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The Water Emission Inventory planning Support System (WEISS): a quantification of environmental pressures following the path from the emission source to the surface water.

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Abstract: According to the Water Framework Directive, Member States should achieve a good water quality by 2015. Especially in highly urbanized regions like Flanders, it's not easy to attain these standards. In order to formulate cost-efficient mitigation measures, the in depth knowledge of the current status of the quality of water bodies, as well as the location of the most important emission sources is paramount. WEISS is developed to address these questions as part of a LIFE+ project carried out by VITO and the Flemish Environment Agency. It is to support the latter in its monitoring and reporting obligations. WEISS is a shell, highly generic and applicable in European watersheds and regions. It is explicitly spatial in its approach: for Flanders, calculations are made for 2.280.000 grid cells at a 1 ha resolution. WEISS incorporates both point and diffuse emission sources and essentially consists of three modules. The first deals with the spatial distribution of the emissions. To the effect it provides spatial algorithms to allocate surface, line and point sources, depending on the type, the detail and the spatial resolution of the information available in the specific study area. The second represents all relevant routes transporting the emissions, including direct discharges, the sewer system and runoff. The third is an accounting module. It enables consulting and reporting the calculations for specific spatial entities in terms of maps and tables in every node of the transport routes. WEISS stores information for several years and enables yearly and inter-annual computations and comparisons. Parameters can be altered and indicators can be computed to analyze the state of the water system as part of decision support exercises. Among others the location of newly built sewage pipelines, improved efficiency of treatment plants, materials used in buildings and infrastructure, etc. can be experimented with. WEISS is a software shell programmed in C++ and is linked to an MS Access database.

Keywords: *WFD; emission inventory; decision support system; model blocks; diffuse sources*

1 INTRODUCTION

This paper presents WEISS, the Water Emission Inventory planning Support System, which has entered its final stage of development by the Flemish Institute for Technological Research (VITO) and the Flemish Environment Agency (VMM).

The main purpose of WEISS is to support competent authorities across Europe in their monitoring and reporting obligations regarding emission data as part of the existing legislation, in particular the Water Framework Directive (WFD), the Urban Waste Water Treatment Directive (UWWTD) and the European Pollutant Release and Transfer Register regulation (E-PRTR). WEISS integrates the data collected in the context of these mandatory reporting tasks. It assists also in the identification of significant emission sources and their contribution to the pollution of water bodies in order to formulate correct mitigation measures.

WEISS allocates the emission sources and the pathways from source to sink (the surface water) at a highly detailed geographical scale by means of raster maps with a resolution chosen by the user. This can be a resolution of 1 hectare or even less. This high resolution is most relevant in areas with high population densities and hence, high environmental pressures. As the most discernible polluting sources have been tackled during the last decennia, there is a need for a more detailed analysis to determine the remaining bottlenecks and to find out which measures would minimize the pollution load to the river to significantly improve the quality and ecological status of the water bodies.

WEISS is currently applied to the Flemish region of Belgium, representing the most densely populated parts of the International River Basin Districts of the Scheldt and the Meuse. However, its generic calculation scheme enables its application to other EU river basin districts equally well.

2 CONCEPTUAL FRAMEWORK

WEISS will above all be developed as a tool to generate a transparent inventory of:

- all significant emissions, discharges and losses caused by human activities affecting the water quality due to eutrophication, organic pollution, hazardous substances or oil;
- losses of substances from relevant natural processes.

WEISS consists of three modules: a) detailed spatial allocation of the emission sources, b) calculation of all possible pathways from the sources to the sinks, and c) accounting of the emission flows in various nodes of the transport routes. Figure 1 shows the linkages among these three modules and thus sheds light on the architecture of WEISS at the highest level of abstraction.
Each module of the system consists essentially of geographical submodels that implement different spatial algorithms. These algorithms contain calculation routines that are commonly recognized like linear or proportial distribution techniques, hereby ensuring the conservation of the mass balance The true geographical nature of the processes are represented at high spatial resolution. These submodels are all integrated into one integrated computer based system, which means a big step forward in the harmonization of the quantification of emission data.
The user- and functional requirements of the WEISS system are largely known since the beginning and have been fine-tuned during the project by consulting potential end-users as well as stakeholders involved in emission reporting and the design of policies and mitigation measures, from Flanders but also from other EU Member States.

In the following, the three modules of WEISS are successively described.

a) The first, “Spatial distribution of the source”, consists of algorithms enabling the appropriate <u>geographical distribution of the source</u> itself and the amount of pollution that it generates.

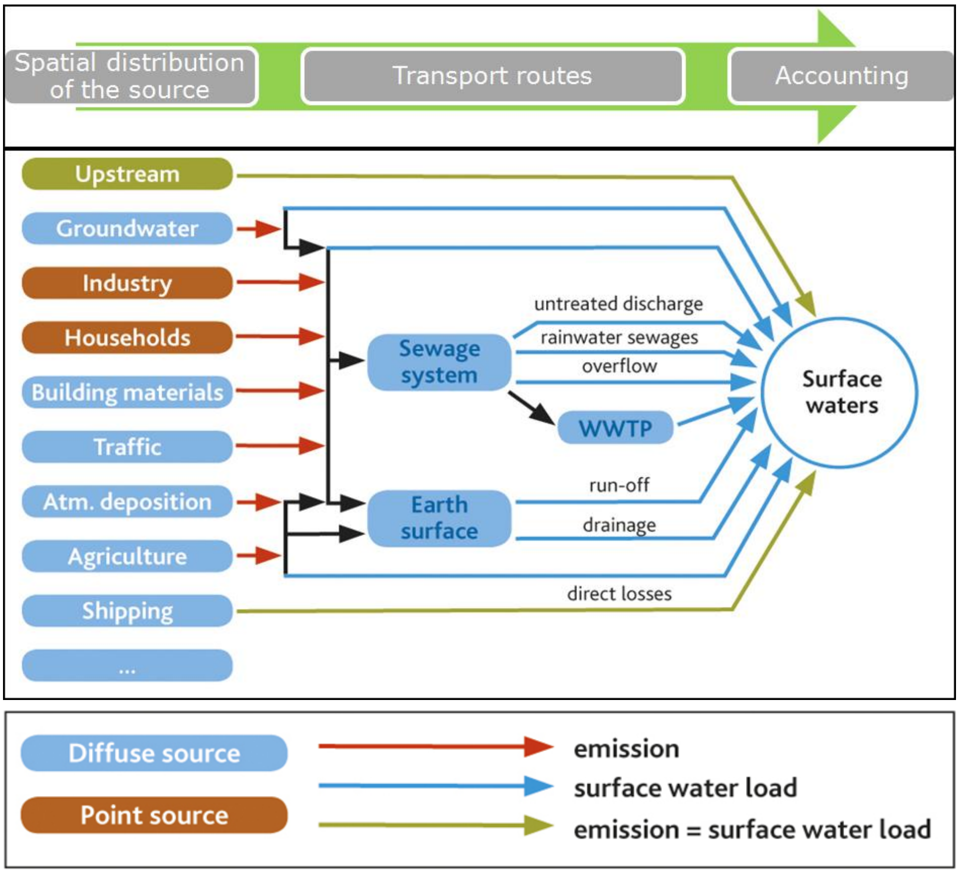

Figure 1. Functional scheme of WEISS

Point sources and diffuse sources are taken into account in WEISS. Each of these types of emission sources need to be allocated by means of the appropriate spatial algorithms operating on ancillary (cartographic) information representative of the location of the source. This is most straightforward for the majority of the point sources as they are monitored and have a known geographical location with precise X-Y coordinates. For the location of diffuse sources, dasymetric mapping[1] is an interesting technique, but other spatial allocation techniques will be implemented too. For line sources for instance, various forms of allocation proportional to the presence of the source on the network, or the intensity of usage of the network will be applied. Hence, depending on the precise characteristics of the source and/or the information available, the most appropriate spatial algorithms can be chosen to establish the spatial distribution of the source.

New sources of pollution can be entered as soon as the required information and knowledge becomes available. When sufficient detailed information is available for such source, a hierarchically nested representation is possible. In the given case, the source is subdivided and represented as a set of sub-sources. In conclusion, WEISS enables to describe the location of sources at different levels of abstraction. The sources are arranged in a hierarchical manner, by means of sectors and subsectors.

[1] Technique enabling the cartographic representation of a spatial feature for which data are available at the level of relatively arbitrary spatial units, reflecting more realistically the precise spatial location of the feature within those spatial units. To that effect, use is made of ancillary (cartographic) information representative of the location of the feature, like a land use map.

Pollutants considered in the current WEISS prototype for Flanders are heavy metals and PAHs. Nitrogen, phosphates, COD, fertilizers, pesticides and other substances will be added as soon as enough information is available. Their contribution to the overall pollution will be estimated on the basis of 2 essential concepts, namely: Emission Factor (EF) and Emission Explanatory Variable (EEV). An Emission Explanatory Variable (EEV) represents the real physical source causing the emission, such as a ‘detached house’ emitting heavy metals, or, a ‘farming activity’ emitting nitrogen. An Emission Factor expresses the amount of the substance released per unit of EEV, such as the amount of zinc emitted per year by a typical detached house, or the amount of nitrogen emitted by one ha of a agricultural plot growing crop X.
The typical end result of the calculations performed at this first step of the analysis are gross emission loads for all pollutants in all sectors analyzed in kg/ha.year. They can be consulted in the accounting part both as aggregated numbers/graphs in a database, and as maps showing the gross emission levels (prior to treatment) on a 1 ha grid.

Two special types of sources are taken into account in WEISS. The first are sources located in rivers, canals or lakes, such as PAHs emitted by the skin of boats. They end up directly in the surface water and need no further processing relative to their transportation. The second special case is groundwater. Because of the complexity of groundwater modeling, WEISS considers groundwater as a source and not as a transport route.
There are also two “special cases” not taken into account in WEISS. Firstly, emissions transported in water courses and loads thus entering the study region are currently beyond the scope of WEISS. Rather, they are dealt with by hydrological modelling tools applied in parallel. Secondly, contaminated watersoils are not incorporated in WEISS.

b) In its second module, WEISS deals with the various <u>pathways</u> or transport routes through which significant pollution quantities are transported or discharged. Overland transport of diffuse sources will be handled by a *run-off algorithm*, incorporating a Local Drain Direction network algorithm and run-off coefficients. Pollutants thus transported will end-up directly in the surface water, via ditches and other drainage networks and/or in the sewage network. Point sources will often deliver their waste waters directly to the *sewage system*. The sewage network will transport the waste waters and dissolved pollutants to the sewage treatment plants (urban WWTP’s) where the pollutants are partly removed. The remainder will be discharged in the surface water as part of the effluent. Another part of the pollutants will infiltrate into the soil and further into the groundwater. They are transported dissolved in the groundwater to feed the surface waters in particular locations where groundwater surfaces. As mentioned above, transport in the groundwater is currently not implemented in WEISS, rather, groundwater is dealt with as a source.
By taking into account the paths and nodes were removal takes place, net emission maps are computed. Figure 2 shows the material flow scheme of the Flemish case. Here, extra features such as overflows, ditches in the run-off process and the possibility to distinguish between rainwater sewage and mixed sewage are taken into account. This level of detail can be attained when the data is available. However, the lack of detailed information will not hamper the pathway calculations, as they can be performed on the basis of rougher data as well.

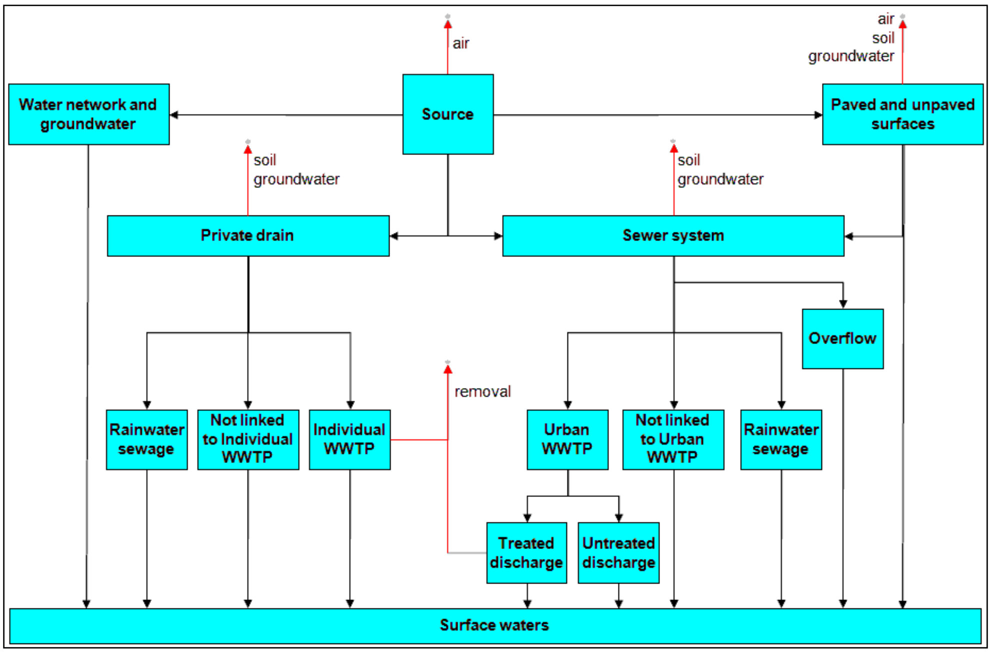

Figure 2. Schematic representation of the principle nodes and flows of the emissions from their source to their sink in the water bodies.

c) The <u>accounting</u> module enables to aggregate the emission loads typically computed at the 1 hectare resolution into totals representing hydrological (for instance river basins) or administrative entities. This can be done for all nodes in the Material Flow Scheme (Figure 2). Aggregated loads are available as tables, graphs and maps enabling trend analysis, source apportionment, listing of the top 10 most important sources etc.. The accounting will typically be carried out for those areas that are mandatory to report for.

For the Flemish case, about 100 sources can be defined. The diffuse ones are quantified by means of EF and EVVs. For every source, the user has to step through the three consecutive steps and modules in order to enter the required information for computing gross and net emission maps. All the required operations are carried out by specific algorithms programmed as model blocs and stored in a model bloc library. Hence, for every emission source, the appropriate model blocs are selected, fed with the required data, and chained to process the three main steps. Figure 3 represents this chaining in a schematic manner for three sources: ‘Corrosion of building materials on detached houses‘, ’Wastewater from the chemical industry‘ and ’Atmospheric depositition of PAHs‘.
The data entered in WEISS are stored in a linked MS Access database. This database can hold data for various years as well as versions within each year. Thus, users can always consult and perform runs based on data from past periods.
WEISS will take advantage of the data stored in its databases and its calculation capacity to support the user in designing and assessing measures aimed at reducing emissions and their impacts on water bodies. The processes are calculated on a high spatial resolution which enables spatially-explicit analyses and design of location specific mitigation measures.
The calculation scheme underlying WEISS is highly generic and robust enabling its implementation in other watersheds. However, parameters representing local physical characteristics, pollution sources and pollutant transport will need to be calculated, calibrated and validated in function of the specific local characteristics and circumstances. This may require local research efforts and measuring campaigns.

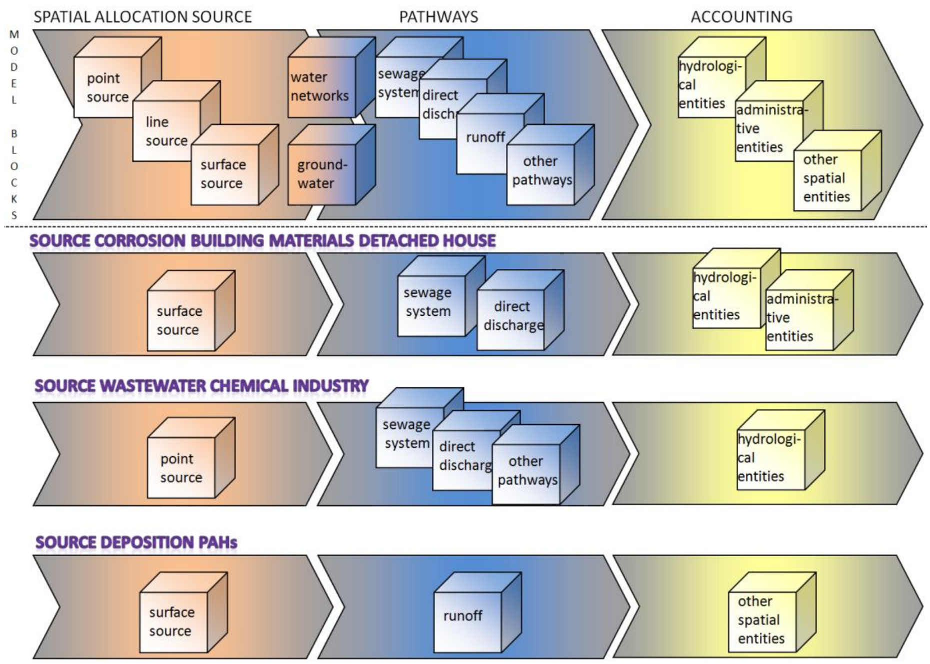

Figure 3. Model blocs of the WEISS library

3 FIRST RESULTS

The project in which WEISS is developed is in its final year, hence most of the calculation framework is up and running, at the least in an experimental mode. Spatial algorithms that are dealing with the spatial distribution of the three types of sources (point, line, surface) are available, the material flow scheme takes all the relevant pathways into account and the most straightforward queries on the results can be established. Things that still have to be incorporated are more sophisticated data analysis of the results, version management and linked to the latter, historical comparisons and scenario exercises. Also still on the agenda is the development of import functionalities enabling to integrate existing databases into WEISS.

A few of the operational functionalities are shown in Figure 4. At the top, two model blocks are presented dealing with the spatial distribution of the source: “Linear distribution technique” and “Dasymetric mapping”. In the middle, the input data for two model blocks concerning the pathways are shown: a part of the Flemish sewage system and the local drain direction model which is the core element of the runoff calculations. Finally, at the bottom, the accounting part is presented with results of the source “Corrosion of building stock, more specifically the corrosion generated in the plumbing system of terraced houses’. On every node of the material flow scheme (gross emission, net emission and in between), the results can be consulted by means of maps and tables. All the steps in the transport routes towards the surface water are taken into account. In this example, the numbers are summarized for the whole of Flanders, but they can also be calculated for any spatial entity overlaid by means of a raster map and larger than the size of a single grid cell (> 1 ha). The pictures in Figure 4 are screenshots of the WEISS system.

As long as the system is not filled with the most important emission sources, it’s not possible to do a validation of the calculations at the location of the urban waste water treatment plants. However, validation procedures have been applied onto the spatial distribution technique of one source. It was concluded that a realistic distribution of the source was achieved. In addition, a comparison between the results of WEISS and the former Emission Inventory Water (EIW) is part of the validation and calibration process. WEISS is able to locate the sources much more precisely compared to the former EIW, but the mass balance should be the same and proved to be that way.

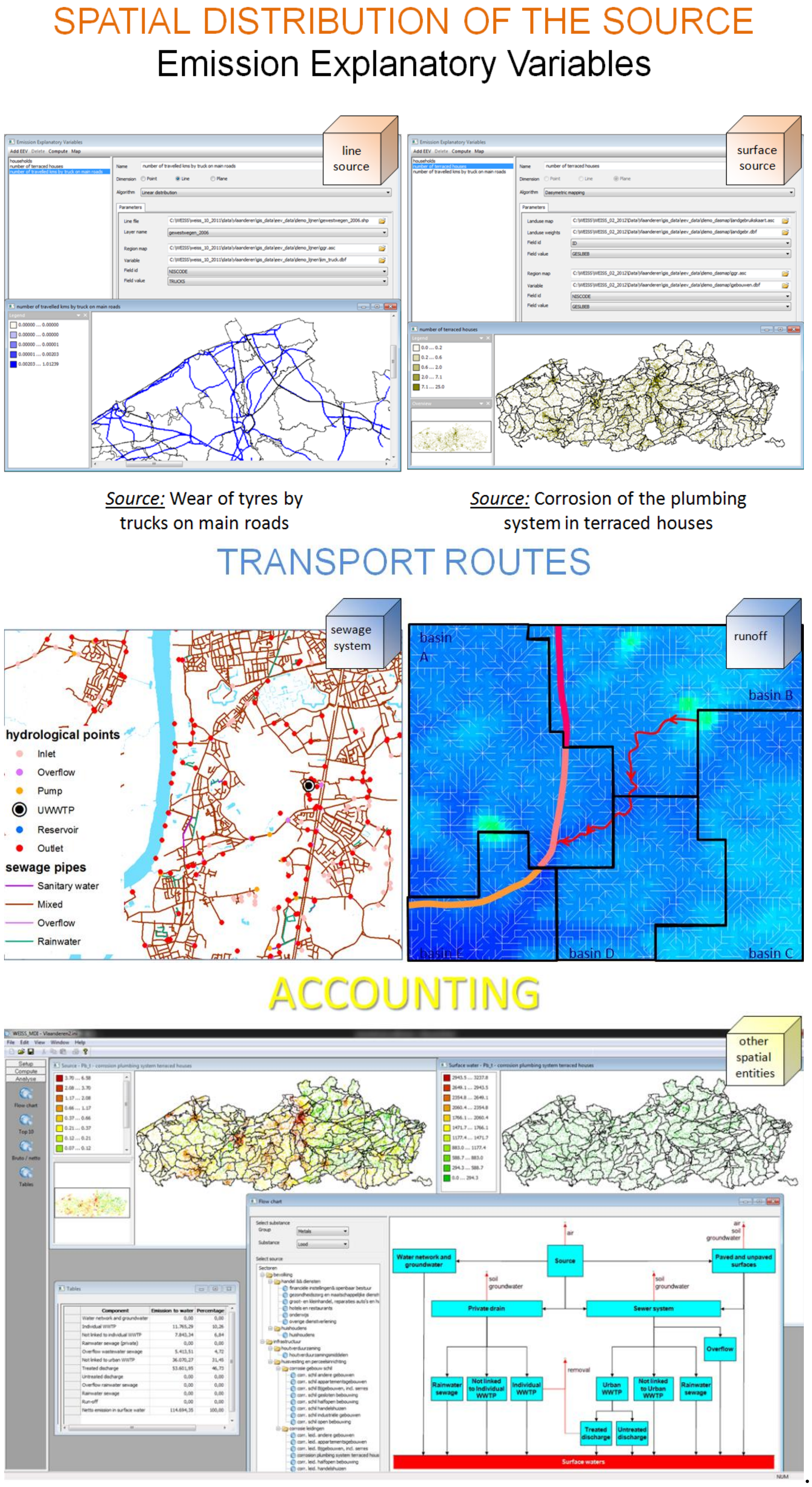

Figure 4. Functionalities of the WEISS system

4 CONCLUSIONS AND RECOMMENDATIONS

Towards the end of 2012, the WEISS system will be available for research centres and environment agencies dealing with emission inventories towards water. It will be delivered as an empty shell, featuring the model block library enabling to set up an application for any specific study area. The user has to fill the system with sectors, sources, emission factors, links to databases, maps, parameters concerning the transport routes, etc. The calculations are done on a raster map and at the chosen resolution. For Flanders, calculations are carried out at a 1 ha grid.

Also, the detailed inventory of sources and pathways requires an important set of high quality data, which may not be available for all sectors and sources. But, the methodology developed will be sufficiently robust to work with poorly as well as richly documented sources. In the meantime, efforts will be invested in the collection of emission data, partly by the realization of research work, partly by collecting existing data and the deployment of a new monitoring program. Moreover, once the WEISS system will be available, it will be instrumental in gathering the required information.

The functionality of WEISS fits perfectly well the imperative need of Europe to increase its knowledge on the identification and quantification of ‘pressures’ i.e. pollutant emissions by all sources, their variation over time and behavior in space. Europe needs to know these, not only because of specific reporting obligations, but also because of their impact on sustainable development.
WEISS provides information on the methodology to use emission estimation techniques and subsequently identify and evaluate the effectiveness of appropriate measures. The first complete implementation of WEISS concerns parts of the Meuse and Scheldt catchments located in Flanders, hence typical coefficients and measurements have to be gathered for this region. It could also be very interesting to realize an integrated river basin management plan to reveal the major pressures and impacts on the receiving waters in the whole river basin with the same accuracy. Fortunately, the robust conceptual framework enables applying the methodology and the specific algorithms from the model library onto any other EU river basin district or parts thereof as well. This flexibility together with the geographical detail and the possibility to analyse the results for any spatial entity are the most important advantages of the WEISS system.

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