catchment
- Two countries quantify inputs from agriculture and managed forestry separately
- Some countries use statistics, literature-based values etc. for e.g. estimating losses from scattered dwellings, storm waters, atmospheric deposition, natural background losses etc.
- Some countries use annual actual data (one year), other countries use an average of several (e.g. 5) years. Further some input parameters for the models might be the average for several years (or large areas), normalized inputs etc.

Many of the challenges described for the load-oriented approach are also valid for the source oriented approach.

Substantially more modelling is involved in the source-oriented approach in comparison with the load oriented approach, including the use of either very small or large modelling units. The results should be compared only very carefully between countries and the source data are not very consistent.

There is a need to further discuss where it is relevant to harmonize the methodologies, and the requirements for documenting the applied models, to be able to assess data and facilitate *inter-comparison of national source apportionment data. It should be further discussed if source apportionment (source-oriented approach) could/should be based on average of 3 or 5 years and/or normalized data.*

A pilot study applying some of the country methods on the same catchment to allow for comparing results could facilitate evaluation of comparability and consistency of these methods.

More detailed information on the applied models by countries are in annex 1.

Retention

Several methods or approaches are used:

- Monitoring incoming and outflow in sub-catchments (mass balance approach)
- National model on lakes calculate individually per lake (MORE, SWAT, Behrendt & Opitz (3 countries), , Michaelis-Menten equation, SMED-HYPE)
- Some countries used different models in monitored and unmonitored catchment, and use different retention coefficient for individual sources

For some countries it is not specified whether retention is taken into account for all lakes, and for several countries it is not describe how and whether retention in rivers is included (or relevant). There is a need to calculate retention in all inland surface waters.

It should be clarified if some countries are including retention in soils, groundwater etc. in the retention estimates.

It should be discussed if and how retention estimation takes into account the location/distribution of major sources - e.g. if a point discharges in the upper or lower part of a catchment.

There is a need to clarify how retention in connecting with flooding is taken into account.

It should be clarified how retention is aggregate from small catchments to the catchment to a Baltic Sea sub-basin.

It should be discussed how to take into account different retention coefficients for individual sources.

Countries use rather sophisticated methods for determine retention, but it would be relevant to compare the applied methods if they provide consistent and comparable results (pilot study applying the different methods on the same catchments).

More detailed information on the applied models by countries are in annex 1.

Transboundary inputs

Several methods or approaches are used:

- "Based" on monitoring at the border and take into account retention in the downstream catchment – either by calculation of load at the border, or using flow weighted concentrations
- Based on fixed proportion agreed between two countries e.g. Narva and Oder (Germany)
- Divide inputs in proportion to division of catchment area
- Modelling approaches
- Based on agreed proportions in PLC5.5
- Disregarding transboundary inputs

Some countries use a specific methods per river.

Some countries have not reported their methodology.

For some transboundary rivers no estimations are made on the shares between countries.

The estimation of transboundary inputs need clearly further work on methodology and cooperation between countries including also countries not being HELCOM Contracting Parties.

It is obvious for some rivers to monitor inputs at the border and estimate the retention in the downstream catchment with agreed method.

But for some rivers crossing the border several times or where the rivers divide in branches, or rivers that are crossing borders of several countries there is a need to agree on a specific methodology for these rivers including how to estimate retention in each country. Overall, for the big/bigger river, sampling at the border is the recommendable method.

For minor rivers it might be possible to divide inputs according to area proportion in the countries if land-use, soil type, hydrology and topography are comparable, and if bigger point sources are taken into account.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Only three countries have (partly) reported on the uncertainty on flow and load, total loads and sources. Although in the MAI and CART assessments an overall estimate has been calculated on total inputs of TN and TP per sub-basin and country per basin.

Denmark has developed a methodology for estimating uncertainty on monitored load (per river), monitored loads per catchment, unmonitored loads and total loads. The methodology is described in the PLC guidelines.

Latvia has used the formula of Harmel et al (2006) in the guidelines to estimate uncertainty on flow measurement and some uncertainty component on loads.

In the revised PLC guidelines (2019) there is a methodology included to estimate uncertainties on monitored and unmonitored inputs and total inputs. Further, uncertainty on point sources loads could be estimated by applying this methodology. Uncertainty estimates for sources and how these estimates should be calculated, is closely related to the methodology and model applied quantifying the sources. Further work is needed to allow for quantifying uncertainty and make them comparable between sources and countries, and this should be including in the next revised PLC guidelines.

Denmark

By Lars M. Svendsen, Henrik Tornbjerg and Søren Erik Larsen, DCE, Aarhus University, Denmark

Calculation of flow and loads (rivers, direct point sources)

Denmark overall follows common agreed methodologies. Danish rivers are overall quite small or very small and even reporting 144 monitored rivers Denmark only covers less about half (48 %) of the Danish catchment area to HELCOM convention. It should be remarked that even in unmonitored catchments discharges from point sources >30 PE are monitored.

Denmark has re-reported flow, annual TN and TP inputs for the complete time series (1995 and onwards) also updating some point source data – the main reason for the re-reported being changed methods to estimated losses from unmonitored areas and retention calculation. A new re-reporting will take place in spring 2021 for takin into account discontinuity in the precipitation time series from the Danish Meteorological Office (potential underestimation of the precipitation after 2010 with about 8 %) and due to laboratories using wrong methodology resulting in underestimation of organic fraction of particularly nitrogen but also for phosphorus.

The monitoring criteria for point sources have also been unchanged since 1989. The Danish monitoring programme has until recently been focused on nitrogen and phosphorus compounds and organic matter. Since late 1990'ties also some heavy metals and hazardous substances have been monitored on very few, selected rivers and selected major point sources (wastewater treatment plants and industries with separate discharge), but these substances are not monitored every year in these rivers. For some heavy metals and most hazardous substances the main part of analysed concentrations has been under the detection limit and no total loads to coastal waters have been calculated as yet.

Analysis has to be performed on accredited laboratories and only few (1-2) laboratories have been involved for the past 4-6 years. Monitoring is until 2006 performed by the Danish Counties, thereafter by the Ministry of the Environment, and they decide which laboratories they contract to perform chemical analysis.

In Denmark all point sources bigger than 30 PE are monitored even if they are situated in the unmonitored (part of) river catchment area. The frequency and sampling method is given in table 1.

Table 1: Annual sampling frequency (minimum) for wastewater treatment plant outflows

Plant capacity (PE)	**Frequency/yr (min.)**	**Sampling method**
30 ≤ x < 200	2	Random samples [1)]
200 ≤ x < 1,000	4	Time-weighted daily samples [2)]
1,000 ≤ x < 50,000	12	Flow-weighted daily samples
50,000 ≤ x	24	Flow-weighted daily samples

1) Time-weighted samples, random samples or empirical values, and 2) Time-weighted samples or random samples if the necessary facilities for collection of flow-weighted samples are not available. PE: Person equivalent to be equivalent to 21.9 kg organic matter per year measured as biochemical oxygen demand (BI_5), 4.4 kg total-N per year or 1.0 kg total-P per year for some years, but the P-value will be reduced in future.

Measurement of the water volume discharged is in general continual registration of the water volume on the day in question.

Calculation of total discharges follow the PLC guidelines.

Plants with a capacity > 500PE covers 99% of the total wastewater load to wastewater treatment plants.

In Denmark all point sources bigger than 30 PE are monitored even if they are situated in the unmonitored (part of) river catchment area. The frequency and sampling method is given in table 2.

Measurement of the water volume discharged is in general continual registration of the water volume on the day in question.

Calculation of total discharges follow the guidelines.

Many heavy metals and hazardous substances are monitored at selected wastewater treatment plants and separate discharging industrial plant.

Table 2 Discharge classes for industries with separate wastewater discharges indicating the amount of nitrogen (total-N), phosphorus (total-P) and organic matter (BI_5 (modified) and COD) discharged together with the sampling frequency.

Discharge class	**Discharge (tonnes/yr)**				**Frequency/yr**
	BOD_5 (mod.)	**COD**	**Total-N**	**Total-P**	
I	$0.6 < x < 4.3$	$1.6 < x < 10.8$	$0.13 < x < 0.9$	$0.005 < x < 0.3$	2 samples
II	$4.3 < x < 21.6$	$10.8 < x < 54$	$0.9 < x < 4.4$	$0.3 < x < 1.5$	4 samples
III	$21.6 < x < 108$	$54 < x < 270$	$4.4 < x < 22$	$1.5 < x < 7.5$	12 samples
IV	$x > 108$	$x > 270$	$x > 22$	$x > 7.5$	12 samples

Storm water and scattered dwelling

TN and TP loads are based on statistical information. For storm waters it used statistics on outlets with rainwater from fortified areas and from overflows with sewage and rainwater. Precipitation is used in the calculation of TN and TP losses.

For scattered dwellings for each household information of type of wastewater cleaning system get a theoretical degree of purification, which is combined with number of inhabitants in different types of households and excretion of TN and TP per person (PE) (annually 4.4 kg TN, 1 kg TP (this number is under revision and will be lowered markedly) and 21.9 kg BI_5). Based on a study from the Technical University of Denmark (DTU) the TP amount in wastewater per person has been revised to the values shown in table 3 (Arildsen & Vezzaro (2019) https://orbit.dtu.dk/files/166318737/MST_rapport_ny_P_PE_jan2019.pdf [2]

Table 3 TP excretion per person (PE).

Year	TP (kg PE^{-1} $year^{-1}$)
Up to 1990	1,3
1991-2007	1,0
2008	0,93
2009	0,86
2010	0,79
2011-	0,72

Rivers

The annual sampling frequency at each river monitoring site is generally 12-18. Stage (water level) is recorded continuously (either sampled every 10 minutes or averaged over 10 minutes) at all river monitoring stations. Discharge (cross section of river monitored in several depths in several depth profiles) is measured at least 12 times per year, and continuously run off is calculated using a well-established stage-discharge relationship which take into account any impounding effects on stage caused by aquatic plants. Transport at each river monitoring station is calculated by multiplying daily discharge with daily concentration, the latter estimated by linear interpolation of measured values.

Inputs from unmonitored areas

Denmark has developed a new standardised method for estimating diffuse losses and loads from unmonitored areas. The new models estimate run off, diffuse losses and loads of nitrogen and phosphorus respectively. To these loads, the load from point sources in unmonitored areas is added. As explain earlier all discharges from point sources >30 PE are monitored, and discharges from scattered dwelling are based on information on number of scattered dwellings and which kind of purification the individual scattered dwellings have. Discharges from storm water overflow are estimated based on precipitation and e.g. the fortified are connect to e.g. an overflow pipe.

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[2] Arildsen, A. L., & Vezzaro, L. (2019). Revurdering af person ækvivalent for fosfor - Opgørelse af fosforindholdet i dansk husholdningsspildevand i årene fra 1990 til 2017 (Re-evaluation of a phosphorus person eqvivalent – Compolation of phosphorus content en wastewater from households during 1990-2017 (in Danish)). Danmarks Tekniske Universitet (DTU) 64 p.

Shortly described run-off is calculated for 1 * 1 km grids with use of The National Water Resources Model from Geologic Survey of Greenland and Denmark (the so called “DK-model”), but adjusted and calibrated by NERI with discharge measurements in a lot of rivers to fit with monitored run off in rivers. The run-off is aggregated to monthly values and for 1.5-30 km^2 polygons (in total 3351 catchments). As one major input the “DK-model” use corrected precipitation calculated on 10*10 km grid from the Danish Meteorological Institute.

Further two models calculate nitrogen and phosphorus monthly flow-weighted concentrations, respectively for different unmonitored catchments. Calculations of diffuse losses are done on a monthly basis for 1.5-30 km^2 polygons (catchments). These flow-weighted concentration are multiplied by the calculated flow from 1*1 km grid to calculate diffuse losses including natural background losses. Relevant point source discharges are added. Thereafter retention of nitrogen and phosphorus in rivers, lakes and wetlands are deducted from the calculated diffuse losses to get estimate of the riverine loads in unmonitored areas. Retention is estimated using lake retention models, denitrification and net retention of phosphorus in rivers and wetlands (and due to flooding) and taking into account lake, river and wetland characteristics. Modelled diffuse losses of nitrogen and phosphorus from unmonitored areas are bias-corrected based on the difference between measured and modelled losses from monitored areas in 10 regions.

The nitrogen model is based on data from 84 agricultural catchments without big lakes and the monthly flow weighted nitrogen concentrations are calculated for 1.5-30 km^2 polygons as a function of:

- soil type (% sandy soils) (based on map scale 1:500000)
- percentages of cultivation (from central detailed database)
- degree of drainage (based on 205*205 m raster map)
- monthly precipitation (daily data from 10*10 km grids provided by Danish Meteorological Institute)
- monthly average air temperature (daily from 20*20 km grid)
- nitrogen surplus based on national

The phosphorus model is based on data from 24 agricultural catchments without big lakes and the monthly flow weighted phosphorus concentrations are calculated for 1.5-30 km^2 polygons as a function of:

- soil type (% sandy soils) (based on map scale 1:500000)
- percentages of cultivation (from central detailed database)
- regional baseflow index (BFI) based on geo-region type, soil type and amount of organogenic soils
- monthly precipitation (daily data from 10*10 km grids provided by Danish Meteorological Institute)
- percentages of meadows, bog and moor.

The total run off and load of nitrogen and phosphorus via rivers from Denmark since 1995 have therefore been recalculated with the above-mentioned new models, and that is the reason for the re-reporting the complete flow and TN and TP loads time series for the PLC-6 assessment. In average for Denmark, the new models result in lowering annual nitrogen loads via rivers with 6-7 %, but on an annual basis with from approx. 15 % lower up to the same loads as compared with former reporting. Concerning phosphorus loads via rivers in average the revised load are 6 % higher, but on an annual basis loads is between 10 % lower to + 15 % higher compared with former reporting. In some catchments there are some major differences compared with former results, and DCE are investigating the reasons behind. A new re-reporting will take place in spring 2021 taking into account discontinuity in the precipitation time series from the Danish Meteorological Office (potential underestimation of the precipitation after 2010 with about 8 %) and due to laboratories using wrong methodology between 2007/08-2015 resulting in underestimation of organic fraction of particularly nitrogen but also for phosphorus. *It is expected that the revised annual TN loads might be increased with up to 10 %*

For further details see: *A distributed modelling system for simulation of monthly runoff and nitrogen sources, loads and sinks for ungauged catchments in Denmark.* / Windolf, Jørgen; Thodsen, Hans; Troldborg, Lars; Larsen, Søren Erik; Bøgestrand, Jens; Ovesen, Niels Bering; Kronvang, Brian. I: Journal of Environmental Monitoring, Bind 13, 2011, s. 2645-2658.

Source apportionment (load and source oriented approach)

Denmark follow the PLC guidelines for the load and source oriented approach.

Atmospheric inputs is calculated on inland surface waters based on national monitoring program and dry and wet deposition of nitrogen which then are modelled to and annual deposition rate. For phosphorus deposition Denmark use 0.04 kg P/ha surface inland waters.

Retention

Retention is modelled for larger lakes, small ponds and lakes, streams and restored wetlands.

Larger lakes:

All larger lakes for which both an inlet and an outlet has been identified are in this context defined as larger lakes. For each lake, the external annual nitrogen load has been estimated using the aboved mentioned model and the annual nitrogen-retention is calculated using a N-retention model. The lake N-retention model includes water residence time and average lake depth. The model is based on monitoring data on annual inflow and outflow of water and nitrogen from 21 lakes over a 15-year period.

Small ponds and lakes:

The Danish landscape is dotted with more than 100.000 small ponds and lakes. With the aim to identify the number of minor lakes having a significant potential for N retention the following criteria were established

- Each lake should at least have an identifiable stream outlet and/or “have contact” with at least two ditches. A total of 5930 smaller lakes were identified to meet the criteria.
- No topographic catchment areas are available for these lakes. Hence the calculation of nitrogen retention is based on assigned lakes area specific mean annual retention rates between 60 and 400 kg N ha-1 per year.
- The ranges of retention rates aim to reflect the differences between lakes located in areas with varying farming intensities and varying soil characteristics.
- Inter-annual variation in the area-specific N retention rates is calculated based on the assumption that it follows the relative inter-annual variation in nitrogen retention in determined from mass balances in 16 Danish lakes.

Streams

The calculation of nitrogen retention in streams are based on 41 referenced studies of nitrate denitrification in streams and rivers in different parts of the world reviewed by Kronvang et al. These showed that annual average nitrate denitrification rates were higher in stream channels wider than 2 m than in stream channels less than 2 m wide. The total length of the different width classes was extracted from a national dataset. Inter-annual variation in N retention rates in streams is presumed to parallel the relative inter-annual nitrogen retention in 16 larger Danish lakes.

Restored wetlands

Experience from Denmark following the effect of restored riparian wetlands shows a net removal of nitrogen amounting up to 190 kg N per hectare restored wetland per year. Data on the location of restored wetlands in Denmark since 1998 are recorded in GIS and information on the annual areas of restored wetlands is extracted and stores in GIS. Inter-annual variation in the nitrogen retention rate is assumed to parallel the inter-annual variation in nitrogen retention in 16 larger Danish lakes.

Transboundary inputs

Denmark has no transboundary rivers to take into account.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Denmark have been working with estimating uncertainty on inputs using the method below. The example is for total nitrogen. Uncertainty estimates Is described for monitored, and unmonitored areas separately, and for total inputs to the sea.

Monitored area:

The calculation of the uncertainty is done by using the statistical principle "Propagation of errors". This principle can be explained as:

Let *X* be the sum of *n* stochastically independent measured loads

$$X = \sum_{i=1}^{n} X_i. \tag{3.1}$$

The variance of *X* can be calculated as

$$\sigma_X^2 = Var(X) = \sum_{i=1}^{n} \sigma_{X_i}^2. \tag{3.2}$$

The standard deviation is then calculated as

$$\sigma_X = \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \tag{3.3}$$

And the relative standard deviation (denoted the precision) is calculated as

$$100 \cdot \frac{\sigma_X}{X} = \frac{100}{\sum_{i=1}^{n} X_i} \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \tag{3.4}$$

The calculation of the total inputs from the monitored areas constitute of measurements from 169 stations in streams. These stations cover approximately 55% of the total Danish catchment area. Bias and precision can then be calculated as

$$bias\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sum_{i=1}^{169} bias_i \cdot X_i, \tag{3.5}$$

$$precision\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sqrt{\sum_{i=1}^{169} (precision_i \cdot X_i)^2}. \tag{3.6}$$

The total uncertainty can then be calculated as

$$uncertainty\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sqrt{\sum_{i=1}^{169} (bias_i \cdot X_i)^2 + (precision_i \cdot X_i)^2}. \tag{3.7}$$

The total input to the Danish marine environment is a sum of two components. One component is from the monitored catchment area and the other is from the unmonitored area. The inputs from the unmeasured area is estimated by using a model. A Monte Carlo study (Kronvang & Bruhn, 1996) based on daily samples has shown that for Danish streams categorized by their catchment area, the following values for bias and precision are valid for TN load calculated using the linear interpolation method:

0-50 km^2:	Bias: -1% to -3%;	Precision: 1-3%
50-200 km^2:	Bias: -0.7% to -3%;	Precision: 1-3%
>200 km^2:	Bias: -1% to -4%;	Precision: 2-5%

These number are valid for the yearly load from one stream station and include the uncertainty of laboratory analysis, yearly variation of concentrations and stream discharge and uncertainty from the method for calculating yearly load (by linear interpolation). The uncertainty from the measurement of the concentration in the stream (placement of the sampling site horizontal and vertical in the stream) is not included and therefore 2% is added to the precision in the 3 categories.

Using the formulae (3.5-3.7), it can be calculated that the total bias is -1% to –3%, the total precision is 0.7% to 1.2% and the total uncertainty is 0.7% to 1.3%. For an average stream station the bias is -1% to -3%, the precision is 3% to 5% and the uncertainty is 3.2% to 5.8%.

The TN input from the unmonitored areas is based on model estimates for 1286 very small catchments covering the rest of the Danish area (45%). The year load from each small catchment is calculated using the formula

$$L = Ndiffuse_{model} + R_{lake} + R_{stream} + N_{waste} - R_{total}, \tag{3.8}$$

$Ndiffuse_{model}$ = the estimated nitrogen inputs from the model

R_{lake}= Estimated nitrogen retention in lakes

R_{stream} = Estimates nitrogen retention in streams

N_{waste} = Nitrogen inputs from wastewater

R_{total} = Total nitrogen retention.

In table 3.2 are shown bias and precision for the components in formula (3.11 based on both numerical calculations, the study by Kronvang & Bruhn (1996) and estimates.

Table 3.2. Bias and precision for nitrogen inputs in formula (3.11) based on both numerical calculations, estimates and Kronvang and Bruhn (1996).

Components	Bias (%)	Precision (%)
Model	15 to 20	12 to 15
Retention lake	-5 to 5	40
Retention stream	-5 to 10	40
Retention total	-5	40
Point source: industry	-1 to -3	1 to 10
Point source: waste water	-1 to -3	1 to 10
Point source: fishfarms	-1 to -3	1 to 20
Point source: rain water	-5	40

Using the formulae (3.5) to (3.7) and the bias and precision indicated in table 3.2 the total bias for the unmonitored area is calculated to 20% to 28%, the total precision is 0.8% to 2.0%

and the total uncertainty is 1.2% to 2.2%. For an average small unmonitored catchment the bias is 27%, precision 15% to 20% and the uncertainty 31% to 34%.

For the total Danish catchment area, combing the calculated bias, precision and uncertainty for both the monitored and unmonitored areas and using special versions of formulae (3.7) to (3.9), we get a total bias of 7.4% to 12.8%, a total precision of 0.5% to 1.1% and a total uncertainty of 7.4% to 12.8% on TN inputs.

With respect to total phosphorus (TP), calculations show that for the measured area the bias is -6 to -3%, the precision is 1 – 2% and the uncertainty is then 1 – 2.5%. For the unmeasured area the bias is between -5 and 30%, the precision is 1 – 3% and the uncertainty is 1 – 4%. These calculations are based on the following values of bias and precision from Kronvang and Bruhn (1996) for TP load (using linear interpolation method):

0-50 km2:	Bias: -16% to -27%;	Precision: 18-37%
50-200 km2:	Bias: -2% to -5%;	Precision: 9-13%
>200 km2:	Bias: -2% to -4%;	Precision: 3-8%

Estonia

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Calculation of flow and loads

The calculations were carried out according to PLC-6 Guidelines. The annual load for every monitored river was calculated for the measurement site. The load from the unmonitored part of the river catchment area was estimated as a part of the unmonitored areas (GUF, GUR, BAP).

The number of monitored rivers, reported for HELCOM, varies slightly and currently the number of these rivers is 15. Among these rivers is one transboundary river (Pärnu River) and one border river (Narva River). All our monitored rivers have both hydrological and hydrochemical monitoring stations; however, in some cases these stations are not located in the same place. For unmonitored load calculation and for compilation of periodic report a simple coefficient-based model (EstModel) is used. Nutrient discharges from different land types are calculated separately. Loads from point sources in intermediate catchment are calculated individually. The load from each source is divided into natural load and anthropogenic load.

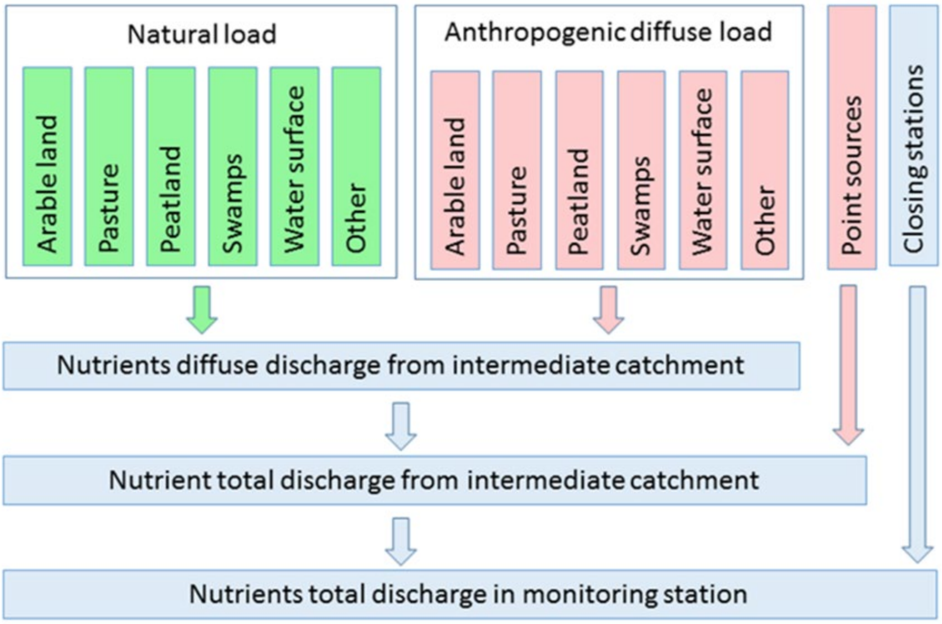

Figure 1. Estmodel calculation units (load types).

EstModel is calibrated against the measured annual load data at the sites of every chemical monitoring stations.

The annual input calculation using daily river flow and daily concentration (interpolated)

At hydrological monitoring stations, the river flow is measured daily and is available thru national monitoring databases. Concentrations are measured at hydrochemical monitoring stations 4–12 times per year based on the schedule of the monitoring program. The daily concentrations are estimated by linear interpolation of measured values. The annual input load is estimated as:

$$L = \alpha \sum_{i=1}^{n} Q_i \cdot C_i$$

where L is the annual input load (kg·a^{-1}), n is the number of days, Q_i is the daily river flow for the day i (l·s^{-1}), C_i is the daily concentration for the day i (unit for nutrients is mg·l^{-1} and unit for heavy metals is µg·l^{-1}), and α is the coefficient to obtain the daily loads over the whole year ($\alpha = 0.0864$ for nutrients and $\alpha = 0.0000864$ for heavy metals).

Values under the limit of quantification

If measured concentrations are below limit of quantification (LOQ), then for these measurements the estimated concentrations are calculated based on the HELCOM method (HELCOM, 2015) using the equation:

$$C_{est} = LOQ \frac{100 - A}{100}$$

where C_{est} is the estimated concentration, LOQ is the limit of quantification, and A is the percentage of measurements values below the LOQ.

Flow in hydrochemical station

If the river flow and concentrations are not measured in the same locations, that means the river's hydrological and hydrochemical monitoring stations are in different locations, then the river flow at the hydrochemical station is calculated as

$$Q_{ch.st.} = Q_{hyd.st.} \frac{S_{ch.st.}}{S_{hyd.st.}}$$

where $Q_{ch.st.}$ is the river flow at the hydrochemical monitoring station (l·s^{-1}), $Q_{hyd.st.}$. is the river flow at the hydrological monitoring station (l·s^{-1}), $S_{ch.st.}$ is the catchment area of the hydrochemical monitoring station (km^2), and $S_{hyd.st.}$ is the catchment area of the hydrological monitoring station (km^2).

Quantification of inputs from point sources.

The annual input loads from point sources are calculated using the quarterly reports forwarded to The Estonian Environment Agency. Every water consumer who has the permission of water use must provide these reports four times per year. Reports contain quarterly average concentrations and quarterly total flow. The annual input load is calculated as

$$L = 0.001 \sum_{i=1}^{n} Q_i \cdot C_i$$

where L is the annual input load (kg·a^{-1}),Q_i is the wastewater volume for the period (m^3), C_i is the average concentration for the period (mg·l^{-1}), and n is the number of quarters in the year ($n = 4$).

Load from scattered population.

Load from scattered population is considered as an anthropogenic diffuse source and it is calculated as

$$L_{scattered}^{N,P} = PE^{N,P} \cdot l_{PE}^{N,P} (1 - R_{catchment}^{N,P}) \frac{365}{1000}$$

where$L_{scattered}^{N,P}$ is the load of nitrogen or phosphorus from scattered dwellings (kg·a^{-1}), $PE^{N,P}$ is the scattered population, as population equivalents, $l_{PE}^{N,P}$ is the population equivalent value (12 g·d^{-1} for nitrogen and 1.5 g·d^{-1} for phosphorus), $R_{catchment}^{N,P}$ is the retention (in model $R_{catchment}^{N,P} = 0.95$ is used for scattered population load), 365 represents days in the year, and 1000 represents grams in kilograms.

Unmonitored area calculation

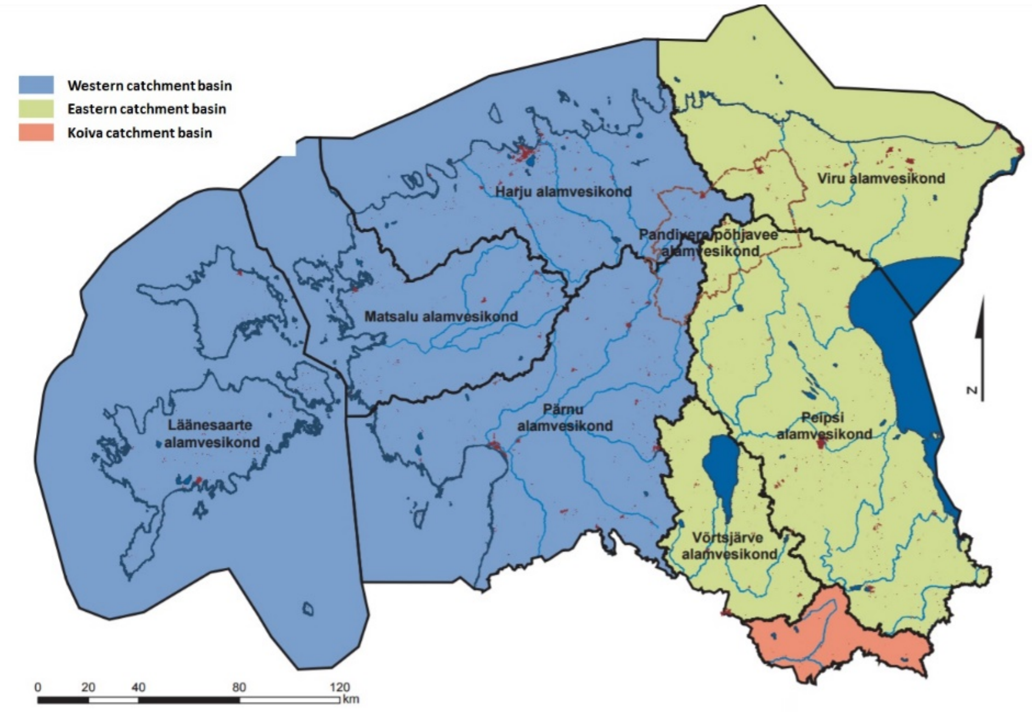

Figure 2. The three catchment basins and eight sub-basins in Estonia.

Estonia is divided into three catchment basins (Western, Eastern and Koiva) and into eight sub-basins (Läänesaarte, Matsalu, Harju, Pärnu, Viru, Peipsi, Võrtsjärve and Koiva). We calculate average specific runoff for every subcatchment area. For the unmonitored area inside the subcatchment, we use the average specific runoff of this subcatchment. For unmonitored area, the loads from point sources and atmosphere are calculated in the same way as in the monitored areas. In calculating the load of the point sources of an unmonitored area, the path of the point source load to the border of the unmonitored area is taken as the retention distance of the point source. Monitored and unmonitored areas may be different for different parameters depending on the monitoring program.

For compilation of the periodic report (source-orientated approach) a simple coefficient-based model (Estmodel) is used. This model is now under development and the first priority is to get more realistic coefficient values. A short description of this model is presented by: Ennet *et al*, 2008.

Source apportionment

Quantifying diffuse losses of nutrients from monitored areas

At the moment the diffuse load of nutrients is calculated provisionally in a simplified form.

$$L_{diffuse} = L_{total} - L_{point} - R$$

where $L_{diffuse}$ is the annual diffuse input load (kg a^{-1}), L_{total} is the annual total input load according to measurements in hydrochemical stations (kg·a^{-1}), L_{point} is the annual point sources input loads (calculated as sum of quarterly reports forwarded to the Environment Agency) (kg·a^{-1}), and R is the retention coefficient (it is assumed that the loss due to retention is 10%).

Annual input loads from point sources are calculated on the basis of reports forwarded to the Environment Agency taking into account the retention.

Atmospheric load.

Atmospheric load onto the water surface area is 440 kg TN/km^2/a and 8.1 kg TP/km^2/a long-term average of monitored data in Estonia).

Natural background losses.

Natural background losses are calculated on the basis of natural concentration. The natural concentrations in calculations are 1.21 mg l^{-1} total nitrogen and 0.04 mg l^{-1} for total phosphorus.

Anthropogenic load.

In EstModel the nutrient concentration includes the anthropogenic component and the natural component. So it is possible to estimate the effectiveness of N, P mitigating measures (reducing the pollution of point sources, limiting the fertilization of fields, and creating buffer zones).

Calculation of retention

Retention of nitrogen and phosphorus may occur in the soil of the catchment area as well as in surface waters of the catchment area. The EstModel only takes into consideration the retention from the surface waters of the catchment area. Retention in surface waters indicates how much of the load entered into waterbodies remains in the waterbodies of the catchment area or is released into the atmosphere. Therefore, it enables to estimate how much of the load entered into surface waters leaves from the calculation area. The value of the retention coefficient is between 0 and 1. To find the values of the retention coefficient, the approach based on the Michaelis-Menten equation (Michaelis & Menten, 1913) to estimate the speed of biological processes was used in the EstModel.

$$R^{N,P} = R_{max}^{N,P} \frac{t}{t_{half}^{N,P} + t}$$

where $R^{N,P}$ is the retention coefficient of nitrogen or phosphorus (0–1), $R_{max}^{N,P}$ is the maximum retention coefficient of nitrogen or phosphorus (0–1), t is the retention time and $t_{half}^{N,P}$ is the retention half-time.

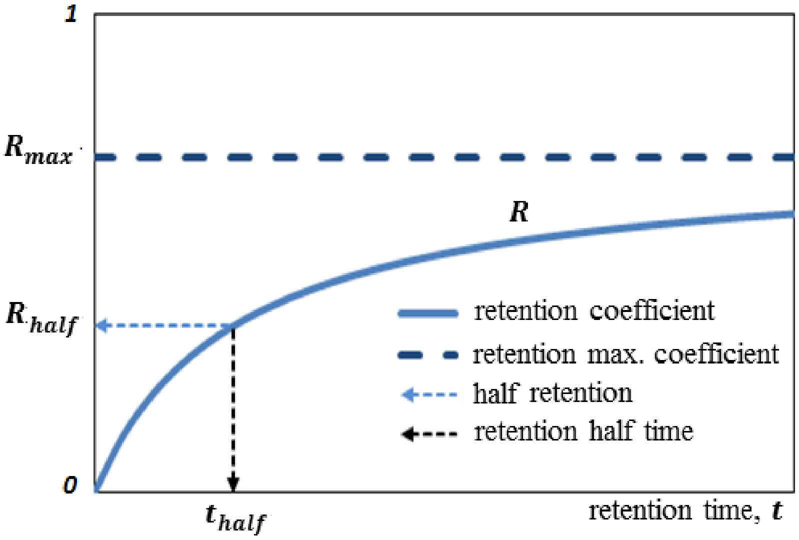

Figure 3. The change in the retention coefficient depending on retention time.

Diffuse load retention

To calculate diffuse load retention, the EstModel uses a simplified method, where the value of the retention coefficient of the surface water is related to the estimated residence time of the nutrients in the waterbody. The input data for the calculations are the estimated maximum retention and the time needed to obtain the half-life of the maximum retention.

$$R_{dif}^{N,P} = R_{dif\_max}^{N,P} \frac{t_{dif}}{t_{dif\_half}^{N,P} + t_{dif}}$$

where $R_{dif}^{N,P}$ is the diffuse load retention coefficient of nitrogen or phosphorus, $R_{dif\_max}^{N,P}$ is the maximum value of the diffuse load retention coefficient of nitrogen or phosphorus, t_{dif}

is the time of the diffuse load of nitrogen or phosphorus stayed in the waterbody (d), and $t_{dif\_half}^{N,P}$ is the time the retention of the diffuse load of nitrogen or phosphorus attain half of maximum value of the retention coefficient (d).

The estimated rate of water exchange in the water bodies is used to find the residence time. The rate of water exchange depends on the amount of water led off from the subcatchment and the total volume of the waterbodies in the catchment. Considering that residence time is inverse value of rate of water exchange, the t_{dif} was calculated as

$$t_{dif} = \frac{S_{water} \cdot H}{Q \cdot 86400}$$

where t_{dif} is the time water is in the waterbodies (d), Q is the average annual flow ($m^3 \cdot s^{-1}$), S_{water} is the total surface area of the waterbodies (m^2), H is the average depth of the waterbodies (m), and 86400 represents number of seconds in the day.

The total surface area of waterbodies is calculated as the sum of the surface area of the stagnant water bodies and surface area of watercourses.

$$S_{water} = S_{water}^{lake} + S_{water}^{stream}$$

where S_{water} is the total surface area of the waterbodies (m^2), S_{water}^{lake} is the the total surface area of the stagnant waterbodies (m^2), and S_{water}^{stream} is the total surface area of the watercourses (m^2).

The surface area of the stagnant waterbodies can be found through a direct geoinquiry from a map layer. In the case of watercourses, the model is based on the total distance of the watercourses. In the absence of data, the average density of Estonian watercourses of 420 $m \cdot km^{-2}$ is used.

Point load retention

The retention coefficient of point load is parameter-based (N, P) and point source-based (the retention of each point source is calculated separately) and is calculated as

$$R_{point,j}^{N,P} = R_{point\_max}^{N,P} \frac{t_{point,j}}{t_{point\_half}^{N,P} + t_{point,j}}$$

where $R_{point,j}^{N,P}$ is the point load retention coefficient of nitrogen or phosphorus for the point source j, $R_{point\_max}^{N,P}$ is the maximum value of the point load retention coefficients of nitrogen or phosphorus, $t_{point\_half}^{N,P}$ is the time the retention of the point load of nitrogen or phosphorus attain half of maximum value of the retention coefficient (d), and $t_{point,j}$ is the time it takes for the point load from point j to reach the monitoring station. The time is based on the flow rate of the river and is calculated as

$$t_{point,j} = \frac{Dist_j}{v \cdot 86400}$$

where $Dist_j$ is the distance between point source j and the monitoring station (m), v is the flow rate of the river ($m \cdot s^{-1}$), and 86400 represents the number of seconds in a day.

The total retention is a sum of retention for each source and the load decrease due to retention is calculated as

$$L\_ret^{N,P} = L^{N,P} \cdot R^{N,P}$$

where $L\_ret^{N,P}$ is the load of nitrogen or phosphorus decrease due to retention, $L^{N,P}$ is the input load of nitrogen or phosphorus, and $R^{N,P}$ is the retention coefficient of nitrogen or phosphorus.

REMARKS

1. Currently our databases are under development and under review. It appears that we have problems with the accuracy of the historical data, especially concerning the point sources.
2. From 2015, we do not have permission to measure the flow in the Narva River. Since 2015, we have been using the estimated flow for the Narva River. The load from the Narva River is an essential part of the Estonian total load.

Transboundary inputs (Border river)

The Narva River is an Estonian and Russian common border river. The total catchment area is 58126 km^2, of which 30.2 % is the Estonia part. It is agreed the Estonian part is 1/3 of the total load. Estonia has on the Narva River two hydrochemical stations (7 km from the mouth and outflow from Lake Peipsi), two hydrological stations (20 km from the mouth, outflow from Lake Peipsi). Unfortunately, since 2015 the hydrological measurements have been stopped (Russian authorities do not give permission). The load is calculated on the basis of estimated flow.

The Pärnu River is an Estonian and Latvian transboundary river. The river total catchment area is 6751.97 km^2 of which 21.31 km^2 is our transboundary area. The load of nutrients from Estonia is a proportion to division of the catchment area

Uncertainty on flow, loads, unmonitored areas and total inputs and on sources

Uncertainties are not estimated.

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Finland

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Calculation of flow and loads

Riverine discharges

Altogether 30 monitored rivers were included in the PLC-6 work. These monitored rivers comprise about 90% of the Finnish Baltic Sea catchment area. Water flow was measured continuously in each river and water quality samples were taken flow proportionally, usually 12 to 20 times per year. Load from unmonitored areas was estimated by extrapolating the results of the nearby monitored catchment areas (with same type of land use and soil characteristics). The annual river discharges for nutrients were calculated by multiplying the mean monthly concentration by the monthly flow and summing up the monthly loads. Missing monthly concentrations were replaced with seasonal means.

Estimation of loading

<u>Point source load</u>
Nutrient load estimation from municipalities and industrial plants were based on regular measurements made according to the guidelines given by the Finnish environmental authorities. In some cases, it is impossible to separate municipal and industrial discharges, because especially wastewaters of food production plants are usually treated in municipal wastewater treatment plants. Nutrient load estimation for fish farms was based on production statistics, amount of feed and nutrient content of the feed, using the equations in the PLC-6 Guidelines.

Source apportionment

Source apportionment was based on statistical modelling and mass balances on the measured (point source) or estimated (diffuse) load figures and retention calculations.

Diffuse load

Small drainage basins and small experimental areas were used in the estimations of diffuse source loading. The network of drainage basins for water quality monitoring consists altogether of 45 basins with different type of land use in different parts of the country. Water flow was measured continuously, and water quality samples were taken flow proportionally 35-55 times per year.

Estimation of the losses of phosphorus and nitrogen from <u>agricultural land</u> to surface waters in Finland is based on the monitoring of N and P fluxes from 11 small agricultural drainage basins and from four agriculturally loaded river basins in south and southwestern Finland

(Rekolainen et al. 1995, Vuorenmaa et al. 2001). The size of the small basins vary from 0.12 to 15 km^2, and the river basins from 870 km^2 to 1300 km^2. The agricultural land use of the basins varied from 23 to 100%. The monitoring schemes were based on continuous water flow measurement and flow weighted water quality sampling. Using this data, annual N and P flux estimates were calculated, by subtracting possible point-source loads and estimated losses from forested areas and the natural background. The up-scaling of the losses of phosphorus to cover whole Finnish arable land area is based on the ICECREAM model, which takes into account the topography, the structure of soil and agricultural production in different river basins (Tattari et al. 2001). The hydrology of the original model has been modified for Finnish conditions. The most remarkable change is in the model the inclusion of snow accumulation, snow melt and soil frost processes. For nitrogen SOILN-N model was used (Johnsson et al. 1987).

The effects of forestry activities (ditching, clear-cut felling, ploughing, hummocking, fertilization etc.) were evaluated on the basis of regional forestry statistics. The specific yearly net load from forestry activities was approximated using leaching coefficients obtained from the Finnish and Swedish surveys.

Nutrient inputs from scattered dwellings were estimated on the basis of estimated annual wastewater production per person and the level of equipment in handling of lavatory and sanitary wastes (table 1). Per capita load estimates were 50 g/d BOD, 14 g/d NTOT and 2.2 g/d PTOT.

Atmospheric deposition on lake surfaces was gained by multiplying specific deposition by the surface area of the lakes. Deposition was measured on 13 stations located in the river catchment areas. Nutrient concentrations were analysed from the integrated monthly samples of rain.

The estimation of natural leaching was based on coefficients obtained from the monitoring programmes of small drainage basins (table 2).

Table 2. Natural leaching coefficients for different parts of Finland.

	kg P km^{-2} a^{-1}	kg N km^{-2} a^{-1}
Southern Finland	6	200
Central Finland	5	120
Northern Finland	5	80
Northern Lapland	2	50

Calculation of retention

The estimation of retention of nutrients in freshwater is based on mass balance calculations. Usually retention of nitrogen and phosphorus was calculated only for the whole catchment area, but in larger river basins it was also calculated for sub-catchment areas in case there were continuous flow measurements and representative concentration measurements (at least 12 times per year). Retention was calculated using data from 2008 - 2014.

The retention was calculated according to the following formula:

$RET = Q_{IN} + (L_{POINT} + L_{AGRI} + L_{ATM} + L_{FOREST} + L_{SCAT} + L_{BACK}) - Q_{OUT}$,

where

Q_{IN} = incoming riverine load

Q_{OUT} = outflowing riverine load

L_{POINT} = point source load (industry, municipalities, fish farming)

L_{AGRI} = agricultural nutrient load

L_{ATM} = direct atmospheric deposition to the lakes

L_{FOREST} = load from forestry activities

L_{SCAT} = load from scattered dwellings

L_{BACK} = natural leaching

Retention of nutrients in freshwaters is in Finland mainly connected to chemical, physical and biological processes taking place in lakes. Unmonitored river catchments and coastal areas in Finland have only very limited number of lakes, and thus retention in these areas is negligible.

Tranboundary inputs

The estimation of transboundary inputs from Finland to Russia is based on monitored inputs of the River Vuoksi and modelled nutrient inputs of the River Seleznevka. Monitoring of the border River Torne between Finland and Sweden is carried out in both countries. The final input is an average of the loads reported by the two countries. Source apportionment is done separately in both countries.

Uncertainty on flow, loads, unmonitored areas and total inputs and on sources

Uncertainty is not estimated.

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Germany

Applied methodology for the PLC 7 assessment from GERMANY

by Antje Ullrich and Wera Leujak, German Environment Agency (UBA)

Calculation of flow and loads (rivers, direct point sources)

Flow and river loads

The load calculations made for German rivers correspond to the recommendations of the PLC-6 Guidelines.

There are numerous and generally, quite small rivers that drain the German Baltic Sea catchment area. Not all of them are monitored and the number of monitored rivers may vary from year to year. For PLC 6 Germany reported 24 monitored rivers which cover about 66 % (about 16.000 km² including the national area of the Stettiner Haff) of the German Baltic Sea catchment area (except the transboundary German catchment area of the river Oder).

The annual load calculations are based on daily river flows and water quality samples that are taken between 10 to 24 times per year. The applied load calculation methods differ between the two German federal states ("Bundesländer"). Schleswig-Holstein calculated the river loads with daily flow and daily interpolated concentrations while Mecklenburg-Vorpommern applied the method using monthly flow and mean monthly concentration.

Direct point source loads

Germany reported 29 municipal and 3 industrial direct dischargers. There are no directly discharging fresh water fish farms in the German Baltic Sea region.

Flow is measured continuously, and concentrations are measured frequently. The legally necessary sampling frequency is specified on the federal level usually depending on plant size. Measurements are carried out by the operator of the plant and controlled by responsible federal authorities using standardized DIN methods.

Inputs from unmonitored areas

Altogether about 34 % (about 8.100 km²) of the German Baltic Sea catchment area is not monitored (about 33 % in WEB and about 30 % in BAP (including German catchment area of the Stettiner Haff)).

For annual reporting calculations of inputs are based on flow and loads from monitored areas assuming similar conditions (concerning inputs from point and diffuse sources) prevailing in unmonitored areas. Loads calculated for all monitored areas are assigned to the unmonitored area based on their proportion. This method may lead to an over- or underestimation of inputs.

For periodical reporting the MoRE (Modelling of Regionalized Emissions; https://isww.iwg.kit.edu/MoRE.php; Fuchs et al. 2011, 2017) model is used to calculate flow and loads for unmonitored areas. MoRE calculates pathway-oriented nutrient and pollutant inputs to surface waters independent of whether the area is monitored or unmonitored (see the following paragraph: “source oriented apportionment”). All relevant pathways (including all point sources (UWWTPs > 50 p.e. and scattered dwellings (defined < 50 p.e. – individual system) and the relevant diffuse pathways) are included.

Source apportionment (load and source oriented approach

Germany generally applies the <u>source oriented approach</u> using nutrient input results from the MoRE model.

The MoRE model is a free software tool for an empirical-based quantification of annual nutrient and pollutant emissions in river basins. It allows a regional and pathway specific quantification for any given aggregation unit. MoRE is based on the MONERIS concept that was developed for modelling of nutrient emissions into the water bodies (Behrendt et al., 2000). The model was later extended to include pollutant emissions.

The considered pathways can be classified into three blocks (Figure 1):

- Pathway-dependent on point-source
  - municipal wastewater treatment plants (MWWTP)
  - Industrial dischargers
- Pathway-dependent on diffuse non-urban sources and
  - Surface runoff
  - Erosion
  - Groundwater
  - Tile drainage
  - Direct atmospheric deposition onto surface waters
- Pathway-dependent on diffuse urban sources
  - Storm water sewer overflows
  - Combined sewage overflows
  - Small wastewater treatment plants (individual systems e.g. septic tanks).

MoRE calculates the inputs based on analytical units (average size 130-150 km²) based on the drainage network. The analytical units can be aggregated to different administrative units, hydrological subbasins, river basins or marine catchment areas.

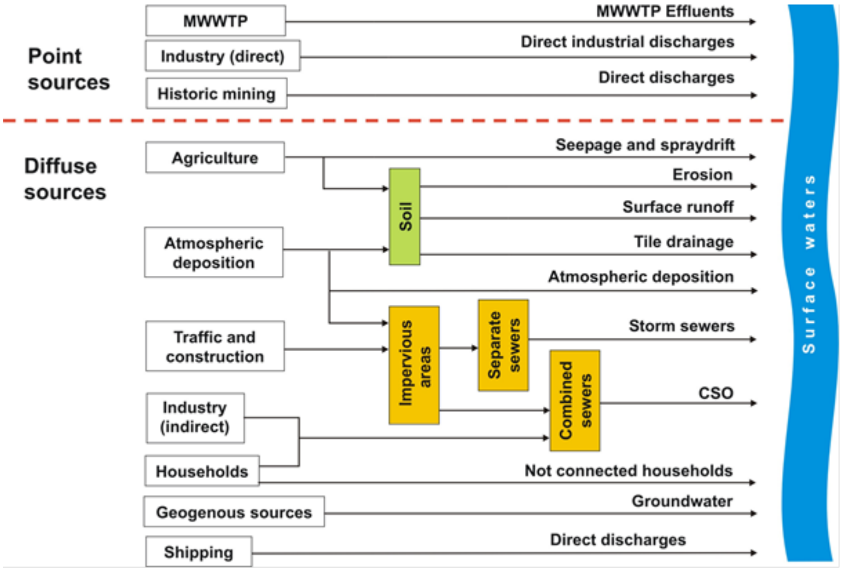

Figure 1. Sources and emission pathways considered in MoRE model (Fuchs et al. 2010; European Commission 2012, Fuchs et al. 2017).

The calculation of emissions from point sources can be straightforward, as data on effluent concentration and the amount of treated wastewater are available or can be derived from statistical data with the required accuracy.

The inputs caused by diffuse non-urban sources are the result of more or less complex interactions with different interfaces, including temporal storage, transformation and losses. These processes have to be integrated into the approaches adequately. Pathways from agricultural diffuse sources include erosion, surface run-off, tile drainage, seepage and spray drift. To calculate direct atmospheric deposition onto surface waters e.g. EMEP products (ecosystem specific deposition) are used. Atmospheric deposition onto land surfaces is not considered separately but included into the other emission pathways (e.g. in surplus calculation for agricultural lands).

The diffuse urban pathways account for various sources including air pollution, wastewater from industries and households as well as primary emissions from construction material and traffic.

To estimate natural background losses of nutrients a separate model scenario was defined, and a MoRE simulation was run. The scenario was defined as pristine. Therefore, the entire German Baltic Sea catchment area (except water surfaces) was assumed to be completely forested without any anthropogenic activity (no fortified area, no population, no point sources). Taking into account obvious lower atmospheric deposition either onto surface waters or onto land surface, nutrient emissions were calculated. Hydrologic conditions were assumed to be unchanged from today.

To satisfy the requirements of the load-oriented approach the MoRE results could be used as well. Actually, the model itself does not distinguish between load-oriented and source-oriented approach. However, taking retention into account the propotions of calculated pathways could be used to apply the load-oriented approach.

Retention

The MoRE model considers riverine retention based on sub-basin specific retention factors (Behrendt and Opitz, 1999). Other retention processes (in soils, groundwater, …) are indirectly includes in the pathway calculations.

Transboundary inputs

In Germany there is one transboundary river, the river Oder. The river Oder enters the Baltic Sea on the territory of Poland. The German territory covers 4.7 % of the entire catchment area operating two hydrochemical (one of them on PL border) and three hydrological stations. The Oder is crossing from Poland into Germany and back to Poland and is bordering the two Countries for some reaches. Therefore, Germans monitoring station do not represent inputs only from Germany. To estimate transboundary inputs coming from the German territory, agreed proportions of total TP (8.5 %) and TN (3.7 %) inputs are used.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainties were estimated based on expert judgement.

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Latvia

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Calculation of flow and loads (rivers, direct point sources)

Water flow is calculated from the automatic measurements of water level and manual water discharge measurements in the main hydrological phases.
Riverine loads are calculated as follows:

$$L=\sum_{i=1}^{12} W\,x\,C$$

W – volume of monthly runoff based on average monthly discharge;
C – monthly water concentration (monthly discrete samples)

Data on point sources are obtained from the national data base "Ūdens-2" (Water-2). Pollution loads there are reported by the operators of waste-water treatment plants.

Inputs from unmonitored areas

Load from unmonitored areas was estimated by areal extrapolation of the monitored load in the upstream or neighbouring catchments with similar natural conditions and anthropogenic pressures.

$L_{unmon} = L_{mon}/A_{mon} * A_{unmon}$,

where: L_{unmon} = unmonitored load (t/y, kg/y)
L_{mon} = monitored load (t/y, kg/y)
A_{mon} = area of the monitored catchment (km^2)
A_{unmon} = area of the unmonitored catchment (km^2)

Source apportionment (load and source-oriented approach)

Load oriented approach was used as described in the HELCOM Guidelines for Waterborne Pollution Inputs to the Baltic Sea (chapter 10).
Data on point sources are obtained from the national data base "Ūdens-2" (Water-2). Operators of municipal and industrial wastewater treatment plants and several fish farms have to quantify and report the pollution loads to the data base according to the requirements of polluting permits. Sampling frequency of polluting substances varies from one to twelve times per year. Wastewater volume in larger WWTPs are measured by flow meters and it is estimated in smaller WWTPs. Loads by rainwater is partly included the estimation of point sources. The rest is not quantified.

Inputs from scattered dwellings are not quantified.

Export coefficients of Ntot and Ptot from diffuse background sources (forest territories) were obtained from the Latvian State Forest Research Institute "Silava". Export coefficients are then multiplied by the area of forest and wetland in the sub-basin.
Atmospheric deposition on inland fresh water is not estimated.

Retention

Retention was calculated following Behrendt H., Opitz D. (1999) Retention of nutrients in river systems: dependence on specific runoff and hydraulic load. In Man and River Systems (pp. 111-122). Springer Netherlands.

Retention coefficient for nitrogen: R_{SN}=6.3((Q*86,4*0.365)/As$^{)-0.78}$
Retention coefficient for phosphorus: R_{SN}=4,7((Q*86,4*0.365)/As) $^{-0.76}$

where Q is a discharge and area of surface waters in catchment As=A_{lake}+0.001*$A^{1.185}$ (A_{lake} – area of lakes in a catchment, A area of a catchment)
Retention R = $R_{SN,SP}$*Load

Transboundary inputs

Transboundary loads are important for the Rivers Bārta, Venta, Lielupe, and Daugava.

At first, measured monthly concentrations at the border station and extrapolated discharges are used to calculate yearly load coming from a neighbouring country. In the case of the Daugava Rivers, the load is distributed between RU and BY by taking into the account the catchment area in these countries as well as the estimates of retention from the Tables 8.2. and 8.3 in "Guidelines for Waterborne Pollution Inputs to the Baltic Sea".

Uncertainty on flow, loads, unmonitored and total inputs and on sources

In following hydrological stations, the uncertainty in flow measurements was estimated to be 7 %: IRBE at VICAKI, BARTA at DUKUPJI. In following hydrological stations, the uncertainty in flow measurements was estimated to be 12 %: SALACA at LAGASTE, GAUJA at SIGULDA, DAUGAVA at JEKABPILS, VENTA at VENDZAVA, LIELUPE at MEZOTNE.

Uncertainty of the monitored river load was calculated following Harmel, R.D., Cooper, R.J., Slade, R.M., Haney, R.L., Arnold, J. G. (2006) Cumulative uncertainty in measured streamflow and water quality data for small watersheds. *Transactions of the ASABE*, *49*(3), 689-701.

$$\mathrm{EP} = \sqrt{\sum(E_Q^2 + E_C^2 + E_{PS}^2 + E_A^2)},$$

where: EP – cumulative uncertainty;
$E^2{}_Q$ – uncertainty in discharge measurements (±%);
$E^2{}_C$ – uncertainty in sample collection (grab sampling at single point, random time) ±25% dissolved; >50% suspended constituents);
$E^2{}_{PS}$ – uncertainty in sample preservation and storage (for N-NO_3 ± 2%, for P_{tot} ± 7%);
$E^2{}_A$ – uncertainty in laboratory analysis (±%, data from the analytical quality checks of the Laboratory of LEGMC);

Uncertainty of total loads and sources was not estimated.

Lithuania

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Calculation of flow and loads (rivers, direct point sources)

Lithuania uses two separate approaches for calculating data required for annual and periodic reporting. Annual flows and loads are calculated from daily river water flow and monthly water quality monitoring data using formulas provided in PLC guidelines. Daily water flow is recalculated to monthly flow averages. Averaged monthly flow and monthly concentrations are used in load calculation (PLC guidelines formula 4.2). As it comes to direct point sources, they are few. Yearly data about them are provided by companies or municipalities responsible for those point sources.

For periodic reporting flow and loads are calculated using the SWAT model. The model has been prepared for all Lithuanian territory with the most detailed data available in the country. Model and its preparation are described in the model preparation documentation.

Additional model and data preparation steps, which are not described in the model preparation documentation, are presented below:

1. Additional data for years 2013 – 2017 were collected in order to extend model simulation period up to the end of year 2017. Data were collected on point sources, important water users, meteorological conditions (wind, temperature, precipitation, dew point, solar radiation) in weather stations, water flow and water quality.
2. All the data were transformed to the formats and forms usable by the modeling system.
3. Model was run and results were checked with previous results as well as with new measurement data.
4. The final version of prepared model was run from 1997 to 2017. However only the last year was used in reporting
5. Required loads and water flow results were extracted using prepared scripts in modeling system:
    a. Loads coming to water bodies from different land uses were extracted;
    b. Routing of the loads was followed through the river system recording retention and apportionment;
    c. Water flows in the rivers were extracted;
    d. Extracted results per sub-basin (1238 sub-basins were used in prepared model for Lithuanian territory) were assigned to following river basins used in reporting to HELCOM: Venta, Barta, Lielupe, Dauguva, Pregolya, Nemunas, Akmena-Dane, Sventoji and BALTLAND. Additionally, all outlets to other countries and the Baltic Sea were identified.
6. Atmospheric loads were included into non-point source loads and not tracked or reported separately.
7. Finally, loads calculated from modelling results were rescaled to mirror the reported annual data, which were calculated from monitoring results. This was done by calculating coefficient of difference between monitoring and modeling results, and by using this coefficient modeling results were increased or decrease for non-point sources in each reported basin to receive same loads at river mouths as in annually reported data.

Inputs from unmonitored areas

Loads and flow from unmonitored areas for annual reporting are calculated using area proportional method described in the guidelines (PLC guidelines formula 7.1). Minija river (neighboring basin to the unmonitored areas) concentrations and flow at the outflow are used together with Minija and unmonitored areas area ratio to calculate loads from unmonitored areas. However, in the periodic reporting modeling approach was used to calculate loads and flows from unmonitored areas.

Source apportionment (load and source-oriented approach)

Source apportionment data are prepared using model results. The model is loaded with physical data about environment, climate, discharges of point sources, agricultural activities, etc. As the SWAT model is in category of physically based and semi-distributed parameters catchment models, processes occurring in the environment are simulated by the model. All sources apportionment data are based on simulation results.

Retention

Retention has been calculated using modeling. The routing of pollutants from different sources has been tracked through river network. This allowed calculating retention of all pollutants as well as track pollutants by sources. The SWAT model is based on physical parameters. It simulates processes occurring in the river channel as diffusion, sedimentation, resuspension, breakdown of pollutants, etc. Thus, total retention is based on simulation of those processes occurring in the river.

Transboundary inputs

Modeling is used to calculate reported transboundary loads and flows needed in the annual and periodic reporting for the exception of loads and flow coming from Belarus. Belarus loads and flow are calculated using monthly concentration and daily flow monitoring data at the border. The calculation is done the same way as for main rivers in the annual reporting (PLC guidelines formula 4.2). Beside modeling and monitoring data, area proportional method is used as well in calculating transboundary loads in areas where prepared model have no coverage (small areas of Belarus and Latvia along the border).

All data for river basins going to Latvia from Lithuania are modeled. Sesupe loads and flow leaving Lithuanian to Kaliningrad and coming back to Nemunas river are not modeled, but returning loads and flow are increased by area proportional coefficient. Loads and flow leaving Nemunas to Kaliningrad through Matrosovka channel is calculated by flow proportional coefficient, which was calculated from measured Matrosovka flow data. More detailed explanations of model configuration could be found in the model preparation documentation.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainties on flow or loads have not been calculated or reported by Lithuania.

Poland

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1. GENERAL

Poland's PLC-7 methodology is in its essence a continuation of that used for the purposes of PLC-6 [1], that is, it is a simple mass-balance approach based, to the extent possible, on monitoring data. However, it has been modified in a number of important aspects, including the list of source categories included, certain unit load values used for estimation and load apportionment method.

1.1 Reporting year

Unless otherwise stated, all Polish data covers the year 2018.

1.2 Monitored riverine flows and riverine loads

All the reported monitored catchment area flows are based on daily flow measurements. Nutrient concentrations were measured on a monthly basis. Reported monitored catchment area loads have been calculated as products of monthly flows and the respective concentrations (no flow – concentration or flow – load regressions were used to estimate annual loads).

1.3 Division into sub-catchments and mini-catchments

In PLC-6 methodology [1], the HECLOM sub-catchments were further divided into over 100 "mini-catchments" for which separate source compilations were prepared. However, retention for these separate "mini-catchments" was NOT calculated and, consequently, the delimitation of the "mini-catchments" had absolutely no impact on the river load apportionment at the river mouths. It is very probable that the reason why no retention and no river load apportionments were eventually calculated for the "mini-catchments" was insufficient data, particularly on flows and on nutrient concentrations in farmland groundwaters.

Under PLC-7, we intended to eliminate at least one of these difficulties by developing a dynamic hydraulic model that would yield reliable and precise flow estimates for each of the "mini-catchments". However, in view of the need to seriously alter the Polish PLC-7 project time schedule, we were forced to put aside the work on the model and adopt the simplest acceptable approach by compiling loads only for the HELCOM sub-catchments. The foregoing of the "mini-catchments" does NOT represent a backslide from PLC-6 since, as pointed out above, the potential of these "mini-catchments" was never really utilized under PLC-6.

1.4 Land cover data

All land cover data used in the Polish PLC-7 report comes from Corine Land Cover 2018.

1.5 Unmonitored areas

Load from unmonitored areas are quantified from the area proportion methodology. The proportion between the unmonitored and monitored area of each river was used to calculate the load from unmonitored parts of river. The load from point sources located at unmonitored catchments was added to load in each catchment. For BAPLAND the load was extrapolated from 7 monitored rivers using the same proportion method.

2. QUANTIFICATION OF SOURCES IN MONITORED AREAS

2.9 Indirect municipal point sources (I_MUN)

Municipal point sources were estimated using two key data sources, namely: a) the 2018 National Municipal Wastewater Treatment Programme Report [2]; b) 2018 statistical data on the number of inhabitants connected to municipal wastewater treatment plants (wwtps) on NUTS-5 level [3]. Source a) includes nearly 1700 municipal wwtps which serve agglomerations of more than 2000 inhabitants and as such fall under the Urban Wastewater Treatment Directive (UWTD). This does not mean that all wwtps included in source a) serve more than 2000 inhabitants; in fact, some of them are much smaller and only serve portions of large agglomerations. For larger wwtps which are obliged to monitor N and P and have provided reliable data, loads were either provided by the wwtp or calculated as the product of annual flow and mean annual concentration. Loads from small plants which did not provide any data or provided data judged unreliable were estimated using unit untreated wastewater loads of 11,01 g N/person x day and 1,67 g P/person x day and reduction efficiencies of 65% and 35%, respectively for N and P. The unit untreated wastewater unit loads represent an average from about 460 municipal wwtps that provided reliable input load and connectivity data. The reduction efficiencies are typical for the modified Lutzak-Ettinger (MLE) activated sludge process which is the most popular process in small Polish wwtps. Loads from wwtps which provided incomplete or suspicious data were estimated by analysing the available information on plant size, design, flows, concentrations etc. In cases where discrepancies could not be resolved in this way, the plant operators were contacted directly. As a rule, plants which reported effluent N concentrations of less than 5 mg N/l were double-checked, while mean effluent P concentrations of less than 0,3 mg P/l in otherwise trustworthy datasets were disregarded and replaced by the value 0,3 mg P/l.

There are a number of small municipal wwtps which do not fall under the UWTD and for which no individual data is available. The number of inhabitants connected to them was estimated as a difference between the official total number of people connected in the country and the number of people connected to the UWTD wwtps. Loads from these small plants were estimated using unit untreated wastewater loads of 11,01 g N/person x day and 1,67 g P/person x day and reduction efficiencies of 65% and 35%, respectively for N and P.

2.10 Indirect industrial sources (I_IND)

Due to statistical confidentiality regulations, it was not possible to gain access to data on individual industrial wwtps with the exception of those which are included in the Pollution

Release and Transfer Register (PRTR). However, since the PRTR only includes releases of more than 50 000 kg N/y and more than 5 000 kg P/y, this source is incomplete even with regard to the plants included in it, as in a number of cases the plants only exceed one of the two thresholds and therefore only report one of the nutrients. The PLC-6 list of industrial sources was reviewed and prioritized in order of potential significance of N and P loads. Questionnaires to about 250 top-priority industrial plants were sent in hope of obtaining a robust dataset that would provide an insight into the flows, input loads, treatment methods and treatment efficiencies in the various industrial sectors, but only a small fraction of the plants responded. Therefore, the only source of information on industrial point sources was the official NUTS-5 level statistics database on N and P loads from about 2500 municipalities [3]. Many small industrial establishments are not required to monitor and report N and P. Bearing in mind the lack of any plant-specific information and the great diversity of industries, no attempt was made to estimate the unreported loads. It is therefore certain that the industrial source loads reported in the Polish PLC-7 report are underestimated, although the level of underestimation is probably not very high, considering that it is clear from PLC-6 that the bulk of e.g. the N load comes from just a handful of chemical plants.

2.11 Indirect aquaculture sources (I_AQS)

Although aquaculture was reported as a separate source in PLC-6, the list of farms included only 5 items, either due to lack of access to individual fish farm data or due to the fact that the vast majority of fish farms do not monitor or report N and P. Due to statistical confidentiality regulations it was not possible to gain access to data on individual fish farms for the purposes of PLC-7. Instead, official statistical data on fish production (NUTS-2 level) [3] and information on the location of about 230 individual salmonid farms [4] was used to estimate the distribution of salmonid production among the sub-catchments. Since no fish feed data was available, N and P loads were estimated using unit loads of 60 kg N/ton of fish and 9 kg P/ton of fish. The unit loads are based on a survey of European, including Polish, publications on nutrient emissions from salmonid farms [5, 6, 7, 8, 9].

In addition to salmonid (almost exclusively rainbow trout) farms, Poland has a strong carp farming sector with an output similar to that of trout farms. However, data on whether these carp farms, which generally represent a much less intensive form of aquaculture, act as sources or sinks of nutrients, is inconclusive [9, 10, 11, 12]. Therefore, the Polish PLC-7 report omits these farms, which amounts to assuming that they have a zero net balance of nutrients.

2.12 Natural background (NBS)

The Polish PLC-6 methodology [1] does not mention natural background. However, natural background loads have been specified in the PLUS database. It is rather clear that this confusion is the result of the “rebranding” of loads from managed forestry and wasteland and presenting them in the database as natural background loads.

In PLC-7, natural background has been clearly separated from managed forestry and wasteland loads. Natural background concentrations of nutrients in waters feeding the river system have been set at 0,02 mg P/l (irrespective of soil type) and at 0,15 mg N/l, 0,36 mg N/l and 0,60 mg N/l for highly permeable, moderately permeable and poorly permeable soils, respectively. For atmospheric deposition, the value of 1,2 kg N/ha x y was used (P deposition was ignored). These concentrations and loads have been selected basing on a review of European and US literature on natural background concentrations in regions with comparable soil and climatic conditions [13, 14], on data from relatively undisturbed small Polish catchments [15] and on global pre-industrial N deposition data [16]. In the context of the Polish PLC-7 report, the term "natural background" should be interpreted as referring to pristine conditions with no anthropogenic pressures, including anthropogenic atmospheric deposition of nutrients. Considering the history of man-made deforestation, the last time near-pristine conditions prevailed in today's Poland was 1-2 thousand years ago [17].

2.13 Agriculture (AGS)

In PLC-7, similarly as in PLC-6, estimates of losses from agriculture are based on the results of a countrywide groundwater and tile drainage water monitoring programme under which nitrates and phosphates are measured in spring and autumn [18].

Loads from agriculture were estimated for all land falling into code category 2 of CLC2018.

Nitrogen

With regard to nitrates, mean concentrations from 583 monitoring points with data for both spring and summer were used. The number of monitoring points per HELCOM sub-catchment varied greatly, from 345 for the SCPL00023 (Vistula) to 0 for nine unmonitored parts of rivers. It is clear that with N concentrations strongly dependent on strictly local conditions (not least the fertilizer application rates on particular plots), only large datasets can be trusted to provide mean concentrations representative of the individual sub-catchments. Such datasets were available for Vistula (SCPL00023) and Oder (SCPL00009), but not for the remaining sub-catchments. Therefore, it was necessary to aggregate the small sub-catchment datasets so as to calculate more robust means, although this was obviously at the expense of ignoring any real differences between the sub-catchments. And so, data from the monitored sub-catchments of the smaller rivers were aggregated to obtain mean concentrations in "the Lakeland belt", while data from the unmonitored sub-catchments were aggregated to represent "the coastal belt".

Table 1. Mean nitrate nitrogen concentrations in farmland groundwater and tile drainage water in 2018.

Area	Mean N-NO3 concentration [mg N/l]	Number of monitoring points
„Coastal belt" (BAPPLAND + unmonitored rivers)	2,69	20
Oder (SCPL00009) + Ina (SCPL00003)	7,10	155
„Lakeland belt" (monitored 54akeland rivers)	3,49	63
Vistula (SCPL00023)	5,04	345

Nitrates in farmland groundwater and tile drainage represent the majority, but not all of the nitrogen load from agriculture. In order to roughly account for the rest of the load, results of a MONERIS modelling exercise covering the period 2003-2008 [19] were used. According to that study, groundwater and tile drainage account for 85% and 90%, respectively, of the transport of N to surface waters in the Vistula and Oder basins, while the remaining 15% and 10%, respectively are accounted for by surface runoff and erosion. In order to take this into account, the nitrogen loads obtained by multiplying sub-catchment flows by the concentrations in Table 1 were further multiplied by appropriate factors.

The final step in the calculation of N loads from agriculture was to deduct natural background losses (see point 2.4 above) from the farmland loads.

Phosphorus

The approach to estimating phosphorus loads from agriculture was basically the same as in the case of nitrogen. There was, however, one major difference. Whereas in the case of N, groundwater and tile drainage water monitoring data for 2018 was available, in the case of P, it was not. Consequently, we had to use 2012 and 2016 P datasets (the only ones made available to us) to infer from them concentrations that could be representative for 2018. The rejected alternative was to use a method completely different from that used for N and completely unrelated to any P monitoring data.

The 2012 and 2016 datasets for N and P were analysed for any relationships, both on individual monitoring point and sub-catchment level, between N and P that could be used to “predict” P levels in 2018. It was found (not unexpectedly) that no correlation existed between N and P levels or between N and P concentration trends from 2012 to 2016, or between P concentrations and flows. In view of the above, the 2012 and 2016 concentrations were averaged, and the means were used as “proxy” concentrations for the 2018 estimate:

Table 2. Mean phosphate phosphorus concentrations in farmland groundwater and tile drainage water in 2012 and 2016 and “proxy” concentrations used for the 2018 estimate.

Area/year	Mean P-PO4 concentrations [mg P/l]		
	2012	2016	“proxy” 2018 values
„Coastal belt” (BAPPLAND + unmonitored rivers)	0,38	0,67	0,53
Oder (SCPL00009) + Ina (SCPL00003)	0,42	0,72	0,57
„Lakeland belt” (monitored 55akeland rivers)	0,35	0,43	0,39
Vistula (SCPL00023)	0,29	0,28	0,29

Phosphate phosphorus in groundwater and tile drainage water represents only a part of the P load from farmland. As with nitrogen, in order to roughly account for the rest of the load, results of a MONERIS modelling exercise covering the period 2003-2008 [19] were used. According to that study, groundwater and tile drainage account for only 28% and 22%, respectively, of the transport of P to surface waters in the Vistula and Oder basins, while the remaining 72% and 78%, respectively are accounted for by surface runoff and erosion.

In order to take this into account, the phosphorus loads obtained by multiplying sub-catchment flows by the concentrations in Table 2 were further multiplied by appropriate factors, which were 2,63 for the Vistula basin, 3,47 for the Oder basin and an intermediate value (3,01) for the remaining sub-catchments. Obviously, the resulting total loads were much higher than e.g. those reported in previous PLC reports. However, these results did not take into account the fact that a large portion (an overwhelming majority, according to some studies) of the P loads associated with surface runoff and erosion is irrelevant from the point of view of eutrophication, because it consists of particle-bound P which is not only non-bioavailable, but also sinks to the sediments of whichever water body it happens to enter. Thus, although this portion of the load may be recorded as entering surface waters, it in fact disappears from the water almost immediately upon entering. To account for this, the assumption was made, basing on literature [20, 21, 22, 23], that 90% of the P load from surface runoff and erosion is immediately deposited in the sediments and/or non-bioavailable and that only 10% should be included as relevant for the riverine load estimates. The opposite approach, i.e. the inclusion of particle-bound non-bioavailable P in the load calculations, would have resulted in very high overall P retention coefficients and in a gross overestimation of the real importance of agricultural sources of P.

The final step in the calculation of P loads from agriculture was to deduct natural background losses (see point 2.4 above) from the farmland loads.

2.14 Urban surface runoff and combined sewer overflows (SWS)

Urban surface runoff loads were estimated for all land falling into code category 1 of CLC2018. Concentrations of 2,0 mg N/l and 0,35 mg P/l were used basing on extensive US surveys [24, 25,26]. The scarce Polish data available [27] confirms that these are realistic figures. Since all types of settlements, as well as quarries, airports etc. (not just the most densely built-up cities) were taken into account, a relatively low surface runoff coefficient of 0,2 was used in the calculations (i.e. it was assumed that on average 20% of the water flow from urbanized areas comes in the form of surface runoff).

In Poland, combined sewer overflows (CSOs) are a relatively minor problem due to the small share of combined sewers in the country. Even though the law limits the number of CSO events to 10 per year, there is no monitoring of the frequency of CSO events, not to mention volumes or pollutant loads. A study on CSOs in the city of Łódź [28, 29] is a rare Polish example of a major effort to quantify the scale of CSO frequency, volumes and loads. Rather surprisingly, the study showed practically no difference between dry weather and wet weather concentrations, which may be attributed to the flushing of sediments in the sewers. In terms of the volume discharged in CSO events annually, it may be estimated at almost 7% of the dry weather wastewater volume. With regard to European literature, CSO volumes and loads (expressed as % of total annual volumes and loads) vary greatly, but typical loads seem to be close to 5% of N and P discharged to the combined sewer systems [30, 31, 32, 33, 34, 35]. According to an Irish study [36], CSOs contribute 12% and 10%, respectively, to the country's total wastewater emissions of P and N.

For the purposes of the Polish PLC-7, a tentative figure of 5% of the total N and P load discharged to combined sewers has been adopted as the basis for estimating CSO loads. Loads discharged to combined sewer systems were very roughly estimated from the share of combined sewers in total (sanitary + combined) sewer length in the approximately 350 Polish cities and towns that do have combined sewers [2].

2.15 Scattered (unsewered) dwellings (SCS)

The number of people not connected to municipal wwtps was determined for about 2500 municipalities (NUTS-2 level) basing on official statistics [3]. According to the same source, the vast majority (90%) of such unconnected households use closed (i.e. theoretically watertight) septic tanks and only 10% have some form of household wwtps. Anecdotal knowledge of the Polish household wwtp market permits us to assume that of the 10% with wwtps by far the most (probably more than 90%) use septic tanks with some form of legal effluent drainage (sand filter etc.).

Basing on official statistics on household water consumption and on the volumes of septic tank wastewater delivered to municipal wwtps [3], the percentage of wastewater reaching municipal wwtps from unsewered areas was estimated at 7%. Considering the low nutrient removal rates in household wwtps, the N and P loads discharged to the environment from unsewered areas were assumed to be 90% of the total N and P loads generated by people in such areas. The total N and P loads were in turn estimated using unit loads of 11,01 g N/person x day and 1,67 g P/person x day (see point 2.1 above).

The most error-prone part of the calculations of loads from unsewered settlements is the determination of the share of the load that reaches surface waters. For the purposes of PLC-7, this share was determined on the basis of the share of nutrients reaching surface waters from fertilizer application. Loads of N and P contained in mineral fertilizers were taken from official statistics [37]. Loads of N in natural fertilizers were estimated using official stats on the amounts of solid manure, liquid manure, slurry and rough unit loads of 3,5 kg N/ton of solid/liquid manure and 7 kg N/ton of slurry/bird manure. Loads of P were estimated on the basis of the N/P ratio, determined in a more detailed calculation based on 2015 figures [38]. Nutrient uptake by crops was assumed to be 56% and 70% for N and P, respectively, basing on official 2016 statistics [3] and other literature on Polish agriculture [19]. According to these calculations, the loads of N and P that reached surface waters from farmland in 2018 were equal to 9,88% and 3,56%, respectively, of the N and P applied to farmland, and 22,38% and 7,77% of the N and P surplus. The latter figures, i.e. 22,38% of N and 7,77% of P were used for estimating the load of nutrients that made the distance from septic tanks to surface waters. Since one should expect that nutrients from illegal discharges of septic wastewater are generally less available to plants than nutrients from fertilizers (not least because illegal septic wastewater discharges are typically located well below the root zone of most crops), the results probably overestimate the actual loading of surface waters by nutrients from unsewered areas.

2.16 Direct atmospheric deposition (ATS)

Estimates of direct atmospheric deposition to surface waters (ATS) were made for all waters under code category 5 of CLC2018. N and P deposition monitoring results from 22 stations were extrapolated over the entire country using Voronoi polygons. The loads calculated for the sub-catchments were corrected for natural background deposition (see point 2.4 above).

2.17 Managed forestry and wasteland (MFS)

All land in code categories 3 and 4 of CLC2018 was taken into account in the estimate. The value of 0,038 mg P/l was adopted as representative for water from all forests and wasteland, regardless of soil type. With regard to nitrogen, the values 0,31 mg N/l, 0,75 mg N/l and 1,22 mg N/l were used for highly permeable, moderately permeable and poorly permeable soils, respectively. All the cited values are flow-weighed concentrations obtained from a number of different studies carried out between the late 1970's and the early 2000' in small, relatively undisturbed forest and wasteland catchments [15]. The values were established as early as PLC-4 and have been used since then to calculate loads from forests and wasteland.

The final step in the calculation of loads from forests and wasteland was to deduct natural background losses (see point 2.4 above) from the farmland loads.

3. SOURCES IN UNMONITORED AREAS

Sources in unmonitored areas were quantified in exactly the same way as sources in monitored areas (see point 2 above).

4. TRANSBOUNDARY LOADS

4.1 Incoming loads

Poland receives transboundary loads from the following sub-catchments:

- SCSL00001 Vistula (Slovakia)
- SCUA00001 Vistula (Ukraine)
- SCBY00004 Vistula (Belarus)
- SCCZ00001 Oder (Czech Republic)
- SCDE00035 Oder (Germany)

Loads from SCSL00001 were calculated basing on Dunajec and Poprad rivers flow and concentration data provided by Slovakia. The monitoring stations used account for virtually 100% of the Slovakian load.

Loads from SCUA00001 come from the catchments of the Bug and the San, both of which run partly along the Polish-Ukrainian border. The load from the Bug catchment was measured on the basis of flow and concentration data at the Włodawa H&C monitoring station and the load was apportioned to Ukraine in proportion to Ukraine's share in the catchment area upstream from Włodawa. Since there are no suitable monitoring stations on the San, the load from the small Ukrainian part of the San catchment was estimated from the ratio of the Ukrainian parts of the San and the Bug (i.e. it was assumed that the unit loads per km2 from the San are identical as those from the Bug)

Loads from SCBY00004 come mainly from the Bug catchment and partly from the Narew catchment. The load from the Bug catchment was measured on the basis of flow and concentration data at the Krzyczew H&C monitoring station and the load was apportioned to Belarus in proportion to Belarus' share in the catchment area between Włodawa and Krzyczew. The monitoring station in Krzyczew is not ideally positioned (i.a. a small share of the load measured there is actually exported from Poland to Belarus and then reexported back to Poland), but it gives a fairly good approximation of the real situation. Since there are no suitable monitoring stations on the Narew, the load from the small Belarussian part of the Narew catchment is estimated from the ratio of the Belorussian parts of the Narew and the Bug (i.e. it is assumed that the unit loads per km2 from the Narew are identical as those from the Bug)

Loads from SCCZ00001 were estimated on the basis of flows and concentrations in the Oder (Chałupki H&C station) and the Olza (Łaziska H&C station) on the Polish side of the border. These two monitoring stations account for 75% of the area of SCCZ00001. The load from the unmonitored parts of SCCZ00001 (1804 km2, mostly in the Sudety Mountains) HAS NOT been taken into account in PLC-7 and has most probably been disregarded in all of Poland's reporting to date.

Loads from SCDE00035 were estimated solely from the ratio of the SCDE00035 to the total area of the Oder catchment upstream from the Gozdowice H monitoring station. The value of the ratio is 5%.

4.2 Outgoing loads

Poland exports loads to Lithuania (the Nemunas SCPL00025) and Russia (the Pregolya SCPL00026).

Of the 2512 km2 of SCPL00025, 1872 km2 are monitored on the rivers Czarna Hańcza (Jałowy Róg H station and Śluza Kudrynki C station) and Szeszupa (Poszeszupie H&C station).

Of the 7181 km2 of SCPL00026, 6749 km2 are monitored on the rivers Łyna (Sępopol H station and Stopki C station), Węgorapa (Mieduniszki H&C station) and Guber (Prosna H station).

The river loads from the unmonitored parts of Nemunas and Pregolya were estimated using: a) source load data; b) flows estimated from the ratio of the area of the unmonitored to the monitored part, c) retention coefficients estimated as described in point 5 below.

5. RETENTION

Retention coefficients and retention of loads in monitored sub-catchments (including the monitored parts of Nemunas (SCPL00025 and Pregolya (SCPL00026) were calculated using the mass balance method, i.e. retention was assumed to be equal to the difference between the sum of loads at sources and the load measured in the river.

Retention coefficients for the unmonitored sub-catchments (including the monitored parts of Nemunas (SCPL00025 and Pregolya (SCPL00026) were calculated as follows:

$R_U = R_M \times A_U/A_M$, where:

R_U – retention coefficient for the unmonitored sub-catchment

R_M – retention coefficient for the respective monitored sub-catchment

A_U – area of the unmonitored sub-catchment

A_U – area of the respective monitored sub-catchment

The R_U retention coefficients were applied ONLY to loads from sources in the unmonitored sub-catchment and NOT to the loads from the upstream monitored sub-catchment. This is tantamount to the assumption that there is virtually no retention in the section of the river between the last monitoring station and the river mouth, but that retention does take place within the unmonitored sub-catchment en route from the sources to the main river.

The PLC-6 methodology report suggests that the Behrendt & Opitz (1999) method was used by Poland for the PLC-6. While the Polish documentation of the PLC-6 work indeed mentions the Behrendt & Opitz method, analysis of the available PLC-6 calculations show that the method was NOT the basis for calculating retention and that a simple mass balance approach was used instead. An exercise carried out in 2015 [39] demonstrated that the Behrendt & Opitz method greatly underestimates retention, at least when applied to Poland and Corine-based land use data.

6. LOAD APPORTIONMENT

The loads reaching the Baltic Sea were apportioned according to their source using a method that assumes that the retention coefficients of nutrients from different sources are not equal. The sources have been divided into two groups, namely:

- Group 1: I_MUN, I_IND, I_AQU, ATS, TRS., i.e. municipal point sources, industrial point sources, aquaculture, atmospheric deposition and transboundary loads
- Group 2: SWS, SCS, AGS, MFS, NBS, i.e. urban surface runoff and overflows, wastewater from scattered (unsewered) areas, agriculture, managed forestry and wastelands and natural background loads

Group 1 includes sources the loads from which are discharged directly into surface waters, usually into rivers and lakes of substantial size. It may be said that in the case of these sources, soil retention and retention in very small water bodies (drainage ditches, small ponds, puddles etc.) plays virtually no role. This is also true for ATS, since ATS was only calculated for water bodies shown on the CLC2018 land use maps which only show relatively large lakes and rivers.

Group 2 includes sources the loads from which must typically travel considerable distances through soil and/or along very small water courses in order to reach main rivers. This is only partly true for SWS, since combined sewer overflows (SCO) discharge wastewater straight into rivers, but this fact has been ignored for simplicity, since SCO events comprise less than 40% of the total SWS loads and the SWS loads comprise less than 1% and less than 2% of the total N and P source loads, respectively.

Riverine load apportionment was calculated according to two extreme scenarios:

- Scenario 1: retention coefficients for all the sources are equal, i.e. the fact that loads from Group 2 (e.g. agriculture or unsewered areas) need to travel long distances with groundwater or via very small water bodies does not increase their retention coefficients as measured in the main rivers
- Scenario 2: retention coefficients for Group 1 are equal to 0 and all the observed retention is attributed only to Group 2 sources in proportion to the different Group 2 loads.

The reality is almost certainly somewhere between these two scenarios, but since there is no reliable way of telling where that point is, mean river load apportionment values were calculated from the two scenarios and adopted as the final result of the apportionment exercise.

7. UNCERTAINTY

Uncertainty of concentration measurements is given in the Polish 2018 annual report. No total uncertainty estimates have been reported by Poland for PLC-7.

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Russia

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In general, Russia follows the methodology described in the PLC-6 guidelines.

Calculation of flow and loads (rivers, direct point sources)

The annual monitored river discharges for nutrients were calculated by multiplying the monthly concentration by the monthly flow and summing up the monthly loads (equation 4.2 from the PLC-6 Guideline). Initial data (flow and concentrations values) provided within state monitoring. In cases, there some of the parameters are missing in the monitoring programme the specific estimates have been used (e.g. Pregolya river total nitrogen and total phosphorous concentrations were obtained from the BASE Project and Soils2Sea Project screening activities), as well as models (such as HYPE and FyrisNP).

Direct point sources load obtained from the state statistical reporting, based on the continuous measurements implemented by nature users.

Inputs from unmonitored areas

Estimation of the nutrient pollution from unmonitored areas has been implemented using HYPE and FyrisNP models.

Source apportionment (load and source oriented approach)

Source apportionment for big catchments like Neva and Narva rivers (case 1) implemented using Institute of Limnology Loading Model. HYPE and FyrisNP models were used to assess sources contribution in Kaliningrad region and smaller river cathcmnts belonging to the Gulf of Finland basin (case 2).

The basic components of the total annual load on catchment (Ltot) of Ptot and Ntot are the loads from point sources (Lp), diffuse load from agricultural production in the area (Lagr), diffuse emission of nutrients from various types of land surface not effected by agriculture (Le), atmospheric deposition (La):

$$L = \left(L_{agr} + L_{c} + L_{P1} + L_{a}\right), \tag{1}$$

For both cases, the point sources include the discharges of sewage waters of the industrial, agricultural and municipal enterprises. The official source of data on sewage discharges are state statistical forms ("2TPVodhoz").

The diffuse load on catchment from the emission of nutrients from various types of land surface (natural and anthropogenic) excluding agricultural areas Lc is calculated as follows:

$$Lc = (Cu\,Au + Cnat\,Anat + Cmix\,Amix)\,y/1000, \qquad (2)$$

where Cu, Cnat and Cmix are the specific concentrations of nutrients in runoff from urban areas, the natural land surface and mixed areas, accordingly [mg l -1],

Au, Anat and Amix are the areas of the mentioned types, respectively, of a land surface [km^2], y is a runoff from the catchment [mm year^{-1}].

In case 1 urban areas represent the input from sparse population that is not connected to sewer networks and treatment facilities. Values of *y* from the whole catchment or its parts can be taken from measurements or calculated using distribution functions or using a hydrological model.

In case 2 nutrient load from scattered settlements was calculated using Swedish Environmental Protection Agency method, described in (Nutrient loads…, 2006). daily load per capita for N total is 13.5 g, for P total is 2.1 g.

In case 2 area type related concentrations were taken based on Swedish data provided in Kvarnäs, 1996.

Kondratyev (2007) reported that the phosphorus load from atmospheric depositions (La = da A) ranges from 0.002 to 0.005 t km^{-2} y^{-1}. Here, a value of 0.0032 t km^{-2} y^{-1} was used. Value La for nitrogen load is zero, if it is assumed that nitrogen deposition from the atmosphere (loss with deposits + fixed by biota) equals removal by denitrification (Behrendt, Dannowski, 2007).

For both cases, nutrient load generated on agricultural areas, calculated based on the method proposed by Institute of Institute for Engineering and Environmental Problems in Agricultural Production (Saint-Petersburg, Russia). It is possible to calculate loads on receiving water bodies from the particular field, farm or district. The method is fitted for North-West region of Russia conditions and based on following equation:

$$L_{agr} = \sum_{i=1}^{n_1} A_i \left(M_{soil\,i} K_1 + (\alpha_1 M_{\min i} + \alpha_2 M_{org\,i}) K_6\right) K_2 K_3 K_4 K_5 / 1000 \quad , \qquad (3)$$

where M soil i , M min i and M org i – N and P content in the plough layer, as well as amount of organic and mineral fertilizer applied on field, owned by i agricultural enterprise, kg/ha;

Ai – field area, owned by i agricultural enterprise, ha; n1 – number of agricultural enterprises;

α1 – coefficient, related to the uptake of mineral fertilizer by crops;

α2 – coefficient, related to the uptake of organic fertilizer by crops;

K1 – coefficient describing nutrients outflow from plough;

K2 – coefficient describing distance of agricultural areas from receiving water bodies;;

K3 – coefficient for soils type (by origin);

K4 – coefficient describing soil texture;

K5 – coefficient for accounting land use structure;

K6 – coefficient for describing status of applying BAT for application mineral and organic fertilizer by agricultural enterprises.

Farm level calculations were performed for coastal catchments of the Gulf of Finland. For upper parts of the catchments average data by municipal districts was used.

In case 1 bckground (natural) load component [t y^{-1}] is a part of the non-point nutrient load calculated as follows:

$$Lnat = Rt\,[da\,A + yCnatA\,(1-W/100)/1000] \qquad (4)$$

where *da* – coefficient for mass exchange with atmosphere;

W – share of lake area in percentage;

Rt – retention factor.

Retention

In case 1 - for calculation of the discharge of Ptot and Ntot from the catchment and loading on water body L [tons $year^{-1}$] the following equation is used (Behrendt, Opitz, 1999):

$$L=Rt\,Ltot+Ldirect = (1-Rr)\,Ltot +Ldirect =Ltot-Lret+Ldirect, \qquad (5)$$

where Rt and Rr are dimensionless factors of discharge and retention, Ltot is the nutrient load on catchment [t y-1], Lret is the retention by catchment (Lret = Rr Ltot) [t y-1], Ldirect – direct load on water body [t y-1].

$$R_r = k_{cal}\left(1-\frac{1}{1+aHL^b}\right), \qquad (6)$$

Value of the hydraulic load HL is proportional to the specific runoff q [dm3 km^{-2} sec^{-1}] and inversely proportional to the lake percentage W [% of catchment total area]:

$$HL=3.15q/W. \qquad (7)$$

The specific runoff q [dm3 km^{-2} s^{-1}] is determined with the runoff y [mm $year^{-1}$] as follows

$$q = 0.03171\,y. \qquad (8)$$

Transboundary inputs

Transboundary load has been defined based on shares and methods used in PLC 5.5 Project and actual monitoring data for 2017.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainty of total loads and sources has not been estimated.

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Sweden

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Calculation of flow and loads (rivers, direct point sources)

Rivers

Daily water flow and monthly concentrations (interpolated to daily concentrations) are used to calculate the monthly and annual loads for the 38 monitoring stations included in the national monitoring programme on river mouths. These monitoring stations are to some degree supported by other national and regional monitoring sites to support the estimation of loads from unmonitored areas. The monitoring stations are situated somewhat upstream to avoid saltwater intrusions (generally covering 95-100% of the catchment areas). The missing part of the monitored rivers are estimated by extrapolating the area specific loads to cover the whole catchment, which is reported to HELCOM (cf. below Unmonitored areas).

Point sources

Wastewater treatment plants (WWTP) with more than 2000 person equivalents (p.e.) and industries are monitored at the facilities on regular bases by the facility operators. As part of the authorities' control, the facility operators are obliged to report the data to the Swedish Portal for Environmental Reporting (SMP). The number of samples monitored per year may vary for different facility operators and depend on the permits given by the authorities. The facility operator reports the annual loads nationally via SMP and the data reported to Helcom are based on those reports. Fish farms also report load data to SMP. These data are typically estimated by the facility operator based on the fish feed consumption and annual growth of the fish population.

Smaller wastewater treatment plants between 200-2000 p.e. are not obliged to report their data to the authorities, therefor the loads are estimated by multiplying the number of p.e. with a coefficient that is based on the treatment technique used. The coefficient and the estimated incoming nutrient content are adjusted to Swedish conditions.

1 PE is for N=13.7 g/day and for P=1.7 g/day which is combined with a removal in the WWTP according to the table below.

Treatment method	**Removal of phosphorus [%]**	**Removal of nitrogen [%]**
Biological or field based treatment	35	40
Chemical treatment	88	33
Chemical and field based treatment	91	54
Biological and chemical treatment	92	42
Biological, chemical treatment and filtration	97	42
Biological, chemical and field based treatment	97	49
Biological, chemical and extra N removal	99	76

Inputs from unmonitored areas

For minor river systems that do not have any national monitoring site in the lower parts of the rivers the loads are estimated with the area-specific load from other adjacent and similar monitored rivers.

The load from unmonitored areas downstream monitoring sites are quantified by the area specific loss from the monitored parts, and the loads are included in the amounts given for the monitored areas. Generally, the monitored parts of the rivers cover some 95-100% of the total areas. Though, there are some exceptions like Rönneån where the monitoring station covers only 51 % of the total area. In addition to the area-specific load from the upper monitored area, the load from the unmonitored area is also estimated with the weighted area-specific load from other similar rivers in the area. Weighted area-specific load is used since the catchment area of the lower stretches do generally contain more farmland compared to the forested upper part of the catchment area.

Source apportionment (load and source-oriented approach)

The Source oriented approach.

The load of nutrients (nitrogen and phosphorus) to lakes and rivers has been calculated for about 24,500 Swedish Water Framework Directive (WFD) water body catchments. The general system approach is described in English by Brandt et al. (2009) and specifically for PLC7 in Swedish by Hansson et al. (2019). The load comes from point sources (WWTPs, industries, and fish farms) and from diffuse sources (land use leaching, stormwater, scattered dwellings, and the atmospheric deposition on lakes). Land use leaching (including overland flow) within a catchment is calculated by land use area (km^2) multiplied by runoff ($l/s/km^2$) and a specific concentration describing the concentration in runoff water for the current land use (mg/l). Atmospheric deposition on land surface is included in the specific concentration.

Daily mean runoff has been simulated using the HYPE model in about 39,600 subcatchments for the year 2017. Based on the daily runoff, yearly and monthly average values have been calculated. The load is calculated specifically for year 2017 (crop area, land use area, point source load, runoff and atmospheric deposition).

The specific concentrations for nitrogen and phosphorus leaching from agricultural land have been calculated using the NLeCCS system. NLeCCS, which is a system for calculating normal leakage from arable land, includes the simulation tools SOILNDB (based on SOIL / SOILN models) for nitrogen and ICECREAMDB (based on the ICECREAM model) for phosphorus. NLeCCS system takes into account the most important factors (both farming methods and natural endowments) that affect the leaching of nutrients from agricultural land. Simulation input data include timing and amount of fertilization (both manure and mineral fertilizer), timing of sowing, harvest and ploughing, atmospheric deposition, crop yield, catch crops, buffer zones, climate data, crop rotations, crops, soil type, soil phosphorous content, and soil slope.

Specific concentrations from land use of forest, clear-cut forest, wetlands, alpine and other open land use are based on data from representative areas within the regional and national monitoring programs and on data from targeted monitoring campaigns in Southern Sweden. The specific concentrations are based on data from streams. Constant values or regression equations depending on either level above the sea or coordinates of the sub-catchments are used.

Stormwater surface runoff coefficients and specific concentrations of urban land use comes from the database of the StormTac model. The specific concentrations were geographically adjusted using weighting by the deposition rate of nitrogen.

Diffuse load from scattered dwellings was calculated using the number of inhabitants not connected to wastewater treatment plants, load per person, reduction efficiencies of treatment techniques and municipal information on the treatment techniques used.

Deposition of nitrogen on lake surfaces is based on calculations using the MATCH model and assimilated data, while the deposition of phosphorus is a median value for all of Sweden based on monitoring data.

Point source load is calculated based on direct measurements at the facility (including data reported to SMP). Load from small point sources of wastewater treatment facilities are calculated based on loads with regard to other data, such as type of treatment technology and number of persons equivalents connected and load per person.

The load-oriented approach.
The net load to the sea was calculated with retention modelled using the SMED-HYPE model for all 39,600 sub-catchments. The total source apportioned load calculated to the river mouths was weighted to the total PLC annual river load reported in monitored and unmonitored rivers, and all sources were adjusted according to the weight.

As far as it was possible, the same methodology was used in the PLC6 and PLC7 calculations. However, one difference in methodology that should be noted is the calculation of the background load of phosphorus from agricultural land. In PLC6 a high background load was calculated because an update of the model turned out to give a presumably too high loss of particulate phosphorus. This has been corrected in the latest model version (PLC7) which is one of the reasons why the background load in PLC7 is lower than in PLC6. There are also other differences between the PLC6 and the PLC7 methods and the reported source apportionment is thus not comparable.

Retention

The retention from source to sea was calculated using the SMED- HYPE model in all 39,600 sub-catchments. SMED-HYPE retention builds upon the HYPE-model (Lindström et. al., 2010). In lakes and rivers, the nutrient processes are described similarly in both HYPE and SMED-HYPE. The major differences are the model descriptions of the diffuse leaching from land (SMED_HYPE land use leaching coefficients described in the source oriented approach above) and the local river retention. Internal load from the lake sediments (negative retention) was reported for lakes where the mass balance was supported by inlet to outlet monitoring data.

Transboundary inputs

Swedish catchments do not contribute to any significant transboundary output to the neighbouring countries. The load from Norwegian and Finnish catchments contributing to

Swedish catchment was calculated using Corine Land Cover as land use representation, thus not including anthropogenic land use sources. Transboundary load was not reported by Sweden in PLC7. Additional calculations have been performed to better represent the transboundary anthropogenic sources contributing from Norway and Finland to Swedish catchments.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

The uncertainty of sources has large variations due to the different underlying data and model performances. The uncertainty of sources has not been reported by Sweden for the PLC7 report.

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Annex 1

Details on the models used by contracting parties with an overview on main in-data and out-data, resolution of these data and model resolution. Elaborated by Michal Pohl, Swedish Agency for marine water and management (SWAM), based on inputs from PLC-7 IG members.

CP	**model-name**	**purpose**	**main indata**				**Model resolution**		**outdata**			**validation/calibration**	
			type	source	temporal	spatial	temporal	spatial	**type**	**temporal resolution**	**spacial resolution**		**english documents**
Estonia	EstModel	nutrient loads, retention and source apportionment	basin and subcatchment boundaries	national database (EELIS)		vector	per year	per subcatchment	nutrient loads	per year	per subcatchment and landcover	diffuse source load and retention: calibration of nutrient loads against observations per measurement station catchment	
			land cover	Corine	6 year								
			crop type	national database (PRIA)	per year								
			soil types	national KeMIT GeoServer		1:10 000							
			drainage	national KeMIT GeoServer	per year								
			harvesting	national KeMIT GeoServer	per year				retention	per year	per subcatchment and landcover		
			fertilizer usage	expert judgement	per year								
			atmospheric deposition	observed and calculated by EKUK		nationwide							
			flow observations	national database (Estonian	per day	53 stations							

				weather service)									
			nutrient observations	national database (KESE)	12 times per year	52 stations							
			Pointsources	national database (KOTKAS)	per quarter	for each site							
			livestock	national database (PRIA)	per year								
Finland	VEMALA (including SYKE-WSFS, ICECREAM, lake biogeochemical model, forest model)	nutrient leaching, export, retention, source apportionment	Hydrology	modelled with SYKE-WSFS	monthly-weekly	all stations	daily	catchment 4th division	nutrient concentrations , loads	daily	catchment 4th division		A National-Scale Nutrient Loading Model for Finnish Watersheds—VEMALA | SpringerLink
			Pointsources	National point load register YLVA	monthly-annual	national							
			scattered settlement load	Built environment register	annual	national							
			land use	CORINE									
			retention in lakes	modelled with VEMALA v3 lake									
			nutrient loads agricultural soils	modelled with ICECREAM									
			nutrient loads from forest soils	modelled with Non-agricultural area model									
	SYKE-WSFS	hydrological modelling	meteorology	Finish Meteorological Institute	daily	all stations	daily	catchment 3th division	runoff	daily	catchment 3th division		A National-Scale Nutrient Loading Model for Finnish Watersheds—VEMALA | SpringerLink
			elevation		-	national							
			hydrology	SYKE	daily	all stations							
	VEMALA v3 lake biogeochemical model	nutrient cycle in lakes (retention)	water quality	SYKE	monthly-weekly	all stations	daily	water body	nutrient concentrations in lakes, retention	daily	water body		http://doi.org/10.1016/j.jhydrol.2017.03.050
			meteorology	Finnish Meteorological Institute	daily	all stations							
			hydrology	SYKE	daily	all stations							

	ICECREAM	nutrient cycle in agricultural cultivated soils	field slope	DEM 2m x 2m		field	daily	field scale	agricultural loading	daily	field scale		[A National-Scale Nutrient Loading Model for Finnish Watersheds—VEMALA | SpringerLink]()
			field soil texture	Soil testing laboratories		field							
			field STP level	Soil testing laboratories		field							
			crops for fields	Finnish Food Authority	annual	field							
			mineral fertilizer usage	National statistics	annual	Regional centers							
			manure fertilizer usage	Finnish Food Authority	annual	farm							
	Non-agricultural area model	nutrient loads from forest soils	forest ditching	Metsäkeskus	annual	Regional centers	daily-annual	catchment 4th division	forestry loading, natural background loading	daily-annual	catchment 4th division		
			forest fertilization	Metsäkeskus	annual	Regional centers							
			forest clear-cut	Metsäkeskus	annual	Regional centers							
Lithuania and Poland	SWAT	source apportionment, retention and nutrient model (unmonitored areas)	atmospheric deposition (N)	national statistics	per year	nationwide	per day	HRUs (hydrological responce units)	nutrient loads	per year	per (sub-)basin		[https://vanduo.gamta.lt/files/3%20priedas_SWAT%20modelis_20150817_SD.doc]()
			basin boundaries	observed	per day	per (sub-)basin			retention	per month	per riverbranch (defined in GIS -0.2 km - 99999 km)		
			crop type	observed and extrapolated	per hour	per riverbranch							
			drainage	maps		per tile							
			elevation	expert judgement									
			fertilizer usage	modelled									
			hydrology						runoff	per day			
			land cover	Corine					source apportionment				
			flowdata/hydrology										
			land use										
			lifestock-density										
			point sources										
			precipitation										
			slope										
			soil types										

			temperature topography yields (agricultural) wind humidity Soil P content solar radiation channel width										
Poland	MIKE HYDRO Basin	river discharge	basin boundaries	expert judgement	per day	per basin	per day	per basin	river discharge in points where are no measurements	per day	per basin	model calibrated	MHydro_Basin_printed.book (mikepoweredbydhi.help)
			drainage	modelled		per riverbranch		per riverbranch			per riverbranch		
			evapotranspiration	observed and extrapolated									
			hydrology	query									
			elevation										
			precipitation										
			temperature										
Sweden	HYPE	runoff, retention, nutrient loads and source apportionment	precipitation and temperature	PTHBV map based on observations	daily	4 km grid	daily	hydrological response units	runoff	daily	per subcatchment and landuse	runoff: calibration against observations	https://www.tandfonline.com/doi/full/10.1080/02626667.2011.637497
			sub-catchments	national SVAR database		median size ~7km2							
			land cover and land use	combination of maps		mixed							
			soil type/texture	combination of maps	-								
			P & N deposition	MATCH model (N) or average from observations (P)		20 km grid			retention	average	subcatchment	retention: calibration of nutrient concentrations	https://iwaponline.com/hr/article/41/3-4/295/822/Development-and-testing-of-

			nutrient loads agricultural soils	modelled with NLeCCS	climate normalized	per crop and soil type (for P also for different slopes and soil P content) of 22 agricultural regions						against observations	the-HYPE-Hydrological
			nutrient load from urban land	calculation based on among others the StormTac database, a query about municipal urban water cleaning and spatial information of cities									
			dam regulations	various sources including dam operators									
			Pointsources	national registers, survey, population statistics and data on treatment technique effectivity									
			Scattered dwellings	survey, population and estate statistics and data on treatment technique effectivity					nutrient loads	daily	per subcatchment and landuse		HYPE information and code: https://hypeweb.smhi.se/
			lake information	SVAR database	-	>35000 lakes							
			Flow observations	SMHI	daily	~450 stations							

			Nutrient observations	SLU national data repository	weekly-monthly	>1000 sites							
	NLeCCs	nutrient loads from agricultural land, climate normalized	nitrogen deposition	MATCH model	yearly	20 km grid	daily	field	nutrient leaching coefficients	climate normalized	per crop and soil type (for P also for different slopes and soil P content) of 22 agricultural regions	N: no calibration (uses database of earlier calibrated soil parameters)	https://pub.epsilon.slu.se/16179/7/johnsson_h_et_al_190527.pdf
			crop distribution	national statistics	year	agricultural region based on IACS field data							
			yields	national statistics based on query	normalised year	agricultural region based on yield regions							
			fertilizer input (manure and commercial)	national statistics based on query	year								
			agricultural management	national statistics based on query	year								
			climate data	observed	day based on hourly data								
			runoff	simulated with HYPE	long-term average based on daily data								
			soil types	map extrapolated from observations	-	agricultural region						P: calibration of detachment of P from observation fields	
			field sizes	IACS	year	field							
			slope	map (laser scanning)	-	sub-catchment							
			soil P content and sub-soil P content	map extrapolated from observations	-	agricultural region							
	MATCH	Nitrogen deposition	obsereved nitrogen deposition	observations					wet and dry deposition of NOx and NHx	year	20 km grid		http://www.smhi.se/en/research/research-departments/air-quality/match-
			climate data	observations									

			initial and border conditions	observations									transport-and-chemistry-model-1.6831
Germany	MoRE (Modeling of Regionalized Emissions)	calculation nutrient and pollutant emissions via pointsources and diffuse pathways to surface waters (annually) on catchment level	basin boundaries	hierarchically: small analytical units - WFD Subunits and RBD - marine catchments (Baltic Sea and North Sea)			annually	smallest resolution (analytical units) witch average size 130 km²	pathway specific emissions (point sources, diffuse pathways) for each analytical unit (nutrients and pollutants (e.g. metals, PAH, Diuron,….)	annually	pathway specific emissions for each analytical unit	using river loads for model result validation	https://isww.iwg.kit.edu/english/MoRE.php
			atmospheric deposition N	EMEP									
			atmospheric deposition P	constant value									
			land use	CORINE	2012	25 ha							
			soil types	harmonized national data set (BÜK1000)		1:1,000,000							
			elevation	NASA (2005)		100x100m							
			drainaged areas	estimation		% of agricultural land on federal state level							
			N-surplus calculated based on agricultural data (life-stock, yields, fertilization)	national statistics on NUTS3-Level	annually	NUTS3							
			UWWTP	UWWTD-data (Plants > 2,000 p.e.) and statistical information for plants < 2,000 p.e. and scattered dwellings	UWWTD-circle (every two years)	> 2,000 p.e. on point source level, < 2,000 p.e. on LAU1/LAU2 level							
			Industries	PRTR	yearly	facility level							
			meteorological data (precipitation, temperature, etc.)	national data set (DWD)									

			water quality data (for model calibration)	national data set (federal state data)									
			flow (for hydrology)	national data set (federal state data)									
			erosion (USLE)	divers input data to calculate single USLE factors									
			soil content P	data from federal states		varying (depending on data availability in federal states)							
Russian Federation	Institute of Limnology Load Model (ILLM)	source apportionment and retention & nutrient model (unmonitored areas)	land cover and land use	geospatial data from satellite imagery	-	per sq.km	annually	per sub-basin	nutrient loads	per year	per riverbranch (defined in GIS -0.2 km - 99999 km)	modelled data against direct measurements	Appendix 3a. BaltHazAR II project, Component 2.2: Building capacity within environmental monitoring to produce pollution load data from different sources for e.g. HELCOM pollution load compilations. Modelling the Luga river. http://helcom.ru/media/Annex%203a_eng.PDF
			input from agriculture	modelled by IEEP model	per year	per municipal district within sub-basin							
			retention coefficients	results of the earlier studies (from articles etc.)	per year	per basin			retention	per year	per riverbranch (defined in GIS -0.2 km - 99999 km)		
			point sources input	statistical data available by query in aggregated form	per year	per sub-basins			source apportionment	per year	per riverbranch (defined in GIS -0.2 km - 99999 km)		
			run-off	direct measurements data	per year	per month							
			leaching coefficients for different land cover/use (except agriculture lands)	results of the earlier studies (from articles etc.)	constant	per basin							
	IEEP model	N and P losses from agriculture (fields)	amount of organic fertilizer applied on field	official statistical data	per year	per municipal district	anually	per field/municipal district/basin	N and P loss to water via surface and	per year	per riverbranch (defined in GIS	calibration included during	https://www.researchgate.net/publication/323802151_CONT

						within sub-basin			subsurface runoff		-0.2 km - 99999 km)	ILLM model run only (above)	RIBUTION_OF_AGRICULTURAL_SOURCES_TO_NUTRIENT_LOAD_GENERATED_ON_THE_RUSSIAN_PART_OF_THE_BALTIC_SEA_CATCHMENT_AREA
			amount of mineral fertilizer applied on field	official statistical data	per year	per municipal district within sub-basin							
			soil type/texture	soil maps	-	per sub-basins							
			crop type	official statistical data	per year	per municipal district within sub-basin							
			topography (distance to receiving watercourse)	land use maps from satellite	-	per sq.km							
Denmark	DK-QNP (the Q is obtained from national water resources model (DK-model) below	Estimating Nutrient load (TN, TP), retention, source apportionment	Nitrogen surplus		Year	National	monthly	ID15	Nitrogen load/runoff	Monthly Year	ID15-subcatchment Subbasin National	Calibration against observations	
			Precipitation	DMI	monthly	10X10km grid							
			Temperature	DMI	monthly	20x20 km grid							
			Landuse	National Field repository	year	Field							
			Drainage percentage	National Soil repository									
			soiltype	National Soil repository									
			Subcatchments	DCE subcatchment-data repository		Mean size 15 km2							
			Flow observations	ODA DCE-national surfacewater data repository	daily	250 sites							

			Nutrient observations	ODA DCE-national surfacewater data repository	Monthly	250 sites							
			Nutrient load Aquaculture	PULS national data repository	year								
			Nutrient load Industries	PULS national data repository	year								
			Nutrient load waste water treatmentplant >30PE	PULS national data repository	Year								
			Nutrient load storm-water outlets	PULS national data repository	Year								
			Nutrient load scattered dwellings	National building repository	Year								
			Retention lakes	Retention model	year								
			Retention streams	Expert judgement	year								
			Retention constructed wetlands	Expert judgement	year								
			Flow unmeasured catchment	GEUS : DK-Model (National Water resource model)	Monthly								
	National water resources model (DK-model)	Modelling of water resources in Denmark	Precipitation	DMI	daily	10X10km grid	daily	500x500	groundwater head	daily	500x500m	calibration on disharge and groundwater head 2000-2010, split-sample validation 1990-2000 + 2010-2020 (discharge and gw head). Optimisation of multi object function using	https://doi.org/10.1016/j.envsoft.2012.09.010
			temperature	DMI	daily	20x20km grid							
			potential evaporation	DMI	daily	20x20km grid							
			crop distribution	national statistics	stationary	100x100m grid							
			topsoil types	AAU - DCA	stationary	250x250m grid							
			topsoil lithology	GEUS	stationary	1 to 25.000				daily			

			Hydrogeology in 3D	GEUS	stationary	100x100m grids						gradient based methods (PEST)	
			bathymetry	national gis database	stationary	100x100m grid			streamflow discharge		appr. 45.000 stations		https://doi.org/10.1016/S0022-1694(03)00186-0
			abstraction	GEUS / national well database	year	station (well field)							
			waster water discharge	national gis database	year	station							
			landuse classification	AAU	stationary	10x10m grid			various water balance variables	daily	500x500m		
			river cross sections	counties / GEUS	stationary	station							
			stream discharge	AAU / national gis database	daily	station							
			groundwater head observations	GEUS / national well database	varying (hour-yearly)	station (well intake)							
Latvia	EXCEL-based calculations	estimation of nutrient retention and source apportionment	nutrient loads	LEGMC	year	13 stations	yearly	catchment	retention	year	catchment	estimated values checked against the observed loads	
			flow	LEGMC	year	10 stations			source apportionment	year	catchment		
			subcatchment area	LEGMC									
			area of surface water	Corine	2012	catchment							
			land use types	Corine	2012	catchment							
			nutrient export coefficients	results of the earlier studies									
			retention of transboundary loads	PLC-Water guidelines		catchment							
			point source loads	2-Ūdens national databse	year								